ECONOMIC ANALYSIS OF HEALTH EFFECTS OF INDUSTRIAL AIR POLLUTION IN KENYA: A CASE OF WEBUYE AND ITS ENVIRONS

BY

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DECLARATION

Declaration by the Candidate

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Declaration by Supervisors

This thesis has been submitted for examination with our approval as the university supervisors

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DEDICATION

I dedicate this research work to my family for their immense love for education and moral support.

ABSTRACT

The significance of the pulp and paper industry either historically or at present cannot be gainsaid. However, this industry has been characterised as resource inefficient and heavy pollutant. In contemporary times, air pollution is considered an important research driver for a global public health protection. This study conducted an economic analysis of the health effects of industrial air pollution in Kenya, specifically in Webuye town and its environs. This was realized by estimating levels of ambient air quality through the use of economic tools, evaluating the economic implication of human health of emission and post emission pollution and examining the willingness to pay measures for associated health effects. The study was anchored on the Theory of Consumer Behaviour and its attendant approaches- Hedonic Pricing valuation and Contingent Valuation. Mixed research design methodology was employed in the form of meta-analysis, correlational study design and observational population-based cohort study. The study conducted a household survey comprising of 566 household heads selected on the basis of the National Sampling Survey and Evaluation Programme IV. The study analysed emission between two time periods of 2007 and 2009 (with emission) and between 2014 and 2015 (without emission). The study found that the mean emission rate for Particulate Matter for Webuye town as 102.1712 $\mu g/m^3$which is about three times the allowed emission rates by Environmental Protection Agency. As regards to respiratory symptoms suffered by households in these neighbourhoods, the study also found out that the most prevalent symptom was a persistent cough since it presented in about seven in every ten respondents in Webuye when emissions were present. Further, prevalence rates of respiratory symptoms were observed to be higher in Webuye at the time of emission. Again, concerning Lower Respiratory Tract Infection, the study finds a significant difference between prevalence in the emission and post emission periods. The study also found a positive association between PM_{10} concentration and prevalence of respiratory symptoms among household members. Regarding willingness to pay, the study found that property structural characteristics were significant and positively related to housing values. Conversely, air pollution was found to have a negative impact on housing values. The study concludes that for a given household, each unit-increment in PM_{10} concentration effects an estimated decrease in housing-unit value of -0.541 times housing-unit value divided by the associated PM_{10} level. These findings point to the fact that industrial pollution when allowed to proceed unabated will lead to a contaminated atmosphere which gravely affects human health and diminishes the quality of life and economic well-being of individuals as expressed in this study on reduced housing values. These conditions are the same irrespective of where the polluting agent is located. The study recommends that an industrial national pollution standard established in Kenya be enforced. The standards should be monitored through a pollution monitoring centre as part of standards enforcement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

COI	Cost of Illness
CVM	Contingent Valuation Method
CAAQS	Canada Ambient Air Quality Standards
EEA	European Environmental Agency
EPA	Environmental Protection Agency of US
HPM	Hedonistic Pricing Model
LRTI	Lower Respiratory tract infection
NAAQS	National Ambient Air Quality Standards
NEMA	National Environmental Management Authority
NO	Oxides of Nitrogen
PM	Particulate Matter
SO_2	Sulphur Dioxide
UNEP	United Nations Environment Programme
URTI	Upper Respiratory tract infection

DEFINITION OF OPERATIONAL TERMS

COI--Cost of illness

The medical costs of treatment (medicine, physician, medical tests and hospitalization) and indirect costs (loss of wages due to illness, opportunity lost due to absence from school, etc.). The COI, however, has serious limitations as it does not consider the willingness to pay of the individual to avoid the occurrence of health damage, and the willingness to pay (WTP) to reduce the risk to death.

CVM ---Contingent valuation method

The CVM is a survey method wherein respondents are asked how much they would be willing to pay to reduce the occurrence of disease (morbidity) and to reduce the risk of death (mortality).

HWA --Hedonistic Wage Analysis

Determines how much workers are paid more for more risky jobs. Considering that different occupations involve differing risks, employers have to pay a wage premium to motivate workers to undertake jobs with higher risks. From a measure of this premium, an estimate of the market value of small changes in fatality risk can be derived.

Willingness to pay

This is the maximum amount an individual is willing to hand over to derive a product or service. The price of the transaction will thus be at a point somewhere between a buyer's willingness to pay and a seller's willingness to accept.

Particulate matter

This is the sum of all solid and liquid particles suspended in air many of which are hazardous. This complex mixture includes both organic and inorganic particles, such as dust, pollen, soot, smoke, and liquid droplets.

Ambient air quality

This is criteria or standards are concentrations of pollutants in the air (usually outdoor air but sometimes indoor air) specified for a variety of reasons including for the protection of human health, buildings, crops, vegetation, ecosystems, as well as for planning and other purposes

Exposure-response function

This measures the relationship between exposure to pollution as a cause and specific outcomes as an effect. In this study, it refers to periods the affected persons remained unhealthy during a specific period regardless of when the pollution occurs

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CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Paper as a commodity is of great importance to humankind as it has continued to define human civilisation. The significance of the pulp and paper industry either historically or at present cannot be gainsaid. The World Bank (2014) reported that pulp and paper products were the second most traded commodities based on quantity globally. This privileged position of the industry means that in addition to direct products of pulp and paper, the industry contributes enormously in terms of employment and improved livelihoods of household at a micro level (Panwar, 2006; Hubacek, 2009). According to Food and Agriculture Organisation of United Nations (FAO) (2014) for the period 1990-2011, the pulp and paper global industry employed directly an annual average of 103 million people of which about 12% were in 7 pulp and paper producing countries of sub-Sahara Africa.

These successes notwithstanding, the pulp and paper industry has been characterised as resource inefficient and heavy pollutant. This industry according to Ince1, Cetecioglu and Ince (2012) use approximately 4% of total energy used worldwide. In addition, large amounts of water are used to support the paper manufacturing processes. This position is aggravated by more than 100 million kilos of toxic pollutants that are released every year from this industry (Cheremisinoff & Rosenfeld, 2010). These toxic pollutants are in the form of wastewater, solid and hazardous waste as well as gas emissions.

Wastewater has been found to contain lignin, carbohydrate and extractives and the treatment of these wastewaters biologically is difficult. In some instances, toxic compounds such as resin acids, unsaturated fatty acids, diterpene alcohols, juvaniones, chlorinated resin acids, (Pokhrel & Viraraghavan, 2004) may subsist. Solid wastes from pulp and paper industries are mainly treatment sludges, lime mud, lime slacker grits, green liquor dregs, boiler and furnace ash, scrubber sludges, and wood processing residuals (Environmental Protection Agency (EPA), 2002).

Extensive research on the subject by EPA (2002) point out to the fact that gas emissions would normally occur in the form of water vapours, particulate or particulate matter (PM) nitrogen oxides, volatile organic compounds (VOCs), sulphur oxides and total reduced sulphur compounds (TRS). EPA has also estimated that U.S. pulp and paper mills release approximately 245,000 metric tons of toxic air pollutants each year. Browne *et al.* (2012) have estimated that globally, pulp and paper industry is responsible for at least 2% of carbon dioxide emissions.

There is a paucity of empirical evidence to indicate air pollution levels that are pulp and paper-specific in developing countries more so Africa (WHO, 2012). While this is the case compared to developed countries where pollution abatement and regulation thrive, pollution levels in developing countries are bound to be greater. However, some scholars have provided seminal estimates of industrial air pollution levels with varied success. Milaku and Kariuki (2001) generated a basic spatial distribution map in respect of TSP using GIS techniques with the aim of giving city planners a much more effective visual perspective of the spatial variations in city air quality in Nairobi, Kenya. An assessment of ozone, nitrogen oxides, air particulate matter (PM_{10}) and trace elements level in the ambient air of Nairobi city revealed that the mean PM_{10} values were much higher than the recommended WHO guidelines; in some cases up to over 150 % or even higher (Odhiambo, *et al.(2010)* cited in Maina (2004) . Omanga, *et al.* (2014) did not commit to measuring air pollution levels in their study which assessed community awareness of rural industrial air pollution.

Nonetheless, air pollution characteristics are not homogenous in the industry. For instance Kraft milling which employs the Kraft chemical recovery process, is responsible for generation and release combustion compounds such as nitrogen oxides (NO_x), sulphur dioxide (SO_2), carbon dioxide (CO_2), and particulates (Staudt (2010); Silva & Mendes (2008); Bordado & Gomes(2002); World Bank (1998); EPA (1993)). This is similar to the plant at Webuye hence the converging interest.

1.1.1 Health Effects of Pulp and Paper Air Pollution

Air pollution became a health issue following the Meuse Valley fog in 1930 (Firket, 1936) and the London smog in 1952 that killed an estimated 4000 people. In contemporary times, air pollution is considered today an important research driver for global public health protection (WHO, 2005). In fact a high-level exposure to these pollutants in the long-term and short-term can lead to some important adverse health effects, ranging from irritation of the respiratory system to contributing to increased prevalence and incidence of respiratory and cardiovascular diseases and premature death in people of all ages. Children are particularly are susceptible given their very fast metabolism (WHO, 2005).

Health effects resulting from long-term or short-term exposure to the pollutant, irrespective of the length of exposure, the effects may be acute or mild. Deaths or mortality occasioned by pollution was observed in London in 1952. The smog episode lasted for only five days. While there is limited empirical evidence on health effects localised to pulp and paper pollution, there are several studies that relate to similar industrial processes that this study may relate to.

Morbidity effects have been observed as either cardiovascular (relating to the heart and circulation system) or respiratory. Farmer *et al.* (2014); Hoek *et al.* (2013); Egondi, *et al.* (2013) Olmo *et al.* (2011) among others have found a positive relationship between a long term or short term pollution exposure to cardio-respiratory diseases. Karakis *et al.* (2009) found Life Prevalence (LP) of upper respiratory tract chronic diseases (URTCD) and asthma in children aged 0-14 years living in the rural Negev, Israel to be associated with indirect measurements of exposure (distance, wind direction and odour complaints). Short-term exposure has been linked to high hospital admission of young children for lower respiratory infections in Vietnam (Le *et al.* 2012) among others. Zúñiga *et al.* (2016) conjectured an association between air pollution in Panama City and an increase in cardiovascular, respiratory, and diabetes mortality.

Over and above incidences of disease and its prevalence, air pollution has been indicated to cause strain on health resources available for dealing with other forms of diseases. Wordley, Walters and Ayres (1997); Nakhlé (2001); Ljungman and, Mittleman (2014) Donaldson, and Wedzicha (2014) found Significant associations between all respiratory admissions, cerebrovascular admissions, and bronchitis admissions and PM10 on the same day or over a period normally not exceeding a week. Over and above admission, emergency room (ER) visit was also seen to be exacerbated by an increase in the level of a pollutant in many cities across the globe. Growing epidemiologic evidence indicates that inhalation of airborne PM increases respiratory and cardiac mortality and morbidity, and produces a range of adverse respiratory health outcomes such as asthma, lung function decline, lung cancer, and chronic obstructive pulmonary disease (COPD) (Ayres *et al...*, 2008, Ristovski *et al..*, 2011). Epidemiologic data also indicate that air pollution also aggravates asthma, with the exacerbation correlating with levels of environmental particles (Schwartz *et al..* 1993). Likewise, the rate of decline seen in COPD patients correlates with the level of air pollution where the patients live (Pope & Kanner, 1993).

In a study carried out in Bangkok, Wong *et al..*, (2010) found the magnitude of the effects for cardiovascular and respiratory mortality to be generally higher than for all natural mortality at all ages. They also report that effects associated with PM10 and O3 in all natural, cardiovascular; and respiratory mortality were found to be higher in Bangkok than in the three Chinese cities. The explanation for these three findings might be related to consistently higher daily mean temperatures in Bangkok, variations in average time spent outdoors by the susceptible populations, and the fact that less air conditioning is available and used in Bangkok than in the other cities since PM10 concentrations were much higher in Bangkok. Similar findings are observed in multi cities in Latin America by Romieu *et al..* (2012).

Since there are numerous emissions in pulp and paper milling over and above PM, this study sought to provide empirical evidence on health effects occasioned by all the possible emissions of pulp and paper milling as a single source pollutant. This evidence includes the prevalence of respiratory symptoms and the relationship between exposure to pollutant and morbidity (sickness events).

1.1.2 Economic analysis

Economic analysis of this study is premised on consumer theory which opines that a rational consumer will strive to pay for the consumption of goods that promises maximum utility. According to Murty *et al.*,(2004) commodities could be distinguished by the characteristics they possess and their prices are functions of these characteristics. From the point of view of the owner, land property could be distinguished in terms of its location, size, and local environmental quality, while from the worker's perspective, a job is a differentiated product in terms of the risk of an on job accident, working conditions, prestige, training and enhancement of skills, and the local environmental quality at the workplace.

As such, environmental characteristics like air or water quality affect the price of land either as a producer good or as a consumer good. Ridker (1967) and Ridker and Henning (1976) provided the first empirical evidence that air pollution affects the property values. Freeman (1974), and Rosen (1974) used the hedonic price theory to interpret the derivative of hedonic property price function with respect to air pollution as a marginal implicit price and therefore the marginal willingness-to-pay (WTP) of individuals for air pollution reduction. More recent studies such as Gonzalez, Leipnik, and Mazumder (2013); Leguizamon (2012); Yusuf and Resosudarmo (2009) have also made similar observations.

The other approach which has been used in this study is the Contingent Valuation Method (CVM). This is based on direct methods of eliciting from individual the value they would attribute to a public good in the market-like environment. Through CVM the study determined the compensating variation (CV) and equivalent variation (EV) and by extension the WTP individuals to obtain the good or to avoid the loss (Desaiguesa, *et al.*. (2011); Lee *et al.*. (2011)).

1.2 Statement of the Problem

Webuye Pan Paper Mills has been operating since its establishment in 1974 despite the several environmental concerns raised by the residents concerning plantation establishment, liquid effluents, air emissions, sludge and solid waste disposal. Experts have questioned the purification process of waste from this mill saying it is inadequate to mitigate against adverse effects of environmental pollution. An air sample taken from Webuye Pan Paper mills by Environmental Law Alliance Worldwide (ELAW) in September 2009 certified that the hydrogen sulphite level was more than 500 times the permissible limit in California and more than 140 times the WHO recommended level (ELAW, 2012)

By sheer observation, the most obvious environmental effect of pulp and paper milling in Webuye and its environs manifests itself in malodorous gasses emitted in the air around the mill. According to Kenya Land Alliance (2008), local people have reported that the smoke from the paper factory causes rusting on iron sheets within a year of building the house hence corroded roofs and discoloured vegetation. The same report indicates that residents suffer from allergies and respiratory diseases due to gaseous emissions from the factory.

Omanga (2014) acknowledges that Kenyans living around industrial polluters acknowledge the risk involved especially on their health. Such recognition though an important milestone, would not provide an empirical basis of pollution abatements such as risk measure in disease prevalence and the attendant cost of pollution. On the other hand, the closure of the mill though stopping the emission of pollutants to the environment does not negate the continuous effect from previous emissions. For instance, Falth(2000) reports that the closure of the mill in Montreal, Canada did not immediately stop the emission effects. The facts that the factory was closed some few years ago, the effects of the pollution are still felt. This study would also endeavour to assess whether the closure of the factory has helped ease the pollution effects among the residents.

This study, therefore, provides a basis of dealing with industrial pollution by estimating ambient air pollution levels, assessing interactions between pollution and disease prevalence as well as obtaining a valuation for these negative effects occasioned by pollution.

1.3 Objectives of the Study

1.3.1 General objective

This study conducts an economic analysis of the health effects of industrial air pollution in Webuye town and its environs, Kenya.

1.3.2 Specific objectives

1. To estimate, using economic tools, the levels of ambient air quality in Webuye town and its environs.
2. To evaluate the economic implications of health effects of emission and post emission pollution.
3. To examine the willingness to pay (WTP) estimates associated with emission

health effects.

4. To examine the willingness to pay (WTP) estimates associated with post-emission health effects.

1.4 Hypotheses

The study tested the following hypothesis.

$H0_1$: There is no significant difference in the levels of ambient air quality between Webuye and its environs and the control site.

$H0_2$: The economic impacts of emission and post-emission exposure effects on human health in Webuye town and environs are not significant.

$H0_3$: Association between Willingness to pay estimates (WTP) and emission health effects in Webuye town and its environs are not significant.

$H0_4$: Association between Willingness to pay estimates (WTP) and post-emission health effects in Webuye town and its environs are not significant.

1.5 Justification of the Study

The Kenya Vision 2030 social pillar has declared that it seeks to build a just and cohesive society living in a clean environment. This cannot be achieved if pollution remains unabated. Similar studies in the environs of Webuye (Orori, 2008; Vymazal, 2008; Achoka 1998 among others) have tended to concentrate on the effect of pulp and paper milling on water pollution while failing to determine the effect on human health. By identifying levels of ambient air pollution from an industrial source this study will add value by providing the basis of building national air quality standards. It may also form a basis of engagement and conversations by all concerned stakeholders.

Establishing relationships between ambient air pollution and respiratory disease prevalence, the study has quantified human health risk factors associated with pollution. This information may be used by health workers to educate masses about the risk of the exposure occasioned by living close proximity to emission cites. Health policy framework could also benefit from the findings of this study.

Valuing pollution services is important for policy planning and improving the socio-economic, environment and well-being of households. However, what motivates this study is the use of SP methods, in other words, hypothetical markets, to examine the WTP values for connecting and improving health services. This is an important exercise, because of the lack of market information/data from health distributors. Also, there are direct and indirect benefits to be obtained from modern forms of pollution abatement. Some of the key socio-economic and environmental benefits include direct benefits such as reduced IAP, income generation, reduced deforestation, as well as indirect benefits, such as security and education.

1.6 Scope of the study

The study was carried out in Webuye town and its environs. The environs considered are Chimoi, Lugulu and Matisi. A control site of Kakamega town was also used. The study was carried out in two phases. While emissions by the factory were ongoing between 2007 and 2009: and when emission had ceased – between 2014 and 2015.

1.7 Limitation of the study

The study focus was on economic assessment of pollution health effects arising from population interaction with emissions from a single industrial source. Though the findings are invariably important, they may not be generalizable to other circumstances since pollution is uniquely in a rural setup and from paper milling specific from the Kraft process.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of extant literature and the theoretical framework which the enquiry undertook in this study is based. The chapter starts by reviewing two theories pertinent to the valuation of non-marketed goods such as ambient air quality. In which case, revealed preference and stated preference theories have been considered. The construct for revealed preference theory in the current study is the hedonic valuation model while the contingent valuation model is the construct for the stated preference theory.

On the other hand, in line with the four objectives of the study, literature has been reviewed to assess and understand previous interactions of the variables under the study in order to adequately address the attendant gaps.

2.2 Theoretical Framework

This research study was guided by the Theory of Consumer Behaviour. Specifically, the study was anchored on revealed and stated preference theories which are operationalisation of the former. A rational consumer is assumed to be motivated by the desire to maximize his or her utility derived from consumption of the bundle of goods offered by the market of goods and services (Samuelson, 1964). In the case of a non-marketed good such as air quality, its price can be estimated by assessing its effects on marketed goods such as housing values. The concepts of willingness to pay (WTP) for improved air quality or willingness to accept (WTA) to endure effects of poor air quality thus come into application in consumer choice.

Economists utilize two approaches to estimate individuals' willingness to pay for environmental improvements, namely revealed preference and stated preference methods. The revealed preference approach is based on the observed behaviour of individuals in terms of their spending on goods and services offered in the market. On the other hand, for the stated preference approach individuals directly express their preferences in their assessment of environmental quality.

In line with the revealed preference approach, research by Rosen ushered in the widespread use of 'hedonic' modelling (Rosen 1974). An environmental good such as air quality is a non-market good.

2.2.1 Revealed Preference Theory

Consumer theory is key to analysing consumer behaviour in a microeconomic environment. This theory is concerned about how consumers maximize their utility by analysing spending decisions subject to budget constraints. This is guided by consumers' revealed or stated preferences. Revealed preference theory has initial attribution to Samuelson [1938] whose work contains the first description of the concept he later called "revealed preference." The initial terminology was "selected over."

According to Samuelson (1938; 1947; 1958) revealed preference is based on the observed behaviour of individuals in terms of their spending on goods and services offered in the market. An individual is able to reveal his or her preference of consumption bundles available in the market. For instance, an individual may prefer consumption bundle A over consumption bundle B even though he could afford either of the two.

Varian (2005) contends that by 1953 the basic theory of consumer behaviour in terms of revealed preference was pretty much in place, though it was not completely rigorous. Subsequent contributions, such as Newman [1960], Uzawa [1960], and Stigum [1973] added increasing rigour to Samuelson's arguments. Chipman [1971], whose work contained a series of chapters also made a significant contribution to revealed preference. Further empirical proof has also been provided much later by Sondermann [1982], in his a one-paragraph proof of the basic revealed preference result.

When this theory is extended to include non-marketed goods, it becomes necessary to find the correlations between market behaviour and non-market goods. For instance, we can determine the change in market value associated with a complementary good (e.g. housing) to assess a value to an environmental amenity (e.g. air quality).

Research by Rosen ushered in the widespread use of 'hedonic' modelling (Rosen 1974). Under this approach, regression techniques are used to identify and estimate the relationships between housing sale prices and their amenities. It is important to realize that most of the amenities identified do not have a specific market price. Prospective homeowners do not buy bathrooms, bedrooms, neighbourhood's schools, hospitals, shopping mall or major roads among others. Instead, they are forced to consider and choose between opposing 'bundles' in the form of housing. By identifying the value implied in these decisions, hedonic regression techniques is a powerful tool for assessing these revealed y*et al.*beit concealed preferences. Consider a set of housing with varying prices y along with a series of amenities denoted by x. From this, we can construct an equation such that:

$$y = \beta x$$

Subsequent work by Freeman (1974; 1993) showed how this framework could be used to interpret existing studies of the property value-air pollution relationship. More recently, major empirical efforts, illustrating the importance of hedonic pricing on valuing air quality is witnessed in the works of Epple (1980); Chay and Greenstone (2005); Palmquist (2005); and Phaneuf, Smith, Palmquist, & Pope(2008).

The Hedonic Pricing Model (HPM), often uses variation in housing prices to estimate the value of the local environmental quality. Thus in this study HPM was considered as an imputing a price for an environmental good by examining the effect which its presence has on a relevant market priced good. By defining inverse demand function relating the quality of the environmental good which in this case is air quality, the individual's marginal willingness to pay (MWTP) for that good was be derived.

2.2.1.1 Hedonic Pricing of Air Quality

In order to understand the pricing of an environmental good such as air quality, “hedonic” modelling pioneered by Sherwin Rosen in applied (Rosen 1974). Property value data is used as a source of information on the benefits to be expected from controlling environmental disamenities such as air pollution, water pollution and noise (Freeman, 1979).

/The pricing of a house can be taken to be a function of its structural, neighbourhood and environmental characteristics. This can be expressed as;

$$PL_i = PL' (Si_1 \ldots\ldots\ldots\ldots Si_j, Ni_1 \ldots\ldots\ldots\ldots Ni_k, Qi_1 \ldots\ldots\ldots\ldots Qi_m)$$

Where S, N, and Q are structural, neighbourhood and environmental characteristics respectively (Freeman 1979).

The function PL_i is the hedonic or implicit price function for housing. Hedonic prices are implicit prices of attributes or characteristics. For instance, air quality is one of the attributes that influence house prices. Other attributes are the number of rooms a house has, the proximity of the house to schools, hospitals, industries and transport facilities. Econometrically, the marginal implicit prices of a characteristic can be found by differentiating the implicit price function with respect to that characteristic.

One of the objectives of this study is to examine the WTP estimates associated with emission health effects. The hedonic pricing model used in this study specifies air quality as one of the explanatory variables of the house price. The proxy for air quality in the model is PM_{10}. The estimated coefficient of PM_{10} is interpreted as the MWTP for any unit change in air quality. This is specified in the model in chapter Three.

2.2.2 Stated Preference Theory

In addition to revealed preference theory, economists also employ the use of stated preference data to assess environmental quality. This class of methodologies uses survey or experimental interactions with respondents to attempt to determine the value of an environmental amenity. Because these methods rely on stated preferences and not actual behaviour, there is some question of their validity in determining actual valuation.

For example, if an individual was asked how much he/she would be willing to pay to

save an endangered species, he/she might posit a number that was well beyond his/her actual preference. Stated preference valuations can be bound by either willingness to pay (WTP) or willingness to accept (WTA) responses. WTP measures are typically preferred because they typically require respondents to state valuations bound by their financial constraints. WTA measures have no practical upper bounds. Therefore, individuals are free to state arbitrarily high values to avoid environmental risks ("You'd have to give me a million dollars to accept that landfill in my neighbourhood"). One type of stated preference technique used by researchers is the contingent valuation method (CVM). Under CVM, individuals are surveyed to determine their WTP or WTA for a change in environmental quality (good or bad).
Typically, the mechanism utilized in the survey for the environmental improvement is imaginary. For example, rather than ask individuals in a certain locality what clean air is worth to them, a CVM survey might ask respondents how much they would be willing to pay for a community air pollution sink device. Such a device would be designed to remove ozone and other air pollutants within a two-mile radius. Although no such device actually exists, the WTP garnered from such a survey can be used to determine the value of requiring a new automotive technology to remove exhaust pollutants to a community or region.

2.2.2.1 Contingent Valuation of air quality

The goal of contingent valuation is to measure the compensating variation (CV) for the good in question. CV is the appropriate measure when the person must purchase the good, such as an improvement in environmental quality. CV is estimated using the

Contingent Valuation Method (CVM). CVM presents consumers with hypothetical opportunities to buy public goods and elicits preferences by asking people about their willingness to pay (WTP) for them, thus circumventing the absence of a real market (Mitchell and Carson, 2013). CV can be elicited by asking a person to report to a WTP amount. For instance, the person may be asked to report his WTP to obtain the good or to avoid the loss of the good. CVM has been in use as a means of evaluating a wide range of environmental goods and services for over 35 years, with over 2000 papers and studies using this method, most of which were from developed countries (Carson, 2000; Whittington, 2004). However, there are few studies in Kenya which have invoked CVM in valuing environmental goods, especially clean air.

2.3 Conceptual framework

The study performed an economic analysis of the health effects of industrial pollution in Kenya by employing the HPM explained earlier. In this case, the dependent variable is the value of housing whereby monthly house rent is used as the proxy of the housing value. The predictor variables in line with the model are structural characteristics; neighbourhood amenities and environmental quality. Structural characteristics were measured as a number of rooms in the house occupied. Neighbourhood amenities such as schools playgrounds and hospitals among others were observed to be fairly common since settlement occurred in relation to factory set-up. However, distance from the factory was considered as a distinguishing characteristic among the study sites used. Environmental quality was measured as PM_{10} emission rate over the period of the study. The relationship between the variables is illustrated in figure 2.1 below.

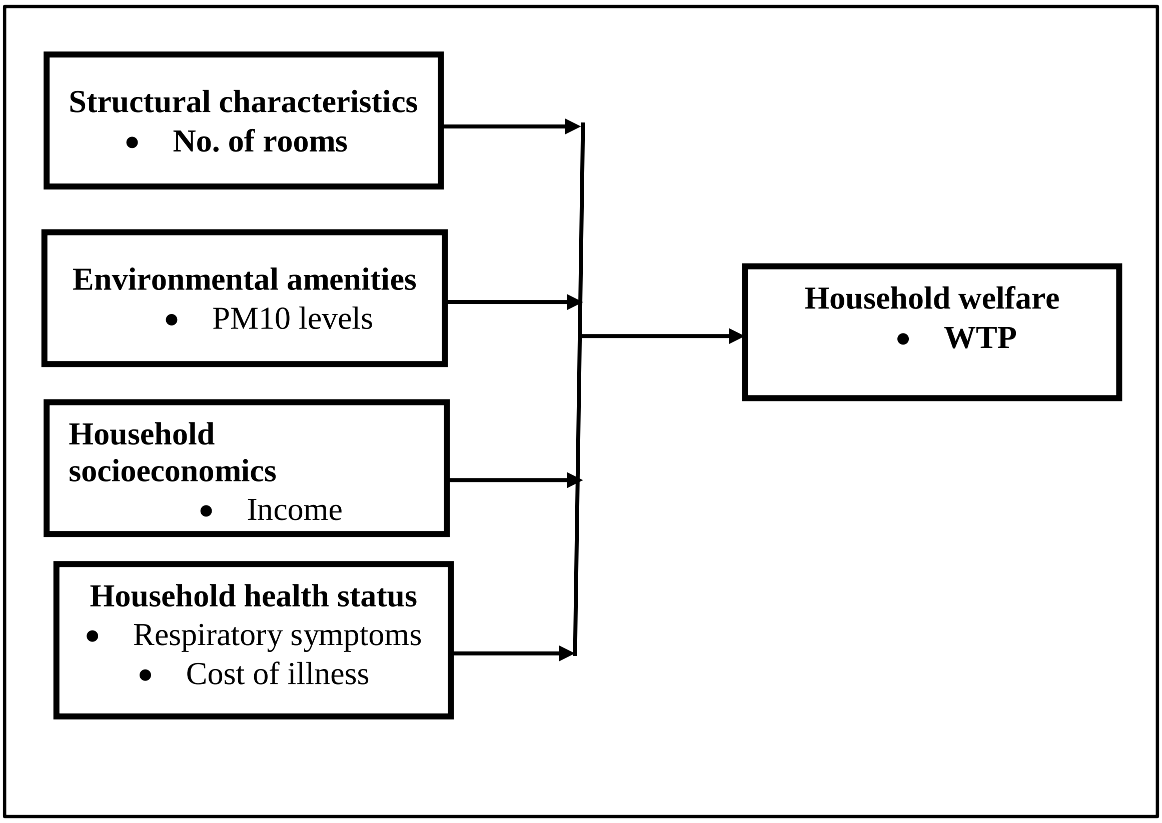

Figure 2.1: Conceptual framework

Other control variables used in the model are owner occupier condition, work site, respiratory illness suffered, average monthly income for the household, cost of treatment for respiratory illness, and smoking behaviour of the household head.

By measuring the effect of air pollution on housing values, the study derived a measure of marginal WTP which is the implicit price of air quality. Air quality does not only affect the value of housing but also affects the health of household members.

2.4 Empirical Literature Review

Many studies on environmental valuation have shown that air pollution has significant health, environmental and economic effects. The empirical strategies for estimating environmental values typically involve obtaining some behavioural data such as home sales and explaining its variation for example air quality.

2.4.1 Estimating levels of ambient air quality

Whereas it is difficult to estimate the level of ambient air pollution (AAP) globally, different authorities have made an attempt to determine the extent to which the world is affected especially arising from man-made activities. WHO maintains a database of ambient air pollution across the globe. In 2014, the database included 93 countries out of the 191 UN recognised countries of the world. Accordingly, WHO (2014) reports that highest annual mean emissions per metre cubed (µg/m3) for particulate matter are 282 µg/m3 in Pakistan while the lowest is 9 µg/m3 as reported in Iceland. The large deviation is in data is an indicator of how turbulent ambient air pollution is.

AAP and attendant human exposure are prevalent in cities. According to UNEP (2014) and World Bank (2013), urban settlements are characterised by commercial and industrial areas some of which are pollution "hot spots" in addition to busy roads. In return, residential areas found in these same cities match exposure. Whereas our study was set in an area that is characteristically different, pollution features and settlement experience were quite similar with these considered here.

Though there are several pollutants that contribute to AAP, studies and pollution abatement and mitigation methods have tended to concentrate on Particulate Matter (PM). PM is a widespread air pollutant, consisting of a mixture of solid and liquid particles suspended in the air. Commonly used indicators describing PM that are relevant to health refer to the mass concentration of particles with a diameter of less than 10 µm (PM_{10}) and of particles with a diameter of less than 2.5 µm (PM2.5).

PM2.5, often called fine PM, also comprises ultrafine particles having a diameter of less than 0.1 µm.

According to WHO (2013) in most locations in Europe, $PM_{2.5}$ constitutes 50–70% of PM10. PM between 0.1 µm and 1 µm in diameter can remain in the atmosphere for days or weeks and thus be subject to long-range transboundary transport in the air.

PM is a mixture of physical and chemical characteristics varying by location. Common chemical constituents of PM include sulphates, nitrates, ammonium, other inorganic ions such as ions of sodium, potassium, calcium, magnesium and chloride, organic and elemental carbon, crustal material, particle-bound water, metals (including cadmium, copper, nickel, vanadium and zinc) and polycyclic aromatic hydrocarbons (PAH). In addition, biological components such as allergens and microbial compounds are found in PM (WHO, 2013) which makes PM exposure to cause negative effects on human health.

While PM emissions may arise from different sources, studies undertaken that emission levels from man-made activities such as manufacturing are significant in causing AAP. Thurston and Spengler (1985) assigned roughly 40 per cent of the fine mass to particles measured in the stacks of coal-fired power plants in Boston despite the fact that this elaborate study considered sources such as soil motor vehicle, oil and salt aerosols.

Schauer *et al.* (1996) attributed 85% of PM emission in Los Angeles to industrial combustion, diesel engine exhaust, gasoline-powered vehicle exhaust, plus emissions from food cooking and wood smoke in that order. Another interesting finding in their study was that the levels of toxicity were directly related to the PM source. A US-wide study by Thurston *et al.* (2011) categorised PM sources in order of intensity as Metals Industry; Crustal/Soil Particles; Motor Vehicle Traffic; Steel Industry; Coal Combustion; Oil Combustion; Salt Particles and Biomass Burning. This AAP was witnessed in highly industrialised cities and major port cities.

The significance of industrial sources as major PM emitters is further highlighted by Zhao *et al.* (2010) 45% of PM emissions in certain regions of China was attributable to coal-fired power plants. Viana (2006) also found industrial emitters to be the predominant source of PM emission in Spain over and above road dust and traffic exhaust. This review so far indicates that industrial sources are important PM emitters like the case of Webuye paper mills which is the focus of this study.

2.4.1.1 Emission characteristics of pulp and paper industry

Pulp and paper industry is considered one of the most polluter industry in the world (Thompson *et al.*, 2001; Sumathi& Hung, 2006). The production process consists of two main steps: pulping and bleaching. Pulping is the initial stage and the source of the most pollutant of this industry. In this process, wood chips as raw material are treated to remove lignin and improve fibres for papermaking. Bleaching is the last step of the process, which aims to whiten and brighten the pulp. Whole processes of this industry are very energy and water intensive in terms of fresh water utilization (Pokhrel&Viraraghavan, 2004).

The major air emissions of the industry come from sulphite mills as recovery furnaces and burns, sulphur oxides (SOx), from Kraft operation as reduced sulphur gases and odour problems, from wood-chips digestion, spent liquor evaporation and bleaching as volatile organic carbons (VOCs), and from combustion process as nitrogen oxides (NOx) and SOx. VOCs also include ketone, alcohol and solvents such as carbon disulphide methanol, acetone and chloroform (Smook, 1992; Ince 2011).

2.4.1.2 Air quality guidelines

WHO's air quality guidelines were first published as Air Quality Guidelines for Europe in 1987 (WHO 1987). Since 1993 the Air Quality Guidelines for Europe has been revised and updated, incorporating a review of the literature published since 1987 (WHO 1999a). Also, the following additional compounds were considered in the review procedure: 1,3 butadiene, environmental tobacco smoke (ETS), fluoride, man-made vitreous fibres and platinum. Parallel to the review of the air quality guidelines for Europe, the Environmental Health Criteria series of the International Programme on Chemical Safety has continued and the health risks of more than 120 chemical compound and mixtures were estimated between 1987 and 1998.

The WHO Air Quality Guidelines for Europe (WHO 1987) were based on evidence from the epidemiological and toxicological literature published in Europe and North America. They did not consider the effects of exposure to the different ambient air particle concentrations in developing countries, as well as the different conditions in these countries. However, these guidelines were used intensively throughout the world. In view of the different conditions in developing countries, the literal application of the WHO Air Quality Guidelines for Europe could be misleading. Factors such as high and low temperature, humidity, altitude, background concentrations and nutritional status could influence the health outcomes after the population has been exposed to air pollution. To make the WHO Air Quality Guidelines for Europe globally applicable, a task force group meeting was convened at WHO Headquarters from 2-5 December 1997. The outcome of that meeting was the publication of globally applicable air quality guidelines.

The objective of WHO's Guidelines for Air Quality is to help countries derive their own national air quality standards. The guidelines are technologically feasible and consider socio-economic and cultural constraints. They provide a basis for protecting public health from the adverse effects of air pollution and for eliminating or reducing to a minimum, those air pollutants that are likely hazardous to human health. Consequently, the instruments of air quality management are also addressed in this study.

Air quality measurements are typically reported in terms of daily or annual mean concentrations of PM10 particles per cubic meter of air volume (m3). Routine air quality measurements typically describe such PM concentrations in terms of micrograms per cubic meter (μg/m3). When sufficiently sensitive measurement tools are available, concentrations of fine particles (PM2.5 or smaller), are also reported.

Small particulate pollution has health impacts even at very low concentrations –

indeed no threshold has been identified below which no damage to health is observed. Therefore, the WHO 2005 guideline limits aimed to achieve the lowest concentrations of PM possible.

Table 2.1 Selected air quality standards for PM10

Country/ regions	Annual mean	24hr mean	Source
WHO	20 $\mu g/m^3$	50$\mu g/m^3$	WHO (2005)
EU	40$\mu g/m^3$	50$\mu g/m^3$	EEA (2005)
US	-	35$\mu g/m^3$	EPA (2014)
KENYA-NEMA	150$\mu g/m^3$	70$\mu g/m^3$	RoK (2014)
CANADA	-	30 $\mu g/m^3$	CAAQS (2005)

In addition to guideline values, the Air Quality Guidelines provide interim targets for concentrations of PM10 and PM2.5 aimed at promoting a gradual shift from high to lower concentrations. If these interim targets were to be achieved, significant reductions in risks for acute and chronic health effects from air pollution can be expected. Progress towards the guideline values, however, should be the ultimate objective. The effects of PM on health occur at levels of exposure currently being experienced by many people both in urban and rural areas and in developed and developing countries – although exposures in many fast-developing cities today are often far higher than in developed cities of comparable size.

"WHO Air Quality Guidelines" estimate that reducing annual average particulate matter (PM10) concentrations from levels of 70 μg/m3, common in many developing cities, to the WHO guideline level of 20 μg/m3, could reduce air pollution-related deaths by around 15%. However, even in the European Union, where PM concentrations in many cities do comply with Guideline levels, it is estimated that average life expectancy is 8.6 months lower than it would otherwise be, due to PM exposures from human sources.

In developing countries, indoor exposure to pollutants from the household combustion of solid fuels on open fires or traditional stoves increases the risk of acute lower respiratory infections and associated mortality among young children; indoor air pollution from solid fuel use is also a major risk factor for cardiovascular disease, chronic obstructive pulmonary disease and lung cancer among adults.

There are serious risks to health not only from exposure to PM but also from exposure to ozone (O3), nitrogen dioxide (NO2) and sulphur dioxide (SO2). As with PM, concentrations are often highest largely in the urban areas of low- and middle-income countries. Ozone is a major factor in asthma morbidity and mortality, while nitrogen dioxide and sulphur dioxide also can play a role in asthma, bronchial symptoms, lung inflammation and reduced lung function.

The recommended limit in the 2005 Air Quality Guidelines was reduced from the previous level of 120 μg/m3 in previous editions of the "WHO Air Quality Guidelines" based on recent conclusive associations between daily mortality and lower ozone concentrations.

2.4.2 Economic Analysis of Health Effects of Pollution

2.4.2.1 Exposure characteristics

When human beings interact with the environment, depending on the nature and levels of ambience, they are bound to be exposed to pollutants. Exposure can be one off depending on the contact with pollutant or several times across a span of time. In effect total daily exposure of an individual to air pollution is the sum of the separate contacts to air pollution experienced by that individual as he passes through a series of environments (also called micro-environments) during the course of the day (e.g. at home, while commuting, in the streets, etc.). Exposures in each of these environments can be estimated as the product of the concentration of the pollutant in question and the time spent in the environment.

There are many factors that can account for the substantial differences between the concentrations of pollutants measured at central sites and those in the breathing zone of residents of the community. Many of these factors can be modelled and such models have been used for estimating dose distributions associated with ambient air concentrations.

The concentrations of classical pollutants in ambient air of European countries and of the United States have been extensively discussed in the Air Quality Guidelines for Europe (WHO 1999a). In developing countries, by contrast, the concentrations of pollution levels in ambient air are higher by an order of magnitude, according to the main source of information on air pollution in developing countries, the Air Management Information System (AMIS).

Indoor air pollutants usually differ in type and concentration from outdoor air pollutants. Indoor pollutants include environmental tobacco smoke, biological particles, non-biological particles, volatile organic compounds, nitrogen oxides, lead, radon, carbon monoxide, asbestos, various synthetic chemicals and others. Degradation of indoor air quality has been associated with a range of health effects, from discomfort and irritation to chronic pathologies and cancers.

On a global scale, biomass fuels are used daily in about half the world's households as energy for cooking and/or heating. Biomass smoke contains significant amounts of several important pollutants: carbon monoxide, particulate matter, hydrocarbons and to a lesser extent, nitrogen oxides. However, biomass smoke also contains many organic compounds that are thought to be toxic, carcinogenic, mutagenic or otherwise of concern. In China, coal burning is a major source of indoor air pollution and coal smoke contains all of these pollutants as well as additional ones, e.g. sulphur oxides and heavy metals such as lead.

An unknown, but significant, the proportion of biomass fuel burning takes place in conditions where much of the air-borne effluent is released into poorly ventilated living areas. Therefore, some of the highest concentrations of particulate matter and other pollutants occur in rural, indoor environments in developing countries. Due to the high pollutant concentrations and the large populations involved, the total human exposure to many important air pollutants can be much higher in homes of the poor in developing countries than in the outdoor air of cities in the developed world.

Altitude, temperature and humidity vary significantly across the globe. Brasseur, *et al.* (2009) observes that at increased altitude the partial pressure of oxygen falls and inhalation increases in compensation. For particles, this increased inhalation will lead to an increased intake of airborne particles. On the other hand, for gaseous pollutants, no increase in effects over those experienced at sea level would be expected. Temperature has a very significant effect on health, whereas humidity is unlikely to have a significant effect on the toxicity of gaseous pollutants.

The age structure of populations differs markedly from country to country. Old people tend to show increased susceptibility to air pollution. Very young children may also be at increased risk. For instance, studies by Patankar and Trivedi (2011) showed that children attending schools located proximate to the pollution sites were likely to suffer certain air pollution-related health conditions than their counterparts in different environments. Also, people with a poor standard of living suffer from nutritional deficiencies, infectious disease due to poor sanitation and overcrowding, and tend to be provided with a poor standard of medical care. Each of these factors may render individuals more susceptible to the effects of air pollution. Diseases which produce a narrowing of the airways, a reduction in the area of the gas-exchange surface of the lung and an increased alteration of inhalation-perfusion ratios are likely to make the subject more susceptible to the effects of a range of air pollutants.

Carlsen (2014), notes that the adverse effects from exposure to air pollution can be more severe in susceptible individuals. These are often considered to be the very old and very young, or individuals with a pre-existing condition which makes them more sensitive to exposure to air pollution. Susceptibility notwithstanding it is important to acknowledge that continued exposure will lead to otherwise healthy individuals becoming sick and hence susceptible, thus one thing leads to another.

2.4.2.2 Effect of pollution exposure on human health

The main effects of air pollution on the body are found in the cardiopulmonary system. The respiratory system is most exposed as humans breathe around 20m3 of air per day. The inhaled air enters the nose or mouth, goes into the bronchi, the bronchioles and the alveoli, where inhaled oxygen (O_2) is exchanged through the epithelium of the alveolar wall. From there O_2 goes into the bloodstream, which delivers it to the cells in the body. Carbon dioxide (CO_2) from the cells is exchanged in the opposite direction to the exhaled air (WHO, 2000).

While it has been illustrated in the preceding review a host of pollutant which plagues ambient air quality, from a perspective of effect on human health, this study concentrated on particulate matter. On the other hand, while morbidity and mortality are feasible end point when it comes to pollution health effects, the study chose to limit its scope to morbidity since its measurement is more plausible in its various instances, unlike mortality which is final and may be confounding. The study moves to consider exactly that in this proceeding section.

2.4.2.3 Morbidity effect of particulate matter (PM) on human health

Particulate matter has been confirmed to affect more people than any other pollutant. The major components of PM are sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. The most health-damaging particles are those with a diameter of 10 microns or less, ($\leq PM_{10}$), which can penetrate and lodge deep inside the lungs. Long-lasting exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer.

Air quality measurements are typically reported in terms of daily or annual mean concentrations of PM_{10} particles per cubic meter of air volume (m^3). Routine air quality measurements typically describe such PM concentrations in terms of micrograms per cubic meter (µg/m3). When sufficiently sensitive measurement tools are available, concentrations of fine particles (PM2.5 or smaller), are also reported.

There is a close, quantitative relationship between exposure to high concentrations of small particulates (PM10 and PM2.5) and increased mortality or morbidity, both daily and over time. Conversely, when concentrations of small and fine particulates are reduced, related mortality will also go down – presuming other factors remain the same. This allows policymakers to project the population health improvements that could be expected if particulate air pollution is reduced.

Health effects of PM were significantly aroused in 2005 and the years that followed spurred by the issuance of 2005 global update of the WHO air quality guidelines (WHO Regional Office for Europe, 2006). These studies have provided considerable support for the scientific conclusions in the 2005 global update of the WHO air quality guidelines and suggest additional health outcomes to be associated with a PM.

Of important mention is the fact that this 2005 global update of the WHO air quality guideline for PM was based primarily on the findings of prospective cohort studies of Pope (2002) on the effects of long-term exposures on mortality, with support provided by the studies of Dockery *et al..* (1993) and Jerrett *et al..* (2005). By extension, if long-term exposure to PM as concluded by these studies led to mortality, it follows that some form of morbidity ought to have predisposed the subjects' deaths.

Additional scientific support for these studies was provided at the time by an independent reanalysis conducted by Krewski *et al..* (2000), Pope *et al*.,(2004) and by a study conducted in Europe (Hoek *et al.*., 2002b). In prospective cohort studies, a sample of individuals is selected and followed over time. For example, Dockery *et al..*

(1993) published results for a 15-year prospective study (the Harvard Six Cities Study) based on approximately 8000 individuals in six cities in the eastern United States. Pope (2002) published results of a prospective study of the mortality experience of approximately 550 000 individuals in 151 cities in the United States, using a cohort participating in a long-term investigation sponsored by the American Cancer Society.

These studies used individual-level data so that other factors that affect mortality could be characterized and adjusted in the analysis. Several different cause-specific categories of mortality were examined, including from cardiovascular plus pulmonary and lung cancer.

The Harvard Six Cities Study and the study of the American Cancer Society cohort have been updated several times, with systematic increases in the number of years of analysis and deaths that were followed and in the sophistication of the statistical methodology (Laden *et al.*., 2006; Lepeule *et al.*., 2012; Krewski *et al.*., 2009). These reanalyses continue to find a consistent, statistically significant association between long-term exposure to PM and the risk of mortality. In addition, the magnitude of the effect estimate (that is, the mortality effect per unit of exposure) remains consistent with that of the original study. Using the 51 cities from the American Cancer Society study for which long-term PM2.5 data are available, Pope, Ezzati& Dockery (2009) reported that metropolitan area-wide reductions in PM concentration between 1980 and 2000 were strongly associated with increases in life expectancy, after adjustment for changes in other risk factors. The importance of this study is that it documents that improvements in air quality are reflected in improvements in public health. The authors found results remarkably similar to the earlier American Cancer Society studies, though the methodology was quite different.

A significant number of new prospective cohort studies from Asia, Canada, Europe and the United States have been reported since 2005. These have provided additional evidence of the effects of long-term exposure to PM2.5 on mortality. Effects have now been observed at lower concentrations levels than in earlier studies. As an example, the Pope, Ezzati& Dockery (2009) study still found significant associations between the lower PM concentrations in 2000 and life expectancy, despite significant gains in life expectancy associated with decreases in PM concentrations between 1980 and 2000.

In a large Canadian study, associations persisted at very low concentrations (Crouse *et al.*., 2012). Specifically, the effects of long-term exposure on mortality have been reported for several new cohorts (Filleul *et al.*., 2005; Miller *et al.*., 2007; Beelen *et al.*., 2008a; Puett *et al.*., 2009; Ostro *et al.*, 2010; Lipsett *et al.*, 2011; Crouse *et al.*, 2012). Some cohort studies have found no associations between PM and mortality (Puett *et al.*, 2011; Ueda *et al.*, 2012), but these do not materially affect the overall assessment and conclusions.

Regarding the European studies, the mortality risk estimated in the Dutch mortality cohort study for PM was 6% per 10 μg/m3 for natural-cause mortality (Beelen *et al.*, 2008a), identical to the estimate from the American Cancer Society study (Pope., 2002). Furthermore, a large ecological study from Norway reported significant associations between PM2.5 and cardiorespiratory mortality (Naess *et al.*, 2006).

These Asian, Canadian, European and United States studies cover a variety of environmental settings, PM mixtures, baseline health conditions, personal characteristics and health practices. As a result, several groups of experts have determined that it is appropriate to extrapolate these findings to populations in other regions, including Europe (Cooke *et al.*, 2007; COMEAP, 2006, 2010; Smith KR *et al.*, 2009). The risk of ischaemic heart disease, which includes heart attacks, has particularly strong and consistent associations with PM2.5. A review of most of these and related studies can be found in the United States Environmental Protection Agency (EPA) integrated science assessment for PM (EPA, 2009).

Since 2005, the evidence for a biological mechanism, derived from both epidemiological and toxicological studies, has also increased and indicates that exposure to PM2.5 is associated with systemic inflammation, oxidative stress and alteration of the electrical processes of the heart (Brook *et al.*, 2010). For example, epidemiological studies now show variations in cardiovascular biomarkers of inflammation such as C-reactive protein and fibrinogen. These biomarkers have been consistently linked to subsequent cardiovascular disease and death. Long-term exposure has also been associated with preclinical markers of atherosclerosis (Künzli *et al.*, 2005) and with progression (Künzli *et al.*, 2010) of this pathology of high relevance to cardiovascular diseases. A series of studies from the German Heinz Nixdorf Recall Study has confirmed associations between various markers of atherosclerosis, including intima-media thickness and coronary artery calcification, and the long-term average PM2.5 concentration and proximity to traffic in Europe (Bauer *et al.*, 2010; Hoffmann *et al.*, 2006, 2007). In a Belgian study, pulse pressure was associated with ambient PM levels among the elderly (Jacobs *et al.*, 2012).

A more complete review of the likely biological mechanisms, strongly supportive of a causal association between PM and cardiovascular disease and mortality, is provided by Brook *et al.* (2010. The studies reporting associations with intima-media thickness in human beings are supported by animal studies that show that a 6-month exposure of mice to particles results in substantial increases in atherosclerosis, compared with mice breathing filtered air (Floyd *et al.*, 2009; Soares *et al.*, 2009; Sun *et al.*, 2005, 2008). The Brook *et al.* (2010) review contained a consensus that there was strong mechanistic evidence from animal studies of systemic pro-inflammatory responses and vascular dysfunction or vasoconstriction, supported by controlled exposure studies in human beings. The overall mechanistic evidence from animal studies was judged to be moderate for enhanced thrombosis or coagulation potential, elevated arterial blood pressure, and enhanced atherosclerosis. The overall assessment was that experimental evidence was increasingly strong, lending biological plausibility to the epidemiological findings (Brook *et al.*, 2010).

Studies have also provided evidence on the effects of long-term exposure to fine particulate air pollution on diseases other than cardiovascular and respiratory diseases. Evidence suggests effects on diabetes, neurological development in children and neurological disorders in adults (Rückerl *et al.*, 2011). The evidence for an association with diabetes, since the first publication (Brook, 2008), has been strengthened significantly. This includes epidemiological studies in Germany (Krämer *et al.*, 2010) and Denmark (Andersen *et al.*, 2012a; Raaschou-Nielsen *et al.*, 2012), supported by mechanistic studies (Basile& Bloch, 2012; Chow *et al.*, 2012; Liu *et al.*, 2012; Peters, 2012).

A recent review of the neurological effects found in experimental and observational studies (Guxens&Sunyer, 2102) concluded that these effects were not conclusive, given the limited number of studies, their small size and their methodological constraints. Associations with PM include impairment of cognitive functions in adults (Ranft *et al.*, 2009) and children (Freire *et al.*, 2010). If these findings are corroborated by further studies, this would significantly increase the burden related to air pollution, given the increase of these diseases in ageing populations. More work is needed to disentangle which component of the air pollution mixture drives the associations. This perspective is important given that in most cases, respiratory diseases, especially in the developing world resulting from pollution, do not get the required attention let alone these other diseases.

Birth cohort studies in Europe and elsewhere published since 2005 have reported significant associations between exposure to PM and respiratory infections and asthma in young children (Brauer *et al.*, 2007; Gehring *et al.*, 2010; MacIntyre *et al.*, 2011; Morgenstern *et al.*, 2007). Several studies have found an association between PM and infant bronchiolitis, an important risk for hospitalization (Karr *et al.*, 2006, 2009).

Exposure to PM has also been linked to low lung function in 4-year-old children in a birth cohort study in the Netherlands (Eenhuizen *et al.*, 2012), supporting previously published studies that reported effects of PM on lung function development, reviewed in Götschi *et al.* (2008). The evidence is increasing for an association of ambient air pollution, including fine particles, with birth outcomes (Parker *et al.*, 2011; Proietti *et al.*, 2013; Ritz & Wilhelm, 2008). A systematic review reported significant associations between exposure to PM2.5 and birth outcomes, including low birth weight, preterm birth and small for gestational age births (Shah &Balkhair, 2011).

The evidence for short-term effects of PM on mortality, morbidity and physiological end-points has also significantly increased since 2005 (Brook *et al.*, 2010; Rückerl *et al.*, 2011). Several new multicity studies have confirmed the previously reported small increases (0.4–1% per 10μg/m3) in daily mortality associated with PM (Samet *et al.*, 2006; Zanobetti *et al.*, 2009; Ostro *et al.*, 2006). Estimates of effects for daily mortality were similar in the United States and Europe, but somewhat larger in Canada (Samet *et al.*, 2009).

One of the measures of morbidity used across studies is hospital admission. A recent study from Stockholm reported associations of daily mortality and admissions with PM (Meister, Johansson & Forsberg, 2012). A study in Barcelona also found a significant association between daily mortality and PM, which was further shown to differ for particles from different sources (Ostro *et al.*, 2011). New evidence of effects on hospital admissions was based on PM in Europe (Brook *et al.*, 2010).

A study covering much of United States reported significant associations with hospital admissions for a variety of cardiovascular diseases, including ischaemic heart disease, cerebrovascular disease and heart failure as well as pulmonary conditions with exposure to PM (Dominici *et al.*, 2006). The association between short-term PM exposure and respiratory-related emergency department (ED) visits, hospital admissions, and physician visits were evaluated in Section 6.3.8 of the 2009 PM ISA (U.S. EPA, 2009). The numerous multi- and single-city studies evaluated reported consistent positive associations with respiratory ED visits and hospital admissions for

COPD, asthma, and respiratory infection in study areas with mean 24-h average PM2.5 concentrations ranging from 6.1 – 22 μg/m3. However, associations for asthma were imprecise, not consistent positively when limiting analyses to children. The evidence from respiratory-related emergency department (ED) visits, hospital admissions, and physician visits studies contributed to the conclusion that a causal relationship is likely to exist between short-term exposures to PM2.5 and respiratory effects. Going by such conjecture, it is plausible to argue that the severity of respiratory effects is bound to increase if long-term exposure to PM is witnessed especially from an industrial source whose emission is perennial.

Additional epidemiologic studies evaluated in the 2009 PM ISA (2009) examined associations between short-term PM exposure and respiratory hospital admissions and ED visits. This limited number of studies demonstrated consistent positive associations with respiratory-related hospital admissions and ED visits with the strongest evidence in children. The evidence from these studies in combination with the evidence from toxicological and controlled human exposure studies led to the conclusion that the collective evidence across disciplines is suggestive of a causal relationship between short-term exposures to PM10-2.5 and respiratory effects. One realisation that arises from these findings is that children are a vulnerable group in suffering exposure in developed countries. Yet in rural third world communities where poverty is the main source of vulnerability, this may not necessarily be the case.

In the US a number of studies published multicity or multi-location analyses to examine the association between short-term exposures and respiratory hospital admissions. Bell *et al.* (2012) represented a consolidated and more detailed account of a number of previous publications, (Bell *et al.*, 2009; Bell *et al.*, 2008; Bell *et al.*, 2007). In an all-year analysis of 187 U.S. counties, short-term exposure to PM was positively associated with respiratory hospital admissions in individuals 65 years of age and older, with the strongest association at (0.41% [95% CI: 0.09, 0.74]). This is interpreted to mean that at 95% confidence interval, there is a 41% chance that a person aged 65 or older will be admitted to hospital after exposure which is quite a high percentage.

In seasonal analyses, the association at was consistently positive across seasons, but the strongest association was at lag 0 (1.05% [95% CI: 0.29, 1.82]) in the winter season with the largest magnitude of an effect in the Northeast region. Of note, the Northeast region comprised 53% of all counties included in the analysis. In an additional analysis using this data (Bell *et al.*, 2009), there was no evidence of a reduction in the association between PM and respiratory hospital admissions when accounting for air conditioning use. In a multi-city study conducted in the New England region of the U.S., Kloog *et al.* (2012a) examined associations between short-term PM2.5 exposure and respiratory hospital admissions in individuals 65 years of age and older. The authors observed a 0.70% (95% CI: 0.35, 1.05) increase in respiratory hospital admissions. The results obtained using the novel approach presented (i.e., 0.70% increase in respiratory hospital admissions) were consistent with the percent increase in respiratory hospital admissions observed in a traditional time-series analysis (i.e., 1.51%).

In addition to the multicity studies presented above, a few single city studies were conducted in the U.S. that examined asthma and acute bronchitis. Silverman and Ito (2010) conducted a study to evaluate the effect of short-term PM exposure on asthma hospital admissions, both general and those that required a stay in the intensive care unit (ICU) in New York City. Analyses focused on four age groups (i.e., <6, 6-18, 19-49, and 50+) and were limited to the warm season (April-August). Positive associations were observed for each age group and for all ages combined when considering general asthma hospital admissions, with the strongest association for the age group 6-18 (15.5% [95% CI: 9.1, 22.0].

When limiting the analysis to ICU asthma admissions, again the strongest association was for the age group 6-18 (21.1% [95% CI: 8.3, 35.5]). The authors also examined the shape of the concentration-response (C-R) relationship using linear, smooth functions, which allowed for a possible nonlinear relationship. This analysis found evidence that the linear fit is a reasonable approximation of the relationship between short-term PM2.5 concentrations and asthma hospital admissions. Grineski *et al.* (2011) primarily focused on examining the effect of dust and low wind events on asthma and acute bronchitis hospital admissions in El Paso, Texas; however, since daily PM data were available the authors also examined associations between short-term PM exposures and each respiratory health effect. The authors found that PM was positively but weakly associated with asthma (OR=1.02 [95% CI: 0.96, 1.09]) and acute bronchitis (OR=1.01 [95% CI: 0.92, 1.12]) hospital admissions.

Of the recent studies identified that focused on short-term exposures to PM and respiratory-related ED visits the majority consisted of single-city studies. However, a couple of large, multi-city studies were conducted in the U.S. and Canada. Zanobetti *et al.* (2009) examined the association between short-term PM exposure and respiratory ED visits in individuals 65 years of age and older in 26 U.S. communities. In an all-year analysis, PM was strongly associated with respiratory ED visits (2.1 [95% CI: 1.2, 3.0], while in seasonal analyses positive associations were observed across seasons with the strongest association in the spring (4.3% [95% CI: 2.2, 6.5]).

Stieb at al. (2009) conducted a study in 7 Canadian cities to examine the effect of air pollution on ED visits for multiple respiratory-related health outcomes including asthma, COPD, and respiratory infection. The authors found no evidence of an association between short-term PM exposure and COPD ED visits at any of the single-day lags examined. In all-year analyses, positive associations were observed for asthma with the magnitude of the association increased (i.e., the strongest association was observed at lag 0, 2.1% [95% CI: -3.0, 7.5]). However, in a warm season analysis (April-September), the magnitude of the association between PM2.5 and asthma was nearly 4 times higher (9.3% [95% CI: 6.3, 12.5]).

A couple of single cities studies were also conducted that examined all respiratory, multiple respiratory effects, or asthma ED visits. Darrow *et al.* (2011) examined the association between short-term air pollution exposure and respiratory ED visits in Atlanta using various exposure metrics (1-h max, 24-h avg, Commute (0700-1000, 1600-1900 hours), Day-time (0800-1900 hours), and Night-time (2400-0600 hours). PM was positively associated with respiratory ED visits across exposure metrics, with the magnitude ranging from 0.2% to 0.4%. Kim *et al.* (2011) examined the associations between short-term PM exposure and hospital admissions in Denver, CO. The authors found no evidence of an association with all respiratory (-0.44% [95%

CI: -5.6, 5.4]), COPD or pneumonia hospital admissions (quantitative results only presented for all respiratory). However, there was evidence of a delayed effect of PM on asthma hospital admissions with effects not occurring until approximately lag day 4. What is obtaining from the immediate discourse is that seasonal analysis operationalized by time series data was handier in capturing the associations. This could be attributed to the fact that the exposure effect is somewhat cumulative on the victim's body.

A number of studies focused on ED visits and hospital admissions for asthma. Strickland *et al.* (2010) conducted an analysis in Atlanta using the same air quality data as Darrow *et al.* (2011) to examine the association between air pollution and paediatric (ages 5-17) asthma ED visits. PM was strongly associated with paediatric asthma ED visits in both all-year (2.2% [95% CI: 0.2, 4.2] and warm season (4.7% [95% CI: 1.7, 7.6]) analyses. The magnitude of the association was robust to the inclusion of in the model. An examination of the C-R relationship through a quintile analysis and a loss C-R analysis using PM concentrations found evidence of increased risk of paediatric asthma ED visits down to relatively low ambient concentrations (i.e., mean 24-h avg concentrations < 14 μg/m3).

In Tacoma, WA, Mar *et al.* (2010) also examined the association between short-term PM exposure and asthma ED visits. Individual lag days of 0 to 5 days were examined with the strongest association occurring at (5.7% [95% CI: 1.4, 10.1]). Li *et al.* (2011) examined the C-R relationship between short-term PM exposures and asthma ED visits in children 2 to 18 years of age in Detroit. Associations were examined in both a time-series and time-stratified case-crossover study design assuming: (1) no deviation from linearity and (2) a change in linearity at 12μg/m3. In the analyses assuming linearity, similar effect estimates were observed in both models for a 0-4 day lag, (time series: RR=1.03 [95% CI: 1.00, 1.07]; case-crossover: OR=1.04 [95% CI: 1.01, 1.07]). In the models assuming a deviation from linearity at 12 μg/m3, the authors reported slightly larger effect estimates, compared to the linear model, for asthma ED visits in the time-series (RR=1.07 [95% CI: 1.03, 1.11]; lag 0-4) and case-crossover analyses (OR=1.06 [95% CI: 1.03, 1.09]; lag 0-4), respectively. Glad *et al.* (2012) conducted a study in Pittsburgh, PA that found PM to be positively associated with asthma ED visits in analyses of all ages and ages 18 to 64 for single lag days and the average of 0-5 days (i.e., all ages: OR=1.04 [95% CI: 0.98, 1.10] and 18 to 64: OR=1.053 [95% CI: 0.99, 1.12] at lag 0-5). Additionally, when stratifying by race there was some evidence for larger effects in African Americans compared to Caucasian Americans.

Fewer studies have been undertaken in developing countries, not because pollution is not an affection but because there are perceptions that more pertinent issues to due dealt with such as food security, general health conditions, unemployment and poverty. Yet evidence continues to indicate that air pollution is just as lethal if not acutely adverse in developing nations.

For instance, a study carried out in Bangladesh in (Utahh, 2010) found out that respiratory disorder was highlighted as a major problem in 11 FGDs and participants in Bagambar village also mentioned the problem of asthma. Although this may be caused by a number of factors studies have shown that occasional high concentrations of hydrogen sulphide found in community air samples were consistent with complaints of headaches, eye irritation, and sore throats (Fielder *et al.*, 2000).

Bhambhani and Singh (1985) also reported that exposure of 42 individuals to 2.5 to 5 ppm (3.5 to 7 mg/m3) hydrogen sulphide caused coughing and throat irritation after 15 minutes. In addition, there is a large body of evidence that shows that textile dyes can act as respiratory sensitizers and can lead to choughs, respiratory tract irritation and asthma (Ahmed *et al.*, 2005).

From the above review, this study can deduce that methodologies are varied some comprising of cohort, epidemiology, toxicology, population and even biological studies. However, the findings go a long way to confirms that there are grave negative effects of exposure to PM irrespective of demographic characteristics of the population studied. The studies have also gone ahead to reveal that lowered exposure levels are significant even to the point of increasing life expectancy which is remarkable.

Conversely, while the studies reviewed provide adequate and remarkable contributions to the effects of PM on morbidity, all of them are drawn from developed world with proper and enforced ambient air quality standards, a serious point of departure from what this study encountered. On the other hand, source pollutants are not localised to single source pollutants as most of them were set in cities like would be the case of a pulp and paper mill. Consequently, this study hoped to fill this gap.

2.4.3 Willingness to pay (WTP) estimates associated with pollution health impacts

Hunt , (2011) warn as that COI (cost of- illness) estimates are a useful measure of financial burden of disease, but they do not measure the monetary value of the full effect of disease on the welfare of the population and are therefore insufficient for a full cost-benefit analysis of public policies aimed at reducing morbidity or mortality. Willingness to pay (WTP) is the more appropriate measure of the change in welfare in the cost-benefit analysis because it reflects not just the financial effect but also the value people place on the effect on quality of life and longevity.

2.4.3.1 Hedonic price analysis and willingness to pay

The first application of environmental hedonic price was conducted by Ridker and Henning in 1967 in the USA in order to demonstrate the detrimental effect of air pollution on the housing prices [Ridker and Henning, 1967]. The use of this model has grown in popularity with similar studies being seen Brack (2002); Kim *et al* (2003); Nowak *et al.* (2006); Anselin and Lozano-Gracia (2007); Jim and Chen (2009) as well as Kuminoff (2010) among others.

Brack (2002) used hedonic modelling to estimate pollution abatement cost of trees in Canberra, Australia. Komarova (2009) valued environmental impact of air pollution in Moscow while Bell *et al.* (2008) determined ancillary human health benefits of improved air quality resulting from climate change mitigation in the US. In addition Kuminoff *et al.*, (2010) expresses confidence in hedonic models ability to recover the marginal willingness to pay for environmental amenities.

Mansfield *et al.*. (2005); Beron *et al.*. (1999, 2001, 2004), and Anselin and Le Gallo (2006), Anselin and Lozano-Gracia (2007) and Sander (2010) used the price of housing as the dependent variable and a proxy for value. However, in Amrusch (2005) the dependent variable is the price per square meter of property, announced by the selling agent.

The choice of value proxy seen in these studies notwithstanding would only take place in an economic environment characterised by a vibrant property market. This study is set in rural Kenya where land ownership tenures are family based and not distinguishable from the housing. In this respect, property prices data is either non-existent or very rare to come by.

Structural characteristics of housing have seen an interesting combination of variables included by authors. Ottensmann *et al.*. (2008) regarded the number of rooms, number of bathrooms, floor space and basement among others. Jim and Chen (2010) included pool, club and age of house given that their study was set in an affluent urban neighbourhood. Sander and Manson (2007) determined that floor height was a significant structural characteristic in determining the value of housing based on HPM. However in an environment where housing remains a dire need, then some of the structural characteristics would not make sense and are by nature overridden by the presence of the house in which case the number of rooms will be relevant.

Komarova (2009) found that additional room was not only significant in determining the value of housing in Moscow but also accounted for 8.7% of the change in value. In which case, the change would take an inverse direction in the presence of air pollution. Price *et al.*. (2010) found a significant positive relationship between the number of rooms and property value in an environment where forest proximity had contributed to pollution abatement. This is however confuted by Jim and Chen (2009) who found that an increase in a number of bedrooms actually decreases housing value. This interesting finding could be attributed to the fact that the environmental amenity of concern was scenic view and not air quality. Conversely, according to Kuminoff *et al.*., (2010) the correlation between the number of room and housing value (irrespective of whether the reference is made to just rooms, or bath or bedrooms) is invariably high hence the suggestion that it could be the most relevant proxy for structural characteristics of housing.

A study carried out in the European Union countries found that open spaces and parks help level the health and socioeconomic inequalities by providing improved quality of life (Mitchel, 2008). Such eye-opening findings may be attributed to the fact that scholars have found significant relationships between the existence of neighbourhood amenities and value of housing (Geoghegan, 2002; Bourassa, Hoesli& Sun 2003(Cavailhes, 2009; Choumert and Travers, 2010; Landry and Hindsley, 2011).

Empirically, amenities have been defined as goods which can only be consumed in time and space (Hjalmarsson&Liljeroos, 2015). However, what form the amenity takes may be a matter of location. Komarova (2009) states that where housing units are found in cities, the city centre and or commercial zones, industries, parks, lakes and rivers may be of interest. In less developed countries amenities will invariably take the form of schools, hospitals, roads, shopping centres, playgrounds among others. However one thing is common, rather than measure the presence of the amenity, studies have found it more appropriate to use the distance to the amenity in respect to the housing unit (Brown, 1980; Hjalmarsson & Liljeroos, 2015).

Hjalmarsson & Liljeroos ibid found proximity to the city to be significant in determining the value of housing and being responsible for 1.04% increase in price. Komarova (2009) found that for each kindergarten in the district increases the housing price by 0.1% as it is for public universities while private schools elevate the price by 0.8%. In a study carried out in Yogyakarta City in Bangladesh, Saptutyningsih, Ahmad Ma'ruf (2015) found the distance from the town centre to be negatively related to the value of the property especially given that the city was considered as a pollution source. Umeh and Oladejo (2015) in a study carried out in Lagos state, Nigeria found a positive relationship between neighbourhood quality and value of housing. The study is however non-committal on what exactly is neighbourhood quality and therefore its importance is limited to that extent.

According to a study carried out by Matooane *et al*. (2004) in South Africa show that the people living in areas with high levels of air pollution normally experience health problems that include respiratory conditions such productive cough, bronchitis, pneumonia, bronchiolitis, wheeze, shortness of breath, sinusitis, runny nose, hay fever, rhinitis and high blood pressure among children. Major sources of ambient air pollution in South Africa originate from industrial pollution, coal burning, vehicles and power generation. However, there exists low data on peoples' vulnerability to air pollution.

The environmental quality relationship has led to the attention of air and water quality. Rehdanza, and Maddison (2006) considered both air and noise pollution towards establishing their effect on quality of life in German cities to which they deduce that both variables have an inverse effect. Bell *et al.*. (2008) opine that reduction of Green House Gases (GHG) does occasion ancillary health benefits owing to reduced ground level pollution that would normally be caused by PM and ozone (O3).

Varying air pollution proxies have been used across studies. Kim, Phipps and Anselin (2003) developed an econometric model of spatial hedonic housing price to estimate the value of a marginal increase in the concentration of SO2 and NOx for the Seoul metropolitan area. They found that levels of SO2 pollution have a significant impact on the price of housing whilst NOx (nitrogen oxides) pollution is not. Murty *et al.*. (2003) found a significant inverse relationship between SPM in two Indian cities Delhi and Kolkata.

Komarova (2009) found that with pollution measured as levels of sulphate and particles (TSP), there was inverse significant on housing prices for areas that suffered uburn pollution in Moscow. In which case reducing the sulphate level on 0.25 mg/day increased the value of houses between $84 and $245 ($ 1960). On the other hand, he found that an increase of 1% in emissions of TSP carries a negative effect on the price of 0.03%. Lavaine (2013) also found a significant negative relationship between SO2 concentration and housing prices. Similar findings are reported by (Tyrväinen and Miettinen, 2000), (Beron *et al.*.., 2001); (Leggett and Bockstael, 2000) (Hite *et al.*.., 2001) Chay and Greeonstone (2005); Brasingtonand Hite (2005) among others. It is regrettable though that similar studies have not been carried out in Africa, a gap this study will ably fill. In addition, the majority of the studies reviewed above have concentrated on pollution in cities which again does not provide evidence on the rural environment where emission is known to be from industrial sources.

According to Bell *et al.*. (2008) WTP generates estimates of preferences for improved health that meet the theoretical requirements of neoclassical welfare economics, by aiming to measure the monetary amount persons would willingly sacrifice to avoid negative health outcomes. Komarova (2009) deduced the marginal willingness to pay to reduce the level of emissions of TSP in 1% equals \$114.6 while marginal WTP to reduce SO2 emissions in 1% equals \$53.48, for CO is \$202.46, and for NOx and hydrocarbons are \$171.9 and \$61.12 respectively for residents of Moscow.

This appears to be within the range of estimate by Chay and Greenstone (2005) who determined an MWTP of \$191 for 1 µg/m3 of TSP. of particular interest is the MWTP for cases where the pollutant is PM10. Bayer, Keohane, and Timmins (2009) estimate MWTP of \$130 for 1 µg/m3 of PM10. This, however, departs majorly from (OECD, 2014) estimate of a reduction of PM10 concentration by 1 µg/m3 associated average value of USD 32.37 in Chinese cities. Again, Huang and Lanz (2015) studying the effect of PM10 pollution in Chinese cities estimate that the elasticity of house prices to PM10 concentration is around -0.71. They also estimate average individual MWTP to be around USD 32.37 for 1 µg/m3 reduction in PM10 concentration which is quite similar to estimates by OECD 2014. It thus remains to be seen the range of MWTP that would be generated by our study given our very differing circumstances.

In relation to health effects of pollution, several studies have weighed in by assessing WTP for morbidity either generally or specific to some conditions. Dziegielewska and Mendelsohn (2005) estimated how much Polish residents would be willing to pay for

Poland’s air quality improvement to match the European standard. To this end, they found that residents were willing to pay 0.8% of the per capita GDP to enjoy a 25% reduction in pollution. When health endpoint such as asthma and bronchitis were considered, the study found average WTP amount was 26-28% of per capita GDP. This is considerably higher compared to findings of USEPA (1999) study reports that WTP of 6% of per capita GDP for morbidity the wealth gap between Europe and Poland notwithstanding.

In a similar study, Wang *et al.*. (2006) found that residents of Beijing were willing to pay about 7% of annual household income for a 50% reduction of harmful substances in the air. Another European study by Istamto *et al.*. (2014) found that residents were willing to pay up to $370 per person per year to avoid pollution from road traffic and the attendant risk of exacerbation of asthma among children, and reductions in life expectancy/LE) hypertension, cardiovascular risks.

Wang and Zhang (2009) observed that 59.7% of respondents were able to express a positive WTP and that the average WTP was $15 per person, per year. They also note that the respondents were for a rural area did not consider air quality their responsibility hence 40% of them lacking the incentive to bear the cost. A more recent study in China by Wang *et al.*., (2015) has indicated that parents are willing to pay much more ($68.7) for air quality improvement especially when it affected their children's’ health. The WTP rises to $80.7 among parents working in a hospital setting probably because of awareness of the dangers of poor air quality. It remains to be seen whether higher WTP measures reported in this study compared to previous ones are reinforced by the one-child policy or by other factors.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter discusses the research methodology used in this study and presents the data collection process. The initial section addresses the research design, which includes the study area, sampling framework, sampling size and sampling unit. This is followed by a discussion on data collection techniques including the meta-analysis technique. Data analysis which encompasses modelling average emission rate for ambient air quality, exposure-response functions, a hedonic function for WTP estimates and contingency valuation for stated preference are discussed at length. Study variables measurement and description are also provided.

3.2 Research Design

Given a general viewpoint of performing an economic analysis of the health effects of industrial pollution the study settled on a case study in order to provide an in-depth understanding of the multifaceted research problem. This study fundamentally sought to determine the levels of ambient air quality in Webuye town and its environs, evaluate the emission and post emission exposure effects on human health and examine the willingness to pay (WTP) estimates associated with emission health effects when omission was prevalent and in the post emission period. Given the diverse nature of specific research objective and the research rigour required to attain each of them mixed research design methodology was employed specifically to each objective as detailed in the section which follows.

3.2.1 Estimating using economic tools the levels of ambient air quality in Webuye town and its environs

The study required to estimate the levels of concentration of various air pollutants identical to pulp and paper milling such as particulate matter, sulphur dioxide and nitrogen oxide. The design employed was correlational study design because it involved modelling the relationship between emission data and metrological data to determine concentration levels similar to studies by Dockery (1993); Naes *et al..*, (1999); Zeka *et al..*, (2005) and Zhu *et al..*, (2011). Emission data obtained from secondary sources through meta-analysis was modelled against secondary quarterly metrological data (wind speed, direction, temperature and distance from emission site) for the periods February 2007 to January 2009. It was necessary to collect time series data for this period because emission effects occur over a long period of time hence the need to observe the trend. This process estimated emission concentrations of pollutants for the quarter in maximum micrograms per cubic meter (µg/m3).

Further, in order to implement correlational design detailed above and estimate the severity of emission concentrations given the proximity of the emission site, case-control design as applied in Monn (2000); Bayer *et al..*, (2008); Ivy *et al..* (2008) and Rechel *et al..* (2011) was employed in which case Kakamega was selected as the control site. This made it possible to test the hypothesis that emission concentrations were similar in the sites proximate to Webuye paper mill and the control site.

3.2.2 Evaluating the economic implications of the health effects of pollution

This second objective was concerned with determining the association between emissions concentration estimated in objective one above and human health from an economic analysis viewpoint. Health is an economic welfare good for the household. The pain and suffering of symptoms associated with pollution are detrimental to the household economic well-being.

A household survey was conducted to this effect. This was so because diseases afflict the household members and cause adverse effects on the economic well-being of the household. The proxy selected for pollution concentration was particulate matter (PM_{10}) while health effects sought were respiratory illnesses and symptoms which the study respondents-household heads would easily identify with even without diagnosis by a medical practitioner. The correlational research design was adopted as seen in the studies by Brunekeef *et al.*. (2008); Kunzli *et al.*. (2001); Hoek *et al.*. (2002) and Hoek *et al.*. (2013) among others.

Further, in implementing this study objective, observational population-based cohort study was conducted. Two cohorts or groups of respondents were selected; one with emission exposure and the other without (from the control site-Kakamega). The cohort comprised of households' heads residents of the study sites. Quarterly visits were made to the same households in which episodes of respiratory symptoms or illness suffered within the quarter were recorded for the period between February 2007 and January 2009. These were analysed against pollution concentration data derived in objective one for the period in the same period. In return, this gave rise to the exposure-response function of particulate matter and respiratory illness for the study area as a test of the hypothesis that there is no association between pollutant exposure and respiratory illness and by extension health effect. This methodology is consistent with studies done by Peled *et al..* (2005); Beelen *et al..* (2008); Patel *et al..* (2010); Ostro *et al..* (2010); R. De Marco *et al..* (2010); Eeftens *et al..* (2011) Hales *et al..* (2012) and Caseroni *et al..* (2013) among others.

3.2.3 Examining the willingness to pay (WTP) estimates associated with emission health effects.

Willingness to pay (WTP) estimates were derived so as to determine the economic implication of adverse human health effects. As such correlation study design was adopted. WTP estimates were obtained through hedonic price model. The hedonic function relates the value of the housing unit (a stock variable) or the rent of the housing unit (a flow variable) to structural, neighbourhood, accessibility, and environmental variables. (Boyle and Kiel, 2001; Haab and McConnell, 2003). (Tyrväinen and Miettinen, 2000), (Baron *et al...*, 2001) (Hite *et al...*, 2001) Jim and Chen, 2007).

A household survey was used to implement the hedonic price model. The survey obtained the structural and socio-economic characteristics of households. Environmental characteristics measured as pollution concentration and health data obtained in objectives one and two were also applied. Using ordinary least squares

(OLS) econometric model, the willingness to pay estimates were derived. This methodology is consistent with studies by Sanders *et al.*., (2010); Jim and Chen (2008) and Bell *et al.*., (2008) among others.

3.2.4 Examining the willingness to pay (WTP) estimates associated with post-emission health effects.

During post-emission period WTP was estimated using contingent valuation method. Data was gathered through a contingent evaluation elicitation or survey. Using the double dichotomous elicitation approach, respondents were required to state whether they would like the factory to be re-opened or not. A follow-up question inquiring how much they would be willing to pay for air quality improvement or compensation for air quality deterioration was administered. This methodology is also consistent with the design adopted by Alberini *et al.*, (1997); Wang and Zhang, (2009), and Carlsson and Johansson-Stenman, (2000).

3.3 Study Area

Pan Paper Mill is located in Webuye municipality in Webuye Division, Bungoma East District Bungoma County. Webuye lies between 0’28’and 1’30’ North of the equator. In Kenya Bungoma is situated on the Southern slopes of Mt. Elgon, forming northerly part of the Western Province (Rep. Of Kenya, 1997). Webuye is at an altitude of 1600m above the sea level and covers an area of approximately 401 Km^2.

Webuye pan-paper mill (WPM) is the pollutant source identified for the purpose of the study. It lies on the Eldoret-Bungoma Highway approximately three kilometres from Webuye town. As indicated in figure 3.1 below, the mill is served by a railway line and is built right on the banks of river Nzoia.

Physical activities of the mill are observable at a glance. Figure 3.1 shows the factory premises. The figures foreground shows logs undergoing the stripping process. Three plumes, which are responsible for releasing pollutants to the atmosphere, are visible in the background.

Figure 3.1: Webuye Pan Paper Mills factory (Source Author, 2017)

Webuye experiences two rainy seasons. The long rains start from March to June or July and the short rains from August to September. The rainfall is heaviest between April and May. Proximity to the equator means that Webuye experience very little seasonal changes in temperature which is solely influenced by its altitude. The highest temperature ranges from 21’c to 28’c in warm weather and the lowest temperature ranges from 7 ’c and 11’c in the cold weather. Annual rainfall varies from about 900m to 1600m (REP. of Kenya, 2012).

According to Molina *et al.*, (2009) cool season propels strong surface inversions and higher peaks of pollutants in the morning. Conversely, the warm season has more ultraviolet radiation which precipitates smog. In addition, drier conditions cause increased aerosol loadings due to dust and biomass burning while the rainy season has lower PM_{10} but continues to have high ozone due to intense photochemistry before the afternoon showers. Subject to these observations air quality is, therefore, a year-round concern even in Webuye and its environs.

3.4 Sample Frame

The sample frame includes all household heads in the study area. This study analysed emission between two time period (between 2007 and 2009, and between 2014 and 2015) because the in the first time period the factory was operational while in the second period the factory was closed. In respect to the emission period study (February 2007 to January 2009), the study area was divided into two. Study site (human settlement within 10 kilometres of PPM) and control site (Kakamega town) which is 46 kilometres south-east of PPM. This being a rural settlement, most socio-economic activities such as farming, herding cattle and trading are conducted outdoors hence pollution exposure.

Kakamega town was used as a control site because of further distance from the emission point. According to Puett *et al.*, (2014) increase in distance between residence and emission reduces the effect of exposure. In addition, Kakamega forest which is between the two towns may act as a buffer to any pollution emanating from the paper mill. In which case these findings have been observed by Chameides *et al.*., (1988), Taha, (1996); Nowak *et al.*, (2000) and Nowak *et al.*. (2014) who have revealed that forests are a viable strategy to help reduce urban pollution levels.

In regards to the post- emission period study (2014 to 2015) the sampling frame remains the study area comprising of human settlement within 10 kilometres of PPM as explained above. According to KNBS (2013), the population of Webuye District in 2009 was about 226,000 persons. The same report indicates that the average household size is comprised of 4 members. Thus, the estimated number of households was 56,600.

3.5 Sample Size and Selection

Selecting the correct sample size is imperative as it increases the precision and accuracy of the data being collected and reduces sampling errors. According to Salant and Dillman (1994), the sample size depends on sampling error, population size, variation in the population, with respect to the characteristics of interest and smallest sub-populations within the sample.

Bateman *et al.*. (2002) urged that selecting a sample size is a trade-off between cost and precision. Two elements, which are essential in selecting a sample size, are the sampling error and power of a statistical test. Therefore, for a well-designed hedonic valuation (HV) study the sample size is important, as a large sample size provides a lower sampling error and higher statistical significance.

The recommended sample size for a HV with closed-ended questions is 300-1,000 responses for a target population of 1 million (Bateman *et al.*. 2002). Since our target population for Webuye was 226,000 persons as indicated above, a similar proportion of 1 percent is used. Since the number of the household were estimated as 56,600 then 1% of this leads to a sample size of 566 households. The same sample size was maintained for the control site (Kakamega town). Upon data collection, 584 responses were returned for Webuye and 560 for Kakamega.

3.6 Sampling Method

The sampling method was based on a sampling framework designed by KNBS (2006) known as National Sampling Survey and Evaluation Programme (NASSEP) IV based on 1999 population census.

Webuye study site was divided into 3 rural clusters comprising of Chimoi, Lugulu and Matisi. Webuye town was also selected to represent the urban cluster. These clusters were within the 10-kilometre distance as explained before in the sampling frame. Each of the clusters was assigned a sample size of 142 households based on the entire size of 566. Zones were landmarked using schools, health centres or administrative offices.

For every zone, footpaths or minor roads leading to rural residences were considered to be a random way for selecting the sub-samples. Consequently, a systematic sampling technique was adopted, starting from the first house, each interviewer selected every third household, to either the left or the right of a footpath or minor road, for the purpose of interviewing. The use of the road terminated upon attaining the 4th household. In respect to Kakamega, the clustering was not applicable. However, a similar sampling technique was applied.

3.7 Sample Unit

In economic valuation studies, the sample unit may consist of individuals or households. For valuation studies, it is important to identify the sampling population whose values are being studied. In this study, the economic agent is the household. Quiggin (1998) emphasised the importance of interviewing the main decision maker to avoid biased WTP. Consequently, the household is the sample unit of analysis with the key interviewee being the head of the household, irrespective of gender.

3.8 Data collection

3.8.1 Primary data

Primary data was collected towards fulfilling the requirements of study objectives two three and four. As shown in table 3.1 below, the study in the conduct of sample household survey used face to face interviews which according to Arrow *et al.*. (1993) are a superior method of surveying for valuation purposes. An interview schedule to elicit household morbidity data in order to establish the exposure effects at household levels was used. In addition, the same instrument was used to get responses of the socioeconomic characteristic for hedonic valuation and determination of willingness to pay in line with objective three. In fulfilling requirements for objective four, bid elicitation interview schedule acquired bids required to assess the post emission WTP based on contingent valuation.

3.8.2 Secondary data

A health effect study has to determine the emission factors for different pollutants that are emitted from the source under the study so that they can be related to endpoint in respondents' health.

To establish effects of air pollution two approaches are used to determine emission levels data. The first approach involves measuring emission data using specialised equipment set at the various points based on the study requirements. The other approach requires that the studies estimate emission levels and construct emission inventories which can be used to model air quality ((EPA, 2002); (Lopes, *et al.*., 2003); (Gavrilescu, 2008). (Laplante & Rilstone 1996) among others. This procedure is illustrated using the schematic diagram figure 3.2 below.

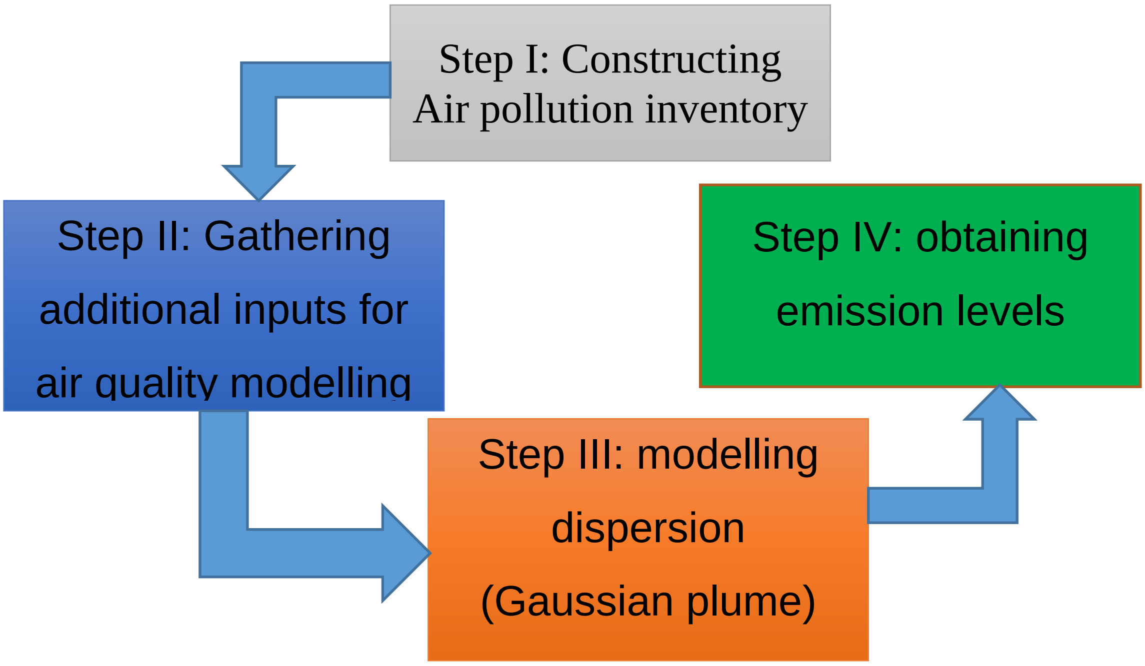

Figure 3.2: Estimating pollution emission levels (Adapted from EPA, 2002)

The above diagram explains the procedure this study followed to collect and obtain data on emission levels in the study site. The first two stages pertain to data collection and are relevant to this section of the thesis and are explained herein. The other two pertain to data analysis and are therefore explained within the subsequent section.

a) Step I: Construction Emission inventory data

Given the uniqueness of pulp and paper pollution characteristics, emission data from other industrial sources could not be referred to. As such, it is necessary to pool together pollution emission data specific to pulp and paper through a meta-analysis technique. Meta-analysis is a quantitative data gathering technique from previous studies which are systematically aggregated for further analysis. This technique has been applied in economic analysis by several scholars. Specific studies relating to pollution effects are done by Aunan & Pan (2004); Weinmayr *et al.*., (2010) and Raaschou-Nielsen *et al*. (2013) among others. The study performed a meta-analysis based on the following two stages as stipulated by Stanley & Jarrell (1989);

i. **Database search to include all Relevant Studies**

A computer search of standard databases—for example, Google Scholar; EBSCO host and Proquest among others was performed to extract as many publications as possible on the subject of pulp and paper emissions. We excluded studies from jurisdictions with a strong national anti-pollution regulatory framework such as EPA. The other exclusion criterion was the absence of pollution mitigation activities and initiatives by the polluting enterprise as reported in the studies. By refining the Boolean search algorithm and using Kraft Milling as a keyword the study netted as many empirical studies as possible that were congruent to the research question as advised by.

ii. **Summary Statistic and Reduction of the Evidence to a Common Metric**

Meta-analysis generates empirical or quantitative data which are findings in the netted studies. The current study identified pulp and paper milling emission characteristics for Sulphur dioxide (SO2), Oxides of Nitrogen (NO) and Particulate Matter (PM10). The summary statistical parameter extracted from each of these studies for further analysis and modelling were mean concentration rates. These were reduced to aggregated means and standard deviations, which were then applied as inputs to model emission rates in Webuye and its environs.

b) Step II: Gathering additional inputs for air quality modelling

In addition to emission inventory constructed in step I, the stud obtained other inputs to facilitate emission modelling. This was principally secondary metrological data in the form of wind speeds and direction and distance from pollutant point to exposure point (EPA, 2002). In all these cases, data analysis guide was used to ensure that the data intended had been obtained.

Emission data were collected between February 2007 and January 2009 and subsequent follow-up on the effects of pollution on residents, after the closure of the Pan Paper factory, was conducted in Webuye to compare the two periods (2007-2009 and 2014-2015). The reasons for comparisons in the two time periods are to evaluate whether the health status of residents has improved in the absence of pollution and to evaluate the economic status post-closure of the mill.

Table 3.1 Data collection strategies

Objective	Data collection method	Data collection instrument	Data collected
1. To estimate, using economic tools, the levels of ambient air quality in Webuye town and its environs.	Secondary data-refereed journal article internet search Meta-analysis metrological secondary data	Document analysis guide	Emission concentration levels. wind speeds, distance and plume height
2. To evaluate the economic implications of health effects of emission and post emission pollution	Primary data	Interview schedule	Household morbidity characteristics
3. To examine the willingness to pay (WTP) estimates associated with emission health effects.	Primary data	Interview schedule (same for objective 2 above)	Household socio-economic characteristics
4. To examine the willingness to pay (WTP) estimates associated with post-emission health effects.	Primary data	Contingency valuation bid elicitation interview schedule	Bids

3.9 Data analysis

This study being essentially a quantitative study generated an impressive amount of data which were subjected to clean up, sorting and analysis in order to answer the research questions. Data collected was in varied scales majority being a ratio or interval scales. Count data was also available. This section deals with specific data analysis techniques used in the study.

3.9.1 Estimating pulp and paper emission concentration

Estimating emission levels is one of the options which scholars have agreed can be used to determine emission rates at a given point in space. Daly and Zanneti (2007) pointed out that despite overwhelming challenges; air pollution models have been developed and have proved effective in their purpose. Air pollution models are the only method that quantifies the deterministic relationship between emissions and concentrations/depositions, including the consequences of past and future scenarios and the determination of the effectiveness of abatement strategies. This makes air pollution models indispensable in regulatory, research, and forensic applications.

Gaussian plume model as applied by Daly & Zannetti, (2007); Venkatram, *et al.*., (2004) and De Wispelaere, (2013) among others is a simple mathematical model that is typically applied to point source emitters, such as coal-burning electricity-producing plants. Occasionally, this model will be applied to non-point source emitters, such as exhaust from automobiles in an urban area.

One of the key assumptions of this model is that over short periods of time (say a few hours) steady-state conditions will be reached with regard to air pollutant emissions subject to meteorological changes. Air pollution is represented by an idealized plume coming from the top of a stack of some height and diameter. The inputs required for the model are the height of the stack from which pollution gases are emitted; emission rate which is the amount to gas exiting the stack in units of grams per second; ambient temperature and atmospheric stability condition.

The model as espoused by Daly and Zanneti (2007) is shown below in Equation 3.1 to estimate pollution at the ground level:

$$C(x,0,0) = \frac{Q}{U}\frac{1}{\pi\,\sigma y\,\sigma z}\,e^{(\frac{-H^2}{2\sigma z})} \text{.............................Eq 3.1}$$

Where:

Q=the rate of emission from the source, U= prevailing wind speed; x= direction; H=height of the plume above ground; C =concentration at any point (x,y,z) and σ_y and σ_z are conditions of atmospheric stability.

The model was implemented using VPLUME 2.1 which is an EPA modelling concentration modelling tool. Data inputs require according to EPA (2001) are the height of the stack in units of meters; Emission rate (the amount of gas coming out of the stack, in units of grams per second); Gas exit velocity (the speed of the gas as it comes out of the stack, in meters per second); Ambient temperature (the temperature of the surrounding air, in degrees Celsius) and the atmospheric stability condition of 1-6 measure of the meteorology of the surrounding air, from very unstable (1) to stable (6).

3.9.2 Exposure-response function

Prevalence of respiratory condition was given as a percentage of persons interviewed either in the study site or control site. The study modelled the relationship between exposure and various morbidity effects using logistic regression. Odds ratio (OR) was computed α= 5%. According to Szumilas (2010), an odds ratio (OR) is a measure of association between an exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposure level, compared to the odds of the outcome occurring in the absence of that exposure. Based on logistic regression modelled, the regression coefficient (b_1) is the estimated increase in the log odds of the outcome per unit increase in the value of the exposure.

For the purpose of hypothesis testing an alpha of 5% (α= 0.05), in which case in instances where p values exceeded alpha, the relationship was considered insignificant hence accepting the null hypothesis. The 95% confidence interval (CI) is used to estimate the precision of the OR.

3.9.3 Estimating the willingness to pay

The study used two different methods to estimate the monetary value of improved environmental quality. During the time when the mill was in operation, the study used the hedonic pricing method for period February 2007 to January. Subsequently, the study used the contingent valuation method to estimate the monetary value without emission of pollutants for the period 2014 to 2015.

3.9.3.1 Hedonic function: model- specification and identification

The hedonic function relates the value of the housing unit (a stock variable) or the rent of the housing unit (a flow variable) to structural, neighbourhood, accessibility, and environmental variables. This function represents a double envelope of bid and offer curves (Rosen 1974). The hedonic function need not be linear (Freeman 1979), and the identification of the proper functional form remains an empirical issue with no guidance from theory. Subsequent work by Freeman (1974; 1993) showed how this framework could be used to interpret existing studies of the property value-air pollution relationship. More recently, major empirical efforts, illustrating the importance of hedonic pricing on valuing air quality is witnessed in the works of Epple (1987) Chay, and Greenstone, D (2005); Palmquist (2005) and Phaneuf, Smith, Palmquist, &. Pope,(2008).

In the context of this study, the hedonic equation is written in the trans-log form (offering the best statistical fit) as:

$$\ln(\text{HOUSRNT})=\alpha_1+\boldsymbol{\beta_1}\mathit{ln}(\text{ROOM})+\beta_2\mathit{ln}(\text{OWNEROCC})+\beta_3\ln(\text{MEDPRICE})+\beta_4\ln(\text{RESPILNES}) + \beta_5\mathit{ln}(\text{INCOME}) + \beta_6\mathit{ln}(\text{PM}_{10}) + \beta_7 \ln(\text{SMOK}) + \beta_8\ln(\text{WKSITE}) + \varepsilon_i$$

Where each independent variable represents one characteristic of the housing unit. The dependent variable in the equation is defined as the market price of the housing unit as stated by the house owner (representing a market value). The independent variables in the same equation are listed in Table 3.1 with summary statistics and are briefly discussed in what follows.

Structural characteristics considered were the number of rooms (ROOM) (other studies have considered floor area and windows and direction of light but in rural developing worlds these characteristics would not make much sense and though initially used were culled in the analysis), Ownership (OWNEROCC) of the housing unit is presented by a dummy variable of course non owners paying a monthly rental charge (HOUSRNT). Respiratory health of the household head is measured using the response function derived in chapter four of this study represented by (RESPILNES), which is affected by smoking habits of household head hence (SMOK) a dummy variable; the accompanying medical cost is the cost of illness suffered because of respiratory illness (MEDPRICE) against the income of the household head (INCOME). Finally, the environmental characteristics include only one variable used as a proxy for air pollution, namely, the PM_{10} concentration (PM_{10}).

The hedonic pricing model (HPM), often uses variation in housing price to estimate the value of the local environmental quality. Thus in this study HPM was considered as imputing a price for an environmental good by examining the effect which its presence has on a relevant market priced good. By defining inverse demand function relating the quality of the environmental good which in this case is air quality, the individual's marginal willingness to pay (MWTP) for that good is derived.

In our case house rent whether real or nominal was used as a proxy for housing value, while the environmental good is ambient air quality represented by the levels of PM10 pollution. Structural characteristics are a number of rooms while social economic characteristics are household income and respiratory illness symptoms suffered.

3.9.3.2 Contingent valuation

To determine the CV of clean air in Webuye and its environs, the study employed Dichotomous choice, which is based on a discrete response this technique was first used by Bishop and Heberlein (1979). The respondent is asked to answer yes or no to the take-it-or-leave-it offer which leads to a qualitative answer (yes/no). These qualitative responses provide much less information about the respondents' actual values (preferences). As such this techniques was complemented by bidding cards. This method has been introduced by Mitchell and Carson (2013). The bidding cards are formulated in such a way that the prices represent for instance estimates of what people in a specific income category paid for selected public services in the preceding years. The respondent is then asked if he is willing to pay one of these prices.

Hence, respondents were presented with a hypothetical situation describing how a change in morbidity would be accomplished through payment towards air quality improvement. Through direct elicitation from respondents data on WTP was derived. Data were analysed to derive mean and median WTPs. Confidence intervals were also determined.

Table 3.2 Definitions and Summary Statistics of Independent Variables

Variable	Definition
HOUSRNT	Average House rent paid monthly(Ksh)
ROOM	No of rooms occupied
OWNEROCC(Dummy)	1=owner occupied 0=otherwise
MEDPRICE	Cost of Illness (Ksh)
RESPILNES	Respiratory symptoms suffered
INCOME	The average monthly income of the household estimated by the households head over the four quarters.
PM_{10}	The monitoring site Average estimate monthly concentration of particulate matter measured in micrograms per cubic meter (µg/m3) over the four quarters.
SMOK (Dummy)	1=household head smocks 0=otherwise
WKSITE (Dummy)	1=work site outdoor 0=otherwise

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter discusses at length the study results in line with the objectives of the study. In the first section, we present the results of emissions from secondary data which was obtained using meta-analysis as well as secondary metrological data in the form of location temperatures, wind speed and direction. Using these three data sets, the study modelled maximum average pulp and paper emission for pollutants for study sites using a Gaussian plume model (Briggs' 1975 and Weil & Brower 1984). Thus, estimating the levels of ambient air quality in Webuye and its environs for sulphur dioxide (SO_2), Oxides of Nitrogen (NO) and Particulate Matter (PM_{10}).

The second section in this chapter are findings of primary data which present the effects of pollution on health effects modelled as response exposure function through a logistic regression analysis.

The last section presents the determination of WTP estimates associated with health effects with pollution (when the factory is open) which were obtained using a hedonic pricing model. On the other hand, WTP estimates have been obtained for the period under which the paper milling factory was closed. In this case, a logistic regression model has been employed. This chapter also presents the results of various hypothesis tested towards meeting the research objectives.

4.2 Estimating the levels of ambient air quality in Webuye town and its environs

Estimating ambient air quality was a core objective from which the others were achieved. In realising this objective, the study collected data in relation to the pollution source and study sites. These findings are presented below with the view of relating the pollution source and the study sites selected for the study.

4.2.1 General metrological characteristic of Webuye and its environs

In order to estimate levels of ambient air pollution in Webuye and its environs, the study needed to collect metrological data required for measuring emission rates of various pollutants. According to EPA (2009), prevailing temperature data and wind speeds are required to determine an index referred to as atmospheric stability condition.

Data on this two metrological characteristic over the period February 2007 to January 2009 are given in figure 4.1(a) and 4.1(b) as obtained from Kenya Metrological Service.

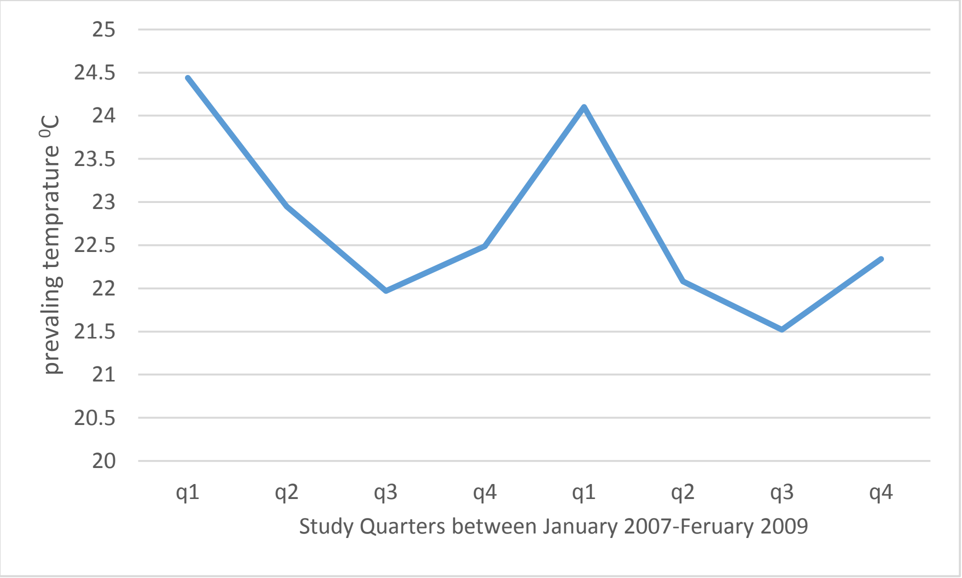

Figure 4.1(a): Prevailing temperature in Webuye and its environs

Based on figure 4.1(a) above, the temperature range for the study period was between 24.4^{0}C to 21.9^{0}C. Hottest periods are observed early in the year while coldest periods are observed in the 3rd quarter or within the months of July and August. The observed temperature range is fairly small at 2.5^{0}C which means that during the period of the study, Webuye experienced almost an even temperature which serves to indicate that atmospheric conditions including those precipitated by pollution were not bound to vary greatly.

Wind data collected by the study is presented as a wind rose in figure 4.1 (b) below. The wind rose for Webuye shows how many hours per year the wind blows from the indicated direction. It can be observed that wind direction during the period of the study was fairly stable with Wind is blowing from South-West (SW) to North-East (NE) and West-South-West (WSW) to East-North-East (ENE) most of the hours during the year. The maximum speed wind observed is about 28km/hr.

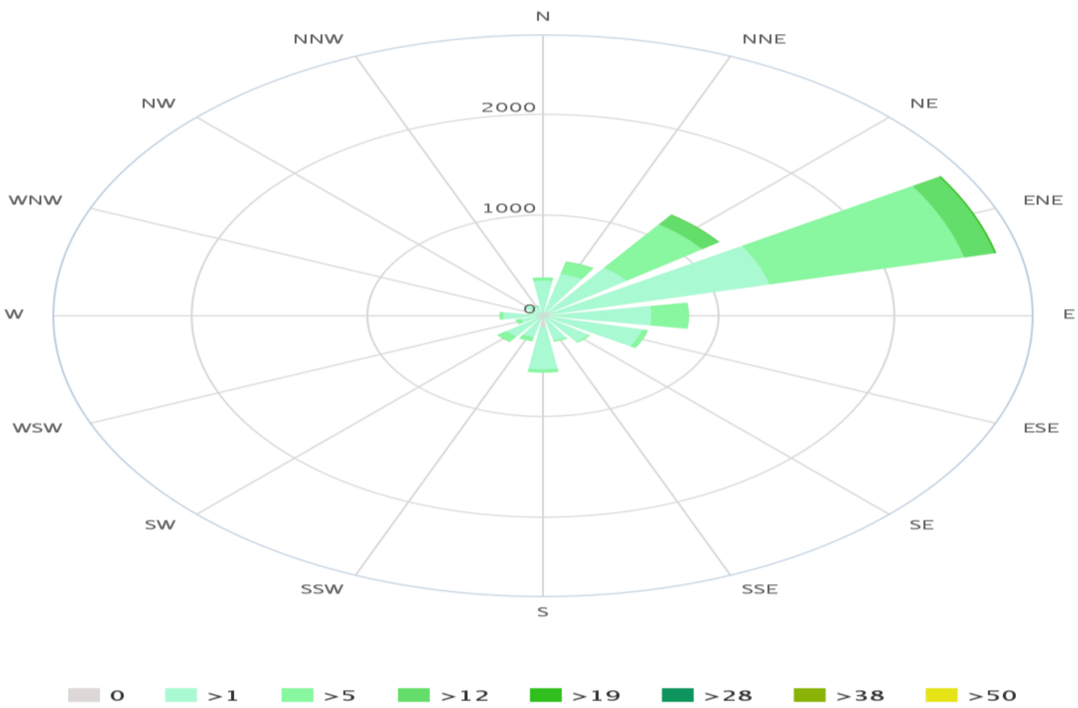

Figure 4.1(b) Wind speed and directions for Webuye and its Environs

Wind is responsible for dispersing pollutants from emission points to other points within the surrounding environment. Given the wind patterns observed, the study can deduce that residents living within the North-East (NE) and East-North-East (ENE) of Webuye town were most susceptible to pollution effects. However since the study sites were mapped around a 10km radius of the emission site, the wind rose projects that the concentration again may be the same. Again, wind patterns indicate that wind rarely blows from the north to the south which is the direction of Kakamega from Webuye hence a justification of using Kakamega as a control site.

4.2.2 Pulp and paper mill emission concentration rates for pollutants

Pollutant concentration data is also a requirement in Gaussian plume modelling. Estimating concentration emission rates for pollutants under consideration required of a meta-analysis of concentration data since primary data was not available.

A health impact study has to determine the emission factors for different pollutants that are emitted from the source under the study so that they can be related to endpoint in respondents' health. This study did not have the advantage of emission measuring equipment or secondary data available from the same source courtesy of another study. To overcome this paucity, the researcher decided to perform a meta-analysis for emission. The Meta-analysis involved selecting studies which have been conducted in countries with high production of pulp and paper mill products.

To this end, the study netted seven studies conducted in fourteen sites from the years 1992- 2004 as indicated in table 4.1 below. This indicated data was meta-analysed and deducted based on 14 observations. Studies included Pöyry (1992), conducted in the Nordic countries in pulp mills using Kraft technology. Girard and Jaegel (1994) conducted a case study of the Samoa Pulp mill. Laplante and Rilstone (1996), surveyed several Kraft mills operating in Canada especially in the Quebec area. Salo (1999) surveyed Kraft mills in Austria while Hekkert (2002) surveyed Western Europe state in Belgium, Netherlands and France. The study by Tarnawski (2004) was included though it was conducted outside the time frame because it was conducted on old Kraft mills and also because it allowed the consideration of Poland as one of the leading world producers of pulp and paper. Studies from other countries in the same league were not available. This study, however, notes that studies were only available in those countries which soon after regulated Kraft pulp and paper milling, meaning that the studies were actually a precursor to the regulation process. The studies used, the country surveyed or the mill studied where applicable is tabulated in Table 4.1 below.

From table 4.1, it can be observed that monthly pollutant emission rates in maximum micrograms per cubic meter (µg/m3) for all the mills considered were relatively high for sulphur dioxide (SO_2), Oxides of nitrogen **(N_2/NO_2),** and Particulate Matter (**PM_{10})** compared to limits prescribed by EPA. Means of the various pollutants are also presented in the table and are observed to be higher than the limits by EPA and European Union (EU). In respect to $PM_{10,}$ the mean pollution rate was found to be more than twice the minimum limits by both EPA and EU.

These findings indicate that irrespective of the location of the mill, Kraft pulp and paper milling is a chronic pollutant emitting high levels of micrograms per cubic meter for pollutants under consideration. The means available from this analysis are considered credible for further modelling of ambient air quality in the study sites.

Table 4.1 Pulp and paper emission concentration rates for pollutants

Study	Mill/ Country	Monthly Pollutant emission rate Max µg/m³		
		sulphur dioxide **(SO_2)**	Oxides of nitrogen **(N_2/NO_2)**	Particulate Matter **PM_{10}**
Pöyry (1992)	Finland	32.8	73.3	89.65
	Sweden	32.3	66.8	88.7
	Norway	33.9	69.3	82.9
Girard and Jaegel, (1994)	Samoa pulp mill	41.2	66.5	96.13
NCASI (1994)	US	42.1	69.1	80.41
Laplante and Rilstone (1996)	Cascades East Angus inc., East Angus	38.6	71.4	87.15
	Emballages Smurfit-Stone Canada inc., La Tuque	40.2	69.8	89.39
	Papiers Fraser inc., Thurso	39.2	67.1	83.3
	Spexelinc., Beauharmois	37.7	69.9	84.71
Salo(1999)	Austria	39.4	70.4	79.51
Hekkert (2002)	Belgium	39.9	66.9	81.92
	Netherlands	40.5	68.2	83.4
	France	41.3	62.8	82.5
Tarnawski (2004)	Poland	41.7	69.7	84.9
Mean		38.63	68.66	85.33
Std. Deviation		3.30	2.64	4.64
EPA (US)		4.0-7.0	30.0-35.5	40.0-70.2
BAT (European Union)		4.0-8.0	32.0-36.0	30-75

Questions concerning whether air pollution and health studies performed in industrialized countries are appropriate for use in developing countries have been raised (Bell *et al...*, 2002). While a growing number of reports from several developing countries confirm that air pollutants such as PM and SO_2 are associated with mortality and illness, with parallel health responses in other nations, there may be differences in the populations, healthcare systems, and nature of pollution. For example, the levels of pollution in the study site may be outside the range of concentrations examined in the original study, and the surviving populations in developed and developing countries may differ in important ways. Thus, locally conducted studies were given highest priority.

4.2.3 Mean study site emission rates for sulphur dioxide (SO_2)

Using Gaussian Plume model applied, the study modelled the mean emission rate sulphur dioxide (SO_2) measured in micrograms per cubic metre ($\mu g/m^3$) in the study site comprising of four locations- Chimoi, Lugulu, Matisi and Webuye Town. Data inputs used to for modelling was the height of the stack in units of meters; mean emission concentration as obtained in table 4.1 above, ambient temperature (the temperature of the surrounding air, in degrees Celsius) wind speed and distance from emission point.

The results are shown in table 4.2 below. The mean emission rates are shown and the respective standard deviation with the highest means being that of Webuye town at $47.9052\mu g/m^3$. The frequency is given as 8 signifying the 8 quarters from which the data was estimated.

Table 4.2 Mean study site emission rates for sulphur dioxide (SO2)

Study site	Mean	Std. Dev.	Freq.
Chimoi	43.7881	2.2264639	8
Lugulu	42.3862	2.5780111	8
Matisi	43.9875	2.3436456	8
Webuye town	47.9052	2.7655018	8

These results indicate that the highest emissions of sulphur dioxide were experienced in Webuye town a finding that can be attributed to the proximity to the pollution source or the paper mill. Lugulu recorded the lowest mean emission rate which could be attributed to the wind direction with respect to the pollution source. The low standard deviation reported indicates that sulphur dioxide emission concentration is fairly evenly distributed within the four locations composing the study site.

4.2.4 Hypothesis testing difference between mean for sulphur dioxide (SO_2) emission in study sites

The study intended to determine whether emission characteristics in the locations making the study site same or different in respect to the mean. In respect to this, the study tested the null hypothesis **H_0: $\bar{x}_K=\bar{x}_L=\bar{x}_M=\bar{x}_W$, (**where $\bar{x}_K$is emission means for Chimoi and so on) using one way ANOVA. The resultant p-value was compared with $\alpha=0.05$ in which case, the null hypothesis would be accepted if the p-value was greater than α and vice versa. The results are presented in table 4.3 below.

Table 4.3 Hypothesis testing difference between mean for sulphur dioxide (SO2) emission in study sites

Analysis of Variance					
Source	**SS**	**df**	**MS**	**F**	**Prob> F**
Between groups	20.241309	3	6.74710301	84.08	0.1102
Within groups	2.24681916	28	.080243542		
Total	22.4881282	31	.72542349		

The *p*-value of 0.1102 is derived. This indicates that the means difference is not significant at 5% level of significance. Hence the null hypothesis is accepted. This means that the study finds that emission characteristics of sulphur dioxide (SO_2) are uniform across the various study sites within Webuye and its environs.

4.2.5 Mean study site emission rates for Particulate Matter (PM_{10})

The study modelled the mean emission rate Particulate Matter (PM_{10}) measured in micrograms per cubic metre in the study site comprising of four locations- Chimoi, Lugulu, Matisi and Webuye Town. The results are shown in table 4.4 below. The mean emission rates are shown and the respective standard deviation with the highest means being that of Webuye town at 102.1712 μg/m^3.

Table 4.4 Mean study site emission rates Particulate Matter (PM10)

Study site	**Mean**	**Std. Dev.**	**Freq.**
Chimoi	92.0531	3.8730711	8
Lugulu	86.9562	4.4846057	8
Matisi	88.6875	4.0769157	8
Webuye town	102.1712	4.8107625	8

These results indicate that the highest emissions of Particulate Matter (PM_{10}) were experienced in Webuye town a finding that can be attributed to the proximity to the pollution source or the paper mill. The standard deviations observed indicate greater variability in pollution concentration within the areas covered in the study sites.

4.2.6 Hypothesis testing difference between mean for Particulate Matter (PM_{10}) emission in study sites

The study intended to determine whether emission characteristics in the locations making the study site same or different in respect to the mean. In respect to this, the study tested the null hypothesis **H_0:** $\bar{x}_K=\bar{x}_L=\bar{x}_M=\bar{x}_W$, **(**where $\bar{x}_K$is emission mean for Chimoi and so on) using one way ANOVA. The results of which are presented in table 4.5 below.

Table 4.5 Hypothesis testing difference between mean for Particulate Matter (PM10) emission in study sites

Analysis of Variance					
Source	**SS**	**df**	**MS**	**F**	**Prob> F**
Between groups	5907.63348	3	1969.21116	105.20	0. 201
Within groups	524.139325	28	18.7192616		
Total	**6431.77281**	**31**	**.72542349**		

Using α=0.05 and comparing it with the *p*-value of 0. 201 shown in table 4.5, the study finds the means difference is not significant hence the null hypothesis is accepted. This indicates that the emission characteristics of Particulate Matter (PM_{10}) in Webuye and its environs are fairly similar.

4.2.7 Mean study site emission rates for Oxides of Nitrogen (NO_2)

The study modelled the mean emission rate Oxides of Nitrogen **(**NO_2) measured in micrograms per cubic metre in the study site comprising of four locations- Chimoi, Lugulu, Matisi and Webuye Town. The results are shown in table 4.6 below. The mean emission rates are shown and the respective standard deviation with the highest means being that of Webuye town at 66.1μg/m^3.

Table 4.6 Mean study site daily emission rates Oxides of Nitrogen (NO2)

Study site	**Mean**	**Std. Dev.**	**Freq.**
Chimoi	64.9	.25358074	8
Lugulu	62.2	.29361948	8
Matisi	65.8	.266927	8
Webuye town	66.1	.31497389	8

Again, these results indicate that the highest emissions of oxides of Nitrogen were experienced in Webuye town a finding that can be attributed to the proximity to the pollution source or the paper mill.

4.2.8 Hypothesis testing difference between mean for Oxides of Nitrogen (NO_2) emission in study sites

The study intended to determine whether emission characteristics in the locations making the study site were same or different in respect to the mean. In respect to this, the study tested the null hypothesis **H_0:** $\bar{x}_K=\bar{x}_L=\bar{x}_M=\bar{x}_W$, **(**where $\bar{x}_K$is emission mean for Chimoi and so on) using one way ANOVA. The results of which are presented in table 4.7 below.

Table 4.7 Hypothesis testing difference between mean for Oxides of Nitrogen (NO2) emission in study sites

Analysis of Variance					
Source	**SS**	**df**	**MS**	**F**	**Prob> F**
Between groups	490.303759	3	163.434586	26.42	0.122
Within groups	173.207706	28	6.18598949		
Total	663.511464	31	21.4035956		

Using a $\alpha=0.05$ and comparing it with the *p*-value of 0.122 shown in table 4.7, the study finds the means difference not significant hence the null hypothesis is accepted. This means that the emission characteristics of Oxides of Nitrogen **(**NO_2) are fairly homogenous.

4.2.9 Hypothesis testing between the means of the study site and control site

To determine whether the ambient air quality in Webuye and its environs was significantly different from the control site, the study performed a one tail student t-test on the mean concentration for the pollutants of study sites(ss) and control site (cs). The hypothesis tested was stated as:

$$\mathbf{H_0:} :\bar{x}_{ss}=\bar{x}_{cs};\ \mathbf{H_1:} :\ \bar{x}_{ss}>\bar{x}_{cs}.$$

The results of the test are given in table 4.8 in the next page.

Table 4.8 Hypothesis testing between the means of the study site and control site

	sulphur dioxide **SO_2**	Particulate Matter **PM_{10}**	Oxides of nitrogen**NO_2**
N	40	40	40
Mean-ss	42.451406	91.075	63.595
Mean cs	33.575	40.467	32.51678
SE	.304624	6.744094	1.964928
Df	38	38	38
T	-19.2907	-19.4934	-17.4292
p value	0.0000	0.0000	0.0000

The mean concentration levels for the pollutants were much lower for the control site in comparison to the study sites. In some case such as particulate matter and oxides of nitrogen, the means for study sites are observed to be almost twice as much of those estimated in the control site.

When the pollution concentration levels are tested for the difference between study sites and control sites, the study finds that for all the three pollutants, when tested at 5% significance level, the *p* values as indicated in table 4.8 above are below the significance level. This means that the null hypothesis is rejected. The study finds that there is a significant difference between the mean pollutant concentrations between the control site and study sites.

This could be attributed to three factors. Distance from the polluting mill, the wind direction and the buffer between the polluting industry and the control site offered by Kakamega forest.

4.3 Evaluating the economic implications of health effects of emission and post emission pollution in Webuye and its environs.

This section considers the findings pursuant to the second objective of the study which was to determine the household economic implications of pollution exposure effects on health. To this end, the study conducted a household survey study. It opens by a description of the socio-economic characteristics of respondents surveyed which are presented in the first part. Prevalence of respiratory symptoms over the survey period was discussed next followed by the relationships between exposure and respiratory morbidity endpoints. The section concludes by estimating the Economic Exposure-Response (E-R) function which is the measure of household health welfare effect for Webuye town and its environs.

While multiple air pollutants, including PM, SO2, and nitrogen dioxide (NO2), have been linked with adverse human health, as discussed in the literature reviewed previously, the consideration of several pollutants simultaneously can lead to overestimation of the effects if the concentration-response coefficients for each pollutant are derived independently. However, consideration of only a single pollutant would likely underestimate the effects by omitting the consequences of other pollutants. This analysis focuses on PM, which has shown consistent and independent associations with health, both in international and in local studies. Therefore this research examines only a subset of the health impacts of air pollution by omitting other pollutants.

4.3.1 Socio-economic characteristics

The study collected data from Kakamega (Control) and Webuye over a period of Twenty Four months within quarterly intervals. A time series prevalence study was achieved as explained in chapter three. Socio-economic characteristics of persons surveyed were highlighted as gender, age, level of education, position in household (whether head or not), length of time at the site, work environment and smoking habits. These findings are presented in table 4.9below.

The survey targeted adults only hence the median age of 37.8 years and 32.4 years for the control and Webuye respectively. The literacy levels of the persons surveyed were fairly high given a cumulative percentage of 75% for control and 66% for Webuye had attended high school and above. The study managed 54% and 55% of household heads respectively. Notable though, the larger proportion of respondents in Webuye had lived there for a duration of two to five years as compared to the control which depicted a stable trend in population movement over the years. Respondents indicated that most of their productive time was spent outdoors in both instances while a paltry 0.31% for Control and 0.21% for Webuye were smokers.

Table 4.9 Socio-economic characteristics of respondents

	Emission period			***Post emission***
Characteristics	**Control (n=560)**	**Webuye (n=584)**	***p* value**	**Webuye (n=472)**
Gender				
Male	55	59	n/s	52
Female	45	41	n/s	46
Median age	37.8	32.4	n/s	
Education level				N/A
Elementary	4	8	<0.05	N/A
Primary	21	26	<0.05	N/A
Secondary	29	51	<0.05	N/A
Mid-level College	37	11	<0.05	N/A
University	9	4	<0.05	N/A
Year lived at site				
2-5 years	18	52	<0.05	
5-10years	39	29	<0.05	
Above 10years	43	19	<0.05	
Work Environment				
Indoor	23	19	n/s	
Outdoor	77	81	n/s	
Smoking Habits	0.31	0.21	n/s	

Susceptibility to air pollution exposure varies greatly among individuals. Individual risk is determined by genetics, age, nutritional state, presence and severity of respiratory and cardiac conditions, and the use of medications. The variability in the estimates found in epidemiological studies may reflect these differences in the populations studied. Age is an important factor as well, with preadolescents (<13 years) and the elderly (>65) at greatest risk (Wilson and Spengler 1996, Ghio and others 1999). Since preadolescents were precluded from the study, the susceptibility of this group could also be assured. On the other hand, median ages depicted by the data ported a situation where upper bound extreme cases (elderly) may have been omitted.

Work environment and smoking habits of respondents are other factors which also affect exposure outcomes. Exposure is more severe (WHO, 2002) if the respondents spend more time outdoors as observed in the study. Smoking occasions its fair share of disease burden making it a strong confounder in pollution exposure studies. In our case the small percentage of smoking respondents is insignificant.

Socio-economic characteristics across the two sites must be compared for validity and reliability. The study hence determined the statistical significance of both sites given $\alpha=0.05$. Corresponding *p* values are computed as shown in table 4.11. Significance difference was noted in the case of education levels and the length of time lived at the site. In all other instances, the differences between the socio-economic characteristics of Control and Webuye were not significant (n/s), meaning that the two sites share similar characteristics for the purpose of a household prevalence study.

4.3.2 Household Prevalence of Lower respiratory tract infections (LRTI)

Monto (2002) and Denny Jr (1995) have concluded that respiratory tract illnesses are the most frequent illnesses of humans. This study distinguished symptoms indicating Lower respiratory tract infections (LRTI) and Upper respiratory tract infections (URTI) the prevalence of which was determined in each case. The prevalence of respiratory symptoms was recorded by means of face to face interview which included describing the symptoms in a language that could be understood by the respondent. Data presented also indicates three scenarios: Webuye with emission, Webuye post emission designated as superscript *a* and *b* and control site from

Kakamega as shown in table 4.10 below.

Regarding LRTI the study found out that the most prevalent symptom was a persistent cough since it presented in 65.7% of the respondents in Webuye when emissions were present. In post-emission, the frequency for the same was 61.4%. This was in sharp contrast with the control site whose prevalence was 12.8%. Generally, the prevalence of LRTI symptoms measured when emission was present are quite high with thick mucus, breathlessness, chest pain and infection of airways being twice as much compared to prevalence without emissions.

In addition, LRTI symptoms determined in the control site were much lower again as compared to the other two scenarios. However, ranges between prevalence for fever and wheezing were fairly close. The difference between prevalence rates points out to the effect of pollution emissions from pan paper mills.

Table 4.10 Household prevalence of Lower respiratory tract infections

Symptoms	**Control (n=560)**	**$Webuye_a$ (n=584)**	**$Webuye_b$ (n=209)**
A persistent cough	12.8	65.7	61.4
coughing up yellow or green phlegm (thick mucus)	9.8	23.6	11.9
Breathlessness	10.1	46.3	22.1
Wheezing	17.3	36.9	31.1
A high temperature (fever)	20.2	48	34.9
Chest pain or tightness	8.8	57.9	23.9
Infection of the airways (Bronchitis)	6.4	41.8	19.6

4.3.3 Household Prevalence of Upper Respiratory Tract Infections (URTI)

The study also sought the prevalence of upper respiratory tract infections among the respondents. Again this was done in three scenarios as shown in table 4.11 below. The study found that a runny nose and sneezing were the most prevalent symptoms of URTI the scores being 65.9% and 61.1% respectively in Webuye during emission. Other symptoms observed were a common cold, flu, the infection of the voice box, and infection of the back of the throat in order of occurrence. A sore throat, however, was least common at 28.3%. These prevalence rates are far much higher than what has been observed for the control site.

With emissions ceasing, levels of prevalence were seen to decrease slightly. For example, the prevalence of common cold dropped from 48.3% to 44.4%. This could be attributed to the fact that other factors may in addition to poor ambient air quality cause these symptoms. The study also finds that not so modest reductions have been witnessed regarding infection of the tonsils and tissues at the back of the throat infection of the sinuses and infection of voice box in which case the study conjectures a direct link between the occurrence of these symptoms and air pollution in Webuye.

Table 4.11 Household prevalence of upper respiratory tract infections

Symptoms	**Control (n=560)**	**Webuye$_a$(n=584)**	**Webuye$_b$ (n=209)**
Common cold	20.5	48.3	44.4
Sore throat	17.8	28.3	59.3
Sneezing	22.1	61.1	60.5
Runny nose	19.3	65.9	54.8
Flu	20.2	46.3	35.4
Infection of the tonsils and tissues at the back of the throat	11.3	42.1	23.9
Infection of the sinuses	5.2	37.7	15.8
Infection of the larynx (voice box)	6.4	43.4	33.4

4.3.4 Testing the hypothesis that there is no difference between household respiratory symptoms prevalence between emission and post emission periods

As seen in the section above, respiratory symptoms data were obtained in the period when emission was present and without emission. While the frequencies or prevalence is detailed above, for inferential purposes, the study sought to test the hypothesis that there is no difference between respiratory symptoms prevalence between emission and post emission periods. The study thus compared the two proportions (F_1) prevalence with emission and (F_2) prevalence without emission. The hypothesis is thus stated as below in Equation 4.1 and tested at 5% significance level. A one tailed-test was performed because it was important to determine whether prevalence was higher with emission than without emission. The results of a Z test are presented in Table 4.12 below.

$$H_0: F_1 = F_2 \text{ and } H_1: F_1 > F_2 \text{ ....Eq (4.1)}$$

Table 4.12: Testing the hypothesis that there is no difference between household respiratory symptoms prevalence between emission and post emission periods

Lower respiratory tract infections	No of observations	Z score	P value
A persistent cough	368(129)[a]	1.02	0.154
Coughing up yellow or green phlegm (thick mucus)	132(25)	4.04	0.000
Breathlessness	259(46)	6.81	0.000
Wheezing	207(65)	1.54	0.061
A high temperature (fever)	269(73)	3.35	0.000
Chest pain or tightness	324(50)	9.39	0.000
Infection of the airways (Bronchitis)	234(41)	6.43	0.000
Upper respiratory tract infections			
Common cold	271(93)	0.97	0.167
Sore throat	281(124)	-2.29	0.989
Sneezing	342(127)	0.08	0.469
Runny nose	369(115)	2.73	0.003
Flu	259(74)	2.76	0.003
Infection of the tonsils and tissues at the back of the throat	236(50)	5.04	0.000
Infection of the sinuses	211(33)	6.74	0.000
Infection of the larynx (voice box)	243(70)	2.55	0.005

[1f]igure in parenthesis represents post-emission observations

Findings arising from the hypothesis test indicate that for LRTI a persistent cough and wheezing symptoms, the proportions of prevalence between emission and post emission data are insignificant at $\alpha=0.05$, hence H_0 is accepted. Regarding other LRTI symptoms considered such as thick mucus; fever; chest pain and infection of the airways, the study finds that they are significant and hence the difference between the emission and post emission periods.

Pertaining to URTI the study finds insignificance among common cold, sore throat and sneezing since the p values indicated in table 4.12 above are all greater than $\alpha=0.05$. Equally the findings indicate that there is a significant difference between prevalence proportions arising with emission and without emission in so far as infection of the tonsils and tissues at the back of the throat, infection of the sinuses and infection of the larynx (voice box) are concerned given the p values at $\alpha=0.05$.

4.3.5 Health effects: Morbidity

To determine the morbidity health effects of single source industrial pollution, the study performed a logistic regression exposure to pollutant and prevalence of various symptoms such as LRTI and URTI. Though there were several pollutants considered in this study, it is Particulate matter (PM_{10}) that was considered since among others, WHO (2004) has emphasised that prevalent symptoms arising out of exposure to PM_{10} are either LRTI or URTI, and this empirical evidence is available for comparison. In addition, the relationship between exposure and prevalence was only feasible at the time when the mill was operational thus between January 2007 to February 2009. As such findings presented below relate to that period only since in the subsequent study period no emissions were observed.

The study modelled the relationship between exposure to Particulate matter (PM10) being the independent and respiratory symptoms being dependent variables measured as sinusitis, running or stuffy nose, sore throat, sneezing, common cold and fever among others. Odds ratio (OR) was computed with α= 5% and 95% confidence intervals to estimate the precision of the odds ratio. The results are shown in table 4.13 below.

The coefficient shows the level of change in prevalence of a respiratory symptom that would occur given a marginal increase in the concentration of PM_{10} other factors remaining constant. The coefficient sign goes to show the direction of the change. The odd ratio read together with confidence intervals ORs(95%CI) shows the odds of prevalence given a certain level of prevalence.

4.3.6 Association between particulate air pollution (PM_{10}) and prevalence of respiratory symptoms in the household

The study modelled the relationship between exposure to Particulate matter (PM10) and the prevalence of respiratory symptoms suffered by members of the household. Respiratory symptoms of interest were those associated with either lower or upper respiratory tract infection as described in the sections above. They include a dry cough, cough with phlegm, wheezing, breathlessness on exertion, chest discomfort and sleep disturbance due to breathing problems. Odds ratio (OR) was computed with α= 5% and 95% Confidence intervals to estimate the precision of the odds ratio. The results are shown in table 4.13 below.

Table 4.13 Logistic regression analysis of the association between particulate air pollution (PM10) and household prevalence of respiratory symptoms.

Respiratory symptom	Odds Ratio	Co-eff	z	Std. error	P>|z|	[95% Conf. Interval]
A persistent cough	1.13248	0.124	0.032	3.876	0.000	(0.061494-0.187326)
Coughing up yellow or green phlegm (thick mucus)	1.021528	0.0213	0.0441	0.483	0.000	(-0.06514 0.107736)
Breathlessness	1.004139	0.00413	0.002	2.065	0.003	(0.00021 0.00805)
Wheezing	1.247323	0.221	0.029	7.621	0.000	(0.16416-0.27784)
A high temperature (fever)	1.364529	2.124	1.4231	1.493	0.000	(-0.66528-4.913276)
Chest pain or tightness	1.02062	0.02041	0.00541	3.773	0.000	0.009806 0.031014
Infection of the airways (Bronchitis)	1.407197	0.3416	0.192	1.779	0.006	-0.03472 0.71792
Common cold	2.517836	0.9234	0.331	2.790	0.000	0.27464 1.57216
Sore throat	1.652187	0.5021	0.14201	3.536	0.0042	0.22376 0.78044
Sneezing	1.393474	0.3318	0.321	1.034	0.000	-0.29736 0.96096
Runny nose	1.524856	0.4219	0.1498	2.816	0.000	0.128292 0.715508
Flu	1.053703	0.052311	0.0214	2.444	0.000	0.010367 0.094255

Infection of the tonsils and tissues at the back of the throat	4.272076	1.4521	0.3299	4.402	0.000	0.805496 2.098704
Infection of the sinuses	2.826672	1.0391	0.3091	3.362	0.005	0.433264 1.644936
Infection of the larynx (voice box)	4.768348	1.562	0.4205	3.715	0.001	0.73782 2.38618

In all instances, the data presented in table 4.13 above finds a positive association between PM10 concentration and household prevalence of respiratory symptoms. The study finds that a marginal increase of PM10 occasions a 12% increase in persistent cough prevalence. In the same vein, common cold increased by 92% while wheezing increased by 22% all factors remaining constant. These findings are fairly telling yet they do not significantly depart from findings by Patel *et al.*. (2010); Lin *et al.*. (2005); Youssouf *et al.*. (2014) and Karakatsani (2012).

The odds ratio and accompanying confidence interval of contracting a common cold given a level of PM10 concentration is 2.11 (0.27464-1.57216). This means that a person in this environment is two times more likely to contract common cold that in the absence of exposure. Similar observations can be drawn regarding findings in this section. In addition, since in all cases, the p values determined are less than $\alpha=0.05$, then the study finds that the positive association is significant. In some cases, the study finds that odds ratios are much higher compared to ranges of less than 2 times reported by Beelen *et al.*. (2008); Rich *et al.*. (2005); Patel *et al.*. (2010); and Karakatsani (2012) for respiratory illnesses. However higher odds seen in regards to common cold, infection of tonsils, sinuses and larynx have been observed in studies by Wong *et al.*. (2008) who found the odds of contracting respiratory illness in Wuhan city in China to be 3.68 times given PM_{10} concentration which again is similar to the odds of contracting a respiratory illness for a smoker subject to findings by Filleul (2004). This goes to show the dire condition of pollution in Webuye and its environs given pollution emission by the mill.

4.4 Willingness to pay (WTP) estimates associated with emission health effects in Webuye and its environs.

The usefulness of economic valuations with respect to the conservation and management of natural resources has been well documented in the literature. When environmental amenities are not jointly consumed with other market goods, a revealed preference framework, rather than a behavioural linkage framework, can help measure people's preferences for the amenity in question.

The environment has become one of the leading issues of development, and an environmental valuation is a basic tool for sound environmental policy. Among several families of valuation methods, the hedonic price technique has been extensively used to measure the effect of urban air pollution on property values in developed urban centres. This study takes advice from such studies to determine the effect of stationary pollution source on the value of property in a comparatively rural setting in Webuye. The overall average concentration of PM_{10} in Webuye was $102.17ug/m^3$ (micrograms per cubic meter) as estimated earlier in the study.

Nonetheless, empirical questions on air-pollution related welfare effects have not been answered as yet.

Therefore, at this point in time, the first goal of this study is to estimate households' average willingness to pay for a marginal improvement in air quality. The second goal is to test the validity of applying the hedonic method to Webuye. Since the pioneering study by Ridker and Hennings (1967), the hedonic price technique has survived lengthy debates concerning several issues. Rosen (1974) provided the theoretical basis for hedonic empirical applications, and subsequently, the debate was not about the validity of the application or the interpretation of hedonic regression results, but rather on issues related to the identification of the functional form and market segmentation among others.

The debate on the identification of the functional form has eventually shifted in favour of simple functional forms (Haab and McConnell 2003). The issue of housing market segmentation is still receiving interest, especially from housing economists. This issue is addressed and empirically tested insofar as pollution effect on property value is concerned.

In an early assessment of the hedonic method, Freeman (1979) noted that "There is much to be learned by studying new cities ..." Since then, the number of investigated cities has increased rapidly, especially in the US. This paper adds a new entry from the developing world to the list of cities studied so far. The results show that the hedonic technique is no less powerful when applied to a typical developing urban centre such as Webuye. The major drawback is the lack of data sources, and efforts must be made to collect micro-data by means of interviews.

In the ideal circumstances, the researcher can collect a relatively small sample with the advantage of the ability to obtain data on each observation, rather than averages from aggregated data.

The remainder of this section is organized as follows: the second section addresses the targeted market scope and data issues. The third section discusses the model used in the estimation. The fourth section presents the estimation results and analysis of marginal benefit. Finally, the last section consists of a summary and conclusions.

4.4.1 Descriptive statistics for the variables

Table 4.14 Definitions and Summary Statistics of Independent Variables

Variable	Definition	Mean	Std. dev.	Exp. Sign
HOUSRNT	Average House rent paid monthly(sh)	3450	1274	+
ROOM	No of rooms occupied	2.43	1.03	+
OWNEROCC(Dummy)	1=owner occupied 0=otherwise	0.34	0.04	-
MEDPRICE	Cost of Illness	234.12	13.22	-
RESPILNES	Respiratory symptoms suffered	3.44	1.27	-
INCOME	The average monthly income of the household estimated by the household head	5600	2100	+
SMOK (Dummy)	1=household head smocks 0=otherwise	0.31	0.01	-
WKSITE (Dummy)	1=work site outdoors 0=otherwise	0.42	0.02	+

4.4.2 Estimated Results of the Household Hedonic Valuation Model

Regression estimation results are listed in column (1) of Table 4.15. Results from further analysis according to specific study sites are shown in columns 2 to 5. Since heteroscedasticity is a typical problem in the estimation of housing hedonic equations, it was feared that a genuine heteroscedasticity would arise. However, a double-log transformation was found to sufficiently eliminate heteroscedasticity (White and Glejser's tests were used). Tests for multi-collinearity resulted in the culling of some variables (not included in Table 4. 15).

Pooled data was used subject to methodologies presented in chapter three of this thesis. A look at column (1) of Table 4.15, the coefficient estimates associated with the variables used to describe property structural characteristics considered were the number of rooms ROOM as expected had a positive sign. Social economic characteristics of the household heads; OWNEROCC, and INCOME had negative and positive signs to their coefficients as expected. Air pollution measured in terms of Particulate Matter concentration PM_{10} has a negative impact on housing prices and so is the prevalence of respiratory illness RESPILNES, and the accompanying cost of illness MEDPRICE. Smoking habits of the household head have also a negative effect.

Empirically available coefficients need to be accurate to support any policy foundations. A test of significance was therefore conducted on the coefficients to determine whether they are important or not. For example for ROOM:

$$H_0\text{: ROOM=0 and } H_1\text{=ROOM} \neq 0.$$

H_0 is accepted if the *p*-value represented in Table 4.15 is greater than $\alpha=0.1$. If otherwise, the null hypothesis is rejected.

All coefficients are significant except OWNEROCC. This could be attributed to the fact that owner occupied properties in rural Kenya are likely to be ancestrally possessed and may never acquire commercial abilities thus are never considered for sale due to custom. The variable, however, remains important distinguishing market characteristic to suit the hedonic model.

Table 4.15: Regression Estimation Results

Variable	Total Sample (1)		Webuye(2)		Matisi (3)		Chimoi (4)		Lugulu (5)	
	Coefficient	P value	Coefficient	P value	Coefficient	P value	Coefficient	P value	Coefficient	P value
Constant	*1.321	0.006	*2.028	0.000	*4.011	0.000	*4.310	0.000	*3.339	0.000
	(0.701)		(0.521)		(0.410)		(0.312)		(0.428)	
ROOM	*0.306	0.002	*0.531	0.001	*0.322	0.002	*0.218	0.000	*0.321	0.000
	(0.0142)		(0.442)		(0.114)		(0.0912)		(0.214)	
OWNEROCC	-0.014	0.212	-0.254	0.218	-0.321	0.314	-0.622	0.225	-0.944	0.216
(Dummy)	(0.391)		(0.0331)		(0.0906)		(0.0142)		(0.0522)	
MEDPRICE	*-0.231	0.003	*-0.462	0.003	*-0.311	0.003	*-0.331	0.003	*-0.428	0.003
	(0.148)		(0.214)		(0.121)		(0.012)		(0.058)	
RESPILNES	-*0.076	0.012	-*0.0124	0.0141	-*0.042	0.012	-*0.055	0.012	-*0.0699	0.012
	(0.021)		(0.005)		(0.0067)		(0.024)		(0.038)	
INCOME	*0.561	0.000	*0.454	0.000	*0.622	0.001	*0.469	0.000	*0.271	0.000

	(0.092)		(0.202)		(0.312)		(0.392)		(0.162)	
PM_{10}	*-0.541	0.021	*-0.743	0.000	*-0.312	0.001	*-0.506	0.000	*-0.192	0.000
	(0.898)		(0.071)		(0.0511)		(0.0541)		(0.097)	
SMOK	**-0.0019	0.063	**-0.0219	0.078	**-0.0141	0.053	**-0.0131	0.069	**-0.219	0.058
(Dummy)	(0.0612)		(0.0432)		(0.0242)		(0.0301)		(0.0361)	
n	584		266		96		104		118	
Adj R^2	0.6671		0.6233		0.6012		0.6310		0.6086	

Note: *, ** stands for 5%, 10% levels of significance respectively. Standard errors are in parentheses.

4.4.3 Willingness to Pay and Welfare Effects

The marginal implicit prices of housing characteristics are not constant due to the nonlinearity of the hedonic function. The marginal implicit price of the variable of interest, particulate matter (PM_{10}), is calculated by differentiating the hedonic price function with respect to PM_{10}. Therefore, for a given household, each unit-increment in PM_{10} concentration results in an estimated decrease in housing-unit value of -0.541 times housing-unit value divided by the associated PM_{10} level. The estimated decreases for varied sites are varied with the highest notable in Webuye at -.743 and the lowest in Lugulu at -.192. These variations concur with estimated pollution levels at the given sites as determined by proximity to the paper mills and direction of the wind.

Over and above this observation, it is necessary to estimate the marginal value of PM_{10} and estimate the WTP for a finite change in this characteristic. Because the undesirable effect is increasing, we measure the WTP to avoid the increase. The marginal value is given by:

$$B(z,\beta) = \frac{\partial h(z)}{\partial z}.$$

Where z is the original vector of attributes for the hedonic model, for PM_{10}, the marginal value is -0.541 for an entire study whose interpretation is, for instance, a household whose housing-units value is Ksh.1,000,000 and located within the study area with an associated level of PM_{10} at 92.47μg/m^3 suffers a marginal damage of ksh5850.7. In other words, this particular household is expected to be willing to pay no more than ksh5850.7 to avoid the damage to property value associated with a one unit-increase in PM_{10} concentration.

The study found out that if the household is quite proximate to the emission site as is with the case of Webuye town, then the marginal value increase to -0.743 meaning that the WTP associated with the housing value stated above would be kshs 7272.1. The converse can be said about further locations such as Lugulu and Matisi.

4.5 Willingness to pay (WTP) estimates associated with post-emission health effects in Webuye and its environs.

During post-emission period WTP was estimated using contingent valuation method. Data was gathered through a contingent evaluation elicitation or survey. Using the double dichotomous elicitation approach, respondents were required to state whether they would like the factory to re-opened or not. A follow-up question inquiring how much they would be willing to pay for air quality improvement or compensation for air quality deterioration was administered. This methodology is also consistent with the design adopted by Alberini *et al*..., (1997); Wang and Zhang, (2009), and Carlsson and Johansson-Stenman, (2000).

4.5.1 Responses by bids

Because CVM uses hypothetical questions, it is a standard practice for the study to include tests on the validity of respondents. In this study, the scenario presented was well accepted by the interviewees and achieved a 93.8% (210/224) completion rate. Interviewees (6.2%) did not answer the WTP questions, which was smaller than but consistent with Carson’s report (1991) report that the typical number of non-responses in a CV study range from 20% to 30%. The relatively low non-response rate of 6.2%

indicated that the bid instrument was constructed successfully.

The respondents were required to indicate whether they would prefer the paper milling factory opened or not. Table 4.16 below shows the yes or no responses and the attendant bid values. The bid values ranged from Kshs 500 to above Kshs 30,000. Of the respondents who wanted the factory to be opened, 23.3% indicated that they were willing to accept a value of about kshs 5000 per month for clean air in their neighbourhood. A cumulative percentage of 43%, however, were willing to accept no less than kshs 10,000 as monthly payment compensation for clean air. This is an indication that majority of "yes" respondents were also willing to receive much higher payments in some cases much higher than the household monthly incomes.

Regarding the "no" responses, a cumulative score of 35.8% were willing to pay between Ksh5000-10000 for clean air in their environment. The frequency however diminished with increased payment bids. It is also important to note that only 40.7% of the households surveyed were positive about opening the factory while the remaining respondents were against the possibility of the same.

Whether the factory should reopen or not	Response bids in Kshs '00'											
	5	20	25	30	40	45	50	10	15	20	30>=	Total
Yes	5(5.8%)	11(12.8%)	6(7%)	0	1(1.2%)	6(7%)	20(23.3%)	10(11.6%)	5(5.8%)	12(14%)	10(11.6%)	86(40.7)
No	6(4.9%)	12(9.8%)	7(5.7%)	24(19.5%)	6(4.9%)	11(9.8%)	22(17.9%)	22(17.9%)	5(4.1%)	7(5.7%)	0	123(59.3)
Total	11	23	13	25	7	13	42	32	10	19	15	211

Table 4.16 Response bids

4.5.2 Bids estimates

Bid distribution is presented in table 4.17 below. The mean amount for respondents willing to be compensated annually was KES 2491.37 while for those willing to remit a tax was KES 1598.00 annually. While the minimum values were the same maximum values for compensation seeking group was about one and a half times that of the sacrificing group. The high standard deviation values indicate that the bid estimates were fairly dispersed.

Table 4.17 Bids estimates

	N	Minimum	Maximum	Mean	Std. Deviation
Amount willing to be compensated annually if the factory is to be reopened	86	400.00	10500.00	2491.37	264.329
Amount to be sacrificed annually in exchange for good air quality	125	310.00	15200.00	1598.00	432.241

4.5.3 Logistic regression Estimation Results for WTP associated with the post-emission period

To estimate WTP for post emission period, the study used Logistic regression. This is so because the research used a dichotomous elicitation method which led to model dichotomous outcome variables hence whether the respondents desired the factory to be opened or not. Opened being 1 and not opened otherwise. This was regressed against average household income, length of stay in Webuye, whether respiratory illness suffered and age of the respondent.

The findings in table 4.18 indicate the coefficient magnitude, sign and significance for the purposes of hypothesis testing. In addition, the model fit is indicated. First, household income is found to co-vary positively with the probability of willingness to pay (WTP) given that a coefficient level of 0.0526 is observed. This means that the probability of WTP increases with an increase in household income levels. Conversely, the length of stay in Webuye, an instance of suffering respiratory illness and age were inversely correlated with the probability of WTP. In which case the coefficients are -0.346; -0.014; and -0.076 respectively.

Further, in respect to instances of suffering from the respiratory symptom, then the model indicates that for a one unit increase in WRES, the log odds of WTP decreases by 0.014. Similar inferences can be deduced for the other predictor variables. In all cases, the posted predictor variables were found to be statistically significant since the p-value was found to be less than the α=0.05.

Regarding model fit, the study found the Psuedo R to be 0.3229 which means that the model is able to predict the change WTP given the probability of opening the factory for up to 32.29%. The likelihood ratio chi-square of 41.46 with a p-value of 0.0001 is an indication that our model as a whole fits significantly.

Table 4.18 Logistic Estimation Results for WTP

Variable	**Coefficient**	**P value**
Constant	-2.369	0.000
Income (INC)	0.0526	0.0021
Length of stay in Webuye(LOS)	-0.346	0.000
Whether Respiratory symptom suffered (WRES)	-0.014	0.000
Age (AG)	-0.076	0.012
N	211	
LR chi2	41.46	
Prob> chi2	0.0000	
Pseudo R2	0.3229	

CHAPTER FIVE

DISCUSSIONS

5.1 Introduction

This chapter discusses the findings of the study forming a nexus between our findings and those of scholars whose work preceded this study. For each research objective, the study considers the findings detailed in chapter four and compares them with findings from previous studies, a conjecture of which is derived in each case.

5.2 Estimating air quality using economic tools in Webuye town and its environs

In estimating the levels of ambient air quality in Webuye town and its environs the study considered interaction between general metrological characteristics including wind speed and direction and emission characteristics. The study did determine the levels of Pulp and paper mill emission concentration rates for pollutants specifically those of sulphur dioxide (SO_2), Particulate Matter (PM_{10}) and Oxides of Nitrogen **(**NO_2).

The observed temperature range is fairly small at 2.5^0C which means that during the period of the study, Webuye experienced almost an even temperature. While the effect of atmospheric temperature on pollution concentration has been confirmed by Diaz *et al.*. (2004); Diaz *et al.*., (2002) and Meng *et al.*. (2012), from this study it can be deduced that fairly even temperature caused almost the same level of intensity of pollution concentration in Webuye and its environs.

Wind is responsible for dispersing pollutants from emission points to other points within the surrounding environment. Given the wind patterns observed, the study can deduce that residents living within the North-East (NE) and East-North-East (ENE) of Webuye town were most susceptible to pollution effects. However since the study sites were mapped around a 10km radius of the emission site, the wind rose projects that the concentration again may be the same. Again, wind patterns indicate that wind rarely blows from the north to the south which is the direction of Kakamega from Webuye hence a justification of using Webuye as a control site.

The study found that irrespective of the location of the mill, Kraft pulp and paper milling is a chronic pollutant emitting high levels of micrograms per cubic meter for pollutants under consideration. The means available from this analysis are considered credible for further modelling of ambient air quality in the study sites.

Questions concerning whether air pollution and health studies performed in industrialized countries are appropriate for use in developing countries have been raised (Bell *et al...*, 2002). While a growing number of reports from several developing countries confirm that air pollutants such as Particulate Matter are associated with mortality and illness, with parallel health responses in other nations, there may be differences in the populations, healthcare systems, and nature of pollution. For example, the levels of pollution in the city of analysis may be outside the range of concentrations examined in the original study, and the surviving populations in developed and developing countries may differ in important ways. Thus, locally conducted studies were given highest priority.

The study found that the mean emission rate for sulphur dioxide for Webuye town as 47.9052μg/m^3. This is about ten times the allowed emission rates by EPA and BAT whose range given is 4.0-8.0μg/m^3 in both cases. This goes to show the severity of sulphur dioxide emissions in the study sites.

In addition, these findings report much higher concentrations than those reported by Routledge *et al.*., (2006) who found mean exposure in London and Birmingham to be 31.4μg/m^3 for the period 2000-2006. Considering that these cities are industrial with multiple industrial emitters during the said period, then our study serves to show the severity of unabated pollution. Further, Beelen *et al.*. (2008) found the mean emission rate to be 13.7μg/m^3, the lower rate being attributable to the fact that the study was localised on motorised pollution in urban centres. The perilous nature of pulp and paper milling conditions even in developed economies has however been confirmed the range of studies by Rich *et al.*., (2005) who found SO_2 emission rate to be 44.2μg/m^3 in Boston and Dockery (1993) who found SO_2 emission rates in some selected cities in the US to be 39.5μg/m^3.

The study also agrees with Jaakkola *et al.* (1990). who their earlier study found the emission rate for pulp and paper milling Karelia to be 117 μg/m3 which was later reviewed in 1999 as 40 μg/m3 which could be attributed to pollution abatement policy and action.

The study also finds that all sites namely Chimoi, Lugulu, Matisi and Webuye Town had similar emission characteristics for sulphur dioxide. This is so because the study accepted the hypothesis that there is no difference between mean for sulphur dioxide (SO_2) emission in study sites. The findings, however, pale in comparison to emission rates of sulphur dioxide reported by Filleul *et al.*.(2005) in urban cities with high traffic in France such as Bordeaux between the periods 1971-1976. This means that some urban populations around the world face as much pollution danger as residents of Webuye at the time of the study.

The study found that the mean emission rate for Particulate Matter for Webuye town as 102.1712 μg/m^3. This is about three times the allowed emission rates by EPA and BAT whose range given is 40.0μg/m^3 in both cases. This goes to show the severity of Particulate Matter pollution in the study sites.

These findings indicate that the highest emissions of Particulate Matter (PM_{10}) were experienced in Webuye town and its environs a finding that can be attributed to the proximity to the pollution source which is the paper mill. These findings further indicate that emission rates observed were in some instances twice or three times as much as those reported by Shah, *et al.*. (2013) based on median PM_{10} concentrations in the US. These levels are incomparable to findings by Miller *et al.*., (2007) who found that in some metropolitan cities in the US overall median concentration of particle pollution were as low as 13.4μg per cubic meter for the period 1994-1998. Similar observations have been made by Lippmann *et al.*., (2000); Evans *et al.*, (2013) and Forastiere *et al.*, (2008) and Wellenius *et al*. (2006).

Conversely, similar or higher levels have been reported in Chinese cities of Wahun and Shanghai by Wong *et al.*, (2008) yet the ascription of such levels to high atmospheric temperatures remains to be seen in Webuye whose temperatures as explained above are relatively mild.

The study found that the mean emission rate for sulphur dioxide for Webuye town as 66.1μg/m^3. This is about two times the allowed emission rates by EPA and BAT lower limit given is 30µg/m^3 for both regulators. This goes to show the harshness of oxides of Nitrogen emissions in the study sites.

Again, these results indicate that the highest emissions of oxides of Nitrogen were experienced in Webuye town a finding that can be attributed to the proximity to the pollution source or the paper mill. These findings are consistent with the findings of Shah *et al..., (*2013) who found that nitrogen oxide was 77.1µg/m^3 as well as Wong *et al...,* (2001) but are 2 times as much Bakian *et al..* (2015) study of salt lakecity county. The high levels observed in this study can be conjectured to have arisen from combustion in the kiln and digester which again is in tandem to findings by Samoli (2006) who attributed rising NO_2 in European cities to increased use of diesel combusted motor vehicles.

5.3 Pollution exposure effects on human health

Vulnerability to ambient air pollution varies significantly among individuals. Individual hazard is determined by genetics composition, age, nutritional state, presence among others. Age wise, important cohorts are preadolescents (<13 years) and the elderly (>65) who experience the greatest risk (Wilson and Spengler 1996, Ghio and others 1999). Since preadolescents were precluded from the study, the susceptibility of this group could also be established. On the other hand, median ages depicted by the data ported a situation where upper bound extreme cases (elderly) may have been omitted.

Work environment, especially for persons working outdoors and smoking habits of respondents, are other factors which also affect exposure outcomes. Exposure is more severe according to (WHO, 2002) if the respondents spend more time outdoors as observed in the study. Smoking occasions its fair share of disease burden making it a strong confounder in pollution exposure studies. In our case the small percentage of smoking respondents is insignificant.

With respect to LRTI, the study found out that the most prevalent symptom was a persistent cough since it presented in about seven in every ten respondents in Webuye when emissions were present. During the post-emission period prevalence was found to be six in every ten respondents which is almost the same. This is in sharp contrast with the control site whose prevalence was observed at about one in every ten respondents. Generally prevalence of LRTI symptoms measured when emissions were present are quite high with thick mucus, breathlessness, chest pain and infection of airways being twice as much compared to prevalence without emissions.

In addition, LRTI symptoms determined in the control site were much lower again as compared to the other two scenarios. However, ranges between prevalence for fever and wheezing were fairly close. The difference between prevalence rates points out to the effect of pollution emissions from pan paper mills.

Prevalence rates of respiratory symptoms are observed to be higher in Webuye at the time of emission. This is attributable to the high pollutant values depicted earlier. Though the majority of studies measure prevalence as the incidence of hospital admission with main concentration being on highly susceptible such as children and elderly, this study aligns with the findings of Darrow *et al.*(2014) and EPA (2013) among others especially in respect to the prevalence of infection of the airways, wheezing and breathlessness. This study also reinforces the fact that respiratory infections are increasingly becoming a severe risk factor in the global burden of disease (Lancet, 2013)

The study found that a runny nose and sneezing were the most prevalent symptoms of URTI the scores being about 65% and 61% respectively in Webuye during emission. Other symptoms observed were a common cold, flu, infection of the voice box, and infection of the back of the throat in order of pre-eminence. A sore throat, however, was least common at about 3 in every ten respondents. These prevalence rates were found to be far much higher than what has been observed for the control site.

With emissions ceasing, levels of prevalence were seen to decrease though not meaningfully for example as regards to a common cold which changed from 48% to 44 %. This could be attributed to the fact that other factors may in addition to poor ambient air quality cause these symptoms. The study also finds that not so modest reductions have been witnessed regarding infection of the tonsils and tissues at the back of the throat infection of the sinuses and infection of voice box in which case the study conjectures a direct link between the occurrence of these symptoms and air pollution in Webuye.

The findings of this study are in tandems with conclusions by Gwaltney *et al.*. (1966); Mbonye (2004); Nokes *et al.*.. (2008) IJpma (2008) who found symptoms of flu, sneezing and runny nose to be present among about 70% of children population and about 40% among adults populations in given prevailing severe weather conditions in different regions across the globe. The pollution is assumed to have the same effects as severe weather conditions such as gale winds, dust storms, tornadoes and tropical cyclones.

By testing the hypothesis that there is no difference between respiratory symptoms prevalence between emission and post emission periods the study found that for LRTI a persistent cough and wheezing symptoms, the proportions of prevalence between emission and post emission data are insignificant at $\alpha=0.05$, hence H_0 is accepted, hence there is no difference between prevalence in the emission and post-emission period. Regarding other LRTI symptoms considered such as thick mucus; fever; chest pain and infection of the airways, the study finds that they are significant and hence the difference between the emission and post emission periods.

Pertaining to URTI the study finds insignificance among common cold, sore throat and sneezing since the p values were observed to be greater than $\alpha=0.05$ in all cases. Similarly, the findings indicate that there is a significant difference between prevalence proportions arising with emission and without emission in so far as infection of the tonsils and tissues at the back of the throat, infection of the sinuses and infection of the larynx (voice box) are concerned given the p values at $\alpha=0.05$.

The multi-directional findings reported above point to stimulating indications. Of importance though is that some of the symptoms during post emission prevalence have reduced comparatively to emission prevalence. In which case, emissions effects are attributable to these changes as evidenced in Foster and Kumar (2011); Rich *et al.*. (2012); Rizwan *et al.*. (2013) Chauhan and Johnston (2003) who concur that emissions reduced either due to closure of pollutant or implantations of air quality standard or cessation of a pollution-causing event has the effect of reducing respiratory symptoms effects in addition to other pollution-related ailments.

However as is in the case our findings, some symptoms do not necessarily fizzle away in the absence of emission principally because air pollution may be just a single cause among many others. In addition, as witnessed in Currie (2014); and Hutchison *et al..* (2005) in some instances closure especially when conducted intermittently may not change emission levels in and by extension disease prevalence. Further, some conditions and symptoms have a long-term effect in the body once the exposure is suffered. This could be the case with a persistent cough and wheezing as determined in this study.

The study found a positive association between PM_{10} concentration and prevalence of respiratory symptoms among all symptoms considered in the study. The study finds that a marginal increase of PM_{10} occasions a 12% increase in persistent cough prevalence. In the same vain, common cold increased by 92% while wheezing increased by 22% all factors remaining constant. These findings are fairly telling yet they do not significantly depart from findings by Patel *et al..* (2010); Lin *et al..* (2005); Youssouf *et al..* (2014) and Karakatsani (2012).

The odds ratio and accompanying confidence interval of contracting a common cold given a level of PM10 concentration is 2.11(0.27464-1.57216). This means that a person in this environment is two times more likely to contract common cold that in the absence of exposure. Similar observations can be drawn regarding findings in this section. In addition, since in all cases, the p values determined are less than $\alpha=0.05$, then the study finds that the positive association is significant. In some cases, the study finds that odds ratios are much higher compared to ranges of less than 2 times reported by Beelen *et al..* (2008); Rich *et al..* (2005); Patel *et al..* (2010); and Karakatsani (2012) for respiratory illnesses.

However higher odds seen in regards to common cold, infection of tonsils, sinuses and larynx have been observed in studies by Wong *et al..* (2008) who found the odds of contracting respiratory illness in Wuhan city in China to be 3.68 times given PM_{10} concentration which again is similar to the odds of contracting a respiratory illness for a smoker subject to findings by Filleul, *et al..* (2005). This goes to show the dire condition of pollution in Webuye and its environs given pollution emission by the mill.

5.4 Willingness to pay (WTP) estimates associated with emission health effects in Webuye and its environs.

The study found that the coefficient estimates associated with the variables used to describe property structural characteristics considered were the number of rooms ROOM as expected had a positive sign. This is in agreement to findings by Komarova (2009) who found that additional room was not only significant in determining the value of housing in Moscow but also accounted for 8.7% of the change in value. In which case, the change would take an inverse direction in the presence of air pollution. Price *et al..* (2010) found a significant positive relationship between the number of rooms and property value in an environment where forest proximity had contributed to pollution abatement.

Social economic characteristics of the household heads; OWNEROCC, and INCOME had negative and positive signs to their coefficients respectively as expected. Air pollution measured in terms of Particulate Matter concentration PM_{10} has a negative impact on housing prices and so is the prevalence of respiratory illness RESPILNES, and the accompanying cost of illness MEDPRICE. Again these findings are supported by Rehdanza, and Maddison (2006) who found an inverse effect on the value of housing in German cities to which they were air and noise pollution was present. Further, Bell *et al.*. (2008) opine that reduction of Green House Gases (GHG) does occasion ancillary health benefits owing to reduced ground level pollution that would normally be caused by PM and ozone (O3). Similar findings are reported by (Tyrväinen and Miettinen, 2000), (Baron *et al.*.., 2001); (Leggett and Bockstael, 2000) (Hite *et al.*., 2001) Chay and Greeonstone (2005); Brasingtonand Hite (2005) among others.

Empirically available coefficients need to be accurate to support any policy foundations. The study found out that all coefficients are important except OWNEROCC. This could be attributed to the fact that owner occupied properties in rural Kenya are likely to be ancestrally possessed and may never acquire commercial abilities thus are never considered for sale due to custom. The variable, however, remains important distinguishing market characteristic to suit the hedonic model.

The study found that, for a given household, each unit-increment in PM_{10} concentration effects an estimated decrease in housing-unit value of -0.541 times housing-unit value divided by the associated PM_{10} level. The estimated decreases for varied sites are varied with the highest notable in Webuye at -.743 and the lowest in Lugulu at -.192.

Given the marginal value is -0.541 for an entire study whose interpretation is, for instance, a household whose housing-units value is Ksh.1,000,000 and located within the study area with an associated level of PM_{10} at 92.47μg/m^3 suffers a marginal damage of ksh5850.7. In other words, this particular household is expected to be willing to pay no more than ksh5850.7to avoid the damage to property value associated with a one unit-increase in PM_{10} concentration.

The study found out that if the household is quite proximate to the emission site as is with the case of Webuye town, then the marginal value increase to -0.743 meaning that the WTP associated with the housing value stated above would be kshs 7272.1. The converse can be said about further locations such as Lugulu and Matisi.

The WTP seems to be relatively low compared to findings made by Komarova (2009) who deduced the marginal willingness to pay to reduce the level of emissions of TSP in 1% equals \$114.6 while marginal WTP to reduce SO_2 emissions in 1% equals \$53.48, for CO is \$202.46, for residents of Moscow. Similarly, Bayer, *et al.*. (2009) estimate MWTP of \$130 for 1 µg/m3 of PM_{10} while OECD, (2014) estimate of a reduction of PM10 concentration by 1 µg/m3 associated average value of USD 32.37 in Chinese cities. This difference may be conjectured to represent different standards of living and elasticity of housing prices between the different study settings.

5.5 Willingness to pay (WTP) estimates associated with post-emission health effects in Webuye and its environs.

The post-emission results indicated that 40.7% of the households surveyed were willing to have the factory re-opened. The mean amount respondents were willing to be compensated with annually was KES 2491.37. The respondents were willing to remit tax KES 1598.00 annually. The WTP estimates in the post-mission period indicated that household income was positively related to WTP, that is, the probability of WTP increases with the increase in household levels. However, the length of the stay in the study site, instances of suffering respiratory illness and age were inversely related to the probability of WTP. The results coefficient were -0.346,-0.014 and –0.076 respectively. These results are consistent with the findings of Faith (2000) which indicated that the closure of pulp and paper mill in Montreal, Canada did not immediately stop the adverse health effects of air pollution.

The closure of the factory, though resulting in the reduction of air pollution in the study area implies a loss of economic benefits derived from the factory when in operation. These benefits include direct employment in the factory and also indirect benefits from the community at large.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter starts by briefly summarizing the findings from the analysis of the objectives of the study. The section also draws conclusions and explores various recommendations from the study that could be of use for policy implementation and outlines remedial measures that are necessary for improving and sustaining the quality of our air environment in general.

The study has looked extensively at the problems and causes of air pollution both in the area of study and other related studies and sites. The study has also evaluated literature in respect to ambient air quality, pollution and health effects in the context of socio-economic studies. The literature suggests that the threat of different pollutants, gases and particles varies with their concentration over time and distance. Thus the impact on health may vary from country to country or among regions. The literature and findings suggest that Webuye Pan-Paper mill has significantly caused a lot of damage to the environment and health of residents as well.

The research used data on the health impact of air pollution from a single source. The unexposed group was also included as a control measure. Ten studies were included for a Meta-analysis to measure emissions. Pollution exposure effect on health was measured by looking at the prevalence of Respiratory symptoms in two years between the exposed and non-exposed group. Regression models were estimated for measuring the association between particulate air pollution and the prevalence of upper and lower respiratory diseases. Lastly, the hedonic Valuation method was used to measure the effect of air pollution on the prices of property. This was to measure the willingness to pay for a marginal improvement in air quality.

The results from the estimated models indicate that there is an environmental health concern that cannot be ignored by the stakeholders

6.2 Conclusions

One of the objectives of the study was to estimate using economic tools the levels of air ambience in Webuye town and its environs, estimate pollution levels, compare the pollution levels with control site and compare with other regions of the world. The study established that the Paper Mills emits toxic gases such as sulphur dioxide (SO_2), Nitrogen Oxide (NO), and particulate matters(TP_{10}). The study concludes that there is no significant difference between emissions levels in Webuye town and the neighbouring locations of Chimoi, Lugulu and Matisi hence proximity to the pulping factory is directly proportional to air pollution levels. Further, the study concludes that there was a significant difference in emission levels of Webuye environs compared to those of Kakamega town which was used as a control site. The study conjectures that this is due to wind direction and the buffer provided by Kakamega forest.

The study also set to establish the household pollution exposure effects on health during the emission period. In this regard, the study concludes that Webuye and its environs exhibits a high prevalence of respiratory diseases as compared to the control site. Specifically, about 6 out of 10 respondents suffered Upper Respiratory tract infection (URTI) or Lower Respiratory tract infection (LRTI). Further, the study concludes that there is a significant difference between LRTI symptoms such as thick mucus, chest pain and fever between the emission and the post emission periods of the study. However, the insignificant difference is observed on URTI symptoms such as common cold, sneezing and sore throat. Regarding morbidity effect of ambient air pollution, the study concludes that there is a positive significant relationship between chronic exposure to PM_{10} and household respiratory symptoms.

The Hedonic valuation model showed that a marginal increase of the PM_{10} reduces the value of houses by 541 Kenyan shillings and this is significant at 10%. A unit increase in smoke emission reduces the value of housing by KES219. The cost of illness is negatively associated with the value of housing. A unit increase in medical bills leads to a reduction in the value of houses by 231Kshs. Therefore there is an implication that the value of Housing or rather the willingness to pay to avoid effects of pollution increase as the level of emissions increase.

These findings point to the fact that industrial pollution, when allowed to proceed unabated, will lead to a contaminated atmosphere which gravely affects human health and diminishes the quality of life and economic well-being of individuals as expressed in this study as reduced housing values. These conditions are the same irrespective of where the polluting agent is located.

6.3 Recommendations

From the study findings, it is clear that either the Webuye Pan Paper mills emissions are in excess of the sustainable emissions. This implies that either the mitigation measures are not enough or the technology in use is outdated. Therefore, there is a need to lay out emission standards and improve on monitoring of the same. The penalty for lack of adherence should be strictly implemented and should be based on the surrounding community's' total willingness to pay to avoid the effects of pollution.

The study notes that industrial pollution in Kenya is not limited to the study site delved into by this study. The study, therefore, recommends that an industrial national pollution standard enacted in 2015 be administered strictly. In addition, such a standard should be monitored through a pollution monitoring centre as part of standards enforcement.

Paper mills should be encouraged to treat and recycle the wastes to reduce air pollution in the area which arises from its processes and affluent. Alternatively, the pan paper mill should resort to using of other raw materials that require fewer chemicals and are easy to produce even though this will require more research and exploration, it can improve health and environmental air quality in the long run. The factory has not been able to improve and apply new processing technologies despite the fact that it has been operating in the area for a very long period of time.

This study has made great consideration of the economic impact of health issues arising out of a single emission source pollutant in rural Kenya. The findings though eye-opening, may not be generalised entirely because of these unique characteristics. As such the study recommends that a similar study is conducted in urban industrialised setups to reinforce the current study.

In the dawn of climate change and the consciousness that has followed conservation and sustainability debate, many efforts have been made towards pollution abatement either in the form of regulation and operational competence. This study presumed and correctly so that the study environment was averse to this reality. The study, therefore, welcomes studies that would be perceived in a different light.

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APPENDIX I: RESEARCH PERMIT

PAGE 2

THIS IS TO CERTIFY THAT:

Prof./Dr./Mr./Mrs./Miss ELVIS KIMANI KIANO

of (Address) MOI UNIVERSITY

P.O. BOX 3900, ELDORET

has been permitted to conduct research in

Location,

BUNGOMA District,

WESTERN Province,

on the topic ECONOMIC ANALYSIS OF INDUSTRIAL AIR POLLUTION AND HEALTH IN KENYA

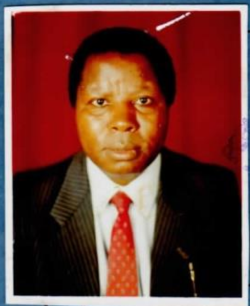
for a period ending 30th March, 20 07

PAGE 3

Research Permit No. MOEST 13/001/34C 72

Date of issue 16th March, 2004

Fee received Shs. 1000



Applicant's Signature

T. MOTURI

For: Permanent Secretary
Ministry of Education
Science and Technology

CONDITIONS

1. You must report to the District Commissioner and the District Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit.
2. Government Officers will not be interviewed without prior appointment.
3. No questionnaire will be used unless it has been approved.
4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.
5. You are required to submit at least two (2)/four(4) bound copies of your final report for Kenyans and non-Kenyans respectively.
6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice.

GPK 6055—3m—10/2003

REPUBLIC OF KENYA

RESEARCH CLEARANCE PERMIT

(CONDITIONS—*see* back page)