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Air pollution exposure and non-communicable respiratory diseases among fish vendors in Bagamoyo and Kunduchi fish markets in Tanzania

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AIR POLLUTION EXPOSURE AND NON-COMMUNICABLE RESPIRATORY DISEASES AMONG FISH VENDORS IN BAGAMOYO AND KUNDUCHI FISH MARKETS IN TANZANIA

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A Dissertation Submitted in Partial Fulfillment of the Requirement for the Degree of Master of Science in Public Health Research of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

Approximately 2.6 billion people in the world use polluting fuels in cooking. Small-scale fish vendors in Bagamoyo and Kunduchi fish markets rely on use of firewood in frying fish for business purposes. Unfortunately, this results in higher levels of air pollutants as an occupational exposure. The study assessed the magnitude of air pollution and related impacts on lung function among small-scale fish vendors along coastal area of Tanzania. The study was a cross-sectional descriptive study, conducted in Bagamoyo and Kunduchi fish markets. Air pollution levels and composition were measured. EasyOne spirometer was used to test for lung function and a standardized questionnaire was used to assess respiratory symptoms among small-scale fish vendors. Data were analyzed using STATA Version 17. Results shows that the average hourly concentration levels of Particulate matter (PM_1, $PM_{2.5}$, PM_{10}), and Carbon monoxide exposure during fish frying were 653.6 (±206.3 SD) $\mu g/m^3$, 748.5 (±200.6 SD) $\mu g/m^3$, 798.7 (±181.7 SD) $\mu g/m^3$ and 62.6 (±12.3 SD) ppm respectively which is higher than the WHO recommended limits. About 32.04% of participants were categorized as having chronic obstructed pulmonary disease which was associated with coughing, wheezing, sputum production and breathlessness among the participants. Findings suggest that three out of ten participants had COPD and the major environmental air pollutants concentration levels were too high, suggesting occupational exposure to biomass smoke may be a major risk factor. This calls for effective approaches to reduce exposure and prevent known acute and chronic respiratory diseases that are associated with such exposure to air pollutants.

Keywords: Air pollution, air pollution exposure, non-communicable respiratory diseases, Chronic Obstructive Pulmonary Disease, fish vendors, Tanzania

DECLARATION

I, Brigitha Massawe Onesmo, do hereby declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concomitantly submitted for degree award in any other institution.

10/8/2023

Brigitha Massawe Onesmo   Date

The Declaration is confirmed by:

10/8/2023

Dr. Jerry Joseph Hella   Date

10/8/2023

Dr. Mwema Felix Mwema   Date

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CERTIFICATION

The undersigned certifies that they have read and hereby recommend for acceptance by the Nelson Mandela African Institution of Science and Technology a dissertation titled "*Air pollution exposure and non-communicable respiratory diseases among fish vendors in Bagamoyo and Kunduchi fish markets in Tanzania*" in partial fulfillment of the requirements for the award of Degree of Master of Science in Public Health Research at the Nelson Mandela African Institution of Science and Technology Arusha, Tanzania.

Dr. Jerry Joseph Hella — Date: 10/8/2023

Dr. Mwema Felix Mwema — Date: 10/8/2023

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DEDICATION

I dedicate this work to my lovely God, parents and child for being there for me, never leaving me and always loving me.

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LIST OF ABBREVIATION AND SYMBOLS

ALRI	Acute Lower Respiratory Infections
ATS/ERS	American Thoracic Society/European Respiratory Society
BMI	Body Mass Index
CO	Carbon Monoxide
COPD	Chronic Obstructive Pulmonary Disease
EPA	Environmental Protection Agency
FEV1	Forced Expiratory Volume in one second
FVC	Forced Vital Capacity
GLI	Global Lung Function Initiative
HCHO	Formaldehyde
IHI-IRB	Ifakara Health Institute- Institutional Review Board
NCDs	Non-communicable Diseases
NEMC	National Environmental Management Council
NIMR	National Institute for Medical Research
NO_2	Nitrogen Dioxide
LMICs	Low and Middle Income Countries
MOHCDGEC	Ministry of Health, Community Development, Gender, Elderly and Children
ODK	Open Data Kit
PM	Particulate Matter
PM_1	Particulate Matter with an aerodynamic diameter less than 1 mm
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter less than 2.5 mm
PM_{10}	Particulate Matter with an aerodynamic diameter less than 10 mm
PAH	Polycyclic Aromatic Hydrocarbons
PPP	Public Private Partnership
REA	Rural Energy Agency
SDGs	Sustainable Development Goals
SO_2	Sulfur Dioxide
TVOC	Total Volatile Organic Compounds
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Non-communicable diseases (NCDs) have recently become a global public health concern and are estimated to contribute to more than 70% of deaths worldwide (WHO, 2021b). The World Health Organization (WHO) has categorized key groups of NCDs to include chronic respiratory diseases, cardiovascular diseases, diabetes and cancer. These NCDs cause about 80% premature mortality in low and middle income countries and about three quarters of all deaths in these countries are from NCDs (Gowshall & Taylor-Robinson, 2018).

Environmental risks, particularly air pollution, increase a considerable burden on NCDs (Campbell-Lendrum & Prüss-Ustün, 2018; Fatmi *et al*., 2020). The WHO estimated that household air pollution as a result of using biomass fuel causes about 4 million premature mortality each year (WHO, 2018). The NCDs are influenced by the people's lifestyle factors such as unhealthy diets, lifestyles, and poor working environments. Air pollution alone puts 90% of people at increased risk for NCDs including cancer, chronic obstructive pulmonary diseases and cardiovascular diseases (WHO, 2021c). Generally, both household and outdoor air pollution results to about 7 million deaths in each year (Fatmi *et al.,* 2020; WHO, 2021c).

Studies conducted in 2018 in India reported an increased threat of developing COPD because of air pollutants from use of biomass solid fuels (Sharma & Vankudre, 2018). Approximately 2.6 billion people in the world use polluting fuels and cook on open fires or simple stoves, which exposes them to air pollutants (Whiting, 2021). In Low and Middle Income Countries (LMICs) more than 40% of people are generating harmful smokes at homes due to inefficient technologies they use in cooking (Prüss-Ustün, 2019). In Tanzania more than 94% of the population use biomass fuel in cooking practices mainly charcoal and wood (TDHS, 2016). However, biomass fuel or biofuel use in homes are the dominant contributors to indoor air pollution (Brakema *et al*., 2019) which also increases outdoor air pollution affecting health of people (Smith *et al*., 2014). Use of biomass fuel has also been reported in business areas like cooking food by food vendors in urban areas (Zhou *et al*., 2011).

Evidence has shown that exposure to biomass smokes increases both respiratory and non-respiratory diseases (Babalik *et al*., 2013). For a human to be exposed to pollutants from air it depends on indoor and outdoor amounts of air pollutants depending on the environment and time a person spent in such conditions (Perez-Padilla *et al*., 2010). Also air pollution from cooking conditions with poor ventilation tends to result in due decline of lung function (Sharma & Vankudre, 2018). Studies have revealed a linkage on use of solid/biomass fuels and pulmonary fitness (Sharma & Vankudre, 2018) especially smoke exposure from home kitchen and respiratory problem where the exposure rate is associated with difficult breathing and affect the lung capacity (Juntarawijit, 2017). Air pollutants like PM, NO_2, O_3 and SO_2 emitted from burning of biomass fuel have the ability to affect the respiratory system and cause respiratory symptoms like phlegm, cough and bronchial hyper responsiveness (Schraufnagel *et al*., 2019). Small scale fish vendors in Bagamoyo and Kunduchi fish markets are exposed to air pollutants when frying fish using firewood in poorly ventilated working conditions.

In Tanzania there is limited information on the occupational impact from air pollution among small-scale fish vendor's who almost always rely on biomass fuel for frying fish prior to selling them. Therefore, the current study intends to measure the magnitude of air pollution and related impacts on lung function among small-scale fish vendors in Bagamoyo and Kunduchi fish markets in Tanzania.

1.2 Statement of the Problem

The Tanzanian government has made some sporadic efforts in promoting use of clean and affordable energy through establishment of Rural Energy Agency (REA) (Uisso, 2009). Despite such efforts some households still use solid/biomass fuel in their homes as energy source and also in business areas due to its affordability and availability to people with low incomes. Biomass fuels have also been reported to be used by food vendors in business areas in urban areas (Zhou *et al*., 2011).

Small-scale fish vendors in Bagamoyo and Kunduchi fish markets rely on use of biomass fuel, particularly firewood in frying fish for business purposes. This results in higher levels of Particulate Matter (PM) pollutants in cooking areas (Zhou *et al*., 2011) which also increases their risk to non-communicable respiratory diseases (Babalik *et al*., 2013). People still suffer from both acute and chronic respiratory diseases because of polluted air resulting from use of biomass fuel. A study which was conducted in Simiyu region Tanzania in 2018 reported that about 99.5% of the people interviewed were using solid fuels in the process of cooking and prevalence of chronic obstructive pulmonary disease (COPD) was estimated at 17.5% (Magitta *et al*., 2018).

In Bagamoyo, the prevalence of acute respiratory illness due to air pollution was 54% among women involved in cooking and under five children (Kilabuko *et al*., 2007). Small scale fish vendors are also at high risk of respiratory diseases as a result of being exposed to biomass smoke, fumes and heat for a long term when frying fish for business purposes. However, there is limited published data on the occupational impact from air pollution among small-scale fish vendor's who largely rely on biomass fuel for frying fish prior to selling them. To date, there is no locally generated respiratory health information pertaining to this key and vulnerable group available despite their daily exposure to air pollutants from biomass fuel in poorly ventilated working conditions. Therefore, the study intended to measure the magnitude of air pollution and accompanying impact on lung function among small-scale fish vendors in Bagamoyo and Kunduchi fish markets in Tanzania.

1.3 Rationale of the Study

Studying the respiratory health of small-scale fish vendors has provided recent data and first-hand information of the problem that will help in advising them on their health status. This information will be useful in planning, design and implementation of a more robust intervention on these groups of fish vendors. Findings from this study will send a realistic message to policy makers, implementing partners and community members to start giving appropriate attention on matters regarding clean energy and air quality. Also, the study will call for better improvement in surveillance systems and regular air quality monitoring which will be helpful in reducing the way people are exposed to air pollutants and improve pulmonary function through designing better intervention to this vulnerable group. The study will facilitate multisectoral and multistakeholder actions to implement effective intervention in reducing premature mortality from NCDs. The findings may also call for engagements of different stakeholders, the private sector, different governmental and non-governmental sectors for an action in control and prevention of NCDs. The study will also set as a basis for further research on the impacts of polluted air and NCDs in the future.

1.4 Research Objectives

1.4.1 Main objective

To assess the magnitude of air pollution and associated impacts on pulmonary function among small-scale fish vendors in Bagamoyo and Kunduchi fish markets in Tanzania.

1.4.2 Specific objectives

(i) To determine the composition and levels of main air pollutants (fine particles, carbon monoxide etc.,) among small-scale fish vendors at their working places

(ii) To assess lung function capacity among small-scale fish vendors

(iii) To determine risk factors associated with poor lung function that could lead to COPD among small-scale fish vendors

1.5 Research Questions

(i) What are the main air pollutants and their levels among small-scale fish vendors' workplaces?

(ii) What is the lung function capacity of small-scale fish vendors exposed to air pollutants as an occupational risk?

(iii) What are factors associated with poor lung function that could lead to COPD among small-scale fish vendors?

1.6 Significance of the Study

This study provides crucial information on occupational exposure to air pollutants from biomass smoke and their effects on lung function among small scale fish vendors and recommend effective control measures.

1.7 Delineation of the Study

As this is the first study to be conducted among fish vendors' work environments to assess occupational exposure in this coastal population, it provides a description of pollutant concentration in the work environment while also describing the lung health of the participants. Following the known health effects of firewood smoke on lung function, the study was conducted by measuring concentration of environmental air pollutants together with measurement of lung function among study participants. Respiratory symptoms among participants were assessed to determine the known effects of biomass smoke to pulmonary function.

The study has some limitations as this occupation involves more men than women. Results of this study may not be appropriate for some cultures where more women are involved in fish frying. The study did not measure/account for personal air pollution exposure (i.e., did not quantify the magnitude of the exposure) due to lack of personal sensors and equipment deficit and hence only environmental measurement of air pollutants were conducted (PM1, PM2,5, PM10, CO, NO, O3, SO2, HCHO, TVOC, temperature and humidity), however the findings of the study are enough to know exposure in that occupational activity.

Given that the data were collected during one period of the year i.e., May to June of 2022, the study did not measure the air pollutant variation during different seasons as there may be difference in pollutant concentration during summer and winter periods as these fish markets are located at the shores of the sea with poorly ventilated structure. Hence differences in pollutant concentration may be underestimated or overestimated. Therefore, there is a need for other studies to measure variation of pollutant concentration according to seasons of the year.

As the study was only descriptive we did not measure the causal association between air pollutants and lung function values. Hence a bigger study with a different design will be useful. The results of the study might also be affected by small sample size and the sampling approach (non-probability sampling approach). This study uses fish vendors from Bagamoyo and Kunduchi fish markets, with only 103 participants, hence may not represent all fish vendors in the country who are exposed to biomass smoke. However, most fish vendors in the country have a similar working environment and similar exposure. Apart from firewood smoke, fish vendors might also be exposed to traffic air pollution and this could lead to skewness of the results.

There is also a need to detect if those with obstructive lung disease have a risk of progressive disease and therefore a longitudinal study is needed to observe disease progression and understand any other risk of progressive disease.

CHAPTER TWO

LITERATURE REVIEW

2.1 Burden of Air Pollution and Non-Communicable Diseases

About 90% of people are at risk for NCDs including cancer, COPD, and cardiovascular diseases because of exposure to air pollution (WHO, 2021c). The WHO estimated that indoor air pollution resulting from the use of biomass fuel causes about 4 million premature mortality each year (WHO, 2018). Globally, both household and outdoor air pollution accounted for 7 million deaths every year (WHO, 2021a). In LMICs over 40% people are generating harmful smokes at homes due to inefficient technologies they use in cooking (Prüss-Ustün, 2019). However biomass fuel or biofuel use in homes are the dominant contributors to indoor air pollution (Brakema *et al*., 2019) which also increases outdoor air pollution (Smith *et al*., 2014). Household air pollution results to about 800,000 premature deaths per year globally due to use of biomass smoke including COPD related deaths (Smith *et al*., 2014).

Studies report that the process of cooking and heating using solid fuels accounts for about 90% among the rural population in the world with a great amount of air pollutants which may damage the lung (Brakema *et al*., 2019). About one third of the people in the world use solid fuels in cooking (Johan, 2015). Biomass fuel includes materials from either plants or from animals in which when humans burn them they produce smoke substances with the tendency to cause respiratory symptoms when inhaled (Bruce *et al*., 2000). In Tanzania biomass fuels are the primary energy source as it contributes to over 90% supply of energy (Johan, 2015; Kilabuko *et al*., 2007).

The NCDs are a worldwide public health concern and are estimated to contribute to more than 70% of deaths worldwide (WHO, 2021b). The major groups of NCDs include chronic respiratory diseases, cardiovascular diseases, diabetes, and cancer which are accountable to 80% of premature deaths in LMICs and about three quarters of all deaths in these countries are from NCDs (Gowshall & Taylor-Robinson, 2018). In Tanzania, these NCDs (diabetes, cancer, cardiovascular diseases, mental health and injuries) are a major source of increasing disability and contribute to about a third of all deaths in the country (MOHCDGEC, 2021).

2.2 Air Pollution Exposure and Non-Communicable Diseases

Environmental health risks such as air pollution result in NCDs. Indoor air pollution has become the major public and environmental health hazard in developing countries which affects the most vulnerable population (Babalik *et al*., 2013). Household air pollution contributes to ambient air pollution which causes premature mortality about 0.4 million deaths (Smith *et al*., 2014). Exposure to ambient levels of polluted air during day time may affect an individual but exposure to indoor emission takes possibly the total daily intake of pollutants (Johan, 2015). Air pollutants emitted from burning of biomass fuel like PM, NO_2, O_3 and SO_2 have the ability to affect the respiratory system and cause respiratory symptoms like phlegm, cough and bronchial hyper responsiveness (Schraufnagel *et al*., 2019).

In developing countries, many urban households use biomass fuels (Zhou *et al*., 2011) as a source of energy. In Tanzania biomass fuel use in heating and predominantly in cooking has become the main cause of indoor air pollution (Jackson, 2009) which also becomes a source of outdoor air pollution by releasing pollutants in air. Inhalation is the primary pathway for air pollutants which increases respiratory disorders (Hulin *et al*., 2012).

Different studies conducted in different countries have established an association between respiratory diseases and inhalation of polluted air. A longitudinal study conducted in Kenya has also established an association between inhalation of polluted air caused by biomass use and acute respiratory infections (Ezzati & Kammen, 2001). The respiratory system becomes affected by air pollutants causing breathlessness for those with chronic respiratory diseases (Schraufnagel *et al*., 2019). The smoke emitted during biomass fuel burning is the major source of both household and ambient air pollution with high ability to affect the respiratory system.

2.3 Biomass Use and Air Pollution

Small-scale fish vendors in Bagamoyo and Kunduchi fish markets rely on biomass fuel in frying fish for selling purposes. They are a susceptible group to air pollution because they have no choice, they have no voice or agency for cleaner energy (Abera *et al*., 2020). The cooking fumes and smoke emitted during the cooking process may penetrate the lungs and increase respiratory symptoms (Sharma & Vankudre, 2018). As a result of no action on this and the kitchen being neglected, the place remains a hazardous smoke environment (Johan, 2015) with high risk of occupants respiratory infection. The exposure occurs because of the low level of knowledge of the group exposed to biomass smoke. They don't consider improved working conditions, safety as important factors in energy efficiency and improved health (Johan, 2015). Burning of biomass in open fires or indoors using poorly functioning stoves increases pollutants in air (Kilabuko *et al*., 2007), which may cause respiratory disorders (Bruce *et al*., 2000). Mixture of health damaging pollutants emitted because of incomplete combustion of biomass fuel including nitrogen dioxide (NO_2), Polycyclic Aromatic Hydrocarbons (PAH), respirable particulate matter and carbon monoxide (CO).

In developing countries exposure to polluted air because of imperfect combustion of the biomass solid fuel is a main public health risk threat (Johan, 2015). Multiple studies have revealed a linkage between respiratory diseases, chronic lung diseases, respiratory tract cancers and air pollution (Johan, 2015). In Tanzania a study conducted in Morogoro municipality reported a linkage between usage of biomass fuel and occurrence of respiratory symptoms (Mahembe *et al*., 2010). Exposure to air pollutants at high concentration makes someone experience symptoms of diseases and is a foundation of chronic respiratory symptoms (Manisalidis *et al*., 2020). The acute respiratory symptoms may account as early symptoms of chronic airway diseases, hence ensuring early identification may be the first step to prevention and intervention process.

2.4 Main Air Pollutants Affecting the Respiratory System

Air pollution is the major public health threat as it causes a great burden on humans by causing high morbidity and mortality (Landrigan, 2017). The most common air pollutants from use of biomass fuel is Particulate Matter (PM) (Manisalidis *et al*., 2020), others are nitrous oxides, carbon monoxide, sulfur dioxide from use of coal, polycyclic organic matter and formaldehyde and many other toxic compounds. When biomass fuel is burnt with inefficient combustion it emits high levels of air pollutants like PM and CO (Gordon *et al*., 2014). Nowadays the focus of air pollution has risen because particulate matter ($PM_{2.5}$) has the ability to penetrate lung tissue and induce local and systemic effects. Those particles with 10 micrometers diameter or below (PM_{10}) and those with 2.5 micrometers diameter or below ($PM_{2.5}$) reported that they may enter deeply in the lung, hence causing damage to health (Xing *et al*., 2016).

Household or neighborhood biomass use are the major sources of PM pollutants in urban homes (Zhou *et al*., 2011). Biomass is also a predominant fuel used by food vendors in business areas (Zhou *et al*., 2011), resulting in higher PM pollutants in commercial areas. Monitoring of these air pollutants is still a challenge especially in African countries. Both outdoor and indoor PMs remain high (Abera *et al*., 2020). Inefficient combustion of biomass fuel emits higher levels of gasses and PM the same as the smoking activity although nicotine is missing (Balmes, 2020).

The WHO recommended guidelines for yearly average concentration of $PM_{2.5}$ should not exceed 5 $\mu g/m^3$ and the 24 hour average exposure should not exceed 15 $\mu g/m^3$ more than 3 to 4 days per year (WHO, 2021a). For PM_{10} the annual mean concentration should not exceed 15 $\mu g/m^3$ and 45 $\mu g/m^3$ in 24 hour mean (WHO, 2021a). Several studies reported measured air pollutants that exceed the WHO limits (Jackson, 2009).

2.5 Impact of Air Pollution to Lung Function

Due to air pollution and exposure to these air pollutants which reduce lung function capacity, the prevalence of COPD was estimated to increase and become a third major causal factor for death worldwide by 2020 (Lamprecht *et al*., 2013). Studies conducted in 2018 in India reported an increased threat of developing COPD because of air pollutants from use of biomass solid fuels (Sharma & Vankudre, 2018). Few cross-sectional studies have measured the lung function of people at risk in Tanzania and associate use of biomass with COPD (Magitta *et al*., 2018) especially when exposure to biomass has occurred for many years. Household air pollution raises the chance of developing lung diseases like COPD, bronchitis etc. (Sharma & Vankudre, 2018). Sometimes occur misdiagnosis of COPD as pulmonary tuberculosis or heart failure especially in African countries, also there is shortage of diagnostic tools like spirometers and lack of expertise which are the main challenges in treatment and proper diagnosis of COPD patients (Magitta *et al*., 2018).

Even though smoking of cigarette is recognized as a main cause of COPD worldwide (Magitta *et al.,* 2018), in developing countries COPD results predominantly from people being exposed to air pollutants (Kurmi *et al*., 2012). In LMICs, household air pollution is mainly caused by use of biomass solid fuel in cooking activities which emits high amounts of pollutants (Kurmi *et al*., 2012). Despite the major progress to reduce impact of biomass on health, exposure to air pollutants continues to become high particularly Particulate Matter in homes because cooking activities conducted in stoves which are poorly ventilated which pose higher public health impact (Balmes, 2020), this may also be because of absent of chimney for smoke ventilation (Gordon *et al*., 2014). Studies have established evidence of airflow obstruction as a result of biomass smoke exposure, and detected the effect of COPD in young adulthood while COPD risk is being doubled (Kurmi *et al*., 2012). A study conducted in Simiyu Tanzania reported high prevalence of COPD among young age especially among males (Magitta *et al*., 2018).

2.6 Health Impacts of Long- and Short-Term Exposure to Air Pollution

Exposure in a long term to biomass smoke causes serious adverse health impacts like ALRI, COPD, lung cancer, chronic bronchitis (Bruce *et al*., 2000; Perez-Padilla *et al*., 2010; Smith *et al*., 2014) which may last for many years or even whole life or even leading to death (Manisalidis *et al.,* 2020). The health effects of air pollutants depends on conditions on the environment, individual susceptibility and dose (Manisalidis *et al*., 2020). The short term effects may range from simple states like nose, and throat irritation, chest tightness, coughing, breathing difficulties and wheezing to a very serious state like pneumonia, asthma, lung problems, and chronic bronchitis (Manisalidis *et al*., 2020).

Studies report a linkage between use of biomass fuel and occurrence of respiratory diseases including COPD and cardiovascular diseases (Bruce *et al*., 2000). A study done in South East Asia in Brunei Darussalam reported that cooking vendors who use biomass fuel were having higher respiratory symptoms and the symptoms were thrice more for those who have worked for more than 10 years (Nor *et al*., 2014). In Tanzania few studies have assessed the effect of air pollution on health including ALRI and chronic respiratory disease (Johan, 2015; Kilabuko *et al*., 2007). Most studies about household air pollution exposure and burden of mortality in developing countries have been reported in rural areas (Bruce *et al*., 2000), however in urban areas also there is biomass use especially among food vendors which also lead to morbidity and mortality because of respiratory diseases.

The health effects resulting after exposure to air pollutants have somewhat been neglected by policy makers, donors and the research community (Bruce *et al*., 2000). This has resulted in social, economic and health related problems associated with lack of attention to problems associated with air pollution (Abera *et al*., 2020). There is also low public awareness due to lack of data and lack of policy action (Abera *et al*., 2020).

2.7 Other Risk Factors for Poor Lung Function

Apart from biomass use and air pollution as a risk factors for poor lung function, studies also suggest some other threats to poor lung function including cigarette smoking, history of TB, age and gender (Magitta *et al*., 2018), due to occupation done by either sex. Packs of cigarettes smoked per year and age may increase risk for high prevalence of COPD (Brakema *et al*., 2019). This all may lead to poor lung function impairing the health of an individual.

2.8 Current Approaches to Air Pollution and Respiratory Diseases

The approaches to COPD can be achieved by knowing the risk factors and areas where the prevalence of disease is high (Brakema *et al*., 2019) and the group more at risk. Globally, there has been an interest of reducing air pollution because of the increase in demand for energy, climate change and the increased awareness of air pollution effects on children and women (Gordon *et al*., 2014). The UN adopted the SDGs with a target specific to air pollution like the goal for good health and wellbeing (Target 3.9), affordable and clean energy for all (Target 7.1) and sustainable communities and cities (Target 11.2, 11.6), this enable most countries who signed the resolution to take measures toward air pollution regulation.

Tanzania is also in line with the SDGs like goal number 7 by which the country through the Ministry of Energy and Minerals promote use of clean and affordable energy in many ways including the establishment of Rural Energy Agency (REA) which ensures affordability and availability of electricity in rural areas (Uisso, 2009). Furthermore, the Tanzanian government through the Health Sector Strategic Plan (2021-2026) has a plan in strengthening Public Private Partnership (PPP) in addressing the health effects of air pollution from business and commercial activities (MOHCDGEC, 2021). The health sector has a plan in improving monitoring systems on air pollution and improving capacity of community groups in using data for priority setting in communities so as to improve community governance level by strengthening advocacy and good representation in the governing bodies (MOHCDGEC, 2021). The MOHCDGEC has a plan to engage the community and promote participation in preventing and controlling NCDs (MOHCDGEC, 2021).

The use of electricity and gas in cooking are important approaches for air pollution prevention especially to high income countries, as they are clean fuel and attractive, while other sources of energy like biogas in villages proves a clean and inexpensive energy for villages despite the need for investment (Gordon *et al*., 2014). A study done by Jackson (2009) suggested outdoor cooking to prevent indoor air pollution, and separation of kitchen from the main house, however this also increases outdoor air pollution which also causes respiratory diseases. The use of improved technologies in cooking lead to health improvement and can make the issue of air pollution become a modifiable exposure which can be modified by improved cooking system, improved fuels, and improved cook stoves (Gordon *et al*., 2014).

There are many different studies which have been conducted on indoor biomass use and the health effects to mother and child (Babalik *et al*., 2013; Balmes, 2020; Dida *et al*., 2022; Hulin *et al*., 2012; Jackson, 2009; Johan, 2015; Van-Vliet *et al.*, 2019), but there is limited study conducted among small scale fish vendors who use biomass fuel in frying fish and the impact of biomass smoke to health.

CHAPTERTHREE

MATERIALS AND METHODS

3.1 Study Design

The study was a cross-sectional descriptive study and was conducted among small-scale fish vendors who operate their business along the coast of the Indian Ocean.

3.2 Study Area

The study was conducted in Bagamoyo and Kunduchi fish markets in Tanzania. All these fish markets are located along the Indian Ocean (Fig. 1). Bagamoyo fish market is located in Bagamoyo District on the coast of the Indian Ocean, approximately 75 kilometers North of Dar es Salaam. The district lies 6° 26′ South of the equator and 38° 54′ East of prime meridian. Because of the closeness of the district to the sea it has high humidity and high temperature. The local people engage mainly with fishing activities in the Indian Ocean, and sell their catches at Bagamoyo Fish market which is the center for commercial activities. The Bagamoyo fish market is located in Dunda ward within the district.

Kunduchi fish market is located in Kunduchi ward in Kinondoni District in Dar es Salaam. It is also along the Indian Ocean, where the local people engage with fishing activities. Fish are being sold either raw or fried. Those who engage with frying fish for selling purposes depend on the usage of firewood as the main source of energy. The use of firewood in fish frying exposes the small-scale fish vendors to air pollution which affects the respiratory system. They work in an area with poor ventilation thus the exposure to smokes becomes very high. All fish vendors at these markets were studied depending on their readiness to take part in the study.

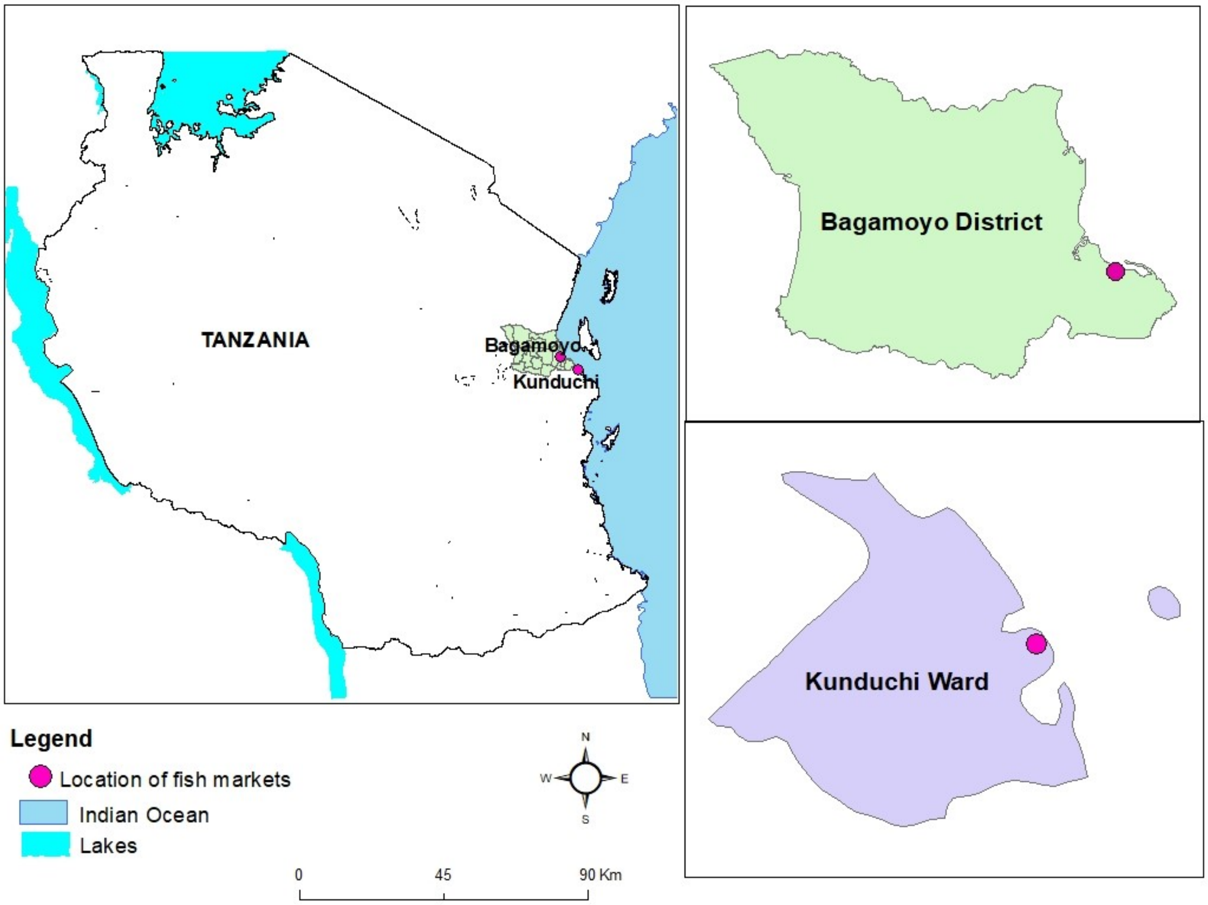

Figure 1: A map of study site showing locations of Bagamoyo and Kunduchi fish markets

3.3 Study Population

The study population was all fish vendors who were 18 years and above and involved in setting fire and frying fish and selling them at these markets. This is because setting fire with firewood emits pollutants which may affect their health and also, they are the one who take high doses of pollutants as they conduct their work on a daily basis.

Spirometry exclusion criteria was all fish vendors with contraindication to perform spirometry i.e., those with abdominal surgery in the past one month, history of any cerebral, thoracic, ophthalmic, or those with heart attacks or heart surgery or any other serious illness (Magitta *et al*., 2018). Both fish vendors were Africans from different tribes in Tanzania

3.4 Sample Size and Sampling Methods

Given a previous study on an informal urban environment (Magitta *et al*., 2019) which reported the prevalence of COPD at 8.13%. This was because it was in an informal urban areas same to the current study area. Sample size was then estimated using a power command on STATA where we anticipated the prevalence of COPD to double (i.e., 16.26%) because the exposure at the study area were much higher than the one reported by the previous study. Using power command on

Stata at an alpha level of 0.05 and 80% power, alternative prevalence of 16.26% yielded an estimated sample size of 109 participants. Hence the sample size was estimated at 109 participants with an addition of 5% non-respondent which yielded 114 participants obtained by the systematic sampling for which all fish vendors who were 18 years and above were listed and every third member were selected for the study. We therefore reached 103 participants as others refused to participate in the study whereby, 37 were from Kunduchi fish market and 66 from Bagamoyo fish market. All 103 participants performed the spirometry test. All fish vendors were Africans from different tribes in Tanzania.

3.5 Data Collection Methods

3.5.1 Composition and Levels of Main Air Pollutants

Both the two markets were monitored for composition and levels of air pollutants particularly fine particles, carbon monoxide, sulfur dioxide at the workplace. This was aerial measurements. The amount of air pollutants in the working environment was measured on a real time basis by repeated measurements. The working environment of fish vendors has more than 100 stoves where they burn firewood on their daily basis. They start operating at different times although most of them start around 02:30 hours to 18:00 hours. The measurement of pollutants was conducted before the fish vendors started their activities in the morning, during the fish frying process and after their work to obtain information concerning the variation of the particles with time.

(i) Particulate Matters (PM) Monitoring (Assessment)

The measurement of particulate matter (PM) emission levels at Bagamoyo and Kunduchi fish markets were conducted using a hand-held Intelligent Air Detector (Igeress series). This is a multifunctional air quality monitor with ability to assess several measures of air quality including concentrations of natural and synthetic volatile organic compounds (TVOC), formaldehyde (HCHO) and fine particulate dust matters like $PM_{2.5}$, PM_1 and PM_{10}. The suspended particulate matter of $PM_{1.0}$, $PM_{2.5}$ and PM_{10} were detected by the meter at a diameter in the range of 0 to 999 micrograms per cubic meter ($\mu g/m^3$). The detection range for HCHO was 0 to 1.999 mg/m^3 while the detection range for TVOC was from 0 to 9.999 mg/m^3. Additionally, meteorological data like temperature and humidity were also detected by the meter. In this study the measurement of air pollutants was real time measurement and was done every five minutes for 1 hour before, during and after fish frying and their average was calculated. During measurement the air detector was placed in the different sites within the fish market to monitor air at different times, i.e. before fish frying, during fish frying and after fish frying. It was placed approximately 1 metre above the ground to capture the inhalable air within breathing zone of fish vendors but was also placed 1 metre from the combustion zone to avoid it being too close to fire as it can be damaged. The monitor has a rechargeable lithium battery with a standby time of 6 to 8 hours.

(ii) Detection of other Gaseous Pollutants

The measurement of other gaseous pollutants levels was determined using two Portable Multi Gas Detectors, the BOSEAN of model BH-4s. They are capable to detect Ozone (O_3) in a range of 0-20 ppm, Sulfur dioxide (SO_2) in range of 0-20 parts per million (ppm), Nitric oxide (NO) in a range of 0-250 ppm and Carbon monoxide (CO) in a range of 0-1000 ppm. They detect all these gases emitted from either point of the fish market into air. During taking measurement, the gas detectors were held at approximately 1 m, the breathing height above the ground.

For both pollutants the monitoring process was conducted for 14 days in the two markets, i.e. Bagamoyo and Kunduchi fish markets with the sampling rate of 5 minutes in one hour. A total of 12 sampling data were collected per one hour, later the average was calculated. Samples were taken by determining the spatial configuration of the market to capture at least 95% of the area (Magitta *et al.*, 2018) by sample on sides of market and at the center before, during and after fish frying. Prior to data collection every day the calibration of equipment was conducted. The amount of these air pollutants was then compared with those specified by WHO guidelines.

3.5.2 Lung Function Capacity Test among Small-Scale Fish Vendors

Lung function was assessed by performing spirometry tests on each participant with no contraindication to spirometry. Age was recorded in full years and physical measurements were conducted by measuring height with a tape measure and body weight with ZOVEC digital weighing scale. All 103 participants were tested for pulmonary functions using a calibrated EasyOne diagnostic Spirometer (ndd Medizintechnik AG 8005 Zurich, Switzerland) after explaining the process involved to each participant. The spirometry test was conducted according to European Respiratory Society (ERS)/American Thoracic Society (ATS) standards (Graham *et al.,* 2019). The FEV1 and FVC was determined and used to calculate the tiffeneau-pinelli index as the ratio of FEV1/FVC.

Additionally, participants were instructed not to smoke cigarette for at least one hour before the spirometry test, not to wear tight clothes and not take any big meal two hours before doing the test. The test was carried out during the evening after the work and after the participant was in a sitting position, then the participant was instructed to take a deep breath followed by forced rapid exhalation into a disposable mouthpiece that is connected to a spirometer. Each participant was instructed to blow three acceptable maneuvers blows in a spirometer and the highest values for

FVC and for FEV1 was considered the best and used in analysis. The participants were allowed to rest 2 minutes between each blow. The spirometry values higher than the lower limit of normal were considered normal (Stanojevic *et al.,* 2021) while values below the lower limit of normal were considered abnormal. This was used to characterize participants as having obstructive lung disease, restrictive lung disease, mixed pattern or normal. The Global Lung Function initiative (GLI) reference values were used. For those who had FEV1/FVC>70% were considered normal and those who had FEV1/FVC<70% were considered with obstructive lung diseases, while those who had FVC<80% were considered with restrictive lung diseases. Participants with FEV1>70% were considered with mild lung obstruction, while those with FEV1 between 60% and 69% were considered with moderate lung obstruction, and those with FEV1<60% were considered with severe lung obstruction.

COVID-19 preventive measures were followed by using only one mouth piece to one participant during the spirometry test, and also the test was conducted to one participant at a time while the research team was wearing a mask. Also, hand sanitizer was available during the research activity. The study sites were having enough space to ensure social distancing of study participants during spirometry testing.

3.5.3 Respiratory Symptoms and Other Factors Associated with Poor Lung Function

A modified St. George respiratory questionnaire (SGRQ) (Jones & Forde, 2014) was used to assess respiratory symptoms including shortness of breath, phlegm, wheezing, coughing, nasal congestion. The questionnaire also assessed disturbances to daily physical activities due to the respiratory problems, and the impact of it to psychosocial function. Respiratory symptoms were measured as symptoms of coughing, phlegm production, shortness of breath, wheezing, or activities which make the participant feel breathlessness like walking uphill, walking up a flight of stairs, playing sports or other physical activity. Participants may experience respiratory symptoms as either many days in a week, few days in a week, few days in a month, or only when having respiratory infection or not experiencing respiratory symptoms at all. Those who reported to have respiratory symptoms for 3 or more days in a week were considered with higher respiratory symptoms. Also if participants experience any of the mentioned respiratory symptom in the past three months for 3 or more than three days consecutives, the person was considered with chronic respiratory problems. Other confounding factors like age, duration of work, Body Mass Index, smoking history, history of asthma, and tuberculosis were assessed and adjusted in the analysis. The questionnaire was administered face to face with the fish vendors. The questions were translated from English version to Swahili version and back using different research assistants. The questionnaire was administered using Swahili language as the respondents are more conversant with Swahili language as compared to English, thus they respond to questions in Swahili language.

3.6 Data Management and Analysis

Data was captured using an electronic platform OpenDataKit (ODK) and was managed in real-time using the same platform. Data was stored in a state-of-the-art database with established backup protocols at Ifakara Health Institute. Data was then exported as .csv files and analyzed using Stata Corps software version 17. All data were imported into Stata for analysis. Descriptive statistics was performed and presented as frequency and proportion as appropriate. Additionally, measures of central tendency were used to summarize the information either as mean with standard deviation or median depending on the data distribution. Logistic regression analysis (univariate and multivariate models) was used to determine factors that are associated with COPD and presented as crude and adjusted odds ratio and their 95% confidence intervals. A stepwise backward selection of variable was used to arrive to a final logistic regression model with Akaike Information Criterion being used to compare between models.

3.7 Ethical Clearance and Consideration

The ethical clearance for study conduct was acquired from the Institutional Review board of Ifakara Health Institute (IHI/IRB/No: 08-2022). Research permission from relevant authorities; ward executive officers, market leaders and fish vendors were also sought before data collection. No data was collected before ethical approval.

Prior to conduct any study procedure, participants provided with written informed consent to seek for voluntary participation in the study and they were assured of confidentiality and anonymity. Description of the objectives of the study, potential benefits and risks were given to the study participants so as to have informed consent. Information about voluntary participation was provided to participants and that they could withdraw from the study anytime they felt to withdraw.

Unique numbers were used to identify participants' data and no individual names or other identifying data were uploaded in the database. All data collected were accessible to researchers only and were not accessible to unauthorized personnel.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Study Population Characteristics

The demographic characteristics of 103 participants captured sex, age, education level, duration of work, working hours per day, working days per week, Body Mass Index and smoking history are presented in Table 1.

Out of 103 participants participated in the study, 35.92% and 64.08% participants were from Kunduchi and Bagamoyo fish markets respectively. Majority of participants were males 82 (79.6%) for which most of them were from Bagamoyo fish market. The average age of participants was 35.47 (SD 8.77) years ranging from 19 to 64 years. Most of participants 45 (43.7%) were aging between 30 to 39 years of age while only 2 (1.94%) participants were above 60 years of age. About 77 (74.8%) of participants were having a primary level of education, while 17 (16.5%) were having ordinary level of education and 9 (8.7%) were with no formal education (Table 1).

At both markets, all fish vendors (100%) practiced open burning/traditional open fires using firewood in frying fish for selling purposes. The long-term exposure to firewood smoke is high, as about 36.9% of participants have used firewood for frying fish for about five to ten years while 25.2% of the participants had fry fish for more than ten years. About 43 (41.8%) and 33 (32%) of the participants work seven days and six days per week respectively.

Of the 103 participants 57 (55.3%) reported to be working from five to eight hours per day, while 43 (41.8%) reported to work for more than eight hours per day. Most of the participants reported to work seven days per week 43 (41.8%), while 33 (32%) reported to work six days per week.

The current health status of participants was 90 (87.4%) fair, 11 (10.7%) good and 2 (1.9%) poor. The mean BMI for all participants was 24.18 (SD 5.02) kg/m^2. Most of the participants were having a normal body mass index 64 (62.14%), while 26 (25.24%) were overweight and 10 (9.71%) were obese and only 3 (2.91%) were underweight. Most women were having higher BMI with a mean of 28.5 kg/m^2 and male were having a mean BMI of 23.07 kg/m^2. Smoking habits of study participants was assessed and presented in Table 1.

Table 1: Demographic characteristics of the study population

Characteristics	Total n=103	Male n=82 (79.6%)	Female n=21 (20.4%)
Age in years			
19-29	30 (29.1%)	28 (34.15%)	2 (9.52%)
30-39	45 (43.69%)	35 (41.68%)	10 (47.62%)
40-49	19 (18.45%)	11 (13.41%)	8 (38.1%)
50-59	7 (6.8%)	6 (7.32%)	1 (4.76%)
60-69	2 (1.94%)	2 (2.44%)	0 (0%)
Education level			
Informal education	9 (8.7%)	9 (10.98%)	0 (0%)
Primary level	77 (74.8%)	59 (71.95%)	18 (85.71%)
Ordinary level	17 (16.5%)	14 (17.07%)	3 (14.29%)
Duration of work			
Less than a year	5 (4.9%)	4 (4.88%)	1(4.76%)
One to five years	34 (33%)	25 (30.49%)	9 (42.86%)
Five to ten years	38 (36.9%)	31 (37.80%)	7 (33.33%)
More than ten years	26 (25.2%)	22 (26.83%)	4 (19.05%)
Working hours per day			
Less than five hours	3 (2.9%)	3 (3.66%)	0 (0%)
Five to eight hours	57 (55.3%)	48 (58.54%)	9 (42.86%)
More than eight hours	43 (41.8%)	31 (37.8%)	12 (57.14%)
Working days per week			
Less than three days	1 (0.97%)	0 (0%)	1 (4.76%)
Four days	12 (11.7%)	4 (4.88%)	8 (38.1%)
Five days	14 (13.6%)	14 (17.07%)	0 (0)
Six days	33 (32%)	25 (30.49%)	8 (38.1%)
Seven days	43 (41.8%)	39 (47.56%)	4 (19.05%)
BMI (kg/m^2)			
Underweight	3 (2.91%)	3 (3.66%)	0 (0.00%)
Normal	64 (62.14%)	57(69.5%)	7 (33.3%)
Overweight	26 (25.24%)	19 (23.17%)	7 (33.3%)
Obese	10 (9.71%)	3 (3.66%)	7 (33.3%)
Smoking History			
Never smoked	70 (67.96%)	49 (%)	21 (100%)
Current smokers	22 (21.36%)	22 (26.83%)	0 (0.00%)
Ex-smokers	11(10.68%)	11 (13.41%)	0 (0.00%)
Packs per year	3.75 (SD 8.06)	3.75 (SD 8.06)	0

Data are presented as n (%) and mean(SD), unless otherwise stated.
BMI: Body Mass Index

4.1.2 Composition and Levels of Main Air Pollutants

The two fish markets (Bagamoyo and Kunduchi fish markets) were monitored for air pollutant concentrations. Occupational air pollution measurements were conducted in both fish markets to assess the levels and composition of air pollutants resulting from burning of firewood before fish frying, during fish frying and after fish frying to determine variation of pollutants over time. Main air pollutants in the two markets were Particulate matter (PM_1, $PM_{2.5}$ and PM_{10}) and Carbon monoxide (CO).

(i) Particulate Matters Concentration

The hourly average concentration of PM_1, $PM_{2.5}$ and PM_{10} in Bagamoyo fish market before fish frying was 14 (SD 3.7) µg/m^3, 17.6 (SD 4.8) µg/m^3 and 20.2 (SD 5.4) µg/m^3 respectively while for Kunduchi fish market was 15.6 (SD 3.9) µg/m^3, 20.6 (SD 5.3) µg/m^3, 25.2 (SD 5.4) µg/m^3 respectively. The hourly average concentration of particulate matter for Bagamoyo and Kunduchi fish market during fish frying for PM_1, $PM_{2.5}$ and PM_{10} are presented in Fig. 2. The hourly average concentration of PM_1, $PM_{2.5}$ and PM_{10} after fish frying for Bagamoyo fish market was 27.9 (SD 27.9) µg/m^3, 36.5 (SD 37) µg/m^3, 41.6 (SD 41) µg/m^3 while for Kunduchi fish market was 14.9 (SD 1.4) µg/m^3, 19.5 (SD 1.5) µg/m^3, and 25.7 (SD 1.7) µg/m^3 respectively.

The overall hourly average concentration of PM_1, $PM_{2.5}$ and PM_{10} before, during and after fish frying (for both markets) are presented in Table 2. The mean concentration level for Particulate Matter (PM_1, $PM_{2.5}$ and PM_{10}) were very high during fish frying as compared to concentration levels before and after fish frying. This shows that emission of particulate matter from firewood is high which has effects on respiratory health of fish vendors.

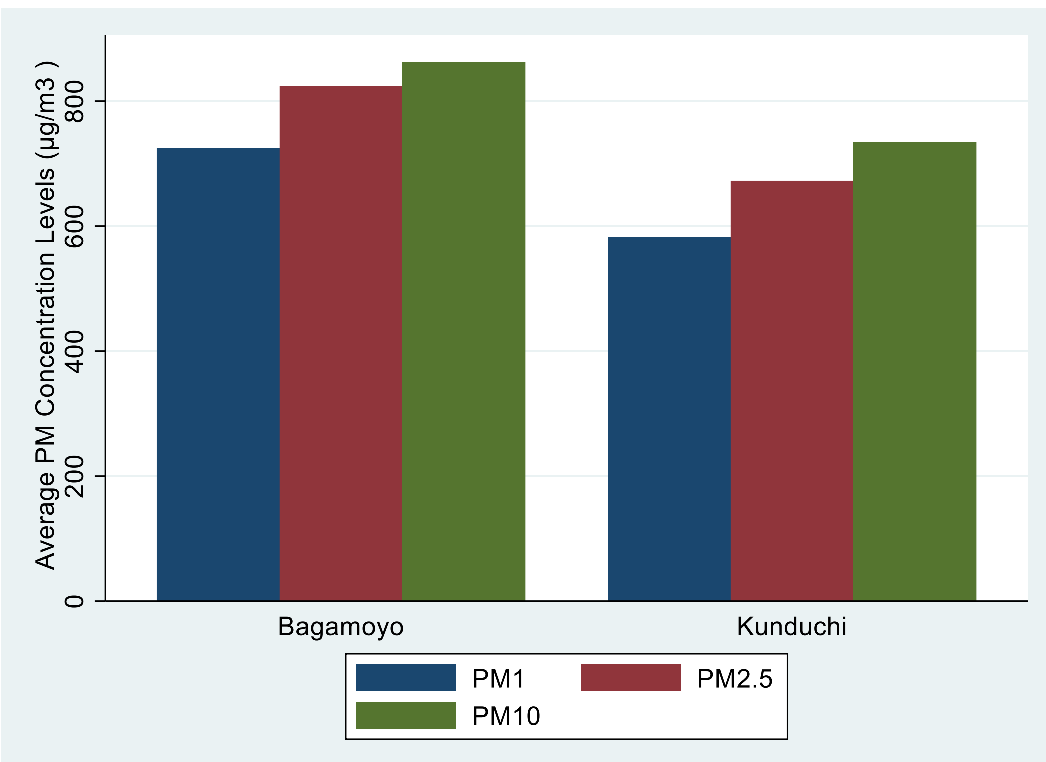

Figure 2: A graph showing mean PM concentration during fish frying for Bagamoyo and Kunduchi fish markets

(ii) Carbon Monoxide Concentration

Carbon monoxide (CO) concentration levels was also measured and the hourly average concentration of carbon monoxide in Bagamoyo fish market before fish frying was zero, and the concentration during fish frying was 55.7 (SD 14.2) ppm and after fish frying was 1 (SD 1.6) ppm. The hourly average concentration of carbon monoxide for Kunduchi fish market before fish frying was zero while concentration during fish frying was 69.5 (SD 3.9) ppm and after fish frying was 1 (SD 0.6) ppm.

The overall hourly average concentration of carbon monoxide before and after fish frying were below the WHO recommended limits. The overall hourly concentration of carbon monoxide during fish frying ranges from 37.3 to 73.6 ppm with an average of 62.6 (SD 12.3) ppm (Fig. 3) which is higher than the WHO recommended limits of 25 ppm or 30 mg/m^3.

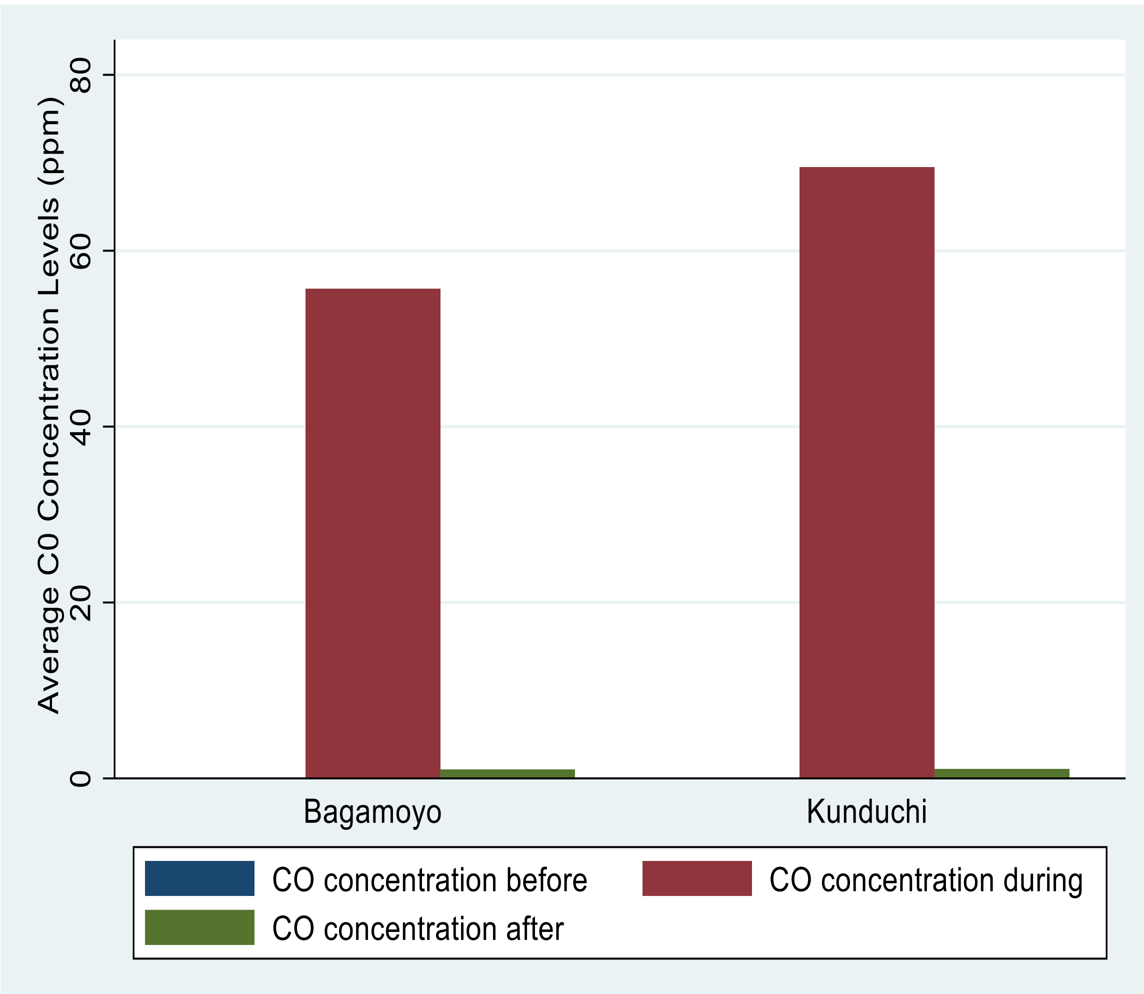

Figure 3: A graph showing CO concentrations before, during and after fish frying for Bagamoyo and Kunduchi fish markets

(iii) Other Gaseous Pollutants

Other gaseous pollutants like formaldehyde (HCHO), Total Volatile Organic Compounds (TVOC) Sulphur dioxide, Ozone, Nitric oxide were measured. The average concentration levels of formaldehyde (HCHO) before, during and after fish frying were 0.007 (SD 0.01) mg/m^3, 0.57 (SD 1.39) mg/m^3, and 0.009 (SD 0.004) mg/m^3 respectively. The average concentration of HCHO during fish frying was 5.7 times the recommended concentration limit which is 0.1 mg/m^3 while the average TVOC concentration before, during and after fish frying was 0.022 (SD 0.015) mg/m^3, 0.91 (SD 0.33) mg/m^3, 0.026 (SD 0.014) mg/m^3 respectively. The concentration levels of TVOC during fish frying was at a marginal level as above 1 mg/m^3 considered higher levels.

The average concentration levels of Sulphur dioxide, Ozone, Nitric oxide were below the recommended limits for both the two fish markets before, during and after fish frying (Table 2). This indicates that Sulphur dioxide, Ozone and Nitric oxide emissions from burning of firewood are very low. All measurements were measured at an average temperature and humidity of 31.76 (SD 1.84) and 52.4 (SD 4.84), respectively.

Table 2: Mean pollutant level concentration before, during and after fish frying

Air pollutants	Before	During	After
PM_1 (µg/m3)	14.79 (SD 3.75)	653.6 (SD 206.3)	21.44 (SD 20.11)
$PM_{2.5}$ (µg/m3)	19.055 (SD 5.11)	748.5 (SD 200.6)	27.99 (SD 26.7)
PM_{10} (µg/m3)	22.72 (SD 5.8)	798.7 (SD 181.7)	33.64 (SD 29.09)
CO (ppm)	0.00	62.6 (SD 12.32)	1.02 (SD 1.165)
SO_2 (ppm)	0.00	0.08 (SD 0.09)	0.008 (SD 0.013)
O_3 (ppm)	0.023 (SD 0.034)	0.05 (SD 0.046)	0.745 (SD 2.7)
HCHO (mg/m^3)	0.007 (SD 0.01)	0.57 (SD 1.39)	0.009 (SD 0.004)
TVOC (mg/m^3)	0.022 (SD .015)	0.91 (SD 0.33)	0.026 (SD 0.014)

Data presented as mean (Standard deviation)
PM: Particulate Matter; CO: Carbon monoxide; SO_2: Sulfur dioxide; O_3: Ozone

4.1.3 Lung Function Fitness of Small-Scale Fish Vendors

All 103 participants were tested for lung function using EasyOne Spirometer after input of age, weight, height and sex and have a reproducible result.

The mean Forced Vital Capacity (FVC) for the participants was 3.52 L (SD 1.21) L ranging from 0.81 to 8.16 L. The mean FVC predicted was 97.53% (SD 27.95%). Mean Forced Expiratory Volume in one second (FEV1) for the participants were 2.52 (SD 0.76) L ranging from 0.71 to 4.22L. Mean FEV1% predicted was 84.32% (SD 21.18%) ranging between 31-145%. Mean FEV1/FVC were 73.26 (SD 14.62) ranging from 31.4 to 94.2.

About 33 (32.04%) were having Obstructive lung disease, 19 (18.45%) were suspected of having restrictive lung disease, 19 (18.45%) were suspected as having mixed lung disease (both obstructive and restrictive lung disease) and 50 (48.54%) were normal (Fig. 4).

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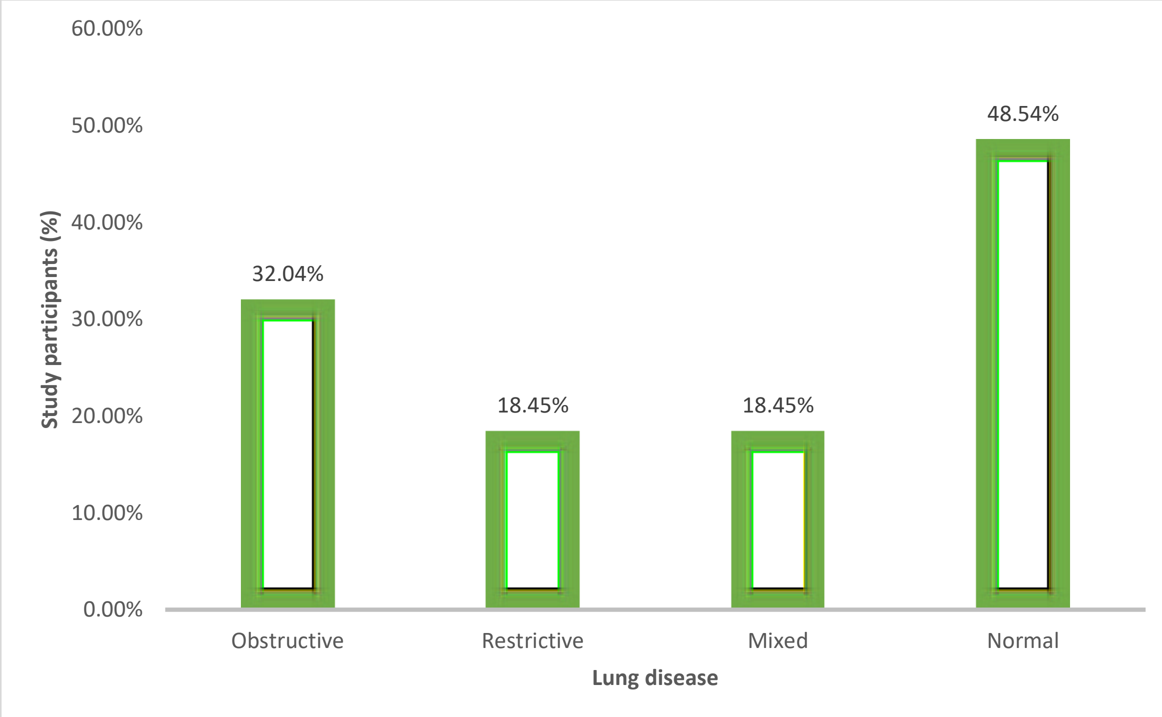

Figure 4: Lung function results of the study participants

About 81 (78.64%) were categorized as having mild lung obstruction, 11 (10.68%) moderate lung obstruction and 11 (10.68%) severe lung obstruction (Table 3). From the results it shows that the fish vendors are affected by firewood smoke. And since lung obstruction is progressive disease, if no immediate intervention is put in place the prevalence of respiratory symptoms will increase year to year.

Table 3: Lung function values of study participants

Lung function values	Total Mean ± SD	Male Mean ± SD	Female Mean ± SD
FEV1 (L)	2.52 ± 0.8	2.73 ± 0.6	1.69 ± 0.7
FEV1 % predicted	83.32 ± 21.2	85.8 ± 17.2	71.9 ± 27.8
FVC (L)	3.52 ± 1.2	3.77 ± 1.13	2.52 ± 1.0
FVC % predicted	97.53 ± 27.9	99.09 ± 25.9	91.5 ± 34.7
FEV1/FVC	73.26 ± 14.6	74.5 ± 13.5	68.43 ± 17.8
Lung obstruction category	**Total n (%)**	**Male n (%)**	**Female n (%)**
Mild	81 (78.64%)	69 (84.1%)	12 (57.14%)
Moderate	11 (10.68%)	9 (10.99%)	2 (9.52%)
Severe	11 (10.68%)	4 (4.88%)	7 (33.3%)

Data are presented as mean + SD and n (%)

4.1.4 Respiratory Symptoms of Small Scale Fish Vendors

The study assessed presence of any respiratory symptoms and how these symptoms affect the daily activities of the participants and their impact on psychological life. In this regard, participants were required to fill a standardized questionnaire. Most symptoms were coughing, sputum production, breathlessness, attacks of wheezing (Fig. 5) and their effect on daily life.

Coughing was reported as the main respiratory symptom by 70 (68%) participants, and sputum production was reported by 75 (72.8%) while wheezing was reported by 86 (83.5%) and shortness of breath was reported by 55 (53.4%). About 32 (31.07 %) reported that they walk slow than others of the same age when on level ground, 52 (50.49%) participants reported that they had to stop for breathing when walking on hurry and 75 (72.8%) reported breathlessness when walking flight of stairs, while 79 (76.7%) reported breathlessness when walking uphill and 15 (14.6%) reported breathlessness when walking on level ground.

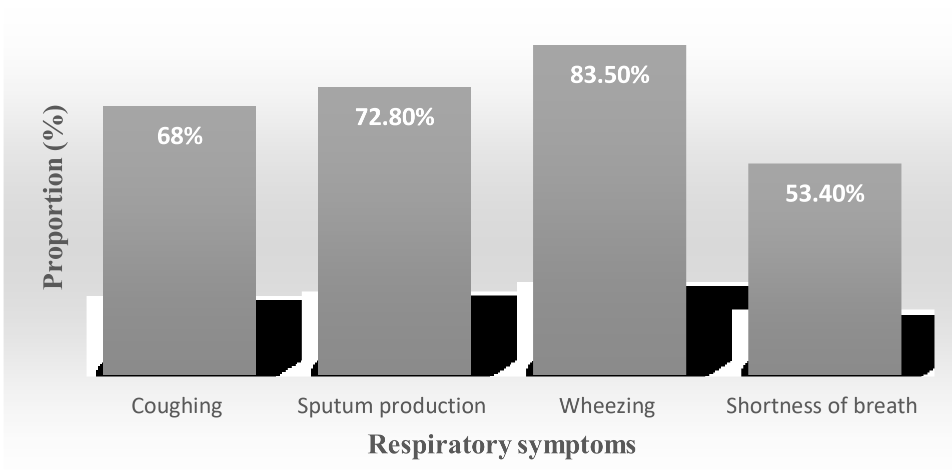

Figure 5: Reported respiratory symptoms

When participants were asked if they had ever had other chest trouble most of the fish vendors complained about dry cough, black sputum production and breathlessness during working and during sleeping. Others reported non respiratory problems like headache every night and tearing of eyes.

4.1.5 Other Factors Associated with Chronic Obstructive Pulmonary Disease

Of the 103 participants who performed spirometry test 1 (0.97%) had a previous neck injury, 2 (1.94%) had a heart trouble, 3 (2.91%) had previously tuberculosis, and about 22 (21.36%) were current smokers and 11(10.68%) were ex-smokers (Fig. 6). The study did not find any association between having previous neck injury, heart trouble and smoking history with obstructive diseases.

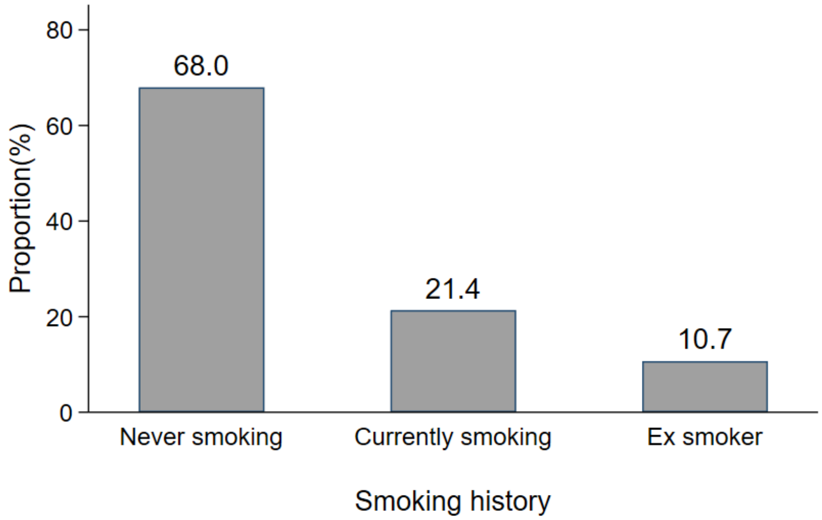

Figure 6: Smoking habits among study participants

In multivariate logistic regression analyses, males had reduced odds for COPD by 75% (AOR 0.25, 95% CI 0.06-1.26) as compared to females, although this observation was non-significant (Table 4). Interestingly, those who were underweight have increased odds for COPD while those who were obese have reduced odds of COPD (AOR 0.09, 95% CI 0.01-0.91) (Table 4). Previous history of TB treatment was associated with a 75% increase in the odds for developing COPD (AOR 1.75, 95% CI 0.2-15.38), again this finding was not statistically significant. Intuitively, increased number of days one worked in frying fish was associated with incremental higher odds for COPD (Table 4). Lastly, participants who reported feeling out of breaths while walking on level ground or when climbing stairs had increased odds for developing COPD with AOR 3.08 and 1.2, respectively (Table 4).

4.1.6 Knowledge of Health Risk of Firewood Smoke and Protective Mechanism

The study wanted to know if fish vendors have knowledge about health hazards of firewood smoke and the protective mechanism they use. The findings showed that most of the fish vendors know well the dangerous effects of inhaling firewood smoke and they believe that drinking fresh milk (60%) and eating fruits (20%) like oranges, cucumber pawpaw, banana and watermelon can prevent the harmful effects of firewood smoke. Others (15%) believe in the use of honey and 5% believe in eating raw eggs as a preventive mechanism against the harmful effects of firewood smoke. None among the participants used any protective equipment like masks.

Table 4: Univariate and multivariate analysis for predictors of COPD

Characteristics	No COPD	COPD	Univariate model			Multivariate model		
			Unadjusted OR	95% CI	P value	Adjusted OR	95% CI	P value
Age, years	35.2 (8.8)	36.1 (8.8)**	1.01	0.96-1.06	0.62	-		
Males	57 (81.43)	25 (75.76)	0.71	0.26-1.93	0.51	0.25	0.06-1.16	0.076
BMI category								
Normal	43 (61.43)	21 (63.64)	1	-	-	1	-	-
Underweight	1 (1.43)	2 (6.06)	4.10	0.35-47.8	0.261	6.91	0.61-78.5	0.119
Overweight	17 (24.29)	9 (27.27)	1.08	0.41-2.84	0.869	0.90	0.33-2.46	0.838
Obese	9 (12.86)	1 (3.03)	0.23	0.03-1.92	0.173	0.09	0.01-0.91	0.04
Education level								
No/informal education	7 (10)	2 (6.06)	1	-	-	-		
Primary level	54 (77.14)	23 (69.70)	3.11	0.5-19.54	0.226	-		
Secondary level	9 (12.86)	8 (24.24)	1.49	0.29-7.73	0.634	-		
Smoking cigarettes	22 (31.43)	11 (33.33)	1.09	0.45-2.64	0.847	0.96	0.31-2.95	0.94
History of TB treatment	2 (2.86)	1 (3.03)	1.06	0.09-12.2	0.961	1.75	0.2-15.38	0.62
Exposure to fish frying								
Less than 1 year	2 (2.86)	3 (9.09)	1	-	-	-		
1 to 5 years	27 (38.57)	7 (21.21)	0.17	0.02-1.24	0.081	-		
5 to 10 years	24 (34.29)	14 (42.42)	0.39	0.06-2.62	0.332	-		
Above 10 years	17 (24.29)	9 (27.27)	0.35	0.05-2.51	0.298	-		
Working days per week								
Not more than 4 days	10 (14.29)	3 (9.09)	1	-	-	1	-	-
5 days	10 (14.29)	4 (12.12)	1.33	0.24-7.56	0.745	4.04	0.47-34.7	0.203
6 days	22 (31.43)	11 (33.33)	1.67	0.38-7.32	0.499	4.34	0.74-25.6	0.104
7 days	28 (40)	15 (45.45)	1.79	0.43-7.50	0.428	4.57	0.80-26.0	0.087
Dry cough	12 (38.71)	3 (21.43	0.43	0.1-1.87	0.262	-		
Productive cough	11 (34.38)	6 (40)	1.27	0.36-4.51	0.709	-		
Wheezing	8 (26.67)	1 (5.88)	0.17	0.02-1.51	0.113	-		
Morning wheezing	15 (21.43)	4 (12.12)	0.51	0.15-1.66	0.262	-		

Characteristics	No COPD	COPD	Univariate model			Multivariate model		
			Unadjusted OR	95% CI	P value	Adjusted OR	95% CI	P value
Breathlessness on level ground	8 (11.43)	7 (21.21)	2.09	0.69-6.35	0.195	3.08	0.88-10.8	0.079
Breathlessness on walking up the stairs	49 (70)	26 (78.79)	1.59	0.59-4.24	0.352	1.20	0.41-3.51	0.733
Shortness of breath	5 (26.32)	4 (36.36)	1.6	0.32-7.90	0.564	-		

** *Mean age (standard deviation)*

COPD, Chronic obstructive lung disease; n, number; OR, Odds ratio; CI, Confidence interval; TB, Tuberculosis

Multivariate logistic regression model adjusted for sex, BMI category, smoking cigarettes, history of TB treatment, duration of exposure per each week, breathlessness at rest and on exertion

4.2 Discussion

This study is the first study conducted among fish vendors in the work environment (Bagamoyo and Kunduchi fish markets) assessing occupational exposure in Tanzania. In both working environments all fish vendors (100%) practice open burning in frying fish for business purposes. These findings are consistent with the Tanzania demographic health survey data which presents more than 94% of Tanzanians using biomass fuel in cooking practices mainly charcoal and wood (TDHS, 2016). The use of wood has also been reported in many parts of the world as a primary cooking fuel in South Asian, African and South American countries with open fires most common in Tanzania, Pakistan, Colombia and Zimbabwe (Shupler *et al*., 2020). Also a study in Tanzania by Magitta *et al*. (2019) at household settings found almost all participants reported exposure to biomass fuel. These findings are similar to many studies in Africa where availability and affordability of biomass fuel have been mentioned as a major motive for biomass fuel use (Ndwiga *et al*., 2014). The constituents of biomass smoke are known to be toxic and cause irritation of the respiratory system. These constituents include Carbon monoxide, Sulfur dioxide, Particulate matter, Nitrogen dioxide, Formaldehydes, Volatile Organic Compounds, Polycyclic Aromatic Hydrocarbons, free radicals and chlorinated dioxins (Lalita & Anthony, 2014). Multiple risk factors for COPD have also been reported in Africa. A cigarette smoker may be exposed to air pollutants or occupational exposure (Magitta *et al*., 2019) hence in this study multiplicity of risk factors may have resulted in the findings observed as all participants were occupationally exposed to air pollutants and 32% were having a history of smoking.

4.2.1 Demographic Characteristics of Study Participants

For this occupation, the number of men is higher than that of women as many men engage in fish frying. This is different from findings from other cross sectional studies conducted in different parts of the world which reported biomass smoke exposure to women and mothers who are more responsible in cooking practices at homes (Dida *et al*., 2022; Jackson, 2009; Mohapatra *et al*., 2017) while in the process of fish frying in Tanzania men are more exposed to air pollution from burning of firewood as an occupational exposure. Other studies have also reported high exposure of biomass smoke to women as they are responsible for cooking at home at their early age and hence cumulative exposure over time which lead to early manifestation of the disease (Lalita & Anthony, 2014).

4.2.2 Composition and Levels of Air Pollutants

Determining the concentration of suspended particles is the best indicator of the health risk. Those particles with 10 micrometers diameter or below (PM_{10}) and those with 2.5 micrometers diameter or below ($PM_{2.5}$) were reported with the ability to enter deeply in the lung, hence causing damage to health (Ndwiga *et al*., 2014). The mean concentration level for Particulate matter (PM_1, $PM_{2.5}$ and PM_{10}) were very high during fish frying as compared to concentration levels before and after fish frying. This shows that emission of particulate matter from firewood is high which has effects on respiratory health of fish vendors. Customers who also spend some time in the market when buying fish are affected.

The overall average hourly for PM_1, $PM_{2.5}$, PM_{10} during fish frying were above the WHO recommended standards. The PM_{10} concentrations were higher than the EPA standards of 150µg/m^3 and $PM_{2.5}$ were higher than the 35 µg/m^3 for a 24hrs average (EPA, 2022). In both Bagamoyo and Kunduchi fish markets the $PM_{2.5}$ levels measured were 20 times higher while PM_{10} were 5 times higher than the United States Environmental Protection Agency recommended limits for a 24-hour average. One study by Romieu *et al.* (2013) reported a wide range of PM concentrations beginning with tens of µg/m^3 to hundreds and sometimes thousands of µg/m^3 during cooking as peak exposures at household level and as this pollutants are most damaging to health especially the small size one (Lalita & Anthony, 2014; Romieu & Schilmann, 2013).

The study conducted in Bagamoyo villages in 2010 assessing indoor air pollution due to cooking fuelwood found very high levels of Suspended particulate matters in rural areas of Tanzania which was also above the WHO recommended standards which was much higher than findings from this study ranging from 13 571 µg/m^3 to 305 798 µg/m^3 (Jackson, 2009). These levels may contribute to respiratory problems now and in the long run if immediate measures are not taken into account.

Studies have reported higher levels of PMs in different settings as indoor air pollutants (Jung & Huxham, 2018), and prolonged exposure leads to respiratory problems and other cardiopulmonary effects. One study conducted in different settings reported PM_{10} exposure ranges from 29 to 2656 µg/m^3 during cooking activity, and 9.4 to 611.3 µg/m^3 after cooking (Kilabuko *et al*., 2007), which is different from findings of this study as the PM_{10} after fish frying were so low below the WHO recommended standards.

The effect of exposure to biomass smoke leads to wheezing, respiratory tract infections, chronic obstructive pulmonary diseases and chronic bronchitis (Lalita & Anthony, 2014) all of which cause health damage. A study conducted by Zhou *et al.* (2011) measures higher levels of PM in cooking areas of $PM_{2.5}$ and PM_{10} and recommends community transition to clean cooking fuels so as to meet the WHO air quality guidelines (Zhou *et al*., 2011).

The overall hourly average concentration of CO before and after fish frying were below the WHO recommended limits while the average concentration during fish frying was so high exceeding the recommended limit. This concur with the study done at household setting in Bagamoyo villages who were using biomass fuel when measuring indoor air pollution where the concentration of CO before cooking was below the WHO recommended standards while the concentration during cooking activities were so high exceeding the recommended limits (Jackson, 2009). The overall hourly concentration of carbon monoxide during fish frying were 2-3 times higher than the WHO recommended limits of 25 ppm or 30 mg/m^3 (WHO, 2010) which is also higher than the recommended standards set by NEMC of 30 mg/m^3 in Tanzania (Tanzania Environmental Management Act, 2007). The study conducted by Bruce *et al*. (2000) also reported higher levels of carbon monoxide during cooking with values ranging from 10 to 500 ppm (Bruce *et al*., 2000). The exposure may become low for outdoor kitchen due to smoke dispersion (Lalita & Anthony, 2014). Higher CO levels lead to CO poisoning in the body as Carbon monoxide combines with hemoglobin in the blood to form Carboxyhemoglobin which reduces delivery of oxygen to tissues (Lalita & Anthony, 2014) and have adverse health outcomes. When CO levels are high leads to respiratory problems including breathing problems and chest pain, headache, nausea and dizziness but other types of indoor air pollutants can lead to this symptoms also (Jung & Huxham, 2018). It is worth noting that repeated exposure to this levels may likely lead to health damage.

The average concentration of formaldehyde (HCHO) during fish frying was 5.7 times the recommended concentration limits which is 0.1 mg/m^3 (Kelly, 2022). As formaldehyde is in a group of carcinogenic organic compounds (Romieu & Schilmann, 2013), higher levels have many health effects. Short term exposure to formaldehyde leads to throat and nose irritation in humans (Lalita & Anthony, 2014). It may also lead to respiratory tract and eye irritation and sensitization of the skin. Burning of firewood emits formaldehyde which is a carcinogenic substance to humans. Therefore, fish vendors by using firewood are exposed to many pollutants which affect their health in one way or another. The process of burning biomass has been confirmed by studies as a major source of Volatile Organic Compounds, with known carcinogenic effects (Romieu & Schilmann, 2013).

The average concentration levels of Sulphur dioxide, ozone, and nitric oxide were below the recommended limits for both the two fish markets before, during and after fish frying. This indicates that Sulphur dioxide, ozone and nitric oxide emissions from burning of firewood are very low. Results show that Sulphur dioxide was below detection limits before and after fish frying, same as findings from the study by Jackson (2009) who concluded that Sulphur dioxide emissions from firewood is very low. During fish frying Sulphur dioxide was 0.083 ppm which is lower than the WHO limits of 500 µg/m^3 for an average time of 10 minutes.

For all air pollutants measured, the average pollutant concentration before and after fish frying was below the recommended standards. Air pollution among fish markets was higher than the WHO recommendations for both particulate matter and carbon monoxide exposure during fish frying. A study conducted in Malawi assessing air pollution at household level found that day to day air pollution exposure which was approximated three times the WHO upper safety limits (Nightingale *et al*., 2019) same as this study as the rates of pollutants exposure in terms of particulate matter, carbon monoxide and formaldehyde were higher than recommended standards.

4.2.3 Lung Function Fitness of Small-Scale Fish Vendors

Participants were tested for lung function. The test was carried out during the evening after the work as many of them complained of breathlessness during working and after the work. In this study no any participant had a previous spirometry test or any diagnosis of lung function same as the previous study at household level (Magitta *et al*., 2018). A study conducted in informal urban environment report the prevalence of COPD to be 8.13% (Magitta *et al*., 2019), although this is a different setting, but still the prevalence of lung obstruction in the current study based on the FEV1/FVC less than the LLN (Pellegrino *et al*., 2005) is much higher than this as in every 10 fish vendors 3 individual have lung obstruction. A study conducted in Malawi on use of biomass fuel among household participants found 40% of participants with abnormal spirometry but mainly restrictive lung diseases (Meghji *et al*., 2016; Nightingale *et al*., 2019) which is different from this study as the higher proportion of abnormal spirometry was found among participants with obstructive lung disease. The same study in Malawi found the prevalence of lung obstruction to be 8.7% (95% CI, 7.0–10.7) (Nightingale *et al*., 2019) which is lower than the findings of this study. The higher prevalence of lung obstruction among fish vendors may be because of daily exposure to firewood smoke, which may have a major public health implication in occupational settings and the community at large. Majority of participants with lung obstruction were having mild to moderate lung obstruction. From these findings it shows that fish vendors are affected by firewood smoke. And since lung obstruction is progressive disease, if no immediate intervention is put in place the prevalence of respiratory symptoms will increase year to year.

The reason for observed higher prevalence of COPD may be due to occupational exposure which results from day to day exposure for 8 to 10 hours. The lower numbers of females who participate in this study (20.4%) make generalization of findings difficult. Avoiding sex bias by including a similar number of both sex was difficult as females who participated in this occupation in Tanzania are few compared to men. The prevalence of lung obstruction in this working population suggests that there are concealed health problems and may be a major potential for health consequences in the future if immediate intervention is not taken into account. Major priority has to be prevention of exposure by promotion of self-awareness among fish vendors on the harmful effects of firewood smoke and among health-care workers and policy makers (Van Gemert *et al*., 2015).

4.2.4 Respiratory Symptoms of Small Scale Fish Vendors

Most reported respiratory symptoms were coughing, sputum production, breathlessness and attacks of wheezing and how they affect their daily life. Almost all fish vendors reported having respiratory symptoms (cough, breathlessness, wheezing and sputum production) which interfere with their daily activities in one way or another. The reported respiratory symptoms of this study are higher than reported findings of the study at household level by Magitta *et al.* (2018) who reported higher percentages of all of this symptoms with 51.7% of patients were having cough, 35.6% had sputum production, 32.3% were having wheezing, 25% reported breathlessness, 84.6% reported walking slower than others of same age, 69.2% they had to stop for breath when walking and 46.2% were having shortness of breathing when at rest. A previous study assessing the effect of household cooking smoke reported cold as the most common symptom (46%), coughing (46.6%), phlegm production (21.2%) (Juntarawijit & Juntarawijit, 2019) same as respiratory symptoms reported in this study.

The reported respiratory symptoms were similar to respiratory symptoms reported elsewhere (Jung & Huxham, 2018; Juntarawijit & Juntarawijit, 2019; Magitta *et al*., 2018; Meghji *et al*., 2016; Ndwiga *et al*., 2014). A study done in South East Asia in Brunei Darussalam reported that cooking vendors who use biomass fuel where having higher respiratory symptoms and the symptoms were thrice more for those who have work for more than 10 years (Nor *et al*., 2014) same as this study where working duration and increased working days per week were associated with higher respiratory symptoms. This may be because the working duration of many years increases the chance of getting higher respiratory symptoms as a result of cumulative occupational exposure overtime.

Both male and females reported experiencing higher respiratory symptoms. There are also some studies on the effect of biomass smoke and respiratory symptoms among adults for which higher risk of those symptoms reported among male (Magitta *et al*., 2019) same as this and the reason was cigarette smoking. Higher risk of respiratory symptoms among the female gender associates with the double exposure as they are responsible for cooking at homes while also exposed to biomass smoke at work. Thus the cross exposure of health risk may balance the exposure risk which are related to gender (Magitta *et al*., 2019). Some symptoms were significantly related to smoking (coughing, sputum production, wheezing and breathlessness when walking uphill) same as other studies at household level which reported an association between chronic respiratory symptoms with smoking (Nightingale *et al*., 2019). It appears that the respiratory symptoms could have results from the daily exposure to biomass smoke while also other risk factors play a role. The results of this study may be explained by the fact that firewood smoke contain many pollutants which are dangerous to health such as carbon monoxide, particulate matter, formaldehydes, nitrogen dioxide, sulfur dioxide, volatile organic compounds, polycyclic aromatic hydrocarbons, free radicals and chlorinated dioxins.

Exposure to wood smoke has association with respiratory effects including acute and chronic changes in the lung function (Umoh & Peters, 2014). Respiratory symptoms like coughing and breathlessness result from high exposure to firewood smoke pollutants and may aggravate lung disease (Orozco-Levi *et al*., 2006) and reduce the strength of the immune system. Thus alternative energy use can contribute to reduction of respiratory symptoms and COPD development. However only longitudinal studies over several years can fully account for the relationship between biomass smokes and self-reported pulmonary symptoms amongst fish vendors.

4.2.5 Other Factors Associated with Chronic Obstructive Pulmonary Disease

The prevalence of current smokers and ex-smokers were higher in this study, however the study conducted by Magitta *et al.* (2018) assessing COPD at household settings reported the prevalence of ex-smokers to 25.2% higher than the one found in this study while the prevalence of current smokers were 5.4% low than the one found in this study (Magitta *et al*., 2018). However, this study did not find any association between smoking history and COPD. The previous study at household setting reported the prevalence of those who had previous history of TB to be 3.63% (Magitta *et al*., 2018) which is higher than the one reported by this study.

In logistic regression analysis age, gender, working duration, being underweight and having a previous history of tuberculosis were associated with COPD although the association were non-significant. This shows that there are some other factors responsible for lung obstruction including exposure to air pollutants of biomass smoke. As COPD was found to be associated with age, this may be due to cumulative risk over time both biologically and epidemiologically plausible thus higher risk of lung obstruction as the person ages (Bruce *et al*., 2000; Magitta *et al*., 2019) but in the current study the association was non-significant. Also the association of lung obstruction with female gender may be explained by social cultural reasons as females are more exposed at early age in homes than males (Mahembe *et al*., 2010) and hence double exposure.

In this study population, COPD is higher compared to other reports in Africa as 3-4 participants out of 10 have COPD. Air pollution is a major determinant of COPD though other risk factors such as gender, having previous TB history and working duration play a role. Improving the working environment and use of clean energy remains an important strategy in controlling lung obstructive diseases in this population.

The study conducted in Simiyu at household setting found no association between COPD prevalence and use of biomass fuel, however it doesn't mean that smoke emitted during burning of biomass smoke is not a COPD risk factor as 99.5% used biomass fuel and the study was not powered enough to detect differences between cases and control population as they were too small to detect any differences and identify biomass smoke as a risk factor for COPD (Magitta *et al*., 2018). The current study was also not powered enough as the study didn't have the control group and hence this study only describes the situation of biomass smoke exposure among fish vendors.

Findings from this study indicate that biomass use is still common in occupational settings including fish frying working environment. Health risks associated by this have been documented in many studies (Babalik *et al*., 2013; Bruce *et al*., 2000; Jackson, 2009; Kilabuko *et al*., 2007; Kurmi *et al*., 2012; Zhou *et al*., 2011) hence there is a need for immediate action to protect this workforce. Fuel price and cost for clean energy have become a challenge (Bruce *et al*., 2000) even to this group of fish vendors, hence the government should look at how to subsidize the costs for clean energy for the safety of this working group. This should also be addressed through policies so as to enable cleaner fuel for the poor (Zhou *et al*., 2011).

This study reports an occupational exposure to firewood smokes and associated respiratory symptoms reported by fish vendors. The findings are concurrent with other reports in Africa (Bruce *et al*., 2000; Magitta *et al*., 2018; Nightingale *et al*., 2019) which report a linkage between being exposed to biomass smoke and respiratory symptoms among household members, among food venders and in the community. The findings of this study may be due to daily occupational exposure to firewood smoke. Also the type of oil used (Nightingale *et al*., 2019) in frying fish may also be a source of respiratory symptoms, although this study did not assess the types of oil used in frying fish. Therefore, this study recommends effective strategies to prevent and control non-communicable respiratory diseases in Tanzania and elsewhere.

4.2.6 Knowledge of Health Risk of Firewood Smoke and Protective Mechanism

The findings showed that most of the fish vendors know well the dangerous effects of inhaling firewood smoke and they believe that drinking fresh milk (60%) and eating fruits (20%) like oranges, cucumber pawpaw, banana and watermelon can prevent the harmful effects of firewood smoke. Others (15%) believe in the use of honey and 5% believe in eating raw eggs as a preventive mechanism against the harmful effects of firewood smoke. These findings are similar to the findings reported by a team of scientists who conclude that intake of green vegetables and fruits adequately, drinking of milk also may contribute to reducing respiratory symptoms and improve lung function (He *et al*., 2008). None among the participants used any protective equipment.

Given that there is much evidence on the health effect of associated with being exposed to air pollutants and the extent of public health impact of this environmental risk factor, immediate intervention to reduce the exposure to this risk factor and air quality improvement are needed to protect public health, requiring both multidisciplinary and multisectoral approaches.

4.2.7 Exposure Assessment and Lung Function Measurement

Participants were tested for lung function using EasyOne diagnostic Spirometer same as the study which was conducted in Simiyu region (Magitta *et al*., 2018) who also used the same device in testing for lung function among household participants. Exposure assessment were conducted using a hand-held Intelligent Air Detector to measure particulate matters and two Portable Multi Gas Detectors, the BOSEAN of model BH-4s were used to measure Carbon monoxide, Sulphur dioxide, Nitrogen oxide and Ozone. The availability and low cost of these instruments are among the reasons for their use. Other study conducted in Bagamoyo at household level (Jackson, 2009) used a filter and vacuum pump to measure Suspended Particulate Matter and a combustion analyzer CA-6200-CALc to measure Carbon monoxide, Nitrogen oxide and Sulphur dioxide.

4.2.8 Strength of the Study

The strength of the study is that it is the first study performed among fish vendors in Tanzania where spirometry and environmental measurements were conducted. This was a descriptive cross sectional study that described the fish vendor's work environment, and its associated occupational exposure and the effects on the respiratory system. The study opens up for the follow up or cohort studies to be conducted in this area.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

Based on this findings the following conclusions were made:

This study quantifies particle mass concentration of air pollutants in fish vendor's work environment and their health status. Air pollutants levels at fish vendor's work environment during performing their activities of frying fish using firewood are higher than the WHO recommended standards. Further investigation is justified because the determined levels are so high and are hazardous to the health of both fish vendors and their customers. Findings also suggest that three out of ten participants had COPD, suggesting that occupational exposure to biomass smoke may be a risk factor. Therefore, based on the nature of the fish vendor's working environment, it is realistic that reported respiratory symptoms were resulted from daily exposure to air pollutants. Interventions should reduce/eliminate exposure levels. This group of fish vendors work in an informal sector where occupational health and safety is nonexistent. This calls for the need for urgent effective approaches to reduce occupational exposure and control mortality and morbidity rate caused by firewood smoke exposure at work. Further research is needed in this neglected occupation as there are limited studies on the effect of air pollution exposure and respiratory diseases to this group of fish vendors.

5.2 Recommendations

Based on this study the following recommendations are made;

(i) There is a need for regular monitoring of business areas for the amount of pollutants, this should include monitoring of carbon monoxide, formaldehyde and particulate matters and providing recommendations.

(ii) The study strongly recommends carrying out other study using larger sample size to substantiate the study results, and using personal sensors to measure personal pollutants inhalation.

(iii) There is also a need to create public awareness by educating fish vendors on the effects of inhaling firewood smoke as it contains many dangerous air pollutants. Public awareness campaigns should be conducted to ensure more knowledge is provided to this community.

(iv) Also development of innovative solutions on matters of energy use and provision of alternative clean energy to fish vendors for them to fry fish is another way to protect them from the dangerous effects of firewood smoke.

(v) There is a need for multi-sectoral and multi-stakeholder collaboration to address the problem of air pollution and NCDs and protect public health. This may involve different public and private sectors to undertake research and interventions.

(vi) There is a need for enforcement and implementation of Air quality standards regulation and development of Tanzania Air quality policy.

(vii) Although more evidence to validate the study is recommended, in view of this study there is a need to take measures against air pollution.

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APPENDICES

Appendix 1: Data Collection Tools: Questionnaire

Identification number ID NO …………

Date of Interview ....

Instructions: This questionnaire should be filled during data collection process through a face to face interview with the participant. Please make sure you read at it is written.

Section A: **Social Demographic characteristics**

1. The date of birth ……………………………
2. Your Sex
   - Male ☐
   - Female ☐
3. Level of education
   - Informal education ☐
   - Primary ☐
   - Ordinary level ☐
   - Advanced level ☐
   - College ☐

Section B: **Occupational characteristics**

4. What type of work do you usually do at this site?
   - fish frying ☐
   - other ☐
   - If other specify ……………………………...................
5. What source of energy do you usually use in frying fish?
   - firewood ☐
   - gas ☐
   - electricity ☐
   - other (specify) ☐
6. When did you start doing this job (months or years)
   - Not more than a year ☐
   - One to five years ☐
   - Five to ten years ☐
   - More than 10 years ☐
7. Hours spent working per day? ☐

Less than five hours
Five to eight hours
More than eight hours

8. Days spent working per week?
   Less than three days
   Four days
   Five days
   Six days
   Seven days

9. How can you describe your present health status?
   Very good
   Good
   Fair
   Poor
   Very Poor

Section C: **Chest trouble questions**

I am going to ask you some questions about your chest, I request you to answer appropriately as you feel

10. Over the past three months I get cough on:
    Many days per week
    Few days in a week
    Only when I have respiratory infections
    Never

11. Over the past three months I bring up phlegm (sputum):
    Most days a week
    Several days a week
    Only with respiratory infections
    Not at all

12. Over the past three months I have shortness of breath:
    Most days a week
    Several days a week
    Not at all

13. Over the past three months I have attacks of wheezing:
    Most days a week

Several days a wee ☐

A few days a month ☐

Only with respiratory infections ☐

Not at all ☐

14. How many attacks of chest trouble did you have during the last year?

3 or more attacks ☐

1 or 2 attacks ☐

None ☐

15. How often do you have good days (with few respiratory problems)?

No good days ☐

A few good days ☐

Most days are good ☐

Every day is good ☐

16. If you have a wheeze, is it worse when you get up in the morning?

No ☐

Yes ☐

Section D: Breathing conditions

17. How would you describe your respiratory problems?

a) Cause me a lot of problems or are the most important physical problem I have ☐

b) Cause me a few problems ☐

c) Cause no problems ☐

18. Questions about what activities usually make you feel breathless. For each statement, please tell me which applies to you these days.

	True	False
a) Sitting or lying still	☐	☐
b) Washing or dressing yourself	☐	☐
c) Walking around the house	☐	☐
d) Walking outside on the level ground	☐	☐
e) Walking up a flight of stairs	☐	☐
f) Walking up hills	☐	☐

19. Some more questions about your cough and breathlessness. For each statement, please tell me which applies to you these days.

	True	False
a) Coughing hurts	☐	☐
b) Coughing makes me tired	☐	☐
c) I am short of breath when I talk	☐	☐

d) I am short of breath when I bend over ☐ ☐

e) My cough or breathing disturbs my sleep ☐ ☐

f) I get exhausted easily ☐ ☐

20. Questions about other effects that your chest trouble may have on you. For each statement, please tell me which applies to you these days.

	True	False
a) My cough or breathing is embarrassing in public	☐	☐
b) My respiratory problems are a nuisance to my family, friends, or neighbors	☐	☐
c) I get afraid or panic when I cannot catch my breath	☐	☐
d) I feel that I am not in control of my respiratory problems	☐	☐
e) I have become frail or an invalid because of my respiratory problems	☐	☐
f) Exercise is not safe for me	☐	☐
g) Everything seems too much of an effort	☐	☐

21. Questions about your medication

a) My medication does not help me very much	☐	☐
b) I get embarrassed using my medication in public	☐	☐
c) I have unpleasant side effects from my medication	☐	☐
d) My medication interferes with my life a lot	☐	☐

22. These are questions about how your activities might be affected by your respiratory problems. For each statement, please tell me which applies to you because of your breathing

	True	False
a) I take a long time to get washed or dressed	☐	☐
b) I cannot take a bath or shower, or I take a long time to do it	☐	☐
c) I walk slower than other people, or I stop to rest	☐	☐
d) Jobs such as house chores take a long time, or I have to stop to rest	☐	☐
e) If I walk up one flight of stairs, I have to go slowly or stop	☐	☐
f) If I hurry or walk fast, I have to stop or slow down	☐	☐
g) My breathing makes it difficult to do things such as walk up hills, carry things up stairs, do light gardening such as weeding, dance, bowl, or play golf	☐	☐
h) My breathing makes it difficult to do things such as carry heavy loads, dig the garden or shovel snow, jog or walk briskly (5 miles per hour), play tennis, or swim	☐	☐

23. We would like to know how your chest usually affects your daily life. For each statement, please tell me which applies to you because of your breathing.

	True	False
a) I cannot play sports or do other physical activities	☐	☐
b) I cannot go out for entertainment or recreation	☐	☐
c) I cannot go out of the house to do the shopping	☐	☐
d) I cannot do household chores	☐	☐

e) I cannot move far from my bed or chair ☐ ☐

24. How do your respiratory problems affect you? Please pick one response.

a) They do not stop me from doing anything I would like to do ☐ ☐

b) They stop me from doing one or two things I would like to do ☐ ☐

c) They stop me from doing most of the things I would like to do ☐ ☐

d) They stop me from doing everything I would like to do ☐ ☐

25. Have you ever had, or been told that you have had:	Yes	No
a) An injury, or operation affecting your chest, neck or lungs?	☐	☐
b) Heart trouble?	☐	☐
c) chronic cough?	☐	☐
d) tuberculosis	☐	☐
e) Asthma?	☐	☐
f) Other chest trouble? (specify)	☐	☐

26. I smoke cigarrete? ☐ ☐

a) How long had you smoking cigarette……….?

b) How many cigarettes do you smoke per day………...?

c) Have you ever smoked as much as one Cigarette a day for as long as one year? ☐ ☐

d) When did you stop smoking cigarette……...? (months or years)

e) How many cigarettes were you smoking per day………?

27. What do you usually do to prevent yourself from the smoke in your work?

a) Use of mask ☐

b) Other (specify) ☐

i) Pulmonary function test form

Name	
Market	
Personal ID	
Date of birth	_____/______/ 19___
Date fieldwork	_____/______/ 2022
Research assistant	
Length	

Weight	
BMI	

Temperature (◦C) ________________ pressure __________________

Best values:

FVC ____

FEV1 ____

PEF ____

Comments

ii) Air pollution monitoring tool

Air pollutant	**Before**	**During**	**After**
PM_1			
$PM_{2.5}$			
PM_{10}			
CO			
SO_2			
O_3			
NO			
TVOC			
HCHO			
Temperature			
Humidity			

Appendix 2: Institutional clearance certificate

F120-ILH-v20.0

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INSTITUTIONAL REVIEW BOARD

March 28, 2022

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IHI/IRB/No: 08-2022

INSTITUTIONAL CLEARANCE CERTIFICATE FOR CONDUCTING HEALTH RESEARCH

On 25th February 2022, the Ifakara Health Institute Review Board (IHI-IRB) reviewed from study titled: ***"Air pollution exposure and non-communicable respiratory diseases among fish vendors in Bagamoyo and Kunduchi fish markets in Tanzania"*** submitted by the study Principal Investigator Brigitha Onesmo.

The study has been approved for implementation after IRB consensus. This certificate thus indicates that; the above- mentioned study has been granted an Institutional Ethics Clearance to conduct this study in **Bagamoyo and Kinondoni Districts**. The Principal Investigator of the study must ensure that, the following conditions are fulfilled during or after the implementation of the study:

1. PI should submit a six-month progress report and the final report at the end of the project
2. Any amendment, which will be done after the approval of the protocol, must be communicated as soon as possible to the IRB for another approval
3. All research must stop after the project expiration date, unless there is prior information and justification to the IRB.
4. There should be plans to give feedback to the community on the findings
5. The PI should seek permission to publish findings from NIMR
6. The approval is valid until 25th February 2023

The IRB reserves the right to undertake field inspections to check on the protocol compliance

Chairperson
Prof. Esther Mwaikambo

IRB Secretary
Dr Mwifadhi Mrisho

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RESEARCH OUTPUTS

(i) Publication

Onesmo, B. M., Mamuya, S. H., Mwema, M. F., & Hella, J. (2023). Prevalence of chronic obstructive pulmonary disease and associated risk factors among small-holder fish vendors along coastal areas in Tanzania. *BMC Pulmonary Medicine*, 2023(23), 1-12.

(ii) Poster Presentation