INTRODUCTION Chapter 1

1.1 Introduction

Indoor air pollution (IAP) refers to dust, dirt, and gaseous substances within indoor spaces that can harm occupants' health when inhaled. It includes, but are not limited to, gaseous pollutants (e.g., volatile organic compounds [VOCs] and inorganic compounds), particulate matter (PM), and biological contaminants [1, 2]. Indoor Air Pollution has become a rising public health concern as individuals spend approximately 80–90% of their time indoors: in homes, educational institutions, workplaces, and public venues such as theatres and restaurants [3-6]. In recent years, there has been growing recognition that indoor environments, both private and public, often harbour elevated concentrations of pollutants up to ten times higher than those found outdoors [7]. This is due to the accumulation of pollutants in confined spaces, where air circulation is limited [8].

The World Health Organization (WHO) estimates that approximately 3.2 million premature deaths occur annually due to exposure to IAP. Various human activities and emission sources within buildings, along with the infiltration of outdoor pollutants, significantly influence indoor air quality (IAQ). Indoor Air Quality refers to the condition of the air within and around buildings and structures, particularly in relation to the health and comfort of occupants [9-10]. Indoor sources of pollutants include emissions from cooking, heating, smoking, and incense burning, as well as off-gassing from paints, textiles, carpets, building materials, and furnishings. Additionally, personal care products, pesticides, and the resuspension of PM during activities like cleaning and walking also degrade IAQ [11-15]. The infiltration of outdoor particles through ventilation systems or open windows aggravates the situation, further worsening IAQ [16].

The construction of increasingly energy-efficient buildings has exacerbated the issue of IAP in recent years. While these structures are designed to conserve energy through airtight construction, reduced ventilation can result in stagnant air, leading to a rapid accumulation of indoor pollutants [5]. The broad range of pollutants that contribute to poor IAQ include PM, volatile organic compounds (VOCs), aldehydes, bioaerosols, and inorganic compounds such as heavy metals [17, 18].

Among different IAQ parameters, PM and Carbondioxide (CO_2) are of particular concern due to their direct impact on both health and work performance [19]. Airborne particulate matter (PM) is a complex mixture of solid and liquid particles suspended in the air, differing in size, shape, and composition. It may include inorganic ions, metallic compounds, elemental carbon, organic substances, and crustal materials. For regulatory and monitoring purposes, PM is classified by aerodynamic diameter [20]. The most extensively studied PM, categorized based on its size include, coarse particles (PM_{10}: 2.5–10 μm) and fine particles ($PM_{2.5}$: 0.1–2.5 μm) [21]**.** $PM_{2.5}$ was first regulated by the U.S. Environmental Protection Agency (US EPA) in 1997 to protect public health and later adopted in China through standards like the Ambient Air Quality Standards (GB 3095-2012) [22]. Since 1970s, numerous studies have addressed the health impacts of ambient $PM_{2.5}$ [23, 24]. However, the decline in IAQ highlights the growing need to investigate indoor $PM_{2.5}$ levels. Exposure to $PM_{2.5}$ has been linked to numerous health issues, ranging from asthma and cardiovascular diseases to pulmonary conditions. Additionally, it is associated with both acute and chronic respiratory illnesses, as well as tuberculosis and negative perinatal outcomes [25]. Similarly, in poorly ventilated spaces with higher occupancy, CO_2 concentrations can rise significantly. The very first attempt was made by Eliseeva et al. [26] to investigate the impacts of exposures to low levels of CO_2. They observed that at a CO_2 concentration of 1000 ppm, respiratory movement amplitude noticeably decreased, indicating altered breathing patterns. Additionally, increased peripheral blood flow suggested an impact on the circulatory system. Other potential health impacts such as headaches, fatigue, and reduced cognitive performance were also reported with higher CO_2 concentrations [27, 28].

In addition to IAQ parameters, indoor settled dust (SD) also plays a significant role in defining the overall health of the indoor environment. Settled dust is the primary source and sink of atmospheric particles [29]. It comprises of minute, dry, solid particles, either airborne or settled and dispersed by natural forces such as wind or volcanic eruptions, as well as by mechanical or human activities like grinding, milling, demolition, sweeping, and shoveling. These particles typically range from 1 to 100 µm in diameter and gradually settle due to gravity [30]. It is present in the indoor environment as a composite of PM resulting from internal and external sources. It acts as a reservoir of various harmful elements, including heavy metals making it another important contributor to IAP [31-34].

Being fine in size, dust particles can easily become suspended in the air, and are readily inhalable. It increases the risk of respiratory conditions, neurological issues, allergies, and other health problems [35]. Monitoring dust levels is essential for assessing the changes in urban environmental quality affected by anthropogenic activities. The composition of indoor SD is determined by the building's geographical location. For example, urban dust tends to contain higher concentrations of heavy metals from anthropogenic sources, while rural areas are more likely to have crustal elements [36]. Furthermore, factors that influence heavy metal concentrations in SD include the structure and characteristics of the building (number of floors, building height, paint type), as well as the activities of the building occupants (fuel type used, smoking habits, sweeping frequency, air conditioning usage, presence of carpets and rugs, the frequency and duration of window openings, and cooking frequency). Heavy metals in SD are particularly concerning due to their persistence, non-biodegradability, and potential for bioaccumulation, posing significant risks to the human health and the environment [37, 31]. The dust can enter the body through various pathways, including inhalation, ingestion, and dermal contact [38,39]. As a result, understanding the composition and impact of SD is crucial for assessing health risks and implementing effective indoor pollution control strategies to improve overall IAQ [40, 41].

Sick building syndrome (SBS) is a group of symptoms associated with the building environment. These symptoms usually improve or disappear shortly after leaving the building [42, 43]. Individuals experience unexplained symptoms of illness or discomfort while occupying a building [44]. These so-called "sick buildings" are characterized by the presence of harmful pollutants at concentrations high enough to trigger a wide range of health issues, from mild respiratory irritation to severe chronic illnesses [45]. In 1983, the WHO formally recognized SBS as a collection of medical symptoms linked to indoor environments. These symptoms are categorized as mucous membrane symptoms impacting the eyes, nose, throat and dry skin, alongside general symptoms such as headaches and fatigue [46,47]. Research indicates that approximately one in five individuals report SBS symptoms attributed to IAQ [48]. The quality of indoor air is affected by a complex interaction of multiple factors, including geographical locations, climate conditions, building design, construction materials, indoor dampness, and occupant activities [49-51]. Symptoms of SBS are common in the general population [50]. However, our understanding of these symptoms and their contributing factors is inadequate, particularly in developing countries like India. Enhancing IAQ in developing countries could lead to a 15% reduction in the prevalence of acute respiratory infections and chronic respiratory diseases, as well as a 10% decrease in the incidence of respiratory tract cancers [51].

1.2 Rationale of the Study

Several studies from abroad have extensively investigated IAQ and the heavy metal composition of SD in various indoor environments such as offices, schools, colleges, universities, and homes [52-57]. Although IAQ research in India has been gaining momentum, it is still in its nascent stages, particularly in the Northeastern region. Several studies conducted across India have reported the elemental composition of SD from households and educational institutions [14, 58-63]. Additionally, numerous studies have monitored IAQ in various indoor settings while evaluating occupants' perceptions of IAQ [51, 63, 64-68].

There remains a significant gap in research on IAQ and SD in Northeast India, with only a few studies conducted in this region [69-72]. To address this gap, the present study was carried out in Guwahati, the largest metropolis in Northeast India, and Tezpur, a fast-growing urban agglomeration in Assam. Given the rapid urbanization and industrial development in these areas, understanding IAQ in the region is critical.

1.3 Scopes and Objectives of the Study

In light of the above discussions the present study aims to achieve the following objectives:

1. Characterization of indoor air in educational institutions and households of Guwahati and Tezpur, Assam
2. Physicochemical characterization of settled dust in different indoor environments
3. Health risk assessment and association of indoor air with sick building syndrome (SBS)

To the best of our knowledge, this is the first comprehensive study to simultaneously characterize indoor air pollutants, residents' perceptions of IAQ, and the physicochemical properties of SD. By examining all these parameters in both households and educational settings, the study aims to provide a more holistic understanding of the overall indoor environment, offering a more comprehensive assessment in Northeast India. The findings are expected to contribute valuable baseline data for policymakers, urban planners, and public health professionals working in similar urban and semi-urban environments.

1.2 References

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