DANGER OF HAZE, INTENSE THIS SIDE:

Analysis of Air Pollution Vulnerability in Urban Slums of Delhi, India

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June 2024

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Thesis submitted in part fulfillment of Masters of Environmental Science and Policy
Central European University
Vienna
Austria

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ABSTRACT

This thesis explores the air pollution vulnerability in the urban slums of Delhi, India, highlighting the profound environmental injustice faced by residents. It examines the socio-economic conditions contributing to their exposure, such as underpaid work and overcrowded living spaces. The findings indicate that mere awareness is insufficient; instead, a comprehensive bottom-up approach is essential. This involves starting at the grassroots level in slum households and extending to administrative actions to enforce and monitor air pollution laws more effectively. The study also emphasizes the need to educate residents about clean energy practices and address harmful industrial and waste disposal activities that exacerbate pollution. Recommendations include enhanced policy enforcement, targeted education, and community engagement to create sustainable solutions. By fostering a thorough understanding of these socio-economic and environmental challenges, stakeholders can work towards improving the health and well-being of slum residents. The ultimate goal is to alleviate the environmental injustices experienced by these vulnerable populations through coordinated efforts across all societal levels.

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Writing my first ever thesis has been a journey filled with both academic challenges and emotional roller coaster. I am thankful to all those who supported and encouraged me along the way, cheering my progress and offering invaluable feedback.

Table of Contents

List of Figures

1.INTRODUCTION

Towering garbage dumps lining the highway, industrial units churning out smoke 24/7 across from your home, clothes hanging outside becoming dirtier as they dry and having to wear it no matter what,
Could you imagine living here?

New Delhi, India, ranks as the most polluted capital city in the world(Kurinji, Khan, and Ganguly, 2021), characterized by alarmingly high levels of pollution attributable to heavy vehicular traffic, industrial emissions, and erratic, inadequate waste management practices. The urban landscape of New Delhi contends with significant environmental challenges; however, the plight of the urban slums is particularly dire. These slums, defined by their congested, scarcely habitable, and poorly ventilated spaces, endure acute exposure to emissions from a multitude of sources. The origins of air pollution are multifaceted, encompassing ubiquitous dust to highly toxic industrial emissions. Beyond environmental degradation, the health repercussions of air pollution are severe and intensified by the city's high population density and frequent traffic congestions.

The elevated pollution levels in Delhi also highlight a stark environmental injustice. Although the entire population of Delhi is vulnerable to air pollution, certain groups suffer disproportionately. Slum areas, often situated adjacent to more affluent urban settlements, present a distressing contrast. It is common to observe families residing along highway lines, beneath metro tracks, and beside busy roads. This proximity to high-pollution zones significantly heightens the vulnerability of these populations. They lack proper shelters and have limited access to public health facilities. Women and children are particularly at risk from exposure to toxic gases and chemicals, in addition to the hazards posed by indoor activities such as cooking and cleaning, which frequently involve further exposure to pollutants(“Air-Pollution in Urban Centres of India.” 2019).

The environmental injustice in Delhi is starkly illustrated by the incidence of affluent and impoverished areas. While the affluent can afford measures to mitigate pollution exposure, the urban poor, particularly those in slums, bear the brunt of environmental degradation. The visible realm of problems in the urban settlements is compounded by the invisible suffering of the slum dwellers. These residents are exposed daily to a cocktail of pollutants, including emissions from vehicles, industrial discharges, and the byproducts of improper waste management.

In many slums, households rely on gas stoves or biomass for cooking, contributing to indoor air pollution. The lack of adequate ventilation exacerbates this issue, leading to severe respiratory problems and other health complications. Children and the elderly are especially vulnerable, exhibiting high incidences of respiratory, immunological and carcinogenic effects(De Vito et al. 2018). The health infrastructure in these areas is woefully inadequate, with clinics often sparse and healthcare services frequently overstretched and under-resourced.

Moreover, the socio-economic disparities are glaring. While certain parts of the city benefit from green spaces and better air quality, slum dwellers exist in an environment where pollution is a daily reality. The close proximity of industrial zones to residential areas ensures consistently poor air quality, with residents reporting foul odors, visible smoke, and particulate matter settling on surfaces within their homes.

The situation is further aggravated by ineffective waste management. Overflowing drains, uncollected garbage, and insufficient sanitation facilities contribute to an environment where waterborne diseases and other health risks are rampant. During the rainy season, these issues are exacerbated as wastewater floods into homes, bringing with it a plethora of health hazards.

The urban slums of Delhi exemplify severe environmental injustice. Residents in these areas endure numerous health risks due to air pollution and substandard living conditions, with limited access to effective healthcare or governmental support. The stark contrast between the living conditions in these slums and the more affluent areas of Delhi underscores the urgent need for policies and interventions to address these disparities and improve the quality of life for all residents.

This thesis explores the challenges faced by households in urban slums, focusing on the environmental and health impacts of exposure to air pollution from industrial and waste disposal areas in the city. It examines the socio-economic standards of the slum population in the context of environmental injustice to understand the disproportionate burden of air pollution they bear. Furthermore, it reviews policy interventions and analyzes them to identify potential areas for improvement in the field of air pollution.

2. LITERATURE REVIEW

Chapter 2, the literature review of the thesis dwells into the scope of conveying the background and status of the study, Air Pollution Vulnerability in Urban Slums of Delhi clear and concise. The chapter notably elaborates the literature on the location's history of air pollution, discussing the past and present of the air pollution levels affecting the country and city as a whole. The air pollution landscape of the region has been directly and indirectly affected by the developmental phase of the country, and hence the resultant actions taken to withstand the pressure of dirty and sooty air along the line. Following this, the chapter explores the various sources of air pollution in the region, all point, line and mobile pollutants ranging from vehicular, industrial to agricultural contributions to the pollution. The review continues to highlight the disproportionate effect of air pollution on slum dwellers of the region, given the high levels of air quality index all around the city.

2.1. Air Pollution- Through Times and Changing Concerns

The global scenario of worsening urban air quality was first recognisable during the period of industrial revolution where the 'age of smoke' was accelerated by factories in Britain, German and US (Mosley 2014). A series of events that triggered the environmental concerns were backed by the burning of biomass and fossil fuels in premodern societies, inefficient use of coal in the modern urbanisation period, followed by the human induced climate change including the phenomena like acid rain, photochemical smog, Chlorofluorocarbons (CFCs), ozone depletion and so on. Surprising evidences for the incidence of air pollution in premodern societies is the scientific discovery of mummified samples related to anthracosis or blackening of lungs from long term exposure to domestic fires (Mosley 2014). Notably evident from the given global scenario, air pollution is highly linked to the changing development agendas and the efficiency of energy expenditure in such large-scale initiatives, undoubtedly from anthropogenic sources.

The skyrocketing pace of development, linked with urbanisation and industrialisation has provided the developing half of the world with unlimited environmental issues and India is no exception. According to the annual average air pollution data of 2023, India ranks third among the world countries and continues to struggle with very poor to severe air quality issues

Fig. 1- PM 2.5 concentration annual average- 2023
Source: IQ Air, 2023 World Air Quality Report

("World Air Quality Report, IQ Air," 2023). Figure 1 illustrates the average PM2.5 concentration across the world over 2023, highlighting India for the high graded poor air quality issues. The map also underscores the air quality gradient visible in developing countries as evident from neighbouring countries of India, where Bangladesh, followed by Pakistan have the highest population weighted PM2.5 concentrations ("World Air Quality Report, IQ Air," n.d.). India, with its development objectives is home to most of the polluted cities in the planet including Delhi, Kolkata, Mumbai, Hyderabad, Bengaluru and Chennai, activating the pollution sprawl across the country, north to south (Fig 2 (a) & (b)) (Krishna, Bhargav 2021) .

Among these cities, Delhi owns the unfortunate distinction of the most polluted capital city in the world (Guttikunda et al. 2023). Delhi is a rapidly evolving city in terms of its development initiatives, hence resulting in significant changes in population, landmass and opportunities.

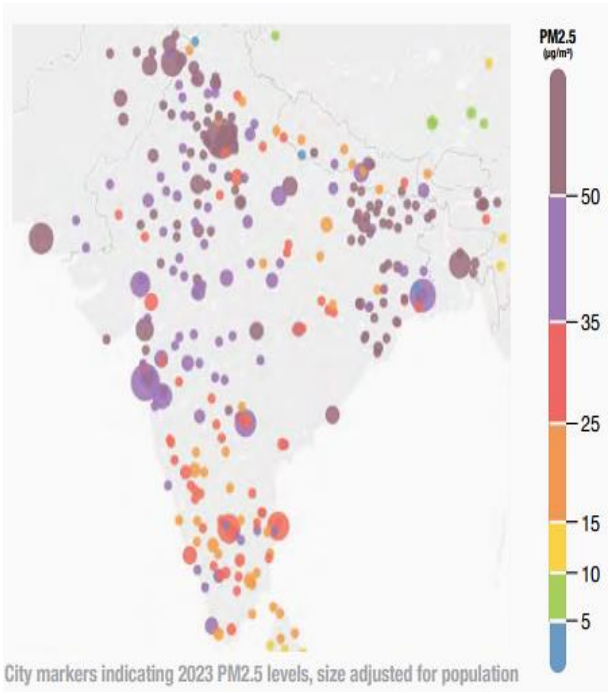

Figure 2 (a): Population adjusted PM2.5 concentrations across India, (b): Annual PM2.5 average of metro cities in India.
Source: IQ Air, 2023 World Air Quality Report

Being the National Capital Region of India, the city plays a crucial role in shaping the country's socio- economic landscape. This dynamic strategy has had profound impacts on the residents of Delhi and its surrounding region for years. Delhi has topped the world's most polluted cities for three years straight in 2020 (Kurinji, Khan, and Ganguly, n.d.). As illustrated in Fig 3, the PM2.5 pollution has peaked for more than 50% of the time (in hours) in annual averages for five years.

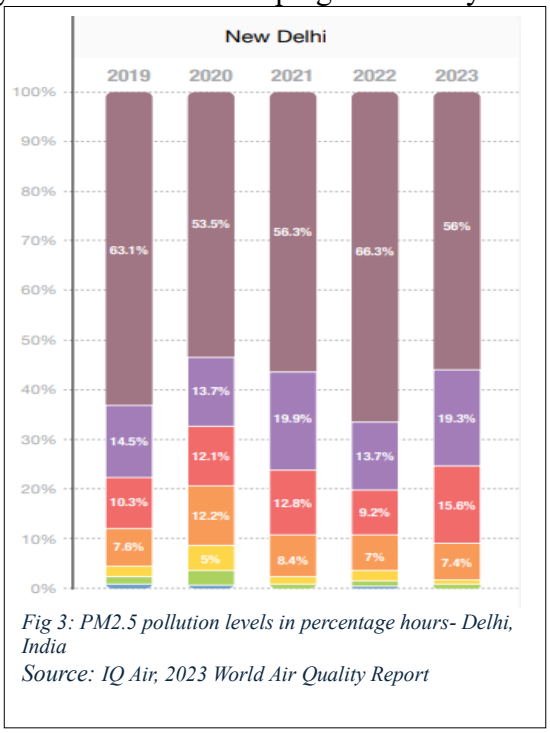

Fig 3: PM2.5 pollution levels in percentage hours- Delhi, India
Source: IQ Air, 2023 World Air Quality Report

The rising pressure of migration from neighbouring states and at times from other countries, provided the increased opportunities in the region, the city faces an increasing demand for expanded facilities. Additionally, the need for further transportation facilities, provision of fuel for residential, industrial, and other sectors to support the growing population has notably strained the city's resources. These factors have collectively contributed to increased vehicular emissions, higher energy consumption, and industrial pollutants stressing the livelihood of the city's residents for over decades. Air pollution has been steadily rising for decades, with only occasional, minor improvements. During 2021-22, the air quality index for PM2.5 concentrations reached levels 20 times higher than the guidelines set by the World Health Organization (WHO). The pace of change from late 1990s to 2021 is illustrated in Fig 4, visibly highlighting the poor air quality from early 2000. In a densely populated region with over 19 million residents and a density of 12,000 persons per square kilometer, the basic living conditions of the inhabitants have been severely compromised (Guttikunda et al. 2023).

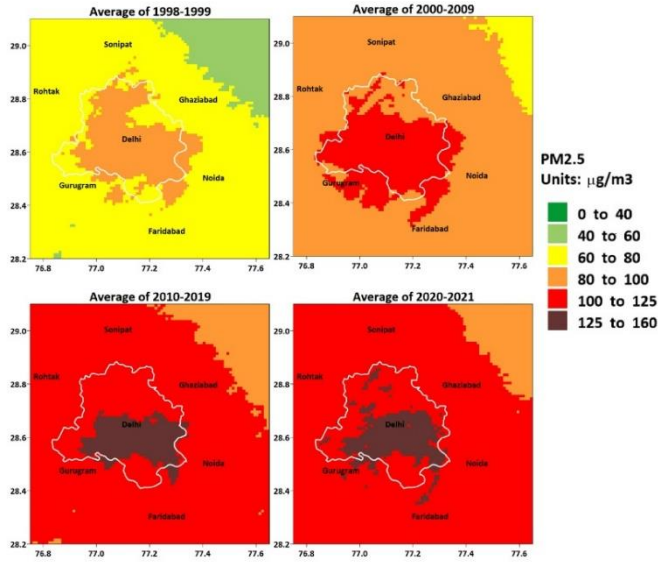

Fig 4: PM2.5 concentrations in Delhi as average of years depicted
Source: (Guttikunda et al. 2023)

The relentless expansion of urban areas has encroached upon vast living spaces, driven by the need for advancements and infrastructural growth. This rapid urbanization has not only strained existing resources but also led to the emergence of informal settlements and slums, exacerbating the living conditions for many. These areas often lack basic amenities such as clean water, sanitation, and adequate housing, further deteriorating the quality of life, disproportionately bearing the burden of nature's injustice or denied environmental justice.

2.2 What Contributes to the Polluted Atmosphere: Sources Explained

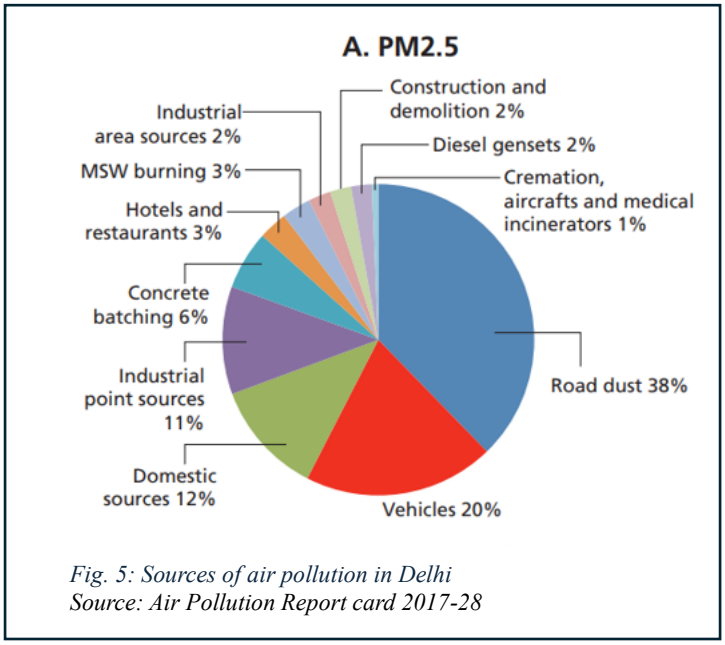

Fig. 5: Sources of air pollution in Delhi
Source: Air Pollution Report card 2017-28

The sources of air pollution (Fig.5) in Delhi are multifaceted, influenced by seasonal variations, weather patterns, and geographical and meteorological factors. Among the various contributors to air pollution, road dust emerges as one of the most significant pollutants, particularly exacerbated by heavy traffic. This road dust, suspended in the air, is a major concern for the city's visible air quality.

The reasons for the prevalence of road dust are numerous. Mobile dust pollutants from different parts of the region can be transported into the city by wind, storms, or rain. During the summer, the hot and dry weather conditions further aggravate the situation. The intense heat dries out particles, making them lighter and more easily suspended in the air. This seasonal effect significantly increases the concentration of airborne dust, contributing to the overall degradation of air quality. Heavy traffic on Delhi's roads exacerbates the problem, as vehicles continuously disturb and lift dust from the ground into the atmosphere.

Following dust pollutants, toxic emissions from vehicles, industries, and harmful fumes from festivities, households and agricultural farming in the region and its surroundings also significantly contribute to air pollution. Pollution from dust and mobile pollutants is further

intensified by construction activities. Construction and demolition waste contribute vastly to mobile sources of pollution, with weather conditions aiding in the movement and spread of these allergic pollutants. This exposure is particularly hazardous to construction workers and labourers who work in close proximity to such environments.

The baseline causes of pollution in Asia are rapid urbanization, industrialization, and insufficient supporting infrastructure (De Vito et al. 2018). This region needs regular monitoring and proactive measures from knowledgeable authorities. The situation is also worsened by the illegal and unsafe operation of industries that lack proper safety measures and pollution controls(De Vito et al. 2018). Despite rising concerns about air pollution and its harmful effects on human life and infrastructure, many industries continue to operate, contributing to economic development while simultaneously degrading social and environmental conditions. Even after two decades of efforts to inform and initiate changes, the city's condition remains plagued by fumes and pollution hotspots (Bhattacharya and Shahnawaz 2021).

2.2.1. The Alarming Transport Fleet and Vehicular Emissions

Vehicular emissions are a major contributo r to air pollution in the city. The transport fleet, active for long hours and frequently idling in traffic and at signals, significantly adds to the region's pollution levels. The prevalence of aging vehicles and inefficient traffic management exacerbates the issue. Beyond public and private transportation, the rise of cab services like Uber further contributes to the inefficiency of the transportation system compared to shared taxis and the use of public transport.

Vehicular emissions primarily stem from the internal combustion of fossil fuels, including coal, which also contributes to greenhouse gas emissions and accelerates climate change. The inefficiency of the combustion process, particularly in older and poorly maintained vehicles, further aggravates the problem. Since traffic-related emissions are closely linked to the road transportation system, the resulting fog-like pollutant buildup significantly increases the risk of accidents due to reduced visibility (Fig. 6).

Fig 6: Road based pollution in Delhi
Source: India Today, 2023

To support the city's ever-growing population, there must be a corresponding increase in infrastructure to meet demand and improve urban living conditions. The development of opportunities and employment in the National Capital Region is closely tied to the provision of adequate transport options. From 2000 to 2015, the number of vehicles increased from 3.37 million to 8.83 million (De Vito et al. 2018), highlighting the strain on the city's infrastructure during a period when air pollution was already a significant issue. Additionally, there was an increase of 9.7 million vehicles between 2016 and 2017, representing a 9.94% rise from the previous year ("Delhi Air Pollution- An Overview," 2018).

It is alarming to note that developmental agendas are significantly contributing to existing environmental problems, thereby exacerbating air pollution and climate change.

2.2.2. The Industry Based Generation of Pollutants

The burning of fossil fuels in industries and power plants has not only significantly contributed to air pollution but also to human-induced climate change, with

chemical emissions from industrial chimneys forming cloud-like pollutants. Many industries are situated near water bodies or in remote regions rich in flora and fauna, further exacerbating the environmental impact. The surrounding areas suffer from exposure to toxic gases, hazardous industrial residues, dust, and particulate matter, increasing the environmental stress caused by industrial development.

Drawing parallels to the pre-modern and modern urbanization periods in ancient Athens and Rome, Delhi's current state of rapid urbanization paired with slow infrastructural progress struggles to meet the growing energy demand, often relying on highly polluting coal (Krishna, Bhargav 2021). This reliance on coal has led to a deterioration in air quality. Notably, there has been a significant increase in industrial establishments, with 875,000 industries, marking an addition of over 117,565 new establishments across five economic censuses(“Delhi Air Pollution- An Overview,” 2018).

This rapid industrial growth has intensified air pollution, compounded by inadequate practices within the sector. Industries, as both point and mobile sources of pollution, often operate without proper filtration units, safety measures, and pollution controls (De Vito et al. 2018). Additionally, the use of low-quality coal to reduce operational costs further exacerbates pollution levels(Majumdar, 2021). These factors collectively contribute to the escalating pollution in a city that is rapidly developing yet progressing slowly in terms of sustainable practices.

2.2.3. Open/Closed Burning in Agriculture, Households and Disposal Systems

Various regions in India follow a seasonally scheduled practice of agricultural activities, including sowing, fertilizing, harvesting, and land preparation. During the preparatory period, fields are often left fallow with the ashes of residues from the

previous harvest. These ashes are believed to have fertilizing properties, preparing the soil for the next cycle. The common practice of burning fields, known as "paralli" or stubble burning (Fig. 7), is closely associated with traditional farming methods. While this practice is a local source of pollution, its impact can extend to vast regions depending on the size of the farm and the quantity of biomass burned. Delhi, bordered by Punjab and Haryana, is particularly affected by the open burning of fields. The extent and spread of pollution from stubble burning are highly influenced by weather conditions such as wind speed, direction, and thermal inversions, and it varies seasonally across the country's four active seasons.

Fig 7: Paralli/ Stuble Burning in fields of Punjab
Source: India Today

Another significant source of pollution is biomass burning for household purposes, including heating, cooking, and sometimes local waste disposal. The energy released from biomass burning is considered inefficient. Many residents, especially those living in slums without access to basic amenities, rely on biomass for cooking and heating because it is a cost-effective alternative to expensive fuels. However, this conventional practice adds to the burden of toxic residues released into the atmosphere. Biomass burning contributes between 1% and 58% to overall pollution, depending on the quantity and duration of burning, and accounts for approximately 7% of the total PM2.5 concentration.

In addition to local waste burning, fires at waste disposal sites and the open burning of garbage in large dumps within the city center also contribute directly to the

smog and haze affecting the capital region. These practices exacerbate air quality issues, highlighting the need for better waste management and cleaner energy alternatives.

2.3. The Slum Dwellers in the Environmental Justice Scale

> *According to UN-HABITAT, a slum household is defined as a group of individuals living under the same roof in an urban area who lack one or more of the following: durable housing that protects against extreme climate conditions, sufficient living space (not more than three people per room), easy access to affordable and safe water, adequate sanitation with a private or shared toilet, and security of tenure to prevent forced evictions. (UN Habitat,2007)*

The given conditions form the checklist for defining a slum household. From an outsider's perspective, imagining life in such a setting can be difficult, yet it is crucial to acknowledge that many people around the world live under these conditions in both well-developed and developing urban areas. These individuals bear the environmental, social, and economic burdens of development while coexisting in the same urban system as the rich, middle class, and poor. The disparity in socio-economic and health aspects between these households and the more privileged ones highlights a stark injustice in environmental development.

In the context of developing countries, the pace of development and growth presents significant challenges. Compromising environmental growth in the name of development often leads to long-term environmental degradation. Unlike the urbanization seen in the global North, which was accompanied by economic growth, the process in developing countries, such as those in Africa, occurs under the pressure of resource scarcity and insecurity(Muindi 2017). This delays the process of development and stagnates the actual intention of growth. The longer this process takes, the more it perpetuates poverty among certain populations, stressing them

with limited employment opportunities, poor living conditions, and uncertain income levels. Consequently, there is a higher incidence of urban slums and informal settlements characterized by poor-quality housing and inadequate public service systems(Muindi 2017).

One major issue with the generation of slums in urban settings as a byproduct of the development process is the creation of "two urban settings in a single city" (citation needed). This is particularly true in the case of Delhi, where 13-14% of the total population resides in slums (Sahu, Mangaraj, and Beig 2023). There are approximately 4 million slum households in Delhi, with an average family size of five members (Sahu, Mangaraj, and Beig 2023).

Despite the considerable percentage of slum households, the physical space allotted to urban slum regions is relatively small, especially considering the high population density they accommodate. Often, families larger than five people live in two-room structures where cooking and living areas are not separated. This severely impacts air quality and emissions within the household. Imagine a family of eight people living in such a setting, comprising various age groups. The exposure to poor air quality in this scenario poses significant health risks to children, women, the elderly, and outdoor workers.

In Delhi, people migrate from different areas seeking better education, employment, and living opportunities, often ending up in minimal settings with very basic facilities. There are almost 500,000 street vendors in Delhi (Sahu, Mangaraj, and Beig 2023). These street vendors rarely live and work in proper conditions, often facing water shortages, heat waves, and flood triggers. In South Delhi, household air pollution sometimes contributes more to outdoor PM2.5 concentrations than the national average (Sahu, Mangaraj, and Beig 2023).

The congested living conditions in slums make residents prone to infectious diseases (Krupnova et al. 2022). Urban slum settings are characterized by limited space, where the walls of one household often connect to those of neighboring homes. In such environments, access to clean air and surroundings poses a significant threat (Fig. 8). The most vulnerable groups to air pollution, as discussed by (Guttikunda et al. 2023), include street vendors, rickshaw pullers, construction workers, slum populations, and those in informal settlements. These groups experience the highest long-term exposure to outdoor pollution from the sources previously mentioned. It is challenging to maintain long hours of work with very low informal income to support their families.

Fig 8: Streets in slums of Samaypur Badli(study region)
Source: India Today

The housing and health of these individuals are at high risk due to poor ventilation and gas exchange in their living conditions. The practice of using biomass for cooking is also common in urban slum households. One widespread practice involves making cow dung cakes called 'UPLAH' (Fig. 9) where cow excreta and coal dust are mixed, dried, and stored for heating and cooking purposes (Sahu, Mangaraj, and Beig 2023). Biomass burning significantly impacts pollution levels in the region. This practice is prevalent in Delhi slums as it provides a cheap and easily accessible

Fig9: Cow dung cakes also known as 'UPLAH'
Source: Shutterstock

energy source. I have personally observed the making of UPLAHs in several regions of India, with the cakes being air-dried for storage.

Moreover, slum dwellers in Delhi often live near industrial zones, waste dumpsites, and areas prone to natural calamities, exposing them to high levels of pollutants and poor air quality (citation needed). Women and children, in particular, suffer from the proximity to indoor pollution sources like biomass burning and cooking. This scenario clearly shows that the burden of environmental degradation is disproportionately borne by slum populations and other vulnerable groups. "Low-income and minority countries bear the disproportionate burden of pollutants" (Boyce and Pastor 2013). The WHO has also reported that the urban poor are the most impacted by rising pollution levels in Delhi (Boyce and Pastor 2013).

Considering the disproportionate burden and stress faced by slum dwellers due to their living conditions and exposure to air pollution, it is essential to intensify efforts in studying, educating, and monitoring the health impacts of air pollution on this vulnerable population.

2.4. What's in Breathing the Bad Air: Health effects explained

The whole point of discussing air pollution vulnerability in the urban slums of Delhi is to understand that air pollution, with its environmental causes, is also closely related to the health of individuals enduring this stress. The health effects of breathing toxic air are particularly severe for slum dwellers and outdoor workers, highlighting the environmental injustice faced by these groups in urban settings. In 2019, the total number of premature deaths attributable to air pollution was 1.6 million, which is 17.8% of the total deaths in the country. This also resulted in an economic loss of 1,207 million USD (Agarwal and Tiwari 2022).

The health effects of air pollution extend in various directions. Several studies provide different examples of these effects on individuals. A study indicates that air pollution is expected to have long-lasting effects on immune status, brain development, the respiratory

system, cardio-metabolic health, low birth weight, and stunted growth (Bhattacharya and Shahnawaz 2021). Another study by De Vito et al. shows a direct correlation between air pollution, respiratory problems, premature death, and mortality levels (2018). The WHO has found that ambient air pollution can have carcinogenic properties (De Vito et al. 2018).

It is significant to note that slum dwellers often neglect the symptoms of these diseases due to the costs associated with treatment, unless the symptoms are severe enough to make them bedridden. Allergic reactions are frequently ignored by slum dwellers to avoid interrupting their livelihood practices. This slow-killing phenomenon affects the functioning of an individual's body, especially the most vulnerable groups: outdoor workers, women, and the elderly. Therefore, it is crucial to inform these people and provide effective measures or interventions to support their health and existence, such as accessible healthcare facilities.

The common pollution is of finer particles that tends to enter the human body through various receptors. Particulate matter (PM) is the sum of all solid and liquid particles suspended in the air, many of which are hazardous. This complex mixture includes dust, pollen, soot, smoke, and liquid droplets (Khan, Kumar, and Awasthi 2009). The fine size and structure of these particles allow them to penetrate the respiratory system, causing acute reactions like allergies and flu, and chronic reactions such as those discussed earlier. These particles can travel deep into the lungs, causing inflammatory diseases. One example is silica in sandblasting factories, which leads to fibrosis and breathing difficulties (Majumdar, 2021).

Further impacts of air pollution extend to non-accidental mortality, respiratory and cardiovascular diseases, premature death, and birth defects (Krishna, Bhargav 2021). Even during the COVID-19 lockdown, when pollution rates decreased, both short-term and long-term exposure to PM2.5 and NO2 increased infection and mortality rates (Agarwal and Tiwari

2022). In 2004, there were 1.6 million deaths related to indoor pollution from households using biomass fuels like animal dung for heating and cooking purposes.

Regarding interventions for air pollution's effect on human health, the WHO has reported that meeting their guidelines could have averted almost 17,256 premature deaths annually (Krishna, Bhargav 2021). If the current scenario continues, mortality projections indicate 1.1 million deaths by 2031 and 1.8 million by 2051 (Fig. 10).

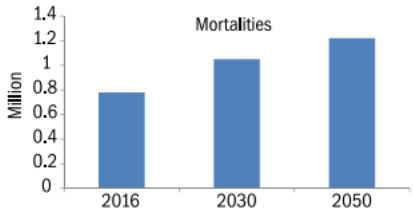

Fig 10: Mortality projection attributed to PM2.5
Source: The Energy and Resource Institute, TERI

Although air pollution concerns the entire city and its residents, a large portion of the vulnerable population, burdened with breathing polluted air, remains uninformed about their exposure. It is significantly alarming that the slum population, which often lacks basic education and information in this sector, might miss out on necessary treatments for their health issues. This underscores the urgent need for monitoring the current situation in the slums, including baseline actions like counting the population, arranging required facilities within accessible distances, ensuring proper housing and ventilation, and relocating residents from areas near industrial regions and waste dumping sites.

2.5. Policy Approaches: Down the Road

Fig 11: Newspaper Headlines regarding air pollution status in Delhi (mixed)
Source: NDTV

The collage in Fig. 11 presents the headlines from national newspapers in India, reporting on recent fluctuations in the air quality index, reactions and responses to policy measures, and the celebrated highs and lows of air pollution status in the city as portrayed in the media. Imagining life in a city lacking basic facilities might seem inconceivable, yet a population of 1.9 billion, comprising people from various socio-economic strata, endures this environmental pressure for extended periods.

These news reports highlight the ongoing struggle with air quality, drawing attention to both the successes and setbacks in tackling pollution. Policies aimed at mitigating air pollution often receive mixed responses, reflecting the complexities of balancing economic growth and environmental sustainability. Celebratory headlines about improvements are frequently tempered by reports of recurring pollution spikes, illustrating the persistent challenge.

Living under such conditions places a significant burden on the residents. The diverse population, ranging from affluent communities to those in informal settlements, experiences

varying degrees of impact. The environmental vulnerability of developing countries like India was first addressed by Indira Gandhi following her participation in the UN Conference on the Human Environment in Stockholm in 1972(De Vito et al. 2018). While the ministry's initial environmental focus was on wildlife protection, she addressed the citizens of India with the following after her successful participation in the conference:

> *Are not poverty and need the greatest pollutants? How can we speak to those who live in villages and slums about keeping the oceans, the rivers and the air clean when their own lives are contaminated at the source?"*
> *Moreover:*
> *"The environmental problems of the industrialised countries are the result of earlier exploitation as well as of present affluence while those of the developing countries are primarily determined by the manner in which machines are used or abused. In the poorer societies these problems are essentially those of inadequate development and of continuing poverty, unsafe drinking water, malnutrition, poor sanitation, inadequate housing and disease…"* (De Vito et al. 2018)

Since then, there have been significant synergies between environmental policies and development *(De Vito et al. 2018)*. Gradually, the need for a good environment and its development became a part of the 'right to life.' During this timeline, the Air (Prevention and Control of Pollution) Act of 1981 and the Environmental Protection Act of 1986 also came into action. The Air Pollution Act of 1981 initiated air pollution control zones, motor vehicle control, and control areas based on the air quality in the state. The government was given the authority to prohibit the use of any fuel other than the approved/allocated ones in the region *("Fighting Air Pollution in Delhi for 2 Decades: A Short but Lethal History," 2019)*.

In 1996, a report called 'Slow Murder' was published by the Center for Science and Environment, Delhi, based on air pollution and its related effects (Fig. 12). This was triggered by multiple events related to air pollution in Delhi, including the visible dirty dust and soot (citation). One of the key activists who led the public protest against air pollution in New Delhi was Mahesh Chandhra Mehta, an activist who actively engaged with the ongoing pollution responses in Delhi*("Fighting Air Pollution in Delhi for 2 Decades: A Short but Lethal History," 2019)*.

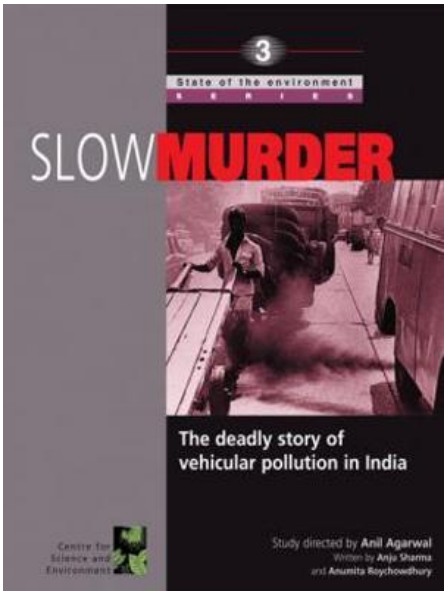

Fig. 12: Slow Murder Report
Source: Center for Science & Environment

In 1996, the first Action Plan was submitted by the Delhi government to the Supreme Court to combat air pollution in the region *("Fighting Air Pollution in Delhi for 2 Decades: A Short but Lethal History," 2019)*. With this collective action, the EPCA - Environment Pollution (Prevention and Control) Authority - came into action in 1998. Later, the National Air Quality Monitoring Programme (NAMP) was initiated, and air quality monitoring stations were installed across the national capital region to monitor the air quality*("Fighting Air Pollution in Delhi for 2 Decades: A Short but Lethal History," 2019)*.

The actions included shifting to cleaner fuels like Compressed Natural Gas (CNG). Although these actions were collectively and actively undertaken, the ever-rising population and the increase in vehicles and activities made the impacts of these actions futile*(Krishna, Bhargav 2021)*.

The second set of actions started in 2009 when the Ministry of Environment revised the policies and implemented stricter monitoring actions. With the initiation of the National Air Quality Index (NAQI), the transparency of monitoring data was ensured, making it easier for

the public to take useful measures during high pollution periods *("Fighting Air Pollution in Delhi for 2 Decades: A Short but Lethal History," 2019)*.

In 2017, the initiation of GRAP - Graded Response Action Plan - categorized responses for 'Moderate to Poor, Very Poor, Severe, and Severe+ or Emergency' air quality levels. The NCR has a series of laws and policies supporting the welfare of the region by improving monitoring and making changes to existing policies *("Fighting Air Pollution in Delhi for 2 Decades: A Short but Lethal History," 2019)*.

The conditions of slums were mostly supported by actions to help reduce indoor air pollution. The provision of cleaner cooking fuels like Liquid Petroleum Gas (LPG) helped reduce the dependency on biomass for cooking *(De Vito et al. 2018)*. Initiatives like the PRADHAN MANTRI UJJWALA YOJANA (translated as 'Prime Minister Bright Scheme') provide these facilities for slum dwellers *(Krishna, Bhargav 2021)*. Another example is the YUDDH PRADUSHAN KE VIRUDH (translated as 'War Against Pollution'), a seven-point action plan that established a war room for monitoring pollution to help combat dust and mitigate air pollution hotspots. It also introduced a mobile application called 'Green Delhi' *(Kurinji, Khan, and Ganguly, 2021)*. This increased the transparency of air quality monitoring and made information more accessible.

2.5.1 External Stresses to the Policy Approaches/ Limitations:

In this scenario, the limitations of the administration in achieving the standards were many. With the increasing population and hence the increasing fleet of transportation, industries, and commodities, it was unable to achieve the expected results. For example, in regions that lack constant power supply, there has been a need for installing diesel power generators, leading to increased pollution *("Fighting Air Pollution in Delhi for 2 Decades: A Short but Lethal History," 2019)*. With the

increased number of industries, there has also been the operation of unsafe and polluting industrial practices as discussed earlier*(De Vito et al. 2018)*.

There have been households using outdoor biomass stoves (Lakdi Ka Chulha- Fig. 13) for cooking and biomass burning for heating. This is to meet the high demand for food in populated households and to cut the cost of buying LPG cylinders.

Fig. 13: Wooden stove- Lakdi Ki Choola
Source: The Times of India

3. METHODOLOGY

Chapter 3, Methodology, outlines the methods used in this thesis to reach the stage of primary data collection and further progress with data collection and analysis. The limitations of this approach are discussed in the final part. The study employs a qualitative research approach, which facilitated the collection and analysis of verbal/script-oriented results with non-numeric terms of expression. Several rounds of background research and revisions were conducted to incorporate environmental injustice into the study of air pollution in Delhi. The target population was the slums of Delhi, with two slums selected based on their accessibility and proximity to pollutant sources. The latter part of the chapter delves into the process in detail.

3.1. Theoretical Framework

The theoretical framework adopted for this study revolves around the concept of environmental justice in the face of urbanization and development. As evident from the literature review, slum areas in Delhi have been the least studied and mentioned regarding vulnerability to air pollution. In the context of air pollution in a developing city like Delhi, understanding the differences in vulnerability is crucial. Although the effects of air pollution are widespread across the region, the denial of just environmental conditions, lack of basic living conditions, and the unforeseen and impactful effects of air pollution highlight significant disparities. This framework aims to voice the issues faced by the slum dwellers in Delhi.

3.2. Data Gathering

3.2.1 Secondary Research/ Review of Studies

The thesis was developed with the comprehensive review of literature emphasizing the severe air quality issues in Delhi. This literature review covered various aspects, including the criticality of pollution in the region, sources and impacts of pollution, the vulnerability of slum dwellers and other disadvantaged groups, and the policy actions timeline in India aimed at improving air quality. The methodology was designed to understand key concepts and debates in the field, supporting and recommending areas for improvement.

The methodology was open-ended, incorporating relevant information, sometimes even contrasting with the primary findings of the study. These internal debates and critical analysis fostered a deeper curiosity, leading to the primary data collection phase.

3.2.2 Primary Data Collection

3.2.2.1 Location

The locations for the study were chosen based on convenience and accessibility through the NGO that supported the process. Accessing the slums was challenging as it was unsafe and informal to randomly interview the slum population. To facilitate this, an NGO, Mar Thoma Social Action (MTSA), supported the research by granting access to their working sites and accompanying their staff in the region. Two locations from the available options provided by the NGO were chosen based on the proximity of the slums to potential pollution sources.

Location 1 - Sanjay Colony:

Fig. 14 (a) : Location 1- Sanjay Colony
Source: Google Maps

This is a major industrial area where most industries are informal and owned by highly reputed individuals. With industries operating twenty hours a day, seven days a

week, the location was considered meaningful and valuable for the study. Sanjay Colony is accessible through a shared auto taxi from Samaypur Badli Metro Station, Delhi.

Location 2 - Bhalswa:

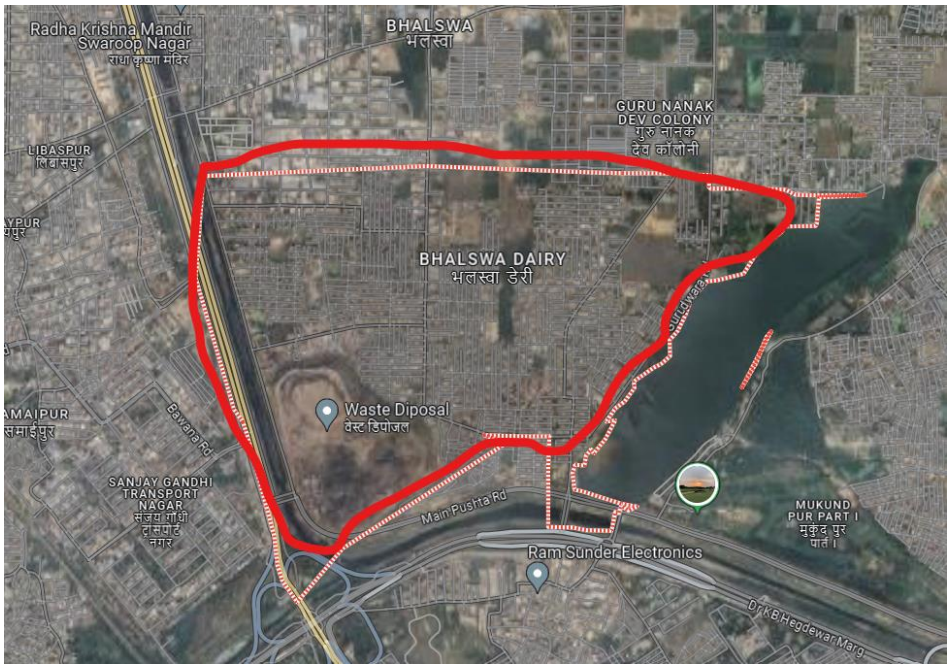

Fig. 14 (b) : Location 2- Bhalswa Colony
Source: Google Maps

Another working site of MTSA, Bhalswa, is situated next to a large waste dumping site within visible proximity. The huge garbage dump (Fig. 15) is visible as one takes a shared taxi from Jahangirpuri Metro Station, lining the roadway during travel. The image was taken on 14.05.2024, the day of data collection,

Fig. 15: Garbage dump lining the main roadway
Dated: 14.05.2024

as I traveled to the interview location. The location is further exacerbated by the sudden occurrence of strong winds that carry mobile pollutants throughout the city, significantly affecting the chosen slum area.

3.2.2.2 Sampling

The sampling for the study employed random sampling, taking into account the limitations of time and safety while staying in the area. The primary interview points were households, and most respondents were women. Given that the interviews were scheduled on a working day, most of the males in the families were out working. Consequently, the available sample points were predominantly women of different ages. This random sampling approach helped increase the sample size, allowing over ten potential interviews each day. Since women were mostly staying indoors, their responses were primarily based on their perceptions of air pollution. Although challenging, responses from working males would have added valuable insights to the interviews. However, accessing factories to interview workers was not feasible, and those who were approached were reluctant to respond. This reluctance indicates a fear of speaking against their employers, considering their current labor and income conditions. This was an anticipated challenge during the preparation phase, so their response did not come as a surprise.

3.2.2.3 Questionnaire

The questionnaire was structured to fit the requirements of a qualitative analysis based on the air pollution perspectives of the slum dwellers. It was designed with an open-ended scope to encourage participants to speak freely, considering the cultural setting of the country and the selected region, which might make participants reluctant to respond. To engage the participants and gather relevant data, the questionnaire began

with demographic questions, such as the name of the participant, age, and house number.

It then moved on to general questions about the number of people residing in the building and the number of rooms available for the members. The theme of the interviews progressed to cover the labor practices of the family members. Since women in the family were expected to bear the burden of household care, questions about energy fuels were included.

The questionnaire also addressed location-based vulnerabilities, such as the proximity to industries in Location 1, Sanjay Colony, and the waste dumping sites in Location 2, Bhalswa. Participants' responses highlighted potential air quality issues faced by the population. They also discussed natural calamities and adverse events like heavy rain and storms that pollute their living conditions, cleanliness issues, access to clean water, and the availability of public toilets.

The questionnaire then explored health issues among the slum dwellers, including their families who are labourers at industries or people exposed to long term pressure of outdoor air pollution and others, if any. Finally, it sought information on governmental support schemes and any other relevant insights on air pollution.

3.2.2.4 Interviews

The interviews were conducted using an open-ended format to encourage respondents to provide detailed and thoughtful answers. However, the process was somewhat challenging due to language barriers in the selected region. This issue was effectively mitigated with the assistance of staff from Mar Thoma Social Action (MTSA), the partnering NGO for this fieldwork.

On May 13, 2024, Mariamma, an MTSA employee working in Sanjay Colony, facilitated my interviews by identifying potential respondents among the residents. Her support was instrumental in gathering comprehensive information from households and outdoor workers, including employees in shops near the industries and other NGO field staff.

On the second day of fieldwork, Parvesh from MTSA, who works in Bhalswa, assisted with the interviews. This day primarily involved conducting household interviews with both male and female respondents.

Establishing trust with the residents to discuss their life challenges posed a significant difficulty. Initial attempts to initiate interviews were not very successful, as the residents perceived the interviews as formal and were hesitant to disclose personal information. In such scenarios, the support from MTSA, with its established presence and rapport in various parts of the city, proved to be extremely valuable.

4.RESULTS

Chapter 4 will present the results of the study, focusing on key findings derived from various demographic features and responses to a series of questions. The demographic analysis includes information such as name, age, and gender, aiming to understand the age distribution of individuals residing in the same household and the number of members sharing the available space.

The results will then delve into several thematic areas based on the questionnaire responses:

Demographic Information, Energy Practices, Labor Practices, Pollution-Related Inconveniences, Health Issues and Safety, Support from Governmental or Non-Governmental Organizations if any.

4.1. Demographic Information

Fig.16: infrastructure congestion in (a): Sanjay Colony, (b): Bhalswa
Dated: (a) 13.05.2024, (b) 14.05.2024

The age distribution of the interviewed population ranged from seventeen to sixty-five, including both men and women. The infrastructural arrangement of the slum was also considered, with the number of people residing in each house and the number of rooms being part of the interview (Fig. 16 (a) & (b)). Most families had an average of 2.2 rooms, with an average of 5.7 persons living per room. The range varied from six people residing in one room to five people residing in seven rooms. These findings will be further analyzed to understand the availability of breathing space and living conditions in the slum. In response to questions about their satisfaction with their living space, one resident remarked,

"We live for our children and we don't care about most of it. You try living here for a week or two, you will be convinced by how we feel."

The households comprised members of different ages, from children to elderly individuals.

4.2. Energy Practices

In both slums, the primary energy source for households was Liquid Petroleum Gas (LPG). However, participants mentioned that the cost and availability of gas stoves sometimes forced them to use wood burners for cooking and heating. When LPG was used indoors, the households were typically equipped with ventilation fans, though some were not functioning. All households had access to electricity, making lighting straightforward and efficient, except during power cuts or when electrical lines were disabled. The high cost of gas stoves also led to biomass-based cooking in some cases.

4.3. Labour Practices and Exposure Patterns

Most of the interviewed women were housewives, spending most of their day indoors except when taking their children to school. In most households, at least one member worked outdoors. In Sanjay Colony, many men were factory workers.

Although these industries provided livelihood and income, participants noted that they often worked in environments that produced toxic fumes. Some men were also drivers, working locally in Delhi or outside the region, often for 13-14 hours continuously. Jawahar Prasad, a shopkeeper across from the industrial street, stated,

"I clean the shop every morning, sweep the dust off the floor, and clean all the groceries. See how it looks at 13:00. The pollution is this easily visible."

The dust and noise from nearby industries had turned the slum into a dirty, noisy area, with large and small trucks frequently passing through, and buildings coated in black soot. Mariamma, who assisted with interviews in Sanjay Colony, mentioned an incident of an oxygen tank explosion in a factory, injuring workers, yet the factory continued to operate fully. Factories in the area included those producing rubber, polythene, and soap. Many participants were unaware of the specific types of industries but noted the distinct smells of fumes emanating from them (Fig. 17). Worker safety and insurance were also significant concerns, as many factories operated without proper measures. In Bhalswa, the labor practices were similar, with men working outdoors and women leaving home only when necessary. The MTSA workers on-site wore masks due to the risk of pollution from the waste dumping site and nearby industries.

Fig. 17: Factory infrastructures covered with black soot
Dated: 13.05.2024

4.4. Pollution-Related Inconveniences

4.4.1. Sanjay Colony

In Sanjay Colony, the visible dirt and soot were pervasive and frustrating. Participants noted that factories operated around the clock, releasing

black clouds of smoke often mistaken for rain clouds. The smoke carried intense odors from polythene, rubber, and polishing industries, suggesting a prevalence of plastic-based industries. Additionally, large trucks navigating the underdeveloped roads contributed to dust suspension and heavy traffic. Industrial wastewater release further complicated the availability of clean water. When water was scarce, slum residents sometimes resorted to using contaminated water while factories continued to operate without disruption.

4.4.2. Bhalswa

In Bhalswa, pollution issues stemmed primarily from the nearby waste dumping site. Pollutants were spread by windy and rainy weather, forcing some residents to cover their heads and faces with towels even indoors. The smell from the garbage dump and recent fires elevated residents' fear and discomfort.

4.5. Health Issues and Safety

Breathing problems, ranging from mild to severe, were the most common health issues reported by slum dwellers in both sites. Participants also reported frequent illnesses such as tuberculosis among factory workers. Long-term exposure to air pollution led some to take medications for respiratory issues for over two years. Skin diseases varied with the seasons: winter exacerbated issues due to stagnant fumes, while summer's heat worsened conditions in plastic factories. Despite these health challenges, many factory workers continued their jobs out of economic necessity, without health insurance or safety measures. One participant's father, working in a gas pipe factory, suffered severe allergies to chemicals but had to keep working. Other health issues included eye problems, rashes, and lifestyle diseases like high blood pressure, flu, typhoid, and diabetes. The lack of proper healthcare facilities further compounded these

problems. Sanjay Colony had a health center 2km away, but it was not always accessible, and some residents hesitated to seek medical help.

4.6. Government Interventions

Participants unanimously reported a lack of government support, except for a few who mentioned centralized waste collection. They were dissatisfied with the government's approach, noting that promises made during election campaigns were often forgotten afterward. A participant observed fluctuations in gas prices around election time, suggesting manipulation:

"The gas price was 1100 INR (12-13 EURO), then reduced to 1000 INR (11-12 EURO) and 800 INR (8-9 EURO) now. I am pretty sure that it peaks back after the election campaigns."

The wealthy owners of the industries in Sanjay Colony were perceived as powerful enough to nullify any complaints, leaving the slum dwellers without recourse.

In summary, this section details the demographic features, energy and labor practices, pollution-related inconveniences, health issues, and government interventions affecting the slum dwellers. The findings highlight the significant challenges faced by this population and underscore the need for targeted interventions to improve their living conditions and health outcomes.

5. DISCUSSION

The discussion chapter of this thesis aims to analyze the findings presented in Chapter 4. Given the challenges of data acquisition from slum dwellers, the analysis incorporates both primary findings and insights from secondary research. The chapter is structured around the research questions, which focus on identifying socio-economic and environmental factors contributing to air pollution vulnerability among slum dwellers. The data collected underscores the vulnerability of residents due to occupational stress, energy demands, and other factors.

5.1. Demographic Stress due to Air Pollution in the Slum Area

As established earlier in this paper, the stress on vulnerable populations spans across different age groups, genders, and household conditions. The study findings distinctly highlight vulnerability, such as men exposed to outdoor air pollution at workplaces, women facing indoor stresses from biomass burning for cooking, and individuals of various ages coexisting in confined spaces. Occupational exposure to air pollution in and around the national capital region, compounded by seasonal variations, significantly impacts health outcomes.

Another significant concern is the coexistence of individuals in cramped households comprising 1-2 rooms. While ideal living conditions promote mental health and overall quality of life without disruptions, the reality for these residents raises critical questions. Participants surprisingly express satisfaction with their living conditions, possibly compelled by the limitations they face. The consolidation of kitchen, living area, and bedrooms within two rooms is alarmingly inadequate, given the potential air pollution emissions from cooking and heating practices. Moreover, the shared walls among neighboring households exacerbate the spread of pollutants across the community.

During observational analysis, the poignant expressions of helplessness among residents reflect concerns about raising children in such environments. There is a strong desire among residents to shield future generations from similar hardships. However, the community

cohesion and ease of communication observed during data collection suggest that social interactions within the neighborhood contribute positively to their quality of life.

5.2. Energy-Related Stress of Air Pollution

The primary energy needs in slum areas predominantly revolve around cooking throughout the year and heating during colder months, as well as serving as an alternative for lighting during electricity shortages. The widespread use of Liquid Petroleum Gas (LPG) for cooking mitigates the air pollution stress compared to biomass, thereby reducing indoor pollution vulnerability among women and children. However, the occasional reliance on biomass fuels such as Lakdi ki Chuhla (wooden stoves) by slum dwellers raises questions about the region's developmental progress and the community's awareness of their environmental impact.

Coming from Southern India where my family owns land, I recall my mother's perspective: "Why spend on gas stoves when we have readily available wood that would otherwise go to waste if unused?" This anecdote underscores the prevalent practice of biomass-based cooking in Indian households, including slums, which aligns with energy poverty trends. Such practices often stem from stakeholder neglect and common misconceptions. The scenario in Delhi's slums mirrors the broader pattern across rural India, where biomass energy, whether from wood or cow dung cakes (uplah), remains the most accessible and affordable energy source. This underscores how economic status dictates energy choices within households, revealing a systemic disparity. Moreover, fluctuations in LPG prices driven by political contexts further underscore the precariousness faced by these communities.

While all slum households have access to electricity, technical issues or power outages often necessitate the use of diesel generators, particularly in urban slums discussed in Chapter 3. This reliance can exacerbate pollution levels in densely packed slum environments where air circulation is limited. During winter, heating practices exacerbate pollution concerns,

especially given the prevalence of visual impairments in the region. Slum dwellers, left with limited alternatives, continue to utilize biomass-based heating techniques despite their own contribution and vulnerability to pollution.

These observations highlight the complex interplay between socio-economic factors, energy choices, and environmental impacts in slum communities. Addressing these issues requires nuanced policy interventions that promote cleaner energy alternatives, enhance infrastructure reliability, and empower communities with sustainable solutions to mitigate air pollution's adverse effects.

5.3. Labour-Based Air Pollution Stress

The intersection of air pollution and occupational stress in the locality exemplifies the stark contrast between increased employment opportunities for slum dwellers and deteriorating environmental health overall. Despite exposure to toxic fumes and dense smog from factory environments, labourers endure these conditions due to socio-economic constraints. Industrial jobs near their residences are often preferred over informal, unpredictable sources of income available elsewhere in the slum. However, the hazardous exposures these labourers face, both within factories and in outdoor settings amid high pollution levels, underscore their vulnerable employment status and economic pressures.

Comparing their wages to European standards, it becomes evident that these labourers earn significantly less. Many work long hours—typically 8-9 hours a day—for wages equivalent to less than 5 EURO, highlighting their dire economic circumstances. Their motivation often stems from the simple satisfaction of being employed, given the low socio-economic standards prevalent in slum communities. This acceptance of dangerous levels of pollution, whether acknowledged or overlooked, reflects the harsh realities of their daily lives.

Instances of workplace accidents, such as fire breakouts, further compound the risks faced by these labourers, who often lack insurance or any form of job security. Despite these hazards, factories continue operations without adequately addressing employee rights or safety measures. This glaring gap in regulatory oversight and enforcement, particularly evident in industries dealing with hazardous chemicals and emitting toxic fumes through chimneys, exacerbates risks for both workers and residents of these localities.

Improving conditions for labourers under such occupational stress necessitates enhanced monitoring and enforcement of employee rights and safety standards. The existing socio-economic disparities and environmental health concerns in slum areas underscore the urgent need for comprehensive policy interventions and regulatory reforms. Addressing these challenges will require concerted efforts to safeguard the well-being of workers and mitigate the detrimental impacts of air pollution on vulnerable communities.

5.4. Health Issues and Safety Analysis

The examination of health and safety conditions in both locations reveals significant deficiencies. A lack of awareness among the population about the hazards they face exacerbates their vulnerability. Despite the limited facilities available in the slums and the reported satisfaction levels among residents, persuading them to alter their current living habits is challenging. Many are unaware of the causes of their health issues, and some hesitate to seek assistance from healthcare centers.

As discussed in Chapter 3, air pollution is strongly correlated with respiratory problems, immunological disorders, and other health issues. Given the harsh living and working conditions experienced by the population, there is a pressing need for increased awareness initiatives among slum dwellers. From skin allergies to life-threatening illnesses, air pollution manifests in various detrimental ways. The socio-economic status of slum dwellers further heightens their susceptibility to infectious diseases due to overcrowded living conditions,

underscoring the critical importance of informing them about their right to a healthy environment and life.

Effective monitoring of factory emissions and robust regulatory measures are imperative to ensure employee safety. Workers should be well-informed about potential health impacts before entering the workplace and should have access to health insurance covering factory-related health issues.

Addressing these issues requires comprehensive efforts to educate and empower slum communities, enhance regulatory frameworks, and ensure compliance with environmental and occupational safety standards. By doing so, we can mitigate the adverse health effects of air pollution and improve the overall well-being of vulnerable populations in urban slums.

5.5. Policy Interventions and Governmental Support: A Timeline Analysis

In the 1970s, Indira Gandhi recognized the vulnerabilities of developing countries, yet the socio-economic and environmental conditions within these nations have since deteriorated, particularly affecting marginalized populations in urban slums. The fundamental right to life, as emphasized in historical contexts, has not been adequately extended to support these vulnerable groups, who endure prolonged exposure to hazardous environments. This timeline analysis examines the effectiveness of policy interventions and governmental support mechanisms in addressing air pollution and its impacts on these communities.

1970s: Initial Awareness and Legislative Foundations: Indira Gandhi's recognition of the vulnerabilities faced by developing nations marked the beginning of a concerted effort to address environmental issues. The enactment of the Air Pollution Act and the Environmental Protection Act laid the groundwork for subsequent initiatives aimed at improving air quality and protecting public health.

1980s-1990s: Emergence of National Programs: The National Air Quality Monitoring Program (NAMP) and the National Air Quality Index (NAQI) were established to systematically monitor and report air quality levels across the country. These programs aimed to provide transparency and raise awareness about air pollution, fostering public engagement and policy responses.

2000s: Strengthening Regulatory Frameworks: The Graded Response Action Plan (GRAP) was introduced to implement a comprehensive approach to mitigating air pollution. This plan included specific measures to be taken during different levels of air quality emergencies, ensuring a structured response to worsening pollution levels.

Recent Developments: Focus on Cleaner Fuels: Efforts to promote cleaner cooking fuels, such as liquefied petroleum gas (LPG), aimed to reduce emissions from biomass burning. Despite these initiatives, many households, particularly in rural and urban slum areas, continue to rely on traditional biomass for cooking and heating. This persistence indicates gaps in both policy implementation and enforcement.

5.5.1. Policy Challenges

The historical timeline of policy interventions reveals both progress and persistent challenges in addressing air pollution. The establishment of monitoring programs and response plans has improved transparency and public awareness. However, the effectiveness of these policies in mitigating air pollution in vulnerable communities remains limited.

Monitoring and Enforcement Gaps

The continued use of biomass for cooking and heating, despite the promotion of cleaner fuels, highlights significant gaps in policy enforcement. The failure to effectively monitor and regulate these practices undermines the intended benefits of cleaner fuel initiatives. This

suggests a need for more robust enforcement mechanisms and support systems to ensure compliance and facilitate the transition to cleaner energy sources.

Targeted Support for Vulnerable Populations

Policies must extend beyond general air quality improvements to specifically address the needs of vulnerable populations. The current focus on transparency and awareness, while important, is insufficient. Policies must be frequently reviewed, updated, and tailored to address the unique challenges faced by marginalized communities, such as those living in urban slums.

5.5.2. Recommendations Forward- Brief

To enhance the efficacy of air pollution policies, the following recommendations are proposed:

Strengthen Enforcement Mechanisms: Develop and implement stricter monitoring and enforcement protocols to ensure compliance with cleaner fuel initiatives and other air quality regulations.

Increase Targeted Support: Provide targeted support and resources to vulnerable populations to facilitate the adoption of cleaner energy sources and improve living conditions.

Regular Policy Reviews: Conduct regular reviews and updates of air pollution policies to ensure they remain relevant and effective in addressing emerging challenges and scientific advancements.

Community Engagement: Foster greater community engagement and participation in policy development and implementation processes to ensure that interventions are contextually appropriate and address the specific needs of affected populations.

By addressing these areas, policymakers can better protect the health and rights of vulnerable communities, ultimately contributing to a more equitable and sustainable environment for all.

6. CONCLUSION

Delhi, ranking as the most polluted city in the world, exemplifies environmental injustice within its regional boundaries. The aim of this thesis was to understand the air pollution vulnerability in the urban slums of Delhi, India. The slum dwellers' exposure to air pollution and other environmental degradation is closely tied to the socio-economic conditions they endure. From the daily struggle to find work for underpaid wages to managing the challenges of living in overcrowded two-room households, the reality for these residents is daunting and distressing.

The scope of change needed in urban slums extends far beyond merely raising awareness and informing the residents about the threats they face. It requires a bottom-up approach, starting at the grassroots level in slum households and extending to administrative levels. This approach is necessary to inform, enact, and enforce adequate actions to mitigate the impact of air pollution. The effects of air pollution in these areas are, to a large extent, the consequences of negligence and ignorance. Given the busy schedule of slum dwellers, who are preoccupied with feeding their families and surviving day-to-day, it is challenging to convince them to seek alternatives.

An effective approach to improve the living conditions of slum dwellers is to strengthen the monitoring and enforcement of air pollution laws and policies. This must include extending aid to the often-overlooked individuals living on the borders of garbage dumps and industrial areas, who disproportionately bear the burden of environmental degradation.

The energy transition ladder, which emphasizes the importance of clean energy and resource management, should be communicated to the slum residents. They need to be educated on how to avoid contributing further to their existing vulnerability. Industrial and waste disposal practices are major contributors to the air pollution problem in these areas. This

study has highlighted the socio-economic barriers that prevent slum dwellers from escaping the intensified effects of air pollution.

In conclusion, addressing the air pollution vulnerability in Delhi's urban slums requires a multifaceted strategy. This strategy must combine stronger policy enforcement, targeted education, and community engagement. By fostering a comprehensive understanding of the socio-economic and environmental challenges, stakeholders can work towards creating sustainable solutions that improve the health and well-being of slum residents. Only through concerted efforts at all levels of society can we hope to alleviate the environmental injustices faced by these vulnerable populations.

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