AMBIENT AIR SHED QUALITY MANAGEMENT WITH NEW COAL POWER PLANT INSTALLATION

K. A. N. Kumarasinghe

(118765V)

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Degree of Master of Science in Environmental Engineering

Department of Civil Engineering

University of Moratuwa
Sri Lanka

September 2015

AMBIENT AIR SHED QUALITY MANAGEMENT WITH NEW COAL POWER PLANT INSTALLATION

K. A. N. Kumarasinghe

(118765V)

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

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

Department of Civil Engineering

University of Moratuwa

Sri Lanka

September 2015

Declaration, copyright statement and the statement of the supervisor

"I declare that this is my own work and this thesis/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 thesis/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:

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

The above candidate has carried out research for the Masters/ MPhil/ PhD thesis/ Dissertation under my supervision.

Signature of the supervisor: Date:

ABSTRACT

Average growth rate of electricity demand over last 15 years in Sri Lanka is about 6.5 % per annum. Energy demand in the country was mainly met by hydropower up to the year 1999, and with time thermal generation has become prominent.According to generation expansion planning study – Base case (2013 – 2032), coal is expected to dominate the thermal power sector consumption (75.7 % share) for the next decades in Sri Lanka. During the planning stage of a coal power plant, proper offset provisions should be implemented in order to minimize air shed degradation by achieving relevant emission standards stipulated in regulations. Different factors that influence on ambient air quality degradation should be investigated before the power plant comes fully on stream. Since coal is not considered as a cleaner fuel, health risk is always linked with its hazardous emissions.

This assessment was carried out in order to investigate the impacts from three criteria pollutants, (SO_2, NO_x and PM) emitted from proposed 1200MW coal power plant in Sampoor. Three different scenarios were considered for the development of proposed power plant and four case studies to investigate different conditions under each scenario. Air Dispersion Modeling (AERMOD) was used to predict the ground level concentration within 20 km radius of the emission source. The results from the modeling assessment were used to identify the exposure assessment and then acute health risk impact was identified through dose response measures.

The study shows that high efficient coal power plant can be satisfactorily employed in a place where degraded air quality is already prevailed and also when considering ground level ambient air quality concentrations, it is more favorable to install the coal power plants with less number of units having higher capacity. The results show that non carcinogenic human health impact was not identified from the population cluster locations in the vicinity to the power plant. Based on the assessment most preferred option for development of the proposed power plant with required mitigation measures was identified.

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

ACKNOWLEDGMENTS

I would like to express my deep gratitude to my supervisor Prof. Ajith De Alwis for the invaluable support given by providing the necessary guidance and encouragement to fulfill my objective. I specially thanks him showing much patients during last few weeks byspending his precious time in his busy and tight schedule for helping me to get best out of this thesis.

I am also grateful to Dr. Jagath Manatunga who coordinated the overall course and provided his continuous support on achieving the success. Iwould like to extend my special thanks to all the academic staff of the department of Civil Engineering, University of Moratuwa for the great work they did for us during the course of study. They all are hardworking professors / lecturers and I believe their academic achievements will continue to increase.

I was fortunate to complete this course just because of precious support provided from my work place, Industrial Technology Institute. The higher management of the institute had granted me leave on attending to the lectures during working day, preparing for exams, and whenever I need to go for the university. Out of all, a special thank must be delivered to Mr. H.N. Gunadasa, former Senior Deputy Director of Environmental Technology Section who is always beside us to support in any matter and specially helping me to arrange my thesis in proper way. I'm obliged to the present Senior Deputy Director of ETS, Mr. Keerthi Fonseka for allowing me to carry out the thesis and other academic work. My endless thanks must always be delivered to the dearest office mates Ms. Dushyanthi, Ms. Hasanthie and other staff members for encouraging me day by day to the way forward.

I would also like to express my sincere thanks to all the support given by the Ceylon Electricity Board of Sri Lanka and special thanks to be delivered to Mr. Buddhika Samarasekara – Chief Engineer and Ms. Dilini – Electrical Engineer in Generation Planning Division.

I owe my deepest thanks to my mother , husband and mother-in law for all the encouragement given during the course of study and helping to take care of my little son all through the writing the thesis.

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Table of Contents

Declaration, copyright statement and the statement of the supervisor……..i

Abstract……ii

Acknowledgement……...iii

Table of Contents…… iv

List of Figures……..vi

List of Tables……..vii

List of Abbreviations……...ix

CHAPTER 01 : INTRODUCTION……01

1.1 Background……...01

1.2 Research Need…..……...…….....06

1.3 Research Question……...…….07

1.4 Objectives of the Study……08

1.7 Thesis outline……...….09

CHAPTER 02 : LITERATURE REVIEW……10

2.1 Coal Combustion……...10

2.2 Coal combustion Technologies……14

2.3 Emissions from coal power plants……...…….16

2.4 Control of emissions from pulverized coal combustion……...……17

2.4.1 Dust Abatement……...…...17

2.4.2 Techniques to reduce SO_x emission……...……18

2.4.2.1 Sea Water Scrubbing……...18

2.4.3 Techniques to reduce NO_x emission……...……20

2.5 Health Impact Assessment……...…….25

2.5.1 Impact Pathway Approach……..……...25

2.5.2 Hazard Quotient Approach……..……...26

CHAPTER 03 : MATERIALS AND METHODS……...…..29

3.1 Case Study Development……...……...32

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

3.2 Emission Load Estimation……...…….32
3.3 Source Emission Characteristics……...……35
3.4 Background Sources……...……..35
3.5 Air Dispersion Model……...……36
3.6 Model input Data……...……...36
3.7 Health Impacts Assessment…….....38
CHAPTER 04 : RESULTS and DISCUSSION……..41
4.1 Meteorological Conditions……41
4.2 Predicted Maximum GLC……43
4.3 Assessment on SO_2 Emission Prediction……..44
4.4 Assessment on NO_x Emission Prediction……...……..47
4.5 Impact of Stack Height on Ground Level Pollutant Concentration……..48
4.6 SO_2 concentration on Population Cluster Locations……54
4.7 NO_x concentration on Population Cluster Locations……...…….57
4.8 Non Carcinogenic Health Risk Assessment……...……..59
4.8.1 Hazard Identification……...……59
4.8.2 Determination of the dose-response relation……...……...60
4.8.3 Exposure Assessment……...……..61
4.8.4 Risk Characterization……...……..61
CHAPTER 05 : CONCLUSION AND RECOMMENDATION……...64
5.1 Conclusions related to study objectives……...…….64
5.2 Recommendations……67
5.3 Future Research Work……...……...67
REFERENCE LIST……68
APPENDICES……70
Appendix – I: Model Description……...……70
Appendix – II: National Ambient Air Quality Standard……...…….....75
Appendix – III: Model Outputs……...……78

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

List of Figures

Figure 1.1: Growth rates of GDP and electricity demand……..01

Figure 1.2: Hydro thermal share in recent pass……..02

Figure 1.3: Schematic diagram of a coal power plant…..……..07

Figure 1.4: Path of identification the most appropriate way of operating coal power plant …..……...08

Figure 2.1: Impact Pathway Approach……...26

Figure 3.1: The proposed location for the development of next coal power plant….30

Figure 3.2: Methodology Followed to predict the ambient pollutant concentrations……..31

Figure 3.3: Methodology Followed to Health Risk Identification…….31

Figure 3.4: Locations of discrete receptors……..37

Figure 4.1: Wind Rose Plot for the Sampoor……..42

Figure 4.2: Wind Class Frequency Distribution…….43

Figure 4.1: Ground Level NO_x concentration variation at 200m Stack Height……..50

Figure 4.2: Ground Level NO_x Concentration Variation at 250m Stack Height……50

Figure 4.3: Ground Level NOx Concentration Variation at 275m Stack Height…...51

Figure 4.4: 01 Hour Average Maximum Predicted Ambient NO_x concentration variation with stack height……...51

Figure 4.5: 01 Hour Average Ambient Sulphur Dioxide Concentration Variations at Mutur……55

Figure 4.6: 01 Hour Average Ambient Sulphur Dioxide Concentration Variations at Sampoor……...55

Figure 4.7: 01 Hour Average Ambient Sulphur Dioxide Concentration Variations at Trincomalee…….56

Figure 4.8: 01 Hour Average Ambient Nitrogen Dioxide Concentration Variations at Mutur……57

Figure 4.9: 01 Hour Average Ambient Nitrogen Dioxide Concentration Variations at Sampoor……...…58

Figure 4.10: 01 Hour Average Ambient Nitrogen Dioxide Concentration Variations at Trincomalee……...……...…58

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

List of Tables

Table 1.1: Generation Expansion Planning Study – Base Case 2013 – 2032…….03

Table 2.1: Indicative analyses of typical coal…….10

Table 2.2: Coal Varities and their characteristics……...11

Table 2.3: Different Coal combustion technologies……...14

Table 2.4: Characteristics of Major Coal Types used to generate Electricity……16

Table 2.5: Techniques for the prevention and control of dust and particle-bound heavy metal emissions……19

Table 2.6: General performance of sea water scrubbing for reducing Sulphur Oxide emissions……21

Table 2.7: General performance of primary measures for reducing NO_x emissions……22

Table 2.8: General performance of secondary measures for reducing NOx Emissions……..24

Table 3.1: Air Dispersion Modeling study for the proposed PP at Sampoor…….32

Table 3.2: Emission factors of the coal power plants……33

Table 3.3: Characteristics of existing and candidate coal power plants (For one unit)……33

Table 3.4: Emission Load estimation……..34

Table 3.5: Emission Load estimation without having pollution control abatements..34

Table 3.6: Source Emission Characteristics……35

Table 3.7: Source Emission characteristics of TPCL Power Plant…….35

Table 3.8: GPS locations of discrete receptors……...38

Table 3.9: Source Data……38

Table 4.1: Emission Concentrations due to operation of coal power plant with FGD……44

Table 4.2: SO_2 Concentrations due to operation of coal power plant without FGD..46

Table 4.3: Maximum allowable Sulphur content of the fueltolerable to comply with respective AAQ standard……47

Table 4.4: Impact of Stack height variation for ground level NO_x concentration…..49

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Table 4.5: Number of grid points exceeding the Maximum Permissible Level – Scenario B……..49
Table 4.6: Estimates of NO_x control costs for different size boiler retrofits in China……..53
Table 4.7: Maximum Predicted ambient SO_2 concentration variation (01 hour average) at different locations……54
Table 4.8: Maximum Predicted ambient NO_x concentration variation (01 hour average) at different locations……57
Table 4.9: The health effects of short term and long term exposure to specific pollutants……59
Table 4.10: Acute Inhalation Reference Exposure Levels……..60
Table 4.11: Hazard Quotient computed for maximum predicted pollutant concentrations during short term exposure……..61
Table 4.12: Hazard Quotient computed for SO_2 short term exposure……62
Table 4.13: Hazard Quotient computed for NO_2 short term exposure……...62
Table 4.14: Hazard Index computed for NO_2 and SO_2 short term exposure……...63
Table 5.1: Ground Level concentration variation of Scenario A and B (For Different capacity Distribution)……64
Table 5.2. Ground Level concentration variation of Scenario B and C (Different technologies for the same capacity)……...65

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

List of Abbreviations

AAQ	Ambient Air Quality
ADM	Air Dispersion Modeling
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
ESP	Electro static Precipitator
FBC	Fluidized Bed Combustion
FF	Fabric Filter
FGD	Flue Gas Desulphuration
GDP	Gross Domestic Product
GLC	Ground Level Concentration
HAPs	Hazardous Air Pollutants
HQ	Hazard Quotient
NH_3	Ammonia
NO_x	Nitrogen Oxides
NOAEL	No Observed Adverse effect Level
PC	Pulverized Coal
PM	Particulate Matter
PP	Powr Plant
REL	Reference Exposure Level
SC	Super Critical
SCR	Selective Catalytic Reduction
SNCR	Selective Non catalytic Reduction
SO_2	Sulphur Dioxide
TPCL	Trincomalee Power Company Limited
US EPA	United States Environmental Protection Agency

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk