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RELATIONSHIP BETWEEN CEMENT DUST EXPOSURE AND ADVERSE RESPIRATORY HEALTH IN A SETTLEMENT RESIDING NEAR A CEMENT FACTORY IN CHILANGA, ZAMBIA.

BY

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Summary

There is paucity of information on whether exposure to emissions from a cement factory has pulmonary ill effects on communities residing close to these factories. This study investigated the association of exposure to cement dust and respiratory health effects in a community located near a cement factory. A cross-sectional study, followed by panel study, was conducted in Freedom Compound, a community bordering a cement factory in Chilanga, Zambia and, as control, Bauleni, located 18 km from the cement plant. In the cross-sectional phase, a modified American Thoracic Society questionnaire was administered to 225 and 198 respondents aged 15–59 years to capture symptoms of mucous membrane irritations and respiratory symptoms. For the panel phase, 118 participants were randomly sub-sampled from those participating in the cross-sectional study and followed up for three climatic seasons (cold dry, hot dry and rainy season). In this phase, exposure to cement dust, measured as ambient $PM_{2.5}$ and PM_{10} concentrations in both communities and respiratory symptoms together with lung function indices were recorded daily for each participant for 14 consecutive days in each of the seasons. Descriptive statistics and generalized estimating equations (GEE) regression models were used in the analysis. A p-value < 0.05 was considered as statistically significant. A higher proportion of respondents in Freedom, compared to Bauleni, reported signs of mucous membrane irritations: 78.2% *vs.* 49.9%, 66.9% *vs.* 29.4% and 73.7% *vs.* 53.3% for eye, nasal and sinus irritations respectively (p value < 0.001). Respondents from Freedom Compound had higher odds of experiencing the irritations; adjusted odds ratio (OR) 2.50 (95% CI: [1.65, 3.79]), 4.36 (95% CI [2.96, 6.55]) and 1.94 (95% CI [1.19, 3.18]) for eye, nose and sinus mucous irritations respectively. Similarly, respiratory symptoms and diseases were more likely reported in Freedom compared to Bauleni: 5.64 (95% CI [3.63, 8.67]); 3.30 (95% CI [2.04, 5.3), 1.60 (95% CI [1.01, 2.54]); 5.76 (95% CI [2.00, 16.07]); and 5.22 (95% CI [1.75, 15.47]) times more likely to suffer from cough, phlegm production, wheeze, asthma and pneumonia respectively. Mean seasonal concentrations of $PM_{2.5}$ and PM_{10} ranges were 2.39 - 24.93 $\mu g/m^3$ and 7.03 - 68.28 $\mu g/m^3$ respectively for Freedom while $PM_{2.5}$ and PM_{10} for Bauleni ranged from 1.69 - 6.03 $\mu g/m^3$ and 2.26 - 8.86 $\mu g/m^3$ respectively. Overall, the mean FEV1 and FVC predicted percentage for Freedom was six and four percentage points lower than the control. A systematic review revealed that the majority of studies conducted in communities used mostly cross-sectional study design. Most studies reported higher levels of PM2.5 and

PM10 in the exposed compared to the controls and demonstrated either a statistically significant difference in the prevalence of respiratory symptoms and reduced pulmonary functions or some degree of association. This review shows that despite showing some degree of association between exposure to cement dust and respiratory ill health, the existing evidence is insufficient to draw firm conclusion mainly because the studies were of low quality. These findings add to existing evidence that there an association between exposure to cement dust emitted from a cement plant and respiratory ill health. Future research, including characterization of air pollutant and source apportionments is required to determine whether the observed excessive respiratory symptoms and lower FEV1 and FVC among participants in the exposed community are due to cement dust emitted from the cement plant.

The thesis proves that Miss Nkhama is conversant with the nature and purpose of this investigation. From this work, Ms Nkhama has published three articles in international journals, while the fourth article is under peer review.

Declaration

I, Emmy Nkhama, declare that the study "Relationship between cement dust exposure and respiratory health in a settlement residing near a cement factory in Chilanga, Zambia", submitted for the degree of Philosphiae Doctor (Public Health) at School of Health Systems and Public Health, University of Pretoria is solely my work and has not been submitted by me for any other degree or for examination by another tertiary institution.

Emmy Nkhama

Signed on this day ________________ of _____________ year ___________________

Ethics Statement

The author, Emmy Nkhama, has obtained applicable ethics approval of this research (157/2012; HUM00070842 and 2012-July-007). The author declares that she has observed the ethical standards required by the University of Pretoria, University of Michigan and ERES Converge (Zambia) Code of Ethics for Researchers and Policy Guidelines for responsible research.

Publications

- Published
  - Nkhama E, Ndhlovu M, Dvonch JT, Siziya S, Voyi K. Prevalence of mucous membrane irritations in a community residing near a cement factory in Zambia: a cross sectional study. Int. J. Environ. Res. Public Health. 2015;12:871-887.
  - Nkhama E, Ndhlovu M, Dvonch JT, Siziya S, Voyi K. Prevalence of self-reported pulmonary symptoms in a community residing near a cement factory in Chilanga, Zambia: a cross sectional study. J Pollut Eff Cont. 2015;146(3):1-9.
  - Nkhama E, Ndhlovu M, Dvonch JT, Lynam M, Mentz G, Siziya S, Voyi K. Effect of airborne particulate matter on respiratory health for a community living near a cement factory in Chilanga, Zambia: Results from a panel study. Int. J. Environ. Res. Public Health. 2017;14:1351
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  - Exposure to cement dust and respiratory health for communities residing near cement factories: A systematic review of the literature.

Dedication

To Atuko and Mankunche, you two have been my “*cheerleaders*” in many ways on this journey.

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List of abbreviations

Institutional abbreviation

ATS	American Thoracic Society
BMR	British Medical Research
CHW	Community Health Workers
EPA	Environmental Protection Agency
ERS	European Respiratory Society
FEPA	Federal Environmental Protection Agency
IRB	Institutional Review Board
MoH	Ministry of Health
MPP	Millennium Promise Programme
NHC	Neighbourhood Health Committees
NIEHS	National Institute of Environmental Health Science
NYHA	New York Heart Association
SHSPH	School of Health Systems and Public Health
UNEP	United Nations Environmental Protection
UMAQL	University of Michigan Air Quality Laboratory
USEPA	United States Environmental Protective Agency
WHO	World Health Organization
WMO	World Meteorological Organisation
ZMD	Zambia Meteorological Department
ZEMA	Zambia Environmental Management Agency

Technical abbreviations

BMT	Billion metric Tons
CI	Confidence Interval
CO	Carbon Monoxide
CO_2	Carbon Dioxide
FEV1	Forced Expiratory Volume in one minute
FVC	Forced Volume Capacity
FEV1/FVC	Ratio between Forced Expiratory Volume and Forced Ventilation Capacity
GEE	Generalised Estimating Equations
IQR	Interquartile Range
MT	Metric Tons
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Poly Chorinated Biphenyls
PCDD/Fs	Polychlorinated dibenzo-*p*-dioxins and dibenzofurans
PM	Particulate Matter
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of 2.5 µm or less
PM_{10}	Particulate matter with an aerodynamic diameter of 10 µm or less
PTFE	Polytetrafluorethelene
RH	Relative humidity
SD	Standard Deviation
SO_2	Sulphur Dioxide
SPM	Suspended Particulate Matter
NO_2	Nitrogen Dioxide
OR	Odds Ratio
$\mu g/m^3$	Microgram per cubic meter

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1.1. Background information

A dynamic and complex mixture of both anthropogenic pollutants and natural sources are the main causes of air pollution. These substances could be gaseous or particulate in nature. Gaseous pollutants include sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and ozone (O_3).[1] Accumulations of any of these substances in the air subsequently affects the quality of the ambient air with effects on both the environment and humans. Environmental effects include changes in the quality of air ranging from reduced visibility to a clear though heavily particle laden atmosphere. In humans, air pollution is a major, and ubiquitous, environmental problem causing undesirable health effects especially on populations living in most cities of the world.[2] Although populated areas in developed countries may have high levels of air pollution, air pollution is a bigger problem of densely populated areas in developing countries.[2,3] This may be due to a combination of high concentration of pollution sources and a relatively poor or non-existent enforcement of environmental regulations.[4]

Expanding human population coupled with insufficient and inappropriate development, results in severe environmental health problems in both developed and developing countries. Industrial development has been associated with the emissions of large quantities of gaseous and particulate substances with resultant deleterious health effects on the inhabitants of the city.[5] The most at risk are the people living in cities where activities that result into air pollution are found; especially those living near factories such as cement plants, living within the fallout/dispersion radius and workers within such plants.[6] The impacts caused by air pollution have been documented as far back as 1930 (Meuse Valley fog, Belgium); 1948 (Donora, Pennsylvania), 1952 (London smog)[7] and in more recent times at the Cherboyl Russia disaster (1986)[8] and Bhopal (1984).[9,10]

Exposure to air pollutants can be acute over a short period of time with catastrophic consequences as was the case with the Bhopal and Chenobyl or might be continuous at low level with insidious development of health consequences. In the latter case, populations are continuously and permanently exposed to air pollution resulting in a range of changes in the most vulnerable body system; the respiratory and cardiovascular systems. These changes include reversible changes in respiratory symptoms and lung functions, changes in airway reactivity and inflammation, structural remodelling of pulmonary airway and impairment of pulmonary host defences, increased rates of hospitalisation among the exposed and premature deaths from cardiovascular diseases.[11,12] Every year, almost 12.6 million people die from diseases associated with environmental hazards, such as air, water or soil pollution, and climate change.[13] The World Health Organization estimates that more than 1500 million people live in urban areas with dangerously high levels of air pollution; with an estimated 2.4 million deaths each year due to deaths directly attributed to air pollution.[14] According to a WHO report, the burden of air pollution is disproportionately experienced more in low and middle-income countries compared to developed countries.[15] Furthermore, an estimated quarter of the global burden of disease including over a third of childhood illnesses are attributed to modifiable factors in the air.[3] The Global Burden of Diseases Report,[16] observed that the effect of ambient air pollution is the third contributor of disease outcomes and fourth for mortality worldwide.[13]

Documented human activities that contribute to air pollution are: mining, tobacco smoking (personal pollution), fossil fuel combustion and construction industries such as cement production and transportation.[17] Most human activities, though resulting in pollution are necessary for development. Such activities include building of houses and infrastructure construction for better living standards. To achieve this kind of development a large amount of cement is required. Cement is a major component of concrete which is used in almost all buildings and structures. It is an important construction material used for housing and infrastructure development, and key to any economic growth of a given society. Cement demand is directly proportional to economic growth and many growing economies are striving for rapid infrastructure development which results in increased cement production.[5] However, the production of cement is not without deleterious environmental and health effects on humans. Despite its popularity, cement industries face challenges due to environmental concerns and sustainability issue.[5] Cement production is an inherent dusty operation resulting in ambient air pollution that lead to the exposure of factory workers and residents of communities situated near cement plants.[18] Air pollution from cement plants travel significant distances downwind, crossing state lines and creating region-wide health problems.[5] These effects have greater impacts on communities disproportionately exposed to the environmental risks and to vulnerable populations, including children.[19]

1.2. Air quality standards

Good air quality is considered a basic human right for promoting the general wellbeing of populations. Evidence suggests that reducing concentrations of particulate matter (PM) in the ambient have health benefits ranging from reduction in long term mortality risk to premature deaths.[20] For instance; in a USA study[21] a decrease of 10 µg/m^3 was associated with a significant increase in life expectancy of as much as 15% in the study areas. Similar gains in health have been reported by a study that demonstrated that reducing personal exposure to PM air pollution has the potential to reduce the incidence of cardiovascular events in patients with coronary heart disease living and working in industrialized or urban environments.[22] Furthermore, a combined study by United Nations Environmental Programme (UNEP) and World Meteorological Organisation (WMO), estimated that about 0.7 to 4.6 million premature deaths due to exposure to $PM_{2.5}$ could predominantly be attributed to exposure to PM in the ambient air.[23] Another study has shown that reduction in exposure to PM could reduce 1.3 million deaths due respiratory ill health by 2050.[24]

The health effects of air pollution are significant even at low concentrations. There is no threshold for PM that has been identified below which no adverse impact to health has been observed.[25] As such, there is no uniformity regarding air quality policy between countries or within regions.[26] Whereas the WHO recommends exposure levels not exceeding 10 µg/m^3 annually and 25 µg/m^3 in 24-hour mean concentration (not exceeding 3 days a year) for $PM_{2.5}$; and 20 µg/m^3 annually and 50 µg/m^3 in 24-hour mean concentration for PM_{10}' countries have established different cut-off levels as safe exposure.[3] The decision for these levels is determined mainly by economic considerations.[27] Developed countries have more stringent standards and advanced strategies to reduce air pollution than developing countries.[27] For instance, the United States Environmental Protective Agency (EPA) standard air monitoring index is set at 35 µg/m^3 annual and 12 µg/m^3 in 24-hour concentration for $PM_{2.5}$ and 150 µg/m^3 in 24-hour not to be exceeded more than once per year over a 3 year period for $PM_{10.}$[28] Emerging economies like China, and India have set their standards as follows 70 µg/m^3 annual and 150 µg/m^3 in 24-hour concentration for PM_{10} and 75 µg/m^3 in 24-hour mean concentration for $PM_{2.5}$ for urban areas.[29] Among countries in the Southern African region, only South Africa has set exposure level standards of PM_{10} of 180 µg/m^3 and 60 µg/m^3 for $PM_{2.5}$ maximum in 24 hour mean concentration.[3] Zambia, like several other countries that have not promulgated their own standards due to local constraints and capabilities, uses WHO air quality values. Together with PM, WHO has also set standards for three other pollutants; ozone (O_3), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) as shown in Table 1.

Table 1-1-1: WHO 2005 guidelines for common ambient air pollutants.

Compound	Averaging time	Guideline values	Reference
PM_{10}	1 year	20	WHO 2006
	24 hour	50	
$PM_{2.5}$	1 year	10	WHO 2006
	24 hour	25	
SO2	24 hour	20	WHO 2006
	15 minute	500	WHO 2000
O3	8 hour	100	WHO 2006
CO	8 hour	10,000	WHO 2000
	1 hour	30,000	
	30 minute	60,000	
	15 min	100,000	

Source: Adopted from Schwela.[30]

1.3. Cement production, PM ambient air pollution and health effects

Next to water, cement is the most widely used commodity worldwide.[5] The infrastructure development of sovereign countries in the recent years is the demand driver for the cement industry.[5] Global cement production grew to approximately 4.18 billion metric tons (Bmt) in 2014 compared to 4.08 (Bmt) in 2014.[31] China and India are the world's largest cement producing countries in the world; amounting to 2.5 (Bmt) and 280 Mt in 2014 respectively.[31] Countries with notably large year-on-year increases in cement production in 2014 included Saudi Arabia (10.5%, 63 Mt), the US (7.62%, 83.3 Mt), Indonesia (7.14%, 60 Mt) and Turkey (5.19%, 75 Mt).[31] Equally, the Zambian cement industry has expanded in size and capacity during the last

30 years; 500 tons of cement was produced in 1964 compared to 2.4 million tons in 2014.[32] Larfage Chilanga, is one of the major producing factories in Zambia accounting for 2.2 million tons cement production.[32]

The production of cement involves the following three steps:

i. Preparation of raw materials (limestone, shale and sand) which involves mixing/homogenising, grinding and preheating (drying) to produces the raw mill.
ii. Burning of raw mill at high temperatures (900-1500 °C) in the pre-calciner to form cement clinker in the kiln.
iii. After cooling, the clinker is ground together with the additive. The finished material is then stored in silos, ready for dispatch in bags or bulk.

Several emissions with capacity to pollute the ambient air are released during these production phases. The emissions include gaseous chemicals such as CO, CO_2, NO_2, SO_2 and PM most of which is respirable.[5,33] PM is of special environmental concern during cement production because it constitutes the largest proportion of the emissions and tends to have effects on the environment and public health; PM affects more people than any other pollutant.[3] Cement industries contribute to total global particulate emissions.[1] The pulverized materials released to the atmosphere in the form of dust, constitute a major source of air pollution.[34] Thus the inherent dusty operation of cement production results in dust exposure of factory workers and residents of communities situated near cement plants. Moreover, construction workers and individuals around construction sites may be exposed to cement dusts particles in their living environment.[35]

Humans become exposed as the emitted particulates and particulate-bound metals are dispersed into the atmosphere.[36] The aerodynamic property determines transportation and removal of these particles from the air and deposition within the respiratory system. Mass and composition tend to be divided into two principal groups: coarse particles mostly larger than 2.5 μm in aerodynamic diameter, and fine particles mostly smaller than 2.5 μm in aerodynamic diameter ($PM_{2.5}$).[6] The sizes of the particles are respirable in size and reach internal organs particularly lungs leading to pulmonary diseases. The trachea-bronchial respiratory zone is the primary target of cement deposition.[37] Other than the direct effect on body tissues, PM harmful effects are due to the presence of dozens of toxic substances carried on the tiny particles: carcinogens, mutagens, teratogens, immune-toxins, respiratory toxins, neurological toxins, developmental toxins, circulatory toxins and many others.[38-40] Of the two, $PM_{2.5}$ is more dangerous since when inhaled, may reach the terminal bronchioles, and interfere with gas exchange inside the lungs.

1.4. Assessing association of cement dust exposure with respiratory health

The assessment of association between cement dust exposure and respiratory health requires precise measurement. Furthermore, the strength of evidence is determined by the epidemiological study design used. Studies of exposure to environmental hazards generally have difficulties of precise measurements of exposure to the hazard.[41] In the case of exposure to dust, and PM particularly, duration of exposure and the quantity an individual is being exposed to pose a great challenge to measurements. Additionally, variation in home/school ventilation, personal habits like smoking, meteorological effects like humidity and wind direction and wind speed could all affect the relationship between exposure and outcome.[42-44] Precise measurement of the extent of an individual's exposure to the environmental dust calls for personal monitoring and obtaining biological markers.[45] Personal monitoring involves placing a measurement instrument, sampler, in the breathing zone of an individual. The samplers record time-integrated concentrations, reading concentrations directly or time integrated samplers that need laboratory analysis. Biological markers, which are more precise measurements and good for assessing dose-response relationships, are measured by obtaining tissue samples from exposed individuals. However, these methods, though precise are usually not feasible for most settings; they are expensive, labour intensive, time-consuming and invasive, and involves study participants carrying the sampling equipment. In assessing exposure to cement dust and respiratory health, few studies have used personal monitoring in occupational setting studies.[45-48] Other studies, especially those based on the community, have used less precise methods of quantifying exposure, the commonest being environmental monitoring.[18,49] This entails placing monitoring devices at specified locations for periods ranging from 8 to 24 hours. This is a proxy measure of exposure for individuals being studied. It has been argued that subjects have been assigned concentrations measured at central region sites or outdoor sites indicating that this may lead to exposure misclassification and diminish the accuracy of exposure response estimates because many people spend most of their time indoor. Although, this may not be true for most communities in developing countries like Zambia where most people tend to spend most of their time outdoor because the houses are very small and are mostly used for sleeping.

Regarding study designs, most of the studies in the current literature used a cross sectional study design in combination with the imprecise methods of measuring exposure.[6,37,50] It is thus difficult to draw firm conclusion on association and/or causal relationships. Cross sectional studies are weak to prove causality because it is difficult to demonstrate temporality between exposure and outcome, a cardinal feature of the Bradford Hills criteria.[51] cohort studies, on the other hand, provide stronger evidence when studying association of exposure and outcome. Panel studies which involve repeated measurements of both the exposure and the outcomes on the same individuals provide even more accurate estimate in the variation of respiratory effects due to the exposure.

1.5. Respiratory symptoms

The main route of entry of cement dust particles into the body is the respiratory tract and/ or the gastrointestinal tract by inhalation or swallowing respectively.[52] Other systems or organs that may be affected include the skin, eyes and the cardiovascular.

The respiratory system extends from the nose to the lungs as shown in Figure 1-1. The nasal passage and the oral opening through which breathing takes place open into the trachea in the throat which in turn leads to the bronchial ramie. It is one of the most exposed systems in the human body owing to the fact that it is in direct contact with the atmosphere, and thus easily affected by changes in the ambient air. For instance, air pollution with particulate matter could easily lead to deposition of these particles in the lungs.[53] The system, however, is endowed with defences such as filtering systems (cilia), production of mucus to trap particulate matter and reflexes such as cough to expel unwanted materials. Several epidemiologic studies,[17,18,19,21,22,33,35] have reported that breakdown in these mechanisms could result in exposure to various environmental hazards leading to acute respiratory symptoms. The commonly reported symptoms are cough, sinusitis, shortness of breath, production of phlegm and wheeze. Epidemiologic studies have also reported that exposure to environmental hazards could lead to respiratory diseases such as pneumonia, bronchitis and exacerbation of asthma. Prolonged exposure to air pollution could affect the pulmonary functions' spirometry parameters. The following subsection highlights respiratory conditions relevant to this study.

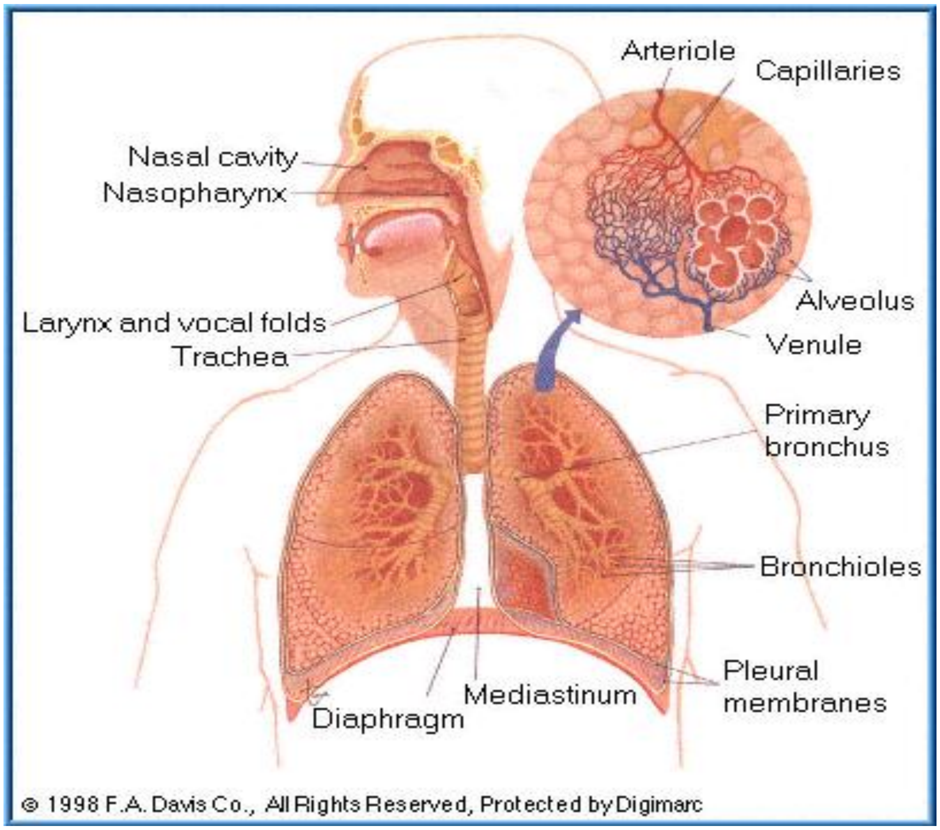

Figure 1-1: Respiratory system; Source: medical essentials[56].

1.5.1. Cough

A cough is a sudden and often repetitively occurring reflex which helps to clear the large breathing passages from secretions, irritants, foreign particles and microbes. Coughing can happen voluntarily as well as involuntarily. It is the commonest of all symptoms found in all ailments of respiratory systems; ranging from mere irritation to serious infections.[19] Coughing may be caused by air pollution including tobacco smoke, particulate matter, irritant gases and dampness in the home. Individual reactions to air pollutants depend on the type of pollutant, the degree of exposure, the individual's health status and genetic make-up.

1.5.2. Shortness of breath

The American Thoracic Society (ATS) defines shortness of breath (dyspnea) as a subjective experience of breathing discomfort that consists of qualitatively distinct sensations that vary in intensity.[54] It is also defined as difficulty in breathing; disordered or inadequate breathing; uncomfortable awareness of breathing; and as the experience of breathlessness, which may be either acute or chronic. It is a subjective feeling of having difficulties in breathing reported by an individual. Objectively it can be measured by the New York Heart Association Classification (NYHA).[55]

1.5.3. Production of phlegm

Phlegm is released from glands in the walls of the bronchi (airways) and from cells lining the nose and sinuses. Normally phlegm is produced as part of the defence mechanism and to maintain the integrity of the respiratory system. Irritation of the airway often leads to excessive production of phlegm.[28] Excess phlegm production may result from infection, allergic reaction or by inhalation of irritants (e.g. smoke and PM). Excess phlegm production can be a sign that there is an imbalance in the respiratory system. This leads to susceptibility to various diseases. The body’s immune resistance may be low, which may be caused by exposure to environmental hazards.

1.5.4. Wheeze

A wheeze is a continuous, coarse, whistling sound produced in the respiratory airways during breathing. For wheezes to occur, some part of the respiratory tree must be narrowed or obstructed, or airflow velocity within the respiratory tree must be heightened. Wheezing is commonly experienced by persons with a lung disease; the most common cause of recurrent wheezing is asthma attacks, though it can also be due to exposure to environmental hazards such PM. Wheezes occupy different portions of the respiratory cycle depending on the site of airway obstruction and its nature. The fraction of the respiratory cycle during which a wheeze is produced roughly corresponds to the degree of airway obstruction. Bronchiolar disease usually causes wheezing that occurs in the expiratory phase of respiration.[22] The presence of expiratory phase wheezing signifies that the patient's peak expiratory flow rate is less than 50% of normal.[36]

Wheezing heard in the inspiratory phase on the other hand is often a sign of a stiff stenosis, usually caused by tumors, foreign bodies or scarring. Inspiratory wheezing also occurs in hypersensitivity pneumonitis. Wheezes heard at the end of both expiratory and inspiratory phases usually signify the periodic opening of deflated alveoli, as occurs in some diseases that lead to collapse of parts of the lung.

1.5.5. Sinusitis

Sinusitis also known as rhinosinusitis, is an inflation of the sinuses resulting in symptoms such as thick nasal mucus, a plugged nose, and pain in the face. It may also result into fever, headaches, poor sense of smell, sore throat and cough. It usually can be caused by infection, allergies, and air pollution. Structural problems in the nose could also lead to sinusitis. Most cases are caused by a viral infection. However, a bacterial infection may be present if symptoms last for ten days. Recurrent episodes of sinusitis are common in individuals with pre-existing conditions such as asthma, cystic fibrosis or those with comprised immune system. Research shows that 10 to 30 % people are affected each by sinusitis in the United States of America and Europe.[21] Similarly, more than 40% of the population in Asia and African are reported to suffer from recurrent sinusitis annually.

1.5.6. Asthma

Asthma is a chronic inflammatory disease of the airways of the lungs that is characterized by recurring symptoms, reversible air flow obstruction and bronchospasm. Symptoms of asthma include episodes of wheeze, cough, chest tightness, cough and shortness of breath.[12] These symptoms may occur a few times a day or few times per week. Asthma may be caused by a combination of genetic and environmental factors. Exposure to air pollution and allergens such as pollens are the most common known environmental factors. There is no cure for asthma, but symptoms can be prevented by avoiding triggering factors; allergens and exposure to irritants.

1.5.7. Pneumonia

Pneumonia, a lung pathology, can range in seriousness from mild to life-threatening. It is most serious for infants and young children, people older than age 65 and people with health problems or weakened immune system. The signs and symptoms of pneumonia vary from mild to severe, depending on factors such as the type of germ causing the infection, and your age and overall health.[17] Mild signs and symptoms often are similar to those of a cold or flu, but they last longer. Signs and symptoms of pneumonia may include: Chest pain when breathing or coughing, confusion or changes in mental awareness (common in adults age 65 and older), cough, which may produce phlegm, fatigue, fever, sweating and shaking chills, lower than normal body temperature (in adults older than age 65 and people with weak immune systems), nausea, vomiting or diarrhea, shortness of breath.[17]

1.6. Epidemiological studies on cement dust ambient pollution and human health

Cement dust pollution of ambient air can be an important pathway for human exposure. The dust comprises various hazardous substances such as crystalline silica (quartz), lime, gypsum, nickel, cobalt and chromium compounds that are emitted during cement production. Potential adverse health effects arise when humans are exposed to the cement dust emissions through skin contact, eye contact or inhalation.[57-59] While communities residing near cement plants may be exposed to relatively lower levels of dust than workers in the factory, the levels are not negligible; the overall contribution of cement plants' ambient pollution to local PM levels can be high.[57] Thus communities residing near cement factories are vulnerable to exposure arising from dust concentration from the plant at relatively low levels but for a long time. Exposure through inhalation accounts for most of the adverse effects on humans.[47-50,52,60-62] The risk of effect depends on the duration and level of exposure.[52]

A review of the literature shows a relationship between exposure to cement dust and deleterious effects on human respiratory health.[45-49,52,53] High prevalence of cough, sinusitis, dyspnea and shortness of breath have been reported in exposed individuals compared to the unexposed.[45-49,63] In other studies, [64,65,66] asthma, chronic bronchitis and pneumonia have been observed to be higher in the exposed group than control. Additionally, lowered lung function indices such as FEV1, FVC, PEF and ventilation capacity (VC) have been observed in exposed group compared to the control in studies focusing on cement dust exposure and respiratory health.[45-66] However, the majority of the studies in existing literature were conducted in occupational setting while very few have investigated the effect of cement dust exposure on the respiratory health of communities residing near cement factories.

Despite several studies included in this review showing some degree of association between exposure to cement dust and respiratory ill health, the existing evidence is insufficient as most studies used a cross sectional design which has an inherent weakness providing evidence of causation or associations. Therefore, the positive relationship, or lack of, could have been spurious. To address this weakness, studying the association of exposure to cement dust and adverse respiratory health effects thus requires a panel study design in which measurements of both exposure and outcomes are repeated simultaneously at predetermined intervals over a period of time. In this study a panel was followed up for three consecutive seasons.

1.7. Research question

The research question addressed in this study was; *Is exposure to cement dust pollution associated with the prevalence of respiratory adverse health effects in communities living within the dispersion fallout range in Chilanga after adjusting for potential confounders?*

1.8. Aim

The aim of this study was to investigate the association of exposure to cement dust and respiratory health effects in a community residing near a cement factory in Chilanga, Zambia.

1.9. Objectives

a) To measure seasonal variations of cement dust ($PM_{2.5}$ and PM_{10}) concentration in ambient air in the exposed and comparison communities over three seasons.
b) To measure the prevalence of respiratory symptoms and lung function indices in the exposed and control communities
c) To investigate the seasonal variations in concentration of cement dust ($PM_{2.5}$ and PM_{10}) in ambient air and its effects on respiratory health effects in a community around a cement factory, in Chilanga, Zambia.
d) To assess short and long term changes in lung function indices associated with exposure to $PM_{2.5}$/PM_{10} in the ambient air in the exposed and comparison communities

1.10. Study hypotheses

i. H_o. There is no difference in the mean change in lung function indices and prevalence rates of respiratory illnesses between the exposed and the control community.
ii. H_a. There is a difference in the mean change in lung function indices and prevalence rates of respiratory illnesses between the exposed and the control communities

1.11. Relevance of the study

Evidence, though not conclusive, shows that the respiratory health of workers in cement plants, their families and the surrounding communities are affected negatively from being exposed to cement dust. The study site Chilanga is situated 15 km South of Lusaka. It has a total population of 104,871 spread over 2,450 km^2.[67] The spatial distribution of the population is uneven with over a third of the population residing in Freedom compound which is located close to a major cement factory. According to the national Annual Health Statistics Bulletin reports of 2009 – 2014,[67,68] respiratory illnesses were among the commonest cause of consultations with a health worker. Clinic records from Chilanga in the same period showed that the incidence of respiratory illness to be above the national average. For instance, the national average for pneumonia in children aged less than five years (Under 5s) was 81 per 1000 while Chilanga reported 136/1000 in 2013.[69] Although respiratory illnesses are often due to pathogens such as bacteria and viruses, the occurrence of such illnesses can be exacerbated due to exposure to dust. The observed difference in the incidence of respiratory illnesses in Chilanga could potentially be associated with cement dust pollution.

Human settlements are most found near industries for economic survival thus being at risk of exposure to industrial emission. Currently, most evidence in literature regarding the effect of the emissions from cement production is from studies conducted within the factory plants and involved mostly workers. Understanding the effects of exposure to cement dust on human respiratory health for communities residing near cement factories is imperative as it would allow for interventions that would balance between cement production and protection of human health. This is possible only when knowledge about the extent of the air pollution and its adverse health effects is measured precisely. Therefore, this research measured the extent of exposure to cement emissions and investigated the prevalence of respiratory illnesses in a community residing near a cement producing plant. Findings from this study will contribute to better policy making decisions; and improvement in guidelines regarding settlements around such factories.

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Chapter 2 : Research methodology

2.1. Study location and study population

The study populations comprised a sample of individuals residing in Freedom and Bauleni compounds as the exposed and control communities respectively.

2.1.1. Freedom compound

Freedom was the exposed community situated on the leeward side at the edge, at geographical coordinates of 15.3875^{o}S and 28.3228^{o}E and to the north-west of Lafarge cement factory, in Chilanga, Zambia (Fig 2-1). This compound, with a total population of 31,062 in 100.4 sq.km, is one of the mostly densely populated areas in Chilanga. It was purposively chosen because it is the most exposed community in Chilanga. The population composition data indicate that 52% of the population is aged 18 years and above and a male to female sex ratio of 1:1. The dwellings in this compound and the immediate surrounding areas comprise of a mixture of formal well-built concrete-block-wall dwellings and some informal mud houses.

Figure 2-1: Map of Freedom (exposed community)

2.1.2. Bauleni compound

The control community, Bauleni compound, was situated about 18 km from the cement factory and on the north-east of the factory (Fig 2-2); outside the cement dispersion area. The area is an improved and serviced site consisting of a mixture of houses made of mud or cement. The houses are roofed with either metal or asbestos sheets similar to Freedom compound. It has a population of 18,373 distributed over 128.6 sq.km.[1] There are no factories within or near to this settlement. The major economic activity is informal trade in furniture, second-hand clothes and vegetables. The choice of the control community was dictated by the need to have a community with a socioeconomic profile as similar to Freedom Compound as possible but outside the fallout zone.

Both the exposed and control sites share similar climatological characteristics. There are three distinct seasons in Zambia; cold-dry, hot-dry and rainy season. The rainy season is from November to April with average maximum rainfall of 195 mm. The cold dry season lasts from May to July with average temperatures ranging from 13 to 26 ^{o}C. The hot dry season is from August to October with average temperatures ranging from 30 to 36 ^{o}C. The mean monthly wind speed varies from as low as 1.6 m/s during rainy season to 22 to 30 m/s during the wet summer months. The wind direction is predominantly East-westerly most of the year with light variable northerlies and north-easterlies during the rainy season.[2] The meteorological data used in this study was obtained from the Zambia Meteorological Department (ZMD).

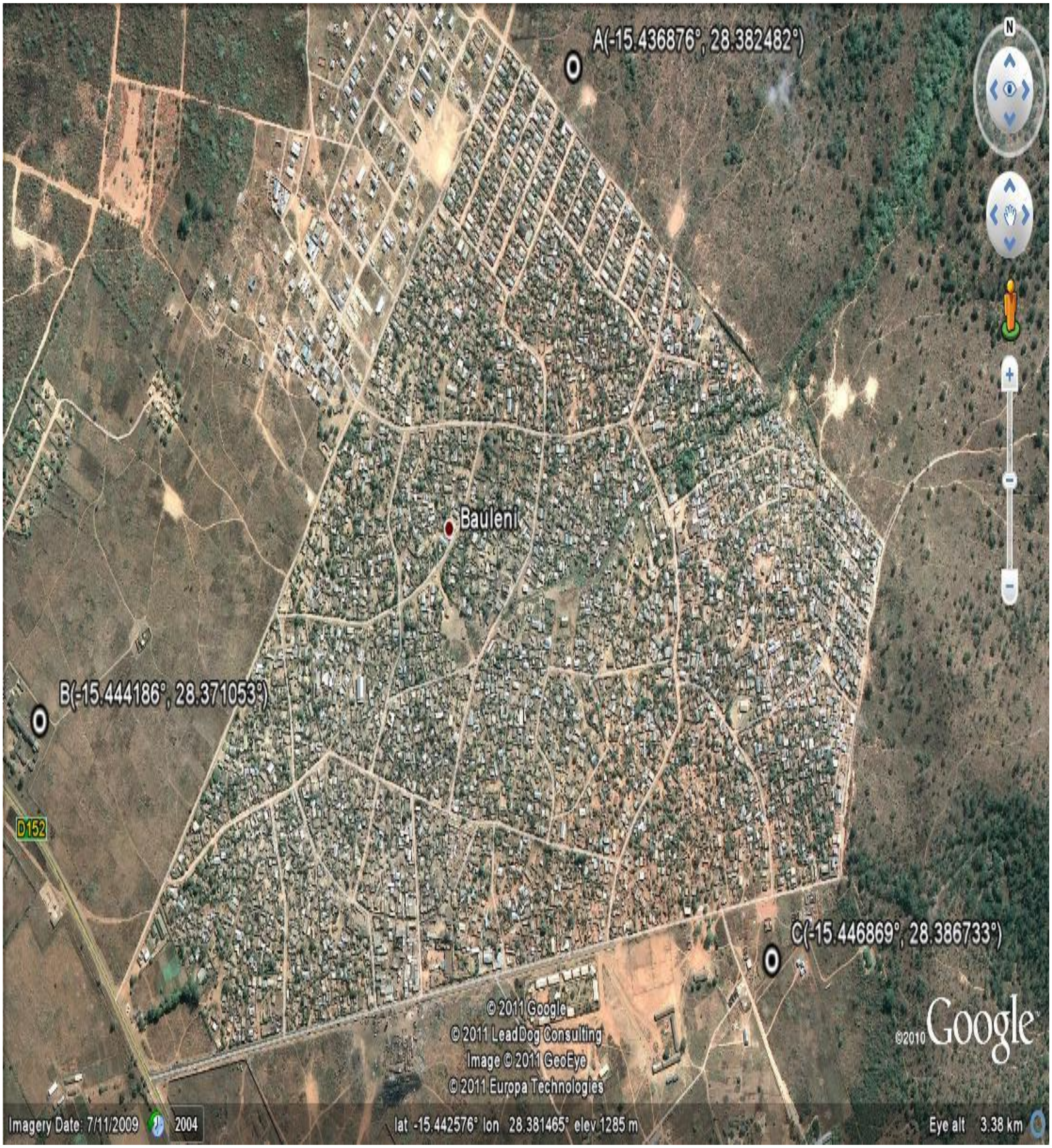

Figure 2-2: Map of Bauleni (Control community)

2.2. Sample size determination

The study was divided into cross sectional and longitudinal panel; thus different sample sizes were used. The following sections show how the sample sizes were determined.

2.2.1. Sample size for cross sectional

The variability and prevalence of parameters of interest in this study were unknown. Therefore, a number of assumptions were made in order to determine the sample size for the cross sectional phase of the study (chapter three and chapter four):

i. For the continuous variables FEV1 and FVC, the population standard error was unknown. However, from epidemiological studies elsewhere in Africa, the mean FEV1 has ranged from 2.24 to 3.04 litres while the standard deviation has ranged from ± 0.08 to ±0.65 Litres.[3] For this study population, the average of these standard deviations, ±0.33 L was assumed. Further, it was assumed that the variance was equal for both populations in the exposed and control communities.

   Based on the above assumptions, the sample size required to detect a difference between means from two population means, is given by formula (Eq.1):[4]

   (Equation 1) $n = (2\delta^2 / \Delta^2)/(Z_\alpha + Z_\beta)^2$

   Where n= number per group to detect a difference in means

   Δ= the precision (± 0.15 L for this study)

   Z_α (two tailed) = 1.96 at alpha (α) level = (0.05)

   $Z_\beta = 0.84$ for $\beta = .20$ i.e. power to detect a significant difference of 80%

   The calculated required minimum sample size, after adjusting for clustering effect with a design effect of two and non-response rate of 30%, was 217 individuals from each study community.

ii. To calculate the sample size needed for the determination of a difference between two proportions, the following formula (2) was used:[5]

(Equation 2) $$n = \frac{p_1(1-p_1)+p_2(1-p_2)}{(p_1-p_2)^2}(Z_\alpha + Z_\beta)^2$$

Where P_1= expected prevalence of respiratory symptoms in the control community and P_2= Expected prevalence of respiratory symptoms in the exposed population.

The values for p_1 and p_2 for the study populations were essentially unknown. However, evidence from studies from other parts of Africa suggests a prevalence of respiratory symptoms (cough) of 30% for cement factory workers and 10% for the control groups.[6,7]

To calculate our sample size for this study, the prevalence for the exposed community was assumed to be equal to that found for factory workers in other studies i.e. p2= 30%. Similarly, the prevalence for the control community was assumed to be close to that for the control groups in other studies i.e. p1= 10%.[7]

Using the above formula, the minimum sample size to detect a 20% difference at 95% confidence level and power of 80% was 170 individuals after adjusting for design effect (DE=2) of two and non-response of 30%.

Given that the minimum sample size to be able to detect a significant difference in mean FEV1 was larger than that for detecting differences in proportion of respiratory symptoms between the exposed and control communities, the study began with recruitment of 220 participants from each community.

2.2.2. Sample size for longitudinal panel

a) Sample size for continuous variables: FEV1, FVC

There was no information on the expected change in the mean FEV1 and its variance for the study group. However, a South African study revealed a yearly average decline FEV1 of 37 mls (SD 66.4 mls) among mine workers.[8] Further, the same study demonstrated a decrease in mean FEV1 for a group of coal miners by 55 mls (SD 171 mls) from baseline levels at 12 months. Assuming similar declines in the mean FEV1 (and variability) for both exposed and control groups over the study period, the minimum number of participants required would range from 50 to 155 per community to be able to detect the anticipated decrease in the mean FEV1, using two-tailed tests, at $\alpha = 0.05$ and power of 80%. The above sample sizes were calculated using the following formula (Eq. 3):[9]

$$\text{(Equation 3)} \qquad n = \frac{2\,\sigma^2_d (Z_\alpha + Z_\beta)^2}{\delta^2}$$

where σ^2_d is the variance of the mean change in FEV1 over time within the exposed community; δ^2 absolute mean change of FEV1 in the exposed community over time and $Z_\alpha = 1.96$ and $Z_\beta = 0.84$

b) Sample size for dichotomous variable: respiratory symptoms

The required minimum sample size to detect a consistent difference in proportions or changes in the proportions of respiratory symptoms over time between two groups, with power 80 % and $\alpha = 0.05$ using two-tailed Chi test, was determined using the following formula (Eq. 4):[10]

$$\text{(Equation 4)} \quad N = ([Z_\alpha (2\overline{p}\overline{q})^{1/2} + Z_\beta (p_1 q_1 + p_2 q_2)^{1/2}]^2[1+(n-1)\rho])/n(p1-p2)^2$$

Where

p_1 = proportion of respiratory symptoms in control group ($q_1 = 1 - p_1$)

p_2 = proportion of respiratory symptoms in exposed group ($q_2 = 1 - p_2$)

$\overline{p} = (p_1 + p_2)/2$

$\overline{q} = (1 - \overline{p})$

n= number of observation time point (42 in this study)

ρ= common correlation across the n observations (0.6 in this study)

N=number of individuals per group

Assuming p_1 (control community) = 0.1 and p_2 (exposed community) = 0.3, the required sample size would be 140; adjusting for non-response of 30% gives the final sample to 160 individuals per group.

Since the sample sizes are different, the higher sample (i.e. the one needed to detect changes in FEV1/FVC) was used in the panel longitudinal arm.

2.3. Selection of study participants

Study participants were selected using multi-stage random sampling approach (Fig 2-3). The first tier sampling frame was obtained by dividing each of the two communities into clusters of households using the latest Google Earth maps of the two communities (Fig 3-1). The cluster size was determined depending on geophysical arrangement of the households e.g. division by main roads, markets, schools or other geographical features like a stream or river. As there was no pre-enumeration of households in both communities, attempts at getting equal number of households per cluster was ensured by making clusters of roughly equal geographical dimensions. This resulted in 25 and 42 clusters in Freedom and Bauleni, respectively.

This was followed by identification and physical mapping of the clusters using Global Positioning System coordinates (geocodes). The delineated clusters for each community were then numbered sequentially and entered into Microsoft Excel to form the first tier sampling frame (one for each community). A subset of 10 clusters from each sampling frame was randomly chosen using random number generator in Excel. Excel was set to generate random number between 0 and 1using the “RAND ()” function. The random numbers were then sorted from smallest to largest and the first ten numbers corresponding to 10 clusters were selected. This ensured that the clusters were selected at random and representative of the community.

The second tier sampling frame comprised all households in the selected clusters. Each household in a selected cluster was numbered using geocodes (and house numbers where possible). Separate sampling frames for each cluster was entered in Microsoft Excel and a random sub-sample of 22 households was obtained following the method described in the previous section. A total of 220 households were thus selected from each community. This was done to ensure the included households were chosen at random and were representative of the community. The chosen households were then visited, aided by the geocodes and house numbers, to determine household eligibility.

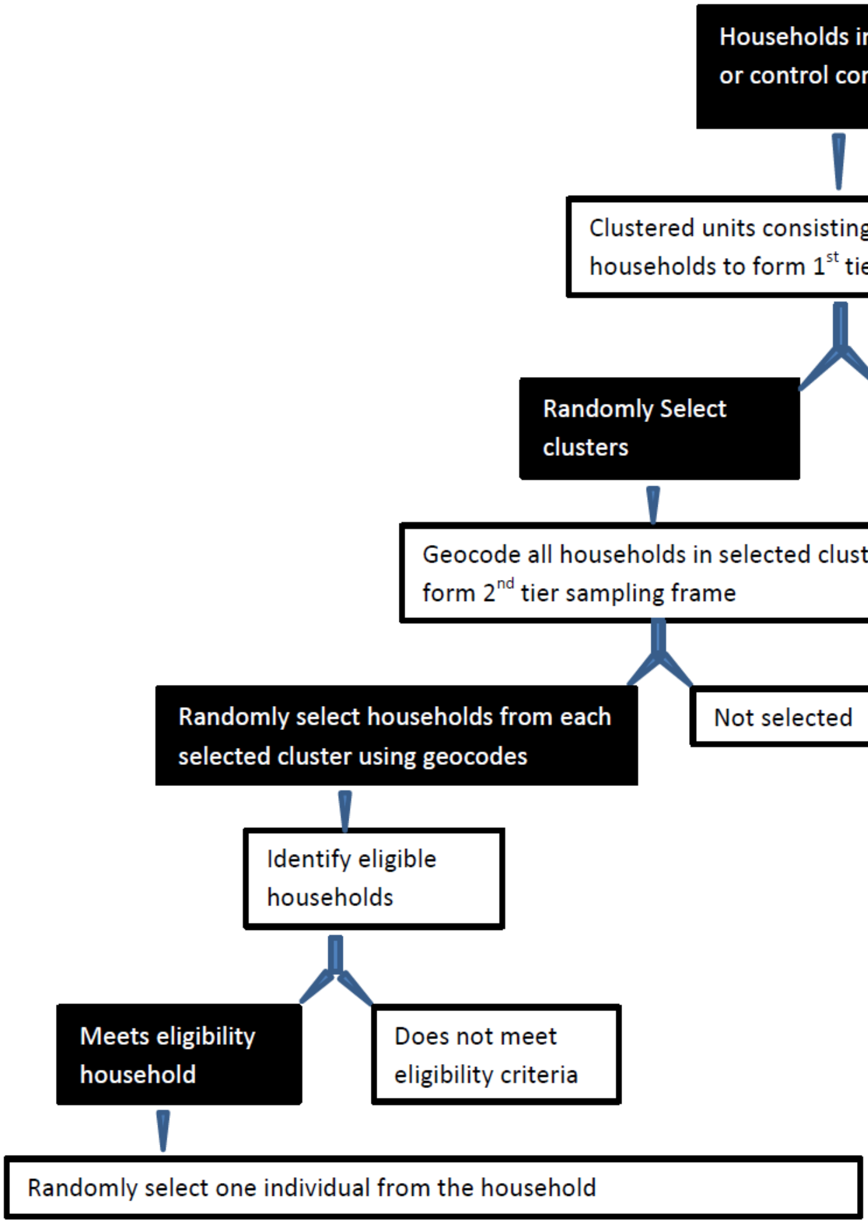

Figure 2-3: Schematic representation of sampling procedure

Consent was sought from the head of each household to participate in the study (appendix 1-Form one). Individuals who met the inclusion criteria (Table 2-1) and gave consent were numbered sequentially on small pieces of paper, which were put in a bag and one selected by lottery. This was followed by administration of a questionnaire. Where there was only one individual meeting the inclusion criteria in the household, that individual was chosen for inclusion in the study. In the event that the head of household declined to participate, the entire house then became ineligible, the next available household was chosen randomly. This was done by numbering clockwise the immediate surrounding households on pieces of paper. Then the pieces of paper bearing the numbers were put in a box, shaken and one paper drawn at random. The chosen household replaced the one that did not meet the inclusion criteria in the initial sampling. If the replacement household did not meet the inclusion criteria, the procedure was repeated. In the repeat sampling all households that did not meet the inclusion criteria were excluded. Individuals with pre-existing respiratory health conditions were included in the study in order to increase the statistical power to address whether such individuals were particularly at increased risk for measurable adverse health effects of exposure to ambient pollution.

Table 2-1: Household and individual eligibility criteria

Inclusion criteria		Exclusion criteria
Household	Individual	
Consent to include the household in the study	Individuals who spent whole or 80% of their time in Chilanga	Cement factory workers, both in exposed and control communities
Availability of at least one appropriate individual who meets the individual inclusion criteria	Individuals above 15 years and above, and adults less than 60 years	Mining, quarrying and any other industry that produces emissions
	Residents in Freedom or Bauleni community for at least 4 months	
	Consenting individuals	

2.4. Study procedure

2.4.1. Introduction of the study to the community

Involvement of the Ministry of Health (MoH) and communities was cardinal in accomplishing this research project. Permission was requested from the MoH headquarters, Lusaka and Chilanga health offices; because these are the custodians of health facilities regarding collecting data on prevalence of respiratory illnesses in the respective communities (appendices 8.4, 8.5). Further, the study was introduced to the communities through Community Health Workers (CHW) who worked at the local health facilities as volunteers. A number of meetings were held with CHWs regarding different tasks that were required to complete the study. From each community, two community leaders serving as Neighbourhood Health Community (NHC) leaders were engaged as research assistants. These, were in addition to the six Clinical Officers (clinicians with diploma in clinical medicine) who engaged as research assistants. The whole team was oriented to the research tools during a research training workshop conducted for two days. Furthermore, the community workers were requested to disseminate the information about the study in their respective communities prior to the commencement of the study.

2.4.2. Pilot study

A pilot study was conducted in the control community, Bauleni, in a predetermined cluster that was not chosen for the final study. The objective of the pilot study was to test the measurement tools (appendix 8.9). No formal sample size determination was required for this phase. Administration of questionnaire was done on randomly selected individuals within the selected control community. Gaps identified in the questionnaire during the pilot study were amended prior to the final data collection.

2.4.3. Phase I: Cross Sectional Study

Following the identification of participants, measurement of respiratory symptoms using an interviewer-administered questionnaire was conducted to determine the prevalence of respiratory illnesses (chapter three and chapter four). A full detailed interview questionnaire modified from the ATS[10] was administered to participants aged between 15 and 60 years. The questionnaire measured prevalence of respiratory illnesses. Respiratory illnesses were referred to as acute respiratory symptoms like cough, wheezing, difficulty in breathing, breathlessness and shortness of breath. Other symptoms that were measured included; nose irritation, sinus irritation, pneumonia, bronchitis and phlegm. Additionally, eye irritation was also assessed. Cough was defined as cough as much as 4 – 6 times per day occurring for most days of the week (>4 days) for at least three months in a year and for at least two consecutive years. Chronic cough or phlegm was defined as coughing or phlegm production for part of a day or the entire day for at least 3 months/year. Chronic bronchitis was defined as a cough and/or phlegm on most days for 3 months or more out of a year. Dyspnea was defined as having to stop for breath when walking at one’s own pace on level ground. Wheezing was defined as a condition of causing a wheezy or whistling sound on inspiration at least occasionally apart from that caused by a cold or acute upper respiratory infection. A current smoker was defined as an individual who smoked one or more cigarettes daily (appendix 8.9).

The questionnaire was used to collect information on age, height, weight, gender, general health, allergies, incidences of asthma, the general health exposure to tobacco, type of fuel used for cooking and social economic status (such as overcrowding, occupation and number of people contributing to income of the household). The results are presented in chapters three and four.

2.4.4. Phase II: Longitudinal panel

A sub-section of participants was randomly recruited from the cross sectional phase to form the sampling frame for the longitudinal panel; the Phase two of the study. The selection criteria of study participants for panel included: consenting individuals, participants who were unlikely to leave Freedom or Bauleni compounds for 1-2 years and aged 15 - 59 years. The panel study comprised three main activities; repeated measurements of the occurrence of respiratory symptoms, lung function measurement and ambient air quality monitoring.

2.5. Performance of measurements

2.5.1. Measurement of exposure (pollution of the ambient air)

The main exposure variables were $PM_{2.5}$ and PM_{10}. Proxy measures of personal exposure to cement dust were obtained by measuring $PM_{2.5}$ and PM_{10} in the ambient air in the exposed and control communities.

2.5.1.1. Air monitoring

To assess daily and seasonal variability of airborne PM concentrations in the two communities, ambient air monitoring was conducted during the three measurement waves reflecting the three climatic seasons: winter (28 July – 14 August, 2015), summer (15 – 28 October), and rainy season (7 - 21 January 2016). A community-level monitoring station was set up in each of the two communities: at the Reformed Church of Zambia for Freedom and Bauleni Clinic for Bauleni, the control community. The choice of the two sites was based on security considerations for the monitoring equipment. The equipment was placed on a building rooftop at each site allowing sampling inlets to be 2 – 3 meters off the ground and away from any interference to air circulation. Filter-based measurements of $PM_{2.5}$ and PM_{10} were made daily during each seasonal exposure assessment field intensive (each two weeks in duration) at each sampling location. All PM samples were collected daily, over 24-hour durations. Measurements were made using 2-µm pore, 47-mm Teflon (PTFE) membrane filters (Pall, Ann Arbor, MI).[11] Vacuum pump systems were used to draw air through the sample at a nominal flow rate of 16.7 L/min using Teflon-coated aluminum cyclone inlets (University Research Glassware, Chapel Hill, NC).[12] Flow determinations were made at the beginning and end of each sampling period using a calibrated rotameter (Matheson Inc., Montgomeryville, PA).[12] For this method, analytical precision was calculated to be within 10% based on replicate analysis with a limit of detection of 5.1 µg (calculated as three times the standard deviation of seven repeated blank filter measurements). All measurements were above the detection limit.

2.5.1.2. Laboratory analyses

All filters collected were prepared and analyzed at the University of Michigan Air Quality Laboratory (UMAQL).[12] All gravimetric determinations of Teflon filters were made using a microbalance (Mettler MT-5; Mettler Toledo, Columbus, OH) in a temperature/humidity-controlled Class 100 clean laboratory and followed the Federal Reference Method,[12] which included conditioning filters for 24 hours in the clean lab. At the conclusion of each study period, collected filters were shipped back to the UMAQL, conditioned for 24 hours, and post-weighed following the same protocol used for filter pre-weight. For this method, analytical precision was calculated to be within 10% based on replicate analysis, with a limit of detection of 5.1 μg (calculated as three times the standard deviation of seven repeated blank filter measurements). All measurements were above the detection limit.

2.5.2. Measurement of outcome variables

The main outcome variables that were measured in this study were prevalence (for cross-sectional phase) and incidence (panel cohort) of respiratory symptoms and variation in lung functions (Table 2-2).

2.5.3. Respiratory symptoms

Respiratory symptoms included wheeze, cough, phlegm, pneumonia, chest illness, breathlessness and difficulty in breathing. All these were self-reported by the participants and captured on questionnaire administered by the research assistants. The symptoms were defined as follows:

i. Any respiratory symptom lasting not less than two days
ii. Any respiratory symptom or event that required a visit to a health facility for medical assistance

NOTE: To differentiate one episode from another, an episode was considered resolved, if there were no symptoms for at least three days.

To capture data on the occurrence of respiratory symptoms, a full detailed questionnaire was administered on day of each data collection wave lasting for consecutive 14 days. For remaining

13 days, a simplified daily diary questionnaire was administered (appendix 8.10). Respiratory illnesses referred to acute respiratory symptoms like cough, shortness of breath, stuffy nose, wheezing, runny nose, breathlessness and sneezing. Other respiratory conditions were also measured that included chronic bronchitis, asthma, pneumonia and phlegm. The questionnaire also collected data on the following variables: age, height, weight, gender, general health, allergies, incidences of asthma, the general health exposure to tobacco, type of fuel used for cooking and socio economic status (such as overcrowding, occupation and number of people of people contributing to income of the household). Additionally, the questionnaire also captured data on medications taken and any visit made to the doctor during the data collection campaign.

2.5.4. Measurement of lung functions

Spirometry was conducted to measure mean change of lung function indices over a period of the study in order to measure a) short term effect of air pollution on the lung function and b) to determine mean change in lung functions over three different seasons. Each participant performed daily spirometry for 14 consecutive days during each of the data collection waves. Before taking measurements, the procedure was explained and demonstrated to each participant at the beginning and during each data collection period until the participant was comfortable to perform the maneuver on their own without any assistance. Standard methods were used to determine the validity and reproducibility of the blows. The EasyOne ultrasonic flow-sensing spirometer manufactured by NDD Medical Technologies, Zurich, Switzerland was used in the study).[13]

Lung function was measured as FEV1, FVC and FEV1/FVC ratio. Lung function was measured consecutively for 14 days for each season. For the daily sessions, performed between 07:30 AM and 09:30 AM, the participant had to blow into the EasyOne spirometer. The maneuver involved the participants inspiring fully, seal the nose with one hand and place the mouth around the mouthpiece of the spirometer, followed by breathing out as fast as they could until the lungs were empty. The measurements were carried out according to guidelines and techniques for performing spirometry according to American Thoracic Society (ATS) standards. The quality of spirometry tests was assessed according to the ATS guidelines.[10]

2.5.5. Measurement of potential confounding variables

Other variables that were measured, because they were considered to be potential confounders, included: age, sex, cigarette smoking, ventilation and type of fuel used for cooking, workers employed nearby farms.

i. Age: measured as age at last birthday
ii. Sex: Male or Female
iii. Cigarette smoking: was categorized either as current smoker, former smoker or never smoked. Current smoking was graded according to the number of cigarettes and number of years.
iv. Source of household energy: Biomass, fossil, electricity. Biomass included cow dung, wood and/or straw. Fossil fuels included kerosene and charcoal.
v. Ventilation: was categorized as follows:

Very good ventilation	Household with more than one window where there was both through and cross ventilation during the period of data collection
Good ventilation:	Household with at least one window where there was through or cross ventilation during the period of data collection
Fair ventilation:	Household with one window and was opened during the period of data collection
Poor ventilation:	Household with no window, was stuffy however the door was open during the period of data collection
Very poor ventilation	Household with no window and door was closed during the period of data collection

Table 2-2: Summary of variables

	Mode of measurement	**Definition**
Outcomes		
Lung functioning *Measure FEV1, FVC, FEV1/FVC ratio*	*Spirometry*	*Monitored daily fluctuations in each participant for* FEV_1 *and FVC within each session were scored as 'valid' or 'not valid' following standard assessment techniques. In addition, 'reproducibility' scores (range 0-6) were also assigned to each session. Standard equations were used to calculate percent of predicted of* FEV_1 *and FVC. The best percent of predicted of sessions with two or more valid blows with reproducibility score of 4 or 6 were considered for* FEV_1 *and FVC, considered one at a time. Finally, using the empirical distribution of the Session Best valid reproducible percent of predicted we kept blows within the 30 and 150 range of percent of predicted for* FEV_1*, and FVC. For the* FEV_1/FVC *percent we considered the largest sum of* FEV_1 *and FVC within the same session, and then the ratio of these two values was assessed. Similarly, as before, based on the empirical distribution of this measure we kept values below 100%.*
Respiratory illnesses i. *Cough* ii. *Phlegm* iii. *Wheeze* iv. *Breathlessness*	*Self-reported symptoms captured on questionnaire*	A respiratory episode was defined as: • *Any respiratory symptom lasting not less than two days* • *Any respiratory symptom or event that required a visit to a health facility for medical assistance*
Exposures		
Cement dust	*Stationary air samplers*	*Measurement of* $PM_{2.5}$ *and* PM_{10} *as proxy measure of exposure*

2.6. Reference

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Chapter 3 : Prevalence of and determinants of mucous membrane irritations in a community near a cement factory in Zambia: a cross sectional study.[1]

3.1. Abstract:

Exposure to cement dust has been associated with deleterious health effects in humans. This study investigated whether residing near a cement factory increases the risk of irritations to the mucous membranes of the eyes and respiratory system. A cross sectional study was conducted in Freedom Compound, a community bordering a cement factory in Chilanga, Zambia and a control community, Bauleni, located 18 km from the cement plant. A modified American Thoracic Society questionnaire was administered to 225 and 198 respondents aged 15–59 years from Freedom and Bauleni, respectively, to capture symptoms of the irritations. Respondents from Freedom Compound, were more likely to experience the irritations; adjusted ORs 2.50 (95% CI: [1.65, 3.79]), 4.36 (95% CI [2.96, 6.55]) and 1.94 (95% CI [1.19, 3.18]) for eye, nose and sinus membrane irritations respectively. Cohort panel studies to determine associations of cement emissions to mucous membrane irritations and respiratory symptoms, coupled with field characterization of the exposure are needed to assess whether the excess prevalence of symptoms of mucous membrane irritations observed in Freedom compound are due to emissions from the cement factory.

Keywords: cement production emissions; air pollution; mucous membrane; community

3.2. Introduction

Cement production inevitably leads to environmental pollution. Emissions from cement production plants include carbon monoxide (CO), carbon dioxide (CO2), nitrous oxides (NOx), sulphur oxides (SOx) and particulate matter (PM). Other emissions include

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polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs), polycyclic aromatic hydrocarbons (PAHs), poly chlorinated biphenyls (PCBs), benzene and other organic compounds. These emissions contribute to pollution with subsequent deleterious effects on the environment and health of the public.[1,2] The major routes of entry after exposure to these emissions include the respiratory system, gastro intestinal tract, the mucous membranes of the eye and the skin.

Epidemiological studies have reported impairment of lung function and increased prevalence of respiratory symptoms among workers exposed to emissions at cement plants.[3–5] Studies have also revealed that the respiratory system for not only the workers in cement plants, but also the surrounding community are affected.[6,7] Children in schools located within the proximity of cement plants are particularly vulnerable to cement emissions.[8] Persistent irritations of mucous membranes could lead to respiratory tract malignancies (laryngeal carcinoma) and various cancers of the intestinal tract such as colorectal, colon and stomach cancers.[9–11] Additionally, heavy metals have been found in urine of residents within the vicinity of cement plants.[12] Other adverse health effects due to exposure to cement emissions include skin and eye problems that lead to increased periods of hospitalization.[7,13]

Given the variety of elements in the emission and its wide dispersion, effects on the mucous membranes of the eyes and nose could potentially affect the quality of life for a population in the vicinity of a cement factory. However, few studies have examined the effect of such emissions on these types of impacted communities. Additionally, most studies have investigated the effect of cement emissions on the respiratory system, especially PM that are small enough to settle in distal parts of the lungs. Zambia produces an estimated 2.2 million tons of cement annually from three cement production plants, half of which is produced at one plant, situated in Chilanga. At the edge of this plant is a settlement of 31,062, people who are potentially exposed to cement production emissions.[14] Although there has been a study into the effects of cement production on the health of workers in the factory, no such studies have been extended to the community living on the plant's periphery. The objective of this study was to determine whether residing near a cement factory increases the risk of irritations to the mucous membrane of the eye and respiratory system.

3.3. Material and Method

3.3.1. Study Design

This was a cross sectional study was conducted in two communities; the exposed community (Freedom compound) and a control (Bauleni). The study was conducted in November and December 2013 a period characterized by wet and warm climate.

3.3.2. Study Area

The exposed community, Freedom, is situated in one of the most densely populated areas in Chilanga. It is located on the leeward side at the edge and to the north-west of the cement factory. It is bounded on the western side by a major intercity tarred road. Access gravel roads coming off this major road cross the breadth and width of the settlement. Traffic on the major road includes heavy trucks, buses, vans and cars. Heavy trucks rarely traverse the inner parts of the settlement. Winds across the settlement are predominantly south-westerly resulting in most traffic emissions from the main road being blown away from the settlement. The control community, Bauleni, is located about 18 km from the cement factory outside the windward cement dispersion area (Figure 1). It is bounded by major tarred roads on three sides and has minor gravel standard roads in the inside of the settlement. Traffic on the major roads and minor roads is similar to that seen in Chilanga except there are fewer heavy trucks moving on the main roads. The major economic activity is informal trade in furniture, second-hand clothes and vegetables. There are no factories within or near to the Bauleni settlement.

3.3.3. Sample Size

The prevalence of symptoms of interest in the two communities was essentially unknown. However, evidence from studies from other parts of Africa suggest that the prevalence of respiratory symptoms is around 30% for cement factory workers; while the prevalence in the control groups were found to be 10%. [15,16] To calculate the sample size for this study, the prevalent for the exposed and the control communities were assumed to be similar to that found in other studies. To detect a 20% difference at 95% confidence level and power of 80% we a required minimum sample size of 170 participants per community after adjusting for design effect of two (DE = 2) and a non-response of 30%. In this study, we targeted to recruit 220 from which we intend subsample for a future panel study.

3.3.4. Sampling of Participants

A multi-stage random sampling method was used to select participants. The study communities were each divided into geographical clusters each containing a number of households. The households in each cluster were enumerated and geocoded (see the Supplementary File). A sub-sample of 10 households per cluster was then obtained randomly. The selected households were visited and one individual from each household who met the inclusion criteria was selected and interviewed by the research assistant. Inclusion criteria were age 15–59 years and respondents must have resided in either of the study areas for at least 4 months prior to the survey. Participants employed in cement factory, construction industry, quarrying and mining were excluded.

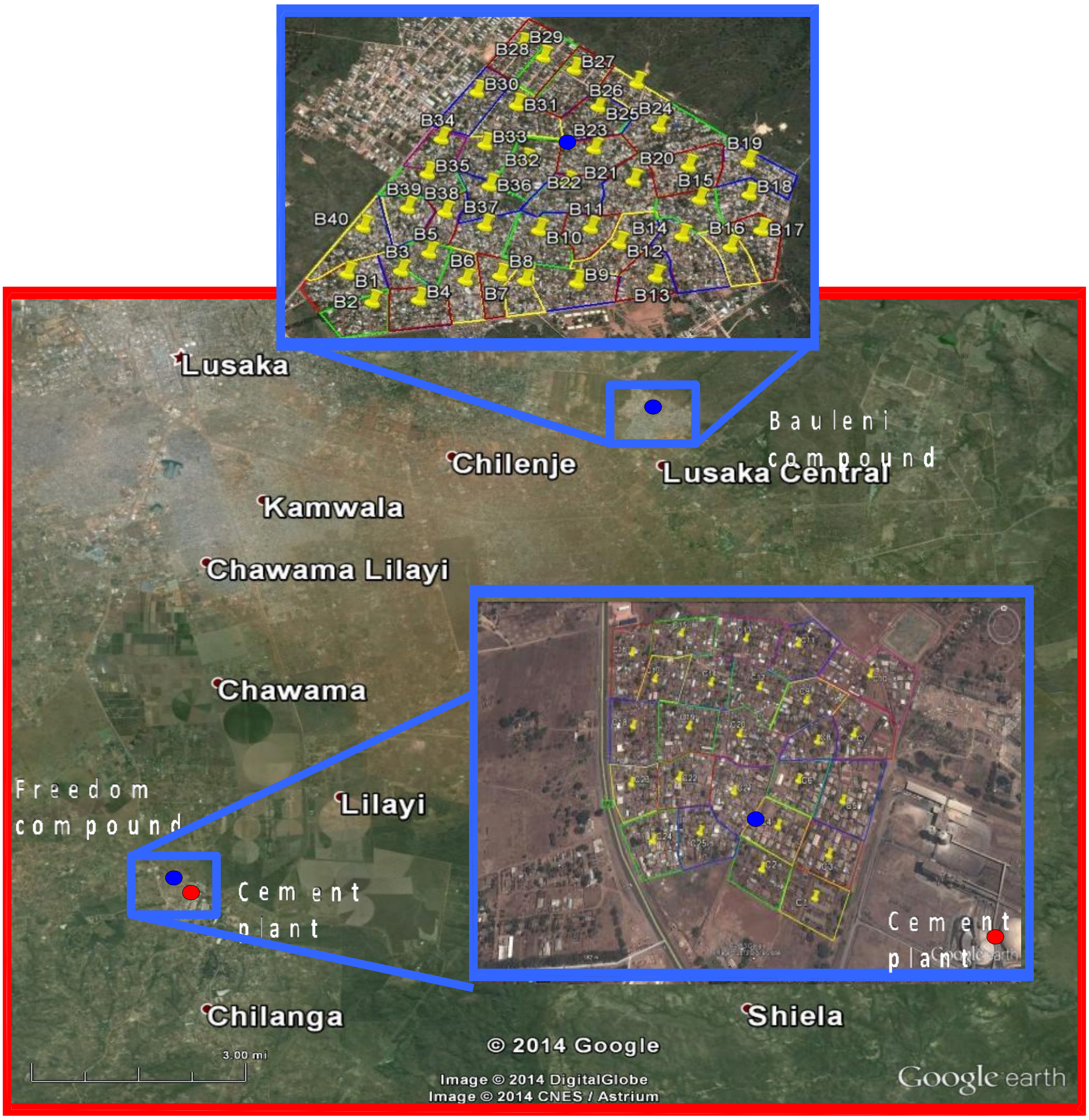

Figure 3-1: Maps of study communities

3.3.5. Data Collection

Data were collected using a modified American Thoracic Society (ATS) questionnaire which was administered to the selected participants by trained community health workers drawn from the health facilities serving the study communities. The data collected included participants' demographic and socioeconomic characteristics, the occurrence of symptoms of mucous membranes irritations, and exposure to tobacco smoke.

3.3.5.1. Measurement of Variables

Table 3-1: Symptoms used to measure three mucous membrane irritations: eyes, nose and sinus

	Symptoms or Complaints	
Eye	**Nose**	**Sinus**
Swelling	Itching	Head or face pain
Discharge	Sensation of fullness or congestion	Blowing out thick mucus
Excessive tearing	Nasal discharge	Post nasal drip [a]
Any of the above of symptoms [c]	Runny nose	Throat clearing or Hoarseness of the voice [b]
	Any of the above symptoms [c]	Any of the above symptoms [c]

[a] dripping of mucous at the back of the nose or throat. [b] hoarseness was defined as changes in the usual quality of the voice. [c] used as the main outcome (binary) in logistic regression.

The exposure variable: residence in Freedom was used as a proxy measure of exposure to cement dust and related emissions from the cement plant. Smoking status was defined as current, ex-smoker or secondary smoker. "Ex-smoker" was defined as cessation of smoking at least 1 year prior to the period study. For all categories, the cigarette was established whether it was manufactured or locally rolled tobacco (or both) how many cigarettes they had smoked per day, and for how long. "Secondary smoking" was if a participant was exposed to any household member that smoked in the house.

3.3.6. Statistical Analysis

Data were double entered, by two trained assistants, independently into a customised Microsoft Access database, with inbuilt validation capability. The two sets were compared, using the CompareIt program (Grig Software, Vancouver, Canada) to identify discrepancies in entries. Any discrepancies identified were checked against the paper based data. Further cleaning and coding was done in Microsoft Excel while analysis was performed using STATA version 12 (Stata Corp L 2011, College Station, TX, USA). The unit of analysis was the individual respondent. To account for multistage cluster sampling and obtain correct estimates, STATA was set to *svy mode*, setting the primary sampling unit as the cluster of households.

Univariate analysis was done to describe the distribution of respondents' demographic and socioeconomic characteristics within and between the exposed and control communities: proportions, median and inter-quartile range (IQR) and 95% confidence intervals were reported. For categorical data the Pearson's Chi-square test was used to compare differences between the communities. All statistical tests were two-sided and a *p*-value <0.05 was considered as statistically significant while *p*-value ≥ 0.05 and ≤ 0.1 were considered marginally statistically significant.

To examine the strength of association between area of residence and each of the three outcomes, bivariate and multivariable logistic regression was used to obtain unadjusted and adjusted odds ratios (ORs), *p*-values, and their respective 95% CI. The following factors were assessed: area of residence, age, gender, marital status, education, occupation, whether respondent ever smoked (and number of pack years smoked), source of energy for cooking and lighting, whether cooking area was located within the main house or sleeping area; and ventilation of the dwelling house and whether respondent spent time home or away from home. For categorical factors, dummy variables were used in the model selection procedure. Furthermore, statistical interactions between community and other factors were investigated.

Three multivariable models, one for each outcome, were utilized. To obtain adjusted ORs for effect of "area of residence" on the outcomes all potential confounders, (*i.e.*, factors with a *p*-value < 0.05 in bivariate analysis) were placed in an initial logistic regression model. This was followed by the addition, in stepwise manner, of variables that were marginally significant in bivariate analyses. Each time a new factor was added to the model, the ORs of the factors already in the model were checked. If the addition of a new factor changed the OR of any already included variable by more than 10%, the additional variable was retained in the final multivariate model otherwise the variable was removed and a different one added. Area of residence was considered the main explanatory variable and therefore was included in all models for each outcome of interest regardless of whether it was statistically significant in bivariate analyses.

3.4. Results

3.4.1. Description of Respondents' Demographic and Socioeconomic Characteristics

In total, 423 respondents took part in the study; 225 and 198 from exposed and control communities, giving a response rate of 100% and 90% respectively. Tables 2 and 3 summarize the demographic and socioeconomic characteristics of the respondents stratified by community. The age distribution and gender was significantly different between the two communities. While 46.2% of respondents in Freedom were in the 25 to 39 years' age group, 39.5% were younger (12–25 years of age) in Bauleni. Although the majority of respondents in both communities were female, there was a significant difference between the community; 84.1% and 73.2% in Freedom and Bauleni respectively. The median number of years' respondents lived in each community as well as the marital status distribution was not different. There were more ($p = 0.003$) unemployed respondents in Freedom (75.5%) than Bauleni (61.6%).

The majority of respondents from both communities had never smoked, with only 23 respondents in the two communities reporting having ever smoked (Table 2). Of these, six were ex-smokers while 17 were current smokers. Overall, there was no statistical difference in smoking status; between the two communities. Respondents pack years smoked ranged from 5 to 35 years for the whole group of smokers.

3.4.2. Socio Economic Characteristics of the Communities

Although, the majority of houses in both communities were made of concrete material, Bauleni compared to Freedom, had a significantly higher proportion (p-value = 0.020) (Table 3-2). The majority of houses in Freedom were roofed with asbestos while metal sheets were used for most houses in Bauleni. A statistically significant higher proportion of houses in Freedom were plastered (p value = 0.010). No statistically significant differences in the distributions of number of rooms and windows were observed between the communities. Most houses in both communities had up to two rooms and up to three windows per structure with no statistically significant difference. Only a minority of houses owned a floor carpet in the two communities; with no statistical significant difference between communities (*p* value = 0.260).

While the source of energy for lighting was the same for both communities, energy source for cooking was statistically significantly different between the communities; majority of households in Freedom used charcoal as source of energy for cooking and had cooking areas located within the dwelling house.

Table 3-2: Description of study participants by demographic characteristics stratified by community

Factor	Total	Freedom (Exposed)	Bauleni (Control)	p-value
	N=423	**N=225**	**N=198**	
	n (%)	***n (%)***	***n (%)***	
Age in years:				
12 -24	158 (37.4)	77 (33.5)	81 (39.5)	
25 – 39	166 (39.2)	101 (46.2)	65 (31.7)	0.005
40+	99 (23.4)	47 (20.4)	52 (28.8)	
Years lived in community [a]		N=217	N=190	
median (IQR)		10 (4 - 21)	14 (5 - 23)	0.080
Gender				
Female	333 (78.7)	187 (83.1)	146 (73.7)	0.021
Male	90 (21.3)	38 (16.9)	52 (26.3)	
Marital status				
Single	138 (32.6)	71 (36.6)	67 (32.8)	
Married	245 (57.9)	135 (57.9)	110 (57.2)	0.099
Widow/divorced	40 (9.5)	19 (5.5)	21 (10.0)	
Education				
None	28 (6.6)	4 (1.1)	24 (9.6)	
primary	241 (57.0)	147 (63.9)	94 (49.7)	
Secondary	145 (34.3)	66 (30.8)	79 (40.3)	<0.001
Tertiary	9 (2.1)	8 (4.2)	1 (0.4)	
Employment status[b]				
Unemployment	270 (67.0)	153 (75.5)	117 (61.6)	0.003
Employed	133 (33.0)	56 (24.5)	77 (38.4)	
Smoking status[c]				
Never smoker	397 (94.7)	209 (94.5%)	188 (96.6%)	
Ever smoker	6 (1.4)	5 (2.0%)	1 (1.0%)	0.381
Current	17 (4.0)	10 (3.5%)	7(2.8)	
Secondary smoke				
Yes	24 (5.7)	9 (3.2)	15 (7.6)	0.060
No	395 (94.3)	215 (96.8)	180 (92.4)	

a missing values 8 and 8 for Freedom and Bauleni respectively. **b** missing values 16 and 4 for Freedom and Bauleni respectively. **c** missing values 1 and 3 for Freedom and Bauleni respectively.

Table 3-3: Description of respondents by social economic status stratified by community

Factor	**Total**	**Freedom (Exposed)**	**Bauleni (Control)**	***p-value***
	N=423	***N=225***	***N=198***	
	n (%)	**n (%)**	**n (%)**	
House ownership				
Owned	180 (42.6)	85 (44.2)	95 (53.9)	0.021
Rented	224 (52.9)	124 (49.4	100 (44.8)	
Other	19 (4.5)	16 (6.2%)	3 (1.3)	
How old house Yrs[a]				
1-20	70 (16.9)	33 (16.8)	37 (20.4)	0.080
21-40	23(5.5)	6 (3.9)	17 (9.4)	
Unknown	322 (77.6)	184 (79.3)	138 (70.1)	
House material[b]				
Mud	49 (12.3)	36 (16.5)	13 (6.6)	0.020
Concrete	351 (87.5)	171 (76.5)	180 (90.9)	
Roof material[c]				
Metal	191 (45.9)	55 (24.1)	136 (71.5)	<0.001
Asbestos	225 (54.1)	167 (75.9)	58 (28.5)	
House plastered				
Yes	205 (48.5)	130 (58.8)	75 (38.5)	0.010
No	213 (50.4)	90 (48.0)	123 (123)	
No. of rooms[d]				
1-2	240 (58.4)	123 (50.8)	117 (53.5)	0.530
3+	117 (41.6)	92 (49.2)	79 (46.5)	
No. of windows[e]				
0-3	305 (73.0)	158 (64.6)	147 (68.9	0.420
>=4	113 (27.0)	64 (35.4)	49 (31.1)	
Carpet in house				
Yes	121 (28.6)	58 (25.0)	63 (31.3)	0.260
No	302 (71.4)	167 (75.0)	135 (68.7)	
Kitchen location				
Outside	225 (53.2)	102 (46.5)	123 (64.6)	0.004
inside	198 (46.8)	123 (53.5)	75 (35.4)	
Source energy cook				
Electricity	199 (47.0)	82 (35.3)	117 (59.0)	<0.001
Charcoal	224 (53.0)	143 (64.7)	81 (41.0)	
Source energy light[f]				
Electricity	288 (73.5)	149 (72.3)	139 (73.4)	0.830
Candle	104 (26.5)	51 (27.7)	53 (26.6)	

2 and 6 values missing for Freedom and Bauleni respectively. **[b]** 18 and 5 missing values for Freedom and Bauleni respectively. **[c]** 3 and 4 missing values for Freedom and Bauleni respectively. **[d]** 10 and 2 values missing for Freedom and Bauleni respectively. **[e]** 3 and 2 missing values for Freedom and Bauleni respectively. **[f]** 25 and 6 missing values for Freedom and Bauleni respectively.

Table 3-4: Proportions of respondents reporting the individual and constituent symptoms for irritations of eye, nose and sinus membranes by community

		Freedom	*Bauleni*	
	N=420	*N=223*	*N=197*	*p-value*
	n (%)	**n (%)**	**n (%)**	
Eye irritation				
Yes	*163(38.8)*	126 (56.4)	37 (18.3)	
No	*257 (61.2)*	97 (43.6)	160 (81.6)	<0.001
Swelling				
Yes	*82 (19.5)*	53 (26.1)	29 (13.7)	
No	*338 (80.5)*	*170 (73.95)*	168 (86.5)	0.007
Discharge				
Yes	*66 (15.7)*	49 (20.7)	17 (10.3)	
No	*354 (84.3)*	174 (79.3)	180 (89.7)	0.020
Tearing				
Yes	*122 (29.0)*	87 (42.8)	35 (18.9)	
No	*298 (71.0)*	136 (57.2)	162 (81.1)	<0.001
Any of the symptoms				
Yes	*268 (63.8)*	170 (78.2)	98 (49.9)	
No	*152 (36.2)*	53 (21.8)	99 (50.1)	<0.001
Nose irritation				
Itching				
Yes	83 (19.8)	53 (25.1)	30 (14.6)	
No	337 (80.2)	170 (74.9%)	167 (85.4)	<0.001
Fullness				
Yes	95 (22.6)	56 (25.0)	39 (17.0)	
No	325 (77.4)	167 (75.1)	158 (83.4)	0.012
Nasal discharge				
Yes	62 (14.7)	38 (17.0)	24 (9.8)	
No	358 (85.3)	185 (83.0)	173(90.2)	0.030
Runny nose				
Yes	115 (27.4)	74 (35.2)	41 (19.8)	
No	305 (72.6)	149 (64.8)	156 (80.2)	<0.001
Any of the symptoms				
Yes	206 (49.0)	141 (66.9)	65 (29.4)	
No	214 (51.0)	82 (33.1)	132 (70.6	<0.001
Sinus irritation				
Head pain				
Yes	188 (44.8)	119 (54.6)	69 (38.4)	<0.003
No	232 (55.2)	104 (45.4)	128 (61.6)	
Thick mucus				
Yes	67 (16.0)	40 (21.4)	27 (11.6)	0.002
No	353 (84.0)	183 (78.6)	170 (88.4)	
Post nasal drip				
Yes	72 (17.1)	44 (21.3)	28 (12.8)	0.040
No	348 (82.9)	179 (78.7)	169 (87.2)	
Throat clearing				
Yes	92 (21.9)	55 (26.9)	37 (16.5)	<0.004
No	328 (78.1)	168 (73.1)	160 (83.5)	
Any of the symptoms				
Yes	260 (61.9)	157 (73.7)	103 (53.3)	
No	160 (38.1)	66 (26.3)	94 (46.7)	<0.001

3.4.3. Irritations of Mucous Membranes of Eyes, Nose and Sinus

Generally, the prevalence of constituent symptoms of either eye, nose or sinus membrane irritations were significantly higher in Freedom compared to the control community (Table 3-4). Larger proportions of respondents in Freedom reported “any combination of symptoms” compared to Bauleni; 78.2% *versus* 49.9%, 66.9% *versus* 29.4% and 73.7% *versus* 53.3% for eye, nasal and sinus irritations, respectively (*p* value < 0.001). Itching and tearing, runny nose and fullness; and headaches and clearing were the most common reported symptoms for eye, nasal and sinus irritations, respectively, in the two communities.

3.4.4. Predictors of Mucous Membrane Irritations

Area of residence, time where respondents spent most of the time, location of the cooking area or kitchen and source of energy for cooking were significant predictors of eye irritation in bivariate analyses (Table 3-5). After adjusting for time where respondents spent most of the time, location of the kitchen and source of energy for cooking, respondents in Freedom were 2.50 (95% CI [1.65 - 3.79]) times more likely to have eye irritation than those in the control community. Respondents who spent time around their home were 1.8 times more likely to have eye irritations controlling for other factors. However, when stratified by area of residence there was evidence of effect modification; respondents from Freedom who spent time around home were 2.8 times more likely to experience eye irritations while respondents of Bauleni were only 1.7 times more likely to experience eye irritations.

In bivariate analyses, residence, age, gender, and source of energy for cooking were found as significant predictors for nose irritation. Although result not included in Table 3-5, duration of living in the community showed effect modification; living in Freedom community increased the odds of nose irritation by 1% (OR 1.01, *p*-value = 0.008) while it had no effect for respondent living in Bauleni (OR 1.00, *p*-value = 0.683). In multivariate models only residence, age and gender retained statistical significance. Compared to respondents from the control community, respondents from the exposed community were 4.36 (95% CI [2.96 - 6.55]) times more likely to have nose irritation.

Independent determinants of sinus irritations included area of residence, age, education, and occupational status, source of energy for cooking and presence of floor carpet (Table 3-5). However, only residence, age and occupation retained statistical significance after adjusting for the other predictors. Respondents from the exposed community were 1.94 (95% CI [1.19 - 3.18]) more likely to have sinus irritation compared to those from the control community adjusting for confounders. Duration of living in the exposed community showed no effect on risk of sinus irritations.

3.5. Discussion

The study investigated the prevalence and determinants of mucous membrane irritations among residents of a community residing near a cement factory and a control community in the area of Lusaka, Zambia. Prevalence of all mucous membrane irritations were higher in the exposed compared to the control community and residence in the exposed community was a strongly significant determinant of all types of mucous membrane irritations.

The excessive prevalence of all types of mucous membrane irritations in the exposed community compared to the control could be attributed to increased exposure to chemical and particulate matter irritants in the ambient air. For instance, excessive tearing and itching of the eye; nasal itching and fullness; and head pain and throat clearing are all common manifestations when mucous membranes of the eyes, nose and/or the sinuses are exposed to chemical irritants. Literature shows that irritations of the eyes due to exposure to chemicals and particulate matter often manifest as excessive tearing with or without itching, while swelling or discharge, which were less often reported, is often related to infections of the eyes.[17–19]

Table 3-5: Significant factors associated with outcomes in Bivariate and multi-variate analyses

Site of irritation	**Independent factors**	**Crude ORs**	***(95% CI)***	**p-value**	**Adjusted ORs**	***(95% CI)***	**p-value**
	Community						
Eye irritation	*Bauleni*	**1**	**-**	**-**	1	-	-
	Freedom	**3.60**	**2.56 – 5.28**	**<0.001**	**2.50**^{a}	**1.65 – 3.79**	**<0.001**
	Time spent						
	Away home	**1**	**-**	**-**	**-**	**-**	
	Around home	**2.45**	**1.63 – 3.70**	**<0.001**	**1.78**	**1.12 – 2.82**	**0.017**
	Kitchen Location						
	Outside	**1**	**-**	**-**	**-**	**-**	
	Inside	**1.56**	**1.12 – 2.18**	**0.012**	**1.62**	**1.12 – 2.34**	**0.013**
	Cook energy						
	Electricity	**1**	**-**	**-**	**-**		
	Charcoal	**1.70**	**1.06 – 2.71**	**0.028**	**1.55**	**1.06 – 2.28**	**0.003**
	Community						
Nose irritation	*Bauleni*	**1**	**-**		1	-	-
	Freedom	**4.83**	**3.15 – 7.41**	**<0.001**	**4.36**^{b}	**2.95 – 6.55**	**<0.001**
	Age (years)						
	12 – 24	**1**	**-**	**-**	-	-	-
	26 - 39	**0.99**	**0.64 – 1.51**	**0.964**	0.73	0.46 – 1.13	0.155
	40+	**0.58**	**0.33 – 1.01**	**0.057**	**0.60**	**0.36 – 0.01**	**0.053**
	Gender						
	Female	**1**	**-**	**-**	1	-	-
	Male	**0.41**	**0.23 – 0.78**	**0.006**	**0.47**	**0.25 – 0.85**	**0.017**
	Cook energy						
	Electricity	**1**			-		
	Charcoal	**1.80**	**1.11 – 2.96**	**0.021**	1.37	0.82 – 2.31	0.214
	Community						
Sinus irritation	*Bauleni*	**1**	**-**	**-**	**1**	**-**	**-**

Site of irritation	**Independent factors**	**Crude ORs**	***(95% CI)***	**p-value**	**Adjusted ORs**	***(95% CI)***	**p-value**
	Freedom	**2.45**	**1.57 – 3.83**	**<0.001**	**1.94**[c]	**1.19 – 3.18**	**0.012**
	Age (years)						
	12 – 24	1	-	-	-	-	-
	25 - 39	**0.53**	**0.28 – 1.00**	**0.052**	**0.46**	**0.21 – 0.03**	**0.044**
	40+	0.70	0.34 – 1.43	0.311	0.83	0.36 – 1.9	0.595
	Education						
	None	**1**	**-**	**-**			
	Primary	**2.41**	**0.98 – 5.97**	**0.055**	1.98	0.66 – 5.88	0.202
	Secondary	**1.46**	**0.6 3– 3.37**	**0.350**	1.25	0.36 – 4.26	0.703
	Tertiary	**2.66**	**0.61 – 11.53**	**0.178**	2.54	0.73 – 8.82	0.132
	Occupation						
	Unemployed	**1**					
	Unemployed	**0.56**	**0.35 - 0. 89**	**0.019**	**0.69**	**0.47 -0.99**	**0.048**
	Cook energy						
	Electricity	**1**	**-**	**-**	-		
	Charcoal	**2.13**	**1.22 – 3.71**	**0.011**	1.68	0.88 – 3-22	0.108
	Floor carpet						
	No	**1**	**-**		-	-	
	Yes	**0.55**	**0.35 – 0.87**	**0.013**	0.66	0.38– 1.14	0.129

[a] adjusted for time spent around home, kitchen location and source of energy for cooking. [b] adjusted for age, gender and source of energy for cooking. [c] adjusted for age, education, occupation, source of energy for cooking and presence of floor carpet in the dwelling house.

Merhaj *et al.* demonstrated similar findings when they reported that 97% of the respondents in a community within the vicinity of a cement factory suffered from eye irritations. [20] Additionally, nasal itching and fullness of the nostrils are often associated with allergic responses to specific, non-infectious particles such as plant pollens, dust mites, animal air, industrial chemicals and medicines, while nasal discharge is often due to infectious or foreign lodgement in the nasal cavity. [18,19] Furthermore, head pain and throat clearing have been demonstrated to be common manifestations of sinus irritation.[21,22] Residence in the exposed community was a common and most significant determinant of all the types of mucous membranes irritations in this study; increased the odds of suffering from irritation by 2.4, 3.6 and 4.8 times for sinus, eye and nasal irritations respectively. The increased risk is associated with exposure to various emissions during cement production among the residents of Freedom compound. Although direct measurements of emissions in Freedom community were not performed, residence in this community was considered an adequate proxy measure of exposure as other studies have demonstrated high levels of PM, NOx and CO in ambient air in communities near cement factories.[1,2]

The likelihood of eye irritations was affected by various other factors. Respondents that spent more time around the home had higher odds of eye irritations after controlling for area of residence and other confounders. Studies have shown that human health risks relate to specific pollutants, their concentration and to exposure as a function of time spent in the contaminated environment.[23] In this study, stratifying the analysis by area of residence showed slight effect modification as respondents from the exposed, compared to the control community, were more likely to experience eye irritations. This finding, suggests higher risks of eye irritation due to higher contamination levels in the environments of the exposed community. Several studies have shown excess risk for eye irritation among exposed individuals, either in community or factory settings. [4,13] However, it is also possible that others factors of the domestic micro-environment that were not considered in this study contributed to these findings.

Using charcoal as a source of energy for cooking was associated with 55% increase in eye irritations for the exposed group. The health effects associated with exposure to emissions of unclean energy fuels have been established. Studies have consistently demonstrated eye irritations ranging from reddening, itching, watering and discomfort to be the most common response to exposure to emissions from combustion of unclean energy such as charcoal.[23,24] Contrary to literature, using "dirty fuels" as source of energy for lighting did not attain statistical significance in the current study. This could in part, be due to the large number of respondents in both communities using electricity for lighting. Related to energy source, respondents whose kitchen location was located inside the main house were more likely to experience eye irritation. Cooking within the same area used for sleeping exposes the eyes to excessive emissions from the cooking process emissions such as the ultrafine particles.[25] Medical literature shows that the eye is a sensitive organ that easily gets irritated when subjected to any of irritants.[17]

Gender was the only factor that was associated with nasal irritation in multivariable model other than community. Females, as revealed in other studies, tend to be more prone to nasal irritation.[26,27] These differences could be due to cooking on open fires, exposure to chemicals found in household cleaning agents and other factors that were not measured in the study. Community, age, education, occupation, source of energy for cooking and presence of carpet were independently associated with sinus irritation in bivariate analyses, but only residence, age and occupation retained statistical significance after adjusting for other predictors. Contrary to what has been found in studies in industrialized communities,[28] floor carpet was not a risk factor in this study. This could partly be explained by respondents' behavior; residents in the studied communities spend most of their time outside their homes such that the effect of floor carpet could not be seen. Additionally, the proportion of respondents owning a carpet was small and could not have given statistical power to detect a small difference.

Weaknesses of this study should be highlighted in interpreting the results. Although the study provides evidence of differences in the prevalence of mucous membrane irritations in the communities, it cannot explain the cause of the difference. This is mostly due to the inherent weakness of cross sectional epidemiological study designs in providing evidence of causation or associations. The study did not measure PM, NOx, SOx and any other possible pollutant in the ambient air; neither did it ascertain the source apportionment of these substances. It is therefore difficult to state, with certainty, that the observed differences in prevalence of irritations in the two communities were due to the presence of emissions from the cement plant. It is possible that there were other sources of pollution in the exposed community that the study did not account for. Furthermore, information regarding allergic tendencies, which are possible causes of symptoms of mucous membrane irritation, was not collected thus limiting interpretations to a certain extent.

Additionally, symptoms were self-reported and not verified with hospital records. Self-reporting could have introduced recall bias especially that has been much media publicity about the adverse effects the cement plant has had on the environment and people in the vicinity of the plant.[29] Therefore, respondents from the exposed community could have exaggerated the occurrence of respiratory problems. There was a likelihood of misclassification of employment status and exposure as most respondents could not accurately describe their occupational tasks. Finally, the results may not be generalisable to both sexes in the study since the proportion of female respondents was far more than would be expected in the general population.[30]

3.6. Conclusion

Irritations to mucous membrane of the eyes, nose and sinuses are common but prevalence is increased several fold in the presence of air pollution. This study shows that residence within the vicinity of a cement production plant increase the odds of experiencing these irritations. Cohort panel studies to investigate mucous membrane irritations and respiratory symptoms coupled with field characterization of exposure to air pollutants are needed to assess causality.

3.7. Ethical consideration

The study protocol was reviewed and approved by a local research ethics committee in Zambia-ERES Converge IRB (00005948) and from IRBs of the Universities of Pretoria (0000 2535 IORG 0001662) and Michigan (00070842).

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3.9. Author contributions

Emmy Nkhama, Kuku Voyi, Seter Siziya and J. Timothy Dvonch conceived and designed the study; Emmy Nkhama, Micky Ndhlovu, Kuku Voyi acquired the data. Emmy Nkhama, Micky Ndhlovu and Seter Siziya analysed and interpreted the data; Emmy Nkhama and Micky Ndhlovu drafted the article; Emmy Nkhama, Micky Ndhlovu, J. Timothy Dvonch, Seter Siziya and Kuku Voyi critically revised the intellectual content of the article.

3.10. Conflict of interest

The authors declared no conflict of interest.

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3.12. Supplementary file: selection of study participants

Study participants were selected using multi-stage random sampling approach. The first tier of sampling frame was obtained by dividing each of the two communities into clusters of households using the latest Google Earth maps of the two communities (Figure S1 and Figure S2).

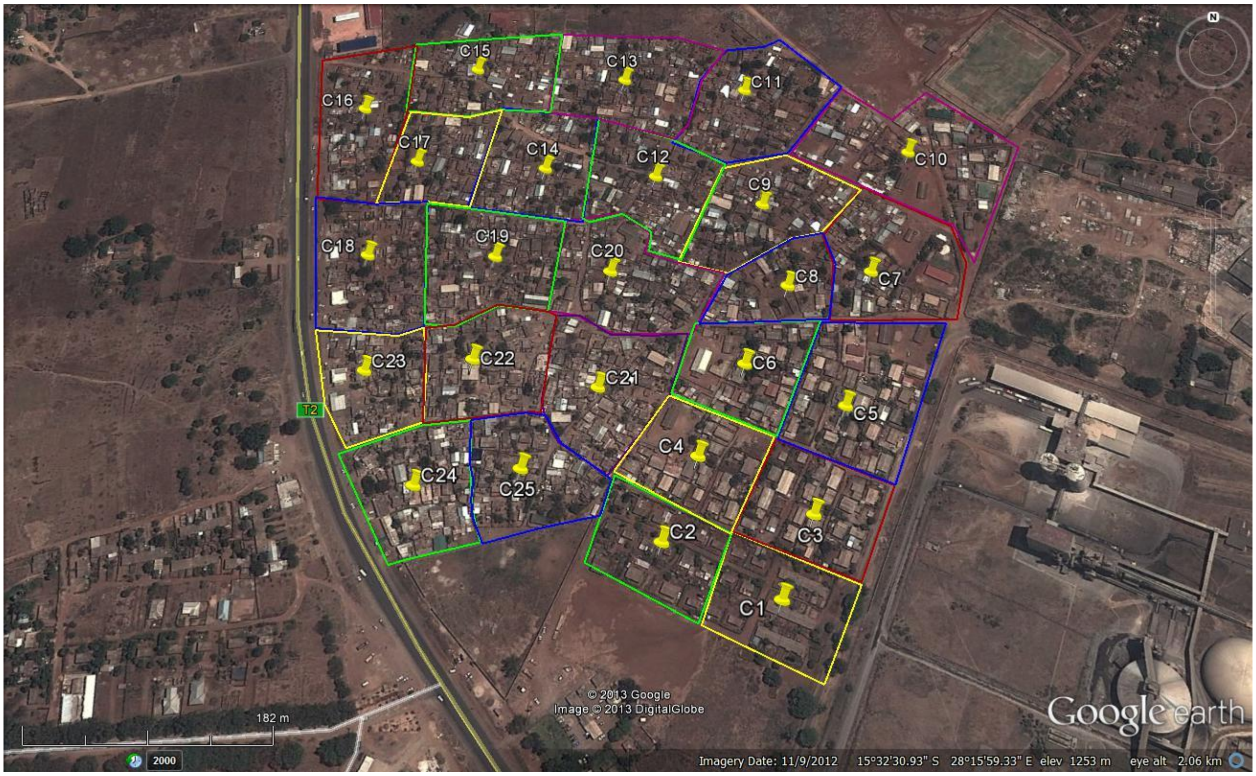

Figure 3-2 S: **Freedom compound showing geographic clusters of household**

The cluster size was determined depending on geophysical arrangement of the households, e.g., division by main roads, markets, schools or other geographical features like streams or river. As there was no pre-enumeration of households in both communities, attempts at getting equal number of households per cluster was ensured by making clusters of roughly equal geographical dimensions. This resulted in 25 and 42 clusters in Freedom and Bauleni.

This was followed by identification and physical mapping of the clusters using GPS coding. The delineated clusters for each community were then numbered sequentially and entered into Microsoft Excel to form the first tier of sampling frame (one for each community). A subset of 10 clusters from each sampling frame was randomly chosen using random number generator in Excel. Excel was set to generate random number between 0 and 1using the “RAND ()” function. The random numbers were then sorted from smallest to largest and the first ten numbers corresponding to 10 clusters were selected.[1] This ensured that the clusters were selected at random and representative of the community.

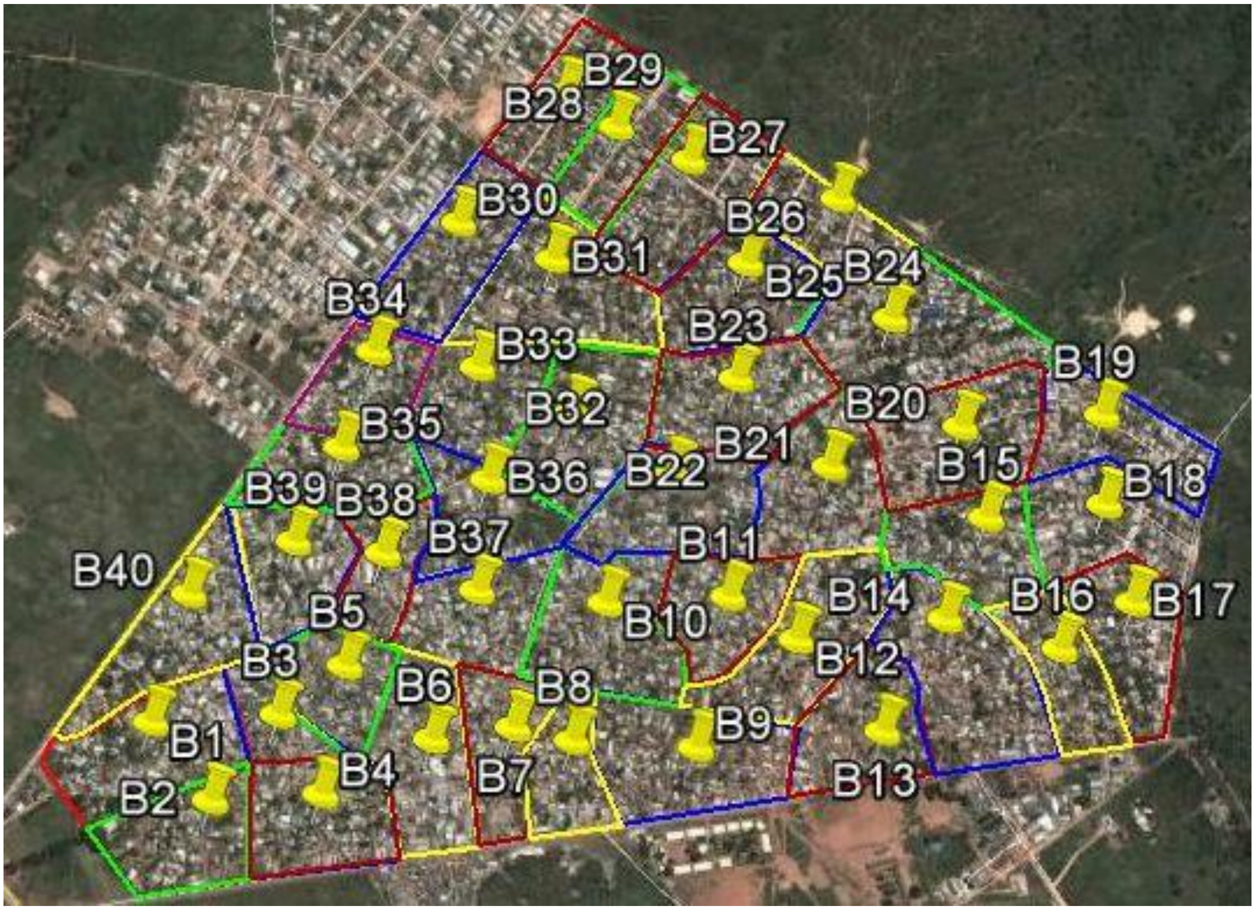

Figure S- 3-3 : Map of Bauleni compound showing geographical clusters of households

The second tier of sampling frame comprised all households in the selected clusters. Each household in each selected cluster was numbered using GPS geocodes (and house numbers where possible). Separate sampling frames for each cluster was entered in Microsoft Excel and a random subsample of 22 households was obtained following the method described in the previous section. A total of 220 households were thus selected for each community. This was done to ensure the included households were chosen at random and were representative of the community. The chosen households were then visited, aided by the geocodes and house numbers, to determine household eligibility.

Consent was sought from the head of each household to participate in the study. Individuals who met the inclusion criteria and gave consent were numbered sequentially on small pieces of paper, which were put in a bag and one selected by lottery. This was followed by administration of a questionnaire. Where there was only one individual meeting the inclusion criteria in the household, that individual was chosen for inclusion in the study.

In the event that the head of household declined to participate, the entire house then became ineligible, the next available household was chosen randomly. This was done by numbering clockwise the immediate surrounding households on pieces of paper. Then the pieces of paper bearing the numbers were put in a box, shaken and one paper drawn at random. The chosen household replaced the one that did not meet the inclusion criteria in the initial sampling. If the replacement household did not meet the inclusion criteria, the procedure was repeated. In the repeat sampling all households that did not meet the inclusion criteria were excluded.

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1. How to create a random sample in excel Available from http://www.wikihow.com/create-a-random -sample-in-excel. Accessed 12.11.2012.

Chapter 4 : Prevalence of self-reported pulmonary symptoms in a community residing near a cement factory in Chilanga, Zambia: a Cross Sectional Study[2]

4.1. Abstract

Background: There is a paucity of information on whether exposure to emissions from a cement factory has pulmonary ill effects on the residents of communities residing close to these factories. We aimed at determining the prevalence of pulmonary symptoms in a community residing near a cement factory in comparison to a control community. ***Methods:*** Using residence in a community bordering a cement factory, as proxy measure of exposure to cement dust emissions, we conducted a cross sectional study in Freedom Compound, Chilanga, Zambia. Prevalence of self-reported pulmonary symptoms was captured using a modified American Thoracic Society questionnaire administered to respondents aged 15–59 years. The prevalence of pulmonary symptoms in this community was then compared to that of a control community, Bauleni, located 18 km from the cement plant. ***Results:*** The prevalence of all pulmonary symptoms was higher in Freedom compared to Bauleni: cough 58.7% vs. 17.4%; increased phlegm, 55.9% vs. 13.9%; wheeze, 45.0% vs. 30.6%; chronic bronchitis 2.8% vs. 1.0%; pneumonia 20.1% vs. 3.5%; asthma 9.7% vs. 1.1% and common cold 46.5% vs. 8.2%. Residents of Freedom were 5.64 (95% [CI 3.63, 8.67]); 3.30 (95% CI [2.04, 5.34]), 1.60 (95% CI [1.01, 2.54]); 5.76 (95% CI [2.00, 16.07]); and 5.22 (95% CI [1.75, 15.47]) times more likely to suffer from cough, phlegm, wheeze, asthma and pneumonia, respectively compared to residents in Bauleni. ***Conclusion:*** The study shows that the prevalence of pulmonary symptoms was higher in residents in a community near a cement factory compared to the control. Furthermore, residents of the exposed community were several times more likely to report pulmonary adverse health effect compared to the control. Characterization of air pollutant levels and source

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[2] This chapter was published in the journal of pollution effects control: Nkhama E, Ndhlovu M, Dvonch JT, Siziya S, Voyi K. Prevalence of self-reported pulmonary symptoms in a community residing near a cement factory in Chilanga, Zambia: a cross sectional study. J Pollut Eff Cont. 2015;146(3):1-9.

apportionment studies in the exposed community are required to determine whether the observed excessive respiratory symptoms are due to emissions from the cement plant.

Key words: Cement production; emissions; air pollution; respiratory symptoms; community, Zambia

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4.2. Background

The cement industry is a potential anthropogenic source of ambient air pollution. Most of the pollution emanates from emissions in the production processes; drilling, blasting, excavation, loading, transportation, crushing, milling and packing. These emissions constitute mainly particulate matter (PM) of aerodynamic diameter size ranging from PM1.0 to PM10 which are known to have various adverse health effects on humans.[1,2] Communities near cement factories are thus at increased risk of exposure to these emissions. The respiratory system and the skin, being the most exposed body surfaces, are the most affected and repeated exposures could potentially lead to breakdown of defence mechanisms especially of the respiratory system. Although studies have shown contrasting findings, some of them[3-6] both in developing and developed countries have demonstrated a relationship between exposure to cement dust pollution and respiratory symptoms such as cough, wheeze, increased phlegm production, bronchitis and asthma. Most of the existing evidence of the deleterious effects of exposure to cement dust on human health is based on studies conducted in occupational setting[3-7] while very few have investigated the effect of cement dust exposure on the respiratory health of communities residing near cement factories.[1,8,9]

The demand for improved living conditions such as improved built environments, dams and bridges has resulted in increased cement production with implicit increased environmental pollution and deleterious health effects on human populations. Globally, the production of cement increased from 3,310 million metric in 2005 to 4,180 million metric tonnes in 2014.[10,11] Similarly, Zambia has experienced a steady increase in the production of cement in the last four years; from 980 000 tons in 2010 to 2.2 million metric tons in 2014.[12] Of this amount 61% is produced by Lafarge Chilanga cement plant which is located in the study area.[12] Chilanga district similar to the countrywide health reports show that respiratory illnesses are the second commonest cause of consultations with a health worker.[13,14] However, the incidence in Chilanga is above the national average. For instance, the national average for pneumonia in children aged less than five years (Under 5s) was 81 per 1000 while Chilanga reported 136/1000 in 2013.[13]

Although respiratory illnesses are often due to pathogens such as bacteria and viruses, the occurrence of such illnesses can be exacerbated by exposure to dust.[15] The observed difference in the incidence of respiratory illnesses in Chilanga could potentially be associated with ambient dust pollution in Chilanga district. The objective of this study was to determine the prevalence of self-reported pulmonary symptoms in Freedom Compound, a community residing near a cement factory in Chilanga, and compare to a control community.

4.3. Material and methods

4.3.1. Study design

This was a cross sectional study conducted in two communities; the exposed community (Freedom compound) and a control (Bauleni). The study was conducted in November and December 2013; a period characterized by wet and warm climate.

4.3.2. Study area

Freedom compound is situated in one of the most densely populated areas in Chilanga. It is located on the leeward side at the edge and to the north-west of the cement factory. It is bounded on the western side by a major intercity tarred road. Access gravel roads coming off this major road cross the breadth and width of the settlement. Traffic on the major road includes heavy trucks, buses, vans and cars. Heavy trucks rarely traverse the inner parts of the settlement. Wind across the settlement is predominantly south-westerly resulting in most traffic emissions from the main road being blown away from the settlement. The control community, Bauleni, is located about 18 km from the cement factory outside the windward cement dispersion area. It is bounded by major tarred roads on three sides and has minor gravel standard roads in the inside of the settlement. Traffic on the major roads and minor roads is similar to that seen in Chilanga except there are fewer heavy trucks moving on the main roads. The major economic activity is informal trade in furniture, second-hand clothes and vegetables. There are no factories within or near to the Bauleni settlement.

4.3.3. Sample size

The prevalence of symptoms of interest in the two communities was unknown. However, evidence from studies from other parts of Africa suggest that the prevalence of respiratory symptoms is around 30% for cement factory workers; while the prevalence in the control groups were found to be about 10%.[3,16] To calculate our sample size for this study, the prevalence of respiratory symptoms for the exposed and the control communities was assumed to be equal to that found in these studies. To detect a 20% difference at 95% confidence level and power of 80% we required a minimum sample size of 170 participants per community after adjusting for design effect of two (DE=2) and a non-response of 30%. In this study, we targeted to recruit 220 participants from each community.

4.3.4. Sampling of participants

A multi-stage random sampling method was used to select participants. The study communities were each divided into geographical clusters each containing a number of households. The households in each cluster were then enumerated and geocoded. Thus, the first tier sampling frame consisted of 25 and 42 clusters of household from Freedom and Bauleni, respectively. A subset of 10 clusters was randomly selected from each sampling frame using random number generator in excel. The second tier sampling comprised all households in the selected clusters. Twenty households were selected from each cluster. Lastly one individual from each selected household was randomly chosen for enrolment into the study. Inclusion criteria included the following: individuals aged 15 – 59 years and respondents must have resided in either of the study areas for at least 4 months prior to the survey. Participants employed in cement factory, construction industry, quarrying and mining were excluded. A detailed description of participant recruitment is given elsewhere.[17]

4.3.5. Data collection

Data were collected using a modified American Thoracic Society (ATS) questionnaire which was administered to the selected participants by trained community health workers drawn from the health facilities serving the respective study communities. The data collected included participants' demographic and socioeconomic characteristics, the occurrence of respiratory symptoms and exposure to tobacco smoke.

4.3.6. Variables and measurements

i. Exposure variable: Residence in Freedom community was used as proxy measure of exposure to emissions from cement factory.
ii. Outcome variable: The primary outcome was prevalence of pulmonary symptoms measured as cough, phlegm, wheeze, pneumonia, asthma and chronic bronchitis (Table 4-1).

Table 4-4-1: Definition of outcome variable (pulmonary symptoms)

Cough	Phlegm	Wheeze
Cough on first going out-of doors. Excluding clearing of throat	Bring up phlegm when going out of doors but not with mucoid discharge	Whistling sound on inspiration at least occasionally
Cough at all on getting up, or first thing in the morning	Bring up phlegm on getting up, or first thing in the morning	Feel out of breath due to attack of wheezing
Cough at all, or during the day OR at night	Bring up phlegm during the rest of day or at night	Required medication for wheezing attack
Cough as much as 4 times to 6 times a day, 4 or more days out of the week	Bringing up phlegm at least 2 times a day, 4 or more days out of the week	
*Any of the above	*Any of the above	*Any of the above

*Composite dichotomous variable if any of the respective symptoms was present. This was used logistic regression

Pneumonia, chronic bronchitis, asthma and phlegm were all self-reported and not confirmed with clinical records.

Smoking status was categorized into current, ex-smoker and secondary smoker. “Ex-smoker” was defined as cessation of smoking at least 12 months prior to the survey. Current smoker was defined as a person who smoked at least one cigarette in the last 11 months prior to the day of the survey. For all categories, it was established whether the cigarette was manufactured or locally rolled tobacco (or both), how many cigarettes were smoked per day, and for how long. “Secondary smoking” was if a participant was exposed to any household member that smoked in the house (Table 4-1).

4.3.7. Data management and statistical analysis

Data were double entered independently, by two trained assistants, into a customised Microsoft Access database, with inbuilt validation capability. The two sets were compared, using Compare It program (Grig Software 2009, Vancouver, Canada) to identify discrepancies in entries. Any discrepancies identified were checked against the paper based data. Cleaning and coding was done in Microsoft Excel.

Analysis was performed using STATA version 12 (Stata Corp L 2011, College Station, Texas, USA). The unit of analysis was the individual respondent. To account for multistage cluster sampling and obtain correct estimates, STATA was set to *svy mode*, setting the primary sampling unit as the cluster of households.

Descriptive analysis within and between the exposed and control communities are reported; proportions, median and inter-quartile range (IQR) and 95% confidence intervals (CI). The Pearson’s Chi-square test was used to compare differences in proportions of respiratory symptoms/conditions between the communities, while the Wilcoxon rank sum test was used to compare differences in the median. All statistical tests were two-sided and a P-value < 0.05 was considered as statistically significant while P-value ≥ 0.05 and ≤ 0.1 were considered marginally statistically significant.

To examine associations between area of residence and each of the outcomes, bivariate and multivariable logistic regression was used to obtain crude and adjusted odds ratios (ORs), *P*-values, and their respective 95% CI. The following factors were assessed for possible confounding effect: age, gender, marital status, education, occupation, current smoking status (and number of pack years smoked), source of energy for cooking and lighting, whether cooking area was located within the main house or sleeping area; and ventilation of the dwelling house and whether respondent spent time home or away from home. For categorical factors, dummy variables were used in the model selection procedure. Furthermore, statistical interactions between community and other factors were investigated.

A model was built for each outcome. To obtain adjusted ORs for the "effect of residence" on the outcomes, all significant determinants (i.e, factors with a p value <0.05 in the Bivariate analysis) where placed in an initial regression model. This was followed by the addition, in stepwise manner, of factors that were marginally significant in bivariate analyses. Each time a new factor was added to the model, the ORs of the factors already in the model were checked. If the addition of a new factor changed the OR of any already included variable by more than 10%, the additional variable was retained in the model otherwise the variable was removed and another variable was added. Area of residence was considered the main explanatory variable and therefore was included in all models for each outcome of interest regardless of whether it was statistically significant in bivariate analyses

4.4. Results

4.4.1. Description of respondents' demographic and socioeconomic characteristics

The majority of the respondents in Bauleni were younger than 25 years (40%) compared to Freedom where the majority of respondents were between 25 and 39 years old (46%) (Table 4-2). Furthermore, there were more female respondents in Freedom than in Bauleni (84.1 vs. 73.2). The median number of years lived and the distribution of marital status were not significantly different between the communities. Although more respondents in freedom than Bauleni had attained primary and tertiary education, a higher proportion in Freedom was unemployed compared to Bauleni (p value=0.001).

Smoking habits in the two communities was not different. Tobacco use was rarely reported. Only 21 respondents in the two communities reported having ever smoked: 17 and 6 were current smokers and ex-smokers respectively. The pack years for those who ever smoked ranged from 5 to 35 years. There was no significant difference in environmental secondary smoking between the two communities.

Table 4-4-2: Description of study participants by demographic characteristics stratified by community

Factor	**Total**	**Freedom**	**Bauleni**	
		(Exposed)	**(Control)**	
	N=423 **n (%)**	**N=225** **n (%)**	**N=198** **n (%)**	***p-value***
Age in years:				
<25	158 (37.3)	77 (33.5)	81 (39.5)	
25 – 39	166 (37.0)	101 (46.2)	65 (31.7)	0.005
40+	99 (25.7)	47 (20.4)	52 (28.8)	
Gender				
Female	333 (78.2)	187 (84.1)	146 (73.2)	0.021
Male	90 (22.8)	38 (15.9)	52 (26.8)	
Marital status				
Single	138 (34.2)	71 (36.6)	67 (32.8)	
Married	245 (57.5)	135 (57.9)	110 (57.2)	0.099
Widow/divorced	40 (8.3)	19 (5.5)	21 (10.0)	
Years lived in community[a]		10 (4 – 22)	5 (14 - 23)	0.080
median (IQR)				
Gender				
Female	333 (77.2)	187 (84.1)	146 (73.2)	0.021
Male	90 (22.8)	38 (15.9)	52 (26.8)	
Marital status				
Single	138 (34.2)	71 (36.6)	67 (32.8)	
Married	245 (57.5)	135 (57.9)	110 (57.2)	0.099
Widow/divorced	40 (8.3)	19 (5.5)	21 (10.0)	
Education				
None	28 (6.5)	4 (1.1)	28 (6.5)	
Primary	241 (54.9)	147 (63.9)	94 (49.7)	
Secondary	145 (36.8)	66 (30.8)	79 (40.3)	<0.001
Tertiary	9 (1.8)	8 (4.2)	1 (0.4)	
Employment status[b]				
Unemployment	270 (66.4)	153 (75.5)	117 (61.6)	0.003
Employed	133 (33.6)	56 (24.5)	77 (38.4)	
Smoking status[c]				
Never smoker	397 (95.8)	209 (94.5)	188 (96.6)	
Ex smoker	6 (1.2)	5 (2.0)	1 (0.6)	0.381
Current	17 (3.0)	10 (3.5)	6(2.8)	

Secondary smoke				
No	399 (94.0)	216 (96.9)	183 (92.4)	
Yes	24 (6.0)	9 (3.1)	15 (7.6)	0.057

[a] missing values 8 and 8 for Freedom and Bauleni respectively
[b] missing values 16 and 4 for Freedom and Bauleni respectively
[c] missing values 1 and 3 for Freedom and Bauleni respectively

4.4.2. Socio economic characteristics of the communities

A higher proportion of respondents in Bauleni (53.9%) than in Freedom (44.4%) owned the houses they inhabited. A significantly higher proportion of houses in Bauleni than in Freedom were made of concrete material and roofed with metal sheets (p=0.020) (Table 4-3). However, Freedom had a higher proportional of houses that were plastered (58.8%), compared to Bauleni (38.8%). Most houses in both communities had one or two rooms and one to three windows per structure with no significant difference.

The major source of energy for lighting in both communities was electricity. However, the source of energy for cooking was different; charcoal was commonly used in Freedom (64.7%) than in Bauleni (%). Additionally, a significantly higher proportion of households in Freedom than in Bauleni had cooking areas located within the dwelling house.

4.4.3. Prevalence of respiratory symptoms

Generally, the prevalence of respiratory symptoms was higher in Freedom than in Bauleni (Table 4-4). Proportions of participants reporting cough, regardless of the time of the day, was higher in Freedom than in Bauleni: “cough morning” (37.6 vs. 23.5%, p value=0.003); “cough night” (48.1 vs. 14.6, p value <0.001); and “increased cough with phlegm” (55.9 vs. 13.9%; p value <0.001). Similarly, proportions of participants reporting phlegm production were significantly higher in Freedom compared to Bauleni (37.9 vs. 19.1, p value=0.003).

A higher proportion of respondents from Freedom reported suffering from wheeze compared to the control community (45.0 vs. 30.6%, p value=0.002) and a similarly higher proportion required medication for the wheeze in the exposed than in the control community (84.4 vs. 31.3 p value<0001).

While there was no significant difference in reported proportions of chronic bronchitis between the two communities, the prevalence of reported pneumonia, asthma, and the common cold were significantly different between the sites. About 20% of respondents from Freedom reported suffering from pneumonia compared to 3.5% from Bauleni (p value<0.001). Among those who reported suffering from pneumonia, on average 37% and 17.3% from Freedom and Bauleni respectively, knew the age of first attack. About ten times more respondents from Freedom reported having asthma compared to Bauleni (p value<0.001). Furthermore, a much higher proportion of respondents from Freedom (46.5%) reported suffering from common cold compared to 8.2% from Bauleni (p value<0.001).

Table 4-4-3: Description by social status stratified by community

Characteristics	Total N=423 n (%)	Freedom N=225 n (%)	Bauleni control) N=198 n (%)	*p-value*
House ownership				
Owned	180 (46.5)	85 (44.4)	95 (53.9)	
Rented	224 (50.4)	124 (49.4)	100 (44.8)	0.021
Other	19 (3.1)	16 (6.2)	3 (1.3)	
How old house (Years)[a]				
1-20	70 (19.1)	33 (16.9)	37 (20.4)	
21-40	23(7.4)	6 (3.9)	17 (9.5)	0.080
Unknown	322 (73.5)	184 (79.3)	138 (70.1)	
House material[b]				
Mud	49 (12.3)	36 (16.5)	13 (6.6)	0.020
Concrete	351 (87.5)	171 (76.5)	180 (90.9)	
Roof material[c]				
Metal	191 (45.9)	55 (24.1)	136 (71.5)	<0.001
Asbestos	225 (54.1)	167 (75.9)	58 (28.5)	
House plastered				
Yes	205 (48.5)	130 (58.8)	75 (38.5)	0.010
No	213 (50.4)	90 (48.0)	123 (61.5)	
No. of rooms[d]				
1-2	240 (58.4)	123 (50.8)	117 (53.5)	0.530
3+	117 (41.6)	92 (49.2)	79 (46.5)	
No. of windows				
None	25 (5.9)	10 (4.4)	15 (6.8)	
1-3	280 (60.7)	148 (58.8)	132 (61.8)	0.310
4+	118 (33.4)	67 (36.8)	51(31.4)	
Carpet in house				

No	228 (55.9)	103 (44.0)	91 (44.2)	0.002
Yes	194 (44.1)	121 (56.0)	107 (55.8)	
Kitchen location				
Outside	225 (58.0)	102 (46.5)	123 (64.6)	0.004
Inside	198 (42.0)	123 (53.5)	75 (35.4)	
Source energy cook				
Electricity	199 (50.4)	82 (35.3)	117 (59.0)	0.001
Charcoal	224 (49.6)	143 (64.7)	81 (41.0)	
Source energy light[f]				
Electricity	288 (73.1)	149 (72.3)	139 (73.4)	0.834
Candle	104 (26.9)	51 (27.7)	53 (26.6)	

[a] 2 and 6 values missing for Freedom and Bauleni respectively
[b] 18 and 5 missing values for Freedom and Bauleni respectively
[c] 3 and 4 missing values for Freedom and Bauleni respectively
[d] 10 and 2 values missing for Freedom and Bauleni respectively
[e] 3 and 2 missing values for Freedom and Bauleni respectively
[f] 25 and 6 missing values for Freedom and Bauleni respectively

Table 4-4-4: Prevalence of respiratory symptoms

		Community		
	Total N=423	**Freedom** N=225 n=%	**Bauleni** N=198 N=%	*p-value*
Cough[a]				
Cough morning	127 (28.7)	81 (37.6)	46 (23.5)	*0.003*
Cough night	133 (26.8)	108 (48.1)	25 (14.6)	*<0.001*
Increased cough with phlegm	135 (27.8)	112 (55.9)	23 (13.9)	*<0.001*
Any cough	164 (32.4)	133 (58.7)	31 (17.4)	*<0.001*
Phlegm[b]				
Increased phlegm	135 (27.8)	112 (55.9)	23 (13.9)	*<0.001*
Phlegm from chest	96 (20.4)	77 (31.1)	19 (12.3)	*<0.001*
Phlegm morning	92 (22.0)	60 (28.2)	32 (18.5)	*<0.023*
Phlegm night	88 (19.1)	69 (31.1)	19 (12.3)	*<0.001*
Any phlegm	116 (25.9)	83 (37.9)	33 (19.1)	*0.003*
Wheeze[d]				
Wheeze	157 (35.9)	94 (45.0)	63 (30.6)	*0.002*
Wheeze requiring medication[e]	101 (55.9)	77 (84.4)	24 (31.4)	*<0.001*
Chronic bronchitis[f]				
Reported	9 (1.5)	7 (2.3)	2 (0.8)	*0.090*
*Confirmed**	6 (57.2)	6 (85.5)	0 (0)	*0.032*
Age (yrs) at 1st attack median (Q_1, Q_3)	14 (5 - 20)	14 (3 - 20)	17 (13 – 21)	*0.378*
Pneumonia				
Reported	55 (9.5)	48 (20.1)	7 (3.5)	*<0.001*
*Confirmed**	24 (32.7)	22 (37.2)	2 (17.2)	*0.339*

Age (yrs) at 1st attack: median (Q_1, Q_3*)*	17 (7.5 -20)	20 (7 - 20)	20 (20)	*0.239*
Asthma				
Reported	27 (4.3)	24 (9.7)	3 (1.1)	*<0.001*
Confirmed	22 (84.5)	19 (67.7)	3 (16.8)	*0.204*
Age at 1st attack median (Q_1, Q_3*)*	18 (10 - 20)	16.5 (10 - 20)	20 (5 - 20)	0.761
Common cold[f] (Yes)	124 (22.2)	105 (46.5)	19 (8.2)	*<0.001*

*Diagnosis confirmed by health worker

[a] one missing value from Freedom

[b] 2 missing values; none from Bauleni and 2 from Freedom

[c] 4 missing values for Bauleni and 1 missing values for Freedom

[d] 2 missing values for Bauleni and 1 missing values for Freedom

[e] denominator only those that reported wheeze

[f] 1 missing value for Bauleni

4.4.4. Predictors of respiratory symptoms

Details of all Bivariate and multivariate analyses are shown in supplementary Table (S1). In bivariate analysis, residence, age, marital status, education, occupation, smoking status, floor carpet and type of energy used for cooking were associated with cough (Table 4-5). However, only residence and marital status retained significance in the multi variable analysis. The ORs for residence reduces from 6.78 (95% CI [4.79, 9.59]) to 5.64 (95% CI [3.63, 8.67]) after adjusting for confounders.

Residence, marital status, education, occupation, smoking status, presence of floor carpet and type of energy used for cooking were significant predictors of phlegm production in bivariate analysis. However, in multivariate analysis only residence, smoking status and presence of floor carpet were statistically significant; and the OR of residence reduced from 4 .06 (95% CI [2.53, 6.51]) to 3.30 (95% CI [2.04, 5.34)) after adjusting for potential confounders.

Independent determinants of wheeze included residence, age, occupation, smoking status and where the respondents spent most of the time. However, in multivariate analysis only residence retained significance. Respondents from Freedom community were 1.60 (95% CI [1.01, 2.54)) times more likely to report episodes of wheezing compared to those from Bauleni community after adjusting for other predictors. Residence was not significantly associated with chronic bronchitis (p=0.110). However, residence was strongly associated with asthma; respondents from

Freedom were 5.76 (95% CI [2.00,16.07]) times more likely to report asthma compared to those from Bauleni, after controlling for other factors.

Residence, education, occupation, time where respondents spent most of the time, type of energy used for cooking and location of the kitchen were independent predictors of pneumonia. However, the ORs for residence, though remaining significant, reduced from 7.03 (95% CI [2.43, 20.34) to 4.38 (95% CI [1.28, 14.95) after adjusting for confounders.

Table 4-4-5: Significant factors associated with outcomes in Bivariate and Multivariate analyses

Symptom/ Condition	**Independent factors**	**Crude ORs**	***(95% CI)***	**p-value**	**Adjusted ORs**	***(95% CI)***	**p-value**
Cough [a]	Community						
	Bauleni	1			1		
	Freedom	6.78	4.79–9.59	<0.001	**5.64**	**3.63 – 8.67**	**<0.001**
	Marital status						
	Single	1			1		
	Married	0.60	0.36– 1.01	0.054	0.63	0.32 – 1.27	0.186
	Widowed/divorced	0.20	0.94– 0.44	<0.001	**0.21**	**0.07 – 0.66**	**0.010**
	Energy for cooking						
	Electricity	1			1		
	Charcoal	2.09	1.41 - 3.12	0.001	1.34	0.82 – 2.19	0.223
Phlegm [b]	Community						
	Bauleni	1			1		
	Freedom	4.06	2.53 - 6.51	<0.001	**3.30**	**2.04 – 5.34**	**<0.001**
	Smoke status						
	Never	1			**1**		
	Ex-smoker	11.78	3.05– 46.06	0.001	**11.23**	**1.52 – 68.18**	**0.021**
	Current smoker	0.62	0.18 – 2.18	0.441	0.45	0.13 – 1.57	0.197
	Carpet						
	No	1			**1**		
	Yes	0.37	0.21 – 0.65	0.002	**0.38**	**0.21 – 0.69**	**0.003**
	Cook energy						
	Electricity	1			1		
	Charcoal	1.60	0.93 – 2.74	0.08	1.01	0.57 – 1.79	0.962
Wheezing [c]	Community						
	Bauleni	1			**1**		
	Freedom	1.86	1.28 – 2.68	0.002	**1.60**	**1.01 – 2.54**	**0.045**

	Age						
	<25	1			**1**		
	25 -39	1.23	0.70 -2.16	0.460	1.13	0.63 – 2.01	0.661
	40+	0.47	0.24 – 0.91	0.027	**0.45**	**0.25 – 0.78**	**0.008**
	Smoke status						
	Never	1			1		
	Ex-smoker	1.58	0.54 – 4.56	0.380	2.40	0.70 – 8.24	0.152
	Current smoker	4.49	1.00- 20.17	0.050	4.94	0.76 – 32.16	0.090
Chronic [d] bronchitis	Community						
	Bauleni	1			1		
	Freedom	3.60	0.73– 17.78	0.110	3.45	0.49 – 24.36	0.198
	Marital status						
	Single	1			**1**		
	Married	4.12	0.95– 17.85	0.057	**4.02**	**1.32 – 12.24**	**0.017**
	Widowed/divorced	2.07	1.48 – 2.8	<0.001	**2.45**	**1.27 – 4.74**	**0.010**
Asthma[e]	Community						
	Bauleni	**1**			**1**		
	Freedom	**9.42**	**3.30 – 26.9**	**<0.001**	**5.67**	**2.00 – 16.07**	**0.003**
	Gender						
	Male	**1**			**1**		
	Female	**0.27**	**0.09 – 0.81**	**0.022**	**0.35**	**0.13 – 0.96**	**0.043**
	Time where						
	Home	**1**			1		
	Away	**14.1**	**2.62 – 76.2**	**0.004**	6.33	0.91 – 43.87	0.060
	Floor carpet						
	No	**1**			1		
	Yes	**0.36**	**0.14 – 0.97**	**0.043**	6.35	0.91 – 43.87	0.065
	Kitchen location						
	Outside	**1**			**1**		
	Inside	**2.10**	**0.01 – 4.33**	**0.046**	**1.96**	**1.00 – 3.83**	**0.049**
	Energy for lighting						
	Electricity	**1**			1		
	Charcoal	**2.10**	**0.01 – 4.33**	**0.003**	2.61	0.85 – 8.07	0.090
	Energy for Cooking						

	Electricity	**1**			1		
	Charcoal	**2.06**	**1.21 -3.349**	**0.010**	0.86	0.22 – 3.411	0.827
Pneumonia[f]	Community						
	Bauleni	**1**			**1**		
	Freedom	**7.03**	**2.43-20.34**	**0.001**	**4.38**	**1.28 – 14.95**	**0.021**
	Energy for cooking						
	Electricity	1			1		
	Charcoal	1.85	0.89 – 3.86	0.092	1.58	0.74 – 2.61	0.289
	Kitchen location						
	Outside	1			1		
	Inside	1.85	0.96 – 3.61	0.066	1.39	0.74 – 3.37	0.218

[a] adjusted for age, marital status, educational attainment, occupation, smoking status, presence of floor carpet and energy for cooking

[b] adjusted for marital status, educational attainment, occupation, smoking status, presence of carpet and energy for cooking

[c] adjusted for age, occupation, smoke status, and time where respondent spent most of the day

[d] adjusted for marital status and time where respondent spent most of the day

[e] adjusted for gender, presence of floor carpet, time where respondent spent most of the day, source of energy for cooking and lighting and location of kitchen

[f] adjusted for Education attainment, time where respondent spent most of the day, source of energy for cooking and location of kitchen

4.5. Discussion

This study has revealed that the prevalence of the various pulmonary symptoms of interest was two to four times higher in Freedom, the exposed community, compared to Bauleni, and that residing in Freedom was a significant determinant for the occurrence of the pulmonary symptoms.

In dust-polluted ambient environments, the main route of exposure to the dust is the respiratory tract. The resultant irritation sets off a physiological response to clear the airways culminating in enhanced cough and phlegm production.[18] In this study the prevalence of self-reported cough and phlegm production was higher among respondents from the exposed community compared to their counterparts from the control community. Irrespective of the time of the day, the prevalence of cough was significantly higher in the exposed than control communities, suggesting a persistent irritant in the ambient environment. Moreover, compared to those from the control community, respondents from the exposed community were 5.64 times more likely to report cough after adjusting for confounders. These findings could be linked to a basic reaction of irritations of the respiratory tract due to a dusty environment; possibly due to cement dust emanating from the cement plant. Similar findings, though reporting lower prevalence, have been reported by Sana[8] and Oyinloye.[9] However, earlier studies did not demonstrate such relationship.[19,20] The disparity could be attributed to the differences in the study settings. The studies that did not find association included only factory workers; a selection criterion that could have introduced bias related to the "healthy worker" effect. This bias could have masked the effects of cement dust on respiratory tract since sick workers were unlikely to be included in the studies as they stayed home. Our study drew participants from the community, thereby increasing the probability of including individuals with compromised respiratory health status and eliminating any selection bias.

The prevalence of phlegm production from the chest was significantly higher in the exposed than control community; 55.9% against 13.9%. The difference was evident even after adjusting for smoking and presence of floor carpet in the household; the two most commonly reported determinants of phlegm production.[21,22] This suggested a positive association of exposure to polluted ambient environment and increased phlegm from the chest as has been observed elsewhere.[5,23,24]

The prevalence of wheeze was observed in 45% of respondents from the exposed community compared to about 31% from the control community. These results are consistent with findings from other studies.[5,6,25,26] Although, these studies used different sets of participants; production line workers as exposed and blue collar workers as control, they revealed that prevalence of wheeze was consistently higher among the production line workers compared to the blue collar workers. The underlying assumption of these studies was that production line workers were more exposed to emission of cement production. Mwaisalage et al, Mengasha et al and Ahmed Hafiz omer et al have demonstrated that the concentration of $PM_{2.5}$, PM_{10} and other pollutants exceeded the exposure limits around the production line compared to other factory plant areas within same premises.[3,23,27] Wheezing is a sign of constriction of the airways resulting from irritants including dust.[28] Therefore, the observed 60% increase in odds of reporting a wheeze among the respondents from Freedom is suggestive of a deleterious health effect of cement dust on the respiratory tract. Although several other factors can lead to wheeze, the results show that there were no significant demographic and socio-economic characteristic differences between the two communities.

The prevalence of chronic bronchitis was similar between the exposed and control communities. Chronic bronchitis is less commonly reported at health facilities in developing nations[29-31] and thus subject to under reporting or misdiagnosis. Our study could have failed to show significant association due to insufficient numbers to attain the necessary power.

Respondents from the exposed community, compared to the control, were five times more likely to report asthma. Asthma is a respiratory disorder characterized by hyper-responsive airways to irritants including dust, pollen and other allergens in susceptible individuals.[32] Asthma is an inflammatory airway disease, characterized by airway hyper responsiveness to a number of trigger factors including but not limited to irritants and allergens. Furthermore, these factors are not causative but triggers of symptoms and exacerbations. Our findings are similar to those of Kyu Tae Cha et al.[33] who showed that the prevalence of asthmatic symptoms were higher among individuals exposed to cement dust. Additionally, results from our study reveal that gender and kitchen location are independent determinants of asthma after adjusting for other confounders. This is congruent with medical literature which shows that the prevalence and severity of asthma is higher in women compared to men in post puberty years.[34,35] Furthermore, this study shows that spending time in or around home, after adjusting for residence, floor carpet, and energy source for cooking increases the risk of asthma and these findings are consistent with results from other studies.[21,36] However, it is possible that factors of domestic micro-environment that were not considered in this study contributed to these finding.

In this study, the infectious disease of pneumonia was highly associated with residence. Evidence from elsewhere suggest that dust in the ambient environment is associated with increased respiratory tract infections ranging from the common cold,[37] pneumonia[38] to tuberculosis.[39] Additionally, a recent study showed that construction workers aged 20-64 years who were exposed to inorganic dust were 1.87 times more likely to die from pneumonia.[38] This observation has been related to the compromised non-specific defence mechanism of mucociliary self-clearance, due to repeated exposure of the airways to dusty ambient environment.[40,41]

Some factors, such as energy for cooking and lighting had unexpected effects in this study. While literature shows that using “dirty fuels” (biomass and fossil fuels) resulted in higher rates of respiratory disorders, both source of lighting and cooking did not achieve statistical significance after adjusting for potential confounders. The effect of “dirty fuels” as source of lighting could not have been significant as the proportion using these fuels in the two communities was similar. This could be due to the small number of respondents with disease conditions such as asthma, pneumonia, and chronic bronchitis.

Interpretations of this study’s findings should take into consideration its limitations. The major limitation is that the reported illnesses were not ascertained with medical records. This could potentially have introduced misclassification bias. Related to this was the ability to accurately report the number of times respondents experienced respiratory symptoms resulting in either over- or under-reporting. More importantly, there has been a lot of media attention on the effect of cement dust pollution on the environment in and around Chilanga. This could potentially have led to over-reporting among respondents from Freedom. Moreover, the number of respondents with pneumonia, asthma and bronchitis was small leading to unreliable estimates of effect size. In this study, the median age (14 years) of respondents reporting chronic bronchitis was unusually low for this disease. This could have been due to respondents not understanding the diagnosis.

4.6. Conclusion

The prevalence of respiratory symptoms was several times higher in the exposed community compared to the control. This could be related to ambient air pollution due to emissions from the nearby cement production plant. However, firmer evidence would require further studies involving chemical characterization of the exposure and source apportionment to determine whether the observed excessive pulmonary symptoms are due to emission from the cement plant.

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4.8. Author Contributions

Emmy Nkhama, Kuku Voyi, Seter Siziya and J. Timothy Dvonch conceived and designed the study; Emmy Nkhama, Micky Ndhlovu, Kuku Voyi acquired the data. Emmy Nkhama, Micky Ndhlovu and Seter Siziya analysed and interpreted the data; Emmy Nkhama and Micky Ndhlovu drafted the article; Emmy Nkhama, Micky Ndhlovu, J. Timothy Dvonch, Seter Siziya and Kuku Voyi critically revised the intellectual content of the article.

4.9. Ethical considerations

The study protocol was reviewed and approved by a local research ethics committee in Zambia-ERES Converge IRB (00005948) and from IRBs of the Universities of Pretoria (0000 2535 IORG 0001662) and Michigan (00070842).

4.10. Conflicts of Interest

The authors declare no conflict of interest.

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Chapter 5 : Effects of Airborne Particulate Matter on Respiratory Health in a Community near a Cement Factory in Chilanga, Zambia: Results from a Panel Study[3]

5.1. Abstract

We conducted a panel study to investigate seasonal variations in concentrations of airborne $PM_{2.5}$ and PM_{10} and the effects on respiratory health in a community near a cement factory; in Chilanga; Zambia. A panel of 63 and 55 participants aged 21 to 59 years from a community located at the edge of the factory within 1 km and a control community located 18 km from the factory respectively; were followed up for three climatic seasons July 2015 to February 2016. Symptom diary questionnaires were completed and lung function measurements taken daily for 14 days in each of the three climatic seasons. Simultaneously, $PM_{2.5}$ and PM_{10} concentrations in ambient air were monitored at a fixed site for each community. Mean seasonal concentrations of $PM_{2.5}$ and PM_{10} ranged from 2.39–24.93 $\mu g/m^3$ and 7.03–68.28 $\mu g/m^3$ respectively in the exposed compared to the control community 1.69–6.03 $\mu g/m^3$ and 2.26–8.86 $\mu g/m^3$. The incident rates of reported respiratory symptoms were higher in the exposed compared to the control community: 46.3 vs. 13.8 for cough; 41.2 vs. 9.6 for phlegm; 49.0 vs.12.5 for nose; and 13.9 vs. 3.9 for wheeze per 100 person-days. There was a lower performance on all lung indices in the exposed community compared to the control; overall the mean FEV1 (forced expiratory volume in one second) and FVC (forced vital capacity) predicted percentage for the exposed was six and four percentage points lower than the control. Restriction of industrial emissions coupled with on-going monitoring and regulatory enforcement are needed to ensure that PM (airborne particulate matter) levels in the ambient air are kept within recommended levels to safeguard the respiratory health of nearby community residents.

Keywords: cement production; emissions; $PM_{2.5}$; PM_{10}; respiratory symptoms; lung function; community; Zambia

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5.2. Introduction and Background

Worldwide, airborne particulate matter (PM) in outdoor ambient air has received increased attention due to its associations with cardiovascular and respiratory morbidity and mortality. The Global Burden of Disease Study ranked PM as the ninth leading risk factor for respiratory and cardiovascular diseases and various cancers.[1] Additionally, in the same year PM was ranked fifth on the list of top causes of all-cause mortality.[2] Globally approximately 3.2 million premature deaths are attributed to exposure to PM annually.[3] Particulate matter of aerodynamic diameter less than 2.5 microns ($PM_{2.5}$) and less than 10 microns (PM_{10}) are of public importance because they are respirable in size leading to pulmonary diseases. Both long term (reductions in lung functions) and short term (cough, wheeze, phlegm and shortness of breath) respiratory effects due to exposure to PM have been reported globally.[4-10] The most commonly reported respiratory symptoms include cough, wheeze, dyspnea, sneezing and phlegm.[11-14] Additionally, lung function measured as forced expiratory volume in one second (FEV1), forced vital capacity (FVC), ratio of forced expiratory volume in one second and forced vital capacity (ratio of FEV1/FVC), peak expiratory flow rate (PEFR) and peak expiratory flow (PEF) has also been shown to be reduce.[10,12,5,16]

Even though thresholds have been identified, the adverse effect of exposure to PM concentrations below these thresholds has been observed. The World Health Organization (WHO) recommends exposure levels not exceeding 10 $\mu g/m^3$ annually and 25 $\mu g/m^3$ in 24-hour mean (not exceeding for more than 3 days a year) for $PM_{2.5}$; and 20 $\mu g/m^3$ annually and 50 $\mu g/m^3$ in 24-hour mean for PM_{10}.[17] Notwithstanding the WHO recommendations, countries have established different cut-off levels as safe exposure.[18] The decision for these levels is determined mainly by economic considerations.[19] Developed countries have more stringent standards and advanced strategies to reduce air pollution with PM than developing countries.[18] For instance, the U.S. Environmental Protection Agency (EPA) air quality standard is set at 12 $\mu g/m^3$ annual and 35 $\mu g/m^3$ in 24-hour concentration for $PM_{2.5}$, and 150 $\mu g/m^3$ in 24-hour not to be exceeded more than once per year on average over a 3-year period for PM_{10}. Emerging economies like China and India are beginning to build their environmental management systems and have set their standards as follows; 70 µg/m^3 annual and 150 µg/m^3 for 24-hour for PM$_{10,}$ and 75 µg/m^3 in 24-hour mean concentration for PM$_{2.5}$ for urban areas.[20] Among countries in the southern African region only South Africa has set exposure level standards; for PM$_{10}$ of 60 µg/m^3 annual and 180 µg/m^3 maximum in 24-hour concentration.[17] Zambia, like several other countries that have not promulgated their own standards due to local constraints and capabilities, uses WHO air quality guidelines.

The cement industry is a major contributor to total global PM emissions.[19,20] Within a cement factory, considerable amounts of PM as dust is generated at almost every stage of the manufacturing process; from quarrying of the raw material to the packing.[22] The PM result as fugitive dust within and in surrounding areas of cement plants. Cement dust derived PM levels above the minimum acceptable values have been reported in both the factory plant and communities residing near the cement plants. For instance, Tiwari et al. reported high levels of PM in a community located about 1.5 km from a cement factory that exceeded the WHO recommendations.[23] In a related study[24] in Nigeria, the total atmospheric dust was reported at an average concentration of 650 µg/m^3, more than 600 µg/m^3 higher than the recommended safe limit of 25 µg/m^3 set by the Federal Environmental Protection Agency (FEPA). Similarly, other cement plant locations have found evidence of total PM concentration ranging from 196.19 µg/m^3 to 423.83 µg/m^3, which is above the 24-hour average WHO guideline value of 120 µg/m^3 for total PM concentration.[22] In a related study,[25] one community lying within a radius of 1.2 km of a cement factory experienced PM$_{10}$ concentrations higher than the recommended 24-hour mean on more than the recommended maximum 35 days annually. Several other studies,[8,26,27] that assessed air quality in similar communities, have demonstrated comparable findings.

Currently, most evidence in literature regarding the effect of the emissions from cement production is from studies conducted within the factory plants and involved mostly workers. Understanding the effects of exposure to cement dust on human respiratory health for communities residing near cement factories is imperative, as it would allow for interventions that would balance between cement production and protection of human health. This is possible only when knowledge about the extent of the air pollution and its adverse health effects is measured precisely. The objective of this study, using a prospective panel study, was to investigate the seasonal variations in concentrations of PM ($PM_{2.5}$ and PM_{10}) and effects on respiratory health in a community around a cement factory, in Chilanga, Zambia.

5.3. Study Methodology

5.3.1. Study Site

The study site is a community called Freedom Compound, situated near one of Zambia's major cement producing plant, Lafarge Chilanga Cement factory. The plant is located 15 km south of Lusaka, the capital city of Zambia, at geographical coordinates of 15.3875°S and 28.3228°E. Freedom compound is located right at the edge and within 1km of the factory, on the north-western and leeward side of the plant. A community (Bauleni) situated 18 km north from the plant and from the study site, was included as control for comparison. The choice of the control community was dictated by the need to have a community with a socioeconomic profile as similar to Freedom Compound as possible but outside the fallout zone. Details of the study sites are given elsewhere.[28]

5.3.2. Sampling of Study participants

Participants for the panel study were randomly selected as a sub-sample from a sampling frame compiled during a cross-sectional study conducted in the two communities over a year earlier. The study was reviewed and approved by a local research ethics committee in Zambia-ERES Converge IRB (00005948) and from IRBs of the Universities of Pretoria (0000 2535 IORG 0001662) and Michigan (00070842). Participant recruitment for the cross sectional study is given elsewhere [28]. For this study, based on a power analysis, a minimum sample size of 55 per community was required to give us power to test our research question of interest. As we assumed loss to follow-up of 30% and further that 50% of the participants from the cross-sectional study may refuse consent or that they may not be found for reasons such as relocation or death, having been recruited a year earlier, we inflated the minimum sample size by 80% giving us a total sample of 98 per community. As illustrated in Figure 1, we then randomly choose 98 potential participants from each sampling frame of each community followed by physically visiting the communities to locate the participant. We located 98 and 79 potential participants from Freedom and Bauleni respectively. We sought verbal consent from the located potential participants for them to take part in the panel study. In Freedom all, except one consented, while three refused consent in Bauleni. The consenting potential participants constituted a second tier sampling frame; 65 were drawn randomly from each community for enrollment to make a panel. However, because data collection commenced a month later after seeking their verbal consent, only 63 and 55 participants from Freedom and Bauleni respectively finally participated (enrolled). Eligibility criteria included: participants should have lived in the community for 24 months and were likely not to relocate within the next 18 months, aged between 21 and 59 years, consenting to be followed-up for the study period, not working for the cement factory or any construction company and spent 80% of the time in either Freedom or Bauleni.

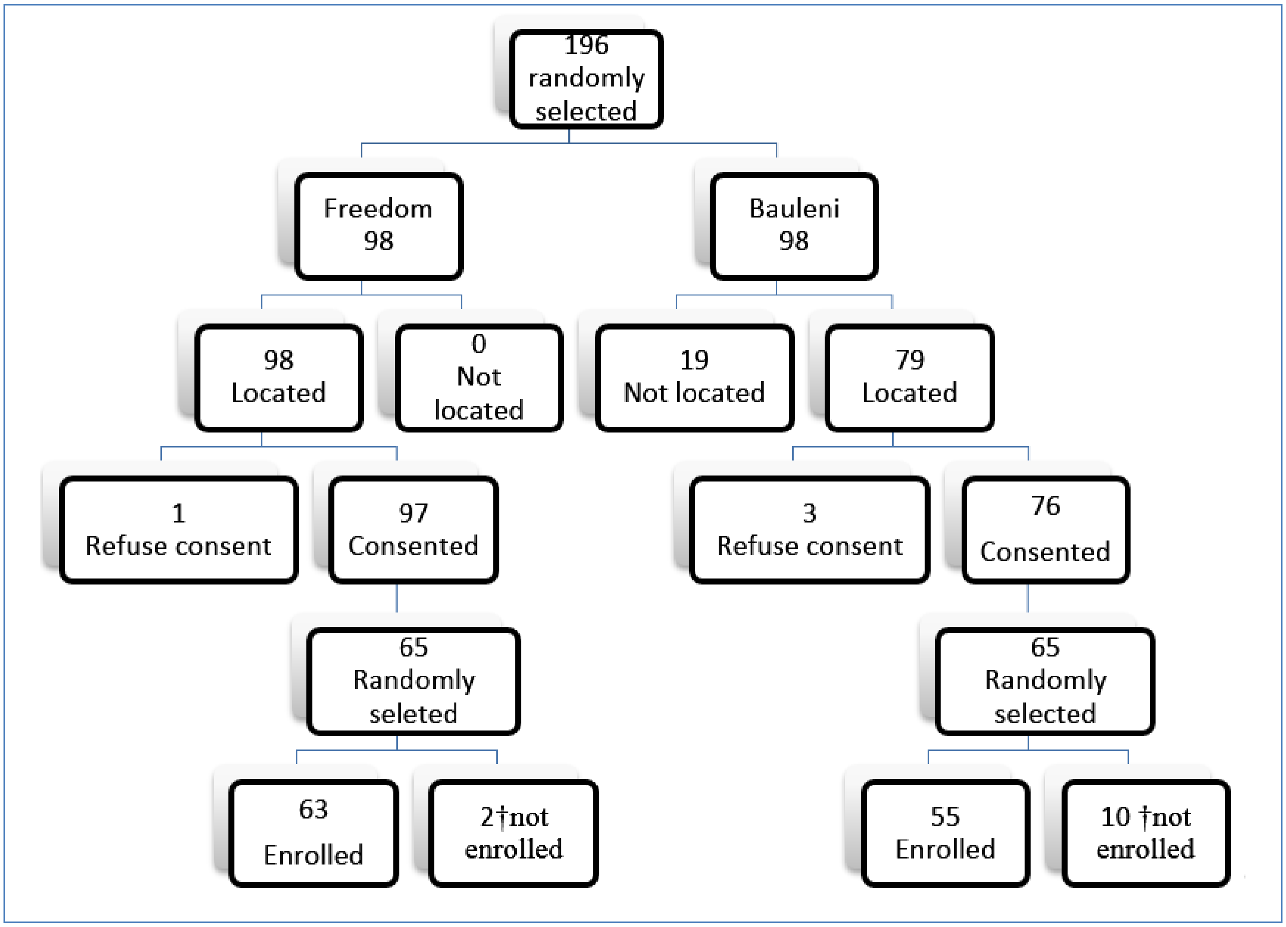

Figure 5-1: Schematic drawing of participant selection.

† total of 12 were not enrolled; 4 changed residential place, 5 found employment outside study area consent and 3 withdrew consent.

5.3.3. Study Design

A prospective panel study was utilized; participants were followed-up over three climatic seasons. In each season (cold dry from 28 July–14 August, 2015, hot dry from 15–28 October 2015, and warm rainy from 7–21 February, 2016) participants were visited daily for 14 consecutive days. On these days, daily symptoms questionnaires were completed and spirometry done for each participant.

The first data collection wave comprised the enrolled 55 and 63 participants from Bauleni and Freedom communities respectively. In the second data collection wave, 51 and 57 participants were followed-up in Bauleni and Freedom respectively. Eight participants, four from each community, were lost to follow up. Of the four participants lost to follow up in Bauleni, three relocated while one found a new job opportunity outside the community; left early and got home very late. Similarly, one participant in Freedom had changed residence and three found jobs away from Freedom community. In the third data collection wave, there was no loss to follow up.

5.3.4. Data collection

5.3.4.1. Measurement of Covariates

The medical personnel that conducted the visit completed questionnaires and conducted spirometry measurements. At the beginning of each data collection wave for each season the gender, date of birth (DOB), height and weight were collected for each participant. Age was calculated as the difference between the DOB and the date at the commencement of the study, height and weight was measured to the nearest centimeter and kilogram (without shoes) using a stadiometer and a balance scale respectively. Smoking status was classified as “never” (reference group), “former” and “current”. Former smoker was any participant who ceased smoking at least two years before the first data collection wave, while a current smoker was any participant who used rolled or manufactured cigarette during the study or ceased smoking less than two years before the first data collection wave. Gender was coded as male and female. Cooking fuel was classified as “electricity” or “charcoal” while lighting fuel referred to “electricity” (torch or electric bulb) or “candle”. Location of the kitchen in relation to sleeping space was measured as “inside” (cooking and sleeping done in the same room) or “outside” (kitchen separate from sleeping space). In multivariate analyses never smoked, use of electricity for lighting and cooking, male and cooking outside the house were used as reference.

5.3.4.2. Air Monitoring

To assess daily and seasonal variability of airborne PM concentrations in the two communities, ambient air monitoring was conducted during the three measurement waves reflecting the three climatic seasons. A community-level monitoring station was set up in each of the two communities. The equipment was placed on a building rooftop at each site allowing sampling inlets to be 2–3 meters off the ground and away from any interference to air circulation. The choice of the two sites was based on security considerations for the monitoring equipment. Filter-based measurements of $PM_{2.5}$ and PM_{10} were made daily during each seasonal exposure assessment field intensive (every two weeks in duration) at each sampling location. All PM samples were collected daily, over 24-hour durations. Measurements were made using 2-μm pore, 47-mm Polytetrafluoroethylene (PTFE) Teflon membrane filters (Pall, Ann Arbor, MI, USA).[29] Vacuum pump systems were used to draw air through the sample at a nominal flow rate of 16.7 L/min using Teflon-coated aluminum cyclone inlets (University Research Glassware, Chapel Hill, NC, USA) .[4] Flow determinations were made at the beginning and end of each sampling period using a calibrated rotameter (Matheson Inc., Montgomeryville, PA, USA).[4] For this method, analytical precision was calculated to be within 10% based on replicate analysis with a limit of detection of 5.1 μg (calculated as three times the standard deviation of seven repeated blank filter measurements). All measurements were above the detection limit.

All filters collected were prepared and analyzed at the University of Michigan Air Quality Laboratory (UMAQL).[4] All gravimetric determinations of Teflon filters were made using a microbalance (Mettler MT-5; Mettler Toledo, Columbus, OH, USA) in a temperature/humidity-controlled Class 100 clean laboratory and followed the Federal Reference Method,4 which included conditioning filters for 24 hours in the clean lab. At the conclusion of each study period, collected filters were shipped back to the UMAQL, conditioned for 24 hours, and post-weighed following the same protocol used for filter pre-weight. For this method, analytical precision was calculated to be within 10% based on replicate analysis, with a limit of detection of 5.1 μg (calculated as three times the standard deviation of seven repeated blank filter measurements). All measurements were above the detection limit.

5.3.4.3. Measurement of Incidence of Respiratory Symptoms

A daily symptom diary questionnaire that collected information on daily respiratory symptoms was administered to each participant. Respiratory symptoms referred to acute respiratory symptoms; cough, shortness of breath, wheezing, runny nose, breathlessness and sneezing. The daily diary symptom instrument was adapted from previous survey instruments.[30,31] The diary questionnaires were completed for each participant daily by the medical personnel that conducted the spirometry. This was necessary to maintain consistency as some of the participants were not able to read and/or write; and to maintain compliance to the study protocol and for quality control.

5.3.4.4. Measurement of Lung Functions

Lung function testing was performed using the EasyOne ultrasonic flow-sensing spirometer (NDD Medical Technologies, Zurich, Switzerland).[32] Before taking measurements, the procedure was explained and demonstrated to each participant at the beginning and during each data collection period until the participant was comfortable to perform the maneuver on their own without any assistance. Standard methods were used to determine the validity and reproducibility of the blows.

Lung function was measured as FEV1, FVC and FEV1/FVC ratio. For daily session, performed between 07:30 AM and 09:30 AM, the participant had to blow into the EasyOne spirometer. The maneuver involved the participants inspiring fully, seal the nose with one hand and place the mouth around the mouthpiece of the spirometer, followed by breathing out as fast as they could until the lungs were empty. The measurements were carried out according to guidelines and techniques for performing spirometry according to American Thoracic Society (ATS) standards. The quality of spirometry tests was assessed according to the ATS guidelines.[30]

5.3.4.5. Measurements of Meteorological Characteristics

The meteorological data used in this study were obtained from the Zambia Meteorological department (ZMD). These included the daily minimum and maximum temperatures (°C), minimum and maximum relative humidity (%), minimum and maximum wind speeds (m/sec), minimum and maximum rainfall (in mm), and hours of sunshine (solar radiation) for the months July/August and October 2015; and February 2016. The wind direction is predominantly east-west most of the year with light variable northerlies and north-easterlies during the rainy season. We calculated the daily average temperature (using daily minimum and maximum temperatures). We also calculated the daily average relative humidity and reported the average of the two.

5.3.5. Statistical Analysis

Descriptive statistics were used to describe the baseline sample characteristics. For time invariant characteristics, means (and their SD (standard deviation)) for continuous normally distributed variables or medians (and the IQR (interquartile range)) for non-normally distributed were calculated while proportions and 95% CI were determined for categorical variables. Baseline (or cross-sectional) comparison for statistical differences of these characteristics between the exposed and control community were tested with student t-test (or Mann Whitney; an equivalent non-parametric test) and the chi-Square test for continuous and categorical variables respectively. For time variant covariates model based generalized estimating equations (GEE) comparisons of longitudinal means were carried out. A p-value of <0.05 was considered as statistically significant. Meteorological data was analysed as 24-hour mean temperatures and humidity. For air quality monitoring 24-hour mean concentrations of $PM_{2.5}$ and PM_{10} were determined.

We used person-day follow-up period to determine the incidence rate (per 100 person-days) of respiratory symptoms in the two communities. The total person-day follow-up time was the sum of the days that each participant was followed-up and completed the symptom diary. Each symptom's incidence was the sum of the number of days that each participant reported a particular symptom. Lung function indices were analysed as percentage of predicted values except for FEV1/FVC ratio where absolute values were used.

Associations between the PM with respiratory symptoms and lung functions were estimated by fitting different multivariate generalized estimating equations (GEE) regression models for each outcome; binomial and Gaussian distribution were assumed for categorical and numeric outcome variables respectively. To account for auto-correlation in outcomes for each panel, we specified exchangeable correlation matrix. Furthermore, potential confounders were adjusted for: sex, age, height, weight, smoking history, socioeconomic status, asthma and meteorological variables. We also tested for lag effect of the exposure on the outcomes for days 1–7. Modification effects for age and gender were investigated with the inclusion of interaction terms. Quasi-likelihood information criterion (qic) was used to select the fit of the models. STATA version 12 (Stata Corp L 2011, College Station, TX, USA) was used for all analyses.

5.4. Results

Table 5-1 provides a description of the cohort study population. We recruited 116 participants; 63 and 53 from Freedom and Bauleni communities respectively with 4753 person-days data points. An 87.1% completion rate was achieved. Loss to follow-up was mostly due to relocation of study participants from the respective study sites. On average 52 participants from both communities completed the daily symptom diary symptom for each season. The average age for participants was 30 and 40 years from the exposed and control group respectively. There was no statistically significant difference in age, weight, smoking status, employment status of the study participants, source of energy used for cooking and lighting between the two communities (p value > 0.05). Very low proportion of participants reported being current smokers; 4.8 and 5.5% for Freedom and Bauleni, respectively. Electricity was the most commonly used source of energy for lighting and cooking in both communities. Generally, the prevalence of all the respiratory symptoms were higher in the exposed than control community and the difference was statistically significant (p value < 0.05).

Table 5-1. **Baseline characteristics study population.**

Characteristic	Freedom *n* = 63	Bauleni *n* = 55	
	n (%)	*n (%)*	*p-Value*
Gender			
Males *n* (%)	33 (52.4)	15 (27.3)	
Female *n* (%)	30 (47.6)	40 (72.7)	0.006
Employed Yes *n* (%)	46 (70.0)	38 (67.9)	0.062
Age (yrs) median(IQR)	30 (24–37)	33 (25–42)	0.173
Weight (kg) median (IQR)	63.0 (60.0–69.0)	61.0 (57–70.0)	0.312
Height (cm) median (IQR)	166 (161–171)	162 (158– 167)	0.004
BMI median (IQR)	25.2 (18.7–41.2)	24.8 (18.3–35.6)	0.297
Asthma	4 (6.3)	2 (3.6)	0.684 ‡
Smoking status *n* (%)			
Never	58 (92.0)	47 (85.4)	0.386
Former	2 (3.2)	5 (9.1)	
Current	3 (4.8)	3 (5.5)	
Source of energy *n* (%)			
Lighting			
Electricity	51 (85.0)	46 (85.2)	
Candle	9 (15.0)	8 (14.8)	0.978
Cooking			
Electricity	33 (55.9)	31 (59.6)	
Charcoal	26 (44.1)	21 (40.4)	0.695

% percentage; kg kilograms; IQR interquartile range; yrs years; ‡ Fisher's exact.

Table 5-2 gives a summary of 24-hour PM concentrations ($PM_{2.5}$ and PM_{10}) in the ambient and meteorological parameters across the seasons from cold dry through to wet season by location. The $PM_{2.5}$ concentrations were higher in the exposed compared to control community. Further seasonal variations were observed in both communities; the highest concentrations were recorded in the hot dry season compared to the other two seasons. For the exposed community, the seasonal 24-hour mean concentrations (in $\mu g/m^3$) ranged from 2.39 in warm rainy to 24.93 in hot dry season whereas the 24-hour mean concentrations for the control community were significantly lower ranging from 1.9 $\mu g/m^3$ in warm rainy season to 6.89 $\mu g/m^3$ in hot season. The 24-hour mean concentrations for PM_{10} for both communities tended to follow the same pattern as that of $PM_{2.5}$. In the exposed community, concentrations ranged from 7.03 $\mu g/m^3$ in warm rainy to 68.28 $\mu g/m^3$ in hot season and from 2.26 $\mu g/m^3$ warm rain to 8.82 $\mu g/m^3$ hot dry season. There was no statistically significant difference in meteorological characteristics (temperature and humidity) between the exposed and control sites during the study period (*p* value = 0.557 and 0.658, respectively).

Table 5-2: Mean concentration (µg/m^3) of particulate matter and meteorological variables for the exposed and control communities.

Variable	Location	Cold Dry	Hot Dry	Warm Rainy	Total
PM$_{2.5}$	Freedom	9.15 (11.58)	24.93 (22.06)	2.39 (2.67)	10.21 (15.55)
$\bar{x}$ (sd)	Bauleni	6.03 (5.25)	6.89 (10.91)	1.69 (1.28)	5.87 (5.87)
	†	0.001	0.025	0.001	0.001
PM$_{10}$	Freedom	31.40 (43.38)	68.28 (53.92)	7.03 (6.32)	36.96 (47.76)
$\bar{x}$, (sd)	Bauleni	7.66 (6.33)	8.82 (6.32)	2.26 (0.71)	6.67 (7.70)
	†	0.001	0.001	0.001	0.001
Temp.	Freedom	20.72(1.60)	30.22 (1.62)	23.27 (3.94)	24.64 (4.79)
°C, (sd)	Bauleni	20.72 (1.60)	30.29 (1.62)	22.16 (3.24)	24.35 (4.79)
	†	1.000	0.004	0.020	0.040
RH	Freedom	44.79 (5.02)	70.47 (10.57)	71.87 (8.09)	61.86 (15,01)
%, (sd)	Bauleni	44.79 (5.01)	70.46 (10.55)	72.30 (7.90)	62.05 (15.05)
	†	1.000	0.200	0.505	0.073

† *p* value for the difference between communities; Temp temperature; RH relative humidity; sd standard deviation.

Cough and nose irritation were the commonly reported symptoms. Additionally, the incidence rates of the symptoms were higher in Freedom compared to the control (Table 5-3). Furthermore, incidence rate of the symptoms showed variation from season to season within each community. However, the variation was wider in the exposed compared to the control (e.g., the incidence rate of cough ranged was 12.4% and 15.9% in Bauleni while 10.4% and 75.1% in Freedom for the warm rainy and hot dry seasons respectively). Similar observations were made of the other symptoms. To be noted also is that the lowest incidence rate for each of the symptoms regardless of community was observed in the warm rainy season and highest in the hot dry season. The transitional probabilities, i.e., the chance of a participant reporting a particular symptom during follow-up given they did not report having the symptom at the beginning, were several folds higher in Freedom compared to the control. For instance, the chance of reporting nose irritation and cough was 10 and 4 times higher respectively in Freedom compared to the Bauleni.

Table 5-3: Symptoms incidence rate (per 100 person-days) by season and community; and transition probabilities.

	Cold		Hot Dry		Warm Rain		Overall		Transition Probability	
	Bauleni	Freedom	Bauleni	Freedom	Bauleni	Freedom	Bauleni	Freedom	Bauleni	Freedom
	[a]N = 726	*N* = 821	*N* = 768	*N* = 889	*N* = 699	*N* = 850	*N* = 2193	*N* = 2560		
symptom	[b]*n (IR)*	*n (IR)*	*n (IR)*	*n (IR)*	*n (IR)*	*n (IR)*				
Cough	94 (12.9)	431 (52.5)	122 (15.9)	668 (75.1)	87 (12.4)	87 (10.4)	303 (13.8)	1186 (46.3)	8.83	27.6
Phlegm	26 (3.6)	386 (47.0)	122 (15.9)	584 (65.7)	16 (9.0)	86 (10.1)	211 (9.6)	1056 (41.2)	6.20	28.23
Nose	72 (9.9)	410 (49.9)	145 (18.9)	653 (73.4)	57 (8.2)	191 (22.5)	274 (12.5)	1254 (49.0)	1.70	10.07
Wheeze	9 (1.2)	90 (11.0)	40 (5.2)	201 (22.6)	37 (5.3)	65 (7.6)	86 (3.9)	356 (13.9)	8.74	36.90

a total number of person-days followed

b number of person-days in which particular symptom was reported

IR incidence rate per 100 person-days

The percentage of the predicted values of the lung function indices of participants is presented in Table 5-4. Overall, the mean percentage of the predicted FEV1 and FVC was lower in the exposed compared to the control by 6% and 4% respectively. The indices showed seasonal variations in both communities; lowest in the hot dry season and highest in the cold dry (89.67 vs. 94.0 for FEV1; and 91.13 vs. 94.61 for FVC). Besides, being lower for Freedom, the percentage of the predicted lung function showed also minimal variation compared to the control community. The FEV1 ranged from 89.7–91.6 for Freedom and 96.5–99.4 for Bauleni while FVC ranged from 91.1–94.2 for Freedom and 94.6–100.0 for Bauleni. The spirometric airflow limitation (FEV1/FVC ratio) was lower for the exposed group compared to the control (0.82 vs. 0.84). A FEV1/FVC ratio of less than 80%, which is the accepted cut threshold, was observed in 32.1% of the exposed participants and 11.5% in the control.

Table 5-4: Percent predicted lung function variations between communities and season.

	Season						**Overall**	
	Cold		**Hot**		**Warm rainy**			
	Freedom	**Bauleni**	**Freedom**	**Bauleni**	**Freedom**	**Bauleni**	**Freedom**	**Bauleni**
FEV1								
Mean (sd)	91.56 (22.45)	96.54 (14.53)	89.67 (19.30)	94.01 (14.21)	91.20 (20.53)	99.39 (14.37)	90.74 (20.62)	96.59 (14.53)
FVC								
Mean (sd)	94.25 (22.37)	97.77 (15.10)	91.13 (19.65)	94.61 (15.98)	93.11 (21.63)	100.97 (17.31)	93.69 (21.16)	97.70 (16.44)
FEV1/FVC ratio								
mean (sd)	0.81 (0.10)	0.83 (0.09)	0.82 (0.10)	0.84 (0.09)	0.83 (0.86)	0.83 (0.88)	0.82 (0.10)	0.83 (0.09)

sd = standard deviation.

Generally, $PM_{2.5}$ was a significant predictor for occurrence of the respiratory symptoms expect for wheeze; a 1 $\mu g/m^3$ increase in $PM_{2.5}$ increased the odds of cough, phlegm and nose irritation by about 2% controlling for season, smoking status and asthma (Table 5-5). However, it had an opposite effect on the odds of wheeze (p value < 0.05). Overall, an increase in PM_{10} concentration reduced the odds of all the symptoms, but was only statistically significant for phlegm and nose irritation. Daily assessment of PM_{10} showed a statistically significant effect for phlegm and nose irritation 3–5 days after exposure (lag 3 and 5); phlegm lag 5 [OR = 1.00 (0.06–1.00)]; and nose irritation lag 3 [OR = 1.00 (1.00–1.10)] and [OR = 1.00 (0.06–1.01)].

Table 5-5: Adjusted OR estimates of association between $PM_{2.5}$ and PM_{10} and respiratory symptoms among participants from Freedom and Bauleni communities.

	Cough	**Phlegm**	**Wheeze**	**Nose Irritation**
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Exposure to $PM_{2.5}$				
$PM_{2.5}$ lag1	1.02 (1.01, 1.04) *	1.02 (1.01, 1.03) *	0.99 (0.98, 1.00) *	1.01 (1.01, 1.02) *
Exposure to PM_{10}				
PM_{10} lag1	1.00 (0.99, 1.00)	0.99 (0.99, 1.00) *	1.00 (0.98, 1.00)	0.99 (0.99, 1.00) *
PM_{10} lag3	-	-	-	1.00 (1.00, 1.01) *
PM_{10} lag5	-	1.00 (1.00, 1.01) *	-	1.00 (1.00, 1.01) *

OR-odds ratio; CI-confidence level by 10 µg/m^3 in $PM_{2.5}$ and PM_{10}, * -*p* value < 0.05. Controlled for time, smoking status, season, asthma. Lag 1 to 7 was investigated for both $PM_{2.5}$ and PM_{10}. Only lags effects that were statistically significant for any given symptoms are shown in the table.

Table 5-6 shows results from single-pollutant models. Although not statistically significant, a 10 µg/m^3 increase of delayed exposure in $PM_{2.5}$ was found to decrease FEV1 by 72.0 mL and 157 mL in the exposed and control respectively. There was an 82 mL decrease in FVC for a 10 µg/m^3 increase in $PM_{2.5}$, however this was not statistically significant. A lag effect, although not statistically significant, was seen in the exposure to PM_{10}; for a 10 µg/m^3 increase in PM_{10} FEV1 decreased ranging from 60 mL to 154 mL with the highest decline observed three days after exposure (lag 3). Similarly, FVC showed a decline ranging from 60 mL to 262 mL on day 5 (lag 5), PM_{10} marginally statistically reduced FVC by 262 mL in the exposed community.

Table 5-6: Adjusted estimates of associations between PM concentrations and lung function

Single pollutant	Freedom Coefficient (95% CI)	*p* Value	Bauleni Coefficient (95% CI)	*p* Value
$PM_{2.5}$ FEV1				
$PM_{2.5}$ lag1	0.29 (−0.25, 0.83)	0.294	0.30 (−0.45, –1.04)	0.435
$PM_{2.5}$ lag2	0.23 (−0.31, –0.77)	0.402	0.65 (0.09, 1.39)	0.085
$PM_{2.5}$ lag3	0.08 (−0.49, –0.65)	0.971	−0.16 (0.87 ,0.55)	0.664
$PM_{2.5}$ lag4	0.12 (−0.42, –0.67)	0.657	0.31 (−0.05, 1.07)	0.424
$PM_{2.5}$ lag5	−0.07 (−0.63, –0.40)	0.800	0.58 (−0.15,–1.31)	0.811
$PM_{2.5}$ FVC				
$PM_{2.5}$ lag1	0.15 (−0.44, –0.73)	0.627	0.15 (-0.71, 1.02)	0.726
$PM_{2.5}$ lag2	0.08 (−0.49, –0.66)	0.775	0.76 (−0.12, 1.62)	0.086
$PM_{2.5}$ lag3	0.17 (0.44 ,0.79)	0.585	0.23 (−0.60, 1.07)	0.582
$PM_{2.5}$ lag4	0.22 (0.35, 0.79)	0.458	0.66 (−0.21, 1.53)	0.136
$PM_{2.5}$ lag5	−0.08 (−0.67, –0.51)	0.787	0.658 (0.18, 1.48)	0.126
PM_{10} FEV1				
PM_{10} lag1	−0.07 (-0.25, –0.11)	0.459	-0.37 (−1.25, 0.52)	0.416
PM_{10} lag2	−0.06 (−0.23, –0.11)	0.488	0.87 (0.01, 1.65)	0.028 [a]
PM_{10} lag3	−0.15 (-0.34, –0.30)	0.098	0.14 (0.90, 20.16)	0.728
PM_{10} lag4	0.08 (−0.10, –0.26)	0.365	0.22 (0.99, 0.51)	0.560
PM_{10} lag5	−0.15 (−0.33, –0.03)	0.092	−0.30 (−1.03, 0.43)	0.424
PM_{10} FVC				
PM_{10} lag1	0.01 (−0.18, –0.21)	0.910	−0.74 (−1.76, 0.27)	0.152
PM_{10} lag2	−0.06 (−0.24, –0.12)	0.514	0.78 (−0.11, 1.68)	0.086 [b]
PM_{10} lag3	−0.13 (−0.33, –0.06)	0.173	−0.04 (−0.94, –0.86)	0.935
PM_{10} lag4	0.79 (−0.07, –1.67)	0.073	0.04 (−0.15, –0.22)	0.704
PM_{10} lag5	−0.26 (−0.45, −0.08)	0.006	0.13 (0.96, 0.70)	0.751

Controlled for age, gender, weight, height, smoking status, asthma, occupation, temperature, humid, lighting fuel, cooking fuel, season, cook outside; [a] statistically significant (p value < 0.05); [b] marginally significant (p value).

5.5. Discussion

In this study, the ambient air of the exposed community had higher concentrations of $PM_{2.5}$ and PM_{10}. Furthermore, there was significant association between PM and incidence of respiratory symptoms and lung function for residents; and all symptoms studied were several folds higher compared to the control community. FEV1 and FVC were observed to be lower in residents living near the cement factory compared to those in the control community while the spirometric airflow limitation (FEV1/FVC ratio) was also lower for the exposed group compared to the control.

The 24-hour averages of PM_{10} and $PM_{2.5}$ levels were above the minimum recommended by WHO; on 21 days of the 42 days' follow-up period PM levels were as high as 5 times the recommended levels. Although our study showed high PM levels, ranging from 3.6 to 168 $\mu g/m^3$ and 0.4 to 54 $\mu g/m^3$ for PM_{10} and $PM_{2.5}$ respectively, similar studies have demonstrated much higher levels of PM in communities residing near cement factories. For instance, Kabir[24] reported an average concentration of 500 $\mu g/m^3$ and 650 $\mu g/m^3$ in two communities; Abdul et al.[22] found concentration levels ranging from 196.19 $\mu g/m^3$ to 423.83 $\mu g/m^3$ (particle size 0 to <150 μg) and Marcon et al.[6] reported average of 1208 $\mu g/m^3$ of PM_{10} 24-hour mean concentration over a period of 9 months. Furthermore, PM_{10} concentrations showed strong seasonal trends; the hot dry season had the highest (68.2 $\mu g/m^3$) compared to cold (35.4 $\mu g/m^3$) and rainy seasons (6.05 $\mu g/m^3$). These findings are consistent with other studies[8,23] and may be attributed to changes in wind velocity, temperature, relative humidity, and precipitation magnitude and frequency.[33] Another factor could be that on certain days more PM emissions could have been released from the plant. Even slight variations in the emissions control could greatly impact the community-level PM concentrations on some days, as there are no other industrial activities nearby.

Evidence in literature shows that excessive exposure to PM, either acute or chronic effects (in a 24-hour period or prolonged period), is associated with increased respiratory symptoms such as cough, phlegm, acute and chronic bronchitis, nasal irritation and reduced lung indices.[14,15,34-36] In this study, concentrations of PM were higher in the exposed community compared to control in all seasons. In this study, concentrations of PM were higher in the exposed community compared to control in all seasons, and $PM_{2.5}$ in the exposed community accounted for a larger proportion of the PM_{10} that was measured, compared to control. Toxicological and epidemiological studies[37,38] suggest that $PM_{2.5,}$ since they are smaller and more likely to penetrate deeper into the lungs and blood streams unfiltered, could lead to respiratory and cardiovascular diseases. Our finding is cause for concern as participants from the exposed community are at risk of suffering from not only respiratory ill effects but also potential cardiovascular effects not investigated in this study.

Cough was the most reported respiratory symptom in both communities, although the incidence was higher in the exposed community than the control. Additionally, the chance that individuals without a cough transitioning to reporting a cough over time was three times higher in the exposed community compared to the control. Cough is the most basic response to airway irritation; nearly any type of irritation would induce cough compared to other symptoms. These findings are similar to other reports[8,25,39,40] and have also been demonstrated by epidemiological research in occupational settings.[13,14,41] Another symptom that was commonly reported in both communities was nasal irritation. In this study, $PM_{2.5}$ and PM_{10} were significant determinants of both cough and phlegm controlling for area of residence.

There was lower performance on lung indices (FEV1 and FVC), reduced percentage of the predicted values for FEV1 and FVC, among the exposed community compared to the control; at baseline and subsequent seasons. Additionally, the mean lung indices for participants from the exposed community showed wider variations, compared to the control. Although the setting are different from other studies, our results are consistent with findings from studies in occupational settings.[14,42] This may be explained due to pre-existing effects of PM on the participants as most of the participants had lived in the area before the commencement of the study. The wider variation on the lung indices could further be explained by the variability of individual response to the atmospheric irritant. The individual response in-turn is dependent on factors such as the extent of lung damage already sustained, physiological adaptation and genetic make-up, and levels of exposure.[43] The reduction in the lung indices in this population may be suggestive of early obstructive lung disease such as chronic asthma, that participants may be suffering from but may not be aware of; literature shows that such diseases are either poorly diagnosed or under reported in most developing countries.[44-46]

In this study, we found associations between PM and respiratory symptoms and lung indices. Assessment of PM and respiratory symptoms revealed that $PM_{2.5}$ increased the odds of cough, phlegm production and nose irritation by 2.4%, 1.8% and 0.8% respectively. However, $PM_{2.5}$ had a protective effect on wheeze. PM_{10} increased the odds of reporting phlegm production and nose irritation but the effect was delayed up to 3–5 days. Lung indices were lowered with increasing concentration of PM. Similar findings have been reported from other studies[26,47] on the association of ambient air pollution and respiratory ill health and also high levels of particulate matter in residents near industrial plants.[23,25,48] Both respiratory symptoms and reduced lung functions have been consistently associated with exposure to PM; duration and frequency of exposure tend to be determining factors.[36,39,40,49,50] Exposure to PM has been repeatedly associated with decreased FEV1 in human studies.[32,42,51] A single or short-time exposure to cement dust may not cause serious harm but exposure to cement dust of sufficient duration may cause serious irreversible health conditions.[36] Several other studies have reported associations between PM_{10} and acute effects such as increased daily mortality and increased rates of hospital admissions for exacerbation of respiratory disease.[52,53] Nkhama et al. reported that respiratory illnesses recorded at the only public health facility serving the exposed area was above the national prevalence rates of 136/1000 in 2013.[28]

The higher sensitivity of respiratory symptoms, compared to lung function, has been found in studies assessing effects of air pollution on respiratory health. Two possible mechanisms have been postulated; a biological effect of chronic exposure to low levels of air pollution without physiological changes or an increased perception of symptoms by people living near exposed areas.[54] The knowledge of levels of air pollution in Freedom compound are quite high; there has been wide media publication about the possible air pollution from the cement factory. Therefore, there is a possibility that residents from this community could have exaggerated the reported effects. However, it is also possible that PM from cement dust acts more acutely on lung function but the changes may be more transient than the occurrence of symptoms or may be more transient than the occurrence of symptoms present in vulnerable subjects.

In this study, there were no significant differences in major confounding variables such as demographic, length of stay in either exposed or control community, age, type of fuel used for cooking or lighting and gender.

The demographic and social characteristic of the two communities, save for gender, were comparable. The proportion of female participants was much higher in Freedom than Bauleni. At the time of enrolment, a high proportion of potential participants in Bauleni had relocated from the community. Most of the relocated were male therefore skewing the distribution of the sampling frame towards female gender. This may not be unexpected as literature shows that mobile populations tend to be males aged 16–29.[55] Gender in this study thus was a potential confounder that needed controlling for in multivariable analyses.

Although this study adds to the evidence of associations of ambient air pollution with lung function in adults at very low levels, our findings should be interpreted with caution. Precise measurements require direct measurements of the pollutant that includes personal air monitoring and biological markers, however, in this study; only fixed community–level monitoring was performed to measure PM. This may not have captured fully the spatial and temporal heterogeneity of an individual's personal exposure due to a combination of personal behaviors and micro-environmental sources. As a result, individual exposure estimates derived from ambient monitoring data may be subject to measurement error. It is also possible that pollutants, other than PM, could be responsible for the observed adverse health outcomes. Moreover, chemical characterization to ascertain the source apportionment was not conducted, making it impossible to conclude with certainty that the difference observed was due to cement dust. Therefore, future studies should comprise a component of chemical characterization in order to increase the certainty of the real cause. Understanding of the chemical constituents and sources of $PM_{2.5}$ are warranted for designing effective emission control policies.[54,56,57] Further, non-participation of some subjects during follow up may bias observed associations or limit generalizability. However, several other elements of the study design strengthen our results. For instance, the daily repeated measures of both exposure and symptom outcomes across multiple seasons and the use of multivariable models allowed for adjustment of within-subject and between subject correlation and also accounted for temporal trends and other potential confounders. Additionally, the policy relevancy of our findings is strengthened by observation that even individuals who are seemingly healthy could be vulnerable to relatively low levels of PM exposure. Further, communities in the windward and downstream may be affected by PM. Future research should include conducting a study that would measure PM in the communities downstream and windward, including assessing chemical characterization in order to quantify sources of PM.

5.6. Conclusions

Findings from this study add to the body of knowledge that even seemingly healthy people are adversely affected due to exposure to PM at low levels. PM increased the likelihood of suffering from respiratory symptoms and lowered lung function indices. With increasing production and use of cement as has been witnessed in Zambia, effective public and environmental health policies that aim to reduce pollution levels for residents near cement industries could reduce the impact on respiratory health.

5.7. Abbreviations

The following abbreviations are used in this manuscript:

PM: Particulate matter
CL: Confidence level
OR: Odds ratio
WHO: World Health Organisation
MoH: Ministry of Health
CHW: Community Health Workers
USEPA: United States Environmental Protection Agency
NIEHS: National Institute of Environmental Health Sciences

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5.9. Author Contributions

Emmy Nkhama, Kuku Voyi, Seter Siziya, J. Timothy Dvonch conceived and designed the study; Emmy Nkhama, Micky Ndhlovu, Kuku Voyi acquired the data. Mary Lynam, J. Timothy Dvonch carried out laboratory analysis; Graciela Mentz carried out spirometry analysis; Emmy Nkhama, Micky Ndhlovu, Seter Siziya, J. Timothy Dvonch, Mary Lynam, Graciela Mentz analysed and interpreted the data; Emmy Nkhama, Micky Ndhlovu, J. Timothy Dvonch drafted the article; Emmy Nkhama, Micky Ndhlovu, Seter Siziya, J. Timothy Dvonch, Mary Lynam, Graciela Mentz, Kuku Voyi critically revised the manuscript. All the authors read and approved the final manuscript.

5.10. Conflicts of Interest:

The authors declared no conflict of interest.

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Chapter 6 : Exposure to cement dust and respiratory health for communities residing near cement factories: A systematic review of the literature[4]

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6.1. Abstract

Objective: To examine the strength of evidence through systematic review of published literature on the association between effects of exposure to cement dust on respiratory health of communities residing near cement plants. ***Design and data sources:*** A systematic search and review of observational studies in Medline, Embase, and Cumulative Index to Nursing and allied Health Literature (CINAHL), and other sources was conducted. ***Eligibility criteria:*** Peer reviewed articles, published from 1996 to 2018 that investigated effects of exposure to cement dust on human respiratory health (pulmonary functions and symptoms) were included. The studies must have been conducted in communities residing near a cement factory; were original research and written in English. The search key words were: cement, cement dust, cement dust exposure, respiratory health, cement respiratory health effect, cement dust exposure respiratory effect, cement pulmonary function, and cement dust pulmonary health. ***Results:*** 433 studies were retrieved and screened. Only 10 of these met the inclusion criteria. The majority of studies were assessed as being of moderate quality; seven of these studies were cross sectional study design and only five studies performed actual measurement of ambient concentration of particulate matter (PM) while the rest assumed high exposure levels based on other studies' findings. Furthermore, all the five studies that measured exposure used environmental monitoring rather than more precise methods of measuring personal exposure. Most studies reported higher levels of PM2.5 and PM10 in the exposed compared to the controls and demonstrated either a statistically significant difference in the prevalence of respiratory symptoms and reduced pulmonary functions or some degree of association. ***Conclusion:*** This review shows that despite showing some degree of association between exposure to cement dust and respiratory ill health, the existing evidence is insufficient to draw firm conclusion mainly because the studies were of low quality. To improve the quality of evidence, future studies should include panel studies, personal monitoring of the exposure, source apportionment and chemical characterisation coupled with using standardized measurement tools for exposure and outcome at predetermined intervals

6.2. Introduction

The cement industry has grown progressively in both developing and developed countries with an estimated global production of 4.18 billion tons in 2014.[1] Though necessary for infrastructural development, the production of cement involves the release of undesired emissions such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and particulate matter (PM).[2] These emissions significantly contribute to pollution of the ambient air with subsequent effects on the health of the public.[3] PM is of special environmental concern because it constitutes the largest proportion of the emission. The major component of cement dust are particles of size 0.05 to 5.0 micrometer.[4] These particles once inhaled will penetrate into the gas exchange regions of the lungs placing the workers and residents of communities at risk of respiratory illnesses.[3,5]

Some epidemiological studies have reported impairment of lung health in individuals who are exposed to cement dust in communities residing near cement factories. The most commonly reported respiratory symptoms include cough, wheeze, dyspnoea, sneezing, sneezing and phlegm.[6-8] Additionally, pulmonary function indices, measured as forced expiratory volume in one second (FEV1), forced vital capacity (FVC), ratio of FEV1/ FVC , and peak expiratory flow rate (PEFR) have also been shown to be reduced.[6,9] However, other studies have reported no statistically significant relationship between exposure to cement dust and respiratory ill health.[10-12] As a result of the inconsistent findings, there is lack of consensus, on the association between exposure to cement dust and respiratory ill health.

To assess quality of evidence of a relationship between exposure to cement dust and respiratory health of residents in communities near cement factories, a systematic review of the published literature was conducted.

6.3. Study methodology

6.3.1. Literature search

The systematic review protocol is registered: CDR 42017081234. PubMed, Embase and CINAHL were searched for qualifying studies between 2nd December 2017 and 20th February 2018 using a combination of the following key search words: *cement dust*, *PM2.5 and PM10* for the exposure; *and respiratory health, cough, phlegm, bronchitis, chronic bronchitis, pneumonia, asthma and reduced lung function, FEV1, FVC and PEFR* for outcome. A further search was conducted for relevant published and unpublished reports from authors' reference list of eligible and relevant articles. The "Google" engine was used to search for abstracts, conference proceedings and unpublished studies. ML conducted the initial search. The studies identified during the search were later screened by two independent reviewers (MN and EN) through reviewing titles and abstracts to identify potentially eligible studies. This was followed by full text screening of the potentially eligible studies. Any disagreements regarding eligibility were resolved by consensus with the help of a third reviewer (SS).

6.3.2. Eligibility criteria

Only studies meeting the following criteria were included:

i. Peer reviewed comparative studies of any design published from 1996 to 2018,
ii. Population included communities near a cement factory and a control group
iii. Measured exposure to cement dust by central monitoring of ambient air or personal exposure or both
iv. Measured respiratory ill health outcome: either as symptoms such as cough, phlegm, sinusitis, asthma, emphysema, bronchitis or lung function indices (FEV1, FVC, FEV1/FVC ration, PEFR) or both
v. Original research and written in English
vi. Studies conducted in any part of the world

6.3.3. Data extraction

The appraisal of each study was based on the assessment of background and rationale of each study, study design, selection of participants, evidence of bias, eligibility of inclusion criteria, validity of the measurement of exposures and respiratory outcomes; and reported strength of measures of association or differences in prevalence. A Microsoft excel spreadsheet used to extract the data that included full description of study (name of author, title of study, name of journal, year of publication, location), period of study, study design, age and sex of study participants, type of exposures assessed (particulate matter of aerodynamic 2.5 ($PM_{2.5}$), particulate matter of aerodynamic 10 (PM_{10}), suspended particulate matter (SPM), and respirable suspended matter (RSPM)); and health outcomes assessed either as respiratory symptoms (cough, wheeze, dyspnea, nose irritation, asthma, pneumonia, acute or chronic bronchitis) and/or lung function (FEV1, FVC, ratio FEV1/FVC, PEFR)

6.3.4. Assessment of methodological quality of eligible studies

The NIH Quality Assessment Quality Tools for Observational Cohort and Cross Sectional and Quality Assessment Cross sectional studies[13] was used to assess methodological quality and risk bias on all studies that met the eligibility criteria. Each study was evaluated for whether there was a clear research question or research objectives; clearly defined study population, sample size justification or participation rate for eligible persons; clearly stated inclusion and exclusion criteria; defined exposure and outcome variables. Cohort studies or panel were assessed whether sufficient timeframe was allocated in order to reasonably expect to see association between exposure to cement dust and respiratory outcomes. Cross sectional studies were assessed whether independent variables were clearly defined and implemented consistently across all study participants. Furthermore, we assessed whether the investigators were able to confirm that the exposure/risk occurred prior to the development of the condition or defined a participant as a case and controlled for potential confounders. Either "Yes", "No", "Not applicable" or "Not reported" was assigned for each item. The overall score for each individual study was allocated a percentage to allow for comparability.[14]

Studies were classified according to how the investigators reported. Where the study design was not explicitly stated, the authors used standard definitions to assign the study design, otherwise the studies were deemed as unclassified

6.4. Results

6.4.1. Description of eligible studies

A total of 433 articles were retrieved from PubMed (41), Embase (190) and CINAHL (139) while 63 studies were from other sources. Two hundred and ninety (290) studies were excluded as irrelevant. Of the 143 studies that remained, 84 investigated effects of exposure to cement dust on the health of factory workers, 22 were duplicates, 17 were commentaries, 2 were written in

Spanish, 2 ex-vivo and 2 were toxicological studies while one did not meet the criteria having investigated the effect of PM_{10} on non-respiratory health of school children and therefore excluded. Two studies were further excluded because they assessed exposure concentrations only in the communities near cement factories. Eleven (11) studies, met the inclusion criteria for analysis but one was further omitted from analysis for having been of weak methodological quality ((figure 1). Of the remaining ten (10) studies, five were conducted in Asia (Korea (2) and India (3)), one in USA (Texas) and four conducted in Africa (Zambia (3) and Nigeria (1)). Details of the studies, are presented in Table 1.

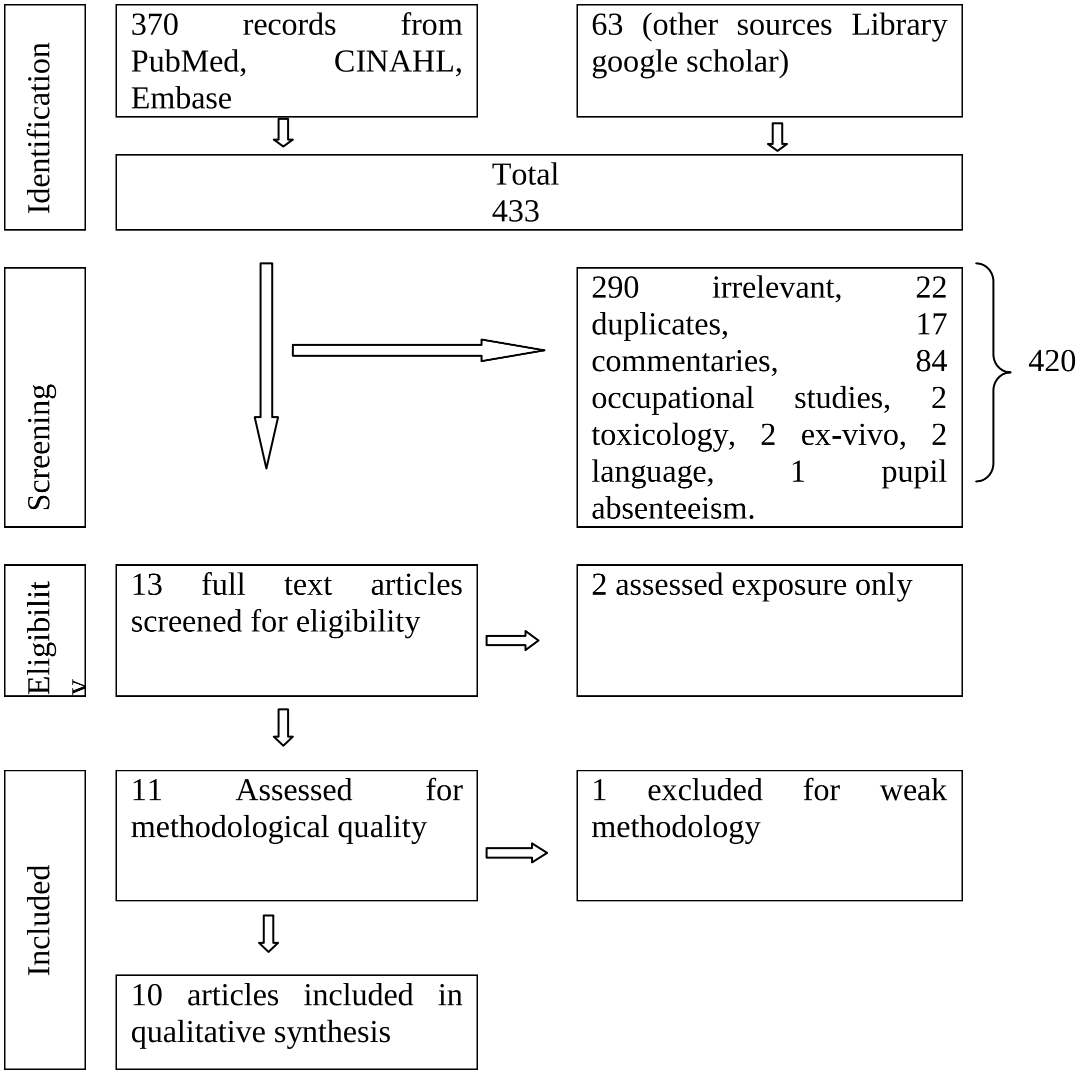

Figure 6-1: Study selection procedure

6.4.2. Bias assessment

Using the NIH quality assessment criteria[13] studies with total scores equal or more than 90% were graded as strong (low risk of bias), those scoring 70-90% as fair quality (moderate risk of bias) while those scoring below 70% were considered weak (high bias). Three studies were assessed to be of low risk of bias (good quality), seven were of moderate risk of bias (fair quality) while one was graded as having high risk of bias (weak) and excluded from analysis. Seven studies used cross sectional study design.[15-21] one used panel.[22] while two studies were not clearly reported by the authors.[23,24] Most studies scored moderate because they neither clearly define the exposure measurement, nor adequately define the exposed and control populations while others did not measure the exposure and failed to control for confounders

6.4.2.1. Selection of study participants: exposed and control groups

Definition of study groups varied widely among studies. The majority of the studies used the community near a cement factory as exposed while identifying communities far from the plant as control. The exposed groups were drawn from communities located near cement plants within a radius of range 1-14 km and mostly situated on the leeward side of the cement plants. In these studies, the distance from source for the control groups ranged from 14 – 19.2km[16,18,19,22-24] to 70km.[17] However, two studies.[20,21] identified two groups from the same community, based on distance from the plant, as representing different exposure levels; 1-5 km for the more exposed group (MEG) and greater than 5 km for the least exposed (LEG). Additionally, the definition of individual participants differed from one study to another; attributes included the age range, and the number of year a participant should have lived in the exposed community prior to the study. For instance, Nkhama et al.[19] included participants aged more than 15 but less than 60 years old, while Sul et al[20] and Seung et al.[21] included participants aged 40 years and older while a study in the USA[15] used participants aged 16 – 76 years. The number of years that participants lived in the exposed community ranged from two[18,19,22] to 5 years[17]. The remainder of the studies did not specify the age range of the participants

6.4.2.2. Assessment of exposure

Broadly, two approaches of assessment of the exposure were used. Five of the ten studies carried out actual measurements of PM concentrations in the ambient air.[16,20,22-24] The rest assumed that the concentration of PM in the ambient air was high in the respective exposed communities based on previous studies and/or retrospective data routinely collected by environmental monitoring agencies. All of the studies that measured the exposure used environmental monitoring using a stationary/central station in the study community. The type of exposure measured varied from one study to another but included $PM_{2.5}$, PM_{10}, suspended particulate matter (SPM), respirable particulate matter (RPM) and atmospheric dust in various permutations. Regardless of the exposure of interest that was measured, the five studies consistently demonstrated elevated PM concentrations in the exposed communities compared to their respective controls. For instance, Mehraj et al.[16] measured total SPM and respirable SPM using high volume respirable sampler and reported an average of 1208.78 $\mu g/m^3$ SPM and 880 $\mu g/m^3$. Nkhama et al.[22] measured 24-hour $PM_{2.5}$ and PM_{10} concentrations in the ambient air at a fixed site for the exposed similar results: the mean seasonal concentrations of $PM_{2.5}$ and PM_{10} as high as 24.93 $\mu g/m^3$ and 68.28 $\mu g/m^3$ respectively in the exposed. The levels were above the WHO standards.[31] Furthermore, Tiwari et al.[23] assessed ambient concentrations of SPM and RPM over three seasons in four sites during winter, summer and rainy months.[23] SPM ranged from 150 to 275 $\mu g/m^3$ while RPM ranged from 78.49 to 105.15 $\mu g/m^3$ with the lowest concentration reported in the rainy and the highest in winter.[23] The findings from these studies were above limits set in the Indian National Air Quality Standards; 70 $\mu g/m^3$ annual and 150 $\mu g/m^3$ for 24-hour for $PM_{10,}$ and 75 $\mu g/m^3$ in 24-hour mean concentration for $PM_{2.5}$ for urban areas.[20]

The concentrations of SPM and RSPM in the ambient air were above the permissible limit of 200$\mu g/m^3$ for SPM, 100 $\mu g/m^3$ for RPM. Nevertheless, the studies used different methods of measuring exposure: 24-hr duration using vacuum pump[22], 8-hour duration using respirable dust samplers,[24] high volume respirable sample.[16]

The five studies[15,17-19,21] that did not measure concentration assumed high exposure levels in the exposed communities based on previous studies or on data routinely collected by other agencies. For instance, Legator et al.[15] in Texas conducted a randomised cross sectional study and assumed exposure concentration levels based on routine data retrospectively collected by the Texas Natural Resource Conservation Commission, 1998.[25]

6.4.2.3. Assessment of health outcomes

The health outcomes measured across all the reviewed studies were generally classified as symptoms and respiratory diseases, and pulmonary functions**.** Studies investigated **s**ymptoms in different combinations; common symptoms being cough, wheeze, production of phlegm and difficulty in breathing while respiratory diseases included asthma, emphysema, bronchitis and pneumonia. Other health outcome measured were irritations of mucous membranes of the sinuses, eyes and nose. In all the studies, symptoms or diseases were participant self-reported and not diagnosed by health professionals. Most of the studies defined the symptoms/disease according to one of the standards: American Thoracic Society (ATS), European Respiratory Society (ERS) or the British Thoracic Society (BTS).[26,27] The symptoms and diseases were measured as either prevalence or incidence, and measures of association were also reported where applicable. Pulmonary function was measured FEV1, FVC, FEV1/FVC, VC and PEFR. These lung indices were reported as percentage predicted or absolute numbers. The following sections discuss each health outcome separately:

6.4.2.3.1. Respiratory symptoms

Four studies investigated cough: Nkhama et al (Cross Sectional, exposed N=223; control, N=197);[18] Nkhama et al (Panel study, exposed N=67; control N=55);[22] Mehraj et al. (cross sectional study, exposed N=1000, control N=1000);[16] Legator et al (cross sectional, exposed N=45, control N=43).[15] Nkhama et al.[18] and Merhaj et al.[16] used the ATS and World Health for aging and Health Council recommended guidelines respectively, while Legator et al.[15] did not report how cough was measured. In the cross sectional study, Nkhama et al.[18] reported higher proportion of participants with cough in the exposed compared to the control community (57% vs. 17.4%; p-value=0.001). Moreover, regardless of the time of the day more people in the exposed community, compared to the control, reported suffering from cough: “cough in the morning” (37.6 vs. 23.5%, p value=0.003) and “cough at night”, (48.1 vs. 14.6, p value <0.001). These results were consistent with the two other cross sectional studies conducted by Merhaj et al.[16] and Legator et al.[15] 96% vs. 15% and 15% vs. 5% (p-value=0.16) respectively. In the fourth study, a panel by Nkhama et al.[22] the incidence rate (per 100-person days) for cough was 46.3 and 13.8 in the exposed and control communities respectively.

Two of these studies[18,22] further investigated whether there was association between exposure and cough. Nkhama et al., in both cross sectional and panel studies, demonstrated statistically significant association between exposure to cement dust and cough; OR 5.64 (95% CI 3.63-8.67; p value < 0.001 and OR 1.02 (95% CI 1.01-1.04) for the cross sectional and panel studies respectively. Both studies controlled for residence, age, marital status, education, occupation, smoking status, floor carpet and type of energy used for cooking and sex, age, height, weight, smoking history, socioeconomic status, asthma and meteorological variables, respectively. However, Legator et al.[15] reported a non-statistically significant difference in prevalence of cough between the exposed and control communities (15% vs. 5% of cough, p= 0.16) after adjusting for smoking only.

The prevalence of wheeze was higher in the exposed community compared to the control in three cross sectional studies[14,16,13] (Mehraj et al., 96% vs. 21%; Nkhama et al.,45.0 vs. 30.6%, p value=0.002; Legator et al., 11% vs.2% p=0.20). One panel study[22] demonstrated that the incidence rate per 100 person-days was higher in the exposed community (13.9 vs. 3.9). However, an association between exposure cement dust and wheeze was found in only one of these studies (OR1.60 95% (1.01-2.54, p=0.045)).[18]

Two studies[15,16] both cross sectional, investigated shortness of breath. A higher prevalence of shortness of breath was reported in the exposed compared to their respective control communities. Mehraj et al.[16] reported 96% vs. 10% while Legator et al.[15] 18% vs. 5% (p-value=0.20) respectively.

Other symptoms investigated were phlegm[18,22] irritation of the mucous membrane such as eye,[16,19] and nasal irritation.[19,22] In all the studies, the prevalence these symptoms were found to be higher in the exposed compared to the respective control communities. Nkhama et al.[18,19,22] demonstrated associations between exposure to cement dust and phlegm, nasal and eye irritations in cross sectional and panel studies. The exposed community in cross sectional study was three times more likely to report phlegm (OR 3.30 (95% CI 2.04, 5.34), p value < 0.001), while this reduced significantly towards the null in the panel study[22] (OR=1.02 (95%1.01, 10.3). Similarly, nasal irritation was four times more likely to be reported in the exposed community (OR=4.36 (95% CI 2.96, 6.55), p value < 0.001) in the cross sectional study[19] while the likelihood reduced to slightly above null in the panel study[22] (OR=1.01 (95% 1.01,1.02). Similarly, Nkhama et.al,[19] in cross sectional study, found that eye irritation was at least twice as likely to be reported in the exposed community compared to the control (OR 2.50 (95%CI 1.65-3.79, p value < 0.001) after adjusting for time where respondents spent most of the time, location of the kitchen and source of energy for cooking. However, the researchers did not investigate this symptom in the panel study. Mehraj at el.[16] also reported higher prevalence of eye irritation (96% vs. 12%), although, the study did not investigate whether there was an association.

In addition to the above symptoms, some studies investigated the prevalence of various respiratory diseases. These included asthma, chronic bronchitis, pneumonia and emphysema in different permutations. The prevalence of all the respiratory diseases was higher in the exposed communities compared to the control. Merhaj et al.[16] and Nkhama et al.[18] demonstrated that asthma was 49% vs 1% and 9.7% vs 1.1% in the exposed compared to the control respectively. Additionally, the exposed community was almost six times more likely to report asthma compared to the control (adjusted OR 5.67, 95% CI 2.00,16.05, p-value=0.003).[18] Similarly, the prevalence of chronic bronchitis was reported higher in the exposed than in the control communities; 57% vs. 0, 11% vs. 2% (p=0.20) and 2.3% vs. 0.8% (p=0.090) in Merhaj et al., Legator et al., and Nkhama at el., respectively.[15,16,18] However, Legator et al.[15] found that the difference in prevalence between the two communities was not statistically significant while Nkhama et al.[18] found only marginal association between residence in the exposed community and chronic bronchitis (OR 3.45 (95% CI 0.49 – 24.56; p-value=0.098). In the case of pneumonia, Legator et al.[15] and Nkhama et al.[18] found the prevalence to be higher in the exposed communities: 5% vs 4% (p=1.00) and 20.1% vs. 3.5% (p value<0.001) respectively. Furthermore, Nkhama at el.[18] demonstrated that the exposed community was four times more likely to report pneumonia compared to the control (OR 4.38 95% CI 1.28 – 14.95; p-value=0.021).

The more exposed group (MEG) was more than twice likely to have emphysema compared to the least exposed group (LEG) OR 2.56 (95 % CI 1.64–3.99) after adjusting for sex, age, BMI, smoking history, residency, and use of firewood.[21] Similarly, Merhaj et al.[16] and Legator et al.[15] measured emphysema and reported higher prevalence in the exposed compared to the control: 9% vs.0% and 2% vs. 0% (p-value=1.00) respectively.

Nkhama et al.[22] also demonstrated that a 1 μg/m^3 increase in $PM_{2.5}$ increased the odds of cough, phlegm and nose irritation by about 2% controlling for season, smoking status and asthma. However, it had an opposite effect on the odds of wheeze (p-value < 0.05). Similarly, an increase in PM_{10} concentration reduced the odds of cough, phlegm, wheeze and cough, but was only statistically significant for phlegm and nose irritation. Furthermore, PM_{10} seemed to have delayed effect with regards to phlegm and nose irritation; a statistically significant effect for phlegm and nose irritation was observed 3–5 days after exposure (lag 3 and 5); phlegm lag 5 [OR = 1.00 (0.06–1.00)]; and nose irritation lag 3 [OR = 1.00 (1.00–1.10)] and [OR = 1.00 (0.06–1.01)].

6.4.2.3.2. Pulmonary functions

Three studies investigated pulmonary functions.[17,20,22] A Nigerian study demonstrated that the mean FVC, FEV and FEV% were found to be lower in the exposed compared to the control communities.[17] Furthermore, the same study found obstructive lung impairment more frequently in the exposed community than the control (17.2% vs. 7.8%; (p=0.0215)).

The second study,[20] evaluated both a pre- and post-bronchodilator pulmonary function tests (PFT) on FEV1 and FVC for a more exposed group (MEG) (N=318) living within a 1 km radius of a cement plant and a less exposed group (LEG) (N=129) living more than 5 km away from the same plant. The FVC% predicted value estimated using the Korean equation showed both lung function impairment to be higher in the exposed compared to the control communities; 9.7% vs. 8.5% for obstructive and 21.6% vs. 12.4% restrictive types of impairments. In that study, adjusting for sex and age, the exposed group was 2.63 (95% CI 1.50,4.61) and 2.55 (95% CI 1.37,4.76) more likely to develop the obstructive and restrictive types respectively compared to the control. The third study[22] found lower performance on lung indices in the exposed community compared to the control: FEV1, and FVC predicted exposed was six and four percentage points lower respectively. However single-pollutant regression models showed a non-statistically significant reduction in FEV1 and FVC over time.[22]

Table 6-1: Summary of studies conducted in community settings

Author	Design	Participants	Measured		Results			Confounders adjusted
Legator et al. 1998, Texas	CS	Exp n=58 Cont n=54	NM	RS	-	Emphysema, 2% vs.0 (p-value: 1.00) Coughing up blood, 2% vs. 0 (p value:1.00) Pneumonia, 4 vs.5% (p-value=1.00) Lung disease, 4 vs. 0 (p-value: 0.49) Wheezing, 11 vs. 2% (p value: 0.20) Persistent cough, 15 vs. 5% (p-value: 0.16) Persistent bronchitis, 11 vs. 2% (p-value: 0.20) Shortness of breath, 18 vs. 5% (p-value: 0.09)		Smoking
Merhaj et al. 2013, India.	CS	Exp n=2000 (~2-3 km) Cont=NS (~40km)	TSPM, PM10, RSPM	RS	880µg/m3	Eye irritation, 97 vs. 12% Shortness of breath, 96 vs. 10 Cough, 96 vs. 15% Wheeze, 96 vs. 21%; Asthma, 49 vs. 1		NR

Author	Design	Participants	Measured		Results			Confounders adjusted
						C. bronchitis, 57 vs. 0 Emphysema, 9 vs. 0		
Nkhama et al. 2015, Zambia[a]	CS	Exp n=223 (1km) Cont n=197 (18km)	NM	RS	-	Eye irritations,78.2 vs. Eye irritation, 78.2 vs. 49.9% (p value<0.001) Nose irritation, 66.9 vs.	OR 2.50 (95%CI 1.65, 3.79) OR 4.36	Age, gender, marital status Occupation Smoke status
						29.4%, (p value<0.001) Sinus irritations, 73.7 vs. 53.3% (p value<0.001)	(95% CI 2.96-6.55 OR 1.94 (95% 1.19-3.18)	Energy for light/cooking
Nkhama et al. 2015 Zambia	CS	Exp=223 (1 km); cont=197	NM	RS	RP	cough morning 37.6 vs 23.5%, (p value =0.003); cough night (48.1 vs. 14.6, p value<0.001); increased cough with phlegm” (55.9 vs. 13.9%; p value <0.001). (45.0 vs. 30.6%, p value	5.64 (95% CI 3.63-8.67); phlegm OR 3.30 (95% 2.04-5.34); wheeze OR 1.60 (95%	Residence, age, gender, smoking status presence of floor carpet, lighting and cooking

Author	Design	Participants	Measured		Results			Confounders adjusted
						=0.002 Pneumonia 20% vs. 3.5%; (p value<0.001).	1.01-2.54); chronic OR 3.34 (95% 0.49-24.36)	energy
Tiwari et al. India, 2012 .	UC	Expo n=200 (< 1.5 km)	RPM, SPM	RS	SPM range: 150.84 µg/m^3 (rainy) to 340.15 in (winter) season RPM range: 83.48 (rain) to 132.28	Respiratory disease 19.63%; eye irritation 17.78%,		NR
					µg/m3, (winter) season			
Priyanka et al. India, 2013.	UC	NS	SPM	RS	281.07 to 342.25 µg/m^3; 322.29 - 387.20 µg/m^3 and 172.25–	RS= 28.35 - 52.54% (five sites)		NR

Author	Design	Participants	Measured		Results			Confounders adjusted
					213.03 µg/m^3			
Merenu et al 2015, Nigeria	CS	Exposed n= 244 (radius of 1 km) Cont n=270 (70 km from plant)	NM	LFT	-	FVC 2.5L (p=0.001 95% CI 0.21,0.59) FEV1 2.2 p=0.024 (95% CI 0.03, 0.37) FEV% 84.9% (p=0.0002 95% CI -7.88, 2.52]		NR
Hyun Seung Lee et al 2016, Korea	CC	Exp=1,046 (1 km) Cont=317 (>5 km)	NM	X-Ray HRTC	-	9.1% LEG with 11.4% on HRCT; 14.3% MEG with 17.8% HRCT	OR 2.56 (95% CI 1.64-3.99	
Sul Ha Kim et al. 2013	CS	Exp: 319 (1 km) Cont=129 1km within (>5km)	PM10	FEV1, FVC	45.5µg/m3 95% Cl 37.8–53.3)>1km [PM10]; 38.5µg/m3 (95% Cl 32.3–44.7) [PM10]	Obstructive=9.7% MEG); 8.5% (LEG) Restrictive= 21.6% MEG); 12.4% (LEG)	OR 2. 63 95% CI 1.50-4.61	Age, sex
					25.5µg/m			

Author	Design	Participants	Measured		Results			Confounders adjusted
					3 (95% Cl 18.7-32.3) < 1km [PM2.5];19 (95% Cl 14.1-24.6) >5 [PM2.5]			
Nkhama et al 2017	Panel	Exp=63 (1 km) Cont =55 (18 km)	PM$_{2.5}$, PM$_{10}$	RS, FEV1, FVC, FEV1/ FVC	PM2.5, PM10 ranged Ranged from 2.39-24.93 µg/m3 and 7.03–68.28 µg/m exposed vs. control community 1.69-6.03	Cough, 46.3 vs. 13.8[‡]; Phlegm production, 41.2 vs 9.6[‡] Nose irritation, 49.0 vs.12.5[‡]; Wheeze 13.9 vs 3.9[‡] FEV1[†] 6% points lower than control, FVC[†] 4% points lower than control Cough OR 1.02 (95%1.01-104) Phlegm=1.02 (95%1.01-		

Author	**Design**	**Participants**	**Measured**		**Results**			**Confounders adjusted**
					µg/m3	10.3 Nose irritation OR 1.01 (95% 1.01,1.02)		

CS, cross sectional; CC, case control; P, panel study; UN, unclassified; Exp, exposed group; cont, control group; total dust; RD, respirable dust; RPM, respiratory particulate matter; SPM, suspended particulate matter; RS, respiratory symptom; NM, not measured; LFT, lung function test; [a], P<0.05; [b], P<0.0001; C, researchers assumed exposure levels based on existing literature; NS, not stated; NR, not reported; HRCT, high resolution computed tomography.† percentage predicted value

6.5. Discussion

This review shows that most studies demonstrated association between exposure to cement dust and respiratory ill health. However, the evidence is not strong as the measures of effects were weak in some cases and there were contradictory findings for some symptoms and pulmonary function indices across studies. Additionally, the majority of the studies were cross sectional and half of the reviewed studies did not perform robust measurement of the exposure. Due to the heterogeneity of studies; the population studied and variance in results, this review will focus on discussing and placing emphasis methods applied in the studies.

The contradictory findings could be attributed to several factors; not least the high variation in sample size, non-uniformity of characteristics of the exposed groups across the studies, and inconsistent methods of measuring the exposure and outcome. For example, Legator et al[15], using a sample size of 58 and 54 in the exposed and control communities respectively, found a higher proportion of participants in the exposed group compared to the control, reporting cough yet the difference was not statistically significant. On the other hand, Nkhama et al.[18] who used a larger sample size of 220 in each of the communities was able to find a statistically significant difference in proportions reporting cough. This could arise from (a) lack of power to detect a difference in the former study compared to the latter, (b) the method of measuring "cough" (c) the study settings (developed versus developing country).

The assessment of association between any exposure and outcomes requires precise and accurate measurements of both. The studies' results are difficult to difficult to compare because different methods used for measuring the exposure and /or outcomes across studies. For instance, one study[18] measured cough as "morning cough" and "night cough" which was then analysed as "composite cough" by combining any of the types while Legator et al.[15] reported "persistent cough".

The methods employed in measuring the exposure were inaccurate making the studies incomparable. Studies either assumed exposure levels based on previous studies or used an environmental monitoring approach as a proxy measure of individual participant exposure. Even with several studies[16,20,22-24] showing that the ambient air in communities near cement factories contains high levels of cement dust and other emissions, relying on retrospective data or extrapolating data from other situations is not a reliable method in assessing relationships. This is because a number of factors, such as temperature, humidity and wind speed,[28] can affect the instantaneous PM burden in the ambient air. Environmental conditions thus could result in wide variability in exposure levels in exposed communities and as such assumptions cannot be made about exposure levels especially in studies investigating associations. Environmental monitoring of the ambient air, though better than the first approach, is also below the minimum requirement as it does not measure the actual individual exposure. There are a number of limitations with this approach especially that it does not account for variation in the micro-environment around the individual participant and activity of the participant. For instance, participants may move out of the study for prolonged period of time in a day meaning that the individual stops being exposed for that period of time. This leads to erroneous conclusions about the exposure level for the individual. Furthermore, there were notable differences in the actual measurements; some studies conducted 24-hour continuous monitoring while the other conducted 8-hour monitoring. The 8-hour[18] monitoring approach is compromised in that not only does it fail to measure individual exposure; the method also fails to reflect daily total exposures for the exposed community. The studies that did not measure exposure but assumed exposure levels based on findings from other studies in different communities could have been incorrect in concluding “effect’.[15,17,18,19,21] These studies arguably did not help in resolving the question of whether or not exposure to cement dust is associated with respiratory ill health. Additionally, chemical characterization was omitted in most studies in this review. Chemical characterization is essential in establishing the source of the exposure. Without knowledge of chemical composition and resultant source apportionment, it is difficult to confidently associate the observed respiratory ill health to exposure to cement dust.

All studies measured self-reported symptoms that were not verified with hospital records. It is possible that self-reporting could have introduced reporting (recall) bias especially because that there had been much media publicity about the adverse effects that cement plant has had on the environment and people living in the vicinity of the plant.[15,18] Therefore, respondents from the exposed community could have exaggerated the occurrence of respiratory problems. Except for Legator at el.[15] none of the studies blinded the respondent in the exposed communities. Blinding of respondents is a useful tool in addressing such bias. However, in assessing community environmental exposures and measurement of effects it is difficult to implement this approach.[29]

Findings from this review suggest that exposure to cement dust has variable effects on the respiratory tract. Whereas cough seemed to be consistently related to the exposure, in almost all the studies regardless of study design, other symptoms showed variable relationships. For instance, wheeze, shortness of breath and phlegm was not significantly associated to the exposure in some studies. This implies that studies must strive to measure and report each respiratory symptom separately to reflect the fact that the respiratory effects are not uniform. The manifestations of the effects on the respiratory system may be related to the constituent elements of the emitted cement dust. It is therefore imperative that studies must go further than measuring total dust concentrations but must also chemically characterise the individual constituents of the emissions. Several studies show that emission consist of sulphur dioxide (SO2), nitrogen oxides (NOx) and carbon monoxide (CO) has been shown to result in cough, wheeze and phlegm.[30]

Limitation

Important limitations were observed for the studies included in this review. Most important is the study design used in investigation this question. Cross sectional studies are ill equipped to answer association question but were the majority. None of the studies reviewed performed chemical characterisation of the exposure, neither was source apportionment done. In the absence of the former it is difficult to associate the exposure with health outcome while with the later even if there were observed increases in the exposure within the exposed communities, it is difficult to account for the amount of particulate matter “cement dust” from the cement factories. There was generally incomplete information in the articles leading to some studies being excluded. One study,[16] although included in this review, did not state the sample size and population characteristics of the control community, an essential component of comparative studies. Similarly, Priyanka et al.[24] and Tawiri et al.[23] did not give proper descriptions of the study participants. The researchers attempted to contact some authors of the studies but received no response by the time this systemic review was completed.

Limitations related to this systematic review included insufficient literature on studies that have assessed the effect between cement dust exposure and respiratory health. Moreover, the studies were varied in terms of sample size, measurement of exposure, specific respiratory symptoms measured and statistical methods making it impossible to conduct a conduct meta-analysis.

6.6. Conclusion

Despite studies included in this review showing some degree of association between exposure to cement dust and respiratory ill health, the existing evidence is insufficient to draw firm conclusion. Most studies used a cross sectional design which has an inherent weakness providing evidence of causation or associations. Other weaknesses included suboptimal measurement of exposure and outcomes. To improve the quality of evidence of association between exposure to cement dust and respiratory ill health, it is recommended that future studies should employ methods that increase accuracy in measuring the exposure and outcomes. These should include personal monitoring of the exposure, source apportionment carried out and chemical characterisation coupled with using standardized measurement tools for exposure and outcome at predetermined intervals. Highlighted in this review is that even without strong evidence as a result of methodological weaknesses, there are sufficient indicators that the quality of air in communities around the cement plants is poor and that the burden of respiratory symptoms and diseases is much higher compared to other communities. It is thus recommended that cement factories should institute measure to reduce emission into the ambient so as to improve the quality of air for communities residing near the plants.

Results from this review, could help to improve the study designs for future research, and inform public health policy even in the midst of the current uncertainty on the relationship of exposure to cement dust and respiratory health.

6.7. References

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Chapter 7 : Conclusion and recommendations

7.1. Background

The key question for this PhD was:

> *Is there an association between exposure to cement dust in the ambient and respiratory adverse health effects for communities living within the dispersion fallout range in Chilanga after adjusting for potential confounders?*

The work described in this thesis attempted to answer this question. There is paucity of information on the effects of cement dust on the respiratory health of communities residing near cement factories. Understanding the effects of exposure to cement dust on human respiratory health, if any, would allow for interventions that would balance between cement production and protection of human health for this and similar communities elsewhere.

This study was conducted in a community situated at the edge of a cement factory in Chilanga, Zambia and a control community located 18 km away from the exposed community. To the best of our knowledge this was the first study conducted on this community focusing on the effect of cement dust derived particulate matter on the respiratory health of the residents of the community.

This thesis comprises seven (7) chapters with the following outlines:

Chapter one: Provided an overview of pollution of the ambient with a focus on cement derived dust “particulate matter” and a review of the literature regarding exposure to the cement dust and respiratory health.

Chapter two: Provided the research methodologies highlighting the two phases of the study: cross sectional succeeded by a panel study that followed up participants for a year at predetermined seasonal interval.

Chapter three: Investigated the prevalence and determinants of mucous membrane irritations among residents of a community residing near a cement factory and a control community. This study showed that residence within the vicinity of a cement production plant increases the odds of experiencing symptoms of irritation of nose, eyes and sinuses. The excessive prevalence of all types of mucous membrane irritations in the exposed community compared to the control could be attributed to increased exposure to chemical and particulate matter irritants in the ambient. In this study, the prevalence of nasal irritation among female participants was higher compared to male counterparts in both communities. The differences could be due to cooking on open fires, exposure to chemicals found in household cleaning agents and other factors that were not measured in the study. These results were consistent with reports in other studies.[1,2] Furthermore, age, residence and type of occupation were predictors of sinusitis in multivariable analysis. The findings were consistent with findings from similar studies conducted elsewhere.[3-5]

Chapter four: Investigated the prevalence of pulmonary symptoms in a community residing near a cement factory in comparison to a control community. The study showed that the prevalence of pulmonary symptoms (cough phlegm production from the chest, wheeze, asthma and pneumonia) was higher in residents in the exposed community compared to the control. The difference was evident even after adjusting for potential confounders such as smoking, presence of floor carpet in the household, source of energy for cooking and for lighting. This suggested a positive association of exposure to polluted ambient and increased pulmonary symptoms.

Chapter 5: A panel study design was conducted to investigate the seasonal variations in concentration of $PM_{2.5}$ and PM_{10} and effects on respiratory symptoms and lung function indices in the community around a cement factory. The concentration of $PM_{2.5}$ and PM_{10} in the ambient was higher in the exposed compared to the control community. There was association between particulate matter in the ambient and respiratory symptoms and lung indices. All respiratory symptoms were reported much more frequently in the exposed compared to the control community. Lung indices should an inverse relationship with concentrations of particulate matter in the ambient.[6-11] PM_{10} increased the odds of reporting phlegm production and nose irritation but the effect was delayed up to 3-5 days. Findings from this study add to the body of knowledge that even seemingly healthy people are affected due to exposure to PM at low levels.

Chapter 6: Focused on systematic review of the literature of studies on cement dust exposure and respiratory health both in occupational settings and communities. Despite studies being conducted in different settings (occupational and community), the review suggested varying associations between exposure to cement dust and respiratory health effects. Additionally, it was demonstrated that there is lack of standard measurement approaches in exposure levels as well as classification of study participants to either exposed or control groups. These lapses make it difficult to firmly associate cement dust with respiratory ill effects.

7.2. Potential bias, limitations and uncertainties

The study encountered the following weaknesses:

- Chapter three and four used cross sectional study design; this has an inherent weakness of providing evidence of causal relationships. Because of this, conclusion on the relationship between cement dust exposure and prevalence of respiratory health symptoms cannot firmly be drawn.
- In the same chapters (three and four) PM, NO_2, SO_2 and any other possible pollutant in the ambient were not measured and, characterization of the pollutant and source apportionment not done. It is therefore difficult to state, with certainty, that the observed differences in prevalence of irritations and/or respiratory symptoms in the two communities were due to the presence of emissions from the cement plant. It is possible that there were other sources of pollution in the exposed community that this study did not account for.
- In chapter three, information regarding allergic tendencies, which are possible causes of symptoms of mucous membrane irritation or respiratory symptoms, was not collected thus limiting interpretations to some extent.
- Symptoms were self-reported and not verified with hospital records. Self-reporting could have introduced recall bias especially that there has been a lot of media publicity about the adverse effects the cement plant has had on the environment and people in the vicinity of the plant.[12] Therefore, respondents from the exposed community could have exaggerated the occurrence of respiratory problems, leading to over-reporting of the effect.
- There was also a likelihood of misclassification of employment status and exposure as most respondents could not accurately describe their occupational tasks nor was daily time spent in the polluted ambient measured precisely.

- The results may not be generalisable to both sexes in the study since the proportion of female respondents was far more than would be expected in the general population. Moreover, the number of respondents with pneumonia, asthma and bronchitis was small leading to unreliable estimates of effect size on these conditions.
- Precise measurements require direct measurements of the pollutant that includes personal air monitoring and biological markers, however, in the panel study only fixed monitoring was performed to measure particulate matter in the ambient. This may not have fully captured the spatial and temporal heterogeneity of an individual's personal exposure due to a combination of personal behaviours and micro-environmental sources. As a result, individual exposure estimates derived from ambient monitoring data may have been subjected to measurement error. It is also possible that pollutants, other than, PM could be responsible for the observed adverse health outcomes.
- Although few, the non-participation of some subjects during follow up (hot dry and rainy season) may bias observed associations or limit generalisability of the results.

7.3. Strength of the study

Despite the limitations highlighted above, several other elements of the study design strengthen results from this study. For instance, the daily repeated measures of both exposure and symptom outcomes across multiple seasons and the use of multivariable models allowed for adjustment of within-subject and between subject variations and also accounted for temporal trends and other potential confounders. Additionally, the policy relevancy of our findings is strengthened by observation that even individuals who are seemingly health could be vulnerable to relatively low levels of PM exposure. Further, communities in the windward and downstream may be affected by $PM_{2.5}$ which tends to remain suspended longer and may travel further than the community of interest in this study. Moreover, the use of multidisciplinary and collaboration team comprising researchers from Chainama College of Health Sciences, Copperbelt University (Micheal Chilufya Sata School of Medicine), University of Michigan (Department of Health Sciences) and University of Pretoria (School of Health System and Public Health), to a certain extent provided external validity of the results.

7.4. Conclusion, future perspectives and recommendations

Effective public and environmental health policies that aim to reduce pollution levels for residents near industrial areas might reduce the burden on respiratory health. Additionally, restriction of industrial emissions coupled with on-going monitoring and regulatory enforcement are needed to ensure that PM levels in the ambient air are kept within recommended levels to safeguard the respiratory health of nearby community residents

7.5. Policy and practice

The work described in this thesis provides evidence that there were associations between $PM_{2.5}$ and PM_{10} on one hand and respiratory symptoms and lung function indices on the other hand in community residing near the cement factory. Regardless of the season, both $PM_{2.5}$ and PM_{10} was raised in the exposed community compared to the control. Moreover, residence was a predictor of higher prevalence of respiratory symptoms and lower lung function indices. Results from this study will contribute to better policy making decisions. For instance, the Zambia Environmental Management Agency, which is a regulatory agency that focuses on environmental management could use these findings to enhance monitoring and ensuring that particulate matter released in the ambient are kept within recommended levels in order to reduce the burden on respiratory health of the resident of the community. Although there had been previous media reports about perceived excessive exposure levels of emissions from the cement factory, this thesis provides objective evidence that could be used to sensitize the community about the adverse impacts of exposure to cement dust on the respiratory symptoms and subsequently provide health education. It is further recommended that community leaders could engage cement factory management to install dust abatement systems in the cement production process that could reduce the amount of fugitive dust in the nearby communities.

7.6. Research

Future research recommendations include:

- Chemical characterization of particulate matter in order to quantify the source. The understanding of the chemical constituents and sources of $PM_{2.5}$ and PM_{10} are warranted for designing effective emission control policies.
- Further research should use standardized measurement tools for exposure and outcome at predetermined intervals
- Future research should involve collaboration between ZEMA and/researchers to establish legal thresholds for $PM_{2.5}$ and PM_{10}. Furthermore, future studies should be undertaken to assess the level and impact of SO_2, NO_2 and heavy metal arising from cement plant, on the residents near cement factories.
- Future studies should provide for panels that are followed up for more than one year, with the use of personal monitoring equipment and biomarkers (i.e sputum) to determine dose of cement in each individual disregarding the microenvironment
- Future research should include conducting a study that would measure $PM_{2.5}$ in the communities downstream and windward, including chemical characterization in order to ascertain source of PM.
- The future research directions and public health implications should include the proposal on establishing pilot registry system for surveillance of exposure (PM) and outcome/ effects on respiratory health.

7.7. Reference

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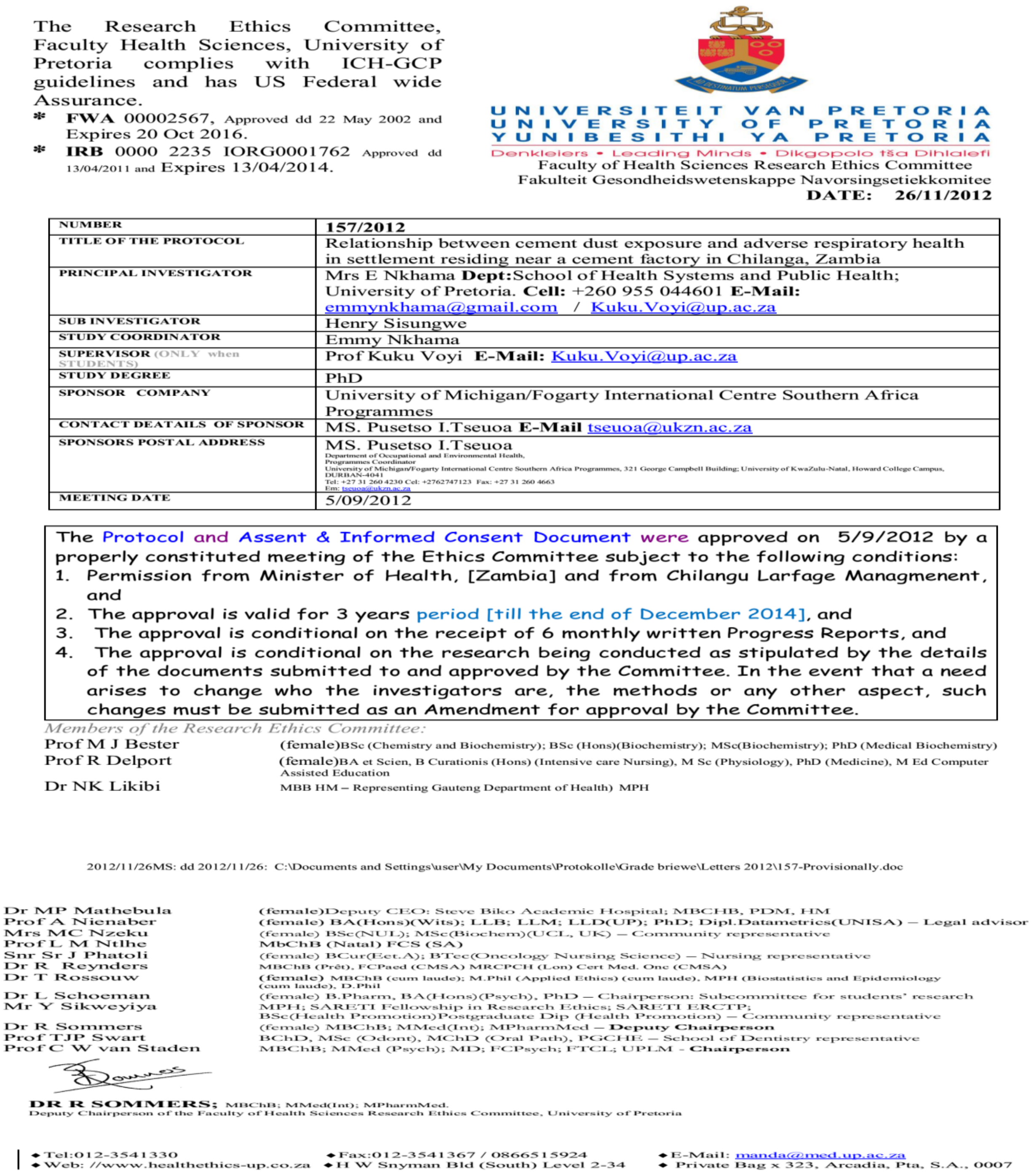
Appendix 1: University of Pretoria research ethics clearance



The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- **FWA** 00002567, Approved dd 22 May 2002 and Expires 20 Oct 2016.
- **IRB** 0000 2235 IORG0001762 Approved dd 13/04/2011 and Expires 13/04/2014.

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Faculty of Health Sciences Research Ethics Committee
Fakulteit Gesondheidswetenskappe Navorsingsetiekkomitee

DATE: 26/11/2012

NUMBER	157/2012
TITLE OF THE PROTOCOL	Relationship between cement dust exposure and adverse respiratory health in settlement residing near a cement factory in Chilanga, Zambia
PRINCIPAL INVESTIGATOR	Mrs E Nkhama **Dept:**School of Health Systems and Public Health; University of Pretoria. **Cell:** +260 955 044601 **E-Mail:** emmynkhama@gmail.com / Kuku.Voyi@up.ac.za
SUB INVESTIGATOR	Henry Sisungwe
STUDY COORDINATOR	Emmy Nkhama
SUPERVISOR (ONLY when STUDENTS)	Prof Kuku Voyi **E-Mail:** Kuku.Voyi@up.ac.za
STUDY DEGREE	PhD
SPONSOR COMPANY	University of Michigan/Fogarty International Centre Southern Africa Programmes
CONTACT DEATAILS OF SPONSOR	MS. Pusetso I.Tseuoa **E-Mail** tseuoa@ukzn.ac.za
SPONSORS POSTAL ADDRESS	MS. Pusetso I.Tseuoa Department of Occupational and Environmental Health, Programmes Coordinator University of Michigan/Fogarty International Centre Southern Africa Programmes, 321 George Campbell Building; University of KwaZulu-Natal, Howard College Campus, DURBAN-4041 Tel: +27 31 260 4230 Cel: +2762747123 Fax: +27 31 260 4663 Em: tseuoa@ukzn.ac.za
MEETING DATE	5/09/2012

The Protocol and Assent & Informed Consent Document were approved on 5/9/2012 by a properly constituted meeting of the Ethics Committee subject to the following conditions:

1. Permission from Minister of Health, [Zambia] and from Chilangu Larfage Managmenent, and
2. The approval is valid for 3 years period [till the end of December 2014], and
3. The approval is conditional on the receipt of 6 monthly written Progress Reports, and
4. The approval is conditional on the research being conducted as stipulated by the details of the documents submitted to and approved by the Committee. In the event that a need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

Members of the Research Ethics Committee:

Prof M J Bester	(female)BSc (Chemistry and Biochemistry); BSc (Hons)(Biochemistry); MSc(Biochemistry); PhD (Medical Biochemistry)
Prof R Delport	(female)BA et Scien, B Curationis (Hons) (Intensive care Nursing), M Sc (Physiology), PhD (Medicine), M Ed Computer Assisted Education
Dr NK Likibi	MBB HM – Representing Gauteng Department of Health) MPH

2012/11/26MS: dd 2012/11/26: C:\Documents and Settings\user\My Documents\Protokolle\Grade briewe\Letters 2012\157-Provisionally.doc

Dr MP Mathebula	(female)Deputy CEO: Steve Biko Academic Hospital; MBCHB, PDM, HM
Prof A Nienaber	(female) BA(Hons)(Wits); LLB; LLM; LLD(UP); PhD; Dipl.Datametrics(UNISA) – Legal advisor
Mrs MC Nzeku	(female) BSc(NUL); MSc(Biochem)(UCL, UK) – Community representative
Prof L M Ntlhe	MbChB (Natal) FCS (SA)
Snr Sr J Phatoli	(female) BCur(Eet.A); BTec(Oncology Nursing Science) – Nursing representative
Dr R Reynders	MBChB (Prêt), FCPaed (CMSA) MRCPCH (Lon) Cert Med. Onc (CMSA)
Dr T Rossouw	(female) MBChB (cum laude); M.Phil (Applied Ethics) (cum laude), MPH (Biostatistics and Epidemiology (cum laude), D.Phil
Dr L Schoeman	(female) B.Pharm, BA(Hons)(Psych), PhD – Chairperson: Subcommittee for students' research
Mr Y Sikweyiya	MPH; SARETI Fellowship in Research Ethics; SARETI ERCTP; BSc(Health Promotion)Postgraduate Dip (Health Promotion) – Community representative
Dr R Sommers	(female) MBChB; MMed(Int); MPharmMed – **Deputy Chairperson**
Prof TJP Swart	BChD, MSc (Odont), MChD (Oral Path), PGCHE – School of Dentistry representative
Prof C W van Staden	MBChB; MMed (Psych); MD; FCPsych; FTCL; UPLM - **Chairperson**

DR R SOMMERS; MBChB; MMed(Int); MPharmMed.
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

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YUNIBESITHI YA PRETORIA

Faculty of Health Sciences Research Ethics Committee

30/03/2017

Mrs E Nkhama

Department of School of Health Systems and Public Health

University of Pretoria

Dear Mrs E Nkhama

RE.: 157/2012 ~ Letter dated 8 March 2017

NUMBER	**157/2012**
TITLE OF THE PROTOCOL	Relationship between cement dust exposure and adverse respiratory health in settlement residing near a cement factory in Chilanga, Zambia
PRINCIPAL	Mrs E Nkhama **Dept:**School of Health Systems and Public

INVESTIGATOR	Health; University of Pretoria. **Cell:** +260 955 044601 **E-Mail:** emmynkhama@gmail.com

We hereby acknowledge and approved the following document:

- Extension for study until 30 December 2017.

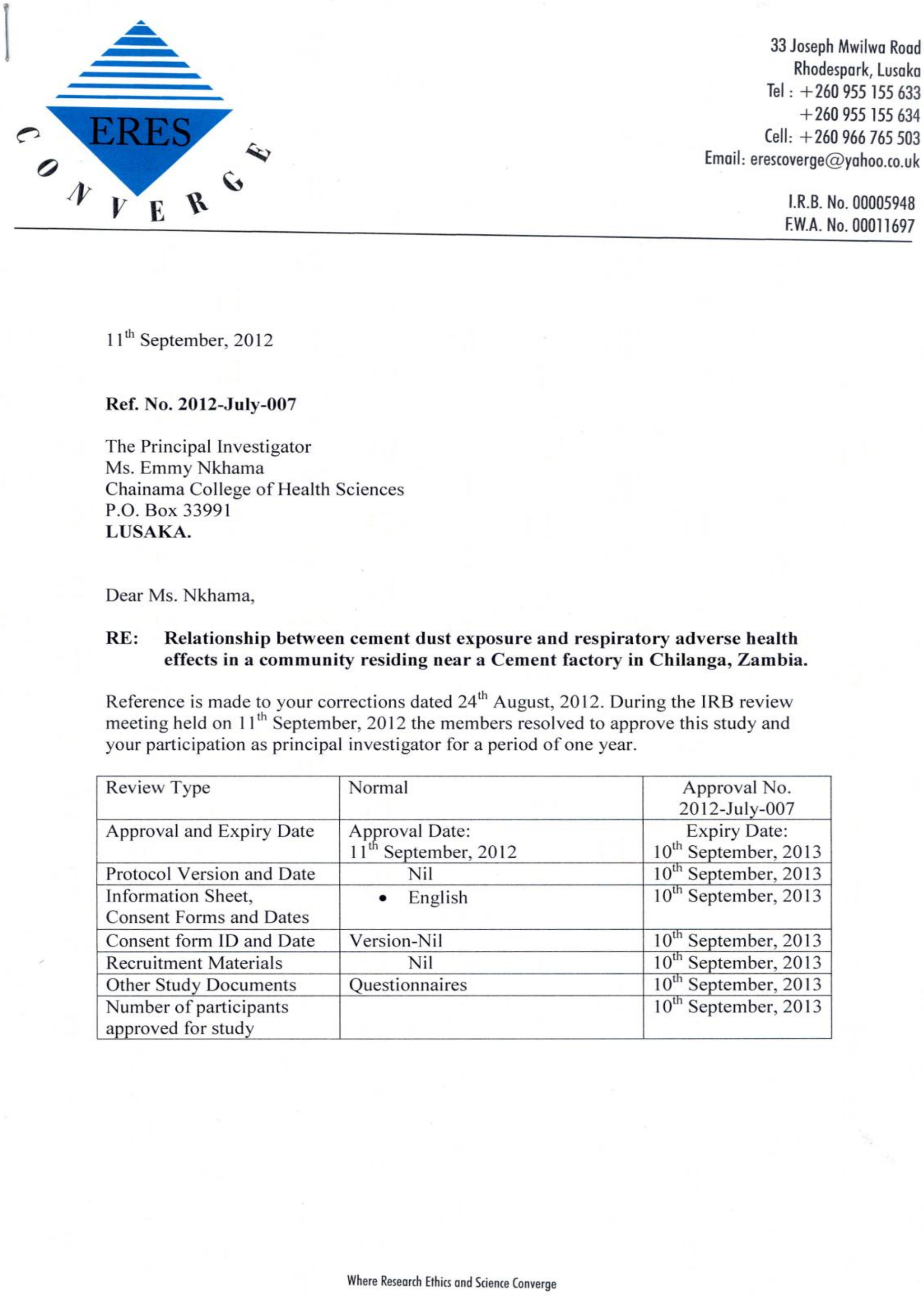
This will be processed in due course and filed.

With regards

Dr R Sommers; MBChB; MMed (Int); MPharMed; PhD

Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

Appendix 2: ERES research ethics clearance



ERES
CONVERGE

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I.R.B. No. 00005948
F.W.A. No. 00011697

11th September, 2012

Ref. No. 2012-July-007

The Principal Investigator
Ms. Emmy Nkhama
Chainama College of Health Sciences
P.O. Box 33991
LUSAKA.

Dear Ms. Nkhama,

RE: Relationship between cement dust exposure and respiratory adverse health effects in a community residing near a Cement factory in Chilanga, Zambia.

Reference is made to your corrections dated 24th August, 2012. During the IRB review meeting held on 11th September, 2012 the members resolved to approve this study and your participation as principal investigator for a period of one year.

Review Type	Normal	Approval No. 2012-July-007
Approval and Expiry Date	Approval Date: 11th September, 2012	Expiry Date: 10th September, 2013
Protocol Version and Date	Nil	10th September, 2013
Information Sheet, Consent Forms and Dates	• English	10th September, 2013
Consent form ID and Date	Version-Nil	10th September, 2013
Recruitment Materials	Nil	10th September, 2013
Other Study Documents	Questionnaires	10th September, 2013
Number of participants approved for study		10th September, 2013

Where Research Ethics and Science Converge

ERES CONVERGE

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I.R.B. No. 00005948
F.W.A. No. 00011697

12th April, 2017

Ref. No. 2012-July-007

The Principal Investigator
Ms. Emmy Nkhama
Chainama College of Health Sciences
P.O. Box 33991,
LUSAKA.

Dear Ms. Nkhama,

RE: Relationship between cement dust exposure and respiratory adverse health effects in a community residing near a Cement factory in Chilanga, Zambia.

We would like to acknowledge receipt of your submission dated 15th March, 2017.

The study is renewed for one year; the new expiry date is **10th September, 2018**.

Yours faithfully,
ERES CONVERGE IRB

Prof. Esther Munalula-Nkandu
BSc (Hons), MSc, MA Bioethics, PgD R/Ethics, PhD
CHAIRPERSON

Appendix 3: University of Michigan research ethics clearance

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Health Sciences and Behavioral Sciences Institutional Review Board (IRB-HSBS) • 2800 Plymouth Rd., Building 520, Room 1170, Ann Arbor, MI 48109-2800 • phone (734) 936-0933 • fax (734) 998-9171 • irbhsbs@umich.edu

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To: Ms. Emmy Nkhama

From:

Thad Polk

Cc:

Aesha Mustafa

Emmy Nkhama

Thomas Robins

Subject: Scheduled Continuing Review [CR00054512] Approved for [HUM00070842]

SUBMISSION INFORMATION:
Study Title: Relationship between cement dust exposure and respiratory health effect for a community residing near a cement factory in Chilanga, Zambia.
Full Study Title (if applicable): Relationship between cement dust exposure and respiratory health for a community residing near a cement factory in Chilanga, Zambia
Study eResearch ID: HUM00070842
SCR eResearch ID: CR00054512
SCR Title: HUM00070842_Continuing Review - Sat Apr 16 13:05:22 EDT 2016
Date of this Notification from IRB:5/4/2016
Review: Expedited
Date Approval for this SCR: 5/4/2016
Current IRB Approval Period: 5/4/2016 - 5/3/2017
Expiration Date: Approval for this expires **at 11:59 p.m. on 5/3/2017**
UM Federalwide Assurance:FWA00004969 (For the current FWA expiration date, please visit the UM

HRPP Webpage)

OHRP IRB Registration Number(s): IRB00000246

Approved Risk Level(s) as of this Continuing Report:

Name	Risk Level
HUM00070842	No more than minimal risk

NOTICE OF IRB APPROVAL AND CONDITIONS:
The IRB HSBS has reviewed and approved the scheduled continuing review (SCR) submitted for the study referenced above. The IRB determined that the proposed research continues to conform with applicable guidelines, State and federal regulations, and the University of Michigan's Federalwide Assurance (FWA) with the Department of Health and Human Services (HHS). You must conduct this study in accordance with the description and information provided in the approved application and associated documents.

APPROVAL PERIOD AND EXPIRATION DATE:
The updated approval period for this study is listed above. Please note the expiration date. If the approval lapses, you may not conduct work on this study until appropriate approval has been re-established, except as necessary to eliminate apparent immediate hazards to research subjects or others. Should the latter occur, you must notify the IRB Office as soon as possible.

IMPORTANT REMINDERS AND ADDITIONAL INFORMATION FOR INVESTIGATORS

APPROVED STUDY DOCUMENTS:
You must use any date-stamped versions of recruitment materials and informed consent documents available in the eResearch workspace (referenced above). Date-stamped materials are available in the “Currently Approved Documents” section on the “Documents” tab.

In accordance with 45 CFR 46.111 and IRB practice, consent document(s) and process are considered as part of Continuing Review to ensure accuracy and completeness. The dates on the consent documents, if applicable, have been updated to reflect the date of Continuing Review approval.

RENEWAL/TERMINATION:
At least two months prior to the expiration date, you should submit a continuing review application either to renew or terminate the study. Failure to allow sufficient time for IRB review may result in a lapse of approval that may also affect any funding associated with the study.

AMENDMENTS:
All proposed changes to the study (e.g., personnel, procedures, or documents), must be approved in advance by the IRB through the amendment process, except as necessary to eliminate apparent immediate hazards to research subjects or others. Should the latter occur, you must notify the IRB Office as soon as possible.

AEs/ORIOs:
You must continue to inform the IRB of all unanticipated events, adverse events (AEs), and other reportable information and occurrences (ORIOs). These include but are not limited to events and/or information that may have physical, psychological, social, legal, or economic impact on the research subjects or others.

Investigators and research staff are responsible for reporting information concerning the approved research to the IRB in a timely fashion, understanding and adhering to the reporting guidance (http://medicine.umich.edu/medschool/research/office-research/institutional-review-boards/guidance/adverse-events-aes-other-reportable-information-and-occurrences-orios-and-other-required-reporting), and not implementing any changes to the research without IRB approval of the change via an amendment submission. When changes are necessary to eliminate apparent immediate hazards to the subject, implement the change and report via an ORIO and/or amendment submission within 7 days after the action is taken. This includes all information with the potential to impact the risk or benefit assessments of the research.

SUBMITTING VIA eRESEARCH:
You can access the online forms for continuing review, amendments, and AE/ORIO reporting in the eResearch workspace for this approved study, referenced above.

MORE INFORMATION:
You can find additional information about UM's Human Research Protection Program (HRPP) in the Operations Manual and other documents available at: http://research-compliance.umich.edu/human-subjects.

Thad A. Polk

Thad Polk

Chair, IRB HSBS

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Health Sciences and Behavioral Sciences Institutional Review Board (IRB-HSBS) • 2800 Plymouth Rd., Building 520, Room 1170, Ann Arbor, MI 48109-2800 • phone (734) 936-0933 • fax (734) 998-9171 • irbhsbs@umich.edu

---

To: Ms. Emmy Nkhama

From:

Thad Polk

Cc:

Thomas Robins

Emmy Nkhama

Aesha Mustafa

Subject: Scheduled Continuing Review [CR00048008] Approved for [HUM00070842]

SUBMISSION INFORMATION:
Study Title: Relationship between cement dust exposure and respiratory health effect for a community residing near a cement factory in Chilanga, Zambia.
Full Study Title (if applicable): Relationship between cement dust exposure and respiratory health for a

community residing near a cement factory in Chilanga, Zambia
Study eResearch ID: HUM00070842
SCR eResearch ID: CR00048008
SCR Title: HUM00070842_Continuing Review - Wed May 6 07:10:23 EDT 2015
Date of this Notification from IRB:6/5/2015
Review: Expedited
Date Approval for this SCR: 5/11/2015
Current IRB Approval Period: 5/11/2015 - 5/10/2016
Expiration Date: Approval for this expires **at 11:59 p.m. on 5/10/2016**
UM Federalwide Assurance:FWA00004969 (For the current FWA expiration date, please visit the UM HRPP Webpage)
OHRP IRB Registration Number(s): IRB00000246

Approved Risk Level(s) as of this Continuing Report:

Name	Risk Level
HUM00070842	**No more than minimal risk**

NOTICE OF IRB APPROVAL AND CONDITIONS:
The IRB HSBS has reviewed and approved the scheduled continuing review (SCR) submitted for the study referenced above. The IRB determined that the proposed research continues to conform with applicable guidelines, State and federal regulations, and the University of Michigan's Federalwide Assurance (FWA) with the Department of Health and Human Services (HHS). You must conduct this study in accordance with the description and information provided in the approved application and associated documents.

APPROVAL PERIOD AND EXPIRATION DATE:
The updated approval period for this study is listed above. Please note the expiration date. If the approval lapses, you may not conduct work on this study until appropriate approval has been re-established, except as necessary to eliminate apparent immediate hazards to research subjects or others. Should the latter occur, you must notify the IRB Office as soon as possible.

IMPORTANT REMINDERS AND ADDITIONAL INFORMATION FOR INVESTIGATORS

APPROVED STUDY DOCUMENTS:
You must use any date-stamped versions of recruitment materials and informed consent documents available in the eResearchworkspace (referenced above). Date-stamped materials are available in the “Currently Approved Documents” section on the “Documents” tab.

In accordance with 45 CFR 46.111 and IRB practice, consent document(s) and process are considered as part of Continuing Review to ensure accuracy and completeness. The dates on the consent documents, if applicable, have been updated to reflect the date of Continuing Review approval.

RENEWAL/TERMINATION:
At least two months prior to the expiration date, you should submit a continuing review application either to renew or terminate the study. Failure to allow sufficient time for IRB review may result in a lapse of approval that may also affect any funding associated with the study.

AMENDMENTS:
All proposed changes to the study (e.g., personnel, procedures, or documents), must be approved in advance by the IRB through the amendment process, except as necessary to eliminate apparent immediate hazards to research subjects or others. Should the latter occur, you must notify the IRB Office as soon as possible.

AEs/ORIOs:
You must continue to inform the IRB of all unanticipated events, adverse events (AEs), and other reportable information and occurrences (ORIOs). These include but are not limited to events and/or information that may have physical, psychological, social, legal, or economic impact on the research subjects or others.

Investigators and research staff are responsible for reporting information concerning the approved research to the IRB in a timely fashion, understanding and adhering to the reporting guidance (http://medicine.umich.edu/medschool/research/office-research/institutional-review-boards/guidance/adverse-events-aes-other-reportable-information-and-occurrences-orios-and-other-required-reporting), and not implementing any changes to the research without IRB approval of the change via an amendment submission. When changes are necessary to eliminate apparent immediate hazards to the subject, implement the change and report via an ORIO and/or amendment submission within 7 days after the action is taken. This includes all information with the potential to impact the risk or benefit assessments of the research.

SUBMITTING VIA eRESEARCH:
You can access the online forms for continuing review, amendments, and AE/ORIO reporting in the eResearch workspace for this approved study, referenced above.

MORE INFORMATION:
You can find additional information about UM's Human Research Protection Program (HRPP) in the Operations Manual and other documents available at: http://hrpp.umich.edu.

Thad A. Polk

Thad Polk

Chair, IRB HSBS

UNIVERSITY OF MICHIGAN
eResearch.umich.edu

Health Sciences and Behavioral Sciences Institutional Review Board • 540 East Liberty Street, Suite 202, Ann Arbor, MI 48104-2210 • phone (734) 936-0933 • fax (734) 998-9171 •irbhsbs@umich.edu

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To: Ms. Emmy Nkhama

From:

Thad Polk

Cc:

Thomas Robins

Emmy Nkhama

Aesha Mustafa

Subject: Scheduled Continuing Review [CR00041531] Approved for [HUM00070842]

SUBMISSION INFORMATION:
Study Title: Relationship between cement dust exposure and respiratory health effect for a community residing near a cement factory in Chilanga, Zambia.
Full Study Title (if applicable): Relationship between cement dust exposure and respiratory health for a

community residing near a cement factory in Chilanga, Zambia
Study eResearch ID: HUM00070842
SCR eResearch ID: CR00041531
SCR Title: HUM00070842_Continuing Review - Sat May 31 10:59:45 EDT 2014
Date of this Notification from IRB:6/17/2014
Review: Expedited
Date Approval for this SCR: 6/16/2014
Current IRB Approval Period: 6/16/2014 - 6/15/2015
Expiration Date: Approval for this expires **at 11:59 p.m. on 6/15/2015**
UM Federalwide Assurance:FWA00004969 (For the current FWA expiration date, please visit the UM HRPP Webpage)
OHRP IRB Registration Number(s): IRB00000246

Approved Risk Level(s) as of this Continuing Report:

Name	Risk Level
HUM00070842	**No more than minimal risk**

NOTICE OF IRB APPROVAL AND CONDITIONS:
The IRB HSBS has reviewed and approved the scheduled continuing review (SCR) submitted for the study referenced above. The IRB determined that the proposed research continues to conform with applicable guidelines, State and federal regulations, and the University of Michigan's Federalwide Assurance (FWA) with the Department of Health and Human Services (HHS). You must conduct this study in accordance with the description and information provided in the approved application and associated documents.

APPROVAL PERIOD AND EXPIRATION DATE:
The updated approval period for this study is listed above. Please note the expiration date. If the approval lapses, you may not conduct work on this study until appropriate approval has been re-established, except as necessary to eliminate apparent immediate hazards to research subjects or others. Should the latter occur, you must notify the IRB Office as soon as possible.

IMPORTANT REMINDERS AND ADDITIONAL INFORMATION FOR INVESTIGATORS

APPROVED STUDY DOCUMENTS:
You must use any date-stamped versions of recruitment materials and informed consent documents available in the eResearchworkspace (referenced above). Date-stamped materials are available in the "Currently Approved Documents" section on the "Documents" tab.

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At least two months prior to the expiration date, you should submit a continuing review application either to renew or terminate the study. Failure to allow sufficient time for IRB review may result in a lapse of approval that may also affect any funding associated with the study.

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SUBMITTING VIA eRESEARCH:
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MORE INFORMATION:
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Thad A. Polk

Thad Polk
Chair, IRB HSBS

Appendix 4: Authority to conduct the study in Chilanga.

All correspondences
Should be addressed
To the District Medical Officer

In reply please quote

REPUBLIC OF ZAMBIA
MINISTRY OF COMMUNITY DEVELOPMENT, MOTHER AND CHILD HEALTH
CHILANGA DISTRICT COMMUNITY MEDICAL OFFICE
P.O BOX 350106, CHILANGA

18TH October, 2013

Emmy Nkhama,
Investigator or Researcher,
Chainama Hills College Hospital,
P.O Box 30043,
Lusaka,
Zambia.

Dear Madam,

Re: **Request for Authority to Conduct Study titled,** *"Relationship between Cement dust exposure and respiratory adverse health effects in a community residing near a Cement factory in Chilanga, Zambia"*

Reference is made to the above captioned subject.

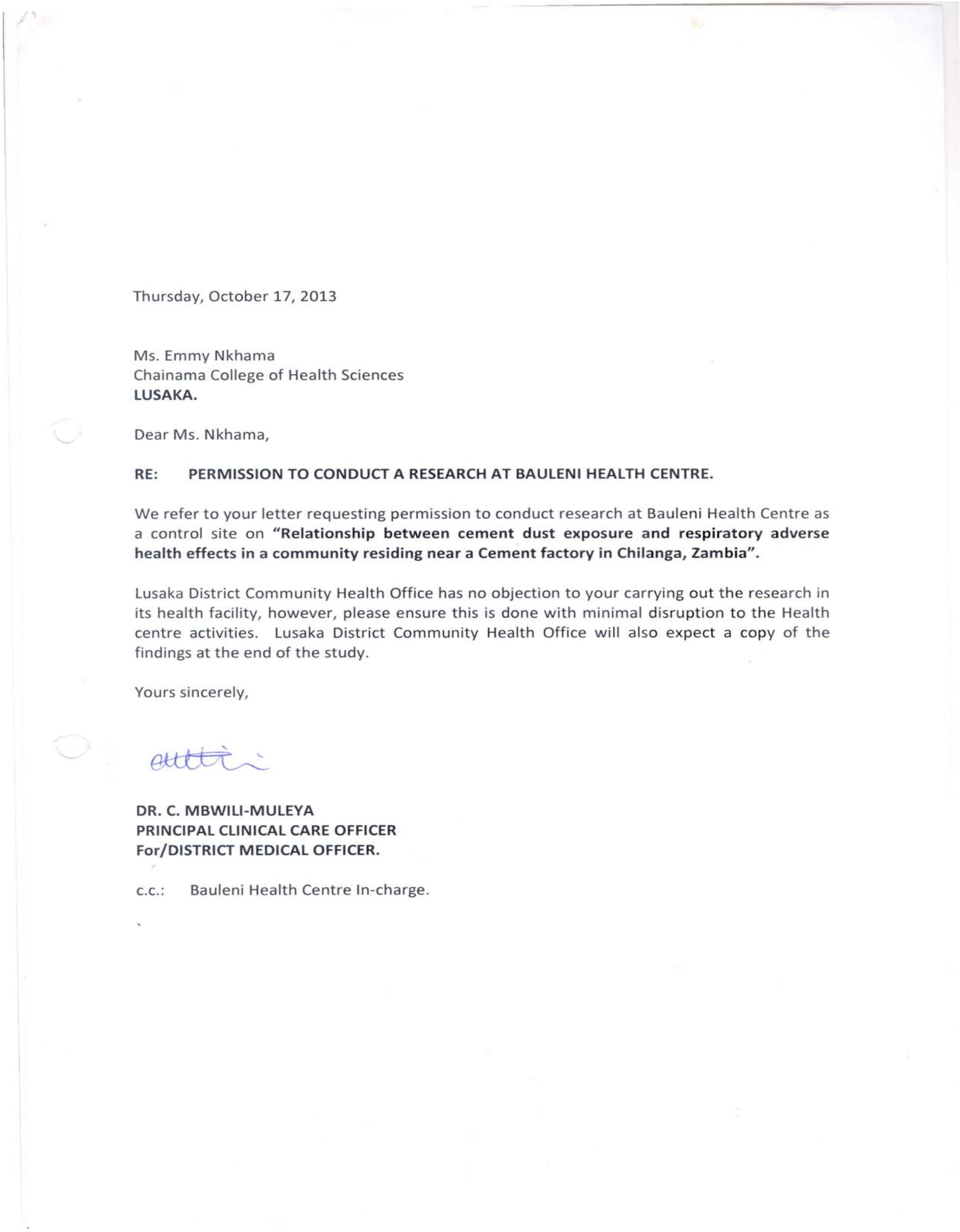
I wish to inform you that following the granting of authority by Ministry of Health for you to conduct a study in Chilanga district, the District Community Medical Office (D.C.M.O) has no objection on condition that you avail us with progress updates of the study.

Kindly inform the D.C.M.O if you are faced with any challenge during your entire period of your study.

Yours sincerely,

Dr. M.K. Lembalemba
District Medical Officer

Appendix 5: Authority to conduct the study in Bauleni



Thursday, October 17, 2013

Ms. Emmy Nkhama
Chainama College of Health Sciences
LUSAKA.

Dear Ms. Nkhama,

RE: PERMISSION TO CONDUCT A RESEARCH AT BAULENI HEALTH CENTRE.

We refer to your letter requesting permission to conduct research at Bauleni Health Centre as a control site on **"Relationship between cement dust exposure and respiratory adverse health effects in a community residing near a Cement factory in Chilanga, Zambia".**

Lusaka District Community Health Office has no objection to your carrying out the research in its health facility, however, please ensure this is done with minimal disruption to the Health centre activities. Lusaka District Community Health Office will also expect a copy of the findings at the end of the study.

Yours sincerely,

DR. C. MBWILI-MULEYA
PRINCIPAL CLINICAL CARE OFFICER
For/DISTRICT MEDICAL OFFICER.

c.c.: Bauleni Health Centre In-charge.

Appendix 6: Information sheet and consent

Title:"Relationship between cement dust exposure and respiratory Health: a study of a settlement residing near a cement factory."

Hello, I am Emmy Nkhama from Chainama College of Health Sciences. I am PhD student with University of Pretoria of South Africa, and conducting a study to assess whether exposure to cement dust could potentially affect respiratory health. You are being asked to participate because the house in which you live has been chosen to be included in the study. From each house, we are randomly choosing one person to participate in the study. You have been chosen in this household but we are only interviewing those who are willing to take part.

The study consists of a series of questions that you will be asked. The researcher hopes that the information collected will help in improving the health of communities living near cement production factories.

To answer this question, the research will collect information pertaining to your personal health. We will collect information continuously for 10 days at an interval of three months for a period of year. Each time, we will be asking you questions using a questionnaire concerning any breathing problems or chest problems that you may be experiencing as well as measure your breathing using specialized equipment. We also will be asking you to breath into a machine that will measure how well the lungs are working. The whole process will be taking 20-30 minutes at each session.

The study poses no personal risk to you apart from the time that you will be asked to afford us at each session.

You will not benefit directly from this research. We hope that the information collected by this research will help to improve the health of the community and the country in future.

Your participation in this study will not cost anything and you will not receive any payment for participation.

Chapter 8

Your participation in this research is completely **voluntary**. You do not need to take part in this research. You will not be punished for refusing to take part in this research. Should you agree to participate now but change your mind in future, you have the right to withdraw from the research at any time.

Your name and address will be protected. Records relating to your participation in the research will remain confidential. Your information will be kept secured in a cupboard in the principal investigator's office. Only permitted members of the research will have access to this cabinet. However, the ERES Converge IRB, University of Pretoria and Michigan University IRB may review the files as part of their responsibility to oversee the research.

You should ask the investigator listed below any questions you may have, now or in the future, about this research study and your rights as a research subject.

Miss Emmy Nkhama,

Principal Investigator

Chainama College of Health Sciences

Po Box 33991

Lusaka.

Mobile No. 0955044601

or

Chairperson

ERES Converge

33 Joseph Mwila Rd

Rhodespark

Mobile No. 0955 155 633

Appendix 7: Consent form

Relationship between cement dust exposure and adverse respiratory Health: a study on a settlement residing near a cement factory in Chilanga, Zambia."

I have read the information sheet concerning this study or have understood the verbal explaination and understand what will happen of me and what will happen to me if I take part in the study. My questions have been answered by project staff.
I understand that at any time I may withdraw from the study without giving a reason.

Participants 18 years and older
I AGREE TO BE PART OF THE STUDY. I UNDERSTAD THAT BEING PART OF THIS STUDY IS MY CHOICE. I UNDERSTAND THAT I CAN REFUSE TO BE PART OF THE STUDY AT ANY TIME WITHOUT PUNISHMENT.

______________________________ ____________________

Participant's signature or fingerprint Date

____

Participant's Name (printed)

______________________________ ____________________

Investigator signature Date

For parent or guardian for participants aged 15-59 years of age

I AGREE FOR MY CHILD TO BE PART OF THE STUDY. I UNDERSTAD THAT BEING PART OF THIS STUDY IS MY CHOICE. I UNDERSTAND THAT I CAN REFUSE TO HAVE MY CHILD BE PART OF THE STUDY AT ANY TIME WITHOUT PENALTY.

______________________________ ____________________

Participant's signature or fingerprint Date

____

Participant’s Name (printed)

__________________________________ ______________________

Investigator signature Date

Appendix 8: Form 1 (Household eligibility)

Hello, I am Emmy Nkhama from Chainama College of Health Sciences, Lusaka. I am doing a research looking into whether cement dust affects people who live near cement producing factories such as the one you have here (Larfage). To find answers to that question, I need residents of this area to take part in the research. During the research I will need to access your house to look at windows, doors, and floor to estimate whether the ventilation in the house is adequate. I will also ask questions regarding the people who live here with you and questions on respiratory health. This will enable me to choose the most suitable households to include in my research

1. Would you allow me or my assistants to gain access to your house during the study?
   (Circle appropriate answer)

   a. Yes
   b. No
2. How long have you lived in this community?
   ……………………….. number of years

3. How many residence changes (changes) have you had in the last 10 years?
   .... number of changes

4. Your household is:
   - Ineligible, thank you very much for your time
   - Is eligible, I now would like to ask for your permission to include your household in this study

(Read and explain the following consent if the household is eligible)

Your house has been included in this study. We require your permission to enter the house once at the beginning of the survey/study to check the type of walls, floor, and number of windows. The study will also involve recruiting one or two members of the household who will be selected at random. The research team will be visiting your household regularly at monthly interval to collect information from the selected individual.

Do I have your permission to include your household in the survey?

Head of household	Interviewer
Sign	Sign
Date	Date

Appendix 9: Initial questionnaire

Relationship between cement dust exposure and adverse respiratory health

The consent has been read and explained to the participants. The implication of their voluntary participation, nature, duration, purposes of the study, methodology used, form in which the study will be conducted, and inconveniences and risks in which they might be involved, have been explained to the participant. Participants have been given every opportunity to ask questions and clear up any doubts they might have with respect to the study. All concerns expressed by the participants have been addressed and the participants are completely satisfied with the answers.

Signature of the interviewer………………………………………………………….. Date ……………………………………..

Household ID on master list	
Unique identifier	
Community	
Years lived in this community	
Respondent’s full name	
Relationship with head of house	
Name of interviewer	
Date of interview	

Demography information

1. Gender Male ☐
   Female ☐
2. What is the ethnic group of the household?
   1. Black ☐
   2. Other ☐ Specify…………………………….
3. What is your marital status?
   1. Married ☐
   2. Single ☐
   4. Divorced ☐
   5. Windowed ☐
4. What is your age at your last birthday?
   ☐☐
5. What is your highest Level of education you have attained?
   1. Primary ☐
   2. secondary ☐
   3. Tertiary ☐
   4. None ☐
6. For how long have you lived in this community? (write where is applicable)
   ……………………months ………………………. years
7. How many people usually live in this household?
   ☐☐

8. How many residences have you had (changed) in the last 10 years?
……………………

9. What are the ages of people in the household and their relation to the head of household?

[Use the following codes to indicate RHH: Householder=1, wife=2, daughter=3, son=4, Age in complete years], Years lived in this community

<u>RHH</u>	<u>Age</u>	Gender	Years in comm
1. …………..		………………	……………
……………			
2. …………..		………………	……………
……………			
3. …………..		………………	……………
……………			
4. …………..		………………	……………
……………			
5. …………..		………………	……………
……………			
6. …………..		………………	……………
……………			

Social Economic Status

10. How many rooms does your house have? (Do not take into account the cooking areas if it is not within the main structure)
-------------------------- rooms

11. The house where you live, is it
    a. Bought
    b. Rented
    c. Borrowed
    d. Other (specify)…………………………………………………………

12. How old (approximate years) is your house?
…………………………

13. How many persons provide economic support for the houses?
………………………………. persons

14. What is your occupation?

1. Cement factory worker ☐
2. Housewife ☐
3. Farm worker ☐
4. Student ☐
5. Other ☐ (Specify)……………………………………………

15. Do you own any of the following appliances or vehicles **(NK= Not Known; NR= Non Response)**

a.	Radio	yes ☐	No ☐	NK☐	NR ☐
b.	Television	Yes ☐	No ☐	NK☐	NR ☐
c.	Refrigerator	Yes ☐	No ☐	NK☐	NR ☐
d.	Bicycle	Yes ☐	No ☐	NK ☐	NR ☐
e.	Motorcycle	Yes ☐	No ☐	NK☐	NR ☐
f.	Car	Yes ☐	No ☐	NK☐	NR ☐

(ask the following and observe)- Household structural characteristics

16. How many rooms does the house have:

1. ☐
2. ☐
3. ☐
4. ☐
5. Others ☐ (Specify)……………………………

17. Number of windows in the house?

1. ☐
2. ☐
3. ☐
4. ☐

5. Others ☐ (Specify)………………………………………………………

18. Number of the doors in the house?

1 ☐

2 ☐

3 ☐

5. ☐

5. Others ☐ (Specify)……………………………

19. What material is the house made of?

1. Brick ☐
2. Mud ☐
3. Concrete ☐
4. Metal sheets ☐
5. Other ☐

Specify………………………………………………………………

20. What is the wall finish of the house?

1. Plastered ☐

2. Un-plastered ☐

21. What is the roof made of?

1. Grass thatched ☐

2. Metal sheets ☐

3. Asbestos sheets ☐

4. Plastic ☐

5. Other ☐

Specify…………………………………………………………

22. Is there a floor carpet in the house?

1. Yes ☐
2. No ☐

23. Observe if the house has the following

1. Is a single structure with the area for cooking located in another room and separated by a wall or partition from the main areas and/or bedroom(s)

2. A single structure where the cooking area is in same area (room) as the rest of the living area/

3. More than one structure, where cooking area is separate from the main area and the bedroom(s); within the a closed structure

4. More than one structure, where the cooking area is separate from the main areas and bedroom(s); within a partially open structure (at least one wall).

Determinants of exposure

24. Where is the kitchen located in reference to main house?

1. Separate from main house ☐
2. within main house ☐
3. Open space ☐

25. If **cooking is done within main house,** is it done in the room where you sleep?

1. Yes ☐
2. No ☐

26. What is the main source of energy for cooking?

1. Electricity ☐
2. Charcoal ☐
3. Firewood ☐

4. Other ☐ (Specify)……………………………….

27. What is the source of energy for lighting?

1. Electricity ☐
2. Firewood ☐
3. Paraffin lamp ☐
4. Others ☐ (specify) ………………………………

28. Form of ventilation?

1. Through ventilation ☐
2. Cross ventilation ☐
2. Good ☐
3. Poor ☐

29. Measure size of the window in relation to floor area? {Excluding toilet and bathroom}

Room	**Floor area**	**Size of window**
1		
2		
3		
4		

Questions on Lifestyle

30. Do you smoke or have you ever smoked cigarette?

1. Never smoked ☐
2. Ex-smoker ☐
3. Smoke now ☐

31. If **ex- smoker**, how long ago did you quit smoking?
……………………years

32. How many cigarettes were you smoking per day?
………………….. cigarettes

33. If **current**, what type of cigarette do you smoke?

1. Factory manufactured cigarette? ☐
2. Locally rolled tobacco? ☐
3. Both ☐
4. Both
5. both

34. If **current smoker**, approximately how many cigarettes a day do you smoke?
☐ ☐

35. How long have you been smoking?
☐☐

36. Does any of the family members smoke?
Yes ☐ No ☐

37. Do they smoke in the house?
Never ☐

Occasionally y ☐

Almost every day but only a few cigarettes (up to 2) ☐

Almost daily many cigarettes (more than 2) ☐

38. Does any other person at home smoke inside the house? ☐☐

39. Where do you spend most of your time?

Away from home ☐

Around home/inside home ☐

Other ☐ (specify)

…………………………………………………...

40. How do you spend most of your time during the day?

1. In and around the home ☐
2. Away from home, but within Chilanga ☐
3. Away from home, out of Chilanga ☐

Quality of life

40. Do you experience any of the following with your eyes? (tick all what applies)
    a. Itching ☐
    ☐
    b. Swelling
    c. Discharge ☐
41. Do you experience any of the following with your nose? (tick all what applies)
    a. Itching ☐

b. Sensation of fullness, congestion ☐

c. Blockage ☐

☐

d. Discharge or runny nose

42. Do you experience any of the following with your sinuses? (tick all that applies)
    a. Head or pain in the face ☐

    b. Blowing out thick mucus ☐

    c. Postnatal drip in the back of throat ☐

    d. Throat clearing or hoarseness of voice ☐

Cough

43. Do you usually have a cough? (Cough with smoke or on first going out-of-doors. Exclude clearing of throat) **[if no skip to question 46]**

Yes ☐ No ☐

44. Do you usually cough as much as 4 times to 6 times a day, 4 or more days out of the week?

Yes ☐ No ☐

45. Do you usually cough at all on getting up, or first thing in the morning?

Yes ☐ No ☐

46. Do you usually cough at all during the rest of the day or at night?

Yes ☐ No ☐

If YES to any of the above (40, 41, 42, or 43) answer the following: If NO to all, check does not apply, go to Question 44

47. Do you usually cough like this on most days for 3 consecutive months or more during the year?

Yes☐ No ☐ Does not apply ☐

48. For how many years have you had this cough?

……………………. days

…………………….. Does not apply

PHLEGM

49. Do you usually bring up phlegm from your chest? (Count phlegm with first smoke on going out-of-door. Excluding from nose. Count swallowed phlegm) [if no skip to 51]

Yes ☐ No ☐

50. Do you usually bring up phlegm at all on getting up, or first thing in the morning?

Yes ☐ No ☐

51. Do you usually bring up phlegm at all during the rest of the day or at night?

Yes ☐ No ☐

If YES to any of the above (46, 47, 48, or 49) answer the following: If NO to all, check does not apply, go to Question 52

52. Do you bring phlegm like this on most days for 3 consecutive months or more during the year?

Yes ☐ No ☐ Does not apply ☐

53. For how many years have you had this cough?

……………………. days

…………………….. Does not apply

EPISODES OF COUGH

54. Have you had periods or episodes of increased cough or phlegm lasting 3 weeks or more (for persons who usually have cough or phlegm)

Yes ☐ No ☐ Does not apply ☐

55. For how long have you had at least 1 (one) such episode?

……………….. Number of years

………………. Does not apply

EPISODES OF PHLEGM

56. Have you had periods or episodes of increased phlegm lasting 3 weeks or more(for persons who usually have phlegm)

Yes☐ No☐ Does not apply☐

57. For how long have you had at least 1 (one) such episode?

……………….. Number of years

………………. Does not apply

WHEEZE

58. Does your chest ever sound wheezing or whistling

1. when you have a cold Yes☐ No ☐
2. occasionally apart from colds Yes ☐ No ☐
3. most days or nights apart from a cold Yes ☐ No☐

If YES, to 1, 2, or 3 in 54,

59. For how many years has this been present

………………….. years

………………….. does not apply

60. Have you ever had an attack of wheezing that has made you feel out of breath?

Yes ☐ No ☐

61. How old were you when you had your first attack?

…………………..years

62. Have you ever required medicine or treatment for the(se) attack(s)

Yes ☐ No☐ Does not apply ☐

BREATHNESSNESS

63. Are you troubled by shortness of breathless when hurrying on the level or walking up a slight hill?

Yes☐ No ☐

If Yes

64. Do you have to walk slower than people of your age on the level because of breathless?

Yes ☐ No ☐ Does not apply ☐

65. Do you ever have to stop for a breath when walking at your pace on the level?

Yes☐ No ☐ Does not apply

66. Do you ever have to stop to breathe after walking a few minutes on the level?

Yes☐ No ☐ Does not apply

67. Are you breathless to leave the house or breathless on dressing or undressing?

Yes ☐ No☐ Does not apply ☐

CHEST COLD AND CHEST ILLNESS

68. If you get a cold, does it usually go to your chest (usually more than ½ the times?)
Yes ☐ No ☐ Don’t get colds ☐

69. During the past 3 years, have you had any chest illness that kept you from work or school, or in doors at home, or in bed?
Yes ☐ No ☐ Does not apply ☐

If YES

70. Did you produce phlegm with any of these chest illnesses
Yes ☐ No ☐ Does not apply ☐

71. In the last 3 years, how many such illnesses with (increased) phlegm, did you have which lasted a week or more?
.... Number of illnesses

…………………….. No such illnesses

……………………. . Does not apply

PAST ILLNESSES

72. Did you have any lung troubles before age of 16? [If participant is over 16 years]
Yes ☐ No ☐

73. Have you had any of the bronchitis?
Yes ☐ No ☐

If YES

1. Was it confirmed by a doctor? Yes ☐ No ☐

2. At what age was the first attack?............ years ………… does not apply

74. Have you had pneumonia (including bronchopneumonia)
If YES

1. Was it confirmed by a doctor? Yes ☐ No ☐

2. At what age was the first attack?............ years ………… does not apply

75. Have had hay fever?
If yes

1. Was it confirmed by a doctor? Yes ☐ No ☐

2. At what age was the first attack?............ years ………… does not apply

76. Have you had chronic bronchitis
If YES

1. Do you still have it? Yes ☐ No ☐ Does not apply ☐

2. Was it confirmed by a doctor? Yes ☐ No ☐

3. At what age was the first attack?............ years ………… does not apply

77. Have you had emphysema?
If YES

1. Do you still have it? Yes ☐ No ☐ Does not apply ☐

2. Was it confirmed by a doctor? Yes ☐ No ☐

3. At what age was the first attack?............ years ………… does not apply

78. Have you had asthma?
If YES

1. Do you still have it? Yes ☐ No ☐ Does not apply ☐

2. Was it confirmed by a doctor? Yes ☐ No ☐

3. At what age was the first attack?............ years ………… does not apply

4. If you no longer have it, at what age did it stop? ………..years stopped? …….. does not apply

Appendix 10: Daily questionnaire for repeated measures of respiratory health

Household ID on master list	
Unique identifier	
Community	
Years lived in this community	
Respondent’s full name	
Name of interviewer	
Height	
Weight	
Age	
Date of interview	

Respiratory health	
79. Did you experience any of the following with your eyes yesterday the night or today? (tick all what applies)	Itching ☐ Swelling ☐ Discharge ☐
80. Did you experience any of the following with your nose yesterday the night or today? (tick all what applies)	Itching ☐ Sensation of fullness or congestion ☐

	Blockage ☐ Discharges of runny nosy ☐
81. Did you experience any of the following with your sinuses yesterday, in the night or today? (tick all that applies	Head pain in the face ☐ Blowing out thick mucus ☐ Postnatal drip in the back of the throat ☐ Throat clearing or hoarseness of voice ☐
82. Did you experience any of the following with your sinuses yesterday, in the night or today? (tick all that applies	Yes ☐ No ☐
83. Did you have cough yesterday or in the night?	Yes ☐ No ☐
84. Did you bring up phlegm at all on getting up, or first thing in the morning?	Yes ☐ No ☐
85. Did you bring up phlegm at all during the rest of the day yesterday at night or today?	Yes ☐ No ☐
86. Did you have an attack of wheezing that made you feel out of br yesterday, or in the night or today?	Yes ☐ No ☐

Appendix 11: Systematic review protocol

Protocol

Are communities residing near a cement factory as likely to suffer from respiratory effects as workers in the factory? A systematic

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Introduction

The cement industry has grown progressively in both developing and developed countries with an estimated production of 4.18 billion tons in 2014 compared to 4.08 billion tons in 2013.[1] However, production of cement comes with significant pollution of the ambient air with particulate matter (PM)[2] whose mass and composition is divided into two principal groups: coarse particles mostly larger than 2.5 μm in aerodynamic diameter, and fine particles mostly smaller than 2.5 μm in aerodynamic diameter ($PM_{2.5}$).[3] These tiny particles are of respirable size and reach internal organs principally through the lungs leading to pulmonary diseases. In the lungs, these particles are mostly deposited in the trachea-bronchial respiratory zone.[4]

Both workers in the cement factory and communities residing near cement factories are affected by PM emission from cement factories. Epidemiological studies have reported impairment of lung health in different study settings; communities residing near cement factories and workers within the cement plants. The commonly reported respiratory symptoms include cough, wheeze, dyspnoea, sneezing, sneezing and phlegm.[5,6] Additionally, lung function indices, measured as FEV1, FVC, ratio of FEV/FVC, PERF and PEF, have also been shown to be reduced.[6-9] However, within each study setting, some studies have demonstrated no statistically significant relationship[10-12] between exposure to cement dust and respiratory ill health. Consequent to the inconsistent findings the relationship between exposure to cement dust and respiratory ill health remains inconclusive.

Research Question

This review seeks to assess quality of evidence of a relationship between exposure to cement dust and respiratory health of residents in communities near cement factories systematic review of the published literature on the relation between exposure to cement dust and effects on respiratory health. Furthermore, we will examine whether there is a difference in effects between the two populations. The PRISMA 2015 checklist will be used in the systematic review protocol.

Methodology

Search strategy

We will search the literature for both published and unpublished research. PubMed, Embase and CINAHL will be searched for qualifying studies using a combination of the following key search words: *cement dust; exposure; respiratory health; reduced lung function; community; occupational settings; workers*. Further search will be done for relevant published reports from authors' reference list of eligible and relevant articles. Additionally, the "Google" engine will be used to search for abstracts, conference proceedings and unpublished studies.

Inclusion criteria

Type of participants

The review will consider all studies that involved human subjects residing near cement factory and exposed to cement emissions. Participants from the community studies will include children, adolescence and adults.

Types of studies

The review will consider original studies that were published in peer reviewed journal from 1996 to 2018 in English. The studies must have focused on effects of cement dust exposure on human respiratory health (pulmonary function and symptoms) and conducted in communities residing near a cement factory.

Type of exposure measure

The studies must have assessed exposure to PM2.5 and PM10.

Type of outcome measure

The primary health outcomes assessed will include either respiratory symptoms [cough, wheeze, dyspnea, nose irritation, asthma, pneumonia, acute or chronic bronchitis] and/or pulmonary function [FEV1, FVC, ratio FEV1/FVC, PEF, PEFR]).

Exclusion criteria

Exclusion criteria will include the following: studies that did not measure both exposure and outcomes, animal studies, ex vivo and toxicological studies, duplicates, summaries, commentaries, review article, case reports and case series.

Critical appraisal

Critical appraisal of the studies will involve screening all the abstracts and titles, two researchers, in order to identify potentially eligible studies. This will be followed by full text screening of the potentially eligible studies (figure 1). Any disagreements regarding eligibility will be resolved by consensus with the help of a third reviewer. The appraisal of each article's findings will be based on the assessment of background and rationale of each study, study design, selection of participants, evidence of bias, whether study meets inclusion criteria, validity of the measurement of exposures and respiratory outcomes; and reported strength of measures of association or differences in prevalence.

Data collection

A standardized form will be used to extract the data that will include full description of study characteristics: name of author, title of study, name of journal, year of publication, location, period of study, study design, age and sex of study participants, type of exposure assessed [$PM_{2.5}$, PM_{10}], health outcomes assessed either as respiratory symptoms [cough, wheeze, dyspnea, nose irritation, asthma, pneumonia, acute or chronic bronchitis] and/or lung function [FEV1, FVC, ratio FEV1/FVC, PEF, PEFR].

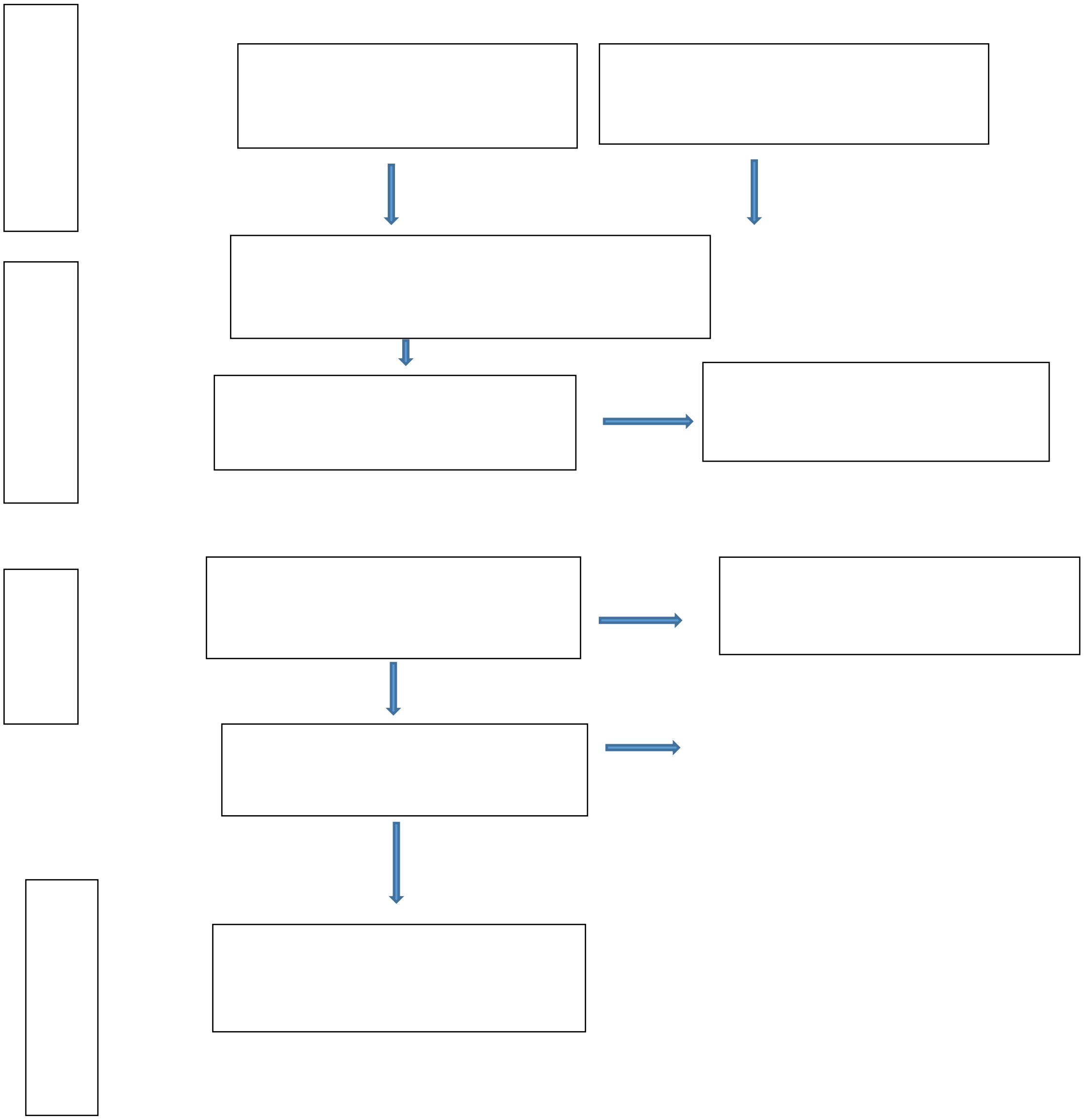

Figure 1: Procedure for the identification and selection of articles. Adopted from Moher et al 2009.

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