

VALUATION OF HEALTH BENEFITS OF WORLD BANK GUIDELINES FOR AIR EMISSIONS IN THERMAL POWER PLANTS

by

ARUN KANSAL
Department of Civil Engineering

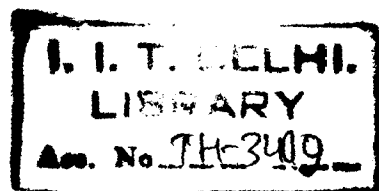
Submitted
In fulfillment of the requirements of the degree of

DOCTOR OF PHILOSOPHY
to the



INDIAN INSTITUTE OF TECHNOLOGY, DELHI.
DECEMBER 2006

1. Thermoelectricity
2. Power generation and supply



7/1
621.8.056
KAN-V



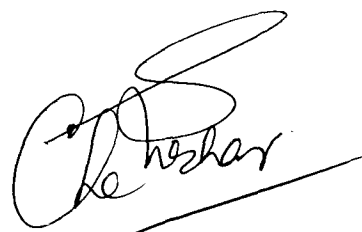
CERTIFICATE

This is to certify that the thesis entitled “**Valuation of health benefits of World Bank guidelines for air emissions in thermal power plants**” being submitted by **Mr. Arun Kansal**, has been prepared under our supervision in conformity with the rules and regulations of the **Indian Institute of Technology, Delhi**. We further certify that the thesis has attained a standard required for the award of a degree of **Doctor of Philosophy** of the institute. This work, or any part thereof, has not been submitted elsewhere for the award of any other degree or diploma.



Mukesh Khare

Professor
Department of Civil Engineering
Indian Institute of Technology, Delhi
New Delhi- 110 016
India



Dr. Chandra Shekhar Sharma

Reader
Shri Ram College of Commerce
University of Delhi
Delhi- 110 007
India

ACKNOWLEDGEMENT

I feel immense pride to acknowledge the skill, care and tireless energy provided by my research supervisors, Professor Mukesh Khare, Department of Civil Engineering, Indian Institute of Technology, Delhi and Dr. Chandra Shekhar Sharma, Shri Ram College of Commerce, University of Delhi, Delhi. I am extremely grateful to Professor Mukesh Khare whose guidance and encouragement has not only enabled me to complete the present work but also inspired me to face and tackle the challenges. It is he, who suggested the problem, guided throughout the course of this work and evaluated the results at every stage. He is such a revered teacher who understood me when I lacked in explanation and explained me when I lacked in understanding. I am indeed indebted to him. The study could not have been completed without the inputs from the discipline of economics. I owe and express my gratitude to Dr. Chandra Shekhar Sharma for his constant inspiration, timely discussions and encouragement to carry out this research work. His invaluable inputs in making this research fruitful are appreciable, thank you sir!

There are special mentors that I must acknowledge due to their importance in my work; I never met them personally but their published work inspired me. Suffice it to say that to all those from, late Professor David Pearce (The Centre for Social and Economic Research on the Global Environment) and Professor James Longhurst (University of West England, UK), thank you!

I would like to express my gratitude to Professor Ashok Gupta, Dr. Geetam Tiwari (Department of Civil Engineering) and Professor S G Deshmukh (Department of Mechanical Engineering) of Indian Institute of Technology, Delhi, for their invaluable suggestions and advise in further shaping this research work.

There are many from behind the scenes who have encouraged and supported my work, and I wish to thank them. The list of people to thank is endless. I thank Dr. Prateek Sharma (GGS Indraprastha University, Delhi), for his advice and suggestions. I also thank Dr. M P George (Senior Scientist, Delhi Pollution Control Committee), Mr. V P Garg (Deputy General Manager, North Delhi Power Limited), Mr. S K Nanda (Deputy Director), Mr. R K Aggarwal (Member, Thermal), and Mr R D Jain (all from Central Electricity Authority, New Delhi) for providing me the required data about thermal power plants in Delhi. I also thank the students of M.Sc. GGS Indraprastha University (2003-05 batch) for helping me to conduct traffic monitoring exercise.

This has been an enormous project, which has taken too many of my evenings and weekends that would not have been possible without the cooperation, understanding and patience that my parents, sister, and son have during my research tenure. I owe them, express my gratitude and extend my wholehearted admirations. My wife Vineeta needs a hearty appreciation for her endurance, cooperation, inspiration and bearing with me all the time.

I gracefully thank Mr. Suresh Jain and Ms. Radha for their cooperation in administrative activities and assistance in editing and proof reading of the thesis. I also extend my thank to all those who directly and indirectly helped me in taking this research to its fullest.

To end with, I thank Professor K K Agarawal (Vice Chancellor, GGS Indraprastha University, Delhi), and Professor Amarjeet Kaur (Dean, University School of Environment Management, GGS Indraprastha University, Delhi) for granting permission to carry out the research.

A handwritten signature in black ink, reading 'Arun Kansal', written in a cursive style.

ARUN KANSAL

ABSTRACT

Amongst all the infrastructure project investments, power sector has got the highest priority in India. The major share amongst the new capacity will be from coal and gas based thermal power plants (TPPs). Many of the TPPs are likely to come up near urban areas, posing a threat to the ambient air quality. As a part of its pollution prevention and abatement handbook, the World Bank (WB) has proposed environmental guidelines for the TPPs (<http://inweb18.worldbank.org>). The guidelines postulate adherence to maximum plant emission levels for achieving the site-specific emission standards. Proposed WB emission guidelines (WBEG) are specifically directed towards protecting the human health, reducing mass loading to acceptable levels, achieving emission standards based on commercially proven and widely used technologies and following the current regulatory and technological trends. The WBEG are stricter than the existing Central Pollution Control Board (CPCB) standards in India. Therefore, the implementation of WBEG may impose significant cost on TPPs in India. These costs may be fairly high (TERI, 1998) and therefore require justification for adoption by estimating *benefits* associated with these investments.

The study estimates the marginal health (morbidity) *benefit* of air pollution control in Delhi and the total health *benefits* of the regulatory intervention viz. adoption of the WBEG by TPPs of Delhi. The study is directed towards estimating the economic value of improving air quality. The study employs emission inventory and source apportionment techniques using industrial source complex- short term version-3 (ISCST3) for *point*, *area* and *line* sources to estimate the air pollution contribution

by TPPs. Synthesis of the literature and primary data collection for all elements of the *causal* chain of health risk has been performed.

Household health production function (*avertive behaviour*) has been used to value health cost of air pollution. The model requires the estimation of three simultaneous equations: household health production function, household *demand* functions for *mitigation* activities, and *avertive* activities. Primary survey has been done to collect the data regarding the health status, socio-economic and structural characteristics of households, awareness of households about effects of air pollution, health status (including chronic disease), *mitigating* and *avertive* activities, habits, pollution control measures etc. The effect of the air pollution at key receptors has been assessed for *mitigating* and *avertive* responses of the people.

The ISCST3 model has performed satisfactorily for total suspended particulates (TSP) and nitrogen oxides (NO_x)¹ at all receptor locations in Delhi. However, its performance is unsatisfactory for sulphur dioxide (SO₂) in 5 out of 7 receptor locations. Vehicle sources are found to be the major contributor of TSP and NO_x followed by TPPs. For SO₂, TPPs are the major contributor. A large number of initiatives have been adopted by the Government of India (GoI) for reduction of emissions from vehicular sources; whereas, the emission reduction measures from TPPs have been ignored. The study has revealed that the ambient air pollution due to TPPs is reduced by 62% to 85% all over Delhi by adopting the WBEG.

Annual *marginal benefits* for a representative household in Delhi due to reduction in exposure to air pollution by 1 µg/m³ is estimated to be Rs 66.50 (US \$1.4778)² which amounts to Rs 15.90 (US \$0.353) per person. This estimate accounts

¹ NO_x as NO₂

² US \$1 = Rs 45.00

only for the effects of the improvement in air quality on health (morbidity). Total annual health *benefits* of WBEG for air emissions in TPPs are estimated at Rs 10583.79 billion (US \$235.19 million) lower than the value estimated by Brandon, Hommann and Kishore (1995) which is in the range of US \$86.40 to \$216.13 per household for India. Their estimates are based on mechanical dose-response functions drawn from epidemiological studies done in developed countries.

TABLE OF CONTENTS

	Page No.
Certificate	i
Acknowledgement	ii
Abstract	v
Table of contents	viii
List of figures	xii
List of tables	xiv
List of abbreviations	xviii
1. INTRODUCTION	1 - 16
1.1 General	1
1.2 Policy instruments for pollution control	2
1.3 India's legislative framework for air pollution control	6
1.4 Institutional framework	9
1.5 Study area	11
1.6 Air quality in Delhi	13
1.7 Outline of the thesis	16
2. RESEARCH OUTLOOK	17 - 24
2.1 General	17
2.2 Scope of the study	21
2.3 Objectives of the study	23
3. LITERATURE REVIEW	25 - 49
3.1 General	25
3.2 Valuing cost of air pollution	26
3.2.1 Direct valuation approach	28

3.2.2	Indirect valuation approach	30
	Travel cost	30
	Avertive behaviour method	31
	Hedonic property pricing	33
	Hedonic wage pricing	35
	Conventional market approach	36
3.3	Comparison of valuation techniques	37
3.4	Selection of health benefit valuation technique and conceptual challenges	40
3.5	Valuation of environmental impact of TPPs and air pollution	42
3.6	Source apportionment and air pollution dispersion modelling studies in India	45

4. PROCEDURE FOR VALUING HEALTH BENEFITS OF AN

	ENVIRONMENTAL REGULATORY INTERVENTION	50-71
4.1	Methodological framework for valuing clean air	50
4.2	Source apportionment and scenario generation	53
	4.2.1 Emission Inventory	56
	4.2.2 Air pollution modelling	57
	Model Selection	59
	ISCST3 input parameters	60
	4.2.3 Model performance evaluation	61
	4.2.4 Scenario generation	62
4.3	Valuation of health benefits of air pollution control	62
	4.3.1 Econometric model	63
	4.3.2 Survey and data collection	65
	4.3.3 Parametric estimates of structural models	68
	Expected sign of coefficients	68
	Identification of the structural model	69
	Simultaneity test	69

	Estimation Method	70
	Selection of functional form	71
5.	DATA DESCRIPTION AND INTERPRETATION	72 - 96
5.1	Emission Inventory	72
5.1.1	Emissions from TPPs	72
5.1.2	Emissions from industries	73
5.1.3	Emissions from vehicles	81
5.1.4	Emissions from domestic sector	87
	Fuel burning	87
	Refuse burning	89
	Waste disposal landfill sites	90
5.1.5	Background concentration level	90
5.1.6	Emissions from TPPs under the WBEG scenario	90
5.2	Meteorology	91
5.3	Household survey	95
6.	MODEL PERFORMANCE, IMPACT PREDICTION AND HEALTH BENEFIT ASSESSMENT	97 - 119
6.1	ISCST3 model results and impact prediction	97
6.2	Econometric analysis results	97
6.3	Estimation of health benefits due to reduction in air pollution	114
7.	FURTHER DISCUSSIONS	120 - 124
7.1	The model performance	120
7.2	Source apportionment under BAU scenario	121
7.3	The WBEG scenario	122
7.4	Econometric analysis	122
7.4.1	Choice of the functional form	122
7.4.2	Significance of the coefficients	123

7.5	Estimation of health benefits	123
8.	CONCLUSIONS	125 - 131
8.1	Emission inventory	125
8.2	Model performance	126
8.3	Source apportionment	126
8.4	Policy intervention – WBEG for TPPs	127
8.5	WTP for air pollution abatement	127
	8.5.1 Health benefit valuation	128
	8.5.2 Annual health benefits under WBEG scenario	128
8.6	Contribution of the present research	129
8.7	Future scope of research	130
	REFERENCES	132
	APPENDICES	155 - 213
	Appendix A-National Ambient air quality standards	155
	Appendix B- Proposed capacity of electricity generation	156
	Appendix C- The industrial source complex model	157
	Appendix D- The statistical indicators	167
	Appendix E – Mathematical model of health production	169
	Appendix F- Household survey questionnaire	176
	Appendix G- Some useful econometric methods	181
	Appendix H- Monthly wind rose of Delhi	186
	Appendix I- Description of source apportionment study results	189
	Glossary	214
	Curriculum vitae of author	220