



**NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY**

**PREVALENCE AND ASSOCIATED RISK FACTORS OF RESPIRATORY DISEASES AMONG RESIDENTS
OF TSUMEB LOCALITY OF NAMIBIA**

By

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“Thesis submitted in fulfilment of the requirements for the degree of Master of Health Sciences,
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DECLARATION

I, Rosalia Pendukeni Nangolo hereby declare that the work contained in the thesis entitled Prevalence and associated risk factors of respiratory diseases among residents of Tsumeb locality of Namibia is my own original work and that I have not previously in its entirety or in part submitted it at any university or other higher education institution for the award of a degree.



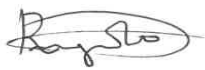
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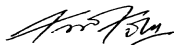
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DEDICATION

I would like to dedicate this piece of work to Ms Saara M Luvinga (my mom) as form of thanking her and appreciating her for believing in me, encouraging me and for all the moral and financial support throughout my entire academic years.

ABSTRACT

Respiratory infections represent a major global health problem, and occurrences of respiratory diseases have been increasing in Southern Africa countries including Namibia due to anthropogenic activities. This study was conducted in Tsumeb, a municipal township located in the Northern part of Namibia. It aimed at determining the prevalence of respiratory ailments among the residents, identify risk factors associated with the prevalence and recommend appropriate measures to prevent exposure of residents to identified risk factors. A combination of experimental and descriptive cross-sectional quantitative approach was adopted in the data collection process. Interviewer-administered questionnaires were presented to respondents for the purpose of data collection on exposure, prevalence and health impacts of respirable dusts on their health. Analysis of heavy metals in collected respirable dust from twelve (12) households was also carried out. Heavy metals were extracted from the dust samples using mineral acid digestion protocol. Qualitative and quantitative analysis of the metals was done by use of the Inductively-Coupled Plasma Optical Emission Spectroscopy (ICP-OES).

From the results obtained, 66% of respondents indicated that the roads that passes by their houses were tarred, 91% reside in single storey dwellings while 78% indicated that the windows of their houses were not protected from the passage of respirable dusts. The 65% of responders confirmed that they noticed changes in the quality of air. About 25.5% of respondents affirmed that reduced air quality may affect their health and possibly lead to other respiratory ailments such as difficulty in breathing, nasal congestion and running nose. Severe coughing was reported to be experienced by 79.5% of respondents. From the heavy metal analyses, metallic values in the analysed respirable dust samples ranged from 72 – 713.4, 0 – 18.0, 1.66 – 15.8, 14.15– 2338.3, 68.9– 1616.6 and 6.86– 897.9 mg/kg for Mn, Cd, Ni, Cu, Zn and Pb respectively. Zinc (Zn) recorded the highest metallic value while Ni recorded the lowest value. Most of the analysed heavy metals were above the acceptable limit with the exception of Ni. Identification of respiratory risk factors is important for the prevention of exposure and development of health problems. Research findings have clearly showed that residents are exposed to respiratory disease risk factors such as poor air quality, air-borne respirable dust that are laden with toxic heavy metals and residual cigarette smoke.

Regular monitoring of air quality in the locality, prevention of the release of heavy metals as a result of anthropogenic activities and sensitization of residents of the need to install appropriate air net on windows and doors of their residences in order to prevent the passage of respirable dust are recommended.

Keywords: Respiratory, Diseases, Dust, Prevalence, Tsumeb, Namibia

LIST OF ABBREVIATIONS

Cd	Cadmium
CDC	Centre of Disease Control
CO	Carbon Monoxide
COPD	Chronic Obstruction Pulmonary Diseases
Cu	Copper
Hg	Mercury
ICP-OES	Inductively-Coupled Plasma Optical Emission Spectroscopy
MMT	Methylcyclopentadienyl Manganese Tricarboxylic
Mn	Manganese
MoE&T	Ministry of Environment and Tourism
MoHSS	Ministry of Health and Social Services
Ni	Nickel
NO _x	Nitrogen Oxides
NSA	Namibia Statistics Agency
NUST	Namibia University of Science and Technology
Pb	Lead
PHE	Public Health, Environmental and Social Determinants of Health
PM	Particulate Matter
SO ₂	Sulphur Dioxide
SPSS	Statistical Package for Social Sciences
VOCs	Volatile Organic Compounds
WHO	World Health Organisation
Zn	Zinc

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CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Tsumeb is located in the Oshikoto Region of Namibia with geographical coordinates of 19° 14' 0" South, 17° 43' 0" East, 17° 26' 59" west (Date and Time.info, 2017) with a population of 19,840 (NSA, 2011). The minimum elevation is 1144m, and maximal elevation 1581m. The climate is sub-tropical having a mean maximum temperature of 29.7 °C and mean minimum temperature 14.4 °C. The average rainfall is 555mm per year. It is well known as the largest town in the Region. Anthropogenic activities such as metal foundry, petrochemicals, quarry and mining are among the dominant industrial ventures in the area among others. Of prominence among these anthropogenic activities in the study area is the copper smelting. This process is known to release toxic gases, heavy metals and particulates to the environment (Dehabadi et al., 2016). These contaminants have the potential to cause serious health problems to residents of the Tsumeb community. As a result of these activities over decades, tremendous footprints would have been created through the release of various contaminants of concern to environmental and human health.

In recent times, appreciable efforts have been made by various environmental impactors towards ameliorating the footprints as a result of their anthropogenic activities. Residual impacts over decades might still pose serious hazards to people. Possible health issues that might be experienced include eye irritation, dryness, itching, and nasal congestion. Eye irritation might be as a result of the presence of high level of sulphur dioxide in air. Sulphur dioxide is a known irritant gas and is one of the gaseous by-products of several industrial processes such as mining (Zhang et al., 2013). Environmental contaminants such as sulphur dioxide (SO₂) carbon monoxide (CO), nitrogen oxides (NO_x) and heavy metals, notably Mn, Fe, Cd, Pb and Zn are known waste by-products of the mining process (Agnieszka et al., 2014). These toxic metals can bind to particulate matters and be inhaled by people within the locality leading to serious health problems. The ecosystems (air, water and soil) are recipients of environmental contaminants. Some of these contaminants are known to be persistent in the ecosystems for long duration. Hence, it becomes essential to examine possible environmental legacy of these contaminants and health hazards they may pose to human beings.

1.2 Statement of the Problem

Anthropogenic activities such as power plant, incinerator, mining, petrochemicals, metal works and others located within the vicinity/close proximity to residential area do have impacts on human and environmental health (Bireescu et al., 2014). The impacts in most cases are as a result of the introduction of contaminants that are detrimental to the health of living organisms (Dehabadi et al., 2016). The contaminants are usually conveyed through environmental components such as air, water and direct deposition on land. The ambient air is part of the biosphere that contains oxygen required for life. The release of contaminants such as sulphur oxides (SO_x), carbon oxides (CO_x), nitrogen oxides (NO_x) and heavy metals, notably Cd, Pb, Cu, As and Zn into this envelop of air will have deleterious effects on the health of living organisms.

The effects of anthropogenic activities in the study area on environmental and human health have been of concern to people and the government (Uugulu, 2011). An area of concern is on the quality of air and possible impact on human health. Deterioration in air quality over a long period of time is known to have serious impact on human health. Possible presence of contaminants such as particulates and toxic gasses such as carbon oxides, Sulphur oxide and nitrogen oxides in the atmosphere could have an impact on the well-being of residents in the locality. Exposure of people to air contaminants at homes, work places, and open commercial places such as taxi ranks, market places, recreation facilities and others can occur through inhalation, absorption through the skin or ingestion. Most exposure occurs through the inhalation of vapours, dusts, fumes or gases as well as chemicals absorption through the skin. Inhalation and skin absorption are known routes through which contaminants find their way into human body (Zhao and Shi, 2014).

Airborne contaminants are known to contribute to respiratory ailments and can worsen pre-existing respiratory conditions such as asthma and chronic obstructive pulmonary disease (Benaissa et al., 2014). There are several anthropogenic activities such as petrochemicals, mining operations, quarry, metal and steel works whose activities have the potential of introducing air toxicants such as toxic gases and particulate matters to the environment. In the past year, some related studies have been conducted in the study area. These include level of heavy metals in plant (Awofolu et al., 2017), environmental health impact assessment (Myers, 2016), and variability of copper isotopes in soil and grass (Kribek, 2018). However, to the best of knowledge of the researcher, none has reported an investigation into the prevalence of heavy metals in respirable and associated risk factors to human health in the study area.

In view of the above, it becomes important to investigate possible effects of environmental factors on the health of people in this local area. Hence, the study intends to assess the influence of these atmospheric conditions on the health (respiratory ailments) and wellbeing of people living in this area as a result of anthropogenic activities taking place over a long period of time.

1.3 Research question

- Are respiratory ailments prevalent among residents of Tsumeb locality?
- What risk factors are associated with the prevalence of respiratory ailments among the residents of Tsumeb?
- Are there any existing measures in place to reduce exposure to risk factors and how effective are such measures?

1.4 Objectives of the Study

1.4.1 General objective

- The main objective of the study was to evaluate the risk factors associated with respiratory ailments among local residents in the study area.

1.4.2 Specific objectives

- To assess possible prevalence of respiratory ailments among members of the community in the study area.
- To establish risk factors that may be associated with possible prevalence of respiratory ailments among residents in the locality.
- To deduce appropriate control and prevention measures for exposure to identified risk factors.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Pollutants such as toxic gases carbon oxides (CO_x), sulphur oxides (SO_x), trace metals (Cd, Pb, Zn, As) and organic compounds find their way into the environment as a result of anthropogenic activities (Bireescu et al., 2014). Activities such as petrochemical, power plants, mining are known to release contaminants into the environment that could affect the health of living organisms including humans (Zhang et al., 2012). Of interest among other anthropogenic activities in the study area is the possible impact of mining and smelting of metal ores. Mining and metal smelting processes are known to release toxic gases and metals into the environment (Zhang et al., 2012). Pirrone et al. (2010) estimated that ore mining and processing is responsible for about 13 % of the global mercury (Hg) emissions. While emissions from this industry in Europe has been reducing in the past 50 years as a result of improved technology (Pacyna et al., 2009), the same cannot be said of developing countries especially in Asia and Africa (Pirrone et al., 2010; Zhang et al., 2011).

For example, Zhang et al. (2011) estimated that up to the year 2007, cumulative emissions from mining, ore dressing and smelting activities in China were about 1.62 Mt of Pb and 3.32 Mt of Zn, with the contribution of the smelting processes accounting for 19% and 27%, respectively. The release of these toxic gases and metals into the atmosphere could drastically have impact on global health. According to WHO (2012), developing countries are reported to suffer most respiratory diseases due to lack of efforts and control measures at sources. Hamatui & Beynon (2017) pointed out that the burden of environmental related respiratory diseases in Namibia has not been well established. The country's diseases burden attributed to outdoor pollution was estimated to account for 10% of all deaths per year (WHO, 2015). WHO (2014) also reported that globally, 14% of Chronic Obstruction Pulmonary Diseases (COPD), acute lower respiratory infections and 6% of lung cancer related deaths were as a result of poor quality air.

Related studies around the world have been conducted where respiratory diseases have been associated with environmental factors (Chhabra et al., 2008; Wilson et al., 2008; Harerimana et al., 2016). In Namibia, some related studies involving clinical and occupational health examination of workers at the Namibia Customs Smelters in Tsumeb (Abrahams et al., 2013), occurrence of dermal diseases from exposure to arsenic fume (Uugulu, 2011), the impact of toxic metals on plant biodiversity (Nunes, 2007) and fact finding mission on operation activities of Dundee Precious Mine in Tsumeb (Popov et al., 2016) have been conducted. The focus of this study, however, is on possible prevalence of respiratory ailments among residents in the study area and associated risk factors.

2.1.1 Air Pollutants and Indoor Air Quality (IAQ)

According to the information released by WHO, Department of Public Health, Environmental and Social Determinants of Health (PHE) indicated that outdoor air pollution originates from natural and anthropogenic sources.

Human activities that are major sources of outdoor air pollution include:

- Fuel combustion from motor vehicles (e.g. cars and heavy-duty vehicles)
- Heat and power generation (e.g. oil and coal power plants and boilers)
- Industrial facilities (e.g. manufacturing factories, mines, and oil refineries)
- Municipal and agricultural waste sites and waste incineration/burning
- Residential cooking, heating, and lighting with polluting fuels
- Poor urban planning, which leads to sprawl and over-dependence on private vehicle transport, is also a major factor in accelerated pollution emissions.

The health consequences caused by air pollution can occur as a result of short- or long-term exposure. The pollutants with the strongest evidence of health effects are particulate matter (PM), ozone (O₃), nitrogen dioxide (NO₂) and sulphur dioxide (SO₂). Although most emissions of ambient air pollution are from local or regional sources, under certain atmospheric conditions air pollution can travel long distances across national borders over time scales of 4-6 days, thereby affecting people far away from its original source. For example, windblown dust from desert regions of Africa, Mongolia, Central Asia and China can carry large concentrations of particulate matter, fungal spores and bacteria that impact health and air quality in remote areas (WHO 2014).

In recent time, there has been growing interest among researchers, environmentalists, health practitioners and the government agencies on Indoor Air Quality (IAQ) due to health problems it has been associated with. Inhalation of air with poor quality as a result of the presence of atmospheric contaminants will serve a serious health hazard. Discussion on the issue of exposure to poor indoor air quality became more important since people spend most of their time at indoor environment. It was report in a previous study that people spend about 90% of their time in both private and public indoor environments, such as homes, gyms, schools, work places, transportation vehicles (Cincinelliand and Martellini, 2017). Consequently, the effect of IAQ on human health is quite enormous and may drastically affect the quality of life. In view of the fact that most human daily activities occur at indoor environment as earlier mentioned, the quality of indoor air that people are exposed to becomes very important.

Many homes are fitted with air conditioning systems and extractors for the purpose of ensuring the removal of impure air from the indoor environment. Children and the elderly have been found to particularly vulnerable to poor indoor air quality than adults. This may be related to the level of immunity in both cases. Contamination of indoor air can take place as a result of indoor and outdoor anthropogenic activities. Vehicular emissions and emissions from industries represent some of the sources of outdoor air pollution. While indoor activities include burning of fossil fuels such as wood, paraffin and coal. Cigarette smoke have also been categorised as one of the sources of indoor pollution especially when the act of smoking take place with the indoor environment. Some studies have reported high level of organic contaminants in indoor air (Orecchio et al., 2017; Vilčeková et al., 2017).

Indoor air contaminants such as volatile Organic Compounds (VOCs) and Particulate Matter (PM) especially the respirable sizes have been found to be harmful to human health. Some of the health effects of exposure include eye irritation, incidence of asthma, headache and nausea (Ghorani-Azam et al., 2016). In a study conducted by Medgyesi et al. (2017) on the impact of the use of biomass for indoor cooking, it was reported that household members developed pulmonary health problems as a result of exposure to high level of PM. In line with the previous study, the incomplete and inefficient combustion of fossil fuel such as paraffin burning stoves will cause the release of toxic gases such as carbon monoxide (CO), sulphur dioxide (SO₂) and others. This inhalation of these gases has been known to lead to health problems such as irritation of the eye, nausea and headache (Ghorani-Azam et al., 2016).

2.1.2 Sources of air pollutants and their associated health effects

Air pollutants or contaminants includes carbon dioxide, carbon monoxide, sulphur dioxide and oxides of nitrogen, Particulate matter etc., These pollutants come from different sources the following are some types of air pollutants, their sources and effects on human health. Carbon Monoxide (CO), mostly released by Fuel combustion from vehicles and engines and its associated with respiratory ailments such as reduction the amount of oxygen reaching the body's organs and tissues; aggravates heart disease, resulting in chest pain and other symptoms. Ground-level Ozone (O₃) Secondary pollutant, formed by chemical reaction of volatile organic compounds (VOCs) and NO_x in the presence of sunlight (Geng and Yang, 2001).

Ground-level Ozone (O₃) reduces lung function and causes respiratory symptoms, such as coughing and shortness of breath, and also makes asthma and other lung diseases get worse. Lead (Pb) produced in smelters (Metal refineries) and other metal industries, combustion of leaded gasoline in

piston engine aircraft; waste incinerators (waste burners), and battery manufacturing. It damages the developing nervous system, resulting in impacts on learning, memory, and behaviour in children, cardiovascular and renal effects in adults and early effects related to anaemia. Fuel combustion (electric utilities, big industrial boilers, vehicles) and wood burning, produce Nitrogen Dioxide (NO₂), resulting in worsens lung diseases leading to respiratory symptoms, increased susceptibility to respiratory infection.

Particulate Matter formed during chemical reaction, fuel combustion (e.g. burning coal, wood, diesel. Industrial processing, farming (ploughing field burning), and unpaved roads construction. Exposure to PM causes health effects that are divided into two categories which are: short-term exposures can worsen heart or lung diseases and cause respiratory problems. Long-term exposures can cause heart or lung disease and sometimes premature deaths. Lastly sulphur dioxide (SO₂) comes from fuel combustion, especially high-sulphur coal; electric utilities and industrial processes. High exposure to this gas over a period of time may lead to aggravates asthma and makes breathing difficult. (Geng and Yang, 2001).

Human health effects caused by exposure to pollutants/particulate exposures fall into two categories: short-term and long-term effects. Short-term effects (or acute effects) have a relatively quick onset (usually minutes to days) after brief exposures to relatively high concentrations of material (acute exposures). The effects may be local or systemic. Local effects occur at the site of contact between the pollutant/ particulate and the body. This site is usually the skin or eyes, but includes the lungs if irritants are inhaled or the gastrointestinal tract if ingested. Systemic effects are those that occur if the pollutants/ particulates are absorbed into the body from its initial contact point, transported to other parts of the body, and cause adverse effects in susceptible organs. Many chemicals can cause both local and systemic effects (CDC, 2015).

Rapidly industrialising towns have most of activities well known to be releasing particulate matters (PM) specifically heavy metals into the environment. The heavy metals can be found in the soil, dust and other surfaces. Dust consist of solid matter or particulate in the form of fine powder (<100 um), lying on the ground or on the surface of objects or blown on the surface of objects or blown about by natural forces or mechanical forces (Adekola and Dosumu 2001; Muhamad et al., 2012). Dust can enter and be found inside the houses and people may ingest contaminated dust with Heavy metals (solid matter or particulates), there is also possibility of inhaling contaminated dust also during respiration process and dermal contact when the skin come into contact with contaminated dust.

Exposure to tobacco smoke within the indoor environment has been known to be responsible for several health problems. Exposure by children is of particular concern due to their low immunity. Exhaled smoke is known to consist of thousands of chemicals of which about 40 have been identified to be carcinogenic (Pugmire et al., 2017). A positive relationship has been found between the rate of mortality and the level of particulate matter (PM) as reported by Pope et al. (1995). In addition, high rate of mortality in infants as a result of exposure to atmospheric suspended particulates has been reported (Chay & Greenstone, 2003).

From the Global Burden of Disease, it was reported that household air pollution is the leading cause of disability-adjusted life years (DALYs) in Southeast Asia and the third leading cause of DALYs globally. In addition, ambient air pollution is the sixth leading cause of DALYs in the Southeast Asia region and the ninth leading cause of DALYs globally (GDBR, 2015). Out of a population of 4.3 million reported deaths from indoor air pollution, about 60% were as a result of cardiovascular diseases while about 40% was from pulmonary diseases (Lu et al., 2015). Exposure to indoor air pollution has been linked to increase in the body mass index of people (Cesur et al., 2013). Children that tend to stay with their mothers during in-house domestic activities have been found to be exposed to VOCs and hence at risk of developing respiratory problems such as asthma, rhinitis, allergies and chest infections (Andra et al., 2015).

2.2 Theoretical Framework

Most industrial and other anthropogenic activities taking place have levels of exposure to contaminants which can be tolerated without adverse health effects. However, it is most important to identify contaminants associated with the activities taking place and then determine the exposure levels considered safe for each of these; the type and extent of exposure; and possible health effects of overexposure. All these are clearly stipulated in different acts and legislations. Even though there are set legislation, not all industries and activities taking place tend to comply with set standards.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter include the methods and procedure involved in data collection. It described the research design, the study area, respondents involved in the self-administered questionnaire, environmental samples, dust sample collection and sampling technique.

3.2 Research Design

Research design has been defined as a strategic framework for action that serves as a bridge between research questions and the execution, or implementation of the research strategy (Durrheim, 2004). Hence, it is a strategic and organised process of providing responses to the research questions through the implementation of applicable methods. Hence, the study employed a mixed method involving a combination of experimental and descriptive cross-sectional study using quantitative research approach.

3.3 Study Population

The population of the study include households/ residents of the Tsumeb Town in the Oshikoto region of Namibia. By resident, the study assumed that these are people that are community members living in the locality. Their livelihood and sustenance are based within the Township and, hence will be predisposed to the prevailing environmental conditions.

3.3.1 Study Area

The study was conducted in Tsumeb Township, a locality in the Oshikoto region of Namibia. The township has a geographical coordinate of 19° 14' 0" South, 17° 43' 0" East, 17° 26' 59" west (Date and Time.info, 2017) with a population of 19,840 (NSA, 2011). The minimum elevation is 1144m, and maximal elevation 1581m. The climate is sub-tropical having a mean maximum temperature of 29.7°C and mean minimum temperature 14.4°C. The average rainfall is 555mm per year. It is well known as the largest town in the region.



Figure 1: Map of Namibia showing the location of Tsumeb Locality (Source:www.nationonline/world/map)

3.4 Sampling method/sampling technique

In view of the large size of the study area and in view of the points mentioned under limitations, the study area was divided into clusters. For representatively and inclusivity, the area was divided into four (4) clusters. The main reason dividing area into 4 cluster was to ensure that 50 participants were taken from each cluster, totalling to 200 participants and a total of 9 sample collected from each cluster and the factors such town/location, population size, presence of the mining industry may differ from one cluster to another, nevertheless the differences between cluster was not one of the study focus. Samples (participants) were selected by simple random sampling. By this, the element of bias would have been eliminated in the data collection process.

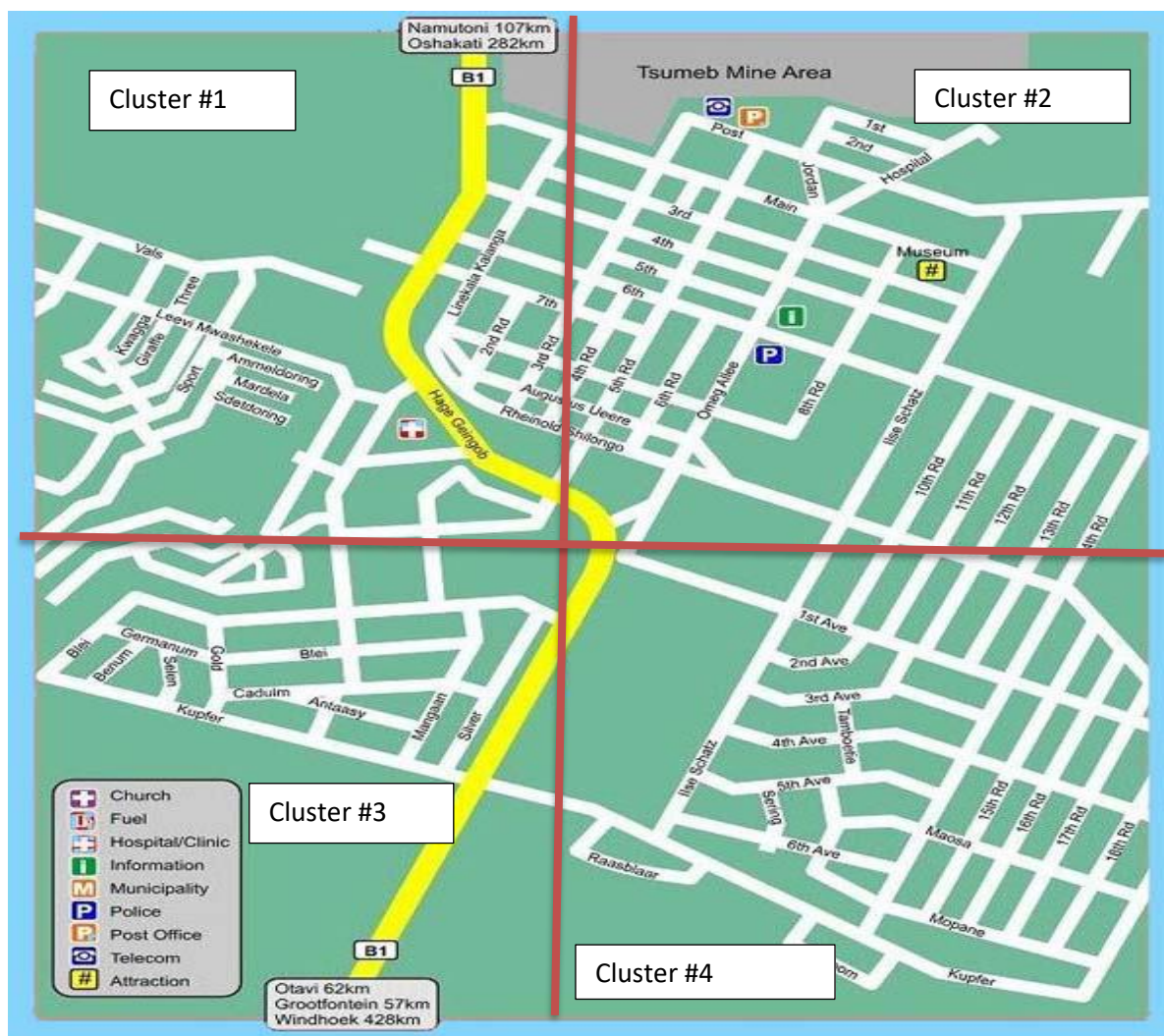


Figure: 2 Location of sample points (Dust) on the Tsumeb map divided into four clusters (South, North, West and East)

3.4.1 Sampling and sample size determination for respondents

The total of 250 questionnaires were distributed for data collection purposes, where by only 200 questionnaires were received back from respondents. The sample is sufficient based on sample size determination (Cochran, 1973) on a population of about 19,000 inhabitants (NSA, 2011) the. A systematic random distribution approach was used to select households (every 5th household), selecting an adult (> 18 years) per household on a convenient basis. Residents that meet the inclusion criteria (residence period and age) were selected for participation in the study.

3.4.2 Data collection method

3.4.2.1 Questionnaires

The information captured includes respiratory symptoms and diseases, family history of respiratory diseases, occupational exposure and history, type(s) of energy sources used for cooking and heating

etc. Adaptations/inclusions in the standardised questionnaire include enquiries on environmental risk factors such as possible presence of irritant gases in the atmosphere, particulate matter (PM) and others that residents might have experienced or exposed to in recent times and in the past years. The questionnaire also solicited for suggestions from respondents on what could be done to reduce exposure, if any to environmental factors. The adapted questionnaire has been previously used to collect data on respiratory diseases in related studies in US and South Africa (Naidoo et al., 2006). Responses were collected from residents that have lived in the area for a minimum of one year and agree to take part in the study.

3.4.2.2 Respirable dust collection

For the collection of respirable indoor dust samples, the same method of sampling area was used as with the questionnaire-participant based. Here, samples were collected from randomly selected households within each of the four (4) clusters as shown in Figure 2. In view of the socio-cultural beliefs, it was difficult to apply any particular sampling collection technique as residents were not totally convinced after explanation that the dust samples were solely for research purpose. Hence, dust samples were collected from households that were convinced of the purpose of the research within each cluster.

Indoor dust samples were collected using a brush and pan following a previously described method by Muhamad et al. (2012) as follow: Dust samples were collected in new clean zipped plastic. Using a clean plastic brush and pan, dust was collected inside the houses by sweeping the living room windows down part area, table surfaces and other items such as TVs. The indoor dust was then transferred into a resealable plastic bag. Sampling was done over a period of three months (July-September 2018). Three (3) samples were collected per household, 4 households per cluster (south, North, East and West) with a total of 12 sample collected per cluster within one period of collection. Hence, a total of 36 samples were collected over three months' period.

3.4.2.3 Sample treatment, reagents and instrument

In view of the small size of respirable dust (0.1-0.25 μm) the samples were no longer subjected to separation (sieving) and were utilised directly for analysis. Hence, all metallic determinations were based on this fine dust samples.

All reagents used in the extraction of heavy metals from dust samples were of Analytical Grade. The multi-element standard solution (1000 mg/L) was purchased from Biodynamics, Namibia, deionised water from Millipore Instrument was used throughout the study and the mineral acids (HCl, HNO_3) used in the digestion of samples were of high purity (>99%). Glassware were washed with liquid soap,

rinsed thoroughly with water and soaked in dilute HNO_3 overnight. They were rinsed with water and finally with distilled water before use. This was to prevent possible extraneous metallic contamination of the analysis since metals are known to adhere to glass.

3.4.2.4 Analysis of dust samples

Labelling of all beakers and flasks was done according to the labelling on zipped plastic bags containing dust samples. Dust sample weighing 0.2-0.25g was placed into the beaker. The 2ml of prepared Aqua Regia (1:3) of HNO_3 : HCl mixture was poured in to the beaker. Swirl gently and placed the beaker on the hot plate. Digested (heat) slowly in the fume hood at a temperature of about 60-70 $^{\circ}\text{C}$. Continued heating until volume was about 1ml or near dryness. The beaker was removed from hotplate and allowed to cool. The digested sample was reconstituted with deionised water and filtered into 25 ml standard flask and filled up to the mark. The heavy metal content of the digested samples was determined using Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) following a previously described procedure (Muhamad et al., 2012).

3.5 Data analysis

The sources of data in this study include the questionnaire and data obtained from the instrumental quantitative analysis of heavy metals from the dust samples. Data from both sources complement one another and are meant to reinforce the questions raised in the study.

3.6 Data Management

Questionnaires were coded. After information collection by questionnaires from respondents, the data was stored accordingly to their codes given and was checked for correctness and completeness. Incorrect entries and incompleteness are treated as missing values. The data were presented in graphical or tabular forms as appropriate. The concentration of heavy metal in dust samples was recorded and calculated accordingly using the following formula:

$$\text{Metal (mg/kg)} = [\text{Concentration of Metals (mg/L)} \times \text{Volume of Sample (L)}] / [\text{Sample Weight (kg)}]$$

3.6.1 Statistical Analysis

Results of the metal obtained from the digested and analysed dust samples were subjected to statistical evaluation using applicable inferential procedures. The Pearson Correlation Coefficient statistical function on the Microsoft Excel version 2016 was used. This is a dimensionless index, which

ranged from –1.0 to 1.0 and also reflects the extent of a linear relationship between two data sets was applied in the interpretation of data. The *r*-value of the regression line is given as:

$$r = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[n\sum X^2 - (\sum X)^2][n\sum Y^2 - (\sum Y)^2]}}$$

3.7 Validity of data collection instrument

Validity of data collection was attained through designing questions that cross-checked each other. The answers in some questions were used to verify and clarify earlier given answers. The questions were properly phrased and logically sequenced.

3.8 Reliability of data collection instrument

Reliability of the data collection instrument was ensured through conducting a pilot test before administering the questionnaire to the respondents. The results of the pilot test were used to make improvement to the questions and produce the copy of the questionnaire used in the actual data collection.

3.9 Ethical Consideration

Approval of the implementation of the project is obtained from NUST through the Faculty of Health and Applied Sciences. Consent to conduct the study is obtained from Tsumeb Town Council. Respondents were assured of total anonymity and confidentiality of information provided and that the study is purely for academic purpose.

3.9.1 Informed consent, voluntary participation, and confidentiality

The respondents were clearly informed that participation in the study was totally at their discretion. Thus, respondents were informed that they have the right to withdraw from participating at any point during the course of the research. In addition, it is within their right not to respond to any question/enquiry as contained in the questionnaire. The informed consent page was part of the administered questionnaire and was the first contact between the research and the participants.

Participants were informed that the research was purely for academic purpose and information provided will be treated with utmost confidentiality. This was even clearer to the participants as their

personal information such as names, age, date of birth, home and work addresses were not required or indicated in the questionnaire.

3.10 Limitation of Study

The major limitation in this study is possible information bias, i.e. not all the people gave relevant, concise and truthful answers. Financial resources were also a limitation because the scope covered is more than the financial resources availed.

3.11 Significance/Contribution of the Study

Identification of risk factors associated with respiratory symptoms is important because control of their exposures may lead to cure for people and prevention of disease. This outcome of the study generated data that will be very essential and useful to a number of stakeholders such as the health service providers, the Industries, government agencies such as the Ministry of Health and Social Services (MoHSS) and Ministry of Environmental and Tourism (MoE&T). By this, the outcome will assist in the strategic policy review and development in an attempt to address health issues especially cardiovascular and respiratory ailments which are leading causes of death in the country.

CHAPTER FOUR: RESULTS

4.1 Introduction

This chapter presents and discuss the research findings of the study. It covers the presentation of data, analysis and interpretation from data generated through survey questionnaires. These also include the data obtained from the analysis of heavy metals in dust samples. The data were subjected to statistical analysis through the use of SSPS Version 25. The findings are presented in both tabular and graphical forms as applicable in order to ensure easy comprehension by readers.

4.2 Socio-demographic Information

The socio-demographic data obtained from a total of 200 respondents that participated in this study is as presented in Table 4.1. The respondents comprised of 104 (52%) male and 96 (48%) female. The ratio of gender participation was quite close which indicate almost equal representation in terms of opinion expressed in the study. Expression of opinion on various issues as contained in the questionnaire is basically based on individual perception and independent of gender orientation. However, there are some issues that the females might feel very strongly about which might be different from those of the male counterpart.

The age group of between 18-30 years constitute the largest block of the age range in the study population with 51.5%, of which 27% were female and 24.5% as male respondents. This revealed that the younger groups were more eager to participate in the study. This might be as a result of the explanation of the purpose of the study that was provided. In addition, a fairly good percentage of respondents are well educated with possession of qualification above the secondary school level. In terms of educational level, 39.5% of the respondents obtained tertiary education out of which 22.5% were male while 17% consist of female respondents.

Most of the respondents (61.5%) were gainfully employed while 19% is that portion occupied by the students. Of the employed populace, 32% of this group are working with varied private organisations, 25.5% with the government, and only 1.5% of respondents were under the employment of different international bodies. With respect to the length of residency in the township, the highest range of 4-6 years were the highest group with 32% (64) and followed closely by the 1-3 years with 30% (60). Those that have been in the township from 7-9 years were about 21% (43) while those above 9 years were 34% (17). Results however revealed that from all the different range of years of residency, the number of males that have been living in the township were more than the female counterpart with the exception of those above 9 years. The highest number of the group that has been living in the area for between 1-3 year might be due to the fact that most of the individuals in this range might be

younger and possibly newly employed individual that have recently settled down in the municipality because of new employment.

Table 4.1: Socio- demographic information of respondents

VARIABLE	MALES	FEMALES	TOTAL
Sex	104 (52%)	96(48%)	200(100%)
Age(years)			
18-30	49(24.5%)	54(27%)	103 (51.5%)
31-40	33(16.5%)	38(19%)	71(35.5%)
41 ⁺	22(11%)	4(2%)	26(13%)
Education			
Primary	7(3.5%)	20(10%)	27(13.5%)
Secondary	37(18.5%)	33(16.5%)	70(35%)
Tertiary	45(22.5%)	34(17%)	79(39.5%)
Post Graduate	15(7.5%)	9(4.5%)	24(12%)
Occupation Status			
Employed	68(34%)	55(27.5%)	123(61.5%)
Self Employed	14(7%)	13(6.5%)	27(13.5%)
Unemployed	12(6%)	19(9.5%)	31(15.5%)
Student	10(5%)	9(4.5%)	19(9.5%)
Sector of employment			
Government	28(14%)	23(11.5%)	51(25.5%)
Industry	35(17.5%)	29(14.5%)	64(32%)
NGOs	12(6%)	11(6.5.5%)	23(11.5%)
International Bodies	2(1%)	1(0.5%)	3(1.5%)
Not Applicable	27(13.5%)	32(16%)	59(29.5%)
Period of residence in the community			
1-3 years	38(14%)	22(11.5%)	60(30%)
4-6 years	34(17%)	30(15%)	64(32%)
7-9 years	23(11.5%)	19(9.5%)	42(21%)
9 ⁺	9(4.5%)	25(12.5%)	34(17%)

4.3.1 Nature of road accessed regularly by respondents

All of the 200 respondents had responded to the question of the type of road which passes through their area of residence. and the information is summarised in Figure 4.1 below, which shows that most (66%) of the respondents resides close to the tarred road, followed by those respondents who stays next to gravel roads as they occupy 19% of the total sample. However, of the sample under study, 5% of the respondents stays next to the bushy roads, and they are least represented.

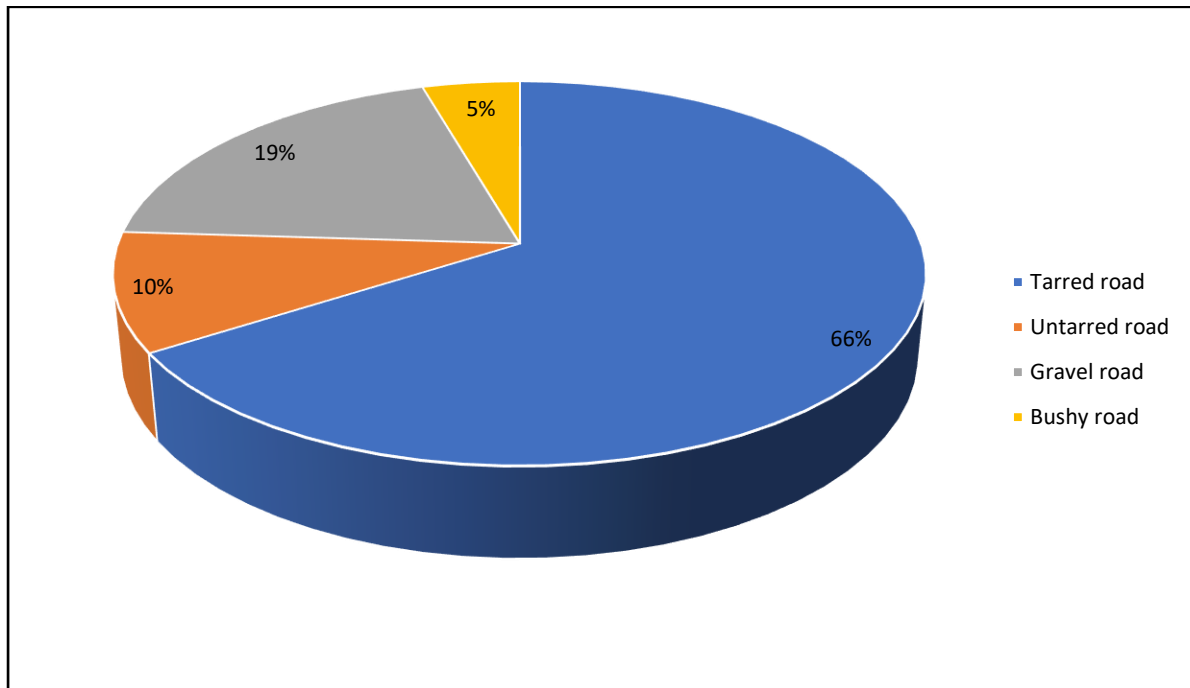


Figure 4.1: Type/nature of the road used by respondents

4.3.2 Number of levels of residence

From the total sample of 200 respondents, most of them (91%) reside in a single storey, followed by 7% who resides in double storey buildings. However, those who resides under a 3-storey are least represented with only 2% of the sample under study as shown in Figure 4.2

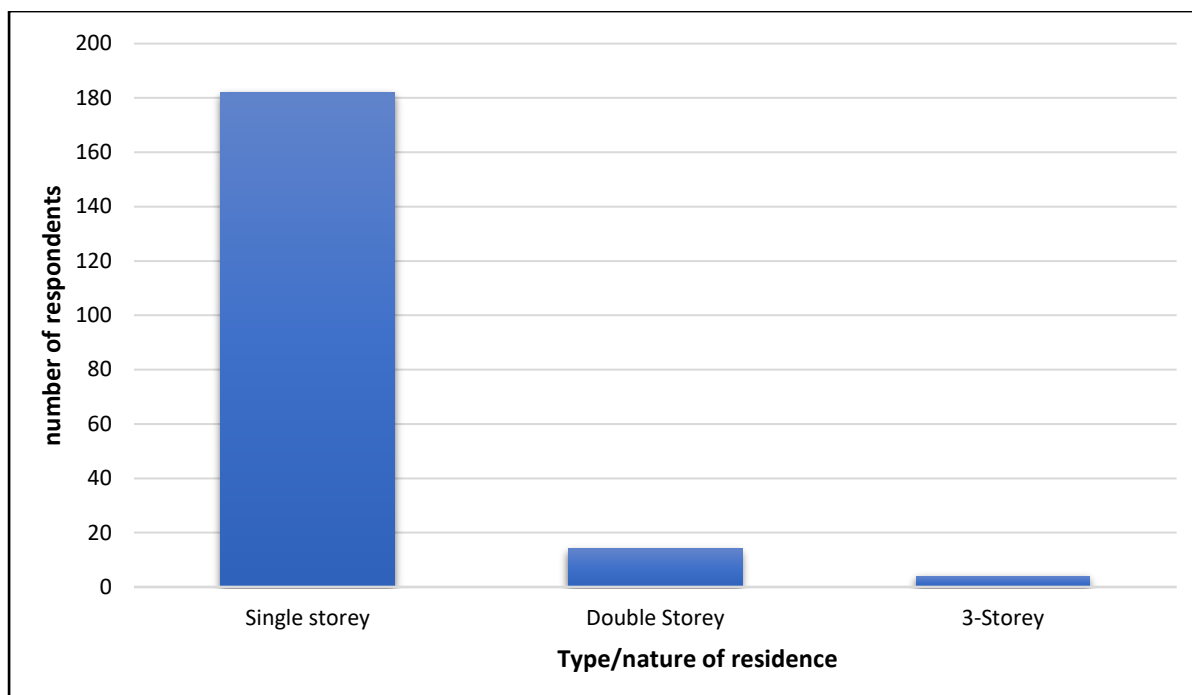


Figure 4.2: Number of levels of residence

4.3.3 Doors and windows protected with nets

Figure 4.3 shows that more than three-quarters of the respondents (78%) had their doors and windows not protected with nets. However, the rest (22%) of the population under study had indicated that their doors and windows protected with nets.

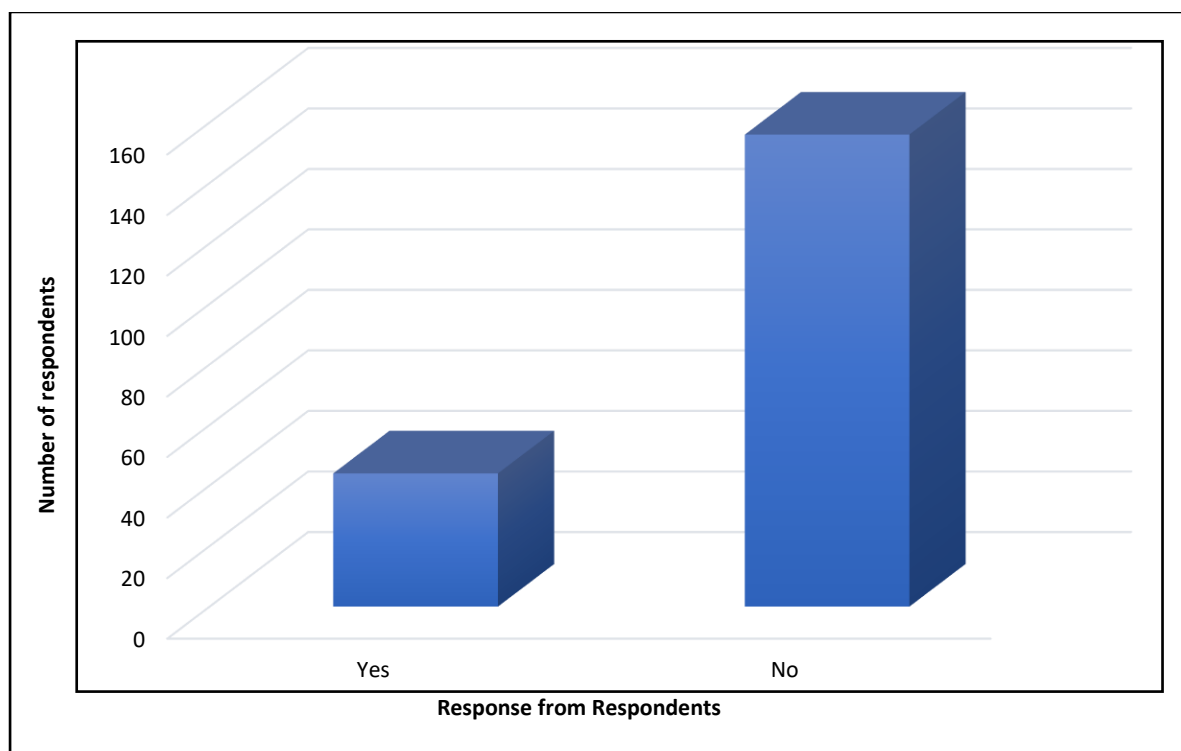


Figure 4.3: Doors and windows protected with nets

4.3.4 Geographical direction of residence

The geographic distribution of residences of respondents is as shown in Fig 4.4. The result shows that the highest proportion of respondents (37%) were from the northern part of the study area, 24% from the eastern section of the town, 21% from the west, while 18% were from the southern section of the study area. The northern section of the town was mainly the residential part that was closer to amenities such as bus terminals, shopping malls and schools. This might possibly be responsible for the high number of respondents from this section of the town. The type of residential location has been reported by other studies to contribute to individual risk of developing poor health outcomes (Clougherty, 2012; Wong et al., 2008.; Hamatui et al.,2016).

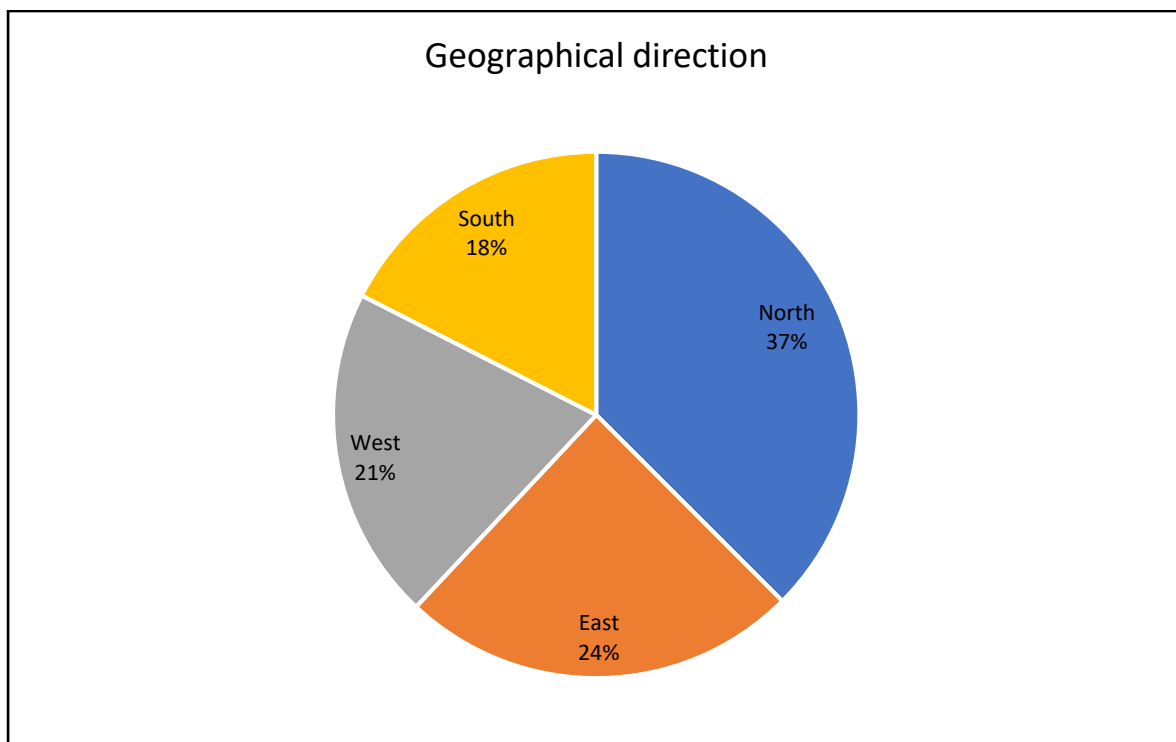


Figure 4.4: Geographical Location of respondents' houses

4.3.5 Changes in air quality

From Fig 4.5, 65% of the respondents who had indicated that they had noticed a change in air quality pointed out that the change might be because of the gaseous pollutants. However, the view is opposed by 11.5% of the respondents who indicated that it was not gaseous pollutants which changes air quality. Of the sample under study, 23.5% of the respondents had no answer to this motion.

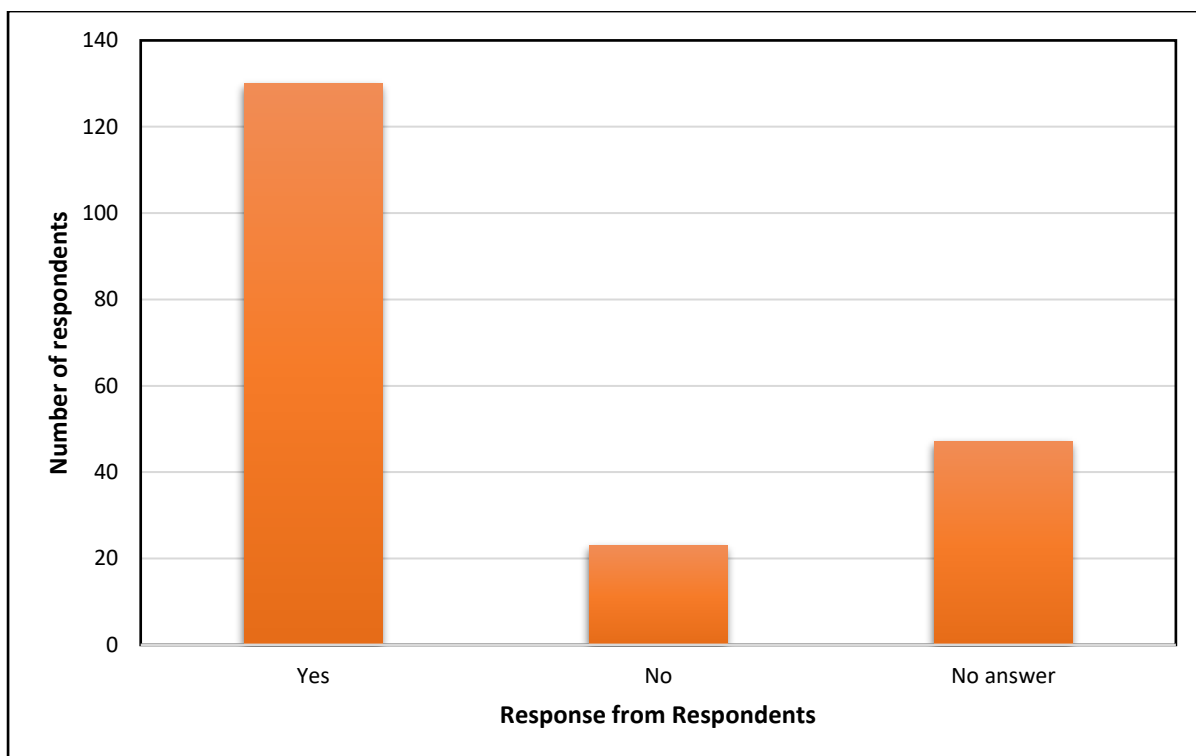


Figure 4.5: Level of gaseous pollutants that may be causing changes in air quality

4.3.6 Rating of overall air quality compared to previous years

The Figure below shows the perception responses of the 200 respondents in line with how they view the overall air quality as compared to the previous years. More than half (57%) of the respondents have indicated that the present air quality is much better as compared to the previous years. The views were followed by 19.5% of the respondents who indicated that the present air quality is a bit better as compared to the previous years. With 15.5% of the sample under study failing to figure out the difference between the present and the past air quality, only 8% of the population had views the present air quality to be worse of as compared to that one of the past years.

It is important to mention at this point that the study area, Tsumeb has been known for its anthropogenic/industrial activities for over 100 years especially mining operations. Other activities include quarry, petrochemicals and agricultural. Hence, the high number of residents' indication observation of changes in the quality of air was based on the experience of exposure to air toxicants possibility emanating from industrial activities.

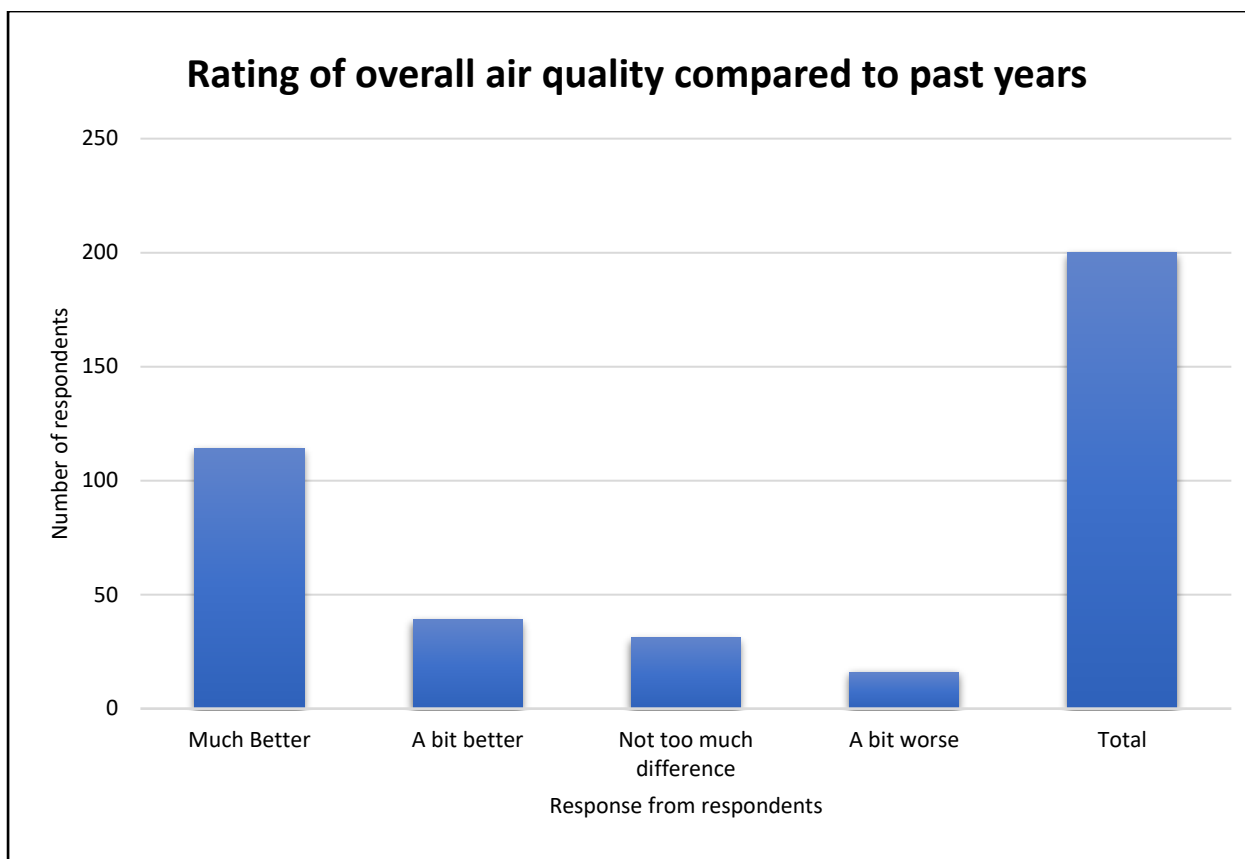


Figure 4.6: Rating of overall air quality compared to years

4.3.7 Rate of Change in air Quality

The rate of change of the quality of air is as shown in Figure 4.7. Generally, atmospheric/climatic conditions are known to influence the level, intensity as well as direction of air toxicants. Majority of respondents had earlier indicated that they were concerned about the quality of air in their township, however, the rate or extent of impact may vary from the different areas of the town. About 30% of the respondents indicated that they observe regular changes in air quality. This was followed by 29.5% of the respondents who indicates that the changes were fairly-regular while 18% indicated that air quality seldom change.

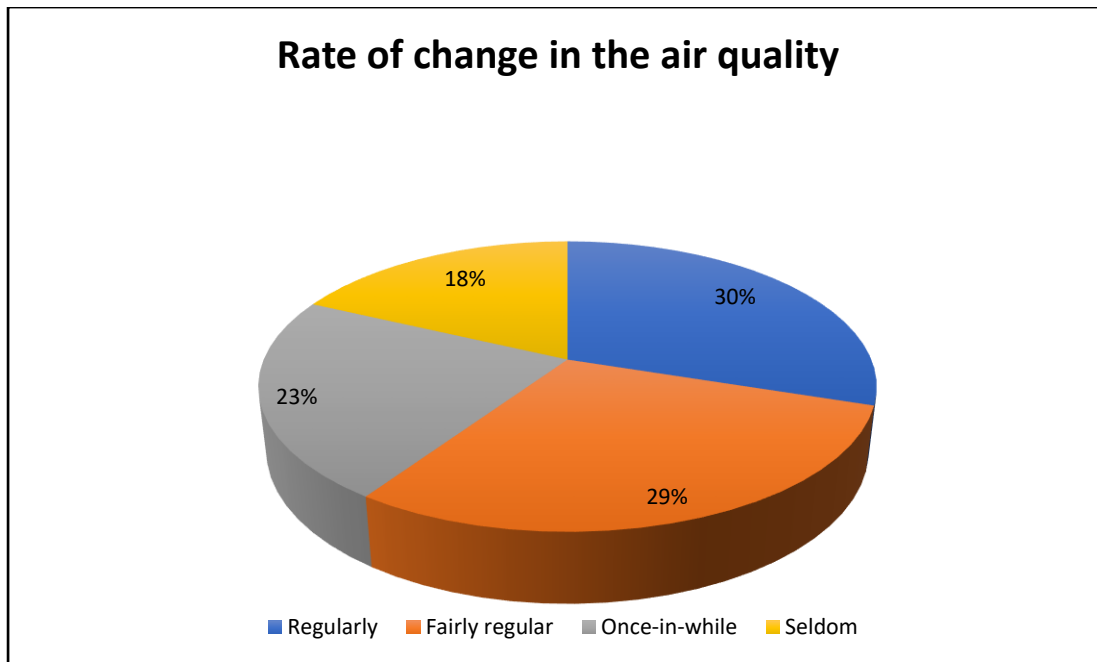


Figure 4.7: Responses on rate of change in air quality in the study area

4.3.8 Sources of pollution

The study conducted by Hamatui & Beynon, (2017) found out that Windhoek (WHK) residents' risk for poor respiratory health outcomes was multifactorial and may include factors such as the environmental exposure to tobacco and poor indoor air quality both at home and at the work place. From the various sources of air pollutions observed by the respondents, it emerged that industrial pollution is the major air pollutant factor in Tsumeb, with 79% of the respondents agrees with the motion. This decision is then followed by burning waste which was pointed out by 61.5% of the respondents. However, household cooking was seen to be the least pollutant factor, as it was only raised by 20% of the sample under study as clearly indicated in Figure 4.8.

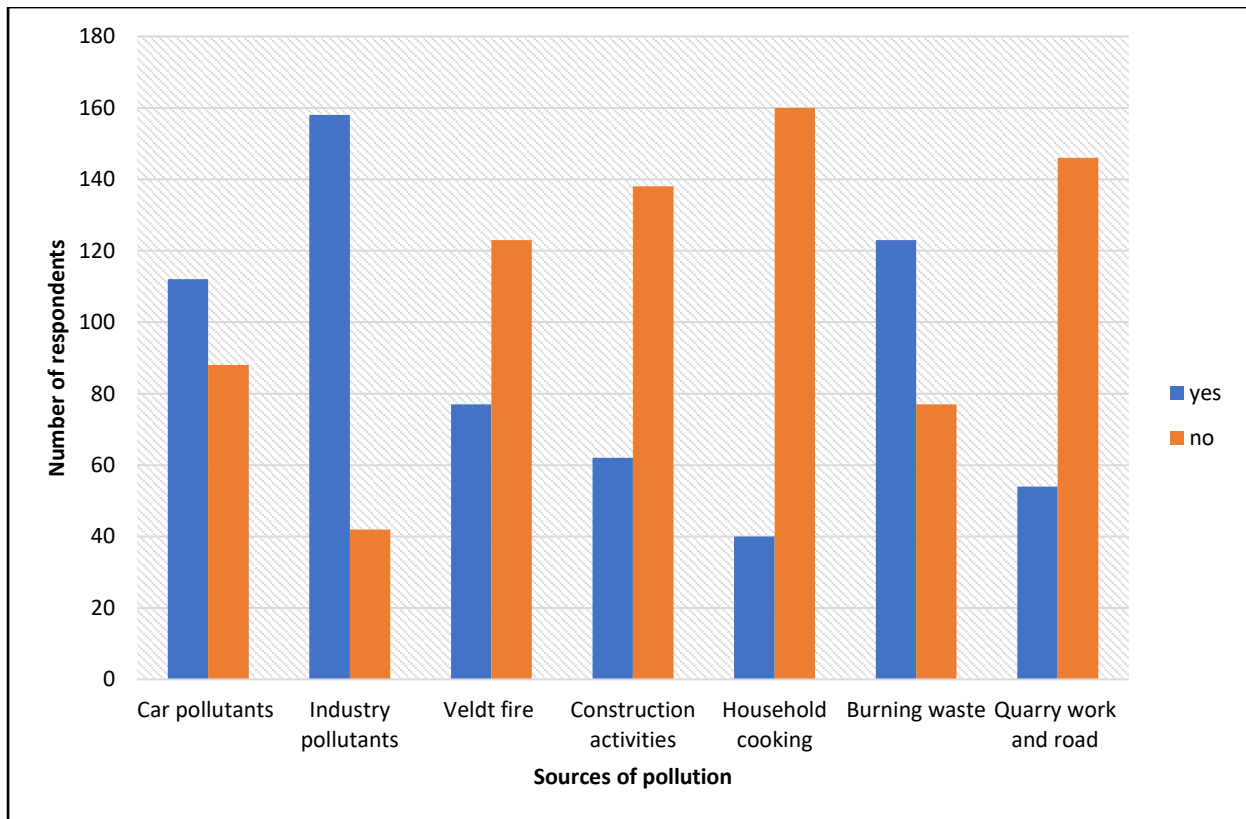


Figure 4.8: Responses on the source of pollution in the study area

4.3.9 Measures to control air quality

As shown in Figure 4.9, 66.5% of the sample under study indicated that there is a need to set up air quality monitoring programme in the community in order to control air quality. The view is then followed by 59% of the respondents posits that regular environmental pollution awareness campaign are necessary so as to control air quality. However, the list view is obtained from 17% of the respondents who suggests planting of trees to be the most appropriate measure to control air quality

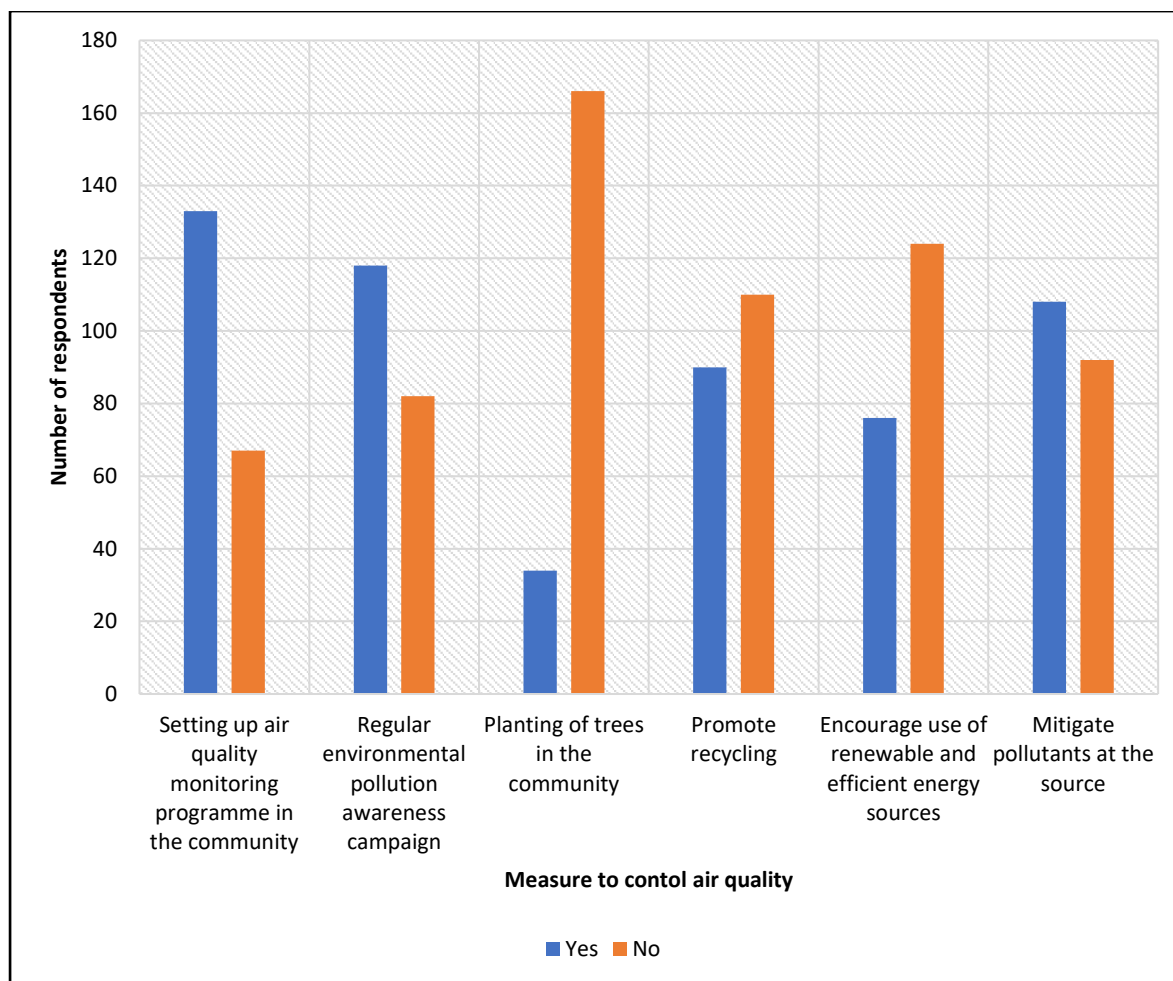


Figure 4.9: Respondents view on measures for the control air quality

4.3.10 The extent considered to be affected by air quality in the community

Figure 4.10 shows that there was little difference on the extent to which respondents are affected by air quality. With, 37% pointing out that they were slightly affected by the air pollution. However, 22% of the respondents stated that they were moderately affected the perceived pollution in the atmosphere while only 19% of the respondents indicated that the air they breathe did not affect them in any way.

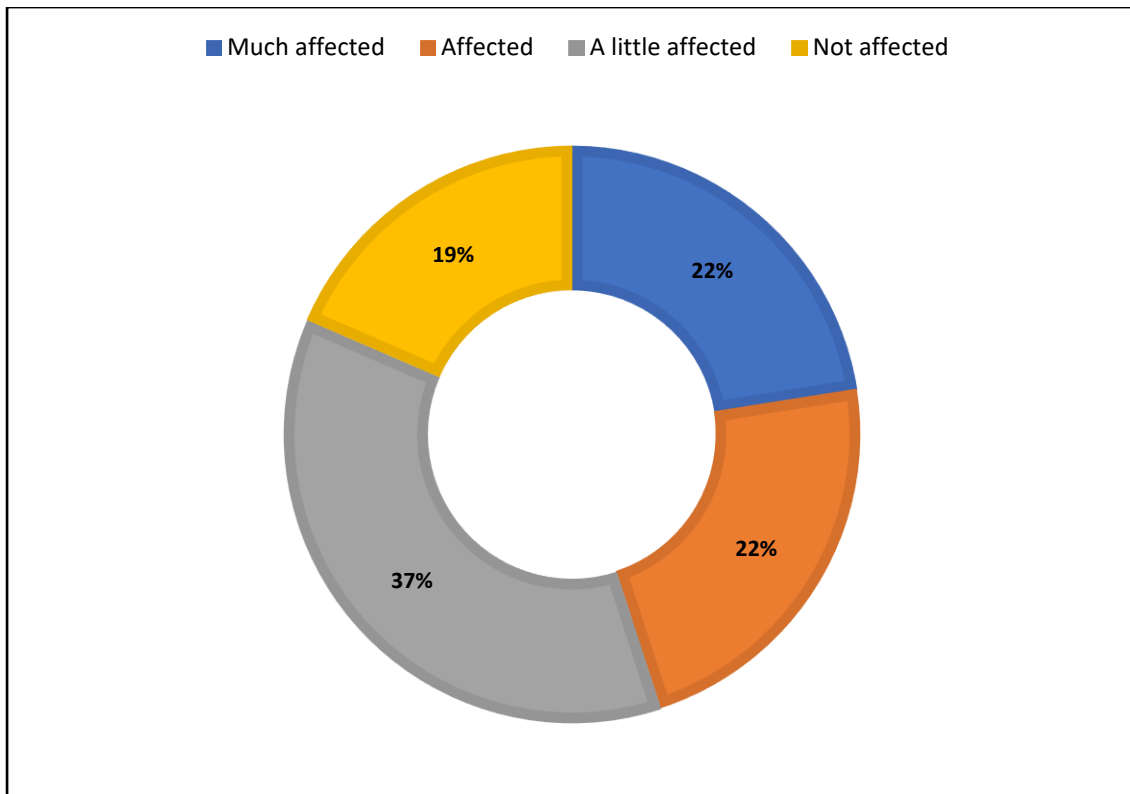


Figure 4.10: Extent to which respondents are affected by air quality

4.3.11 Effects of poor air quality

Figure 4.11 presents the extent to which respondents are affected by the air they breathe. Air pollution continues to be great concern in view of the multifaceted impact on the environment and human health. The rate of pollution has been reported to be increasing as a result of several anthropogenic activities. About 25.5% of the respondents indicated that their quality of life has been affected by air quality. In terms of how their health has been affected by the quality of air they inhale, 17.5% of respondents indicated that air quality causes difficulty in breathing. In addition, poor visibility especially in the morning was also indicated as part of the impact of the pollution. However, 15.5% of respondents pointed out that they are considering relocating to other locality due to air quality.

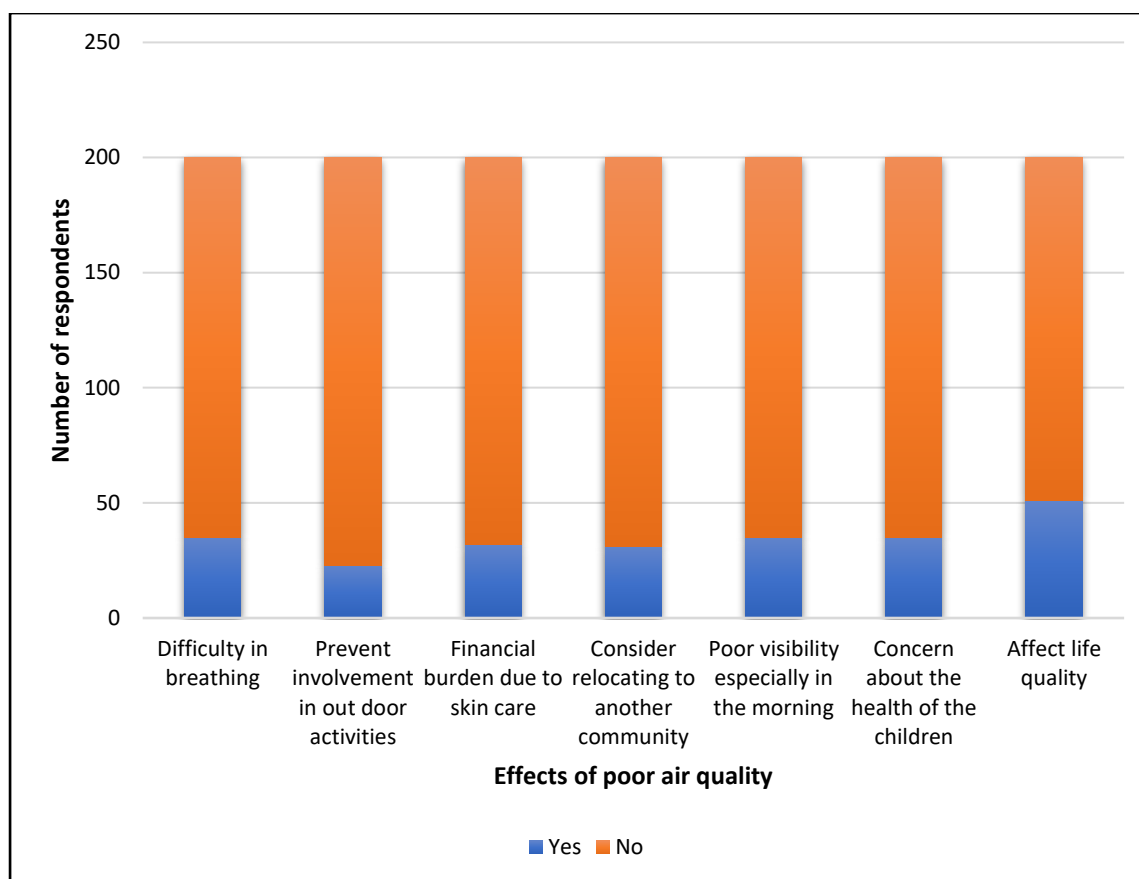


Figure 4.11: Responses on the effects of poor air quality on their health based on respondent option

4.3.12 Diseases associated with poor air quality

From the results of possible diseases/ailments respondents might be experiencing as a result of the quality of air they are exposed to on a daily basis, majority of respondents, 79.5% indicated that they experienced severe coughing as a result of the poor air quality is shown in Figure 4.12. This opinion was followed by 60% of respondents where it was pointed that the poor air quality causes sneezing. However, only 7% of the respondents had indicated that the poor air quality might be causing lung. Increase in standard of living as ushered by advancement in scientific and technological development over the millennia is accompanied by huge amount of wastes that are released into the environment.

This rate of air pollution in developing countries have been increasing over the past decades as witnessed by various emissions from automobile, industries and forest fires (Chen, 2014). About 4.3 million people have been reported to die from household air pollution and 3.7 million from ambient air pollution where majority of this pollution are from Asia (Chung et al., 2011). As revealed from the graph, coughing, sneezing and coughing with and without the discharge of sputum were the highest health effects indicted by respondents that they experienced and might be associated with the poor

air quality. Lung cancer, asthma and coughing with blood stain were the least health problems indicated by respondents.

It is important at this point to stress that the relation between poor air quality and various health problems indicted by respondents they may be experiencing was basically on a causal and probability relationship since no medical examination was conducted and medical records of respondents were not examined.

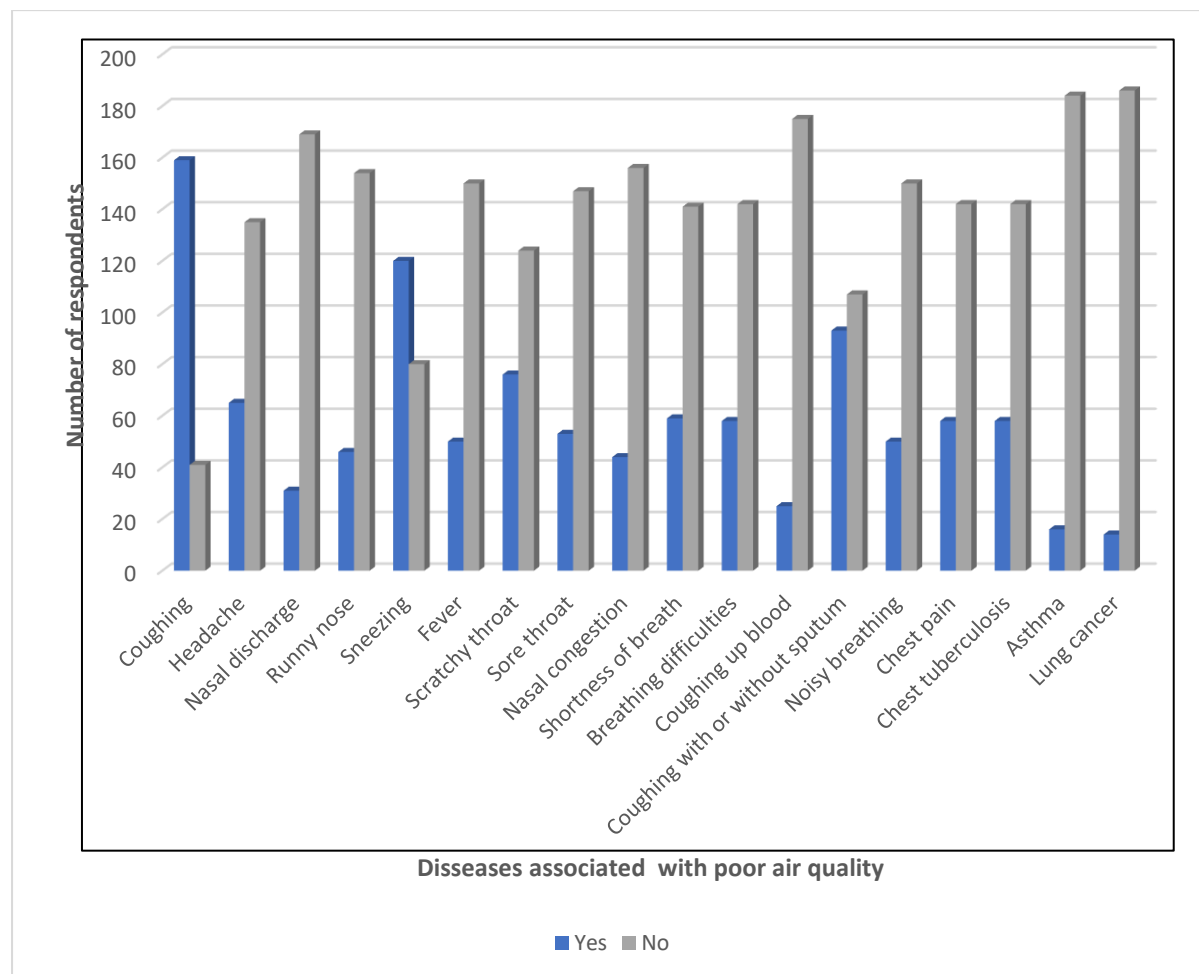


Figure 4.12: Diseases associated with poor air quality based on respondent option

4.4 Relationship between risk factors and respiratory ailments

4.4.1 Relationship between Road type and respiratory ailments

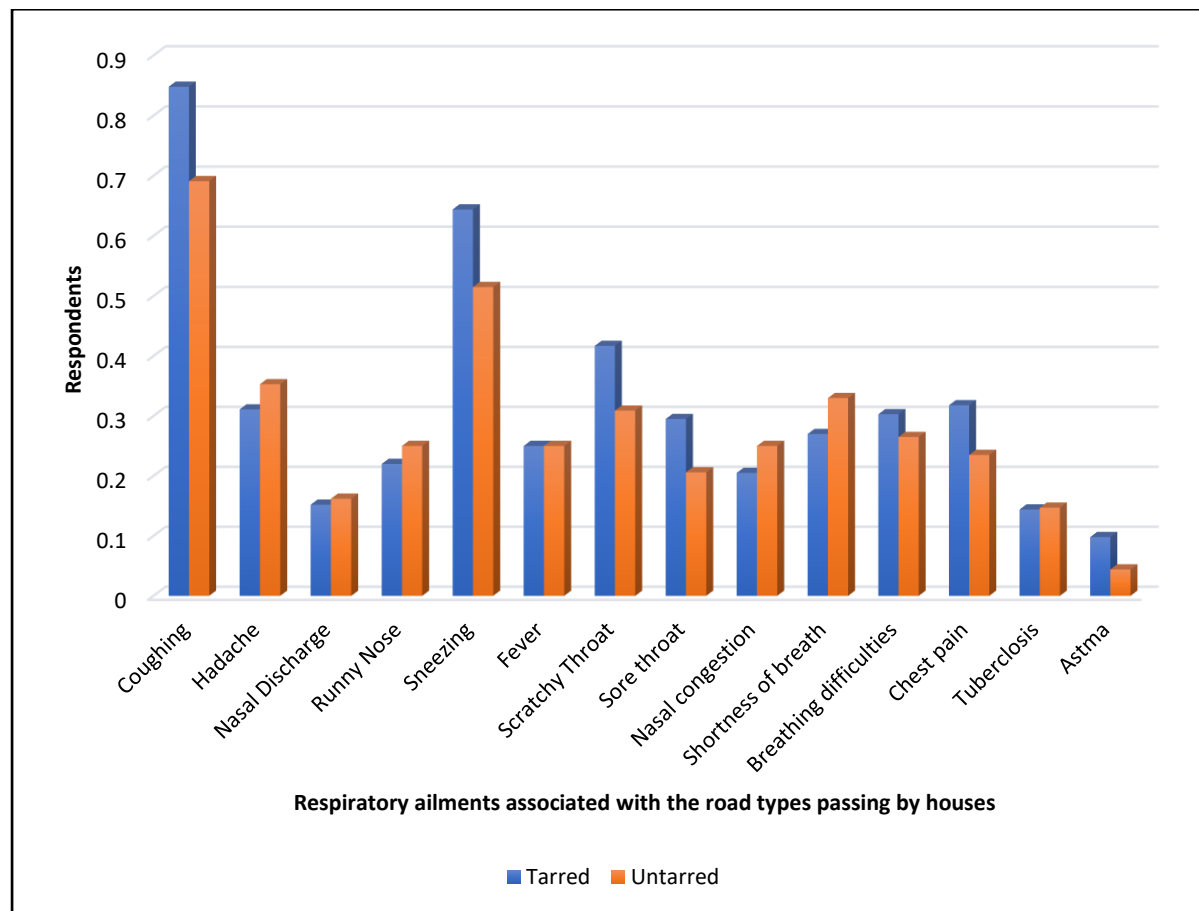


Figure 4.13: Road type and associated respiratory ailments

Fig 4.13 shows that, of those who indicated that they cough, 84.4% stays close to tarred, while 69.1% of those who cough stay close to untarred road. However, of the respondents who indicated that they suffered from asthma, 9.8% stays close to the tarred road. The majority of respondent reported to have unsurfaced road (gravel road) passing near their homes, which contribute to the increase of dust cloud in the location as well as the presence of dust on indoor surfaces, mainly due to vehicle movement (Hamatui et al., 2016).

4.4.2 Relationship between indoor Dust and respiratory ailments

The concentration of indoor dust could be attributed to anthropogenic activities such as, building construction related activities and vehicular movement in the town. (Hamatui et al., 2016).

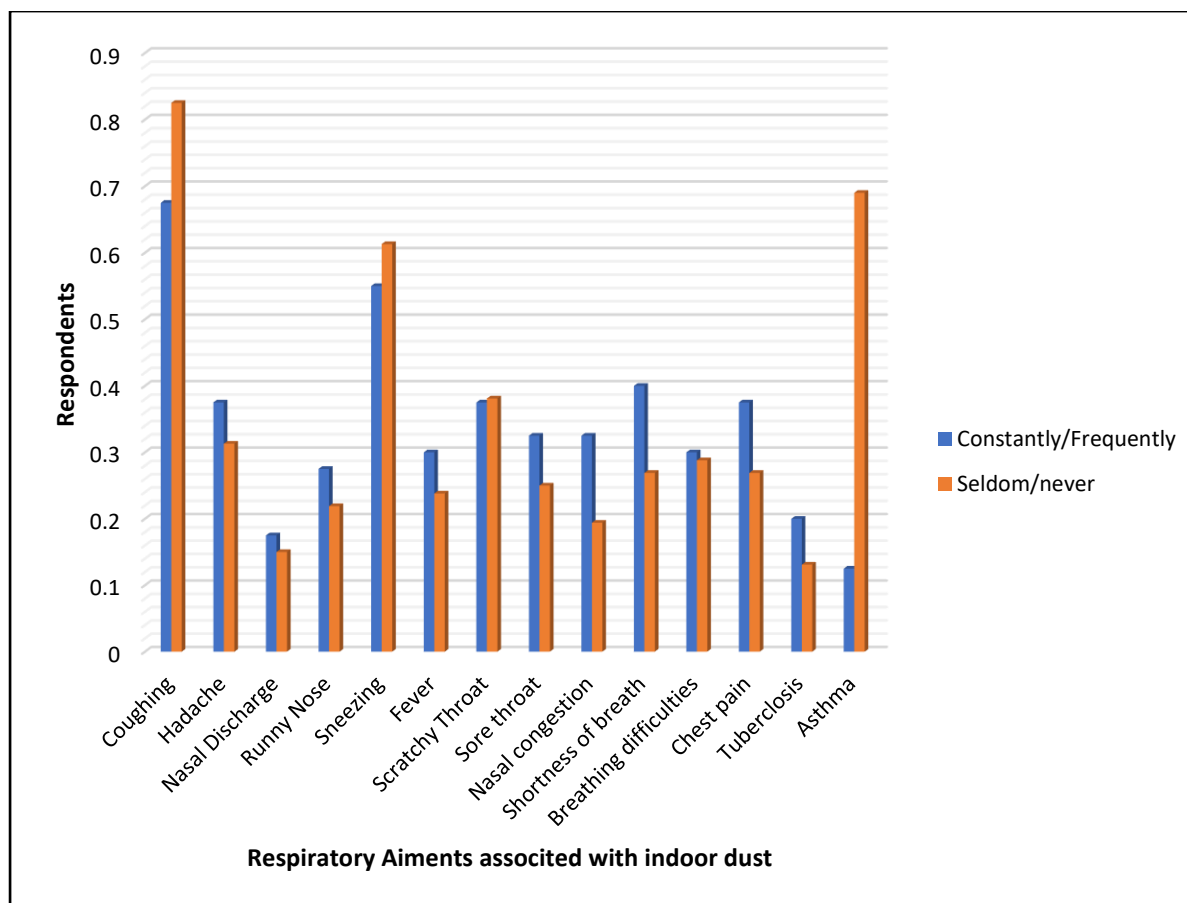


Figure 4.14: Result of indoor dust and its association with respiratory ailments

Figure 4.14 shows the result of the investigation of possible impact of indoor dust on the health of respondents. About 75% of the respondents associate coughing to the problem of fine dust particles in their residences. They further mentioned that the experience was of persistent one. However, 3.9% of the respondents' state that they never suffered from tuberculosis due to indoor dust. Poor quality of indoor air can be very harmful to inhabitants. Children and the elderly are most vulnerable to the impact of poor indoor air.

4.4.3 Relationship between cigarettes smokers and respiratory ailments

From Figure 4.15, smoking cigarettes is considered as a one of the major causes of indoor air pollution which may potentially lead to coughing among other ailments by the smoker. This view was shared by majority of respondents in this study. However, they were of the opinion that the developing asthma as a result of smoking cigarette is low. Smoking related studies affirmed that smokers had increased risk of developing poor respiratory health outcomes due to synergistic effect observed between smoking and dust exposure (Hamatui et al., 2016).

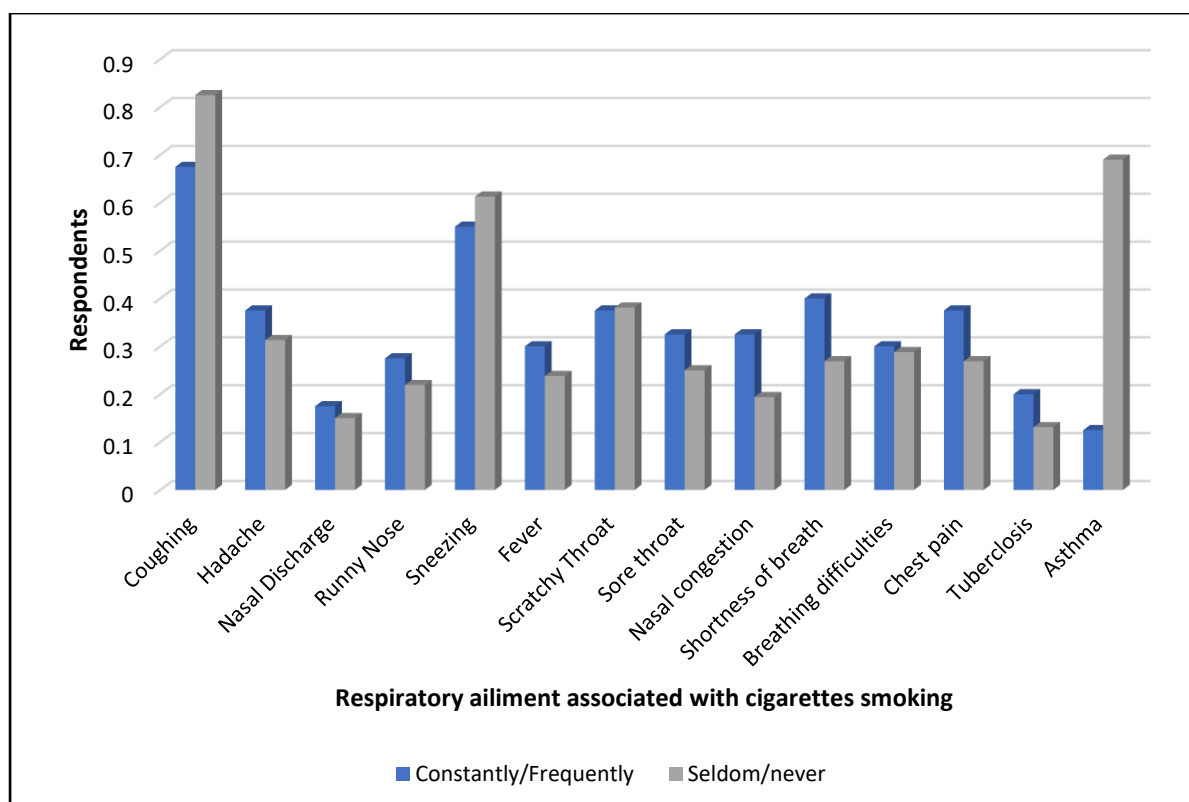


Figure 4.15: Result of the respiratory ailments that may be associated with cigarettes smoking

4.5 Heavy metals analysis in respirable indoor dust

Results of the investigation of the presence and level of some toxic heavy metals are as presented in Tables 4.2.1 – 4.2.4. From Table 4.2.1 below, the level of Mn ranged from 184.9 – 695.1 mg/kg; Cd from 0 – 6.6 mg/kg; Ni from 1.7 – 15.8 mg/kg; Cu from 14.2 - 1812.7 mg/kg; Zn 89.9 - 1616.6 mg/kg and Pb from 6.9 - 897.9 mg/kg across the three houses in southern sampling section/area of study. The mean concentration of heavy metals across the period of sampling revealed that the highest level of all analysed metals was obtained at House 1 (H1).

Although, the dispersal of particulates could be influenced by climatic conditions such as wind direction, wind speed and rate of precipitation, other anthropogenic factors such as disposal of petrochemical wastes and old batteries on land might also influence the level of heavy metals at a particular location. This section of the study area is relatively closer to industrial activities such as petrochemical, quarry, and mining operations.

In view of the fact that there are no specific guidelines in terms of the maximum allowable limits of heavy metals in street and indoor dust (Leung et al., 2008), it becomes plausible to use the limits specified for heavy metals in soil. It is generally known that a good amount of street and indoor dust emanates from soil through suspension and remobilisation processes (Ferreira-Baptista and De

Miguel, 2005). From the result obtained in this study, the mean concentrations of Cu and Zn at H1 from the Southern section of the study area were higher than the maximum permissible limits of 19.2 mg/kg for Cu and 55.7 mg/kg for Zn (Sezgin et al., 2003).

Table 4.2.1: Level of heavy metals (mg/kg) in dust samples from houses across the sampling period from Southern Section of study area (July-Oct 2018); n = 9

Section	House	SP	Metals					
			Mn	Cd	Ni	Cu	Zn	Pb
S	1	SP1	695.1	6.6	15.8	1812.7	1616.6	656.2
		SP2	363.1	2.4	8.4	705.5	1127.6	897.9
		SP3	354.9	2.8	9.8	706.6	931.1	723.2
		X	471.0	3.9	11.3	1074.9	1225.1	759.1
	2	SP1	713.4	0.0	7.3	195.0	364.3	188.4
		SP2	238.6	0.0	5.1	80.93	267.8	120.8
		SP3	270.8	0.6	4.6	56.22	163.6	76.9
		X	407.6	0.2	5.7	110.7	265.2	128.7
	3	SP1	233.5	0.0	3.6	14.2	168.5	6.9
		SP2	184.9	0.0	1.7	22.5	89.9	37.6
		SP3	197.6	0.0	1.7	23.6	97.5	34.3
		X	205.3	0	2.3	20.1	118.6	26.3

SP = Sampling Period; **1-3** = Periods of Sampling; **S** = Southern Section of Study Area; **X** = mean

The correlation co-efficient can measures the interrelationship between two variables. In this case, correction between the analysed heavy metals was carried out to check possible association between them. From Table 4.2.1.1 below, strong correlation between Cd and Ni ($r = 0.92$), Cu and Cd ($r = 0.99$), Cd and Zn ($r = 0.95$), Zn and Pb ($r = 0.9$), Cu and Zn ($r = 0.96$). All these strong correlations showed strong relationship between the metals and possibly from similar source.

Table 4.2.1.1: Correlation co-efficient of heavy metals from the Southern Section of the study area

	<i>Mn</i>	<i>Cd</i>	<i>Ni</i>	<i>Cu</i>	<i>Zn</i>	<i>Pb</i>
Mn	1					
Cd	0.58	1				
Ni	0.78	0.92	1			
Cu	0.66	0.99	0.95	1		
Zn	0.62	0.95	0.94	0.96	1	
Pb	0.43	0.76	0.78	0.76	0.90	1

In Table 4.2.2, the concentration of heavy metals varied across the three sampled houses in the Northern section/part of the study area from Mn: 5.4 – 430.3 mg/kg; Cd: 0 – 18.0 mg/kg; Ni: 4.0 – 919.8 mg/kg; Cu: 87.1 – 2338.3 mg/kg; Zn: 136.0 – 1116.2 mg/kg and Pb: 30.9 – 460.0 mg/kg

Table 4.2.2: Level of heavy metals (mg/kg) in dust samples from houses across the sampling period from Northern Section B of study area (July-Oct 2018); n = 9

Section	House	SP	Metals					
			Mn	Cd	Ni	Cu	Zn	Pb
N	1	SP1	5.4	10.6	569.7	525.0	329.9	384.7
		SP2	15.2	12.4	919.8	713.0	502.6	400.6
		SP3	8.9	13.6	691.0	701.8	482.8	442.5
		X	9.8	12.2	726.8	646.6	438.4	409.3
	2	SP1	261.1	0.0	4.0	35.6	142.2	52.6
		SP2	294.5	0.0	7.8	51.6	188.0	48.3
		SP3	196.5	0.0	2.5	47.0	136.0	40.9
		X	250.7	0	4.8	44.7	155.4	47.3
	3	SP1	430.3	18.0	9.6	2338.3	1115.2	460.0
		SP2	138.8	3.33	3.7	786.8	547.3	188.3
		SP3	236.8	0.0	4.1	87.1	153.5	50.3
		X	268.6	7.1	5.8	1070.7	605.3	232.9

SP = Sampling Period; **1-3** = Periods of Sampling; **N** = Northern Section of Study Area; **X** = mean

Correction between the analysed heavy metals was also carried out. From Table 4.2.1.2 below, there is strong correlation between Cd and Pb ($r = 0.98$), Cu and Zn ($r = 0.99$). All these strong correlations showed strong relationship between the metals and possibly from similar source.

Table 4.2.1.2: Correlation co-efficient of heavy metals from the Northern Section of the study area

	<i>Mn</i>	<i>Cd</i>	<i>Ni</i>	<i>Cu</i>	<i>Zn</i>	<i>Pb</i>
Mn	1					
Cd	-0.19	1				
Ni	-0.81	0.60	1			
Cu	0.30	0.82	0.08	1		
Zn	0.24	0.82	0.12	0.99	1	
Pb	0.36	0.98	0.70	0.74	0.76	1

Table 4.2.3 presents the results of the heavy metal analysis from the Eastern section of the study area. The metallic load varies from Mn: 72.0 – 198.9 mg/kg; Cd: 0 – 6.9 mg/kg; Ni: 2.1 – 7.5 mg/kg; Cu: 22.2 – 579.4 mg/kg; Zn: 68.9 – 548.9 mg/kg and Pb: 34.3 – 409.2 mg/kg.

Table 4.2.3: Level of heavy metals (mg/kg) in dust samples from houses across the sampling Period from section Eastern Section of study area (July-Oct 2018); n = 9

Section	House	SP	Metals					
			Mn	Cd	Ni	Cu	Zn	Pb
E	1	SP1	198.9	0.0	4.1	77.7	68.9	93.1
		SP2	237.9	0.0	2.3	29.7	118.4	46.9
		SP3	179.5	0.0	2.2	22.2	101.8	34.3
		X	205.4	0	2.9	43.2	96.4	58.1
	2	SP1	335.1	6.9	7.5	579.4	548.9	409.2
		SP2	79.6	2.6	3.5	131.6	120.5	86.4
		SP3	72.0	1.9	2.3	107.3	105.6	78.5
		X	162.2	3.8	4.4	272.8	258.3	191.4
	3	SP1	230.3	0.0	3.9	34.9	127.8	43.5
		SP2	255.2	0.0	3.5	22.4	111.2	43.5
		SP3	244.4	0.0	2.1	28.8	122.7	47.3
		X	243.3	0	3.2	28.7	120.6	44.8

SP = Sampling Period; **1-3** = Periods of Sampling; **E** = Eastern Section of Study Area; **X** = mean

Correlation between the analysed heavy metals was revealed in Table 4.2.1.3 below, strong correlation between Cu and Cd ($r = 0.97$), Cd and Zn ($r = 0.91$), Cd and Pb ($r = 0.94$), Pb and Ni ($r = 0.91$), Cu and Zn ($r = 0.96$) Cu and Pb ($r = 0.99$) and Pb and Zn ($r = 0.97$). All these strong correlations showed strong relationship between the metals and possibly from similar source.

Table 4.2.1.3: Correlation co-efficient of heavy metals from the Eastern section of the study area

	<i>Mn</i>	<i>Cd</i>	<i>Ni</i>	<i>Cu</i>	<i>Zn</i>	<i>Pb</i>
Mn	1					
Cd	0.21	1				
Ni	0.55	0.80	1			
Cu	0.41	0.97	0.89	1		
Zn	0.59	0.91	0.86	0.96	1	
Pb	0.48	0.94	0.91	0.99	0.97	1

The levels of heavy metals in respirable dust collected from the Western section /part of the study area is as shown in Table 4.2.4. The level of analysed metals across the three houses and periods ranged from Mn: 200.1 – 536.6 mg/kg; Cd: 0 – 9.6 mg/kg; Ni: 3.0 – 15.0; Cu: 19.4 – 848.4 mg/kg; Zn: 112.5 – 554.8 mg/kg and Pb: 24.1 – 480.0 mg/kg.

Table 4.2.4: Level of heavy metals (mg/kg) in dust samples from houses across the sampling period from Western Section of study area (July-Oct 2018); n = 9

Section	House	SP	Metals					
			Mn	Cd	Ni	Cu	Zn	Pb
W	1	SP1	222.5	0.0	3.3	29.6	118.9	44.9
		SP2	200.1	0.0	3.0	23.9	112.5	24.1
		SP3	211.6	0.0	3.5	19.4	125.0	28.6
		X	211.4	0	3.3	24.3	118.8	32.5
	2	SP1	235.2	0.0	3.7	57.4	229.6	134.3
		SP2	209.4	0.0	3.5	21.6	119.0	20.0
		SP3	280.7	9.6	9.9	848.4	554.8	480.0
		X	241.8	3.2	5.7	309.1	155.8	211.4
	3	SP1	304.4	0.0	5.3	61.8	144.4	60.1
		SP2	361.3	2.2	11.5	580.2	391.3	291.1
		SP3	536.6	2.9	15.0	441.9	522.2	352.0
		X	400.8	1.7	10.6	361.3	352.6	234.4

SP = Sampling Period; **1-3** = Periods of Sampling; **W= Western** Section of Study Area; **X** = mean

The association of correlation between the analysed heavy metals are shown in Table 4.2.1.4 below, strong correlation between Mn and Ni ($r = 0.92$), Cu and Cd ($r = 0.92$), Ni and Zn ($r = 0.91$), Cu and Zn ($r = 0.93$), Cu and Pb ($r = 0.97$) and Pb and Zn ($r = 0.99$). All these strong correlations showed strong relationship between the metals and possibly from similar source.

Table 4.2.1.4: Correlation co-efficient of heavy metals from the Western Section of the study area

	<i>Mn</i>	<i>Cd</i>	<i>Ni</i>	<i>Cu</i>	<i>Zn</i>	<i>Pb</i>
Mn	1					
Cd	0.31	1				
Ni	0.92	0.60	1			
Cu	0.53	0.92	0.80	1		
Zn	0.73	0.84	0.91	0.93	1	
Pb	0.64	0.99	0.85	0.97	0.99	1

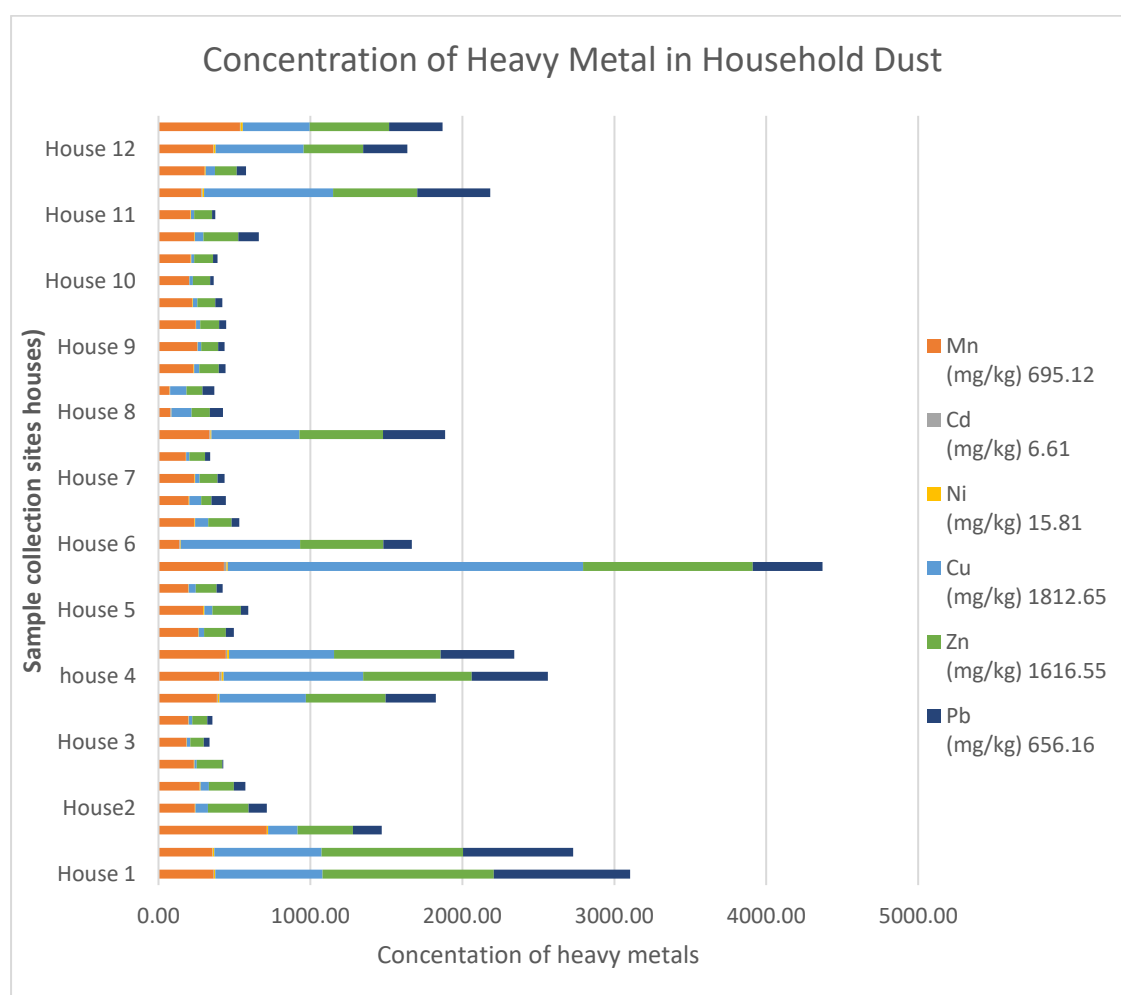


Figure 4.16 Heavy metal concentrations in dust from Tsumeb households

It is observed from the Table 4.3 that the concentration (maximum, minimum and mean) for Nickel was less than the reference value while cadmium concentration values were close to the reference value. The values for Manganese, Zinc, Copper and Lead were very high compare to the reference

value indicated in the table. This indicates that 67% of heavy metals analysed are above the acceptable limit and only 33% that are within and close to the acceptable level of heavy metal in household respirable dust. This indicates that the dust was polluted by these metals especially Manganese, Zinc, Copper and Lead (Muhamad et al., 2012).

Table 4.3: Metal concentration (mg/kg) in respirable dust samples from households

Metals	Mn	Cd	Ni	Cu	Zn	Pb
Max	713.4	18.0	15.8	2338.3	1617.0	897.9
Min	72.0	0	1.66	14.2	68.9	6.90
Mean	289.1	2.48	5.98	340.6	355.3	200.4
Reference value	527.7	0.1	24.5	19.2	55.7	18.8

CHAPTER 5: DISCUSSION OF RESULTS

5.1 Discussion

In the present study, most of the study participants were male, which exactly represent demographic characteristics of the population in Tsumeb. In addition, more than half of the population was aged between 18-30 years, implying that the population comprise the young and economically productive group. Most half of them were illiterate and also, they are employed. Only 20% of the respondents had ever smoke cigarette for the previous years. Last six to nine years. In particular, cigarette smokers were likely to be; physically inactive; spend less time out-doors and share cigarette and drinking equipment. These backgrounds indicate that most of the respondents were typically drawn from a poorly educated and socio-economically deprived segment of the general population. So, they may have a number of undiagnosed health problems and could be at a greater risk of acquiring respiratory health related problems.

At the same time, poor environmental conditions, overcrowding, unhygienic environment, and limited access to health care may exaggerate the already established risks and bring them to be more susceptible to respiratory disease. As a result, coughing which is driven by these under-privileged conditions may be an ever-present danger in this high-risk population. Hence, developing and implementing coughing related diseases control strategies will give an opportunity to screen, treat and prevent this problematic disease.

The mean concentration of heavy metals in the household dust samples are summarized in the table 4.3. The highest mean concentration was Zn with the 355.33 mg/kg and Cadmium with the lowest mean of 2.89 mg/kg. Some heavy metals are abundant elements in earth crust. These elements have been produced by friction and distributed or transported via wind blow and can be associated with dust. (Muhamad et al., 2012). According to Muhamad, Heavy metals find their way inside the building either as airborne dust or through items used or activities carried out by occupant's activities. Pb is a universal pollutant in an urban environment due to automobile emission (Al Rahji and Seaward, 1996; Muhamad et al., 2012), and despite the gradual shift from leaded to unleaded petrol as fuel for automobile, it still remains as a major pollutant for some urban areas including Shah Alma city. Other metals such as Zn, Cu, Cr, Ni and Ba were also related to automobile emission (Muhamad et al. 2012). The source of Zn in dust may have its origin from automotive sources i.e. wear and tear of vulcanized rubber tyres, lubricating oils and corrosion of galvanized vehicular parts (Li et al., 2001; Al-Khashman, 2004; Adachi and Tainosho, 2004; Muhamad et al., 2012). The source of Cu, Cr and Ni in dust is believed to be from car components, tyre abrasion, lubricants corrosion of cars, engine wear, thrust

bearing, brushing, bearing metals and brake dust respectively (Al Rahji and Seaward, 1996; Al-Khashman, 2004; 2007; Muhamad et al., 2012).

Because the data from both sources (Questionnaires and Heavy metal analysis) complement each other, the concentration of heavy metals in households depends upon road pass by their houses (44% untired road), window not protected by nets (78%), vehicle movements (gases pollutants 65%), used and many more as indicated by responded in the questionnaires. Meaning the surrounding area or activities with the vicinity also contribute to indoor dust and may directly or indirectly characterize the type of metal found indoor.

Heavy Metals have health effects to people and threat to the ecosystem. Mostly elderly people and children are at risk of such health effects due to the fact that they are immune age-compromised and immature respectively. Heavy metals accumulate in our bodies' fatty tissues, thereby affecting our central Nervous system. They might also accumulate in the body circulatory system, which may lead to disruption of the performance of our internal organs. High level of Lead (Pb) concentration into the blood is well known to affect the central nervous and skeleton system, while Ni, and Cd are some of the heavy metals associated with cancer and other respiratory ailments (Xiufeng, 2017).

5.2 Health effects of heavy metals in human

Heavy metals are associated with many effects depending on their exposure and also the immunity of human being exposed. Following are some of effects associated with heavy metals. Lead is said to be the most dangerous heavy metal that can affect nearly every system in the body including respiratory system. Exposure to lead often occurs with no obvious symptoms, it normally goes unrecognised. Cadmium has been noticed to accumulate in the human body affecting negatively several organs such as; liver, kidney, lung, bones, placenta, brain and the central nervous system. The health Effects of cadmium exposure are worsened by the relative incapability of human beings to excrete cadmium because It is excreted but then re-absorbed by the kidney. Acute high-dose exposures can cause severe respiratory irritation. Manganese has recently become a metal of global concern because of the introduction of methylcyclopentadienyl manganese tricarbonyl (MMT) as a gasoline additive. Proponents of the use of MMT have claimed that the known link between occupational manganese exposure and the development of a Parkinson's disease-like syndrome of tremor, postural instability, gait disorder, and cognitive disorder has no implications for the relatively low levels of manganese exposure that would ensue from its use in gasoline (Michael, 2002)

5.3 Conclusion

The findings indicate that poor environmental factors are highly associated with respiratory disease in Tsumeb. It had been revealed that male respondents appear to be more affected than female respondents. The study also pointed out that most respondents take cigarettes and they end up infected with respiratory ailments diseases. The heavy metals analysis of household dust of Tsumeb indicated their concentration. The results show the concentration of heavy metals in dust collected from 12 houses of Tsumeb shows that Cu is having the biggest range and Ni having the smallest. The concentration of heavy metals could be also associated to the Respiratory health effects such Shortness of breath, breathing difficulties, coughing up blood, coughing with or without sputum, noisy breathing, Chest tuberculosis, asthma, as indicated by Tsumeb respondent to the questionnaires. Which shows that indoor dust is mostly likely to result in coughing as this is supported by 75% of those respondents who indicates that they constantly or frequently cough due to indoor dust. The concentration of heavy metals in household dust can be influenced directly or indirectly by factor such as road that pass by their houses, window not protected by nets, vehicle movements, ventilation types used and many more as indicated by responded in the questionnaires. Therefore, it's very important to consider identified contributing factors to minimise respiratory health effects associated with heavy metals. Basing on results from chapter 4, recommendations will deliberate the appropriate measures to be taken and possible solutions to be implemented.

5.4 Recommendation

The most effective method to ensure respiratory health is to prevent illnesses before they occur. Recognising and preventing the factors that cause respiratory diseases is the appropriate management and control measures. In addition, respiratory diseases are often linked to the environment, and this was clearly supported by majority of respondents in this study. From the above, the following recommendations are made for the prevention of risk factors that may be responsible for the development of respiratory diseases among residents in the study area:

1. Improving the quality of the air by firstly, eliminating the sources of pollutants in the area.
2. Avoid tobacco smoke in households and prevent the smoke of burning fuels in houses through the use of clean energy sources such as electric stove instead of the use of paraffin stove.
3. Reducing air pollution from traffic and industrial sources, and avoiding inhaling contaminated dust toxic particles, fumes or allergens reduces the prevalence of respiratory ailments.
4. Setting up air quality monitoring programme in the community by relevant authorities and conduct regular community environmental pollution awareness campaign.

5. Planting of trees in the community reduces the concentration of carbon dioxide in the atmosphere.
6. Promoting recycling and encourage use of renewable and efficient energy sources reduces piling up pollutants that may decay and release toxic gaseous in the atmosphere.
7. Halt/Mitigate pollutants at the source by installing eco-friendly chimneys especial for industries operating day by day, to avoids pollutants to enter into the atmosphere and environments.

It's unfortunate that there is not much done on respirable indoor dust in Namibia, there are no published research specifically on heavy metals contained in indoor dust, and their limit. Soo, there is a need of funding of more research in similar field to create awareness and for future reference. Mostly the reference that were used in this, were the research done in Asia. Therefore, global cooperation is needed to address international flows and sources of air pollutants, complementary to local and regional efforts in air pollution management

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APPENDIX A: RESEARCH QUESTIONNAIRE



**NAMIBIA UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF HEALTH AND APPLIED SCIENCES; DEPARTMENT OF HEALTH SCIENCES**

RESEARCH QUESTIONNAIRE

**TITLE: PREVALENCE AND ASSOCIATED RISK FACTORS OF RESPIRATORY DISEASES AMONG
RESIDENTS OF TSUMEB LOCALITY OF NAMIBIA**

Study ID No. _____

CONSENT OF PARTICIPATION IN THE STUDY

Dear Participant,

My name is Ms Rosalia Pendukeni Nangolo, a Master of Health Science student in the Department of Health Sciences at the Namibia University of Science and Technology, Windhoek. I am conducting a research on the above stated topic which is purely for academic purpose. This study involves collection of information or data using this questionnaire. It will be appreciated if you can spare a bit of your time to complete this questionnaire. Participation in this survey is completely voluntary and you have the right to withdraw from participating at any time during the survey and the right not to provide answer to any question(s) in the questionnaire that makes you uncomfortable.

I sincerely thank you for your willingness to assist and participate in the study and any information that is provided will be treated with utmost confidentiality and anonymity. Your signature below is an assurance of your consent and voluntary willingness to participate in the study.

I thank you sincerely.

Kindly indicate your willingness and voluntary participation in this study by ticking the applicable option in the box below. To protect your privacy, no name or consent signature is requested.

I hereby confirm that I am willing to participate in this study.

YES	NO
-----	----

Signature of participant

Signature of researcher

General Instructions

- No names are required.
- Please answer all questions by underlining or ticking/filling the appropriate box of your choice.
- You may skip any question which is not applicable to you.

SECTION A: GENERAL STUDY AREA INFORMATION:

- Suburb/Area: _____
- Distance (in m or cm) of residence from the road/street: _____
- Type of road passing through your residence (a) Tarred road ☐; (b) Untarred road; (c) Gravel road ☐ (d) Bushy ☐
- Number of level of your residence: (a) single storey (b) double storey (c) 3-storey
- Residence windows and doors are protected with nets: Yes ☐; No ☐
- The geographic direction of residence is towards the: (a) North ☐ (b) East ☐ (c) West ☐ (d) South ☐

SECTION B: SOCIO-DEMOGRAPHIC INFORMATION

Please, tick [V] the correct answer.

- Kindly indicate the age group that is applicable to you.
(a) 18-30 years ☐; (b) 31- 40 years ☐; (c) 41-50 years ☐; (d) 51-60 years ☐; (e) > 60 years ☐
- What is your gender? (a) Male ☐ (b) Female ☐
- What is your highest level of education?
(a) Primary education ☐; (b) Secondary education ☐; (c) Tertiary education ☐; (d) Post graduate ☐

Specify (others):

- What is your occupational status?
(a) Employed ☐ (b) Self-employed ☐ (c) Unemployed ☐ (d) Student ☐

Specify (others):

- If employed (i.e. working for an organisation), which sector is your current employment?

- (a) Government []; (b) Industry [] (c) NGOs [] (d) International Bodies []

Others (please specify):

6. How long have you been residing in the community?

- (a) 1-3 years [] (b) 4-6 years [] (c) 7-9 years [] (d) > 9 years []

SECTION C: AIR QUALITY IN THE STUDY AREA AND CONTROL MEASURES

Kindly tick as applicable

6. Have you noticed any changes in air quality (i.e. not clean as before) over the past years due to the presence of toxic gas pollutants (i.e. gases that can make people sick)? (a) Yes []; (b) No []
7. These changes might be due to the presence of any or combination of gaseous pollutants such as SO₂, CO₂, NO, NO₂, PM Etc? **[Tick one box only]** (a) Yes [] (b) No []
8. How would you rate the overall air quality in the community now compare to past years?
(a) Much better [] (b) a bit better [] (c) not much difference [] (d) a bit worse []
9. How will you describe the rate of change in the air quality? **Tick one box only**
a) Regularly []; b) fairly regular []; c) Once-in-awhile (d) Seldom []

10. What do you think could be the source/cause of the changes in air quality? **You can tick more than one box as applicable**

i.	Pollutants are released by cars	
ii.	Pollutants are released by industries/companies	
iii.	Pollutants released by veldts fires	
iv.	Construction activities	
v.	Household cooking and heating	
vi	Burning of wastes	
vii	Dust from quarry work and road sides	

Kindly tick one box only:

11. Are you aware of any measures/programmes designed for the control and prevention of risks associated to respiratory ailments in the community? (a) Yes [] (b) No []
12. If (yes), do you think these measures are adequate in addressing the risk factors associated with respiratory ailment in the community from air pollutants? (a) Yes [] (b) No []
13. Would you consider the measures listed below as appropriate for the control and prevention of exposure to identified risk factors? **(You may select more than one options [v])**

i.	Setting up air quality monitoring programme in the community	
ii.	Regular environmental pollution awareness campaign	
iii.	Planting of trees in the community	
iv.	Promote recycling	
v.	Encourage use of renewable and efficient energy sources	
vi.	Halt/Mitigate pollutants at the source: install eco-friendly chimneys	

SECTION D: POSSIBLE IMPACT OF AIR POLLUTANTS ON HEALTH AND QUALITY OF LIFE

(Kindly note that this section requires you to provide information on respiratory system).

Tick one box as appropriate

14. To what extent would you consider yourself affected by the quality of air in your community?
 (a) Much affected []; (b) Affected []; (c) a little affected []; (d) Not affected []

If your answer in (14) is either (a), (b) or (c),

15. In which of the following ways are you affected? **(May tick more than one as applicable)**

i.	Difficulty in breathing	
ii.	Prevent involvement in out-door activities	
iii.	Financial burden due to skin care	
iv.	Consider relocating to another community	
v.	Poor visibility especially in the morning	
vi.	Concern about the health of the children	
vii.	Affect life quality	

16. Have you experienced any of the below upper respiratory ailments in the past years? **(May tick more than one as applicable).**

i.	Coughing	
ii.	Headache	
iii.	Nasal Discharge	
iv.	Runny nose	
v.	Sneezing	
vi.	Fever	
vii.	Scratchy throat	
viii.	Sore throat	
ix.	Nasal congestion	

17. Have you experienced any of the below lower respiratory ailments in the past years? (May tick more than one as applicable).

i.	Shortness of breath	
ii.	Breathing difficulties	
iii.	Coughing up blood	
iv.	Coughing with or without sputum	
v.	Noisy breathing	
vi.	Chest pain	
vii.	Chest tuberculosis	
viii.	Asthma	
ix.	Lung cancer	

SECTION E: SOCIO-ENVIRONMENTAL ISSUES

Please, tick [V] the correct answer.

18. Have you ever smoked cigarettes? (a) Yes [] (b) No []

IF 'YES' continue IF 'NO' go to Question 19

(i). Do you consider yourself as an active smoker? (a) Yes [] (b) No []; if (yes)

(ii) How long have you been smoking?

(a) 1-2years [] (b) 3-4years [] (c) 5-6 years [] (d) > 7 years []

(iii) If you have stopped smoking cigarettes completely, how long have you stopped.

(a) 1-2years [] (b) 3-4years [] (c) 5-6 years [] (d) > 7 years []

(iv) Do you take in smoke released from cigarette or other tobacco products breathe out by the smoker. (a) Yes [] (b) No []

IF ANSWER TO D ABOVE IS "YES"

(e) How often does it happen? **Tick one box only**

a) Constantly []; b) Frequently []; c) Seldom [];

19. Do you experience any of respiratory symptoms due the presence of indoor allergens (mites, some moulds, and insects) or outdoor allergens (pollens and some moulds)?

(a) Yes [] (b) No []

20. Do have respiratory ailment (asthma, cardiovascular diseases and other chronic diseases) confirmed by the Doctor associated with your diet and nutrition?

(a) Yes [] (b) No []

21. Do you have family history of respiratory ailments (Asthma, cardiovascular diseases and other chronic diseases) confirmed by the Doctor?

(a) Yes [] (b) No []

22. Have you ever held any job for more than one (1) year, which exposed you to dust or pollutant gaseous? (a) Yes [] (b) No []

SECTION F: HOUSING ASSOCIATED RISK FACTORS

Please, tick [V] the correct answer.

23. How many years have you lived in your current house?

(a) 1-2years [] (b) 3-4years [] (c) 5-6 years [] (d) > 7 years []

24. Does your home have any of the following? **(May tick more than one as applicable).**

	Responses	Yes	No
i	Central heating		
ii	Ducted air heating (forced air heating)		
iii	Air conditioning		

25. What kind of stove do you mostly use for cooking?

Tick one box only

i.	coal, coke or wood (solid fuel)	
ii.	gas (gas from the mains)	
iii.	Electric	
iv.	paraffin (kerosene)	
v.	Microwave	
vi	Other	

26. How often do cars pass your house? **Tick one box only**

a) Constantly []; b) Frequently []; c) Seldom []; d) Never []

27. Do you find dust on your house surfaces 'indoor? **Tick one box only**

a) Constantly []; b) Frequently []; c) Seldom []; d) Never []

Kindly place the questionnaire into the envelope provided by the researcher

THANK YOU FOR TAKING PART IN THIS STUDY