Understanding the Health Effects of Exposure to Air Pollution and Estimating the Public Preferences for Air Quality Improvement: A Study from Siddharthanagar Municipality of Nepal

Survey Report

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Executive Summary

Siddharthanagar municipality of Nepal is currently at the crossroad of urban growth and environmental fragility. The worsening air quality of the municipality, in particular, has posed a serious threat to the public welfare. Due to lack of studies, however, information regarding the effects of air pollution in the municipality are not well understood. In addition, there is no amply understanding of the public's perception of the air quality and their preferences for air quality improvement in the municipality. In the summer of 2019 (June-July), we conducted a survey in the municipality by interviewing 611 randomly selected households to fulfill this research need. The study was funded by the South Asian Network for Development and Environmental Economics (SANDEE)—ICIMOD.

The surveyed households were asked about their perception, knowledge and awareness about air pollution, their health conditions, their work location and time-use pattern, the type of fuels/stoves they use at home, the preventive measures they use to avoid pollution exposure, and their willingness to pay for air quality improvement in the municipality. During the survey, lung capacities (a biomarker of respiratory health) of respondents from 306 households were also measured using a *Spirometer* device.

In our preliminary analysis, we found that households have some basic understanding of air pollution and its effects. A large percentage of households were able to identify some of the causes of air pollution and the diseases that can be caused by it. However, misconceptions about the nature of air pollution, such as the belief that clear looking and non-smelling air is not polluted, was found to be high among the households. Likewise, a majority of households were not aware that fatal diseases, such as cancer, pneumonia, and bronchitis, are associated with air pollution. It is interesting to note that households' perception of the air quality and how strongly they feel that they are being affected by air pollution varies widely by ward, suggesting that the effects of air pollution are not felt uniformly by the residents of the municipality. It came as a surprise that only one-third of the households have received information about air pollution through any source and less than 5% have received information from the municipality and government agencies.

Our data indicate that one-fifth of the respondents are required to work outdoors and as many as 6.5% of the respondents remain outdoors for more than 12 hours a day, which exposes them to the ambient air pollution for a long period of time. A majority of respondents who spend

more than 12 hours in a day outdoors are either daily laborers, farmers, or businessmen. Housewives and those who are unemployed tend to spend less time outdoors.

The exposure to household air pollution is largely determined by the fuels/stoves used for domestic purposes and the type of kitchen in the house. Although a majority of households in Siddharthanagar municipality are currently using environmentally friendly fuels, such as liquefied petroleum gas (LPG), as a primary source of energy in their houses, a significant percentage of households are still relying on biomass. Furthermore, many of such households do not have partitioned kitchen and/or chimney facilities inside their houses.

We found that the use of facial masks is the most common preventive measure used by households to reduce their exposure to air pollution. Staying more indoor, going out when the pollution level is low, and using cleaner stoves and fuels are the other popular preventive measures. We found a strong correlation between households' awareness about the health impacts of air pollution and their use of preventive measures. Intriguingly, the use of facial mask (and other preventive measures) was found to be low among daily laborers and farmers who are required to work outdoors for a long period of time. When asked what prevents households from using preventive measures, households identified the lack of money, time, resources, and knowledge as the main factors, although several households deemed that the use of any preventive measures is unnecessary for them.

Our data on lung capacity (biomarker of respiratory health) reveals that nearly one-fourth of the respondents have obstructive lungs disorder. The obstructive disorder is more prevalent among respondents who are required to work outdoors: daily laborers and farmers. We also asked the households to report any illnesses they suffered from in the past 30 days. Roughly one-sixth of the households reported that member(s) of their household got sick, with dust allergy, nausea and headache, and cough with phlegm being the most prevalent sicknesses. These sicknesses were more common among females and households that use biomass for domestic purposes. We further found that nearly one-tenth of the households missed their work and/or school due to illness and the average illness treatment cost for the overall sample was NRs. 1525. Intriguingly, the percentages of households that have obstructive lungs disorder, that suffered from illnesses, the average number of days of work and/or school missed, and the average illness treatment costs vary widely by ward, further suggesting that the effects of air pollution are not uniform across the municipality.

Finally, we analyzed how much the households are willing to pay for air quality improvement in the municipality. We found that nearly half of the households are willing to pay and NRs. 980 is the mean willingness to pay for the overall sample. Our preliminary analysis suggests that households' willingness to pay is determined by their education level and their wealth. More than half of households who reported that they are not willing to pay expressed that they cannot afford to pay at this time.

Acknowledgement

The survey was conducted by the Nepal Study Center (NSC) of the University of New Mexico (UNM) in collaboration with Pratiman Neema Memorial Foundation (PNMF), Nepal. The research team consisted of Dr. Alok K. Bohara (Professor, Department of Economics, UNM; Director, NSC), Niraj Khatiwada and Mohammad Mashiur Rahman (Doctoral students, Department of Economics, UNM), Ms. Swati Thapa, Mr. Prakash Rayamajhi, Mr. Dharma K. C., Mr. Anup Poudel, and Sharada Pathak (Research Team, PNMF). We would like to extend our graduate to the South Asian Network for Development and Environmental Economics (SANDEE)—ICIMOD for providing us funds to conduct this research. We would also like to thank all the municipality officials, ward officials, health professionals, representatives of the women's group, and the locals who participated in our focus group discussions. We would also like to express our gratitude to our field supervisor, Mr. Krishna Neupane, and our enumerators—Suraj Kahar, Manoj Kumar Prajapati, Dharm Nath Harijan, Bijay Baniya, Rakesh Agrahari, Imran Ali, Dinesh Yadav, Ganga Sagar Chaudhary. Finally, we are very thankful to all our survey respondents for their valuable participation in our study.

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A. Study Site and Research Motivation

In the last few decades, Siddharthanagar municipality of Nepal has experienced rapid urbanization. As the municipality is in close proximity to a bustling Nepal-India open border (Sunauli) and the world heritage site of Lumbini, it has become one of the busiest cities in Nepal in terms of transportation and tourist influx. With the completion of the Gautam Buddha International Airport in sight, the municipality is expected to experience further urban growth. In the absence of careful governmental planning, however, the rapid expansion of the municipality has posed a serious threat to the environment, especially the air, and put sustainable development and public welfare at risk.

There are currently no policies or programs in place to adequately address the problem of air pollution in Siddharthanagar municipality. Moreover, hardly any study has been conducted to assess municipality residents' current respiratory health conditions and amply understand their knowledge, awareness, attitude, belief, and behavior towards air pollution. Without enough information, it is not clear whether the municipality residents have accurate information about the level of air pollution in the municipality and to what degree their health is being affected by air pollution. Additionally, there is no vivid understanding of the public preferences for improving the air quality in the municipality. The overarching aim of this study was to fulfill these very research needs.

This study had three main objectives: to understand the health effects of exposure to air pollution, to examine the public preferences for air quality improvement in the municipality by estimating households' willingness to pay for the improvement, and to estimate the economic cost of air pollution in the municipality in terms of expenditure on illness treatment and lost working days due to illness. We envision that our findings will help policymakers in designing interventions and policies to address the problem of air pollution in the municipality.

Survey Procedure

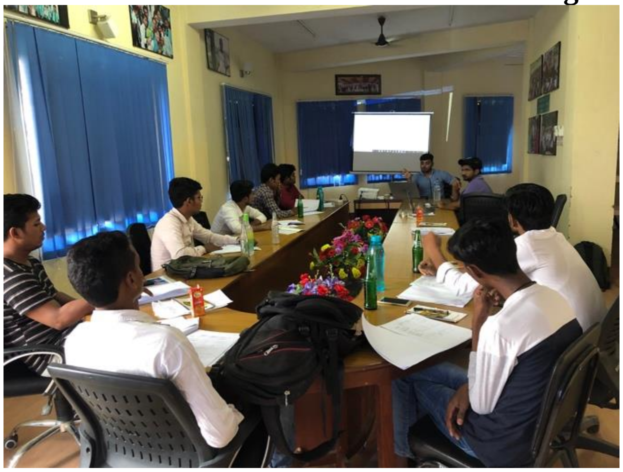
The research team did a thorough literature review on issues pertaining to air pollution before preparing the questionnaire. Selected questions were included in the questionnaire to precisely address our research objectives. The original questionnaire was drafted in English, which was later translated into Nepali. Following the clearance from the Institutional Review Board (IRB) of UNM, the research team went to Siddharthanagar in the first week of June 2019.

Immediately after arriving in Siddharthanagar, the team conducted two rounds of focus group discussions (FDG) with the local representatives to discuss the questionnaire. The participants of the FDG included municipality officers, ward officers, health professionals, women's group representatives, and some locals.

The research team taking part in the focus group discussion

The team also conducted five debriefing and training sessions with the enumerators. Eight local enumerators who were familiar with the local surroundings and dialects were selected to take part in the study. The enumerators were trained on how to sample the households, how to approach the households, and how to ask questions and record the answers.

The research team conducting training sessions for the enumerators



After the FDG and debriefing sessions, the questionnaire was modified to incorporate the suggestions from the local representatives and the enumerators and was then tested in a pre-test survey on 64 households. The pre-test survey provided an opportunity for the research team to know whether the respondents were able to understand the questions, whether the enumerators were able to follow the survey process, and how long it took to complete a survey. The questionnaire was further modified and finalized after incorporating the feedback from the pre-test survey.

Sample Selection

The final survey comprised of 611 households from the municipality. The municipality is subdivided into 13 wards, so the proportional sampling was based on the number of households in each ward. For example, there are 18,763 households in the municipality and 922 of them reside in ward number 2 (4.91% of the total households in the municipality). So, the number of households to be sampled from ward 2:

$$\frac{922}{18,763} \text{ X } 611 = 30 \text{ households}$$

The same technique was applied to calculate the sample for the other 12 wards. The number of households sampled from each ward is presented in Table A1.

Table A1. Ward-wise sample selection

Ward	Total HH per ward	HH sampled per ward
1	2570	80
2	922	30
3	2170	68
4	1228	39
5	552	20
6	1375	47
7	625	21
8	2475	82
9	1736	60
10	636	18
11	769	27
12	2412	80
13	1293	39
Total	**18763**	**611**

Source: Siddharthanagar Municipality, 2019

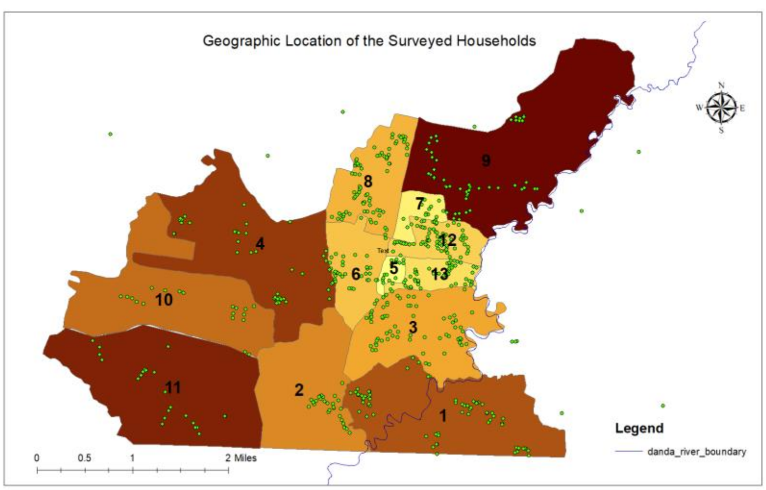
In each ward, the enumerators randomly chose a starting point and surveyed every 5th household. The enumerators were instructed to interview household representatives who are 18 years or more. Each enumerator interviewed 4 households per day. During the interview, spirometry tests were also conducted on randomly chosen 306 respondents.

Enumerator conducting the survey

Respondent taking a spirometry test

The following GIS map (Figure A1) shows the households that were surveyed in the municipality. In total, 611 households were surveyed. Since the sampling was based on the number of households in each ward, the map clearly shows that more households were sampled from wards in the municipality that are densely populated (for example, ward number 1, 3, 8, 12).

Figure A1. GIS map showing households that were surveyed in Siddharthanagar, Nepal



Source: Nepal Study Center, UNM: Summer 2019
Note: The green dots represent the households that we surveyed, and the numbers represent the wards

Table A2. Socio-economic characteristics of the surveyed households (and respondents)

	Full Sample
Male	59.3%
Average age (in years)	38.9
Average HH size (number)	6.3
Caste/Ethnicity:	
Brahmin	10.4%
Chhetri	10.7%
Janajati	14.1%
Madhesi	35.4%
Others	29.4%
Married	78.1%
Education of the HH head:	
No formal education	20.9%
Grade 1 to 8	35.0%
Grade 9 to 12	35.5%
Beyond grade 12	8.6%
Occupation of the HH head:	
Businessman	33.1%
Housewife	13.2%
Daily laborer	12.7%
Farmer	10.7%
Others	30.3%
Financial Indicators:	
Own residence	80.5%
Own land	46.3%
Income	
Less than NRs. 20,000	43.4%
NRs. 20,000 to 50,000	36.3%
More than NRs. 50,000	4.2%
Don’t know/ Refused to answer	16.1%

Source: Nepal Study Center, 2019

Table A2 presents the socio-economic characteristics of the surveyed households (and respondents). The sample has relatively more male respondents (59.3%). The average age of the respondents is 38.9 years and approximately 80% of the respondents are below the age of 50 years. Similarly, the average household size is 6.3 and 25% of the households have 8 or more members. Roughly one-third of the sample belongs to Madhesi ethnicity (35.4%). In the sample, the majority of household heads are either businessman (33.1%), housewife (13.2%), daily laborer (12.7%), or farmer (10.7%). In terms of education, only 8.6% of the household heads have studied beyond grade 12 and 20.9% of the households have no formal education. Likewise, in terms of the financial indicators, less than half of the sample own land in the municipality and of the households that reported their income, only 4.2% of them earn more than NRs. 50,000 (~ 450 USD) per month.

B. Knowledge, Awareness, and Subjective Assessment of Air Pollution

Key Highlights

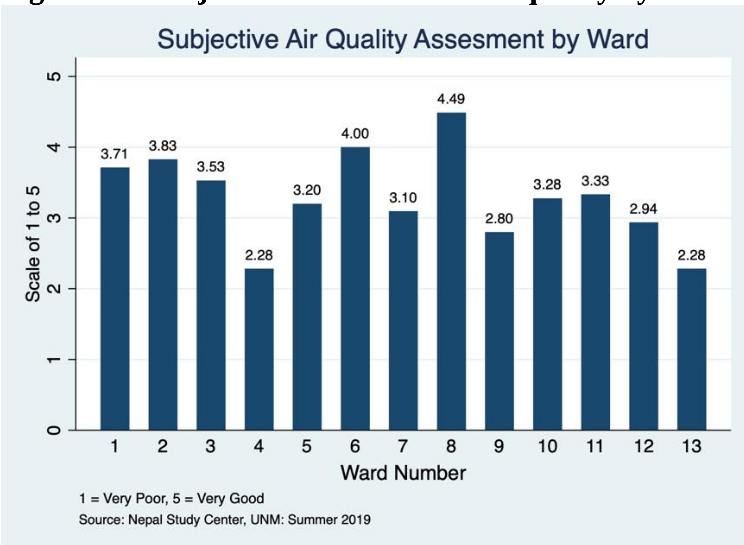
- Households' assessment of the air quality and the effects of air pollution varies by ward
- The households identify vehicle emissions, waste burning, industrial emissions, and construction activities as the main factors that contributes to air pollution in the municipality
- A majority of households agree that the problem of air pollution will continue if nothing is done to reduce it
- 43% of the sample have the misconception that clear looking air isn't polluted
- 81.15% of the sample have at least some awareness about the health impacts of air pollution
- Only 33% of the sample have read or heard about air pollution in the last 30 days and a majority of them (81%) heard about it through television

Discussion

Subjective assessment of air pollution

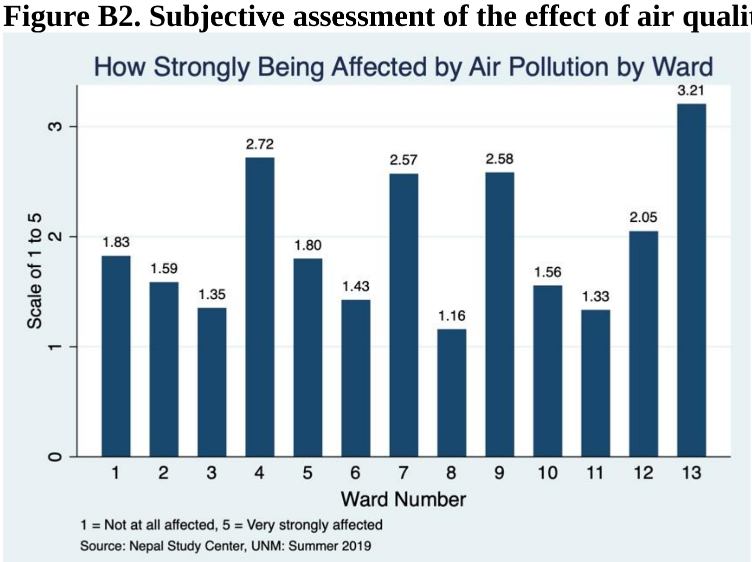
Perception about the air quality has been identified as one of the major factors that drive behavioral change (Semenza et al. 2008). In the survey, the respondents were asked: on a scale of 1 to 5, where 1 means "very poor" and 5 means "very good", how they rate the air quality near where they live. Only 16% of the respondents reported that the air quality is poor and 34% reported that the air quality is acceptable. It is important to note that the remaining 50% assess the air quality to be either good or very good. Interestingly, the assessment of the air quality is different by ward (Figure B1), suggesting that households perceive the air quality differently at different spatial regions within the same city.

Figure B1. Subjective assessment of air quality by ward



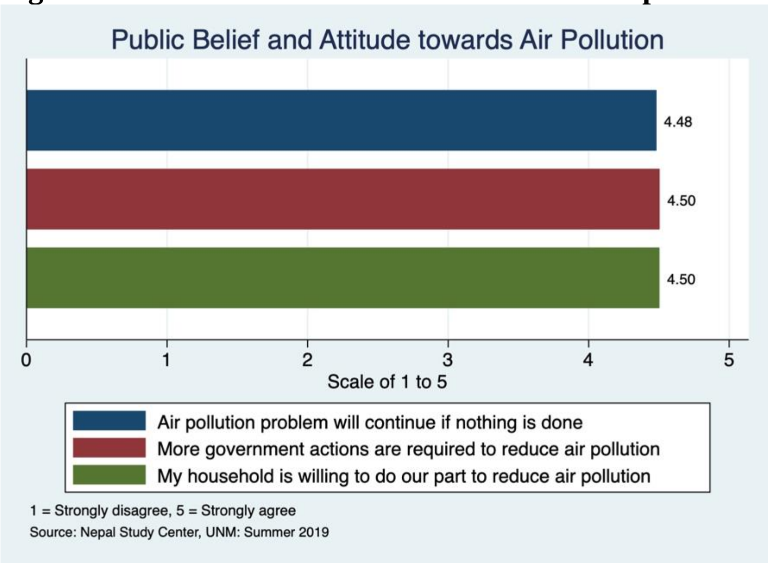
The respondents were also asked how strongly they feel that their households are being affected by air pollution. Around 49% of the respondents reported that they are not being affected at all, while 12% reported that they are either strongly or very strongly being affected. Again, the ward-wise comparisons (Figure B2) show that the assessment of the effect is different by the ward. A Chi-square test of association between the assessment of the air quality and the assessment of the effect demonstrates that the two assessments are strongly associated (Chi-square-value: 402.7). That is, households that perceive the air quality in their area to be poor feel that they are strongly being affected by air pollution.

Figure B2. Subjective assessment of the effect of air quality by ward



While the assessment of air quality and the effect is different for different households, the majority of households agree that the problem of air pollution will continue if nothing is done to reduce it, the government should do more to reduce air pollution, and the households are willing to do their part to reduce air pollution (Figure B3).

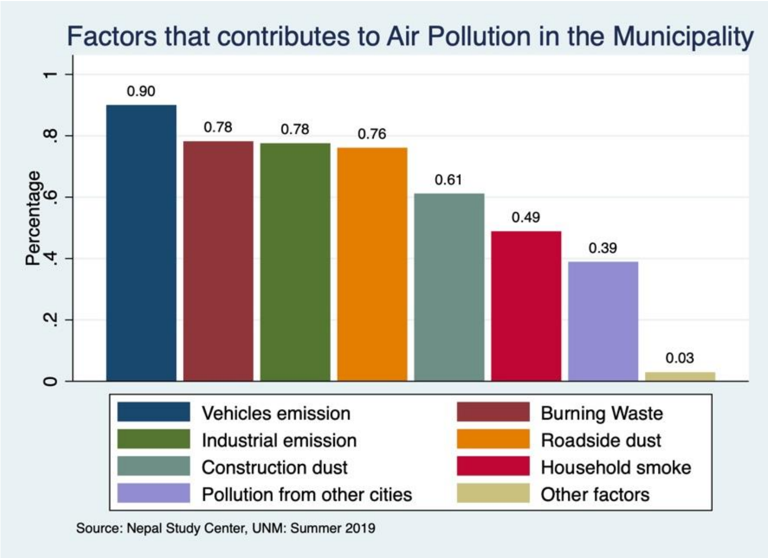
Figure B3. Public belief and attitude towards air pollution



Factors that contribute to air pollution

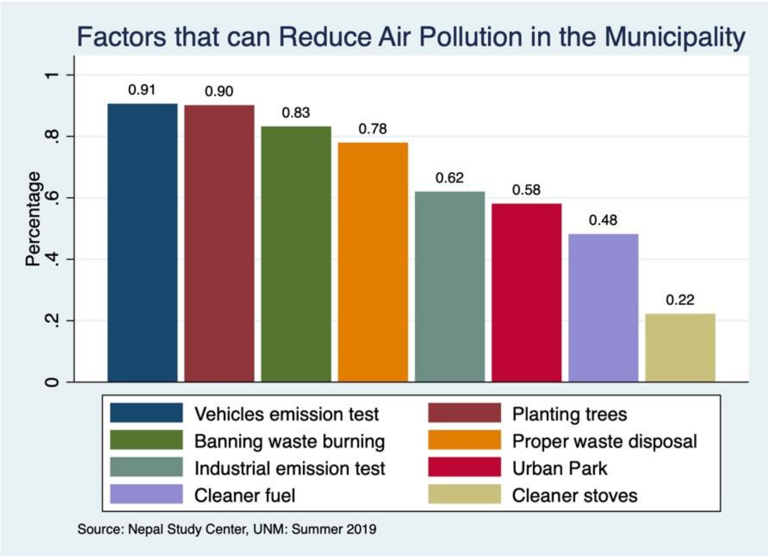
When asked what factors they think contribute to air pollution in the municipality, households identified vehicle emissions, waste burning, industrial emissions, construction activities, and household smoke as the main factors that contribute to air pollution in the municipality (Figure B4). It is interesting to note that 39% of the households also identified pollution from other cities as a factor that contributes to air pollution in the municipality, which closely aligns with the findings in Rupakheti et al. (2017) that the air pollution originating in the South Asian and the Indo-Gangetic Plain region also gets transported to the region around Lumbini.

Figure B4. Factors that respondents think contribute to air pollution in the municipality



Correspondingly, the households think that the air pollution in the municipality can be reduced if vehicles and industries are regularly tested for emissions, waste is properly disposed instead of burning, tree plantation and urban parks are prioritized, and households are encouraged to use cleaner fuels and stoves (Figure B5).

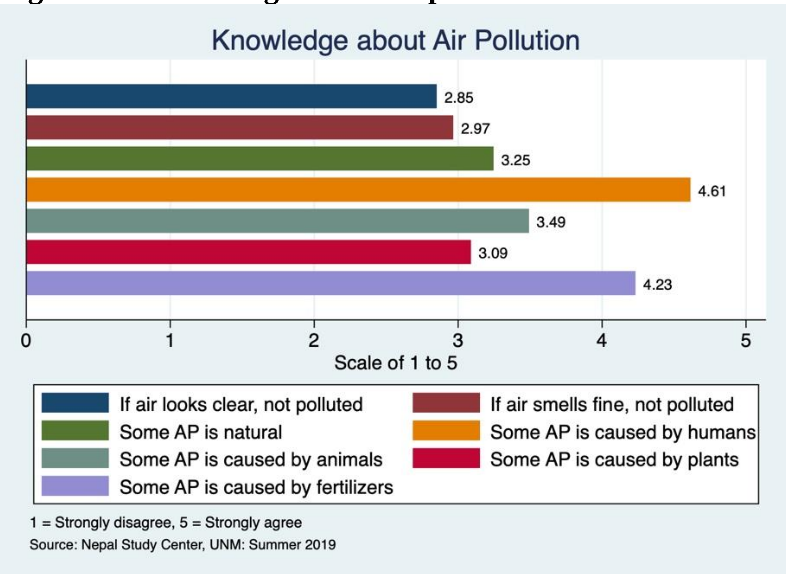
Figure B5. Factors that respondents think can reduce air pollution in the municipality



Knowledge, awareness, and information about air pollution

Several questions were asked to the respondents about the nature of air pollution. The objective was to assess their knowledge about air pollution. Most respondents affirmed that human activities and the use of fertilizers are responsible for air pollution (Figure B6).

Figure B6. Knowledge about air pollution



A study conducted by Yazdanparast et al. (2013) assesses the knowledge of Iranian students about the nature of air pollution and compares it with the knowledge of students from England, Australia, and Hong Kong. The comparison, as presented in Yazdanparast et al. (2013), is shown in Table B1. We asked some of those knowledge questions to our survey respondents from Siddharthanagar. Table B1 presents the percentage of respondents who agreed to the given knowledge statements about air pollution. The data indicates that the misconceptions that clear looking and non-smelling air isn't polluted are pretty high among the survey respondents from Siddharthanagar.

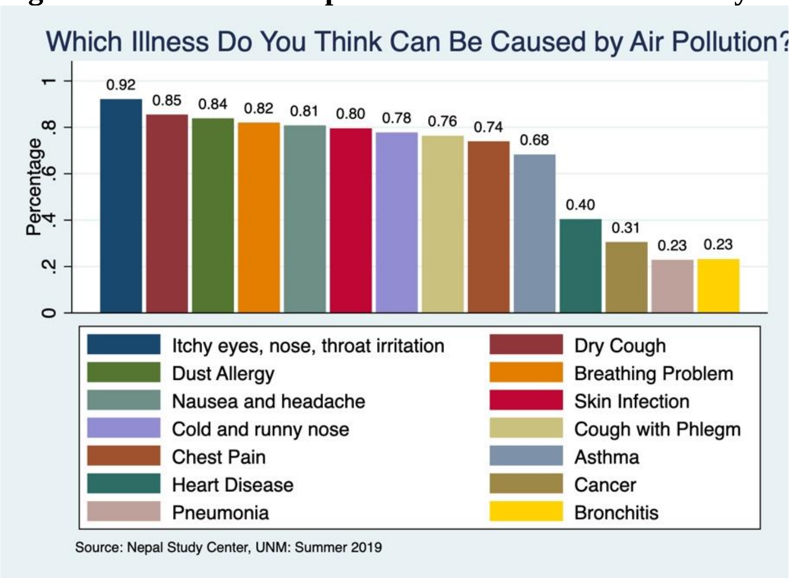
Table B1. Percentage of respondents who agreed to air pollution related knowledge statements

	Siddharthanagar	Iran	England	Australia	Hong Kong
If the air looks clear, it isn't polluted	43%	48%	10%	13%	11%
If the air smells all right, it isn't polluted	47%	35%	12%	14%	9%
Some air pollution is natural	56%	52%	44%	57%	36%
Some air pollution is caused by animals	65%	56%	45%	63%	60%
Some air pollution is caused by plants	53%	31%	26%	33%	28%

Source: Nepal Study Center, 2019; Yazdanparast et al., 2013

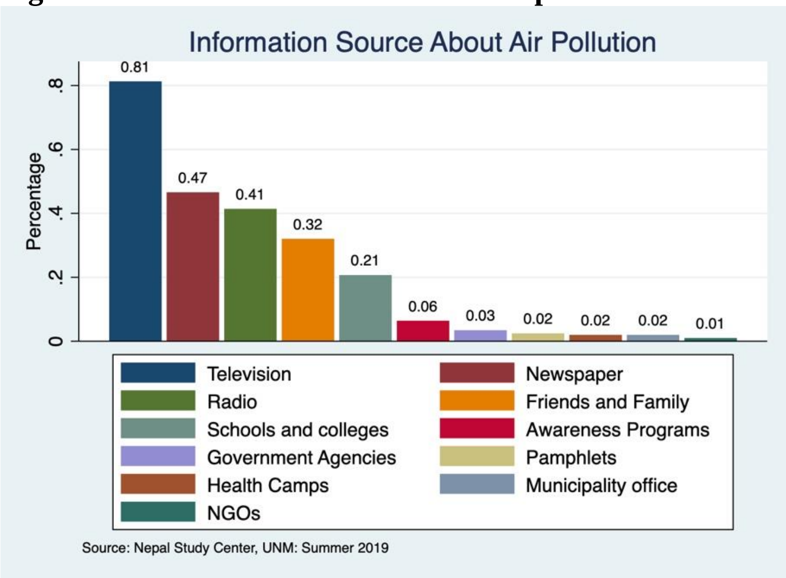
When asked if they are aware that air pollution causes various illnesses, 81.15% of the respondents reported that they are aware of the health impacts of air pollution. The respondents were presented with 14 illnesses (all of which can be caused by air pollution) and were asked to identify the illnesses that they think are related to air pollution. A high percentage of respondents were aware that illnesses such as itchy eyes, nose, and throat irritation, dry cough, dust allergy, breathing problem, nausea and headache, runny nose, cough with phlegm, chest pain, and asthma can be caused by air pollution (Figure B7). However, many respondents were not aware that air pollution can cause fatal illnesses such as heart problems, cancer, pneumonia, and bronchitis.

Figure B7. Illness the respondents think can be caused by air pollution



When asked if they have read or heard about air pollution through any source in the past 30 days, only one-third of the households reported that they have received information about air pollution, suggesting that information about air pollution has not been adequately disseminated in the municipality. Of the households that received information about air pollution, 81% of them reported that they received the information through television (Figure B8). Newspaper (47%), radio (41%), friends and family (32%), and schools and colleges (21%) were the other major sources.

Figure B8. Information source about air pollution



C. Work Location, Time-Use, and Mode of Transportation

Key Highlights

- A majority of respondents (50%) work/study at home, while 20% work outdoors
- 6.5% of the respondents remain outdoors for more than 12 hours in a day
- Mostly daily laborers, farmers, and businessmen remain outdoors for more than 12 hours
- Motorcycle (21%), bicycle (14%), and walking (11%) are the 3 most common modes of transportation
- The average time needed to go to workplace/school for those who commute is 18.3 minutes

Discussion

Work location and time use

Several studies (Gurung and Bell 2012; Dibben and Clemens 2015) have found that work location and time use patterns can determine an individual's air pollution exposure level. In the survey, we asked the respondents where they work, how much time they spend outdoors, and what time of the day they usually go outdoors. Half of the respondents reported that they work/study at home, while the percentages of respondents that work/study inside office/school buildings and outdoors are 28% and 20% respectively (Figure C1).

Figure C1. Work/study location

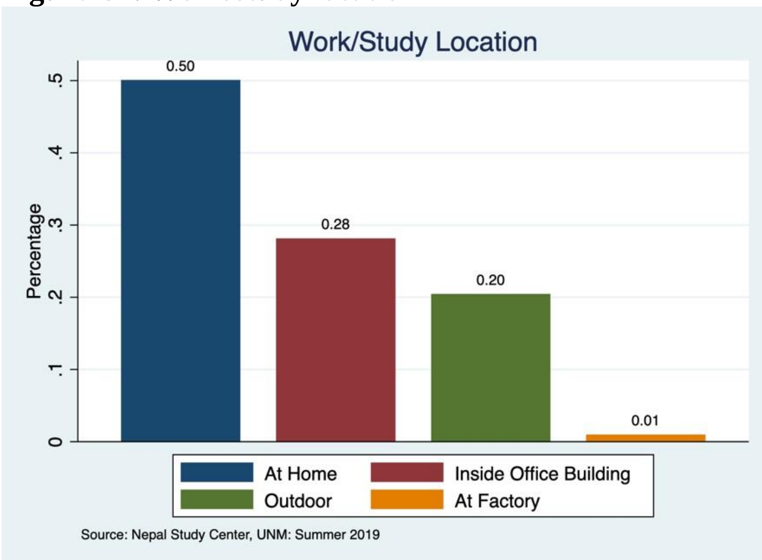
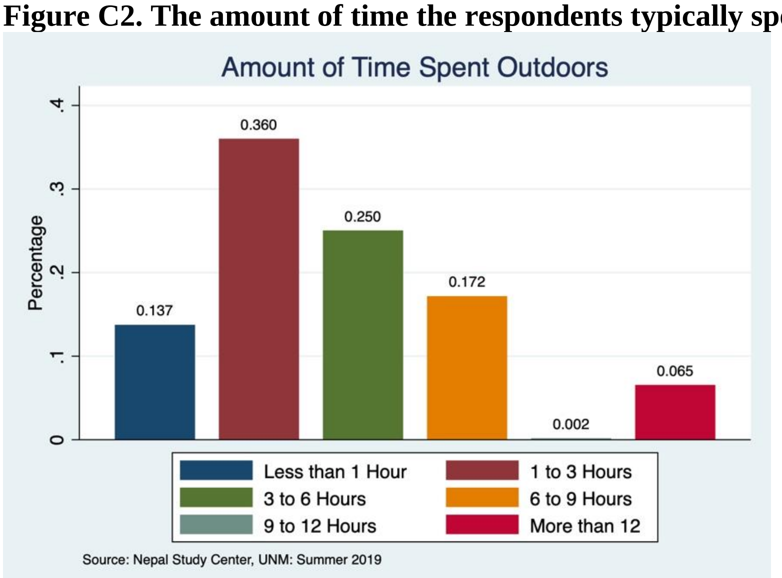


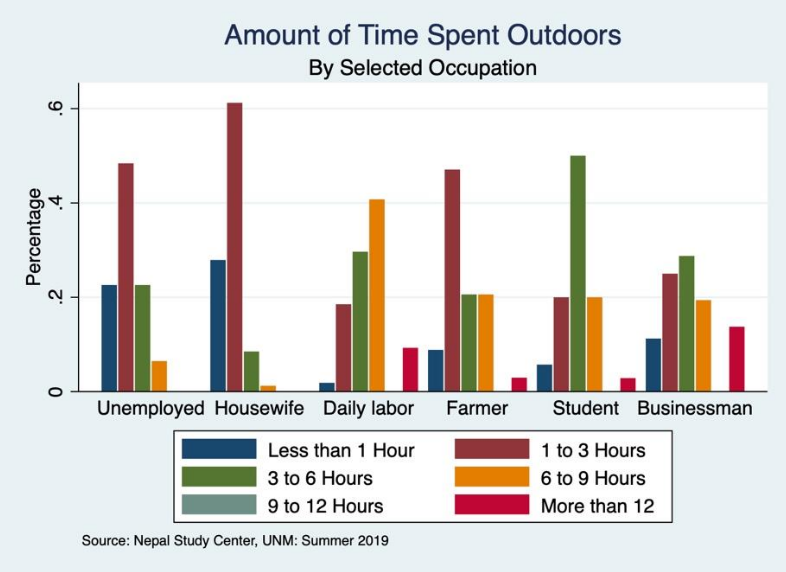
Figure C2 shows the amount of time the respondents typically spend outdoors in a day. Nearly half of the respondents spend less than 3 hours outdoors, while 25% of the respondents spend between 3 to 6 hours and 17.2% spend between 6 to 9 hours outdoors. It is interesting to note that 6.5% of the respondents spend more than 12 hours outdoors.

Figure C2. The amount of time the respondents typically spend outdoors in a day



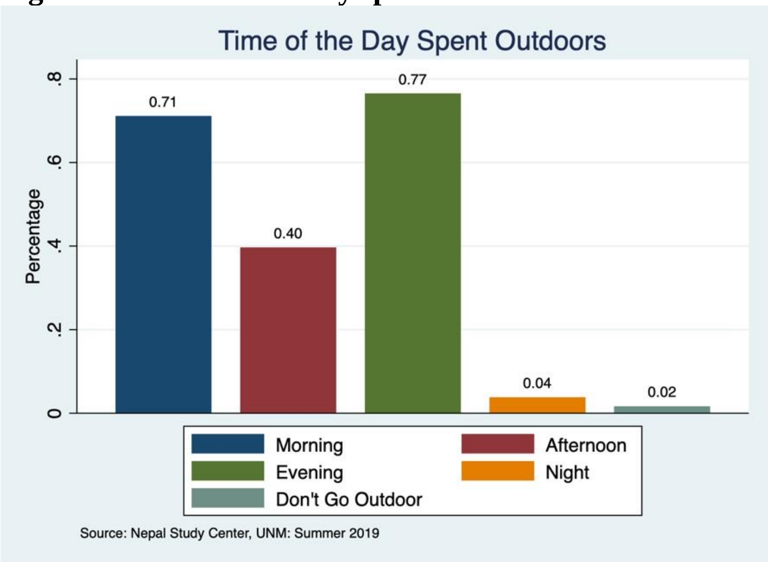
The occupation of the respondents is crucial in determining how much time the respondents spend outdoors in a day. As depicted in Figure C3, unemployed and housewives tend to spend less time outdoors, whereas, daily laborers, farmers, students, and businessmen are very likely to spend more time outdoors.

Figure C3. The amount of time spent outdoors by occupation type



We also asked the respondents what time of the day they are typically outdoors. A majority of respondents reported that they go outside in the morning and evening (Figure C4). People usually commute to the workplace/school in the morning and return home in the evening, therefore the spikes in the morning and evening are expected.

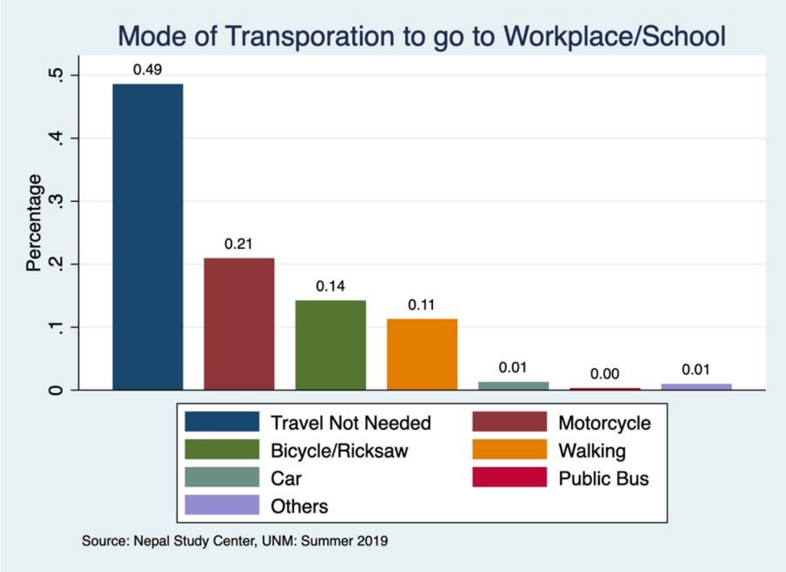
Figure C4. Time of the day spent outdoors



Mode of transportation

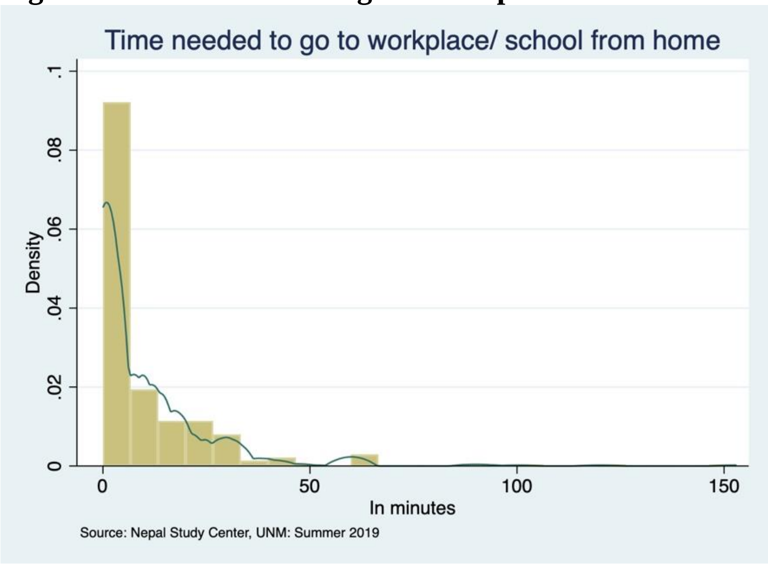
Nearly half of the respondents reported that they do not need to travel to go to their workplace or school (Figure C5). Given that 50% of the respondents work/study at their home, it is reasonable that a high percentage of respondents do not require traveling. Among those who commute to the workplace/school, motorcycle is the most popular mode of transportation, followed by bicycle (or rickshaw) and walking.

Figure C5. Mode of transportation



The following histogram (Figure C6) shows the time needed for the respondents to go to their workplaces/schools from home. The average time for a one-way commute is 9.2 minutes. If only those that require traveling are considered, then the average time for a one-way commute is 18.3 minutes. Approximately 3% of the respondents reported that they need one hour or more for a one-way commute to the workplace/school.

Figure C6. Time needed to go to workplace/school from home



D. Household Air Pollution and Smoking Behavior

Key Highlights

- 12.9% of the households have non-partitioned kitchen inside the house
- A majority of households (94.8%) do not have chimney facility in their kitchen
- While LPG gas is the most popular source of energy, 18.5% of the households use firewood and 5.3% use animal residue as their primary or secondary energy source
- The percentage of respondents who smoke and use smokeless tobacco products are 6.1% and 13.4% respectively
- 64% of the respondents who smoke, smoke 2-5 cigarettes per day

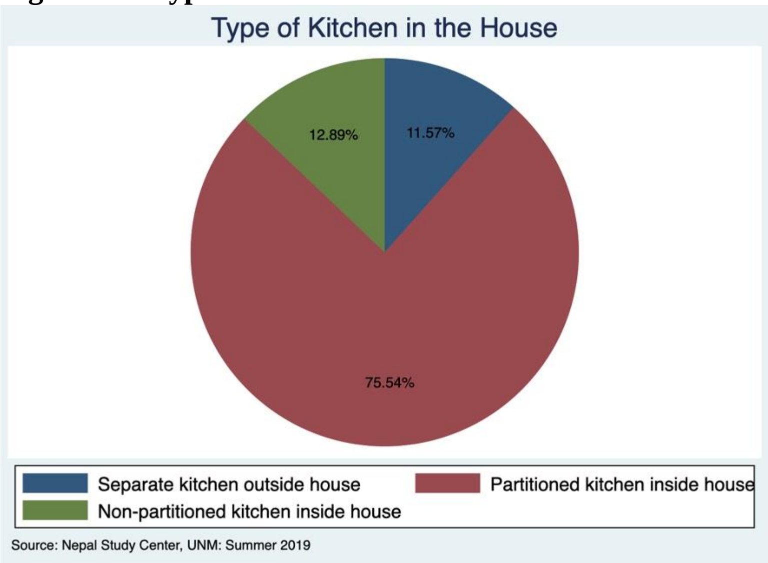
Discussion

Sources of household air pollution

In South-East Asia, smoke from the use of biomass for domestic purposes (such as cooking and space heating) is a major source of air pollution (Duflo et al. 2008). Households that primarily use biomass as an energy source are therefore very likely to be exposed to high levels of air pollution. In the survey, we asked several questions to the households to understand what type of kitchen they have in their houses and what cooking fuels and stoves they primarily use.

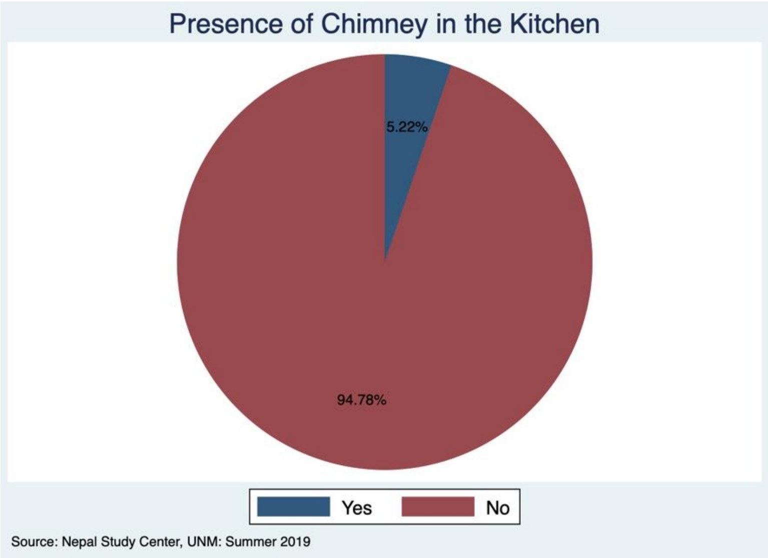
Nearly three-fourths of the households reported that they have partitioned kitchen inside their houses (Figure D1). Similarly, 11.57% have separate kitchen outside of their houses. The remaining (12.89%), however, have a non-partitioned kitchen inside their houses.

Figure D1. Type of kitchen in the house



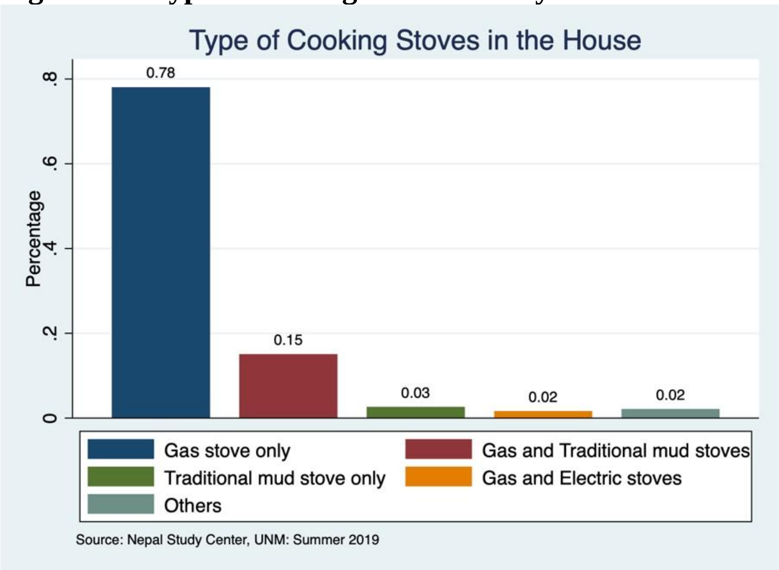
It came as a surprise that only a small percentage of the households (5.22%) have chimney facilities in their kitchens (Figure D2). In houses with no chimney facilities, the smoke emitted from cooking, especially in houses where biomass is used, is likely to remain trapped inside the houses, which could lead to health consequences.

Figure D2. Presence of chimney in the kitchen



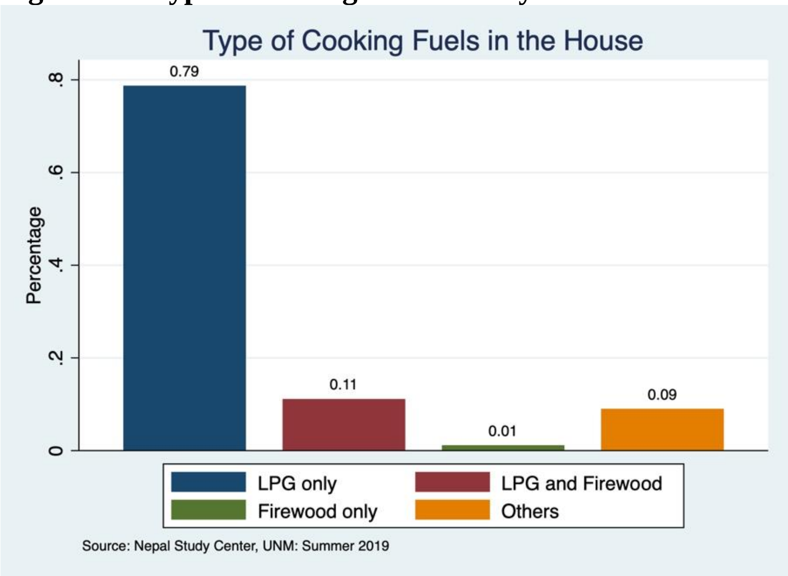
Encouragingly, a majority of households in Siddharthanagar municipality are currently using cleaner cooking stoves in their houses—78% are using gas stoves only and 2% are using gas and electric stoves (Figure D3). A significant percentage of the households are, however, still using traditional mud stoves for cooking.

Figure D3. Type of cooking stoves used by the households



Correspondingly, the use of LPG (Liquefied Petroleum Gas) is common among the households in the municipality (Figure D4). The other popular cooking fuels are firewood, animal residue, and kerosene.

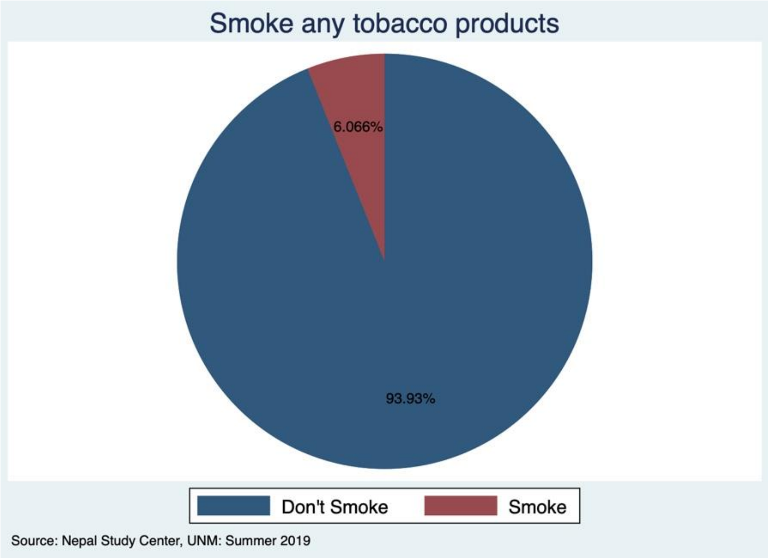
Figure D4. Type of cooking fuels used by the households



Smoking behavior

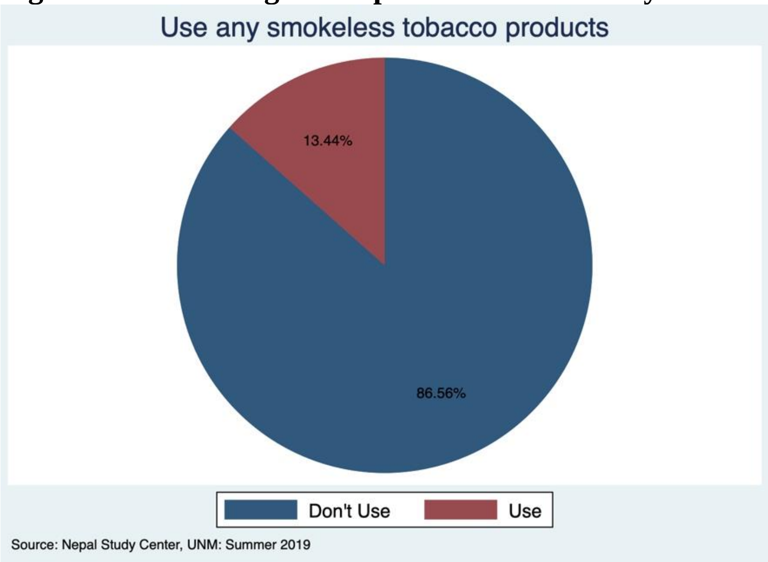
One of the important (control) factors that largely impact the respiratory health of individuals is smoking behavior (Lundbäck et al. 2003). Encouragingly, in the survey, only 6.1% of the respondents reported that they currently smoke (Figure D5). And of those who are currently smoking, 64% of them smoke 2 to 5 cigarettes per day.

Figure D5. Percentage of respondents that smoke any tobacco products



The percentage of respondents that use smokeless tobacco products, such as khaini, surti, chewing tobacco, is relatively higher (13.44%) than smoking (Figure D6).

Figure D6. Percentage of respondents that use any smokeless tobacco products



E. Pollution Exposure Preventive Measures

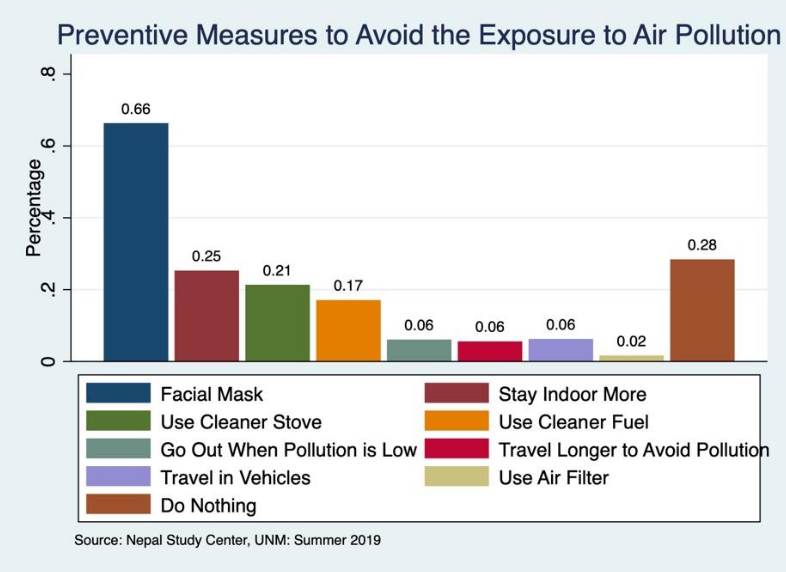
Key Highlights

- 72% of the households use at least one preventive measure to avoid air pollution exposure and 48% of the households use two or more preventive measures
- Facial mask (66%), staying indoor more (25%), using cleaner stove (21%) and fuel (17%) are the most popular preventive measures
- Awareness about the health impacts of air pollution has a strong positive correlation with the use of preventive measures
- Nearly one-third of the households are currently not using any preventive measures
- These households identify lack of money, resources, time, and knowledge as the major factors that prevents them from using any preventive measures

Discussion

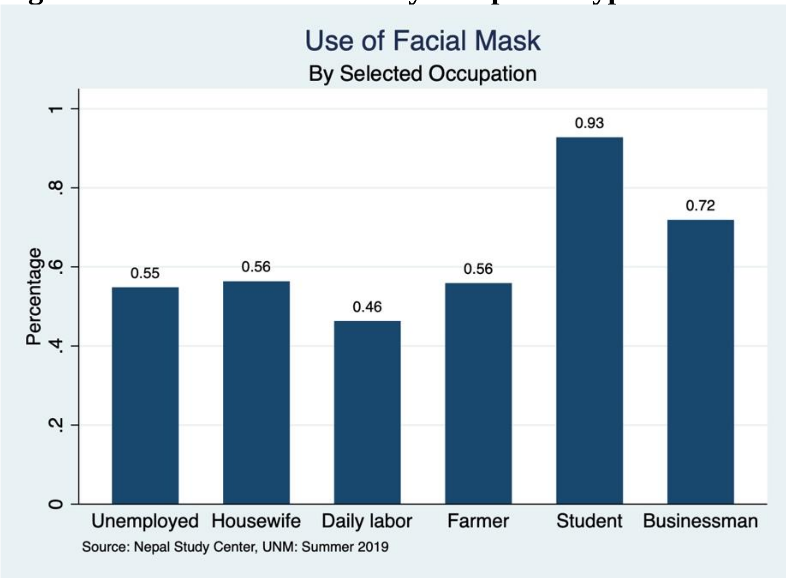
In the survey, we asked the respondents if they are currently using any preventive measures to avoid air pollution exposure. 72% of the households reported that they are using at least one preventive measure to avoid the exposure. Using facial masks (66%), staying indoor more (25%), using cleaner stove (21%), using cleaner fuel (17%), and going out when the pollution in low (6%) are the popular preventive measures adopted by the households. Roughly half the households (48%) reported that they are using more than one measure to avoid air pollution exposure.

Figure E1. Types of preventive measures used to avoid air pollution exposure



The use of facial masks is the most popular preventive measure. The use of facial masks is highest among students and businessmen and lowest amongst daily laborers, farmers, unemployed, and housewives (Figure E2).

Figure E2. Use of facial mask by occupation type



Does awareness about the health impacts of air pollution influence households to use facial masks?

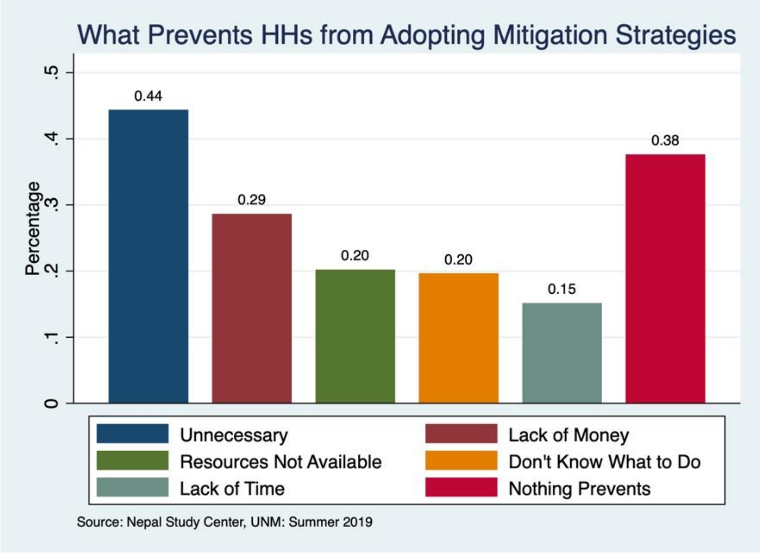
We ran a simple logit regression model to examine what factors influence households to use facial masks to reduce their exposure to air pollution. We were particularly interested to see whether awareness about the health impacts of air pollution influence households to use facial masks. We also took media information, wealth, gender, and age as other control factors that could possibly influence households to use facial masks. The location (ward) fixed effects were also controlled.

$$Facial\ Mask_i^* = \beta_0 + \beta_1\, Awareness_i + \beta\, X_i + \eta_i + u_i$$

The regression results show that awareness about the health impacts of air pollution strongly influence the households to use facial masks ($p<0.01$). Similarly, household wealth also has a strong positive influence on the use of facial masks ($p<0.01$). The coefficient on age is negative and significant ($p<0.01$), which indicates that older population are less likely to use masks.

Nearly one-third of the households (29%) reported that they are currently not using any preventive measures. We asked them what factors prevent them from using any preventive measures. 44% of the households deem that preventive measures are not necessary for them. Households that feel that prevention measures are necessary, but they have not adopted any, identify lack of money, resources, time, and knowledge as the major factors that prevent them from using any preventive measures.

Figure E3. Factors that prevent households form adopting preventive measures



F. Health Conditions

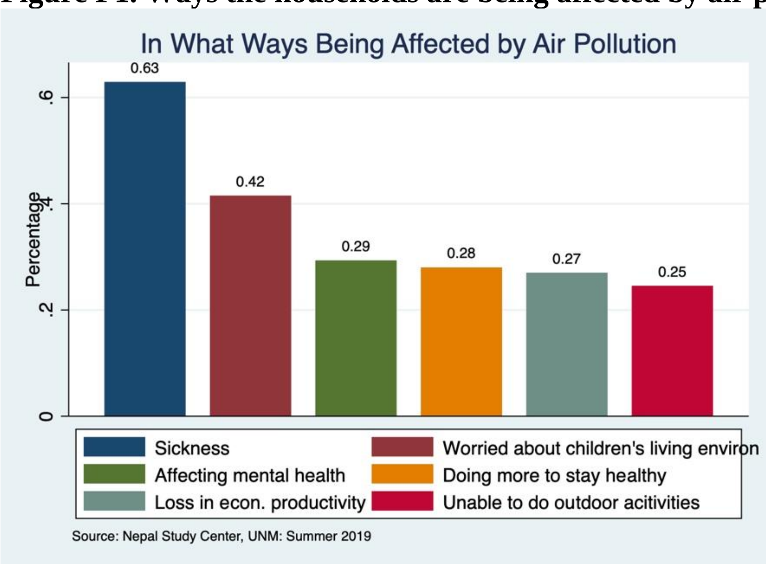
Key Highlights

- One-fourth of the respondents (27.2%) have obstructive lungs disorder
- Those who work outdoors (daily laborers and farmers) have relatively lower lung capacity
- 16.1% of the respondents reported having suffered from at least one sickness
- Dust allergy, nausea, and cough with phlegm are the most prevalent sicknesses
- Sickness is more prevalent in female

Discussion

We asked the respondents in what ways they are being affected the most by air pollution. More than half of the respondents (63%) reported that physical sickness is how they are being affected the most by air pollution (Figure F1).

Figure F1. Ways the households are being affected by air pollution



The linkage between air pollution and poor health is well-documented in the literature. American Lung Association report (2001) highlights that individuals living in polluted urban areas are very likely to suffer from respiratory illnesses like the common cold, asthma, and bronchitis, some of which can be very fatal. In addition to respiratory health degeneration, Anderson et al. (2011) find evidence that both short- and long-term exposures to high levels of particulate matter also severely affect cardiovascular health.

One of the main objectives of this study is to understand the health effects of exposure to air pollution. This study uses two methods to discern the health conditions: objective measurement (measuring lung capacity and taking it as a biomarker of respiratory health) and self-reports of illnesses. We used portable *Spirometer* devices (NDD EasyOne model) for lung capacity measurement.

Lung capacity

Spirometry is a widely used method for COPD diagnosis. In the survey, spirometer tests were conducted to access survey respondents' lung capacity. The two indicators used for lung capacity are: forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1). FVC measures the total amount of air that can be exhaled, and FEV1 measured the amount of air that exhaled in the first 1 second. The spirometer device also calculates the percentage of predicted normal values of FVC and FEV1 accounting for an individual's sex, age, height, and race.

An obstructive lung disorder is a lung condition in which the ability of a person to breath normally is impaired due to some obstruction in the airway. An individual with an obstructive lungs disorder has a predicted normal value of FEV1 $< 80\%$ and FEV1/FVC ratio < 0.7. Exposure to air pollution can cause obstructive lungs disorder. A restrictive lung disorder is a lung condition in which the size of the lungs is reduced. Individuals with restrictive disorder may be able to breathe normally (i.e. the FEV1/FVC ratio is normal) but the total volume of air they can exhale is low. An individual with a restrictive lungs disorder has a predicted normal value of FEV1 and FVC $< 80\%$ and FEV1/FVC ratio > 0.7 (Bell and Gurung 2012; British Thoracic Society 2005).

Among the respondents that took part in the spirometry, 27.15% of them were found to have an obstructive lung disorder and 45.70% were found to have a restrictive lung disorder. The ward-wise comparison of the lung capacity reveals that a large proportion of the sample from ward 1 and 13 have obstructive lung disorder (Figure F2). Likewise, approximately one-third of the sample from ward 3, 6, and 7 have obstructive lung disorder. Contrastingly, the prevalence of an obstructive lung disorder is very low in ward 5, 10, and 12.

Figure F2. Obstructive lungs disorder by ward

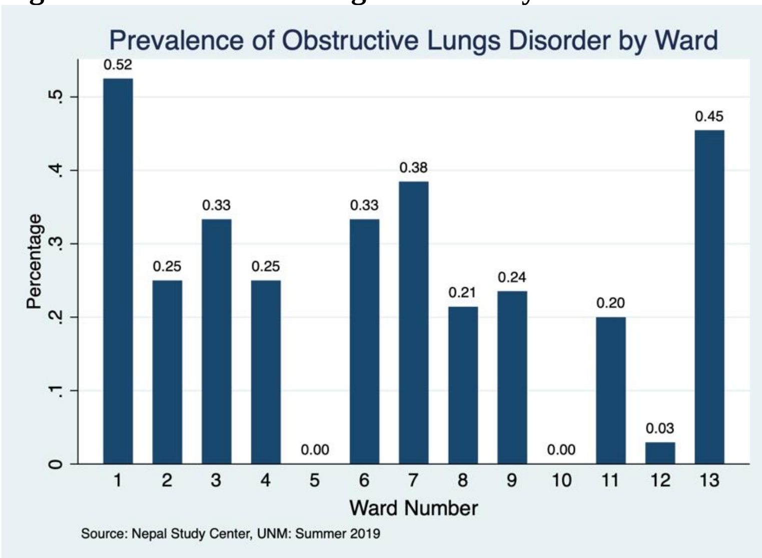
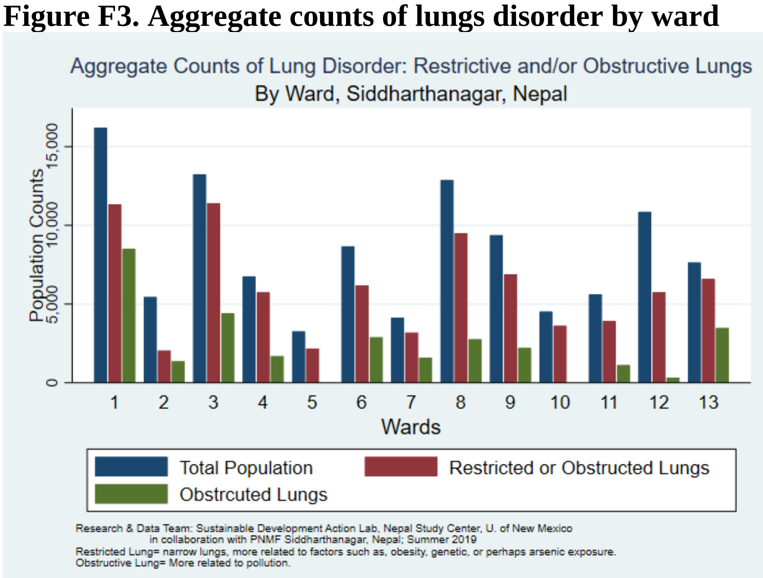


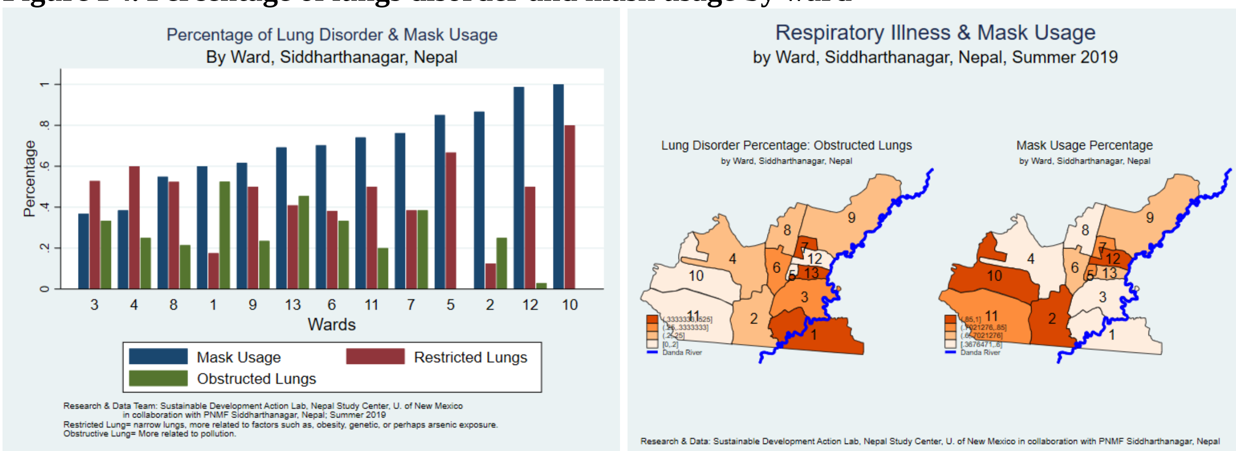
Figure F3 shows the aggregate counts of residents suffering from lung disorder by ward. The count is calculated by multiplying the population of a ward to the percentage of respondents suffering from lung disorder from the ward. Both ward 1 and 3 have a high population as well as a high percentage of lungs disorder. Therefore, the aggregate counts of lung disorders in these two wards are higher than 10,000. The lowest counts of lung disorders are observed in ward 2, 5, 7, 10, and 11—all have less than 5,000 counts of lung disorders.

Figure F3. Aggregate counts of lungs disorder by ward



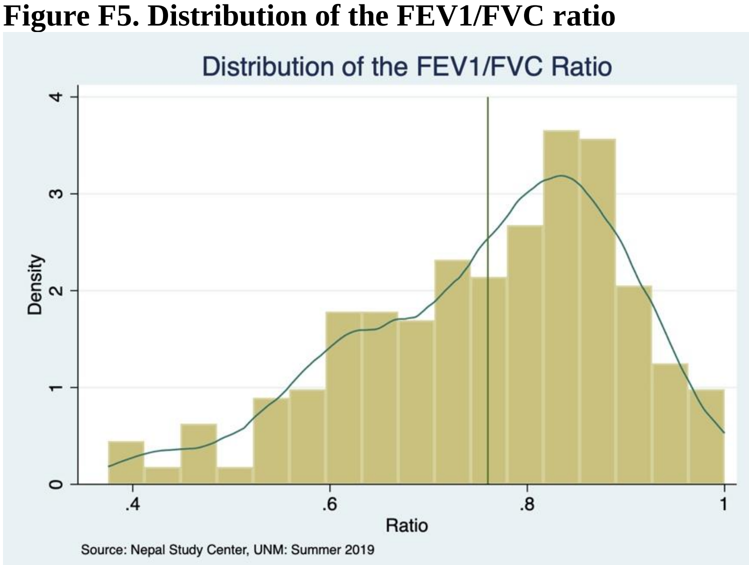
The following two graphs (Figure F4) shows the relationship between facial mask usage and lung disorder by ward. The graphs suggest a likely negative correlation between facial mask usage and obstructive disorder: ward 5, 2, 12, and 10 have high percentages of mask usage and low percentages of the occurrence of obstructive disorder. The other nine wards have low percentages of mask usage and relatively high percentages of the occurrence of obstructive disorder.

Figure F4. Percentage of lungs disorder and mask usage by ward



In the literature, the continuous ratio of FEV1 to FVC (FEV1/FVC) often taken as an indicator of lung capacity (Foster and Kumar 2011). Lower ratio suggests lower lung capacity and higher lung obstruction. The following histogram (Figure F5) shows the distribution of the ratio. The mean ratio for the sample is 0.76.

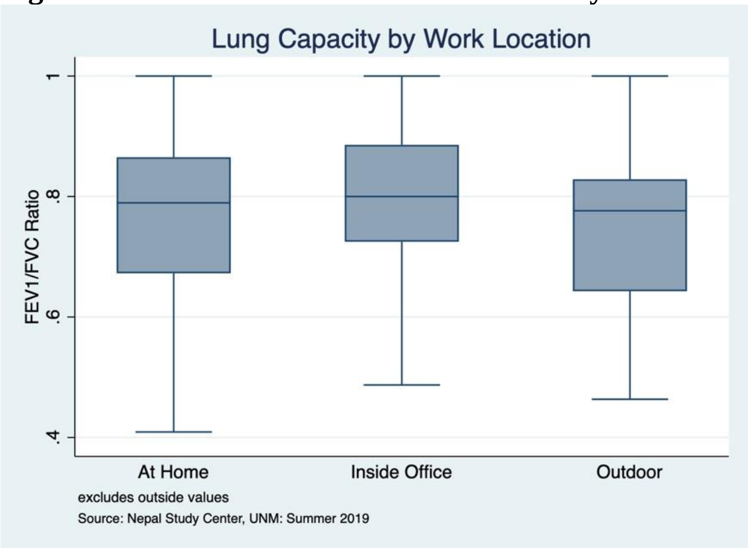
Figure F5. Distribution of the FEV1/FVC ratio



Note: The vertical line on 0.76 indicates mean

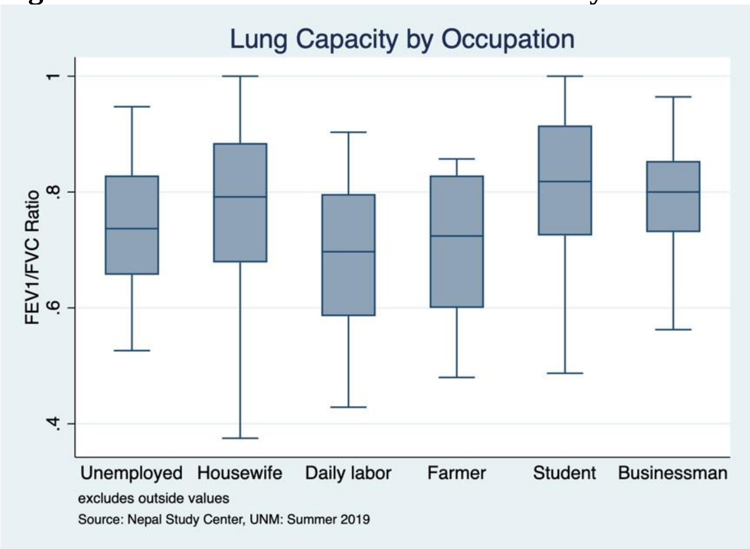
Figure F6 shows the distribution of the FEV1/FVC ratio according to the work location of respondents. The lung capacity is found to be low for those that work outdoor as compared to those who work at home and inside office buildings.

Figure F6. Distribution of FEV1/FVC ratio by work location



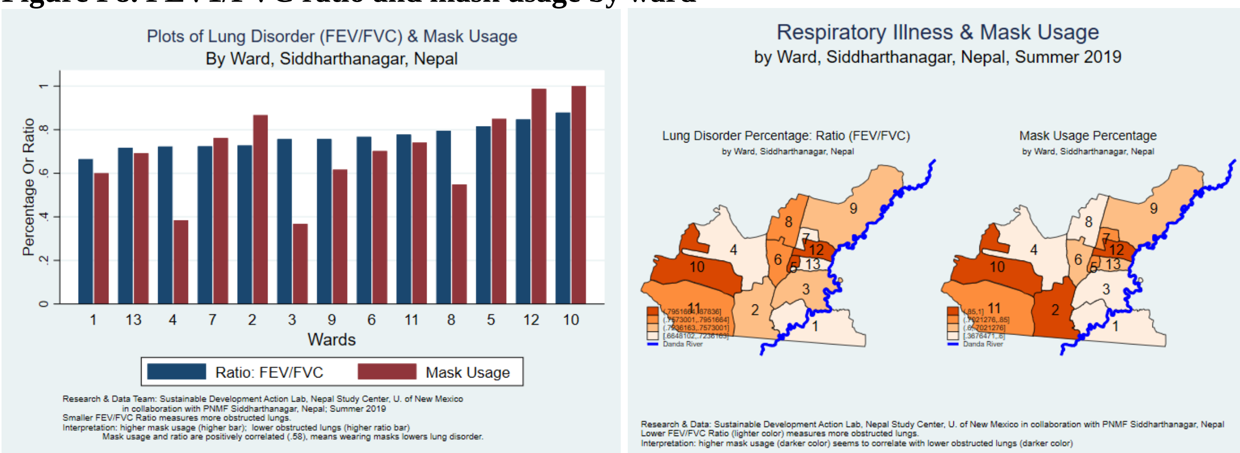
Similarly, Figure F7 shows the distribution of the FEV1/FVC ratio according to the occupation of the respondents. The graph clearly indicates that daily laborers and farmers, who are mostly required to work outdoors, have relatively lower lung capacity. The ratio is also found to be low for respondents who are unemployed.

Figure F7. Distribution of FEV1/FVC ratio by selected occupation



The following two graphs (Figure F4) shows the relationship between facial mask usage and the FEV1/FVC ratio by ward. Again, the graphs suggest a likely correlation between facial mask usage and the ratio: ward 5, 2, 12, and 10 have high percentages of mask usage and higher FEV1/FVC ratios (less lungs obstructions).

Figure F8. FEV1/FVC ratio and mask usage by ward



Does working outdoor have an effect on people's lung capacity?

We ran a simple OLS regression model to examine whether working outdoor (proxy for exposure to ambient air pollution) has an effect on people's lung capacity. In the regression model, we also took use of firewood, smoking, use of facial mask, gender, and age as other control factors that could possibly effect people's lung capacity. The location (ward) fixed effects were also controlled.

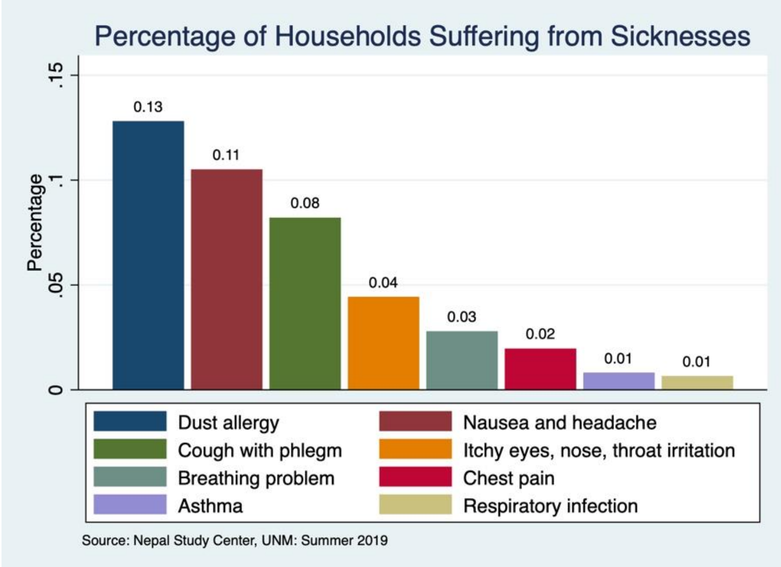
$$Lung\ capacity_i = \beta_0 + \beta_1 Work\ outdoor_i + \beta X_i + \eta_i + u_i$$

Regression results suggests that those who work outside are significantly ($p<0.05$) more likely to have lower lung capacity (and higher lungs obstruction). Interestingly, our preliminary analysis reveals that use of facial mask has no significant effect on lung capacity. There could, however, be an endogeneity issue here because, as shown earlier, facial mask usage itself is strongly influenced by awareness about air pollution impacts. Therefore, the impact of mask usage on lung capacity needs further investigation. Other important control factors like the use of firewood, smoking, gender, and age also have no significant effect of lung capacity.

Self-reports of sicknesses

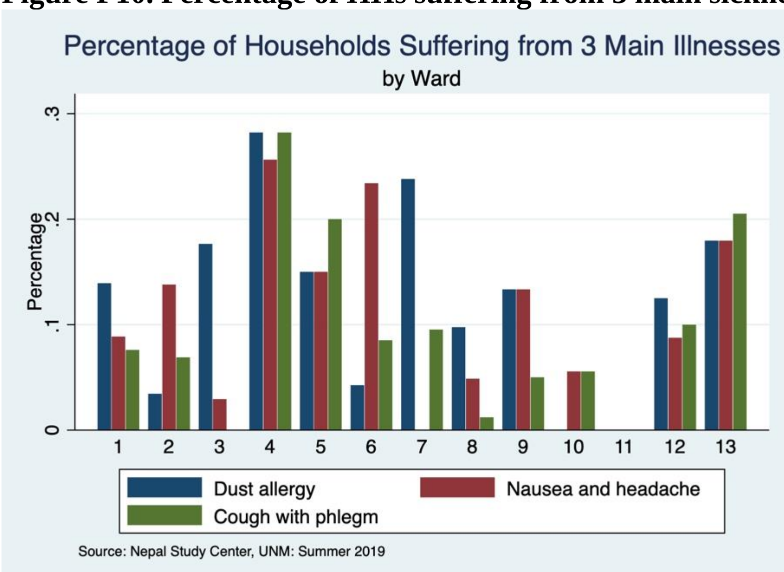
In the survey, we asked the respondents whether anyone from their households have suffered from any of these air pollution-related illnesses: dust allergy, nausea and headache, cough with phlegm, itchy eyes, nose, and throat irritation, breathing problem, chest pain, asthma, and respiratory infection. Approximately 28% of the respondents reported that someone from their households suffered from at least one of those illnesses. Dust allergy (13%), nausea and headache (11%), cough with phlegm (8%) are the 3 most prevalent illnesses (Figure F9).

Figure F9. Percentage of HHs suffering from air pollution related sicknesses



The ward-wise comparison shows that dust allergy, nausea and headache, and cough with phlegm are more prevalent in ward 4, 5, 6, 7, and 13 (Figure F10). It is interesting to note that obstructive lung disorder was also found to be more prevalent in ward number 6, 7, and 13.

Figure F10. Percentage of HHs suffering from 3 main sicknesses by ward



Does the use of firewood as the main cooking fuel increases the chances of getting sick?

We ran a simple OLS regression model to examine whether the use of firewood as the main cooking fuel (proxy for indoor air pollution) increases the chances of getting sick. The dependent variable in the regression is the number of air pollution related diseases the survey respondent suffered from. In the sample, 12.32% of the respondents reported that they suffered from one illness and 3.78% reported that they suffered from multiple illnesses. We also took smoking, working outside, use of facial mask, gender, and age as other control factors that could possibly have an effect respondent's health.

$$Number\ of\ illnesses_i = \beta_0 + \beta_1\, Use\ Firewood_i + \beta\, X_i + \eta_i + u_i$$

The finding from the regression is that respondents from households that use firewood as the main cooking fuel are more likely to get sick. Another important finding is that women are more likely to get sick than man.

G. Socio-Economic Burdens

Key Highlights

- 8.4% and 7.5% of the households have family members who missed work and school due to sickness respectively
- The average illness treatment cost for those who treated is NRs. 5,900

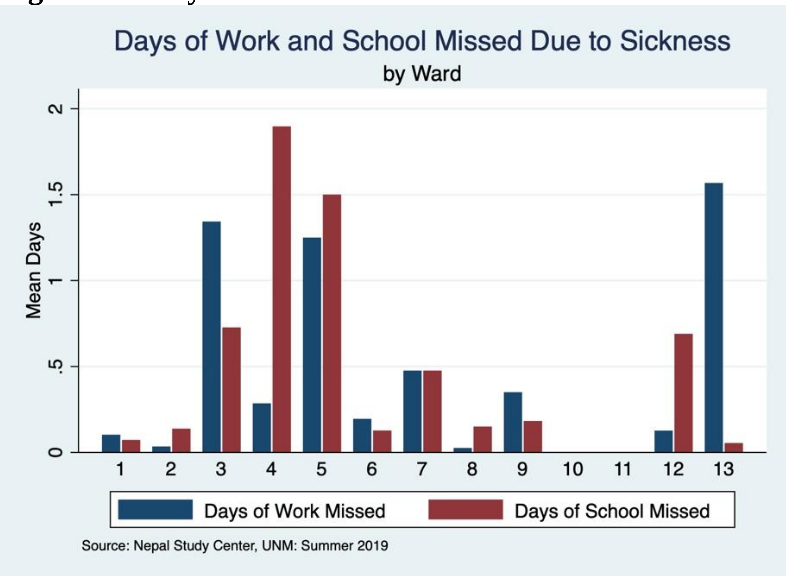
Discussion

The surveyed households reported that physical sickness is how they are being affected the most by air pollution (Figure F1). In addition to physical sickness, the households feel that the current air pollution problem is making them worry about their children's living environment and affecting them mentally. Furthermore, the households reported that air pollution is degrading their economic productivity and they are doing more to stay healthy. The households also reported that air pollution is restricting them from engaging in outdoor activities and is, therefore, hampering their social life.

Days of work and school missed

A large number of studies have found that air pollution decreases productivity (Smith 2000; Zivin and Neidell 2012). In the survey, several households reported that members of their households had to miss their school (7.5%) and work (8.4%) due to air pollution-related sicknesses. The comparison by ward (Figure G1) shows that members of households from ward 3, 4, 5, and 13, on average, were affected the most.

Figure G1. Days of work and school missed due to sicknesses by ward



In the survey, households identified dust allergy, nausea and headache, and cough with phlegm as the 3 main illnesses they suffered from. T-test comparisons (Table G1) between the average days of work and school missed for those who suffered from these illnesses and those who did not suffer demonstrate that the days of work and school missed are significantly higher for those that suffered from these illnesses.

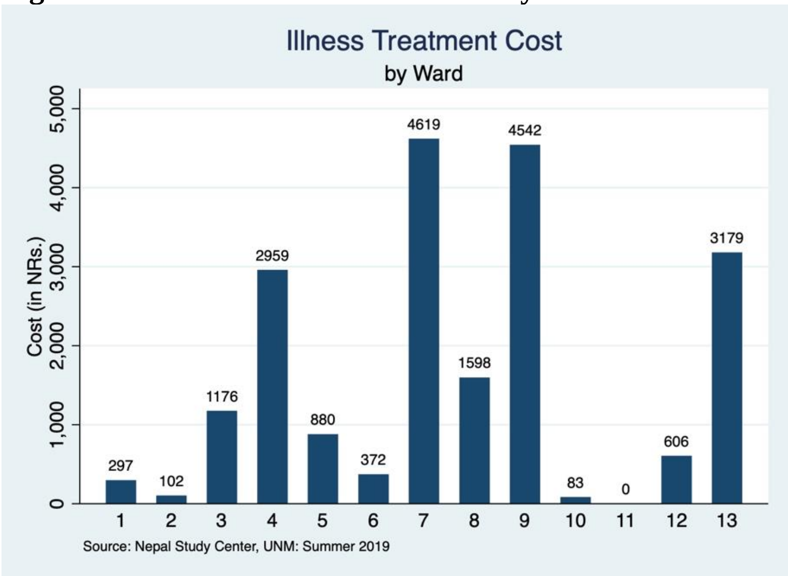
Table G1. Association between sickness and the days of work and school missed

	Dust allergy	Nausea and headache	Cough with phlegm
Days of work missed	Significant	Significant	Significant
Days of school missed	Significant	Significant (at 85%)	Significant

Treatment cost

We asked the households how much they had to spend on the treatment of the air-pollution related illnesses they suffered from. The treatment cost would include any incurred costs such as hospital fees, medicine costs, and transportation to the health care provider. Roughly one-fourth of the households said that they had to spend some money on treatment. The average treatment cost for the entire sample is NRs. 1525 and for those who treated is NRs. 5,900. 3.4% of the households reported that they had to pay NRs. 10,000 or more for the treatment. The following graph (Figure G2) shows the average treatment cost of illnesses by ward. As clearly depicted in the graph, the treatment cost widely varies by ward, with households from ward 4, 7, 9, and 13, on average, paid more for illness treatment. It is interesting to note that households from these four wards had rated the air quality in their areas to be poor and that they are strongly being affected by air pollution.

Figure G2. Treatment cost of illnesses by ward

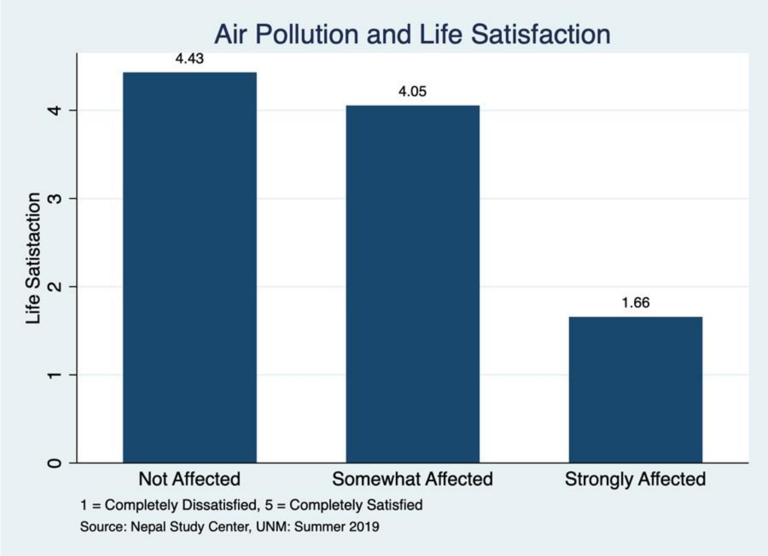


Air pollution and life satisfaction

Several past studies (Ferreira et al. 2013; Yuan et al. 2018) have linked air pollution with life satisfaction. These studies discuss the important role of air pollution in determining how satisfied people are with their lives. Their findings suggest that people living in high air pollution environment are less satisfied with their lives. Our preliminary results concur with this finding (Figure G3). We asked the respondents, on a scale of 1 to 5, 1 being “completely dissatisfied” and

5 being "completely satisfied", how satisfied are they with their lives. The bivariate relationship between life satisfaction and how strongly households feel that they are being affected by air pollution shows that those being affected very strongly by air pollution are very dissatisfied with their lives and vice versa.

Figure G3. Association between air pollution and life satisfaction



H. Public Preferences for Air Quality Improvement

Key Highlights

- Nearly half of the households (46%) are willing to pay for air quality improvement and NRs. 980 is the mean willingness to pay
- Households that are wealthier and have higher education are more likely to pay for air quality improvement
- A majority of households (70.7%) think that the municipality should collect and handle funds
- 55.6% of the households that are not willing to pay reported that they cannot afford to pay at this time

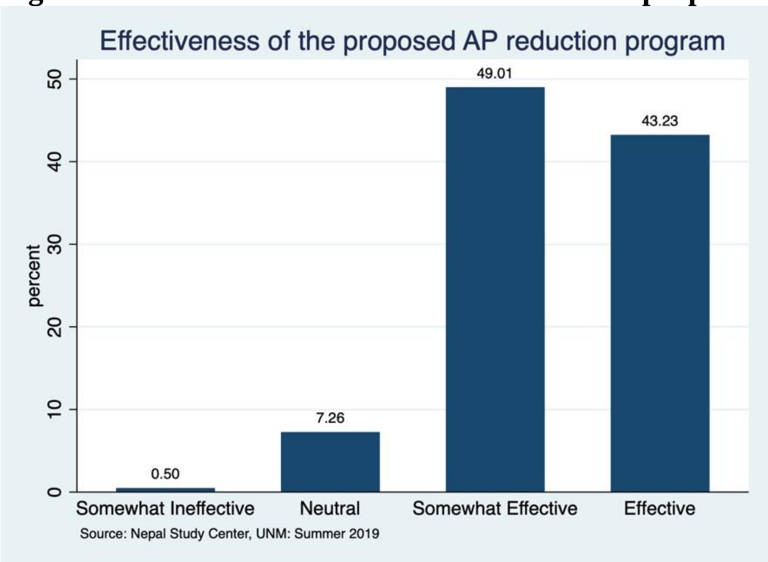
Discussion

One of the main objectives of this study is to understand the public preferences for air quality improvement in Siddharthanagar municipality. This study uses the contingent valuation method (CV) to estimate households' willingness to pay for air quality improvement. A plethora of studies (Carlsson and Johansson-Stenman 2000; Wang et al. 2015; Sun et al. 2016) have previously examined public preferences for air quality improvement using the contingent valuation (CV) method to estimate willingness to pay (WTP) and have found that the public is generally willing to pay to support policies and programs that assure to improve the air quality.

In the survey, we presented a hypothetical scenario about a program that will reduce the ambient air quality in the municipality to the level where the air pollution-related diseases in the municipality decreases by 50%. The program would consist of regulating emissions from vehicles and factories, purchasing fuel-efficient and low-pollution public vehicles, reducing traffic congestion, regulating waste burning, and planting trees.

The respondents were then asked how effective they think the proposed program will be. A majority of respondents deemed that the program will be somewhat or completely effective (Figure H1). Less than 1% of the respondents said that the program will be somewhat ineffective.

Figure H1. Assessment of the effectiveness of the proposed air pollution reduction program



The respondents were then asked if they would be willing to pay an annual fee (a randomly chosen bid amount) to reduce air pollution in the municipality. The 6 bid amounts were NRs. 100, 300, 700, 1200, 2000, and 3000. The households were also told that the money will be collected in the form of a local municipality tax for the next 5 years and were made aware that their payment decision will affect their household budget. 46% of the respondents reported that they are willing to pay the given bid amount to reduce air pollution in the municipality. Figure H2 shows the proportion of 'Yes' response for each of the 6 bid amounts. The proportion of 'Yes' response goes down for every increase in the bid amount. The estimated average willingness to pay (WTP), taking only the bid amount as covariate, is NRs. 980.

Figure H2. Proportion of Yes response for each bid amount

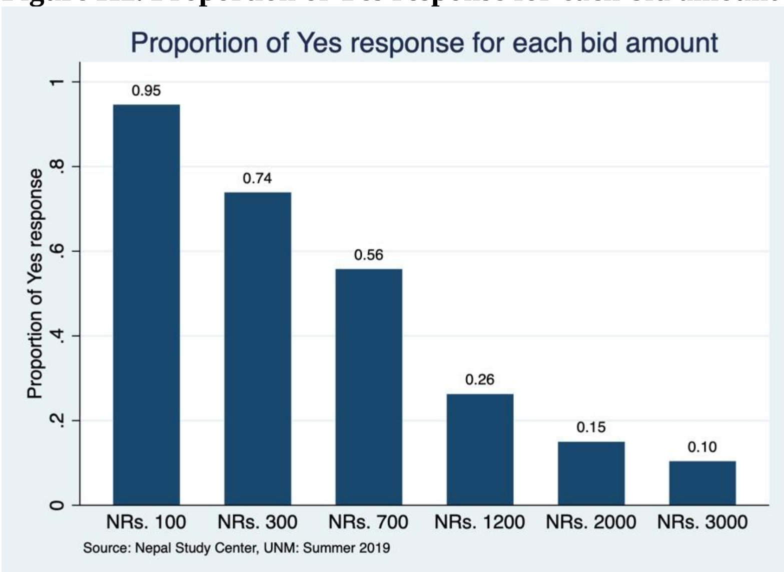
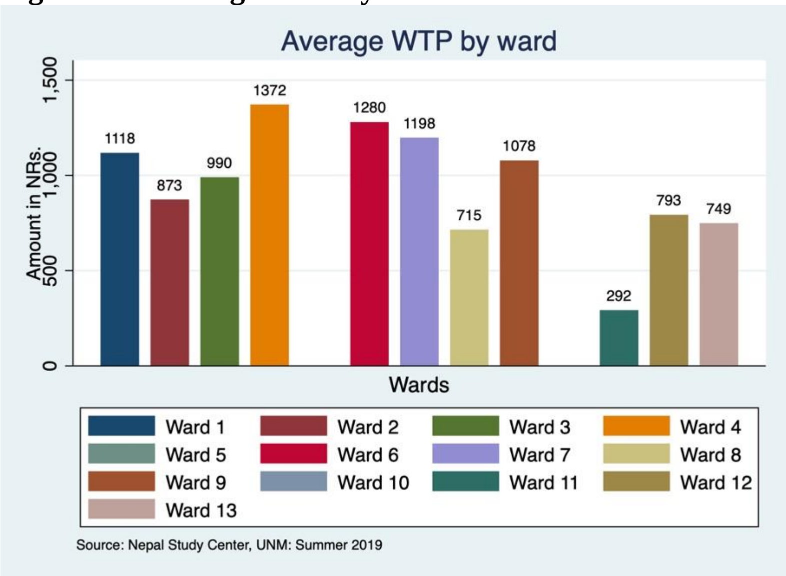


Figure H3 shows the estimated average WTP values by wards (taking only the bid amount as covariate). The average WTP values are high in ward number 1, 4, 6, 7, and 9. It is interesting the note that the average treatment costs were also high in ward number 4, 7, and 9. Conversely, the average WTP value is low in ward number 11, which also had one of the lowest average treatment costs.

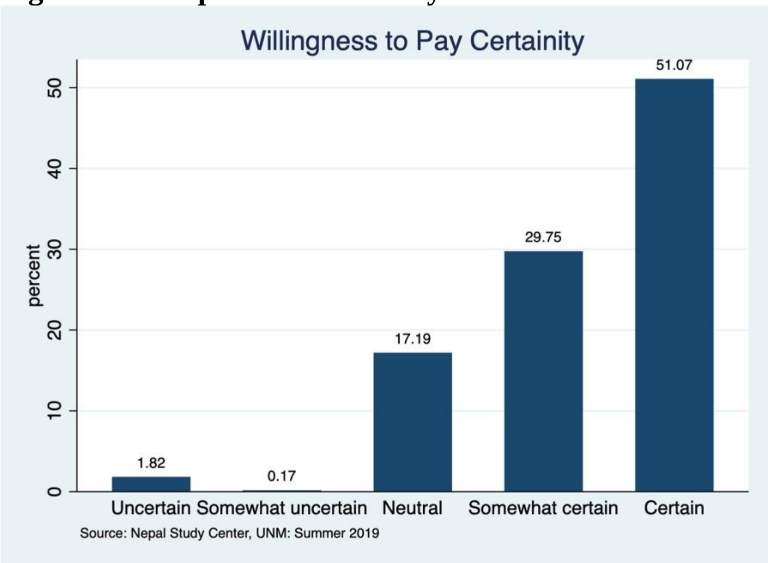
Figure H3. Average WTP by ward



Note: Mean WTP values are negative for ward 5 and 10

Following their WTP choice, we also asked the respondents how certain they think that they will pay (or not pay) if the proposed program is truly implemented. While 51.1% of the respondents were completely certain about their WTP choice, 29.8% said that they were somewhat certain (Figure H3). Less than 2% of the respondents said that they are somewhat or completely uncertain about their WTP choice.

Figure H4. Respondents certainty about their WTP choice



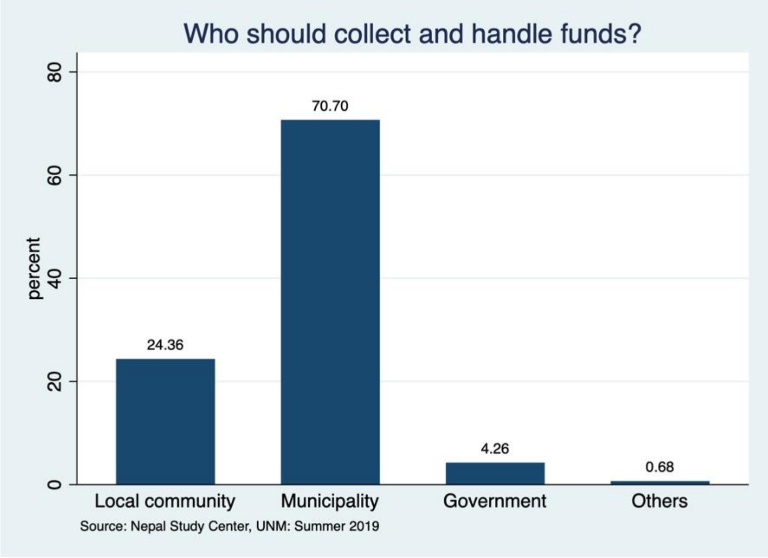
The respondents who were not willing to pay were asked the main reason behind choosing not to pay. More than half of the respondents (56.55%) reported that they cannot afford to pay at this time (Table H1). Protest responses like "I do not believe that the municipality will use the money effectively", "I think the municipality should focus on other important issues", and "I am opposed to collecting any fee for the program" are also common.

Table H1. The main reason behind choosing not to pay

I can't afford at this time	56.55%
I don't believe that the municipality will use my money effectively	20.00%
I need more information before making a commitment	6.90%
I don't think that air pollution is a serious problem	6.21%
I think the municipality council should focus on other important issues	5.52%
I am opposed to collecting any fee for the program	3.45%
I don't feel responsible for air pollution	1.38%

The respondents were also asked who they think should collect and handle the funds for the program. A majority of households (70.7%) think that the municipality should collect and handle funds (Figure H4). One-fourth of the respondents think that the local community should be in charge of the funds. Based on the choices, the level of trust in the central government is found to be low among the respondents.

Figure H5. Respondents preference for collection and handling of funds



Does education influence household willingness to pay for air pollution reduction?

We ran a simple logit regression model to examine whether education influences household willingness to pay (WTP) for air pollution reduction. We also took the log of bid amount, household wealth, awareness about the health impacts of air pollution, gender, and age as other control factors that could possibly influence household WTP decision. The location (ward) effects were also controlled.

$$WTP_i = \beta_0 + \beta_1 Education_i + \beta X_i + \eta_i + u_i$$

The regression results show that those who have completed bachelor's degree of more are significant more likely to pay ($p<0.10$). The effect of household wealth is also positive and significant. Similarly, the bid amount has a strong negative correlation with WTP ($p<0.01$). Factors like gender and age do not seem to have a strong effect on WTP.

I. Preliminary Policy Propositions

The initial policy recommendations, based on our preliminary analysis, are as follows:

1. More than two-thirds of the sample were not aware that fatal diseases such as cancer, pneumonia, and bronchitis can be caused by air pollution. This calls for the need to provide adequate awareness about the health impacts of air pollution.

2. Similarly, knowledge about the nature of air pollution is found to be low among the respondents. A large proportion of the sample held the misconception that clear looking and non-smelling air is not polluted at all. Therefore, in addition to providing awareness about the health impacts of air pollution, it is also important to impart knowledge about the nature of air pollution.

3. The lack of information about air pollution in the municipality is evident from this study as only one-third of the respondents reported that they received information about air pollution through any sources. Furthermore, less than 5% of the respondents reported that they received information from governmental agencies and the municipality. The concerned authorities should, therefore, increase its awareness actions and programs to reach more people in the municipality.

4. One-fifth of the households that are not using any preventive measures identified lack of knowledge and unavailability of resources as the reasons behind not using any preventive measures. Therefore, while it is important to impart knowledge about air pollution exposure prevention measures, it is also crucial for the government and municipality to make the resources easily available to the public.

5. The lung capacity was found to be low among respondents who mostly work outdoors: daily laborers and farmers. It is interesting to note that the proportions of daily laborers and farmers who use preventive measures (such as facial masks) are also low. These findings stress the importance of designing intervention programs targeting people who are required to work outdoors and are more exposed to ambient air pollution.

6. Many households in the municipality are still using biomass for cooking. Respondents from these households were found to be more likely to get sick. This highlights the importance of promoting cleaner types of fuel (such as LPG) and making them available to the public.

7. The assessment of the air quality, the prevalence of lungs disorder and other illnesses, and the cost of illnesses significantly vary by wards, indicating the spatial variation of air pollution within the municipality. This emphasizes the need for identifying sources (or factors) that are contributing to air pollution in the wards that are being affected the most and making necessary interventions.

J. Further Analysis Under Consideration

1. Our preliminary findings suggest that exposure to air pollution and the health effects are likely to be different for individuals depending on their work location, occupation, and where they reside (ward) in the municipality. Further analysis will rigorously examine these findings to determine which groups of individuals are mostly being exposed to air pollution and affected by it. In our analysis, we plan to identify pollution sources, such as factories, paved and unpaved roads, in the municipality and examine whether residing close to these pollution sources affects an individual's respiratory health (lung capacity). We will also examine in depth the factors that influence individuals and households to use preventive measures to avoid air pollution exposure and whether the use of preventive measures has a positive effect on respiratory health. This will be done using a simultaneous equation model.

2. In our preliminary analysis, we only explored the single bounded dichotomous WTP choice. In the survey, following the WTP question, the respondents were asked if they are willing to pay the double (or half in the case of 'No') of the given bid amount for air pollution reduction. The next stage of WTP analysis will incorporate the second WTP choice. Additionally, the next stage of analysis will also incorporate respondents' uncertainty about their WTP choice. We also plan to investigate whether individuals that are affected the most express higher WTP for air quality improvement.

3. In our survey, we collected data on the economic burdens of air pollution-related illnesses. The preliminary findings are discussed in the *Socio-Economic Burdens* section of this report. Next, following Freeman (1993) and Gupta (2008), we plan to econometrically estimate the total health-related economic cost of air pollution in Siddharthanagar municipality by estimating the expenditure on illness treatment and the opportunity cost of illness measured in terms of lost working days.

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