Harmful Consequences of Air Pollution on Human Health in Nepal: A Review

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Abstract	Article Info.
This paper examine and study the negative effects of air pollution on people's health in Nepal. Air pollution happens because of using bad fuel and not very good ways to produce energy. Usually, when the economy gets better, we need to use more energy. This directly affects people because it impacts the air we breathe. A detailed look at past records, along with a thorough examination, would be the approaches taken during the scientific evaluation. The Air Quality Index (AQI) shows different levels of air quality, with 0 to 50 being good, 51 to 100 being moderate, 101 to 200 being unhealthy, 201 to 300 being very unhealthy, and 301 to 500 being dangerous. In the Kathmandu valley of Nepal, local air pollutants like carbon monoxide, tiny particles in the air, and hydrocarbons make the air worse and can harm people's health. Families who have lower incomes and live in rural areas are not interested in having a better indoor air quality. The biggest reasons for air pollution come from energy, industry, and transportation. This is mainly due to using poor quality fuel and not using energy in good ways. Generally, when the economy grows, it needs more energy. Pollutants found in our area, like carbon monoxide, tiny particles, and hydrocarbons, can lower air quality and harm people's health. To handle and keep track of air pollution well, we need strong plans and rules. *Keywords*: air pollution, environment, human health, pollutants, pollution	

Introduction

Air pollution is a big danger to the environment in important cities in Nepal. The main cause of air pollution comes from cars, dust in the streets that gets stirred up when it's dry, dark smoke from brick factories, and burning trash. We need strong strategies and rules to properly manage and keep an eye on air pollution (Chauhana, 2022).

Vehicle air pollution and how many people use vehicles is very important in developing countries like Nepal when we think about the environment and living well in cities. There was a strong connection found between two types of small particles, PM2.5 and PM10, which come from similar pollution sources like dust on the roads and exhaust from vehicles. A study that compared these particles showed that bigger particles were more common both outside and inside vehicles. The RRS area had the highest levels of PM10 and PM2.5, likely because the roads from Kalanki to

Gongabu are not in good shape and there is loose dirt from what's happening beside the roads. There is a big difference in pollution levels between busy hours and quieter hours due to how many vehicles are on the road at those times. The higher number of people using UCR1 and UCR2 shows that there is more need for transport in busy parts of the city, both on weekdays and weekends, compared to the Ring Road area (Bhusal P, 2024).

Bricks have been made in Nepal for many years, and they are an important part of the country's art and buildings. Every day, brick kilns release a lot of harmful materials, including fine dust particles. Being around these harmful substances can negatively affect both the environment and people's health. This research aimed to find out how common breathing problems are and how much dust workers in brick kilns are exposed to. Issues like chronic cough (14.3%), phlegm (16.6%), and bronchitis (19.0%) were found to be more significant (P< 0.05) in brick workers compared to those who work in grocery stores (6.8, 5.8 and 10.8%) (Sanjel, 2017).

One of the biggest problems we face today is air pollution. This issue not only affects our climate but also harms the health of people due to more illnesses and deaths. There are many different pollutants that contribute to diseases in people. One of these is Particulate Matter, which consists of tiny particles that can get into our lungs when we breathe. These particles can lead to lung and heart diseases, problems with reproduction and the nervous system, and even cancer. While ozone high up in the atmosphere is good because it protects us from harmful rays, too much ozone close to the ground can be dangerous for our lungs and hearts. Additionally, substances like nitrogen oxide, sulfur dioxide, Volatile Organic Compounds, dioxins, and polycyclic aromatic hydrocarbons are also harmful air pollutants for humans (Manisalidis I, 2020).

Literature Review

The health effects of air pollution discussed here are probably lower than they really are. This is because it doesn't take into account the effects from other air pollutants like nitrogen oxides or ozone, and it leaves out health problems that don't have enough evidence yet, such as premature birth or low birth weight. This report uses a combined approach to show three types of information and how they relate to each other: 1) the data on PM2.5 and PM10 measurements from the 2016 WHO outdoor air quality database; 2) the predicted levels of PM2.5; and 3) the related health issues (WHO, 2016).

The rare event of a nationwide shutdown was used to look into how air quality changed in Nepal, especially in its special urban area, the Kathmandu Valley, during the lockdown. This study looked at different seasons: the dry time before the monsoon and the wet monsoon season, using information from satellites and air quality monitors on the ground. The results showed a big improvement in air quality during the dry season across the country while the lockdown was in place. The average levels of aerosol optical depth (AOD), nitrogen dioxide (NO2), and carbon monoxide (CO) dropped by 27.7%, 12.7%, and 5.12%, respectively, when compared to how things were before the pandemic began. In the Kathmandu Valley, the levels of PM2.5 (tiny particles with a diameter of 2.5 micrometres or less), AOD, NO2, and CO fell by 38.1%, 38.0%, 16.5%, and 6.03%, respectively, during the dry season of the lockdown. It is important to point out that the drop in AOD and NO2 levels was significantly greater in the Kathmandu Valley compared to the rest of the country (Dhital, 2022).

The Kathmandu Valley in Nepal is a dip in the land where a lot of people live, and the air there is really dirty, which can make the 3.5 million people who live there sick. From April 11 to April 24 in 2015, scientists studied the air quality in the Kathmandu Valley as part of a project called the Nepal Ambient Monitoring and Source Testing Experiment, or NAMaSTE, during the time just before the rain season. They measured the amounts of tiny particles in the air, which they call PM25 and PM10, along with PM1, certain gases like ammonia,

nitric acid, sulfur dioxide, and hydrochloric acid, and carbon gases such as carbon dioxide, carbon monoxide, methane, and 93 other chemicals that do not include methane. These measurements were taken in a place near the middle of the valley that isn't fully city-like. The amount and types of these chemicals showed that they mainly came from cars that are not well kept, burning wood or other materials, and the evaporation of solvents and gasoline (Islam, 2020).

Air pollution, which happens both inside buildings and outside, is a big issue in developing countries like Nepal. The quality of air keeps getting worse, which is affecting people's health in many ways. Looking at the current data from some busy city areas, the Air Quality Index (AQI) shows it's getting worse because there are more cars, factories, and not enough steps taken to protect the environment. In the countryside, smoke from burning wood, the burning of leftover crops, using solid fuels, and pesticides are becoming the main causes of air pollution. Research on how air

pollution impacts the health of the environment, pollutants that cross borders, and regular checks of indoor air quality still need a lot of work, and the country's efforts to fight air pollution need to be strengthened. Right now, air quality monitoring stations are set up in only a few places, and there are plans to expand these to both rural and city areas (Devkota Pousel, 2021).

During the time when everyone had to stay home, air quality levels for PM2.5 and PM10 in all of Nepal were mostly at a moderate level. Because of the lockdown, the biggest and most noticeable decrease in PM2.5 was found in Damak with a drop of 26.37%, and in Nepalgunj, it went down by 80.86%. Likewise, the largest immediate drop in PM10 occurred in Surkhet at 37.22%, and the final drop was in Nepalgunj at 81.14%. This shows that less traffic and fewer emissions from vehicles really matter, which points to the need for using different types of fuels to make the air cleaner and help people's health. The AQI range, level of concern and description of air quality is following:

Table 1

AQI Range and Air Quality Levels

AQI Range	Level of Concern	Description of Air Quality
0-50	Good	The air is clean enough, and there isn't much danger from pollution.
51-100	Moderate	The air quality is okay. Still, some individuals might be at risk, especially those who are more sensitive to pollution in the air.
101-150	Unhealthy for sensitive groups	People who belong to vulnerable groups might face health issues. Regular people are usually not as likely to be impacted.
151-200	Unhealthy	Some people in the community might have health issues. People who are more vulnerable may face even more serious health problems.
201-300	Very Unhealthy	Healthy notice: The chances of health problems are higher for everyone.
301-500	Hazardous	Notice about serious situations: anyone can be impacted.

Note. Baral (2021)

Diseases related to breathing because of pollution are rising all over the world, and this is mainly due to environmental issues. One of the biggest problems in the environment is air pollution, which poses a serious risk to people's health. Breathing in too much Particulate Matter that is

smaller than 2.5 micrometres, carbon monoxide, and nitrogen dioxide can cause infections in the breathing system for kids and can lead to long-term health problems for adults. The big cities in Nepal are now seen as unhealthy places because of a growing population, poor city planning, and

emissions from factories and vehicles. In addition to these, the lack of proper enforcement of rules and programs is also a key factor causing more air pollution in the Kathmandu Valley (Karki et al., 2016).

The Kathmandu Valley has seen fast urban growth, a rise in vehicle traffic, and extensive urban infrastructure development, all of which have been facilitated by materials. houses, schools, hospitals, and businesses. The building of this infrastructure necessitates brick kilns, boilers, and other pollution sources. Furthermore, there is road construction, unfinished roads, unpaved sidewalks, and the careless dumping of building waste, which causes poor air quality (USAID & JSI, 2022).

The traffic officers of Kathmandu, Nepal, have physical health issues. Over half of them experience eye issues (52.3%) and upper respiratory tract issues (52.3%). problems with the lower respiratory system, such as 55.4%, and skin issues, such as 55.9%, caused by air pollution. Traffic police officers suffer from dryness, which affects their mental and physical well-being. eye itching, eye redness, nasal dryness, nasal irritation, nasal congestion, throat pain, shortness of breath, chest pain, wheezing, and dryness skin redness, cough, breathing issues, and skin allergies (Shrestha et al., 2020).

In Nepal, air quality has been a significant issue for the environment and public health. There are now 28 monitoring sites throughout the nation that are constantly monitoring air pollution. daily air pollution data (PM2.5) was gathered for 21 stations in 6 of Nepal's provinces and 19 districts (with the exception of Sudurpaschim). Annual outpatient cardiovascular and respiratory illness morbidity was similarly collected for the years 2018/19–2019/20 across 14 districts over a period of roughly two and a half years, from 2019 to May 2021. to evaluate the air pollution situation and categorization characteristics of Nepal, descriptive and discriminant analysis were conducted for the districts for which air pollution data was available (Shrestha, 2021).

With a population of about 4 million, the Kathmandu Valley in Nepal is among the most polluted cities in the world. The severe particle matter (PM) pollution, which can be as bad as in cities like Beijing and elsewhere, is a major issue in the valley. Black carbon (BC), also known as soot, is a particularly harmful element of PM in Delhi. It is associated with cancer and respiratory problems and heart disease. Giri et al. conducted a study in 2007 that found PM in the Kathmandu Valley to be the cause of heart disease, even though data for the area is limited. BC is also a short-lived climate-forcing pollutant (SLCP) that causes regional atmospheric warming and changes in the Asian monsoon, resulting in more than 17,000 premature deaths annually. Accelerated melting of snow and ice in the Himalayas, monsoon rainfall patterns, and other pertinent SLCPs include ground-level ozone, a pollutant that causes regional ozone pollution. By harming plant cells, BC causes warming, lung damage, and, most notably, has been shown to lead to substantial crop losses. Ozone and the effects of BC are listed below. Other pollutants pose significant risks to food, water, and energy security in the area, with consequences for millions of people as well as for the environment. The region's overall sustainable development (ICIMODE & IASS, 2015).

One of the main air pollutants in Kathmandu Valley is PM2.5, and its release and the valley's peculiar atmospheric circumstances make it particularly harmful. Harmful to human health. A significant health risk is the air pollution caused by particulate matter, which has several detrimental effects on us. This study seeks to address the issue of particulate matter air pollution. To measure the health effects of PM2.5 exposure on the people of the Kathmandu Valley. WRF-Chem was used to simulate the valley's ambient PM2.5 concentration. The WRF-Chem-derived concentration was used as input in the health equation after being modelled with a 3×3 km horizontal grid resolution. This quantitative assessment of atmospheric pollution

was used to determine the human exposure to PM2.5 in Kathmandu Valley using an intervention model (Tuladhar A, 2021).

The fourth-highest risk factor driving total morbidity in low-income nations like Nepal is indoor air pollution (IAP), which is caused by the indoor combustion of biomass fuels. morbidity and death. We provide the first evaluation of the geographic and socioeconomic factors that influence the indicators of IAP, such as fuel types, cooking techniques, and indoor environments. In a nationally representative sample of Nepalese households, the prevalence of smoking was assessed. Over 80% of the households showed at least one sign of IAP, with 66% of the household 45% of households lacked a separate kitchen for cooking, 43% smoked indoors, and 45% used dirty fuel. Choosing the proper fuel and maintaining clean indoor practices are essential. Dependent on the family's socioeconomic position. The geographic variation in the distribution of IAP markers necessitates public health measures aimed at low-income families in rural communities (Ghimire & Singh, 2019).

Air purifiers (APs) and home sealing are interventions used to help protect U.S. diplomats against particle pollution in the home when working in polluted cities. We investigated the effect of these interventions on home indoor and personal PM2.5 exposure in Kathmandu, Nepal. Twenty-one participants underwent repeated 48 hour personal monitoring before and after intervention. We analysed these measurements by microenvironment. Indoor-outdoor ratios (I/O) using the home indoor PM 2.5 values were calculated in order to assess the air filtration capacity at home in light of increasing outdoor PM2.5 post-intervention. To quantify the effect of intervention on home indoor PM 2.5, we conducted a meta-analysis of the results of dwelling-by-dwelling regression of indoor-on-outdoor (I/O) PM2.5 concentrations (Edwards, 2023).

Millions of individuals have experienced serious health issues as a result of air pollution, which has often been shown to be a major issue, particularly for hawkers. Because of the heavy traffic flow, I have to spend many hours every day at the side of the road, which means that I am very vulnerable to air pollution. The great intensity of the exposure rate led to an increase in health risks for a wide range of illnesses and a lack of suitable adaptive strategies. Even mask wearers experienced health issues. Due to the low quality of the masks. The results indicate that more education about personal protective equipment (PPE), such as masks, is needed. Among street hawkers with the backing of the local government and private businesses. In order to properly monitor air quality, an air quality monitoring station must be set up in the bus park area.

Nepal's Kathmandu Valley has severe air pollution, particularly during the dry winter months. The daily concentrations of PM 2.5 were exceptionally high during the course of the research. The concentrations varied between 72 and 149 μgm−3 at the urban Ratnapark location in Kathmandu, between 88 and 161 μgm−3 at the suburban Lalitpur site, and between 40 and 74 μgm−3 at rural Dhulikhel, which is located on the eastern outskirts of Kathmandu. The Kathmandu Valley. In the meanwhile, the values of PM 10 were between 194 and 309, 174 and 377, and 64 and 131 micrograms per cubic meter, respectively (Islam & Tuladhar, 2022).

Unregulated and unplanned urbanization that lacks a migration policy has a negative impact on the environment and public welfare of Kathmandu Valley, the largest city in the valley. Nepal. The pollution of the air and water is a major health concern for the people of the valley. Air pollution and traffic-related dust are major sources of emissions traffic. Possible danger; the winter months are the worst. This is due to the increased accountability for air pollution in automobiles. The primary pollutants that cause respiratory issues are inexcusable. Particulate matter includes illnesses and other health problems (Dong, 2018).

The Terai region of Nepal produces bananas commercially and in larger quantities. The benefits are more consistent and significant from September

to February, throughout the winter season. Pesticides and insecticides are used seven to twenty-four times daily in Nepal's banana-growing area. India imports items into Nepal at Nijgadh. Growing bananas has twice the benefits of growing sugarcane and grain crops. The soil is deteriorated by costs that are 60 to 70% cheaper. After decays, there is a decline in production and poison. It's imperative to educate farmers in the Nijgadh area, and it should be shown after a There will be significant difficulties in the future if the extensive usage and damage to human life continues. In time, Nepal's local, regional, and national infrastructure will be severely affected. Organic production and supply will have to be experimented with at central markets (Ghimire & Pandey, 2024).

The children and parents of Chepang community to know their health status in comparison with other communities. Chepang is an indigenous ethnic group living in Central and Southern Nepal especially in Chitawan, Gorkha and Dhading districts and also known as one of the isolated tribal groups of Nepal. They have their own language known as Chepang but is called Chyo-bang by the people themselves. The Chepang settlement is often on very steep land, unfertile and not easily accessible. Chepang are found back in health seeking practices than the other communities. Cent percent mother had reported that they had given the birth of 1st baby before 20 years of her age. Though, health status of Chepang children found better than other communities' children (Ghimire, 2014).

The foreign employment as Returnee Workers has qualities like entrepreneurial spirit, job prospects, leadership aptitude, accountability, responsibility, and teamwork in entrepreneurship. Whether or not Returnee Workers characteristics affect the degree of entrepreneurship among returnee participants (Mishra A K, 2023).

Nepal is an extremely disaster-prone country, especially when it comes to floods, landslides, drought, wildfires, and annual hot and cold waves of viral illnesses. As a result of the heavy summer rainfall. In Nepal's river hills and Terai area, landslides are more common during the summer months (June–September) because of this. The intense monsoon rains that occur throughout this period. Flooding is more common in the up-stem area of rivers, and the down-stem area experiences the full force of the monsoon. Rivers have a dipping problem. Sedimentation is bad for people's health, agriculture, and homes simultaneously. The purpose of the study is to identify dietary disparities among youngsters under the age of five. Weight, height, and mid-upper arm circumference (MUAC) were used to determine if the youngsters had flood or not. Children who experienced floods are generally more undernourished than those who do not. Social spaces. Unimaginable floods in the Karnali River bring human existence to a halt. During the floods, the majority of families flee their homes for one to four days. This scenario, in which waste remains in community structures (community homes, schools, and Godam buildings) for weeks, happens 1–3 times during the Karnali River floods. Every year. The upkeep of their house, toilet, and hand pump is quite expensive following each flood, making it difficult for them to return to normalcy (Ghimire, 2023).

The impact of poultry farming entrepreneurship on the income and employment of people in Nepal's mid-Terai area. Poultry production is quite lucrative. Broiler chicken farming, in particular, has been recognized as a profitable short-term farming endeavor in rural areas of the mid-Terai region. The research discovered that with a net income of between NPR 320,000 and NPR 900,000, managing 100 broilers can produce an annual income of between NPR 800,000 and NPR 900,000. In addition, poultry two people can find employment in agriculture (Timilsina R K, 2014).

Regularly occurring in Nepal are earthquakes, floods, landslides, droughts, heat waves, cold waves, and vector-borne illnesses, making it a very disaster-prone nation. The nation is also susceptible to vector-borne diseases, monsoon floods, and landslides. Every year, landslides impact the most

susceptible populations in the hills and plains. The purpose of the book is to examine the consequences of nutrition during floods on youngsters. In Nepal, the floods impacted women, children, and the elderly. The main monsoon months in Nepal are from June through September. Floods destroy homes, crops, The Terai region of Nepal is impacted by floods. In Bhutan, Bangladesh, India, and Nepal, floods have been found to impact youngsters between the ages of three and five (Mayanath, 2023).

The goal of the research is to compare child nutrition in flood-affected and non-affected homes based on perception. Malnutrition was seen in both areas. However, the flood-affected region was more severely impacted than the non-flood region. The Karnali, which is Nepal's deepest river, is hit by floods one to three times every year. Staying in secure locations like community centres, schools, and Godam for one to four weeks (seven to thirty days) each year is one of the ways it affects society (Mayanath, 2023).

The current snacking habits of community schoolchildren and the sustainable, affordable, and impactful impact of snacks on dietary habits and health status. The School Day Snacks aid in the attachment of children to school, enrolment, and regular attendance. Many parents want to send their children to school without daytime snacks. It is seeing hunger as an opportunity to access education for deserving children.

Mid-day meals are problems in central hills and perhaps elsewhere to provide schoolchildren with nutrition as well. Similarly, to raise nutrition awareness and the availability of nutrient rich foods for children. Added fruits and vegetables for health development, growth, and detection of disease for children.

Junk food consumption among adolescent students is remarkably high in both public and private schools. According to the Day Snacks Management Guidelines 2020, each kid should consume 150–200 grams of cereals, gedagudi (peas, grains, pulses, etc.), green vegetables, and fruits. Also needed were 50–60 grams of animal-related protein foods. It is said in Nepal that ''Harek bar Khana char'' (every four different types of foods like rice, vegetables, animal related foods, and pulses) must (Ghimire & Pandey, 2024).

The current snacking habits of community school children's dietary habits and health status. There were severe wasting total (1) 4.5%, Moderate wasting (1) 4.5% and normal (20) 90.9% in Mangal Secondary School, Kirtipur -10, Kirtipur, Kathmandu whereas Moderate Wasting was (3) 11.1%, and normal (24) 88.9% were in Mahendra Adarsha Secondary School. At Mangal Secondary School, Kirtipur -10, Kirtipur, Kathmandu, the prevalence of stunting by age based on height-for-age Z-score showed severe stunting in children aged 42-53 months at 9.1%, moderate stunting at 13.6%, and normal height at 77.3%. Similarly, at Mahendra Adarsha Secondary School, Mahalaxmi -4, Imadol, Lalitpur, the total prevalence showed moderate stunting in children aged 42-53 months at 33.3% and normal height at 66.7%. Mid Upper Arm Circumference (MUAC) is used for emergency and screening purposes to assess the nutritional status of children (Ghimire &Pandey, 2024).

Health check-up during pregnancy and after pregnancy is a must because of the critical health status of the mother and baby. The study identifies the health seeking behaviour of mothers of Chepang and Non-Chepang communities of Makawanpur and Chitwan district of Nepal regarding the ANC and PNC check-up. The study was cross sectional descriptive design. The result found that Non-Chepang community was found more aware and better practice of health check-up than Chepang communities in both districts. Nepal Government should focus on Chepang or similar types of marginalized and backward communities to increase their access on health services as well as concerned authorities should be responsible to address their problem which become as barrier to change their health seeking behaviour (Ghimire, 2014).

This empirical study examines the complex link between employee commitment and Human

Resource Development (HRD) practices in the Nepalese organizational environment. a major hole in the existing literature. The conceptual framework that underpins this study sees employee commitment as the dependent variable, which is susceptible to The independent variables include training and development, career advancement, and organizational growth, with demographic factors operating as moderating variables. This structure functions as a a systematic lens through which to examine and understand the intricate relationship between HRD practices and employee commitment in the unique organizational setting of Nepal (Thakur, 2023).

Problem Statement

The interactions between humans and their physical surroundings have been extensively studied, as multiple human activities influence the environment. The environment is a coupling of the biotic (living organisms and microorganisms) and the abiotic (hydrosphere, lithosphere, and atmosphere). Pollution is defined as the introduction into the environment of substances harmful to humans and other living organisms. Pollutants are harmful solids, liquids, or gases produced in higher than usual concentrations that reduce the quality of our environment.

The air pollution is a gift of industrial civilization. Lack of development of a culture of air pollution control has resulted in serious air pollution problems in the developing countries like Nepal. In our country, outdoor air pollution is a problem in the major cities like Kathmandu valley.

Logical framework

Due to the environment contamination being a greater threat to human health, Nepal has more air pollution. Excessive particle inhalation and exposure. The primary contributors to this contamination are emissions of SO_2, NOx, volatile organic compounds, and a variety of hazardous compounds, including heavy metals and persistent organic pollutants. Energy use and transportation-related pollutants. The main effects are eutrophication of soils and waters,

acidification of water and soil, and summer smog produced by tropospheric ozone. Acidification and eutrophication are caused by SO_2, NOx, and NH_3. Heavy metals and persistent organic pollutants promote bioaccumulation of hazardous chemicals, while NOx and volatile organic compounds deplete ozone.

Air pollution is often classified into three general categories: ambient, indoor, and Tran's boundary. The air near the ground, which is referred to as ambient air, is typically broken down into these three categories. refers specifically to air within structures, whether at work or at home, and is in direct connection with the living environment; Additionally, pollutants that have entered the upper atmosphere and travel far from their source are referred to as trans-boundary air pollution.

Objective

To examine and assess the negative effects of air pollution on human health in Nepal.

Methodology

The subject-related research publications were reviewed and analyzed. The process of scientific review was used in the study, and the results were combined to find solutions to the effects of air pollution on human health. The usage of low-quality fuel and inefficient energy production methods results in air pollution. Typically, economic expansion necessitates increased energy consumption. Through respiration, it has a direct impact on people. During the scientific review, strategies would include in-depth archival analysis followed by an intensive review. Qualitative and quantitative research methods would be useful depending on the type of data that is accessible. The review was carried out methodically by gathering research papers, reports, and facts.

Result and Discussion

The comprehensive results and discussion reveal that local pollutants such as carbon monoxide, suspended particulates, and hydrocarbons significantly contaminate the air in Nepal, posing severe threats to human health. In major cities like

Kathmandu, air pollution sources include vehicular emissions, street dust, black smoke from brick kilns, and garbage burning. The social and environmental aspects of sustainable urban mobility in developing countries like Nepal depend heavily on managing vehicle emissions and air pollutant loads.

Particulate matter (PM) with minute diameters enters the respiratory system, leading to diseases such as cancer, cardiovascular and respiratory illnesses, and neurological and reproductive disorders. Key pollutants, including inorganic trace gases (NH_3, HNO_3, SO_2, and HCl) and carbon-containing gases (CO_2, CO, CH_4), are found in high concentrations especially before the pre-monsoon season in semi-urban areas near the valley's center. Both indoor and outdoor air pollution are critical issues, with indoor air pollution (IAP) from biomass fuel burning being the fourth leading risk factor for morbidity and mortality in low-income countries like Nepal.

Efforts for controlling air pollution remain inadequate, with limitations in ecosystem health monitoring, control of trans-boundary pollutants, and insufficient real-time air quality monitoring stations, especially beyond urban centers. The Air Quality Index (AQI) classification delineates risk levels from 'good' (0–50 AQI) to 'hazardous' (301–500 AQI). Kathmandu Valley regularly experiences poor air quality, particularly in dry winter months, with PM2.5 concentrations reaching hazardous levels (up to 161 µg/m³ in suburban Lalitpur and 149 µg/m³ in urban Kathmandu), increasing health risks for valley residents.

Urbanization, population growth, traffic congestion, and unregulated construction activities are critical contributors to worsening air pollution in Nepal, particularly in rapidly growing urban centers like the Kathmandu Valley. The demographic expansion has led to a significant rise in vehicular traffic, industrial activities, and construction, all of which emit pollutants such as particulate matter and harmful gases. These emissions exacerbate the already poor air quality due to geographical factors, including the valley's bowl-shaped topography that limits pollutant dispersion (FHI360, 2024). The political ecology of urban expansion has also prioritized development over environmental protection, leading to gaps in regulatory enforcement and urban planning policies, which further worsen air pollution (Acharya, 2024).

Street vendors and other outdoor workers who spend extended periods near busy roads are particularly vulnerable to air pollution hazards, emphasizing the urgent need for providing personal protective equipment (PPE) such as masks. This protects the health of these socioeconomically disadvantaged groups who often bear disproportionate exposure risks (Mishra & Aithal, 2023).

Economic and infrastructural aspects are vital in combating air pollution. Cost-effectiveness research by Mishra and Chaudhary (2018) offers valuable analytic frameworks useful for evaluating intervention strategies. Ongoing assessments of construction project performance (Mishra & Bhandari, 2018) and financial analyses of contractor stability (Mishra & Regmi, 2017) provide comprehensive approaches to ensuring sustainable urban development that can reduce pollution sources. These methodologies, when applied within the context of rapid urbanization, are essential to integrate public health considerations with infrastructure planning and economic feasibility.

Therefore, addressing Nepal's air pollution challenge necessitates a multidisciplinary effort involving ethical institutional leadership (Mishra et al., 2024), targeted human resource strategies emphasizing health and safety (Mishra & Aithal, 2021;b), economic evaluations, culturally sensitive policy frameworks (Mishra, 2022), and inclusive urban governance. This holistic approach will facilitate effective policies and interventions to improve air quality and safeguard human health in Nepal's dynamic urban environments.

Conclusion

Cleaner interior environments, such as using clean fuel, cooking in a separate kitchen, not smoking indoors, and consequently no indoor pollution, were preferred by females and the household head's educational level in adjusted binary logistic regression. On the other hand, rural areas and households in the lower wealth quintile did not want a cleaner indoor environment.

The local government and commercial sectors must work together to provide street vendors with high-quality personal protective equipment (PPE), such as masks.

The main causes of air pollution are the energy, industrial, and transportation sectors. The use of subpar fuel and ineffective energy production techniques. Economic expansion typically necessitates higher energy consumption. Pollutant emissions are a product of current energy consumption trends. Local contaminants like carbon

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