EFFECT OF AMBIENT PARTICULATE MATTER ON RESPIRATORY HEALTH OF SCHOOL CHILDREN IN THE CITY OF DAR ES SALAAM, TANZANIA.

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By

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A Dissertation submitted in (partial) fulfillment of the requirements for the Degree of Master of Public Health at

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October 2024

CERTIFICATION

The undersigned certify that they have read and hereby recommends for acceptance by Muhimbili University of Health and Allied Sciences a dissertation titled "**Effect of ambient particulate matter on respiratory health of school children in the city of Dar es Salaam, Tanzania"** in (partial) fulfilment of the requirements for the degree of Master of Public Health of the Muhimbili University of Health and Allied Sciences.

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DECLARATION AND COPYRIGHT

I, Justus Kamara, declare that this dissertation is my own original work and that it has not been presented and will not be presented to any other university for similar or any other degree award.

Signature: ..... Date: .....

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DEDICATION

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ABSTRACT

Background: In Dar es Salaam, Tanzania, the escalating urbanization and industrial activities have significantly contributed to the deterioration of air quality, with ambient particulate matter (PM2.5 and PM10) posing a major public health concern. The impact of these pollutants on the respiratory health of vulnerable populations, particularly schoolchildren, has remained inadequately studied.

Objective: This study aimed to determine the level of ambient particulate matter (PM2.5 and PM10) and its association with respiratory symptoms among school children in Dar es Salaam, Tanzania.

Material and Methods: Employing a cross-sectional analytical design in Dar es Salaam, Tanzania, this study targeted schoolchildren aged 9-16 to explore air pollution's impact on respiratory health. With a sample of 427 children selected through stratified random sampling, it combined primary and secondary data. Standardized questionnaires and air quality monitoring for PM exposure were used to collect data. Analysis methods included descriptive statistics, logistic regression, and geospatial analysis to elucidate the relationship between PM exposure and respiratory symptoms.

Results: The prevalence of respiratory symptoms among the schoolchildren was notably high, with 35.1% reporting coughing, 26.7% wheezing, 31.4% breathlessness, and 28.1% severe chest illness. Significant associations were found between proximity to pollution sources, household smoking, and the use of biomass for cooking with the occurrence of respiratory symptoms. Ambient PM levels, particularly PM2.5 and PM10, exceeded WHO limits in several locations and seasons. WHO recommends PM2.5 levels below 5 $\mu g/m^3$ and PM10 below 15 $\mu g/m^3$, while Dar es Salaam recorded PM2.5 between 35-50 $\mu g/m^3$ and PM10 between 75-100 $\mu g/m^3$, significantly higher than recommended?

Conclusion: The study emphasizes the significant impact of air pollution on the respiratory health of schoolchildren in Dar es Salaam, calling for targeted interventions to reduce particulate matter exposure, particularly in high-risk urban areas.

Recommendations: Key actions include strengthening emission standards, improving traffic management, and establishing continuous air quality monitoring and health surveillance. Public awareness campaigns and promoting green spaces are also crucial, alongside collaborative efforts and further research for comprehensive air quality management.

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LIST OF ABBREVIATIONS AND NOTATIONS

- **CO** - Carbon Monoxide
- **COPD** - Chronic Obstructive Pulmonary Disease
- **IRB** – Institutional Review Board
- **GIS** - Geographic Information System
- **PM_{10}** - Particulate Matter with a diameter of 10 micrometers or less
- **$PM_{2.5}$** - Particulate Matter with a diameter of 2.5 micrometers or less
- **SPSS** - Statistical Package for the Social Sciences

DEFINITIONS

- **$PM_{2.5}$ (Particulate Matter with a diameter of 2.5 micrometers or less):** Airborne particles or droplets that are 2.5 micrometers in diameter or smaller. These fine particles can penetrate deep into the lungs and have been associated with various health problems, including respiratory and cardiovascular diseases.
- **PM_{10} (Particulate Matter with a diameter of 10 micrometers or less):** Particles or droplets in the air that are 10 micrometers in diameter or smaller. These particles are capable of being inhaled and can cause health issues, particularly in the respiratory system, but are less likely to reach the deepest areas of the lungs compared to PM2.5.
- **COPD (Chronic Obstructive Pulmonary Disease):** A chronic inflammatory lung disease that causes obstructed airflow from the lungs, characterized by long-term breathing problems and poor airflow. Main symptoms include breathing difficulty, cough, mucus (sputum) production, and wheezing.
- **IRB** – (Institutional Review Board) A committee that applies research ethics by reviewing the methods proposed for research to ensure that they are ethical. This review includes ensuring the protection of the rights and welfare of human research participants.
- **SPSS (Statistical Package for the Social Sciences):** A software package used for interactive, or batched, statistical analysis. It is widely used by researchers for analyzing and managing statistical data.
- **GIS (Geographic Information System):** A system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. In environmental health research, it is often used to study the relationship between location, environmental exposures, and health outcomes.

1.0 INTRODUCTION

1.1 Background

Air pollution is among the major concerns affecting the world in this century. It is among the areas that need public awareness and functional strategies to combat effectively.(Hisamuddin and Jalaludin, 2019) In urban settings, vehicular traffic emerges as a principal emitter of atmospheric pollutants, significantly contributing to levels of ambient particulate matter, alongside contributions from domestic heating and the transport of particulates from other regions. (Irvine *et al.*, 2023) Furthermore, in densely populated areas, the exposure to ambient particulate matter underscores the urgent need for comprehensive air quality management to safeguard respiratory health, especially among vulnerable populations such as schoolchildren. The major concern in air pollution studies is ambient particulate matter (PM), especially $PM_{2.5}$ and PM_{10}. This is because particulate matter has effects on human health. These particles, categorized according to their size, come from different sources, mainly human activities.(Chen *et al.*, 2023) $PM_{2.5}$ are 2.5 micrometers in diameter and can penetrate deep into the respiratory system, directly to the lungs and even into the bloodstream.(Hisamuddin and Jalaludin, 2019) Vehicle emissions, industrial processes, and burning fossil fuels are the sources of $PM_{2.5}$. PM_{10}, although being slightly larger, also causes important health effects such as mortality, exacerbation of asthma, and chronic bronchitis. Grzywa-Celińska et al. (2020) and Bergstra et al. (2018)

Ambient particulate matter has been increasing and different scholars have tried to find reasons to this rise. Studies such as (Kiunsi, 2013) and (Njee *et al.*, 2016) have consistently emphasized the role of urbanization in worsening PM levels. In cities like Dar es Salaam, the rapid increase in vehicular traffic contributes significantly to ambient particulate matter ($PM_{2.5}$ and PM_{10}) concentrations (Njee et al., 2016; Hisamuddin and Jalaludin, 2019). The combustion of diesel and petrol in vehicles releases a considerable amount of these particulates, worsened by traffic congestion and inadequate emission control measures.(Ristovski *et al.*, 2012) Industrial activities, is another factor that leads to urbanization, also contribute substantially to the PM

levels through the release of pollutants from manufacturing processes.(Bergstra, Brunekreef and Burdorf, 2018a)

These particles cause significant health effects as said by (Ristovski *et al.*, 2012). Health implications of these particles have been a main point in environmental health research conducted by different scholars.(Ristovski *et al.*, 2012) and (Sierra-Vargas and Teran, 2012) have shown the penetration capability of PM2.5 into the human respiratory system, causing various adverse health effects. The risk of these adverse effects is particularly acute and severe in densely populated urban areas where industrial and vehicular emissions are highest.(Njee *et al.*, 2016)

In addition, the nature of PM is another important factor in its health effects. PM can consist of a wide range of materials, such as metals, nitrates, sulfates, and organic compounds which can differ according to origin and health effects.(Sierra-Vargas and Teran, 2012) Local sources and environmental conditions affect the chemical composition of these particles, which makes the evaluation of their health effects even more complicated.(Grzywa-Celińska, Krusiński and Milanowski, 2020)

Another focus is the vulnerability of children to air pollution in public health, especially ambient particulate matter such as $PM_{2.5}$ and PM_{10}. The young generation suffers from air pollution because of the developing respiratory systems and increased physical activity. (Patel *et al.*, 2010). The same studies show in detail how their low body mass and high rates of breathing make them even more susceptible since they are exposed to significantly higher concentrations of air pollution in relation to their size. Studies have revealed a strong connection between occupation to PM and numerous respiratory diseases in children like asthma, and bronchitis among others including reduced lung function.(Hisamuddin and Jalaludin, 2019),(Bergstra, Brunekreef and Burdorf, 2018a)

Studies by (Orru, Ebi and Forsberg, 2017) and (Patel *et al.*, 2010) provide insights into acute respiratory symptoms among children with heavy traffic-related air pollution exposure. These studies highlight the direct relationship between PM exposure and an increase in respiratory symptoms development among children. Chronic respiratory diseases can be a long-term result

of exposure to high PM levels, and lung development in children may also suffer harm. This effect, however, is not limited to physical well-being but can also have cascading effects on cognitive development and academic performance as shown by some studies.

Children are particularly at risk in urban areas like Dar es Salaam, where PM levels are high due to traffic congestion and industrial activities. (Mpogole and Msangi, 2016) This necessitates focused research on understanding the specific impacts of PM on this vulnerable group, and the development of effective strategies to mitigate these impacts.

Air pollution is one of the challenges facing Dar es Salaam as a growing urban center. The high concentration of particulate matter ($PM_{2.5}$ and PM_{10}) in the city can be attributed to rapid urbanization, and industrial activity as shown by (Njee *et al.*, 2016)and (Hisamuddin and Jalaludin, 2019). They continue to report that some significant factors like traffic congestion contribute to air pollution levels in Dar es Salaam City. This is concurrent to the global trend where urbanization has been closely linked with poorer air quality as shown by (Kiunsi, 2013). This situation highlights the need to include environmental health aspects in urbanization policies.

The implications of air pollution for public health, especially in urban areas, are complex and extreme. (Sierra-Vargas and Teran, 2012) The increased exposure to ambient particulate matter ($PM_{2.5}$ and PM_{10}) poses significant health risks, necessitating urgent and effective public health interventions.(Wang *et al.*, 2015) Studies by (Orru, Ebi and Forsberg, 2017) and (Patel *et al.*, 2010) show the immediate health impacts of air pollution and highlight its long-term consequences. Some of the effective effective strategies to combat urban air pollution include improving traffic management, enhancing emission standards, promoting public transportation, and increasing green spaces.(Rycroft *et al.*, 2012) The insights from this research will inform policy decisions and public health strategies, aiming to mitigate the adverse effects of air pollution and protect vulnerable populations, particularly children.

1.2 Problem statement

In urban areas, particularly in developing cities like Dar es Salaam, air pollution, due to elevated levels of ambient particulate matter ($PM_{2.5}$ and PM_{10}) presents a critical public health challenge.(Njee *et al.*, 2016) In Dar es Salaam, PM concentrations frequently exceed the World Health Organization (WHO) recommended limits, with PM2.5 levels reaching up to five times higher than the safe threshold, posing significant health risks to residents (WHO, 2021).The rapid urbanization and industrialization of Dar es Salaam have significantly contributed to this problem, primarily through increased vehicular emissions and industrial activities.(Mpogole and Msangi, 2016) This increased pollution brings severe risks to the respiratory health of the city's residents, especially school children, who are more vulnerable due to their developing respiratory systems and higher exposure rates. (Hisamuddin and Jalaludin, 2019)

Studies form different scholars have consistently linked exposure to ambient particulate matter ($PM_{2.5}$ and PM_{10}) with respiratory diseases, with children particularly susceptible to such pollutants (Orru, Ebi and Forsberg, 2017; Patel et al., 2010). The impact of air pollution on children extends beyond immediate health issues, potentially affecting their long-term physical and cognitive development as explained by (Hisamuddin and Jalaludin, 2019). However, despite these risks, there is a lack of comprehensive local data on the cumulative effects of PM exposure on children's health in urban African settings, which this study seeks to address. In the context of Dar es Salaam, where traffic congestion and industrial emissions are prevalent, understanding the specific health effects of PM on children is important.

This study addressed the gap in knowledge regarding the cumulative effect of ambient particulate matter ($PM_{2.5}$ and PM_{10}) on children's respiratory health in an urban African setting. By examining the interplay of these environmental factors in Dar es Salaam, the study provided critical insights for public health policies and interventions aimed at reducing air pollution's impact and protecting the health of vulnerable groups, particularly children.

1.3 Conceptual Framework

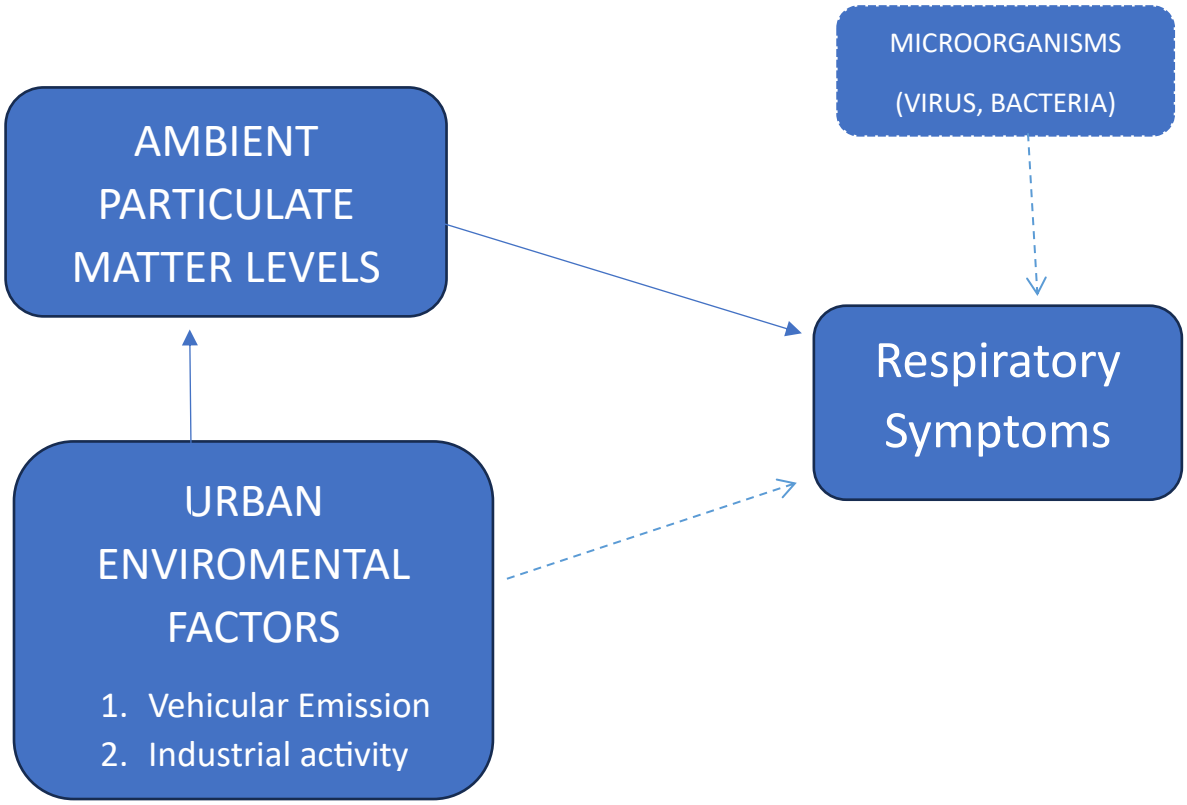


Figure 1: Conceptual framework for study on ambient particulate matter ($PM_{2.5}$ and PM_{10}) and respiratory symptoms. (adapted from Wallington et al., 2022)

The framework identifies vehicular emissions, industrial activities, and construction sites, as key urban factors contributing to ambient particulate matter levels in the city. These levels of $PM_{2.5}$ and PM_{10} are then linked to the occurrence of respiratory symptoms in children, underlining the direct effect of environmental pollutants on child health.

1.4 Rationale

The rationale for this study was centered on its potential to provide critical evidence and information necessary for addressing the health effects of air pollution, particularly ambient particulate matter ($PM_{2.5}$ and PM_{10}) in Dar es Salaam. By comprehensively analyzing how these particulates affected the respiratory health of school children, the study aimed to fill a significant knowledge gap in this field. The findings are instrumental in guiding policy decisions and public health interventions, particularly in urban areas facing similar challenges. Key stakeholders include public health officials, who can use the findings to design targeted interventions and policies to protect vulnerable populations; government policymakers, who can update urban planning and industrial regulations to reduce emissions; educational institutions, which can implement health awareness programs; environmental NGOs, which can use the evidence to advocate for stricter environmental laws; and local communities, who can take preventive measures to minimize. This research not only contributed to the broader understanding of environmental health but also offered practical insights for mitigating the adverse effects of air pollution on vulnerable populations.

1.5 Research Questions

1.5.1 Broad research question.

How is ambient particulate matter ($PM_{2.5}$ and PM_{10}) level associated with respiratory health symptoms among school children in the city of Dar es Salaam, Tanzania?

1.5.2 Specific research questions

1. What is the prevalence of respiratory symptoms among schoolchildren in the city of Dar es Salaam, Tanzania?
2. What are the urban environmental factors that are associated with the occurrence of respiratory symptoms among school children in urban areas in the city of Dar es Salaam?
3. What is the level of ambient particulate matter ($PM_{2.5}$ and PM_{10}) in the city of Dar es Salaam, Tanzania?
4. How is exposure to ambient particulate matter ($PM_{2.5}$ and PM_{10}) associated with respiratory symptoms among school children in the city of Dar es Salaam, Tanzania?

1.6 Objectives

1.6.1 Broad Objective

To determine the association between level of ambient particulate ($PM_{2.5}$ and PM_{10}) matter and respiratory symptoms among school children in Dar es Salaam city, Tanzania.

1.6.2 Specific Objectives

1. To determine the prevalence of respiratory symptoms among school children in the city of Dar es Salaam, Tanzania.
2. To identify urban environmental factors associated with respiratory symptoms among school children in the city of Dar es Salaam, Tanzania.
3. To determine the levels of ambient particulate matter ($PM_{2.5}$ and PM_{10}) in the city of Dar es Salaam, Tanzania.
4. To determine the association between ambient particulate matter exposure and respiratory symptoms among school children in the city of Dar es Salaam, Tanzania.

2.0 LITERATURE REVIEW

2.1 Introduction

Air quality and its impact on human health, particularly in rapidly urbanizing cities, is an issue of growing global concern.(Bergstra, Brunekreef and Burdorf, 2018b) The case of Dar es Salaam, Tanzania, a city experiencing rapid urbanization and industrialization, shows the challenges faced by many developing urban areas.(Othman, 2010) The focus of this literature review is to examine the spatial and temporal variation of ambient particulate matter ($PM_{2.5}$ and PM_{10}), temperature, and humidity in Dar es Salaam, and to evaluate their effects on the respiratory health of school children. This introduction provides an overview of the existing literature, highlighting key findings and identifying gaps that this study aims to address.

Globally, studies have shown that urban areas often struggle with elevated levels of ambient particulate matter, leading to significant public health concerns.(Lai *et al.*, 2024) The research by Kelly and Fussell (2015) further emphasizes the interaction between these pollutants and meteorological factors like temperature and humidity, which can exacerbate their health effects. In the context of East Africa, and specifically Tanzania, this problem is mirrored but complicated by unique local factors. (Njee *et al.*, 2016)provide essential insights into the spatial variability of PM in Dar es Salaam, yet there remains a lack of comprehensive data on the temporal aspects and the combined effects of these environmental factors.

Furthermore, the respiratory health of children, a particularly vulnerable demographic to air pollution, has been a focal point of several studies such as (Rovira *et al.*, 2014), and (Bergstra, Brunekreef and Burdorf, 2018b). Patel et al. (2010) and Hisamuddin and Jalaludin highlight the acute respiratory effects of PM exposure in children, an issue that is yet to be thoroughly investigated in the Tanzanian setting. The literature also indicates a gap in understanding the specific impacts of Dar es Salaam's air quality on lung function in children, with studies like those by Ristovski et al. (2011) and Graham et al. (2019) underscoring the global importance of such research.

The current literature review, therefore, aims to bridge these gaps. By examining the levels of ambient particulate matter ($PM_{2.5}$ and PM_{10}) in Dar es Salaam. The study seeks to provide a

comprehensive understanding of the city's air quality. Additionally, it aims to correlate these environmental factors with the prevalence of respiratory symptoms and the lung function of school children in the city, contributing valuable insights to the global body of knowledge on urban air pollution and its health impacts.

2.2 Prevalence of respiratory symptoms

Respiratory symptoms include a variety of symptoms related to difficulties in breathing. These include but are not limited to, dyspnea (difficulty breathing), coughing, wheezing (a high-pitched whistling sound during breathing), chest tightness, and sputum production. These symptoms are indicative of underlying conditions affecting the lungs, heart, or respiratory tract, triggered by diseases, environmental pollutants, allergies, or infections.

The prevalence of respiratory symptoms refers to the incidence and distribution of respiratory conditions within a population. These respiratory symptoms are commonly associated with exposure to air pollutants, including particulate matter (PM) and gaseous pollutants. (Esposito, Tenconi, *et al.*, 2014)

Globally, studies such as (Kelly and Fussell, 2015) has demonstrated the negative health effects of particulate matter (PM) and toxic gases on children, emphasizing the importance of understanding exposure levels and developing effective mitigation strategies. Research conducted in Dhaka, Bangladesh, by (Roy *et al.*, 2023) found significant correlations between PM levels and decreased lung function among school children, indicating an unacceptable risk for human health due to air pollution exposure within school environments.

A study by (Fsadni *et al.*, 2018)in the Indian Journal of Occupational and Environmental Medicine found significant correlations between PM concentrations and deteriorations in lung function among Maltese school children, indicating unacceptable health risks associated with PM2.5 and PM10 exposure. The study documented that for each 10 μg/m^3 increase in $PM_{2.5}$ and PM_{10}, there was a significant increase in the odds of school absence due to respiratory issues. Other studies, such as those conducted in Malta, emphasize the correlation between indoor pollutants and respiratory conditions like atopy, highlighting the role of vehicular traffic near schools in exacerbating respiratory symptoms(Fsadni *et al.*, 2018). Another study in

Christchurch, New Zealand by (Epton *et al.*, 2008)focused on the respiratory health impacts of wood smoke pollution on students, employing urinary 1-hydroxypyrene as a biomarker for exposure. This proposed research underscores the nature of pollution's health impacts, revealing that while some small effects on respiratory symptoms and lung function were observed, especially in asthmatic students, the overall effects on healthy students were minimal.

Regionally, the focus was on traffic-related pollution's effects on children with asthma or wheezing, revealing a significant association between pollution levels and increased respiratory morbidity. The study also highlighted the protective role of green areas, and the heightened risk associated with high traffic density areas.(Esposito, Galeone, *et al.*, 2014) In Europe, research underscores the importance of mitigating exposure to air pollutants, especially in areas with heavy traffic. The findings suggest a clear link between environmental factors and respiratory health outcomes in children, advocating for policy interventions aimed at reducing children's exposure to harmful pollutants(Fsadni *et al.*, 2018). Another study by (Epton *et al.*, 2008) also highlights the potential of using biomarkers like urinary 1-hydroxypyrene to assess exposure levels and the need for tailored public health policies to address the unique environmental challenges faced by different communities. One case-crossover study in Qingdao, China linked ambient particulate matter levels directly with increased respiratory-related school absences, especially among younger children aged 6 to 12 years, suggesting that short-term variations in particulate matter concentrations significantly impact respiratory health and school attendance .(Geng *et al.*, 2021)

These studies collectively reveal a knowledge gap in the context of Tanzanian cities like Dar es Salaam, where urban air pollution is rising, but localized research on its impact on school children's respiratory health is limited. This gap underscores the need for targeted research in Dar es Salaam to inform policy and interventions tailored to the unique environmental and urban characteristics of Tanzanian cities.

2.3 Factors associated with respiratory symptoms among school children.

Recent studies have increasingly focused on the association between urban environmental factors and the prevalence of respiratory symptoms among school children.(Fsadni *et al.*, 2018) and (Epton *et al.*, 2008)highlight the direct impact of school indoor and outdoor environments on children's respiratory health, identifying significant associations between high exposures to indoor air pollutants and the characteristics of school buildings, including proximity to heavy vehicle traffic, which was associated with current wheezing. These findings underline the importance of assessing urban factors, such as vehicular emissions and industrial activities, that contribute to poor air quality and subsequent respiratory health issues in children.

Furthermore,(Esposito, Galeone, *et al.*, 2014) in their research, emphasizes the detrimental effects of traffic-related pollution on children with asthma or recurrent wheezing, suggesting that proximity to high-traffic areas exacerbates asthma symptoms and increases the frequency of respiratory infections. Their study underscores the role of urban air pollution as a significant factor influencing the health of children with pre-existing respiratory conditions.

2.4 Determining particulate matter levels.

Globally, the significance of monitoring and analyzing ambient particulate matter ($PM_{2.5}$ and PM_{10}) has grown due to their impact on air quality and public health. Research such as 'Spatial Variability of Ambient Air Pollution Concentration in Dar es Salaam' by (Njee *et al.*, 2016) highlights the high levels of PM in urban areas. This trend is prominent in rapidly developing cities, marked by significant contributions from industrialization and traffic to air pollution. These studies point out the variability in PM levels, emphasizing the differences observed across various urban and suburban regions.

In the East African region, studies such as (Njee *et al.*, 2016) and (Othman, no date) have highlighted a growing concern regarding the levels of $PM_{2.5}$ and PM_{10}, primarily driven by urbanization and industrial activities. It is reported in East African cities, including Dar es Salaam, face challenges in managing air quality due to increasing vehicular emissions and industrial growth.(Kiunsi, 2013) Their findings suggest that PM concentrations often surpass

the recommended limits set by the World Health Organization (WHO), posing significant health risks.

In Tanzania, one of the developing countries particularly in Dar es Salaam, the situation reflects a similar pattern observed in other urban areas in East Africa. The study "Spatial Variability of Ambient Air Pollution Concentration in Dar es Salaam" by (Njee *et al.*, 2016)provides valuable insights into the local context. It highlights the considerable spatial variability in PM levels within the city, primarily due to factors such as traffic congestion and industrial emissions. This study is pivotal in understanding the local distribution of ambient particulate matter ($PM_{2.5}$ and PM_{10}) in Dar es Salaam.

Although these studies provide a foundation for understanding PM levels globally and regionally, there remains a significant knowledge gap in the specific context of Dar es Salaam, particularly concerning the temporal and spatial variation of particulate matter. Most existing studies offer a snapshot of the situation, lacking continuous and updated data that reflect the rapid changes in urban development and industrial activities in the city. There is a critical need for ongoing research to track these dynamic changes and understand their implications on air quality and public health.

2.5 Association between particulate matter and respiratory symptoms in school children

Globally, there is a growing number of studies exploring the connection between particulate matter (PM) exposure and respiratory health, particularly in children. Studies such as "Traffic-Related Particulate Matter and Acute Respiratory Symptoms among New York City Area Adolescents" by (Patel *et al.*, 2010) have documented the acute respiratory effects of PM exposure in urban adolescent populations. This research and research by (Ren *et al.*, 2020) emphasize the enhanced sensitivity of children to air pollution and the potential for exacerbation of respiratory symptoms.

In East Africa, the impact of air pollution on respiratory health is an emerging concern, with urban areas showing increasing levels of particulate matter.(Jackson, 2009) However, there is a lack of extensive research specifically focusing on the respiratory health of school children in relation to PM exposure in this region. Studies like "Traffic Related Air Pollution and Its Impact

on Respiratory Health among Children" by (Hisamuddin and Jalaludin, 2019) while not region-specific, provide relevant insights into how similar environmental factors might affect children in urban African settings.

In Tanzania, and more specifically in Dar es Salaam, the study by (Njee *et al.*, 2016) sheds light on the distribution of PM across the city. However, the direct correlation between these pollution levels and the respiratory health of school children in Dar es Salaam is less explored. This presents a significant gap in understanding the local health impacts of air pollution.

There exists a notable gap in localized studies that specifically examine the association of prevalence of respiratory symptoms and conditions among school children in Dar es Salaam and with ambient particulate matter ($PM_{2.5}$ and PM_{10}) levels. While global and regional studies provide a foundation, the unique environmental and demographic context of Dar es Salaam necessitates focused research to understand the specific respiratory health challenges faced by schoolchildren in this rapidly urbanizing city.

3.0 MATERIALS AND METHODS

3.1 Study design.

A cross-sectional analytical study with a quantitative approach was conducted. It involved the collection and analysis of both secondary and primary data.

3.2 Study area

This study was conducted in Dar es Salaam, Tanzania's largest city with a population of over 6 million, located on the eastern coast of the country. As one of the fastest-growing urban centers in Africa, Dar es Salaam faces significant environmental challenges, particularly air quality degradation due to rapid urbanization, heavy traffic congestion, and industrial activity. The city consistently records particulate matter ($PM_{2.5}$) levels exceeding WHO guidelines by 3 to 5 times. The study was carried out across four key municipalities: Ilala, the central business district with dense traffic and industrial zones; Temeke, an industrial hub with high emissions from factories and port activities; Ubungo, a major transport hub where bus and truck traffic contribute significantly to vehicular emissions; and Kigamboni, a fast-developing area with growing residential and industrial presence. These municipalities capture a diverse cross-section of the city's urban and industrial environments, each contributing to the high levels of ambient particulate matter ($PM_{2.5}$ and PM_{10}) that result in increased public health risks, particularly among children. The study was conducted in the city of Dar es Salaam, specifically focusing on primary schools situated in areas with varying levels of air pollution. Schools within 5km of areas of high traffic congestion and industrial activities were analyzed.

3.3 Study population

3.3.1 Study population

The study targeted school children aged 9 to 16 years attending primary schools in the city of Dar es Salaam, Tanzania. This age group was selected due to their vulnerability to air pollution and the potential effects on their developing respiratory systems.

3.4 Sample size and selection

The calculation of sample:

The sample size for the study was calculated using the prevalence of 50% since no study was found to have a general prevalence of respiratory symptoms.

Using the formula; $n = z^2 p(100-p)/ \varepsilon^2$

Where n = the desired minimum sample size

z = the standard normal deviate (set at 95% confidence interval which is equal to 1.96)

p = the expected prevalence with a characteristic of interest (p = 50%)

ε = margin error = 5%

Therefore, $n = 1.96^2 \times 50 (100-50)/ 5^2$

n = 384

considering a 10% non-response rate,

n adjusted = (n/ (1-0.1))

n adjusted = (426.67)

n adjusted = 427

School selection method:

Schools were selected in Dar es Salaam from Ilala Municipal, Ubungo Municipal, Kigamboni Municipal, and Temeke Municipal, with one school from each municipality, except for Ilala where two schools were chosen, for a total of five schools. The schools selected were Amani Primary School (Buza), Diamond Primary School, Olympio (Faith) Primary School, Mlimani Demonstration Primary School, and Vijibweni Primary School. The selection was based on their proximity within 5 km of main roads and industrial sites, areas with higher levels of ambient particulate matter ($PM_{2.5}$ and PM_{10}).

Stratified random sampling was used to ensure representativeness within the school population. Schools were stratified based on characteristics such as location and school size. For each selected school, a proportionate number of students was determined according to the total

student population size. For example, larger schools contributed a higher number of students to the sample to ensure proportional representation. Within each school, students aged 9 to 16 years were randomly selected, providing a balanced representation of the target age group for the study. The random selection process was designed to ensure a diverse sample, capturing variations in exposure levels to air pollution and representing the overall student population in Dar es Salaam.

3.5 Eligibility

3.5.1 Inclusion Criteria

The inclusion criteria for the study focused on schoolchildren aged between 9 to 16 years. These children were required to be enrolled in a school participating in the study, located within the city of Dar es Salaam. Additionally, these children were required to be willing to participate in the study and have obtained consent from their parents or guardians.

3.5.2 Exclusion Criteria

Children who had pre-existing chronic respiratory conditions, such as asthma, were excluded from the study to prevent any interference with the assessment of air pollution's effect, as these conditions could potentially skew the results. Furthermore, the study also excluded children who had lived in the study area for less than one year. This criterion was set to ensure that the exposure assessment to air pollution was consistent among participants.

3.6 Variables in the Study

SN	Variable	Type	Measurement
1	Prevalence of respiratory symptoms	Categorical (respiratory symptoms)	Questionnaire (occurrences of coughing, wheezing, or shortness of breath)
2	Urban factors associated with respiratory symptoms	Categorical (urban factors)	Proximity to main road, industrial sites; household smoking, biomass cooking

SN	Variable	Type	Measurement
3	Ambient Particulate Matter ($PM_{2.5}$ and PM_{10}) levels	Continuous (PM levels)	PurpleAir sensors measuring $PM_{2.5}$ and PM_{10} levels in micrometers
4	Association of respiratory symptoms and Particulate Matter	Categorical/Continuous (association)	Questionnaire (respiratory symptoms) and PurpleAir sensor data for PM exposure

3.7 Data collection methods

Collection of Secondary Data

Data Source

Secondary data on ambient particulate matter levels ($PM_{2.5}$ and PM_{10}) was collected using PurpleAir sensors installed throughout Dar es Salaam. This data was accessed through the PurpleAir online platform, which offers real-time air quality monitoring. The extraction process was focused on data recorded from 2021 to the present, utilizing information captured at 2-minute intervals to ensure comprehensive and up-to-date analysis of air quality trends in the area.

Collection of primary data:

Standardized questionnaire: The study utilized a standardized questionnaire aimed at schoolchildren aged 6 to 16 years in Dar es Salaam. This questionnaire was designed to collect information concerning respiratory symptoms, medical history, and other relevant factors. The questionnaire, which was digital, was administered within schools to the children. The questionnaire used in this study was adapted from the ATL-DLD-78-A (American Thoracic Society and Division of Lung Diseases Questionnaire).

3.8 Investigation tools.
Tools for data collection

PurpleAir Sensors: The PurpleAir sensors used in this study are low-cost air quality monitors that measure particulate matter ($PM_{2.5}$ and PM_{10}) in real-time. These sensors use a laser particle counter to count particles in the air. Data is transmitted via Wi-Fi to a cloud-based platform where it is accessible for analysis. The study used PurpleAir sensors to collect secondary data on ambient particulate matter, specifically $PM_{2.5}$ and PM_{10} levels. These sensors were chosen for their proven accuracy in measuring air quality parameters, having been calibrated and standardized against industry benchmarks. Their widespread use in air quality research underlined their reliability and consistency in providing readings, making them a valuable tool for long-term environmental monitoring in the study.

3.9 Data management and the analysis plan
Data Management:

For data handling, the collected data was securely stored in a digital format, utilizing spreadsheets to ensure organization and accessibility. Before analysis, a rigorous pre-processing phase was involved the cleaning and filtering of the data to eliminate any anomalies or outliers, guaranteeing the integrity and reliability of the information used for further analysis.

The study's data analysis plan involved using various statistical methods to assess the prevalence of respiratory symptoms among school children, determine associated urban factors, measure particulate matter levels, and examine the association between particulate matter exposure and respiratory symptoms. Descriptive statistics were used to summarize data, while advanced statistical techniques like logistic regression and GIS mapping provided deeper insights into relationships and patterns. Stata Version 17 was used for statistical data analysis.

Table 1: Data analysis for each study objective

Objective	Analysis	Details
Prevalence of Respiratory Symptoms	Descriptive statistics	Calculated frequencies and percentages to summarize the prevalence of respiratory symptoms among school children.
Urban Factors Associated with Respiratory Symptoms	Descriptive statistics, Multivariable logistic regression	Utilized frequencies and percentages to describe urban factors (e.g., vehicular emissions, industrial activities). Applied logistic regression to examine the association between urban factors and the presence of respiratory symptoms, adjusting for age, gender, socioeconomic status, and indoor environmental factors (e.g., parental smoking).
Determination of Particulate Matter Levels (PM2.5 and PM10)	Descriptive statistics, Time series analysis, Spatial analysis	Computed mean for $PM_{2.5}$ and PM_{10} levels. Analyzed trends and patterns over time in PM levels, showing monthly variations. Utilized GIS techniques to map and analyze the spatial distribution of ambient particulate matter across Dar es Salaam.
Association of Respiratory Symptoms and Particulate Matter	Chi-Square test, Logistic regression analysis	Used chi-square tests to compare the prevalence of respiratory symptoms between children in high-pollution areas and control areas. Applied logistic regression analysis to examine the association between PM exposure levels and respiratory symptoms, adjusting for age, gender, socioeconomic status, and indoor environmental factors.

3.10 Ethical issues

Ethical approval was secured from MUHAS ethics review board, ensuring adherence to ethical standards in human research. Informed consent was obtained from the guardians, who are teachers at the respective schools, and the children assented to participate in the study. The consent process involved clearly explaining the study's purpose, the nature of the data to be collected, and the intended use of this data to both guardians and children, ensuring transparency and understanding. Participation was entirely voluntary, with the right to withdraw at any stage without penalties.

Confidentiality was strictly maintained, with all participants' identities and responses anonymized. The collected data was securely stored, accessible only to the study team, and protected through password-secured electronic access. Data security measures were robust to safeguard sensitive information. Additionally, the study minimized any potential risks to participants, ensuring their safety and well-being throughout the research process.

3.11 Study limitations and mitigation

Certain factors limited this study. The reliability of secondary data from PurpleAir sensors was a potential issue due to factors like sensor calibration, location, and maintenance. The study's reliance on these sensors might have introduced data reliability concerns despite efforts to cross-check data with other sources.

Selection bias was another limitation, as schools were selected based on their proximity to high-pollution areas. Although stratified random sampling was used to ensure a representative sample, the selection process could still have led to biased results.

The accuracy of self-reported data in health surveys was also a concern, with potential recall bias or misunderstandings of questions by participants. Despite designing clear survey questions and providing assistance during administration, these issues might have affected data quality.

Confounding variables, such as indoor air pollution and socioeconomic factors, could have influenced respiratory health outcomes. While the survey included questions to account for these variables and statistical methods were used to adjust for them, some confounders may still have impacted the results.

Lastly, the findings from Dar es Salaam may not be generalizable to other cities or regions. The study's scope and context were specific to Dar es Salaam, and while the results provide valuable insights, they might not be directly applicable to other urban settings.

4.0 RESULTS

4.1 Introduction

This study assessed the prevalence of respiratory symptoms among school children in Dar es Salaam, identified associated urban environmental factors, measured the levels of ambient particulate matter (PM2.5 and PM10), and examined the association between particulate matter exposure and respiratory symptoms. The data was collected through comprehensive surveys and air quality measurements across various schools and locations in the city. The results are presented in alignment with the study objectives to provide a clear understanding of the impact of ambient particulate matter on the respiratory health of school children in Dar es Salaam.

4.1 Socio-demographic Characteristics of the School Children

The study included 427 school children from 5 schools in Dar es Salaam, with a mean age of 11.5 years (SD = 2.1). The mean age provides a central value for understanding the typical age of the participants, which is relevant to respiratory health outcomes in children. The standard deviation indicates variability within the sample, offering insight into how age differences may impact the analysis of respiratory symptoms. The socio-demographic characteristics of the participants are summarized in Table 1. The sample consisted of a majority of females with 237 females (55.5%). The children were from different grades, with majority of 218 in Standard VII (51.1%). Majority of the study participants were older than 12 years. These socio-demographic characteristics provide a comprehensive background for understanding the respiratory health outcomes observed in the study. The demographic distribution of the participants is summarized in **Table 2**.

Table 2: Socio-demographic characteristics of the school children (N=427 participants)

Variable	Category	n (%)
School	Amani PS(Buza)	110(25.8)
	Diamond PS (DIT)	53(12.4)
	Faith PS(DIT)	49(11.5)
	Mlimani SKY City PS	53(12.4)
	Vijibweni PS(Kigamboni)	58(13.6)
	Vingunguti PS	104(24.4)
Gender	Male	190(44.5)
	Female	237(55.5)
Class	Std IV	209(48.9)
	Std VII	218(51.1)
Age	Mean (SD)	11.5(2.1)
Age group	<10years	118(27.6)
	10-12years	109(25.5)
	>12years	200(46.8)

4.2 Prevalence of Respiratory Symptoms among School Children in Dar es Salaam City

To determine the prevalence of respiratory symptoms among school children, this study conducted a comprehensive survey across several schools in Dar es Salaam.

It assessed the prevalence of respiratory symptoms such as coughing, wheezing, breathlessness, and severe chest illness. The findings indicated that 35.1% of the children reported experiencing coughing, 26.7% reported wheezing, 31.4% experienced breathlessness, and 28.1% reported severe chest illness at least once in the past year. These results are detailed in **Table 3**.

Table 3: Prevalence and frequency of respiratory symptoms among primary school children (N=427 participants)

Variable	Response	n(%)
Cough	No	277(64.9)
	Yes	150(35.1)
Frequency of coughing in the past year	Occasionally	62(41.3)
	Monthly	51(34.0)
	Weekly	37(24.7)
Wheezing	No	313(73.3)
	Yes	114(26.7)
Frequency of wheezing in the past year	Occasionally	56(49.1)
	Monthly	38(33.3)
	Weekly	19(16.7)
Breathlessness	No	293(68.6)
	Yes	134(31.4)
Frequency of experiencing shortness of breath in the past year	Occasionally	61(45.5)
	Sometimes	34(25.4)
	Often	40(29.9)
Severe chest illness	No	307(71.9)
	Yes	120(28.1)
Frequency of shortness breathing in past year	Once	77(64.2)
	Twice	34(28.3)
	More than twice	12(10.0)

4.3 Urban Factors Associated with Respiratory Symptoms among School Children

To identify urban environmental factors associated with respiratory symptoms, the study collected data on various potential risk factors, including proximity to pollution sources, household smoking, and the use of biomass for cooking. Descriptive statistics for these variables are presented in Table 4.

Table 4: Reported risk exposure (N=427 participants)

Variable	Response	n(%)
Proximity to pollution	No	304(71.2)
	Yes	123(28.8)
Notice pollution in the living area	No	301(70.5)
	Yes	126(29.5)
Household smoking	No	362(84.8)
	Yes	65(15.2)
Biomass cooking	No	224(52.5)
	Yes	203(47.5)

The current analysis revealed significant associations between several urban factors and respiratory symptoms. Children living closer to pollution sources or in households with smoking were more likely to report respiratory symptoms. The adjusted odds ratios (AOR) are presented in Table 5.

Table 5: Association between respiratory symptoms and environmental factors (N=427 participants)

Factor	n	Cough n(%)	Wheezing n(%)	Breathlessness n(%)	Severe chest illness n(%)
Proximity to pollution					
No	304	43 (14.1)	10 (3.3)	28 (9.2)	15 (4.9)
Yes	123	107 (87.0)***	104 (84.6)***	106 (86.2)***	105 (85.4)***
Notice pollution in the living area					
No	301	48 (16.0)	13 (4.3)	31 (10.3)	21 (7.0)
Yes	126	102 (81.0)***	101 (80.2)***	103 (81.8)***	99 (78.6)***
Household smoking					
No	362	111 (30.7)	77 (21.3)	96 (26.5)	83 (22.9)
Yes	65	39 (60.0)***	37 (56.9)***	38 (58.5)***	37 (56.9)***
Biomass cooking					
No	224	36 (16.1)	10 (4.5)	25 (11.2)	13 (5.8)
Yes	203	114 (56.2)***	104 (51.2)***	109 (53.7)***	120 (28.1)***

*P-Value: *<0.05, **<0.01 and ***<0.001*

This table highlights the association between environmental factors (proximity to pollution, pollution in the living area, household smoking, and biomass cooking) and respiratory symptoms. The data shows significant differences in symptoms based on environmental exposures. For example, a much higher percentage of participants living near pollution sources

or in households with smoking experience symptoms like cough, wheezing, breathlessness, and severe chest illness compared to those without such exposure.

Table 6: Factors associated with prevalence of respiratory symptoms using Modified Logistic Regression: Unadjusted Analysis

Factor	Cough, uPR 95%CI	Wheezing, PR 95%CI	Breathlessness, PR 95%CI	Severe chest illness, uPR 95%CI
School				
Amani PS(Buza)	1.7(1.01-2.9)*	1.2(0.7-2.2)	1.4(0.8-2.5)	1.4(0.8-2.6)
Diamond PS (DIT)	1.3(0.7-2.4)	1.1(0.5-2.2)	1.2(0.6-2.2)	1.2(0.6-2.4)
Faith PS(DIT)	1.3(0.7-2.5)	0.9(0.4-19)	1.0(0.5-2.0)	1.2(0.6-2.4)
Mlimani SKY City PS	Ref	Ref	Ref	Ref
Vijibweni PS(Kigamboni)	1.3(0.7-2.4)	1.1(0.5-2.1)	1.2(0.6-2.2)	1.2(0.6-2.3)
Vingunguti PS	1.5(0.9-2.6)	1.5(0.8-2.6)	1.5(0.9-2.5) ^	1.8(1.0-3.2) ^
Gender				
Male	Ref	Ref	Ref	Ref
Female	1.1(0.8-1.4)	1.0(0.7-1.3)	0.9(0.7-1.2)	1.0(0.8-1.4)
Class				
Std IV	Ref	Ref	Ref	Ref
Std VII	1.0(0.7-1.2)	1.0(0.7-1.3)	1.0(0.8-1.4)	1.0(0.7-1.3)
Age group				
<10years	1.1(0.9-1.5)	1.1(0.7-1.5)	1.2(0.9-1.7)	1.1(0.8-1.6)
10-12years	0.8(0.6-1.1)	0.9(0.6-1.3)	0.9(0.6-1.3)	0.9(0.6-1.4)
>12years	Ref	Ref	Ref	Ref
Proximity to pollution				
No	Ref	Ref	Ref	Ref
Yes	6.2(4.6-8.2)***	25.7(13.9-47.5)***	9.3(6.5-13.4)***	17.3(10.5-28.5)***
Notice pollution in the living area				
No	Ref	Ref	Ref	Ref
Yes	5.1(3.7-6.7)***	18.6(10.8-31.8)***	7.9(5.6-11.2)***	11.2(7.3-17.2)***
Household smoking				
No	Ref	Ref	Ref	Ref
Yes	2.0(1.5-2.5)***	2.7(2.0-3.5)***	2.2(1.7-2.9)***	2.4(1.9-3.3)***
Biomass cooking				
No	Ref	Ref	Ref	Ref
Yes	3.5(2.5-4.8)***	11.5(6.2-21.4)***	4.8(3.2-7.1)***	9.1(5.2-15.6)***

*P-Value:^<0.2, *<0.05, **<0.01 and ***<0.001, uPR (Unadjusted Prevalence Ratio)*

Table 6 presents the unadjusted prevalence ratios (uPR) and 95% confidence intervals (CI) for the association between various factors and the prevalence of respiratory symptoms (cough, wheezing, breathlessness, and severe chest illness) among schoolchildren. The table includes data for different schools, gender, class, age group, proximity to pollution, noticing pollution in the living area, household smoking, and biomass cooking. The key variables and their associations with respiratory symptoms are analyzed using unadjusted logistic regression.

The analysis revealed that proximity to pollution, household smoking, and biomass cooking were strongly associated with the prevalence of respiratory symptoms in schoolchildren. Proximity to pollution showed a particularly high association with wheezing (uPR 25.7, 95% CI: 13.9–47.5) and severe chest illness (uPR 17.3, 95% CI: 10.5–28.5). Students from Amani PS had significantly higher odds of coughing (uPR 1.7, 95% CI: 1.01–2.9), while those at Vingunguti PS showed a higher likelihood of severe chest illness (uPR 1.8, 95% CI: 1.0–3.2). In contrast, no significant associations were observed between gender, class, or age group and respiratory symptoms.

Table 7: Factors associated with prevalence of respiratory symptoms using Modified Logistic Regression: Adjusted Analysis

Factor	Cough, aPR 95%CI	Wheezing, PR 95%CI	Breathlessness, PR 95%CI	Severe chest illness, aPR 95%CI
School				
Amani PS(Buza)	1.5(1.01-2.1)*	0.9(0.6-1.2)	1.2(0.8-1.6)	1.0(0.8-1.4)
Diamond PS (DIT)	1.2(0.8-1.8)	0.9(0.6-1.3)	1.0(0.7-1.5)	1.0(0.7-1.4)
Faith PS(DIT)	1.3(0.9-2.0)	0.8(0.6-1.2)	1.0(0.7-1.4)	1.1(0.8-1.6)
Mlimani SKY City PS	Ref	Ref	Ref	Ref
Vijibweni				
PS(Kigamboni)	1.3(0.9-1.9)	0.9(0.6-1.3)	1.1(0.8-1.7)	1.0(0.7-1.4)
Vingunguti PS	1.1(0.8-1.6)	0.9(0.6-1.2)	1.0(0.7-1.4)	1.1(0.8-1.5)
Proximity to pollution				
No	Ref	Ref	Ref	Ref
Yes	3.4(2.3-5.0)***	7.0(2.9-17.2)***	3.9(2.3-6.6)***	6.4(3.3-1.2)***
Notice pollution in the living area				
No	Ref	Ref	Ref	Ref
Yes	1.9(1.4-2.7)***	3.6(1.8-7.4)***	2.6(1.6-4.1)***	2.3(1.4-3.7)**
Household smoking				
No	Ref	Ref	Ref	Ref
Yes	1.0(0.9-1.2)	1.2(1.02-1.4)*	1.1(0.9-1.3)	1.2(1.01-1.4)*
Biomass cooking				
No	Ref	Ref	Ref	Ref
Yes	1.3(1.0-1.8)	2.4(1.4-4.0)**	1.4(1.0-2.1)	2.3(1.4-3.8)**

*P-Value: *<0.05, **<0.01 and ***<0.001, aPR(Adjusted Prevalence Ratio)*

The above table, table 7 presents the adjusted prevalence ratios (aPR) and 95% confidence intervals (CI) for the association between various factors and the prevalence of respiratory symptoms (cough, wheezing, breathlessness, and severe chest illness) among schoolchildren. The table includes data for different schools, proximity to pollution, noticing pollution in the living area, household smoking, and biomass cooking. The key variables and their associations with respiratory symptoms are analyzed using adjusted logistic regression, controlling for confounding factors.

The adjusted analysis revealed that proximity to pollution remained a strong factor associated with higher prevalence of respiratory symptoms, particularly wheezing (aPR 7.0, 95% CI: 2.9–17.2) and severe chest illness (aPR 6.4, 95% CI: 3.3–1.2). Noticing pollution in the living area was also significantly associated with an increased prevalence of all symptoms, including coughing (aPR 1.9, 95% CI: 1.4–2.7) and wheezing (aPR 3.6, 95% CI: 1.8–7.4). Household smoking showed a significant association with wheezing (aPR 1.2, 95% CI: 1.02–1.4, $p < 0.05$) and severe chest illness (aPR 1.2, 95% CI: 1.01–1.4, $p < 0.05$). Additionally, biomass cooking remained significantly associated with wheezing (aPR 2.4, 95% CI: 1.4–4.0) and severe chest illness (aPR 2.3, 95% CI: 1.4–3.8).

4.4 Levels of Ambient Particulate Matter (PM2.5 and PM10)

The levels of ambient particulate matter ($PM_{2.5}$ and PM_{10}) were measured at different locations across Dar es Salaam over multiple years. Descriptive statistics, including mean, standard deviation, were computed for these measurements. The average monthly levels of $PM_{2.5}$ and PM_{10} by site and year are detailed in Tables 8 and 9, respectively.

Table 8: Average monthly PM2.5 by year and site using ANOVA

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	P-Value
Year 2021													
Buza Hospital	ND	ND	ND	ND	35.0	33.0	29.5	36.2	32.7	28.9	29.3	25.5	<0.001
DIT	ND	ND	ND	ND	24.8	24.0	24.6	29.4	15.2	20.4	14.4	13.9	<0.001
Mlimani City	ND	ND	ND	ND	26.7	23.0	23.3	29.7	19.8	20.1	16.5	13.8	<0.001
Sinza Hospital	ND	ND	ND	ND	28.9	28.0	28.7	36.1	26.4	23.3	21.4	19.3	<0.001
Vijibweni Hosp	ND	ND	ND	ND	26.7	22.0	23.8	28.7	18.1	19.2	14.9	12.1	<0.001
Vingunguti	ND	ND	ND	ND	37.5	40.0	42.1	42.6	30.3	35.9	31.9	27.0	<0.001
Year 2022													
Buza Hospital	25.1	31.9	34.3	35.7	38.4	41.0	42.2	45.4	46.8	49.3	51.7	53.3	<0.001
DIT	12.9	16.5	18.8	19.8	22.2	26.0	26.3	29.8	31.0	33.0	36.4	37.3	<0.001

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	P-Value
Mlimani City	14.0	17.7	21.8	23.1	25.8	28.4	29.5	33.1	34.1	36.5	39.5	40.5	<0.001
Sinza Hospital	19.5	21.6	23.2	24.9	27.7	29.6	31.4	34.5	36.0	38.3	40.7	42.4	<0.001
Vijibweni Hosp	16.5	19.0	19.3	21.1	24.0	25.7	27.6	30.6	32.2	34.6	36.8	38.6	<0.001
Vingunguti	29.9	35.9	35.6	36.6	40.3	41.8	43.2	47.0	48.0	50.6	53.0	54.2	<0.001
Year 2023													
Buza Hospital	55.9	58.0	60.1	62.1	64.8	66.0	68.9	71.3	72.3	74.5	75.2	74.3	<0.001
DIT	39.7	42.1	44.8	46.0	49.3	51.0	52.6	53.5	54.9	57.7	60.9	61.6	<0.001
Mlimani City	43.3	45.4	47.6	49.2	52.6	53.6	56.1	58.8	60.1	62.8	65.4	66.0	<0.001
Sinza Hospital	45.2	47.0	49.0	51.0	53.9	55.5	57.9	60.2	61.9	64.7	66.6	68.4	<0.001
Vijibweni Hosp.	41.5	43.2	45.1	47.2	50.1	52.0	54.2	56.3	58.1	61	62.7	64.6	<0.001
Vingunguti	57.8	59.2	60.9	63.0	66.4	67.5	69.8	70.9	72.3	74.8	76.2	77.2	<0.001
Year 2024													
Buza Hospital	77.5	77.4	77.3	74.5	75.5	ND	ND	ND	ND	ND	ND	ND	0.084
DIT	64.2	65.3	66.0	68.8	70.3	ND	ND	ND	ND	ND	ND	ND	<0.001
Mlimani City	69.1	70.0	71.3	74.0	74.8	ND	ND	ND	ND	ND	ND	ND	<0.001
Sinza Hospital	71.5	73.0	74.3	77.3	76.2	ND	ND	ND	ND	ND	ND	ND	<0.001
Vijibweni Hosp	67.6	69.3	70.7	73.7	75.0	ND	ND	ND	ND	ND	ND	ND	<0.001
Vingunguti	75.4	73.9	76.3	76.3	77.8	ND	ND	ND	ND	ND	ND	ND	0.063

Key: ND: No data (as sensors were first installed in Dar es Salaam in May 2021)

This table presents the average monthly concentrations of $PM_{2.5}$ (in micrograms per cubic meter) at various sites across Dar es Salaam, including Buza Hospital, DIT, Mlimani City, Sinza Hospital, Vijibweni Hospital, and Vingunguti, from 2021 to 2024. The data were analyzed using ANOVA to determine the statistical significance of variations in $PM_{2.5}$ levels across months and sites. For each site, significant changes in $PM_{2.5}$ levels over the years are highlighted, with p-values indicating the significance of these changes.

Across all sites, there were significant increases in $PM_{2.5}$ levels from 2021 to 2023 ($p < 0.001$ for most sites), with the highest levels observed in 2023. Vingunguti consistently had the highest average $PM_{2.5}$ concentrations, reaching up to 77.2 µg/m³ in December 2023. Buza Hospital and Sinza Hospital also showed substantial increases in $PM_{2.5}$ levels, with averages of 74.3 µg/m³ and 68.4 µg/m³ respectively by December 2023. By 2024, data was only available for the first five months, but $PM_{2.5}$ levels remained elevated, particularly at Vingunguti (77.8 µg/m³ in May 2024) and Mlimani City (74.8 µg/m³ in May 2024). Sites such as Buza Hospital and Vijibweni Hospital had slightly lower $PM_{2.5}$ levels but still exceeded recommended thresholds.

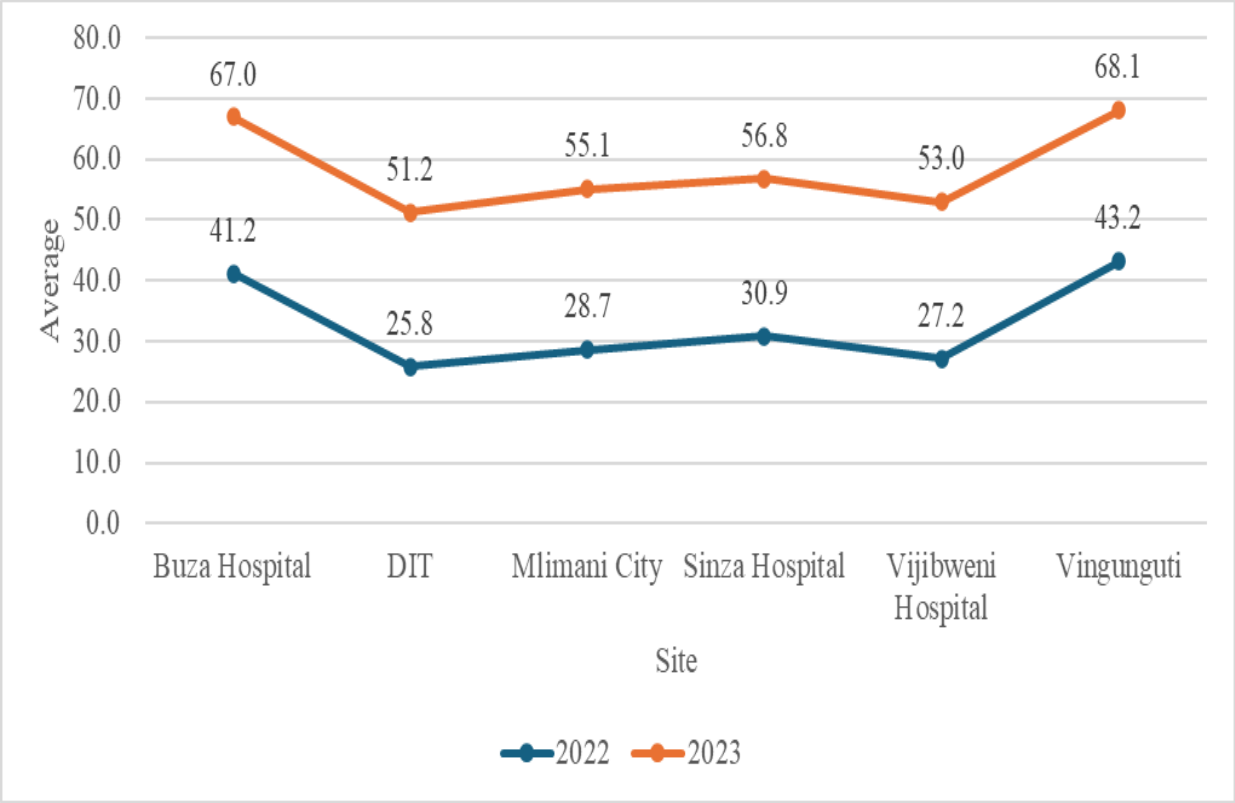
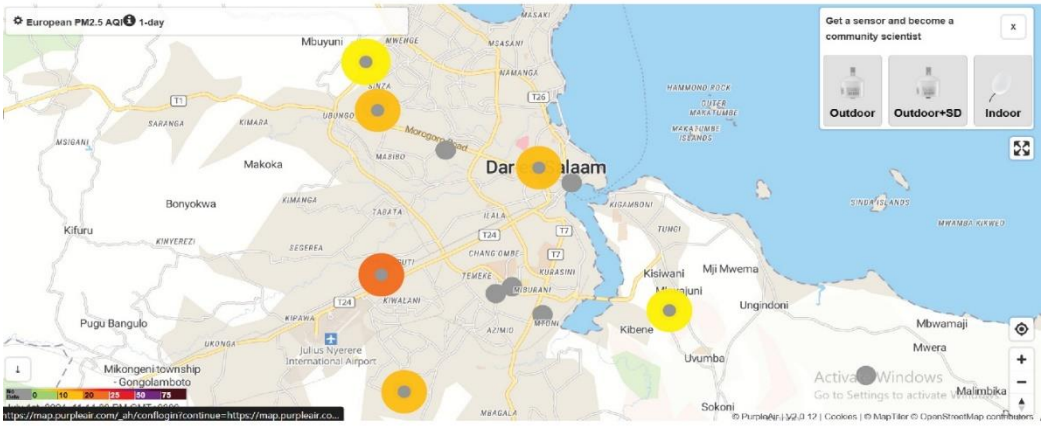


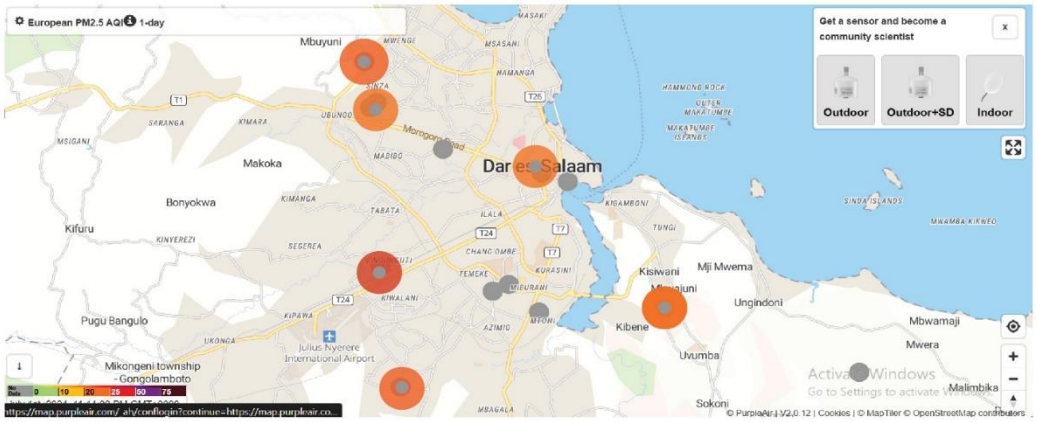
Figure 2: Annual $PM_{2.5}$ mean comparison by site for year 2022 and 2023 (The difference in mean of each site between years was significant with p<0.001); Level of annual mean: Good: ≤ 5 µg/m³, Fair: > 5 to 15 µg/m³, Poor: > 15 to 25 µg/m³, Very Poor: > 25 µg/m³.

This figure illustrates the significant differences ($p < 0.001$) in mean PM2.5 levels across six sites between 2022 and 2023. The mean was used to summarize overall air quality at each site, providing a representative value of exposure over the year, which accounts for fluctuations and highlights long-term trends. $PM_{2.5}$ levels were consistently in the "Very Poor" category (> 25 µg/m³), with Vingunguti showing the highest increase in 2023.

GIS Map showing $PM_{2.5}$ levels in Dar es salaam2022



GIS Map showing $PM_{2.5}$ levels in Dar es salaam2023



$PM_{2.5}$ Scale:

1. Good: ≤ 45 µg/m³
2. Fair: > 45 to 75 µg/m³
3. Poor: > 75 to 100 µg/m³
4. Very Poor: > 100 µg/m³
5. Extremely Poor: > 100 µg/m³
6. Hazardous: > 100 µg/m³

Figure 3: GIS Maps Showing $PM_{2.5}$ Levels in Dar es Salaam for 2022 and 2023

The figure above with GIS map illustrate the spatial distribution of PM2.5 levels across Dar es Salaam for 2022 and 2023. The color-coded scale indicates air quality, with yellow representing "Good" (≤ 5 µg/m³) and dark orange indicating "Hazardous" (> 50 µg/m³). In 2022, $PM_{2.5}$ levels were predominantly in the "Fair" to "Very Poor" range, while 2023 saw an increase in $PM_{2.5}$ concentrations, with several areas, particularly in the city center and Vingunguti, moving into the "Hazardous" range. This highlights the worsening air quality over time, especially in industrial and highly urbanized areas.

Table 9: Average monthly PM_{10} by year and site using ANOVA

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	P-Value
Year 2021													
Buza Hospital	ND	ND	ND	ND	39.4	38.0	34.8	43.7	40.9	36.9	36.7	31.1	0.002
DIT	ND	ND	ND	ND	27.9	26.8	27.6	34.2	18.1	24.2	17.0	16.1	<0.001
Mlimani City	ND	ND	ND	ND	27.8	24.3	24.5	31.1	21.0	21.3	17.3	14.5	<0.001
Sinza Hospital	ND	ND	ND	ND	31.1	30.3	31.1	39.1	28.9	25.6	23.1	20.8	<0.001
Vijibweni Hosp.	ND	ND	ND	ND	29.3	24.3	26.7	31.8	20.6	22.0	17.0	13.6	<0.001
Vingunguti	ND	ND	ND	ND	46.6	51.3	57.4	58.5	42.9	51.4	46.3	34.5	<0.001
Year 2022													
Buza Hospital	33.0	40.3	44.9	46.9	50.6	54.1	56.0	60.3	62.4	65.9	69.3	71.5	<0.001
DIT	16.8	20.4	23.3	25.0	28.3	32.7	34.0	38.7	40.6	43.5	47.9	49.4	<0.001
Mlimani City	15.1	18.8	23.6	25.7	29.3	32.8	34.7	39.2	41.1	44.4	48.2	50.0	<0.001
Sinza Hospital	21.6	23.7	25.8	28.4	32.1	34.8	37.5	41.4	43.8	47.1	50.3	52.8	<0.001
Vijibweni Hosp.	19.9	23.2	23.9	26.5	30.3	32.9	35.4	39.5	42.2	45.3	48.3	50.8	<0.001
Vingunguti	41.0	47.5	47.1	48.7	53.7	55.8	57.9	62.9	64.5	68.1	71.6	73.2	<0.001
Year 2023													
Buza Hospital	75.1	78.8	81.0	83.4	85.1	85.8	84.3	84.9	84.3	80.7	80.9	82.7	<0.001

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	P-Value
DIT	52.7	56.0	59.3	60.6	64.3	66.2	68.8	72.2	73.5	77.0	80.2	81.8	<0.001
Mlimani City	53.7	56.6	59.8	62.3	66.6	68.4	71.6	74.2	75.9	79.5	81.6	83.1	<0.001
Sinza Hospital	56.6	59.1	62.1	64.9	68.8	71.1	74.4	77.6	80.2	83.9	86.6	89.6	<0.001
Vijibweni Hosp.	54.9	57.2	60.0	62.9	67.0	69.1	72.3	75.7	78.0	82.1	84.7	85.7	<0.001
Vingunguti	78.2	80.1	81.8	84.2	86.1	88.1	90.5	92.7	89.3	89.8	89.5	92.9	<0.001
Year 2024													
Buza Hospital	84.9	85.7	84.6	80.0	82.5	ND	ND	ND	ND	ND	ND	ND	0.002
DIT	84.9	86.5	87.4	84.7	86.8	ND	ND	ND	ND	ND	ND	ND	<0.001
Mlimani City	85.0	86.6	87.9	86.9	86.0	ND	ND	ND	ND	ND	ND	ND	<0.001
Sinza Hospital	91.2	91.8	93.8	94.2	95.4	ND	ND	ND	ND	ND	ND	ND	<0.001
Vijibweni Hosp.	89.6	91.7	93.2	94.6	94.3	ND	ND	ND	ND	ND	ND	ND	<0.001
Vingunguti	93.1	84.3	85.4	88.8	91.3	ND	ND	ND	ND	ND	ND	ND	0.063

Key: ND: No data (as sensors were first installed in Dar es Salaam in May 2021)

This table presents the average monthly concentrations of PM_{10} across various sites in Dar es Salaam from 2021 to 2024, analyzed using ANOVA. The data indicate significant changes ($p < 0.001$) in PM_{10} levels over time. In 2021, PM_{10} levels were notably lower, with Vingunguti showing the highest concentrations (57.4 $\mu g/m^3$ by July). However, by 2023, PM_{10} levels increased across all sites, with Sinza Hospital reaching an average of 89.6 $\mu g/m^3$ in December and Vingunguti peaking at 92.9 $\mu g/m^3$. By 2024, data was available only for the first five months, with PM10 levels remaining elevated across all sites, particularly at Sinza Hospital and Vijibweni Hospital, both exceeding 90 $\mu g/m^3$. The significant rise in PM_{10} levels highlights worsening air quality, particularly in industrial areas like Vingunguti and Sinza Hospital.

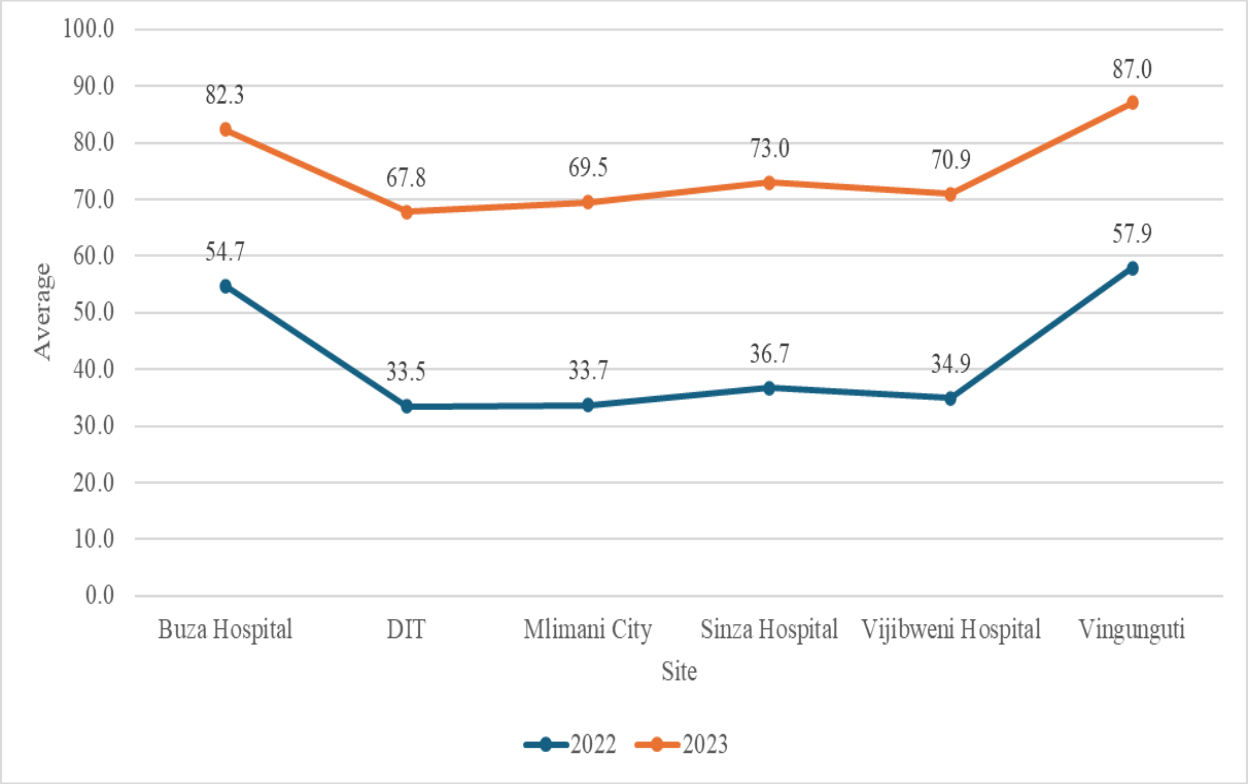


Figure 4: Annual PM10 mean comparison by site for year 2022 and 2023 (The difference in mean of each site between years was significant with p<0.001); Level of mean: Good: ≤ 45 µg/m³, Fair: > 45 to 75 µg/m³, Poor: > 75 to 100 µg/m³, Very Poor: > 100 µg/m³

This figure compares the annual mean PM_{10} concentrations across six sites in Dar es Salaam between 2022 and 2023. The results show significant differences in PM10 levels ($p < 0.001$), with all sites showing increases in 2023. In 2022, most sites had PM_{10} levels in the "Good" (≤ 45 µg/m³) to "Fair" (> 45 to 75 µg/m³) range. However, by 2023, sites like Buza Hospital (82.3 µg/m³) and Vingunguti (87.0 µg/m³) had entered the "Poor" range (> 75 to 100 µg/m³). The increase in PM_{10} levels highlights a significant decline in air quality, particularly at industrial and urban sites.

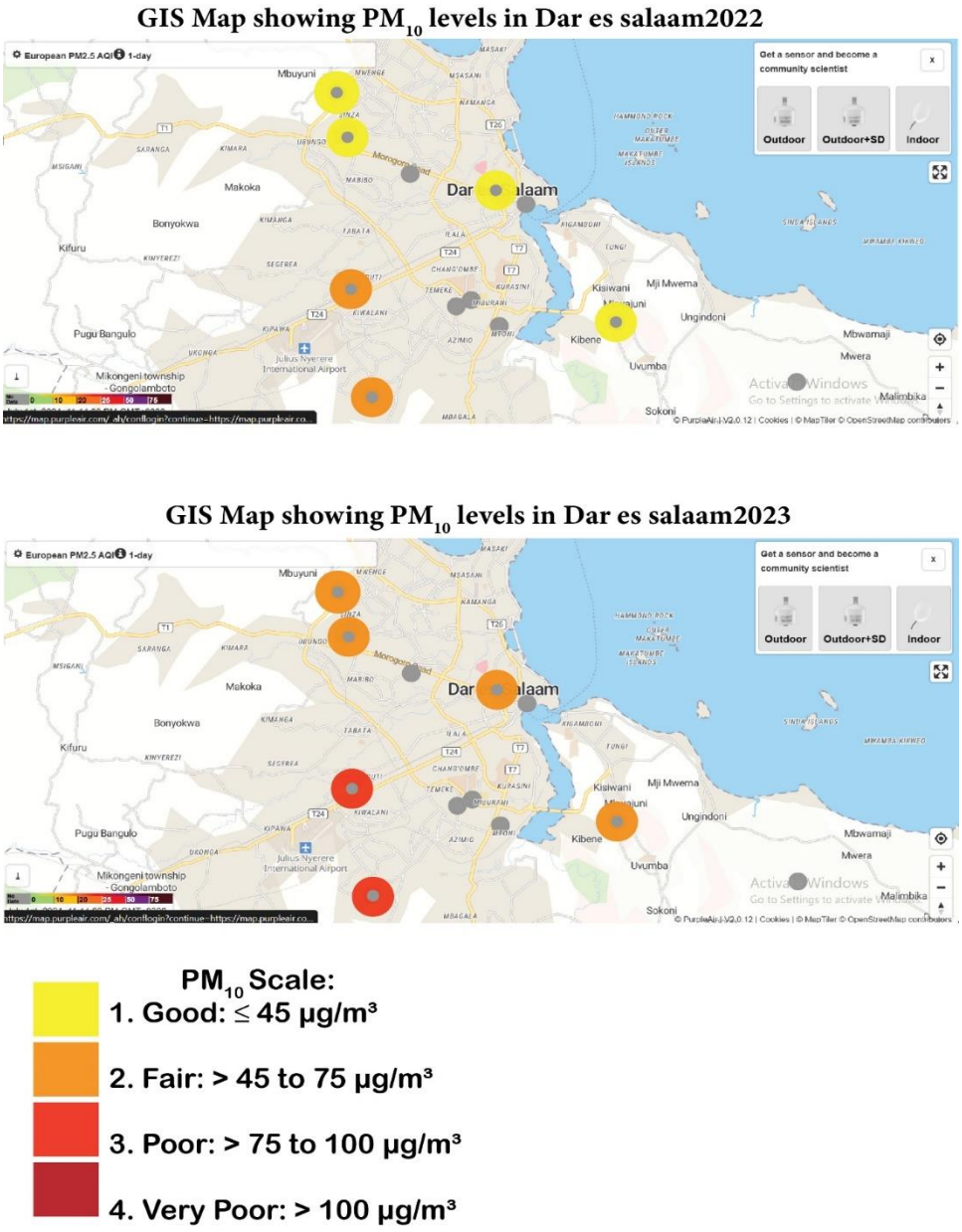


Figure 5: GIS Map showing PM_{10} Levels in Dar es Salaam for 2022 and 2023

The GIS map illustrate the spatial distribution of PM_{10} levels across Dar es Salaam in 2022 and 2023. The color-coded scale indicates air quality, ranging from "Good" (≤ 45 µg/m³) to "Very Poor" (> 100 µg/m³). In 2022, PM_{10} levels across most sites were in the "Fair" (> 45 to 75 µg/m³) to "Poor" (> 75 to 100 µg/m³) range. By 2023, there was a notable increase in PM_{10} levels, with

several sites, particularly in urban and industrial areas, experiencing "Poor" to "Very Poor" air quality. Sites like Vingunguti and Buza Hospital exhibited the most significant increases in PM_{10} concentrations, highlighting the deterioration in air quality over time.

4.5 Association between Respiratory Symptoms and Ambient Particulate Matter

To determine the association between respiratory symptoms and exposure to ambient particulate matter, chi-square tests and logistic regression analyses were conducted. The prevalence of respiratory symptoms was compared between children in high-pollution areas and those in lower pollution areas.

Considering PM10, Chi-square tests indicated significant differences in the prevalence of respiratory symptoms between high and low pollution areas ($p < 0.05$). Un adjusted Logistic regression analyses further revealed that higher levels of $PM_{2.5}$ and PM_{10} were significantly associated with increased odds of respiratory symptoms. This indicates a strong association between the level of ambient air pollution and the incidence of respiratory issues among school children. However, after adjusting for potential confounders the models experienced convergence issues, meaning the adjustment process could not be completed due to limitations in the data structure (Tables 10 and 11). This is a common occurrence in complex models and does not affect the validity of the unadjusted findings. No association analysis was done for $PM_{2.5}$ since all annual average were under category of very poor i.e. >25 $\mu g/m^3$ (Figure 2). However, such elevated levels of particulate matter highlight the severe air quality issues in Dar es Salaam and their potential impact on public health, particularly for vulnerable populations such as school children These associations are summarized in Table 10.

Table 10: Association between respiratory symptoms and PM levels using Chi-Square Test

Factor	N	Cough, n(%)	Wheezing ,n(%)	Breathlessness ,n(%)	Severe chest illness, n(%)
PM10.0 Level					
Fair:> 45 to 75 µg/m³	213	65(30.5)	49(23.0)	57(26.8)	50(23.5)
Poor:> 75 to 100 µg/m³	214	85(39.7*	65(30.4)*	77(36.0)*	70(32.7)*

*P-Value: *<0.05, **<0.01 and ***<0.001*

This table shows the association between PM_{10} levels and the prevalence of respiratory symptoms (cough, wheezing, breathlessness, and severe chest illness) in schoolchildren. The results indicate a significant association between higher PM10 levels and increased respiratory symptoms. In areas with "Poor" air quality (PM_{10} > 75 to 100 µg/m³), a higher percentage of children reported symptoms, all with p-values < 0.05.

Table 11: Association between PM10.0 and prevalence of respiratory symptoms using Modified Logistic Regression: Unadjusted Analysis

Factor	Cough, uPR 95%CI	Wheezing, uPR 95%CI	Breathlessness, uPR 95%CI	Severe chest illness, uPR 95%CI
PM10.0 Level				
Fair:> 45 to 75 µg/m³	Ref	Ref	Ref	Ref
Poor:> 75 to 100 µg/m³	1.3(1.0-1.7)*	1.3(1.0-1.8)^	1.3(1.01-1.8)*	1.4(1.0-1.9)*

*P-Value: *<0.05, **<0.01 and ***<0.001*

Table 11 shows that children in areas with "Poor" air quality (PM10 > 75 to 100 µg/m³) had significantly higher odds of experiencing respiratory symptoms (cough, wheezing, breathlessness, and severe chest illness) compared to those in areas with "Fair" air quality (PM_{10} > 45 to 75 µg/m³), with all associations showing p-values < 0.05.

The pie chart in Figure 4 illustrates the levels of respiratory risks among primary school children (n=427). The majority of children (73.8%) fall into the low-risk category (0-5 points), indicating that most of the children have minimal respiratory risk. A smaller portion (14.5%) is classified as having moderate risks (6-15 points), and an even smaller group (11.7%) is identified as high risk. This distribution suggests that while a significant majority of the children are at low risk for respiratory issues, there is a noteworthy proportion that requires attention due to moderate and high-risk levels.

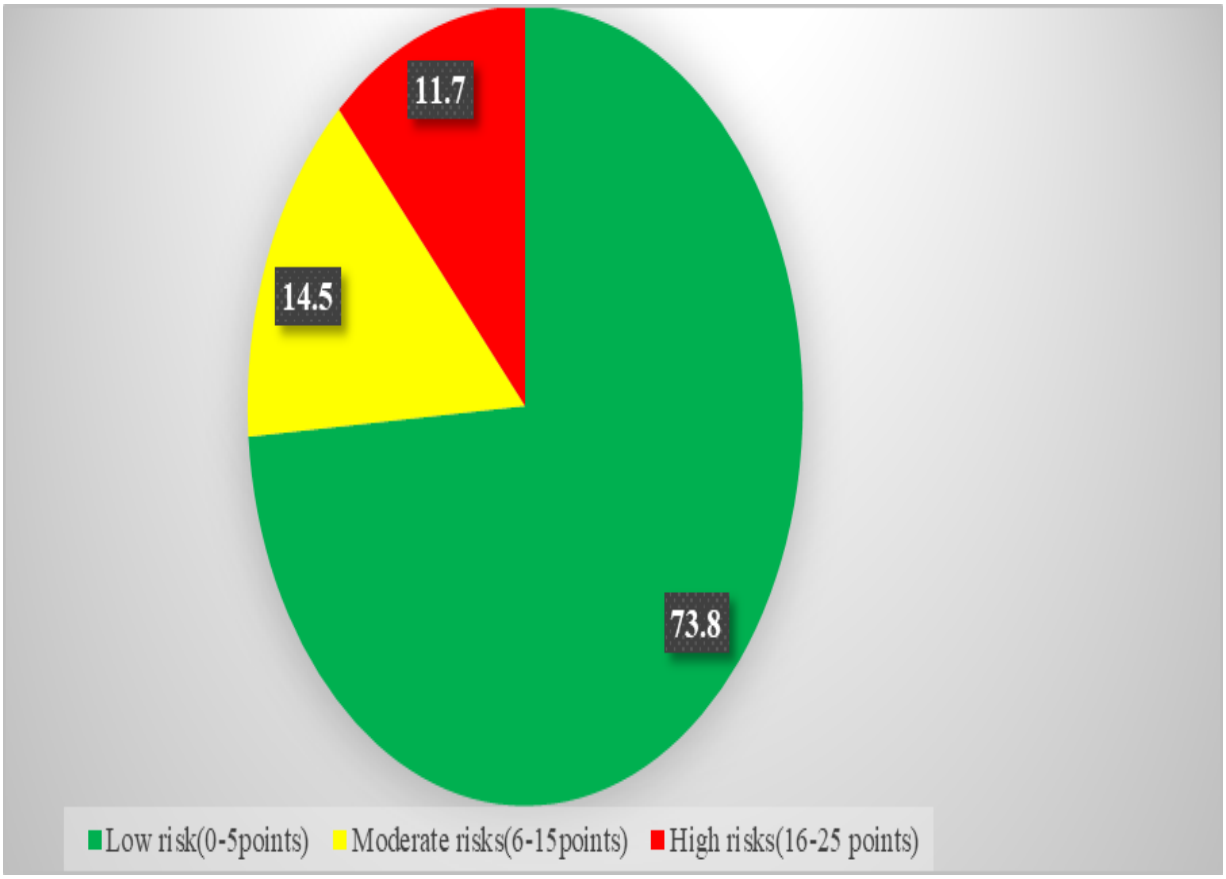


Figure 6: Level of respiratory risks among primary schooling children (n=427)

5.0 DISCUSSION

5.1 Prevalence of Respiratory Symptoms among School Children in Dar es Salaam City

The prevalence of respiratory symptoms among school children in Dar es Salaam is significantly high, with 35.1% of children reporting coughing, 26.7% reporting wheezing, 31.4% experiencing breathlessness, and 28.1% reporting severe chest illness at least once in the past year. This is consistent with recent findings, such as a 2023 study by the European Respiratory Society, which shows that urban children exposed to high levels of ambient particulate matter (PM) have a significantly higher risk of respiratory symptoms, particularly wheezing and breathlessness (Aithal, Sachdeva and Kurmi, 2023). Similarly, the American Academy of Pediatrics has identified the strong connection between air pollution and respiratory health in children, linking higher pollutant levels with increased prevalence of asthma and other chronic respiratory conditions.(Andina Martínez *et al.*, 2024) Moreover, research by (Ren *et al.*, 2020) emphasizes the chronic respiratory impacts of prolonged exposure to urban air pollution.

The high prevalence of these symptoms suggests a substantial burden of respiratory conditions among school-aged children in Dar es Salaam, which may be attributed to various environmental and socio-economic factors prevalent in the city. Recent studies, such as those by the World Health Organization (‘WHO’, no date)underscore the role of poor living conditions and increased pollution exposure in low-income urban areas as major contributors to these health issues**.** Additionally, (Dondi *et al.*, 2023) emphasizes that these environmental exposures disproportionately affect vulnerable populations, including children in rapidly urbanizing areas like Dar es Salaam. Furthermore, the study by (Ren *et al.*, 2020) underscores the intersection of environmental and socio-economic determinants in respiratory health outcomes.

5.2 Urban Factors Associated with Respiratory Symptoms among School Children

The analysis of urban environmental factors revealed significant associations between several risk factors and the presence of respiratory symptoms among school children. Children living closer to pollution sources or in households with smoking were more likely to report respiratory symptoms. This finding is consistent with previous research highlighting the detrimental effects of air pollution and secondhand smoke on children's respiratory health. For instance, a study by

(Patel *et al.*, 2010) found that children exposed to secondhand smoke and living near busy roads had higher incidences of asthma and other respiratory symptoms. Additionally, (Sierra-Vargas and Teran, 2012) reported similar findings, indicating that proximity to busy roads significantly increases the risk of respiratory issues among children. Furthermore, (Ren *et al.*, 2020) emphasized the chronic respiratory impacts of living near pollution sources.

Proximity to pollution sources such as busy roads and industrial areas is a major contributor to respiratory problems. A 2023 study by the American Academy of Pediatrics emphasized that children exposed to higher levels of particulate matter, particularly $PM_{2.5}$ and PM_{10}, are at a heightened risk of developing respiratory issues, including asthma and bronchitis. (Andina Martínez et al., 2024). This is further supported by the European Environment Agency (2022), which points out that children are particularly vulnerable due to their developing respiratory systems and higher inhalation rates of polluted air close to the ground.

In addition to outdoor pollution, household smoking significantly increases the risk of respiratory symptoms. A recent report by the American Lung Association (2024) reiterated the elevated risk of respiratory illnesses in children exposed to secondhand smoke, noting that it exacerbates existing conditions like asthma and can lead to more severe respiratory infections. Furthermore, the use of biomass for cooking is another significant risk factor, contributing heavily to indoor air pollution in developing countries. The World Health Organization (2022) highlights that biomass cooking fuels are a leading cause of indoor pollution, particularly affecting children's respiratory health.('WHO', no date) This is consistent with earlier findings by (Graham *et al.*, 2019), which showed that indoor air pollution from biomass fuels severely impacts children's lung development and respiratory health.

5.3 Levels of Ambient Particulate Matter (PM2.5 and PM10)

The levels of ambient particulate matter ($PM_{2.5}$ and PM_{10}) measured at different locations across Dar es Salaam indicate significant seasonal variations and an overall increasing trend over the study period. The average monthly levels of $PM_{2.5}$ and PM_{10} often exceeded the recommended limits set by the World Health Organization (WHO), posing a substantial health risk to the city's residents, especially children. Recent data published by the ('WHO', no date) sets the

recommended annual average for $PM_{2.5}$ at 5 µg/m³ and for PM_{10} at 15 µg/m³, far lower than the values recorded in Dar es Salaam, indicating an alarming public health concern.

Seasonal variations in particulate matter levels are driven by meteorological conditions and pollution sources. During the dry season, particulate matter concentrations are higher due to dust and industrial emissions. Recent research by (Chen *et al.*, 2023) emphasizes that dry seasons in urban environments lead to elevated PM concentrations due to a lack of precipitation to remove particles from the air. Similarly, (Ghosh *et al.*, 2024) highlighted how increased vehicular traffic and industrial activities during dry periods exacerbate air pollution. These findings are corroborated by studies from Bangladesh (Yosenov, Bachtiar and Zulkarnaini, 2023) which also showed that particulate matter levels rise during specific weather conditions like dry spells, largely due to enhanced dust and vehicular pollution. The study by (Ren *et al.*, 2020) also reported that increased industrial activities and traffic congestion are major contributors to elevated particulate matter levels during specific periods.

Furthermore, (Graham *et al.*, 2019) observed that traffic-related air pollution is a significant source of PM2.5 and PM10, contributing to higher concentrations during peak traffic hours. An assessment by the PurpleAir company highlighted the impact of local sources such as biomass burning and vehicular emissions on particulate matter levels in Dar es Salaam. Proximity to industrial areas and heavy traffic are major contributors to high PM levels. A recent study in 2023 by (Yosenov, Bachtiar and Zulkarnaini, 2023) observed similar trends in cities where industrial emissions and vehicular traffic were the dominant sources of $PM_{2.5}$ and PM_{10}, further supporting the notion that Dar es Salaam's high particulate levels are driven by these factors.

These consistent findings across multiple studies underscore the importance of addressing the sources of particulate matter to mitigate health risks. Implementing strategies to control emissions from industrial activities, managing traffic congestion, and promoting dust control measures during dry seasons can significantly reduce $PM_{2.5}$ and PM_{10} levels and protect public health.

5.4 Association between Respiratory Symptoms and Ambient Particulate Matter

The association between respiratory symptoms and exposure to ambient particulate matter was evident in this study. Higher levels of PM_{10} were associated with increased odds of respiratory symptoms. For instance, (Qi *et al.*, 2022)found a direct relationship between increased $PM_{2.5}$ and PM_{10} levels and higher rates of hospitalizations due to respiratory diseases in children. Similarly, (Afifa *et al.*, 2024) reported that elevated particulate matter exposure is associated with increased respiratory issues such as asthma exacerbations and chronic obstructive pulmonary disease (COPD) among urban populations.

The logistic regression analyses indicated that children in high-pollution areas were more likely to experience respiratory symptoms compared to those in lower pollution areas. This association highlights the impact of air pollution on children's health, particularly in urban settings like Dar es Salaam, where traffic and industrial emissions are prominent. Recent findings by (Yosenov, Bachtiar and Zulkarnaini, 2023) confirm that proximity to pollution sources such as major roadways and industrial areas significantly raises the risk of respiratory diseases among children. Similar findings were reported by (Graham *et al.*, 2019), who observed that children living in high pollution areas had significantly higher rates of respiratory symptoms and conditions.

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study aimed to investigate the effect of ambient particulate matter ($PM_{2.5}$ and PM_{10}) on the respiratory health of school children in Dar es Salaam, Tanzania. The findings highlight significant associations between high levels of particulate matter and increased prevalence of respiratory symptoms among children. The study found a high prevalence of respiratory symptoms, with 35.1% of children experiencing coughing, 26.7% wheezing, 31.4% breathlessness, and 28.1% severe chest illness. These symptoms are significantly higher compared to children in areas with lower pollution levels. Proximity to pollution sources, such as busy roads and industrial areas, and household smoking were identified as significant risk factors for respiratory symptoms. Measurements of $PM_{2.5}$ and PM_{10} across different locations in Dar es Salaam revealed seasonal variations and overall high levels, often exceeding WHO recommended limits. Higher levels of PM_{10} were significantly associated with increased odds of respiratory symptoms in children. These findings align with previous studies conducted globally and regionally, confirming the detrimental effects of ambient particulate matter on respiratory health. The study emphasizes the need for urgent interventions to address air pollution and its impact on vulnerable populations, especially children.

6.2 Recommendations

1. Strengthen emission standards: As the study revealed high levels of particulate matter significantly associated with increased respiratory symptoms, it is essential to implement stricter emission standards for both vehicular and industrial activities to reduce the exposure of children to harmful pollutants. Implement stricter emission standards for vehicles and industrial activities to reduce the release of particulate matter into the air. Improve traffic management: The study showed that schools near high-traffic areas had significantly higher pollution levels, suggesting that traffic management strategies, including promoting public transportation and carpooling, are necessary to reduce congestion and mitigate emissions. The responsibility for enforcing stricter emission

standards lies with the government, particularly the Ministry of Environment, in collaboration with local authorities and industrial regulators.

2. Continuous air quality monitoring: Given that this study used air quality sensors to capture the real-time data on $PM_{2.5}$ and PM_{10}, establishing a robust and continuous air quality monitoring system across the city will allow authorities to track pollution trends and take timely action. Establish a robust air quality monitoring system to continuously measure PM2.5 and PM10 levels across different parts of the city. Public access to this data can increase awareness and inform policy decisions. The environmental monitoring agencies, alongside local governments, will be responsible for installing and maintaining air quality monitoring infrastructure. Health surveillance: The study revealed a high prevalence of respiratory symptoms such as coughing, wheezing, and breathlessness among school children. Therefore, regular health surveillance in schools is critical for early detection and management of respiratory illnesses.

3. Community engagement: Since household smoking and other behaviors exacerbate children's exposure to pollutants, public education campaigns should focus on promoting smoke-free environments and reducing outdoor exposure during peak pollution times. Educate the public about the sources and health impacts of air pollution through community programs, school curricula, and media campaigns, emphasizing the importance of reducing exposure, such as avoiding outdoor activities during peak pollution times. Promote smoke-free homes: Encourage households to adopt smoke-free policies and reduce the use of biomass for cooking by promoting cleaner alternatives, such as electric or gas stoves. The Ministry of Health, in collaboration with community health organizations and schools, should take the lead in public education campaigns and promoting smoke-free environments.

4. Green spaces: The study's findings underscore the need for green spaces to filter pollutants and provide cleaner environments for children in highly polluted areas. Zoning regulations: Implement zoning regulations that separate residential areas from high-pollution industrial zones and busy roads, ensuring that schools and playgrounds

are located in low-pollution areas. The responsibility for creating and maintaining green spaces and implementing zoning regulations lies with urban planners and local government authorities.

5. Further research: While this study provides valuable insights into the short-term health impacts of PM exposure, further longitudinal research is necessary to assess the long-term effects on respiratory health in children. Investigate the role of other pollutants and environmental factors in respiratory health. Collaborative efforts: Foster collaborations between government agencies, non-governmental organizations, research institutions, and the private sector to develop comprehensive strategies for air quality management and health protection. Academic and research institutions, in collaboration with health organizations and government agencies, should spearhead further research into air pollution and its long-term health impacts.

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APPENDICES

Appendix I: Questionnaire – English Version
Respiratory health questionnaire for schoolchildren

(Based on the ATS-DLD-78-A form for assessing respiratory health.)

A. Demographic Information

1. Age:…….
2. Gender: Male / Female
3. Grade:……

B. Respiratory Symptoms

4. Do you cough more than four days in a row? Yes / No
    - If yes, how often does this happen? _____
5. Do you have episodes of wheezing or whistling in your chest? Yes / No
    - If yes, how often? _____
6. Do you get short of breath when you run or exercise? Yes / No
    - If yes, how often does this affect you? _____
7. Have you ever had a severe chest illness that required a hospital visit? Yes / No
    - If yes, how many times? _____

C. Environmental Exposure

8. Do you live near a busy road or industrial area? Yes / No
9. Do you notice air pollution such as smoke or dust where you live? Yes / No

D. Health History

10. Have you ever been diagnosed with asthma or any other respiratory condition? Yes / No

- If yes, please specify: _____

E. Lifestyle

11. Is there anyone who smokes inside your home? Yes / No

12. Do you use any form of biomass (wood, charcoal) for cooking at home? Yes / No

Additional Comments

13. Please describe any other health symptoms or concerns you have related to respiratory health: _____

Appendix II: Questionnaire: Kiswahili version.
Dodoso la afya ya kupumua kwa wanafunzi wa shule

(Kulingana na fomu ya ATS-DLD-78-A ya kutathmini afya ya kupumua.)

A. Taarifa za kidemografia

1. Umri:
2. Jinsia: Kiume / Kike
3. Darasa:

B. Dalili za kupumua

4. Je, unakohoa zaidi ya siku nne mfululizo? Ndio / Hapana
    - Ikiwa ndio, hutokea mara ngapi? _____
5. Je, una vipindi vya kubanwa kifua au kusikia sauti za filimbi kwenye kifua chako? Ndio / Hapana
    - Ikiwa ndio, mara ngapi? _____
6. Je, unapata shida ya kupumua unapokimbia au kufanya mazoezi? Ndio / Hapana
    - Ikiwa ndio, hii inakuathiri mara ngapi? _____
7. Je, umewahi kuwa na ugonjwa mkali wa kifua uliohitaji kutembelea hospitali? Ndio / Hapana
    - Ikiwa ndio, mara ngapi? _____

C. Mfiduo wa mazingira

8. Je, unaishi karibu na barabara yenye shughuli nyingi au eneo la viwanda? Ndio / Hapana
9. Je, unaona uchafuzi wa hewa kama moshi au vumbi unakoishi? Ndio / Hapana

D. Historia ya afya

10. Je, umewahi kugundulika na pumu au hali nyingine yoyote ya kupumua? Ndio / Hapana
    - Ikiwa ndio, tafadhali eleza: _____

E. Hali ya maisha

11. Je, kuna mtu yeyote anayevuta sigara ndani ya nyumba yako? Ndio / Hapana
12. Je, unatumia aina yoyote ya biomasi (kuni, mkaa) kwa kupikia nyumbani? Ndio / Hapana

Maoni ya Ziada

Tafadhali elezea dalili zingine za afya au wasiwasi ulio nao kuhusiana na afya ya kupumua:

Appendix III: Consent form – English Version
DESCRIPTION:

Introduction: Greetings. I am Justus Kamara, a student from Muhimbili University of Health and Allied Sciences. I warmly invite you to partake in a study that seeks to explore the effects of ambient particulate matter ($PM_{2.5}$ and PM_{10}) on the respiratory health of schoolchildren in Dar es Salaam, Tanzania.

Aim: The main purpose is to investigate how exposure to particulate matter affects the respiratory health of schoolchildren and identify potential risk factors associated with increased susceptibility.

Participation: Your participation will involve answering questions about your health, lifestyle, and environment. This questionnaire will take approximately 10 to 15 minutes. For children participants, parental or guardian consent is required.

Benefits and Risks: Your participation will add to a better insight of the environmental factors affecting respiratory health in children, which could inform public health policies and interventions. There aren't known health or economic risks related to participating in this study.

Compensation: There isn't financial compensation for participating in this research.

Confidentiality: All information collected from you will be kept confidential. Your data will only be accessed by the appropriate team. There won't be any information that will make you known and if there is, it will removed before the analysis and publication of the research.

Right to withdrawal: Involvement in this study is entirely voluntary. You have the right to withdraw from the study at any moment, even after obtaining consent, without any consequences.

Who to contact: Incase have any queries regarding the research, please reach Justus Kamara at +255754382946 and justusjucoin@gmail.com or my supervisor: Dr. Stephen Kishinhi through email address: kishinhi@gmail.com

You may reach the Chairperson of the Senate Research and Publications Committee, Muhimbili University of Health and Allied Sciences, P.O. Box 65001, Dar es Salaam. Tel: 2150302-6.

II. CERTIFICATE OF CONSENT

I have clearly read the information above (or it has been read to me). I have had the opportunity to ask questions and have received satisfactory answers. I understand the purpose of the study, as well as the benefits of any kind, risks of any kind, and my right to withdraw from the research. I consent solely to participate in this research.

Participant Sign (or Parent/Guardian if the participant is a minor):

_____

Date: _____

Researcher Sign: _____

Date: _____

Appendix IV: Consent Form – Swahili Version
FOMU YA RIDHAA (TOLEO LA KISWAHILI)

Maelezo:

Utangulizi: Salamu! Naitwa ni Justus Kamara, mwanafunzi kutoka Chuo Kikuu cha Afya na Sayansi Shirikishi Muhimbili. Ninakualika kwa moyo mkunjufu kushiriki katika utafiti unaolenga kuchunguza athari za chembechembe ndogo za uchafuzi wa hewa (PM2.5 na PM10) kwenye afya ya kupumua ya wanafunzi wa shule za msingi Dar es Salaam, Tanzania.

Lengo: Lengo kuu la utafiti huu ni kuchunguza jinsi uchafuzi wa chembechembe ndogo unavyoathiri afya ya kupumua ya wanafunzi wa shule na kutambua vihatarishi vinavyoongeza uwezekano wa madhara.

Ushiriki: Ushiriki wako utahusisha kujibu maswali kuhusu afya yako, mtindo wa maisha, na mazingira yako. Dodoso hili litachukua takribani dakika 10 hadi 15. Kwa washiriki ambao ni watoto, ridhaa ya mzazi au mlezi inahitajika.

Faida na Hatari: Ushiriki wako utachangia uelewa bora wa mambo ya mazingira yanayoathiri afya ya kupumua kwa watoto, ambayo yanaweza kuongoza sera za afya ya umma na hatua za kuingilia kati. Hakuna hatari za kiafya au kiuchumi zinazojulikana zinazohusiana na ushiriki katika utafiti huu.

Fidia: Hakuna fidia ya kifedha kwa kushiriki katika utafiti huu.

Usiri: Taarifa zote zitakazokusanywa kutoka kwako zitabaki kuwa siri. Timu ya utafiti pekee ndiyo itakayokuwa na ufikiaji wa data yako. Taarifa zinazotambulika zitaondolewa kabla ya uchambuzi na uchapishaji wa matokeo ya utafiti.

Haki ya Kujitoa: Ushiriki wowote katika utafiti huu ni wa hiari. Una haki zote az kujitoa kutoka kwenye utafiti na unaweza kuganya hivyowakati wowote, hata baada ya kutoa ridhaa ya kukubari, bila matokeo yoyote kwako.

Mtu wa kuwasiliana naye: Ikitokea una maswali yoyote kuhusu utafiti, tafadhali wasiliana na Justus Kamara kwa +255754382946 na justusjucoin@gmail.com au msimamizi wangu: Dr. Stephen Kishinhi kupitia anwani ya barua pepe: kishinhi@gmail.com

Kwa mambo yoyote kama maswali, au haki zako, unaweza kuwasiliana na Mwenyekiti wa Kamati ya Utafiti na Uchapishaji wa Senate, Chuo Kikuu cha Afya na Sayansi Shirikishi Muhimbili, S.L.P 65001, Dar es Salaam. Tel: 2150302-6.

II. CHETI CHA RIDHAA

Nimesoma vizuri hizi taarifa zilizotolewa (au zimesomwa kwangu). Nimepata fursa ya kuuliza maswali na nimepata majibu yanayoridhisha. Naelewa madhumuni ya utafiti, faida zake, hatari, na haki yangu ya kujitoa. Ninatoa ridhaa yangu kwa hiari kushiriki.

Sahihi ya Mshiriki (au Mzazi/Mlezi ikiwa mshiriki ni mdogo):

_____

Tarehe: _____

Sahihi ya Mtafiti: _____

Tarehe: _____

Appendices V: Approval for ethical clearance

UNITED REPUBLIC OF TANZANIA

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY

MUHIMBILI UNIVERSITY OF HEALTH AND ALLIED SCIENCES

OFFICE OF THE DIRECTOR – RESEARCH, PUBLICATIONS AND INNOVATIONS

Ref. No.DA.282/298/01.C/2278 Date: 31/05/2024

MUHAS-REC-05-2024-2278
JUSTUS KAMARA
SHOOL OF PUBLIC HEALTH AND SOCIAL SCIENCES
MUHAS

RE: APPROVAL FOR ETHICAL CLEARANCE FOR A STUDY TITLED: EFFECT OF AMBIENT PARTICULATE MATTER ON RESPIRATORY HEALTH OF SCHOOL CHILDREN IN THE CITY OF DAR ES SALAAM, TANZANIA.

Reference is made to the above heading,

I am pleased to inform you that the Chairperson has on behalf of the University Senate, approved ethical clearance of the above-mentioned study, on recommendations of the Senate Research and Publications Committee meeting accordance with MUHAS research policy and Tanzania regulations governing human and animal subjects research.

APPROVAL DATE: 31/05/2024
EXPIRATION DATE OF APPROVAL: 31/05/2025

STUDY DESCRIPTION:
Purpose:
The purpose of this cross-sectional analytical study is to determine the association between ambient particulate (PM2.5 and PM10) matter levels and respiratory symptoms among school children in Dar es Salaam city, Tanzania.

The approved protocol and procedures for this study is attached and stamped with this letter, and can be found in the link provided: https://irb.muhas.ac.tz/storage/Certificates/Certificate%20-%2015630.pdf and in the MUHAS archives.

The PI is required to:

1. Submit bi-annual progress reports and final report upon completion of the study.
2. Report to the IRB any unanticipated problem involving risks to subjects or others including adverse events where applicable.
3. Apply for renewal of approval of ethical clearance one (1) month prior its expiration if the study is not completed at the end of this ethical approval. You may not continue with any research activity beyond the expiration date without the approval of the IRB. Failure to receive approval for continuation before the expiration date will result in automatic termination of the approval for this study on the expiration date.
4. Obtain IRB amendment (s) approval for any changes to any aspect of this study before they can be implemented.
5. Data security is ultimately the responsibility of the investigator.
6. Apply for and obtain Data Transfer Agreement (DTA) from NIMR if data will be transferred to a foreign country.
7. Apply for and obtain Material Transfer Agreement (MTA) from NIMR, if research materials (samples) will be shipped to a foreign country.
8. Apply for and obtain permission to publish the results from National Institute for Medical Research. The application should be before submitting to a publisher and not concurrently through the email publications@nimr.or.tz.
9. Any researcher, who contravenes or fail to comply with these conditions, shall be guilty of an offence and shall be liable on conviction to a fine as per NIMR Act No. 23 of 1979, PART III section 10 (2)
10. The PI is required to ensure that the findings of the study are disseminated to relevant stake holders.
11. PI is required to be versed with necessary laws and regulatory policies that govern research in Tanzania. Some guidance is available on our website https://drp.muhas.ac.tz/.

Dr. Nahya Salim Masoud,
Chairperson, MUHAS Research and Ethics Committee

Muhimbili University of Health and Allied Sciences
DIRECTOR
Research, Publications & Innovations
Box 65001

Appendices VI: Introduction Letter

UNITED REPUBLIC OF TANZANIA
MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY
MUHIMBILI UNIVERSITY OF HEALTH AND ALLIED SCIENCES
OFFICE OF THE DIRECTOR – POSTGRADUATE STUDIES

In reply quote;
Ref. No. HD/MUH/T.633/2023 03rd June, 2024

The Regional Administrative Secretary,
P.O. Box 5429,
DAR ES SALAAM

Re: INTRODUCTION LETTER JUSTUS KAMARA

We would like to inform you that the bearer of this letter is **Justus Kamara** with Reg. No. **HD/MUH/T.633/2023** is a student at Muhimbili University of Health and Allied Sciences (MUHAS) "pursuing **MPH-Regular Track.**

As part of his studies, he will be doing an elective research titled: **"Effect of Ambient Particulate Matter on Respiratory Health of School Children in the City of Dar es Salaam."**

The research has been approved by the Chairman of University Senate.

Kindly provide him the necessary assistance to facilitate the conduct of his research.

We thank you for your cooperation.

Ms. Victoria Mwanilwa
For: DIRECTOR, POSTGRADUATE STUDIES

c.c **Justus Kamara**

9 United Nations Road; Upanga West; P.O. Box 65001, Dar Es Salaam: Tel. G/Line: +255-22-2150302/6; Ext. 1015; Direct Line:+255-22-2151378;Telefax:+255-22-2150465;E-mail:dpgs@muhas.ac.tz;Web:https://www.muhas.ac.tz

Appendix VII: Permission letters

JAMHURI YA MUUNGANO WA TANZANIA
Ofisi ya Rais
TAWALA ZA MIKOA NA SERIKALI ZA MITAA

MKOA WA DAR ES SALAAM
Anwani ya Simu:
Simu: 2203156/58
Fa: +25522203213
Tovuti: www.dsm.go.tz
Barua Pepe: ras@dsm.go.tz
Unapojibu Tafadhali taja:

OFISI YA MKUU WA MKOA
3 Barabara ya Rashidi
Kawawa,
S. L. P. 5429,
12880 - DAR ES SALAAM.

10 Juni, 2024

Kumb. Na. EA.260/307/01B/143

Mkurugenzi wa Halmashauri ya Jiji,
S. L. P. 20950,
DAR ES SALAAM.

Wakurugenzi wa Manispaa,
Kinondoni, Ubungo Temeke na Kigamboni,
DAR ES SALAAM.

YAH: UTAMBULISHO WA UTAFITI

Tafadhali husika na kichwa cha habari hapo juu.

2. Ofisi ya Mkuu wa Mkoa wa Dar es Salaam inautambulisha utafiti ujulikanao ***"Effect of Ambient Particulate Matter on Respiratory Health of School Children in the City of Dar es Salaam"*** ikiwa ni sehemu ya kukamilisha Mafunzo ya Shahada ya Uzamili ya **Justus Kamara** ambaye ni Mwanafunzi katika Chuo Kikuu cha Sayansi na Afya Shirikishi Muhimbili.

3. Kibali cha kufanya utafiti huu kimetolewa na Chuo Kikuu cha Muhimbili (MUHAS-REC-05-2024-2274) ambacho kinaanzia **tarehe 31 Mei, 2024 hadi 31 Mei, 2025**. Utafiti huu umepangwa kufanyika katika Halmashauri zote tano za Mkoa wa Dar es Salaam.

4. Kwa barua hii, namtambulisha kwako **Justus Kamara** ambaye ndio msimamizi mkuu wa utafiti huo ili aweze kufanya utafiti huu muhimu.

Nashukuru kwa ushirikiano.

Dkt. Mohamedi Mang'una
Kny; KATIBU TAWALA MKOA
DAR ES SALAAM

Nakala: Katibu Tawala Mkoa,
DAR ES SALAAM. – Aione katika jalada

UNITED REPUBLIC OF TANZANIA

PRESIDENT'S OFFICE

REGIONAL ADMINISTATION AND LOCAL GOVERNMENT

KIGAMBONI MUNICIPAL COUNCIL

[All letters should be addressed to Municipal Director Kigamboni]

Tell No: +255 22-2928468
Fax : +255 22-2928469
Email : info@kigamboni.go.tz
Web: www.kigamboni.go.tz

S.L.P. 36009,
KIGAMBONI,
DAR ES SALAAM,
TANZANIA.

REF.NO.AC.24/283/01C

20/06/2024

Head Teacher,
Vijibweni Primary School,
P.O. Box 36009,
DAR ES SALAAM.

REF: RESEARCH PERMIT

Reference is made to the above.

2. This is to inform you that, permission is granted to Mr. Justus Kamara who is a bonafide student at **MUHIMBILI UNIVERSITY FOR HEALTH AND ALLIED SCIENCES (MUHAS)** to conduct research in your school.

3. He is Working on the research under the topic "**Effect of Ambient Particulate Matter on respiratory health of school children in the City of Dar Es Salaam**". Starts from 31 May 2024 to 1 Sept 2024. Either research takes place in the school and does not affect the timetable of the sessions.

4. I therefore highly request your close assistance to enable him complete research.

5. Best regard.

FRANK J. MAKINGI
FOR: KIGAMBONI MUNICIPAL DIRECTOR
KIGAMBONI MUNICIPAL COUNCIL

For: MUNICIPAL DIRECTOR
KIGAMBONI

JAMHURI YA MUUNGANO TANZANIA

OFISI YA RAIS
TAWALA ZA MIKOA NA SERIKALI ZA MITAA
HALMASHAURI YA JIJI LA DAR ES SALAAM

Tafadhali unapojibu taja

Kumb. Na.DCC/CR.7/VOL.VI **Tarehe**: 25/06/2024

Walimu Wakuu,
Shule za Msingi Diamond, Faith na Vingunguti
Halmashauri ya Jiji la Dar es salaam.

Yah: KIBALI CHA KUFANYA UTAFITI

Husika na kichwa cha habari hapo juu.

2. Idara ya Elimu Msingi inapenda kumtambulisha mwanachuo Justus Kamara kutoka Chuo Kikuu cha Muhimbili kufanya utafiti katika shule zenu. Mada ta utafiti ni "**Effect of Ambiet Particulate matters of school children**" kuanzia tarehe 31 Mei, 2024 hadi 31 Mei, 2024.

3. Mpeni ushirikiano, aidha taratibu na sheria za shule zifuatwe na kuzingatia ratiba ya masomo darasani.

Nakutakia utekelezaji mwema.

Kny: MKURUGENZI WA JIJI
HALMASHAURI YA JIJI LA DAR ES SALAAM

D. Mnyone
Kny: MKURUGENZI WA JIJI

Nakala:- Mkurugenzi wa Jiji
Halmashauri ya Jji la Dar es salaam (Aione kwenye jalada)

" Maafisa elimu Kata
Kata za Upanga Mashariki na Vingunguti
Halmashauri ya Jiji la Dar es salaam (Kwa taarifa)

OFISI YA MKURUGENZI, 1 MTAA WA MISSION, S.L.P 20950, 11883 DAR ES SALAAM, SIMU NA 2128800, 2128805, Tovuti:www.dcc.go.tz, Barua Pepe: info@ilalamc.go.tz

JAMHURI YA MUUNGANO WA TANZANIA

OFISI YA RAIS,
TAWALA ZA MIKOA NA SERIKALI ZA MITAA

HALMASHAURI YA MANISPAA YA UBUNGO

Unapojibu tafadhali taja:

Kumb.Na.GA/254/288/01/73 Tarehe: 20 Juni, 2024

Mwalimu Mkuu,
Shule ya Mlimani Demonstration,
Halmashauri ya Manispaa ya Ubungo,
DAR ES SALAAM

Yah: **KIBALI CHA KUFANYA UTAFITI**

Tafadhali husika na mada tajwa hapo juu.

2. Ofisi ya Mkurugenzi inamtambulisha kwako **Ndugu Justus Kamara** kutoka Chuo Kikuu cha Sayansi na Afya Shirikishi Muhimbili kwa ajili ya kufanya utafiti kuhusu **"EFFECT OF AMBIENT PARTICULATE MATTER ON RESPIRATORY HEALTH OF SCHOOL CHILDREN IN THE CITY OF DAR ES SALAAM"**.

3. Utafiti utafanyika kuanzia tarehe 31 Mei, 2024 hadi tarehe 31 Mei, 2025. Pamoja na kibali hiki hautakiwi kukiuka malengo yako pamoja na sheria, na taratibu za shule.

4. Naomba umpokee na kupatia ushirikiano.

Kny: MKURUGENZI WA MANISPAA
HALMASHAURI YA MANISPAA YA UBUNGO
DAR ES SALAAM

Denis A. Nyoni
Kny: **MKURUGENZI WA MANISPAA**

Nakala: Mkurugenzi wa Manispaa - Aione kwenye jalada
MANISPAA YA UBUNGO

Mkuu wa chuo
Chuo Kikuu cha Sayansi na Afya Shirikishi - Kwa Taarifa
DAR ES SALAAM.

Afisa Elimu Kata
KATA YA UBUNGO - Kwa taarifa

Ndugu Justus Kamara

Barua zote zitumwe kwa Mkurugenzi wa Manispaa. Luguruni, Barabara ya Morogoro, S.LP: 55068, Dar es Salaam,
Unaweza pia kuwasiliana nasi kwa Simu. 0222-926341, Nukushi: 0222-92342, Tovuti; www. ubungomc.go.tz,
Barua pepe; info@ubungomc.go.tz

THE UNITED REPUBLIC OF TANZANIA
PRESIDENT'S OFFICE, REGIONAL
ADMINISTRATION AND LOCAL GOVERNMENT
TEMEKE MUNICIPAL COUNCIL

In reply please quote:

Ref. No. TMC/ED/R.22/19/VOL I/55. Date: 21TH June, 2024.

TO HEAD TEACHERS,
AMANI AND BUZA PRIMARY SCHOOL,
TEMEKE MUNICIPAL COUNCIL.

REF: RESEARCH CLEARANCE.

Please refer to the heading above.

We received a letter from Executive Director Office with dated on **20th June, 2024** concerning **JUSTUS KAMARA** – Student/Researcher from **MUHIMBILI UNIVERSITY** who is required to conduct research titled, **"EFFECT OF AMBIENT PARTICULALER MATTER ON RESPIRATY HEALTH OF SCHOOL CHILDREN IN THE CITY OF DAR ES SALAAM."** I would like to inform you that we granted permission to conduct his field research in Temeke Municipal, through Education Department Schools that mentioned above. Assist him to the period on which will conduct his research.

The study will be conducted from **31ST May, 2024** to **31ST May, 2025.**

Thank in Advance.

Abdul Buhety
FOR; MUNICIPAL PRIMARY EDUCATION

92 Barabara ya Mandela / Taifa, S.L.P 46343, Dar es Salaam, Simu +255222928132, Nukushi +255222928137,
Barua Pepe: temeke@temekemc.go.tz , Tovuti: www.temekemc.go.tz

Appendix VIII: Digital Receipt

turnitin

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

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Assignment title:	Dissertation Reports
Submission title:	Effect of Ambient Particulate Matter on Respiratory Health o...
File name:	Justus_Kamara_research_report_2024_July_10.docx
File size:	2.65M
Page count:	69
Word count:	13,068
Character count:	78,040
Submission date:	15-Jul-2024 10:14AM (UTC+0300)
Submission ID:	2417123217



EFFECT OF AMBIENT PARTICULATE MATTER ON RESPIRATORY HEALTH OF SCHOOL CHILDREN IN THE CITY OF DARES SALAAM, TANZANIA

Justus Kamara (MD)

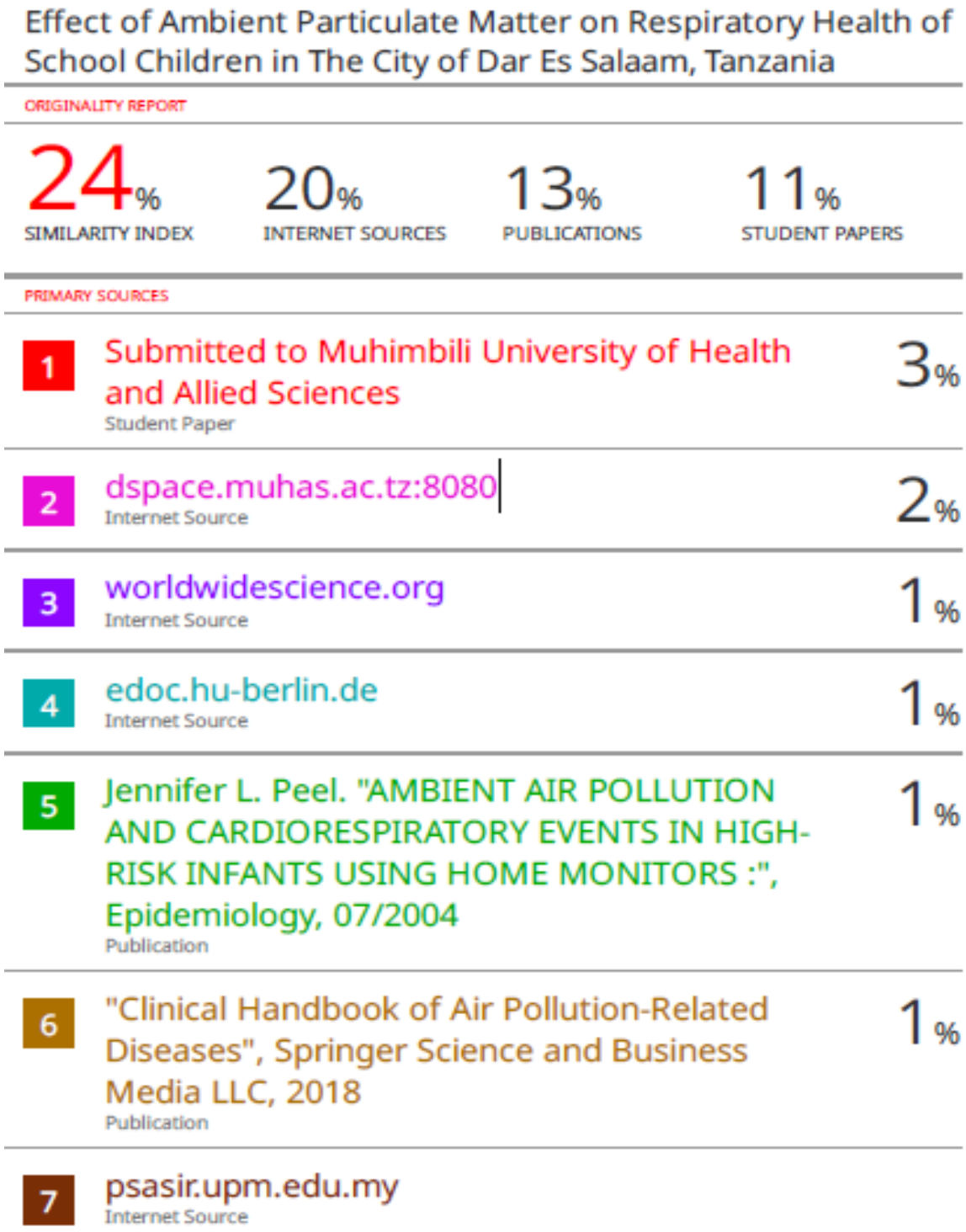
Master of Public health Dissertation

Muhimbili University of Health and Allied Sciences

July 2024

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Appendix IX: Plagiarism Report



Effect of Ambient Particulate Matter on Respiratory Health of School Children in The City of Dar Es Salaam, Tanzania

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