academicJournals

Vol. 7(7), pp. 718-724, July 2013
DOI: 10.5897/AJEST2013.1523
ISSN 1996-0786 © 2013 Academic Journals
http://www.academicjournals.org/AJEST

African Journal of Environmental Science and Technology

Full Length Research Paper

The economic cost of air pollution in Mangaung metro municipality: A case study in South Africa

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Accepted 22 July, 2013

Economic and domestic activities have been causing a profound deterioration of air quality in developed and developing countries. The health problems arising from air pollution have become apparent which result in welfare losses in society such as increased workdays lost and high health cost. This study shows the mitigating cost and workdays lost as a result air pollution related illness and the factors influencing these economic parameters (mitigating cost and workdays lost). Our results demonstrate the economic impact of air pollution which will provide information that could be used to know the significance of air quality, to value the benefits of air pollution control programs, social benefits (in terms of government subsidising clean energy source), policies or strategies to ensure a safe and acceptable air standard to minimise health effects.

Key words: Air pollution, air quality, workdays lost, mitigating cost.

INTRODUCTION

Over the past two decades, there has been continued deterioration in air quality. Intensified processes of industrialisation coupled with the rapid growth of transportation have resulted in the degradation of the air quality (Amanna et al., 2011). Combustion of traditional biomass fuels and coal, poor environmental regulations, less efficient technology of production, congested roads, age and poor maintenance of vehicle are other factors contributing to air pollution.

Past research has indicated that many major cities in developed and developing countries experience severe levels of air pollution which poses a major environmental risk to human health (WHO, 2007). Constant exposure to air pollution often leads to morbidity and mortality (Duflo et al., 2008). Approximately, 2 million premature deaths occur worldwide per year due to indoor air pollution which accounts for 4 to 5% of total mortality worldwide (WHO, 2011a). The observed health effects include eye irritation, respiratory diseases, cardiovascular diseases and premature deaths especially in children (Fatmi et al., 2010).

Thus, to evaluate the effects of air pollution, the valuation of its health impacts is crucial. Air pollution effects worldwide have been found to contribute over 90% of the total health cost in monetary terms (ExternE, 2004). The economic cost of air pollution is the total cost incurred due to health problems associated with air pollution. High economic cost as a result of air pollution related health problems results in low gross domestic product (GDP), meaning when economic damages accumulate, it leads to a loss in income which means lower gross domestic product (GDP) and savings and therefore less investment and lower economic growth will occur over time (Mayeres and Regemorter, 2008). The economic cost of air pollution can also be measured in terms of morbidity or restricted activity days (RAD).

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Indoor air quality has continued to deteriorate in the townships of Mangaung metro municipality, South Africa due to households' energy choice for their domestic activities most especially for cooking and space heating. Unavailability of electricity or the high cost of its usage has been identified and has the reason for the use of unclean fuels for these domestic activities (Department of Environmental Affairs, 2009). There is also deterioration in the quality of air outdoors which arises from burning of refuse by households. As a result, people suffer from illnesses such as bronchitis, heart problems, respiratory problems, etc., which invariably reduce the efficiency of people at work. Thus, measuring the economic cost of air pollution is crucial for the township areas of Mangaung metro municipality in order to help policy makers create more effective measures to counter air pollution and to improve on more public awareness.

For convenience, this paper incorporates the workdays lost and mitigating cost as a result of air pollution related ailments, as the economic cost parameters for air pollution. Factors influencing workdays lost and mitigating cost were also explored.

DATA AND PROCEDURES

A structured questionnaire was used to gather information of the households in order to estimate the economic cost of air pollution. A questionnaire developed by Alberini et al., (2004) to value the health effects of air pollution in developing countries was used as a basis to design the questionnaire. The questionnaire was developed to measure respondent's health status. The reason for probing into the health challenge(s) of respondents is based on the hypothesis of Gupta (2008) which states that an individual who has a chronic disease is more susceptible to negative health effects of air pollution and is likely to have higher medical expenses and number of workdays lost. The questions were developed to explore the incidence of symptoms of acute illnesses linked to air pollution exposure. This is to test the awareness of households about the illnesses that occur due to air pollution. The air-pollution related ailments are mostly respiratory linked and it include runny or blocked nose, sore throat, cough, eye irritation, ear irritation and sinusitis. The questions include the method of treatment (mitigating activities), cost of treatment (mitigating cost), number of visits for treatment, number of workdays lost, duration of illness, number of deaths and number of times respiratory ailments occur in a year.

This research was carried out in Phahameng and Rocklands located in the township area of Bloemfontein within Mangaung metro municipality, South Africa. These two areas were selected as they are considered hot spots for air pollution (South Africa National Standards for Ambient Air Quality, 2010). Samples of the households in the areas were selected using the stratified random sampling technique. 300 households were surveyed in total. Based on the total number of households in the areas, 111 households were surveyed in Phahameng, and 189 households in Rocklands. A pilot survey was conducted in which 20 households were surveyed in Phahameng. The purpose of the pilot survey was to ascertain that terminologies were clearly understood, to indicate the number of subjects that could be handled with ease during one data collection session, to correct misunderstandings and to include other relevant questions. The questionnaire was modified after the pilot survey and then used to interview all 300 households in face-to-face interviews during November and December, 2011.

Factors influencing workdays lost and mitigating cost was also investigated. Workdays lost is measured as the number of days lost for the last episode (prior to interview) of an ailment related to air pollution. For employed respondents, workdays lost is considered as the number of days they were not able to go to their place of work. If the respondent for the household is a student, the workdays lost is measured as number of days absent from school. For self-employed or unemployed respondents, workdays lost is measured as the number of days not able to perform daily routine or activities. Mitigating cost on the other hand is the total cost incurred as a result of treating the last episode (prior to interview) of air pollution related ailments. The cost include consultation fee, cost of medication, hospitalisation and transportation fee. The determination of workdays lost and mitigating cost is from the survey data.

The method of determination of the factors influencing workdays lost and mitigating cost has been strongly and clearly guided by the form of the dependent variables considered in the study. The dependent variables (workdays lost and mitigating cost) considered takes the form of a numeric or continuous variable. Knowing the nature of the dependent variables, which is continuous, Ordinary least square method (OLS) is found appropriate to investigate the factors that influence workdays lost and mitigating cost. OLS is probably the most widely used statistical methodology in existence and is found appropriate to determine the factors that influence workdays lost and mitigating cost. OLS is a statistical technique that uses sample data to estimate the true population relationship between two variables and has been successful in solving problems with a continuous dependent variable (Gujarati, 2003). Thus, two OLS models were fitted. The first model was used to investigate the factors that influence workdays lost while the second OLS model investigate the factors that influence mitigating cost. The analysis of the data was done in Eviews 7. The generic equation of the OLS model is written as:

$$Y_i=\beta_0+\beta_1 X_i+\ldots\ldots\ldots\ldots\ldots\ldots.+u \tag{1}$$

Where: Y_i is the workdays lost or mitigating cost of respondents, X_i is the selected characteristics of the respondents i, β_1 is the corresponding vector of coefficients and u is the normally distributed error term with mean and zero variance σ^2 (~N (0, σ^2).

Number Cruncher Statistical System, NCSS (2007) was used to test for multi-collinearity before running the regressions. The following factors were hypothesised to influence workdays lost.

The treatment methods variables OTC (over-the-counter), NMED (no medication), TRAD (traditional treatment), health (HEALTH), district (DISTRICT), ailment (AILMENT), number of visits to a doctor or pharmacy for treatment (VSTNR) and number of times air-pollution related ailment(s) that occurred in a year (NRTIMES) are all expected to positively influence workdays lost. Duration of illness (DLNES), age (AGE) and mitigating cost (MGTCOST) are ambiguous variables hypothesised to positively or negatively influence workdays lost. The monthly income variables are low income (LOWINC) and high income (HIGHINC). High income is expected to have a negative influence on workdays lost, while low income is expected to have a positive influence on workdays lost. The following factors were hypothesised to influence mitigating cost.

The variables associated with the employment status of respondents are self-employed, unemployed and student. Respondents that are working on their own (SELFEMPLYD) are expected to have a positive sign while those that are not working (UNEMPLYD) or studying (STUDENT) are expected to have a negative sign. Low income (LOWINC) is hypothesised to have a negative influence on mitigating cost while HIGHINC is expected to have a positive influence on mitigating cost. DLNES, VSTNR and workdays lost (WKDLOST) are ambiguous variables hypothesised to have either positive or negative influence on workdays lost. The treatment methods are all expected to have a negative influence

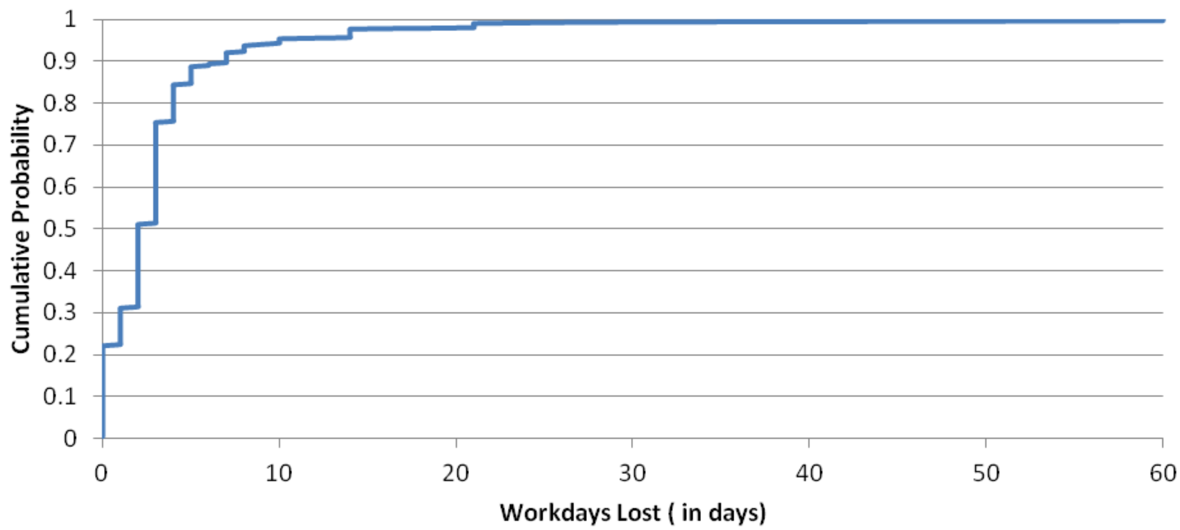

Figure 1. Cumulative probability distribution of workdays lost in the study areas.

on mitigating cost.

RESULTS

The workdays lost on average per person due to air pollution related ailments is estimated as 3.40 days in Phahameng and 3.44 days in Rocklands. The workdays lost in both study areas ranges from 0 to 60days. Some respondents did not have any days lost during the last episode of air pollution related ailments. The maximum number of workdays lost (during the last episode of air pollution related ailments) observed in the study areas was 60 days. The cumulative probability distribution in Figure 1 reports the workdays lost in the study areas.

Figure 1 show that 20% of the sample did not lose workdays during their last episode of illness due to air pollution. About 94% have lost 10 workdays or less while 98% have lost 20 workdays or less due to illness as a result of air pollution. Only 1% of the respondents lost more than 30 days workdays. The cumulative probability distribution of workdays lost in both study areas reveal that the economic impact of air pollution in Phahameng and Rocklands is a big concern considering the number of days lost due to ailments associated with air pollution. Thus, the economic cost of air pollution in the study areas is considered to be high.

An Ordinary Least Square Regression Model (OLS) was used to determine the factors influencing workdays lost. Table 1 shows the result of the OLS model of the variables hypothesised to influence workdays lost. In the interpretation of Table 1, the focus is on the sign of the coefficient, indicating the direction of influence of the variables on workdays lost. If a variable is not significant up to 10%, then it does not allow for explaining variation in workdays lost due to air pollution ailments.

From Table 1, the model gives R-square value of 0.86 which indicates that the independent variables included in this study explain 86% of the variation in the dependent variable. Thus, the R-square value implies that the model is a good fit. Based on the results from Table 1 as well, six variables are statistically significant at 1, 5 and 10% level of significance. Health (HEALTH), DLNES, number of visits to doctor or pharmacy for treatment (VSTNR) and mitigating cost (MGTCOST) are statistically significant at a 1% level, confirming them as the principal factors influencing workdays lost. As hypothesised, health has a positive influence on workdays lost; meaning that respondents with chronic illness (such as high/low blood pressure, diabetes, tuberculosis, etc.) will have more workdays lost. This is in accordance with the findings of Gupta (2008) where history of having chronic illness such as tuberculosis was found to have a positive coefficient and statistically significant. Duration of illness was found to have a positive influence on workdays lost. Depending on the number of days it took an individual to recover from air pollution ailment, longer duration of illness will lead to increase in number of workdays lost and vice versa. The mean duration of illness in this study is 9.83 days; perhaps explaining the reason duration of illness has a positive influence on workdays lost. Number of visits to the pharmacy or to see a doctor was predicted to have a positive influence on workdays lost. As predicted, number of visits was found to have a positive coefficient meaning that as the number of visits to pharmacy or to see a doctor increases, the number of workdays lost will also increase. Mitigating cost was found to have a positive influence on workdays lost as hypothesised. As the number of visits for treatment increases, the mitigating cost will increase resulting to more workdays lost.

District (DISTRICT) is statistically significant at 5% level, and has a positive coefficient predicted implying that respondents in Phahameng have more workdays lost. Age (AGE) is statistically significant at 10% level of

Table 1. OLS regression results of factors influencing workdays lost.

Variable	Coefficient	Standard error	t-Statistic	Probability
C	-0.629	0.670	-0.939	0.348
HEALTH	1.032	0.312	3.310	0.001***
DLNES	0.303	0.009	34.366	0.000***
AGE	-0.017	0.009	-1.823	0.069*
OTC	0.274	0.392	0.701	0.484
TRAD	-0.712	0.706	-1.009	0.314
NMED	-0.218	0.679	-0.321	0.748
LOWINC	-0.409	0.465	-0.881	0.379
HIGHINC	-0.009	0.627	-0.014	0.989
DISTRICT	0.693	0.292	2.372	0.018**
AILMENT	-0.431	0.468	-0.918	0.359
VSTNR	0.773	0.130	5.943	0.000***
NRTIMES	-0.067	0.057	-1.174	0.241
MGTCOST	0.007	0.001	5.240	0.000***
R^2		0.860		
R^2 Adj.		0.854		

C, Constant; HEALTH, Dummy, 1 if ill, 0, not ill (illness is not air-pollution related); DLNES, duration of illness; AGE: age of respondent (in years); OTC, over-the-counter medication; TRAD, traditional medication; NMED, no medication; LOWINC, monthly income of household ranging from <, R2000 to R3500; HIGHINC, monthly income of household ranging from >R5000 to R6500 and above; DISTRICT: the two study areas (1, Phahameng, 0, Rocklands); AILMENT: air pollution ailment; VSTNR, number of visits for treatment; NRTIMES, number of times air-pollution related ailment(s) occurred in a year; MGTCOST, mitigating cost; ***significant at 1% level, **significant at 5% level and *significant at 1% level.

significance. Age was hypothesised to positively or negatively influence workdays lost. Age was found to have a negative influence on workdays lost. From the study areas, the mean age is 47.61 years. According to literature, the marginal effect of age on workdays lost is negative at a younger age but positive as age progresses and may explain why age in this study has a negative influence on workdays lost. Over-the-counter medication (OTC), traditional treatment (TRAD) and no medication (NMED) may be interpreted as determinants of workdays lost. However, over-the-counter variable with positive coefficient is not significant.

The total cost incurred on treatment (medical fees plus transportation fee) of air pollution refers to the mitigating cost in this study. From the survey, 4.30% of the respondent have medical insurance or went to the clinic which offers free medical services. Therefore, transportation cost only is considered as their mitigating cost. An assumed amount of R80 (Rand, 2011; 1USD = R8.0), which is the average cost of transportation, is therefore considered as the total cost incurred.

The average mitigating cost per person in Phahameng is estimated at R116.83 and R109.59 for the sampled households in Rocklands. The maximum mitigating cost in Phahameng is R1000 while that of Rocklands is R350. The cumulative probability distribution in Figure 2 shows the mitigating cost of the study areas.

Figure 2 shows that 7% of the sampled households have zero mitigating cost and it can be inferred that this 7% are those respondents who took no medication during their last episode of ailments due to air pollution or respondents that were not sick. About 64% of the respondents paid R100 or less while 99% paid R500 or less on their last episode of sickness due to air pollution. About 1% paid more than R500 on mitigating cost.

Ordinary Least Square Regression Model (OLS) was used to determine the factors influencing mitigating cost, the second economic parameter considered in this study. Table 2 shows the result of the factors influencing mitigating cost.

From Table 2, the R-square value of 0.42 indicates that the independent variables included in this study explain about 42% of the variation in the dependent variable. A small R-squared value indicates that there are some other factors not considered in this model and which have a major influence on the total cost of illness as a result of air pollution. It is of interest however, to mention that most of the variables are statistically significant.

Similarly, most of the statistically significant variables have the expected signs. HIGHINC, DLNES, WKDLOST, AILMENT and OTC are statistically significant at 1% level of significance. High income was found to have a positive influence on mitigating cost as was hypothesised. The reason is that respondents in the high income category

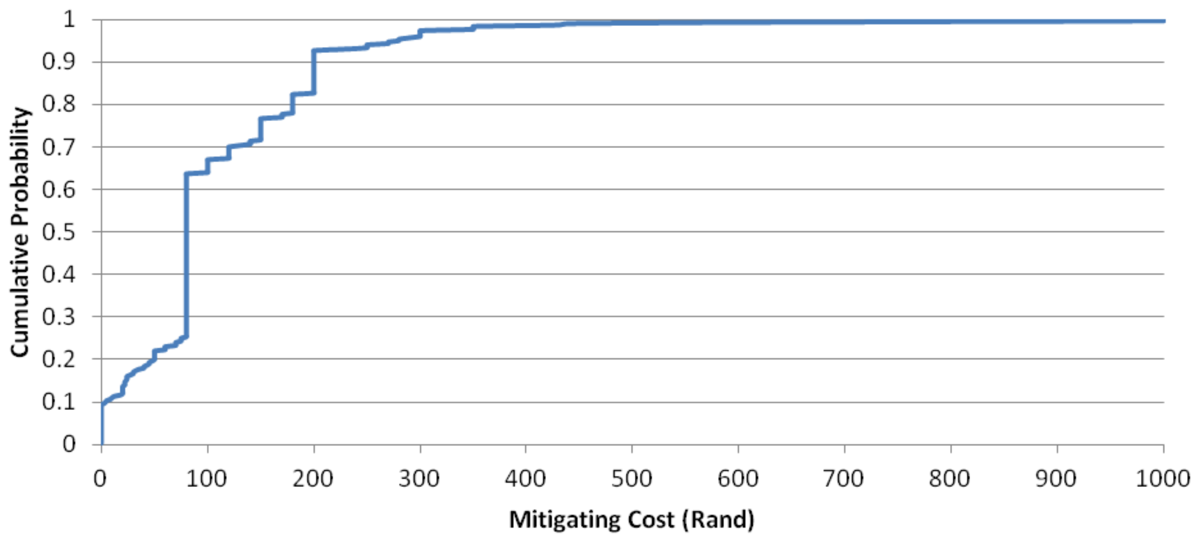

Figure 2. Cumulative probability distribution of mitigating cost in the study areas

Table 2. OLS regression results of factors influencing mitigating cost.

Variable	Coefficient	Standard error	t-Statistics	Probability
C	-5.210	24.649	-0.211	0.833
LOWINC	1.117	17.904	0.062	0.950
HIGHINC	65.702	23.511	2.795	0.005***
DLNES	-1.984	0.746	-2.660	0.008***
DISTRICT	23.778	11.119	2.138	0.033**
AILMENT	117.525	19.378	6.065	0.000***
WKDLOST	11.580	2.124	5.452	0.000***
OTC	-75.709	14.146	-5.352	0.000***
TRAD	-47.106	26.599	-1.771	0.078*
NMED	-48.678	26.168	-1.860	0.064*
SELFEMPLYD	-13.391	18.775	-0.713	0.476
STUDENT	26.797	23.552	1.137	0.256
UNEMPLYD	-27.057	12.951	-2.089	0.038**
VSTNR	6.281	4.746	1.323	0.187
R^2		0.420		
R^2 Adj.		0.394		

C, Constant; LOWINC, monthly income of household ranging from <, R2000 to R3500; HIGHINC, monthly income of household ranging from >R5000 to R6500 and above; DLNES, duration of illness; AILMENT, air pollution ailment; WKDLOST, number of workdays lost (for employed respondents) or number of days not able to perform daily routine or activities (for self-employed or unemployed respondent) or absenteeism from school (for student) (in days); OTC, over-the-counter medication; TRAD, traditional medication; NMED, no medication; SELFEMPLYD, self employed; STUDENT, student; UNEMPLYD, unemployed; VSTNR, number of visits for treatment; ***significant at 1% level, **significant at 5% level and *significant at 1% level.

are assumed to choose the option of seeking a medical practitioner for treatment of air pollution ailments which will result to high mitigating cost. Unexpectedly, duration of illness was found to have a negative influence on mitigating cost. The finding indicates that respondents who took a long time (average duration of illness is 9.83 days) to recover from ailments associated with air pollution have less mitigating cost. Possible reasons for this could be that the respondents might not make subsequent visits to the pharmacy or to see a doctor after been treated at the first visit or the respondents' that have long duration of illness might have chosen other treatment methods (over-the-counter medication, traditional treatment or no medication) which are less expensive relative to consulting a medical practitioner. Workdays lost was hypothesised to positively or negatively influence mitigating cost. The results shows a positive coefficient for workdays lost meaning the more number of days lost as a result of air pollution ailments, the higher the mitigating cost. Ailment has a positive influence on mitigating cost as hypothesised. Respondents with air pollution ailments and having chronic health challenges before are assumed to have high mitigating cost. Over-the-counter medication has a negative influence on mitigating cost as predicted; meaning that respondents that use over-the counter-medication have a lower mitigating cost.

DISTRICT and respondents that are UNEMPLYED are statistically significant at 5% level of significance and have the expected signs. District has a positive coefficient signifying Phahameng respondents have a higher mitigating cost. Unemployed respondents have a negative coefficient meaning respondents that are unemployed will have a lower mitigating cost. Traditional treatment (TRAD) and no medication (NMED), variables of the treatment methods used to treat air pollution ailments, are statistically significant at 10% and also have the expected direction of influence. Traditional treatment and no medication have a negative influence on mitigating cost implying that respondents that choose these treatment methods have a lower cost to pay for treatment.

DISCUSSION

Investigating the economic cost of air pollution in terms of workdays lost and mitigating cost and identifying factors that could influence these economic parameters is of great importance to provide households and policy makers with correct and relevant advice to reduce air pollution, both indoors and outdoors, to a level that will not be detrimental to health. The protection of human health and the natural environment is an explicit goal not only in economic decisions but also in political decision making. Unfortunately, there is no previous study carried out within Mangaung metro municipality addressing air pollution issues, hence the relevance of this research. No measures have never being taken in any township of Mangaung metro munipality to reduce air pollution as it is believed that air pollution is not a problem. The results have proved that air pollution is a significant problem in the study areas. The effect of air pollution is measured by higher mitigating cost and workdays lost during period of illnesses. These findings provide a basis for setting priorities for action in the municipality. The results may also prove to be useful since every economic decision is based on recognising the seriousness of the problem. Thus, whether in physical or in economic terms, some control measures to reduce air pollution, both indoors and outdoors, could lead to considerable economic benefit.

Conclusion

The result from the OLS model fitted to investigate the factors influencing workdays lost revealed that health, duration of illness, number of visits to doctor or pharmacy for treatment, district, age and mitigating cost are statistically significant confirming them as the principal factors influencing workdays lost. Over-the-counter medication, traditional treatment and no medication may be interpreted as a determinant of workdays lost. However, none of the treatment methods were found to be statistically significant. Over-the-counter variable with positive coefficient is not significant.

High income, duration of illness, district, ailment, workdays lost, over-the-counter medication, traditional treatment, no medication and the unemployed were all found to be statistically significant implying that these factors are important as they influence the cost incurred on the treatment of air pollution ailment.

In conclusion, air pollution is a significant problem in Phahameng and Rocklands, within Mangaung metro municipality; considering the high health cost incurred from treatment of air pollution ailments and the duration of the illness which invariably lead to more work lost days. The greatest source of indoor air pollution experienced by the community is due to the burning of paraffin heaters to heat their homes. A means to ensure the community does not experience much air pollution related illnesses is by incentivising the rural community to use a cleaner energy source (e.g. electricity, gas) for space heating. The greatest source of outdoor air pollution is the burning of refuse by the community. Waste collection service level must be improved to ensure cleanliness of the community. Thus, all households in informal settlements must be provided with access to refuse removal. Environmental awareness can be created to ensure that the communities are aware of the causes and effects of air pollution. Further development in the use of solar energy or wind power is an important area to consider for reducing indoor air pollution to a level that will not be detrimental to health.

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