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Respiratory Illness and Household Air Pollution: Problem Identification and Intervention

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Introduction

Household air pollution (HAP) is a contributing factor to air quality all around the world. “3 billion people worldwide are exposed to toxic amounts of HAP every day because they use solid fuels, a term that includes biomass fuels (derived from plant sources) or coal for combustion resulting in the release of products of incomplete combustion such as carbon monoxide and particulate matter (PM)” (Gordon et al., 2014). The most common biomass fuel used around the world is wood; the next most common biomass sources used as fuel are cow dung, crop residues, and grass (Sussan et al., 2014). In developing, or third world countries, the use of biomass fuel sources to heat a home or to cook causes the release of chemicals and fine particles that contribute to poor air quality. “Solid fuels can be biomass or coal and during combustion can release a complex mixture of air pollutants including inorganic gases such as CO, NO2, particulate matter (PM), organic compounds, hydrocarbons and free radicals” (Rumchev et al., 2017). Exposure to the toxins released by burning biomass fuel sources contribute to the global mortality rate; household air pollution can be related to respiratory illness in several low-income countries. “Household air pollution is associated with an increased risk of adverse health effects, with the strongest association observed for respiratory diseases such as COPD and lung cancer” (Lee et al., 2020). “According to the 2016 Global Burden of Disease estimates, HAP was responsible for 2.9 million annual deaths and 81.1 million DALYs lost. These estimates show that 26% of HAP deaths were attributed to lower respiratory infections, 5% to tracheal, bronchial and lung cancers, and 23% to COPD” (Simkovich et al., 2019). There is current evidence that identifies HAP to contribute to the risk for respiratory illness development in the populations regularly exposed to the related toxins release by

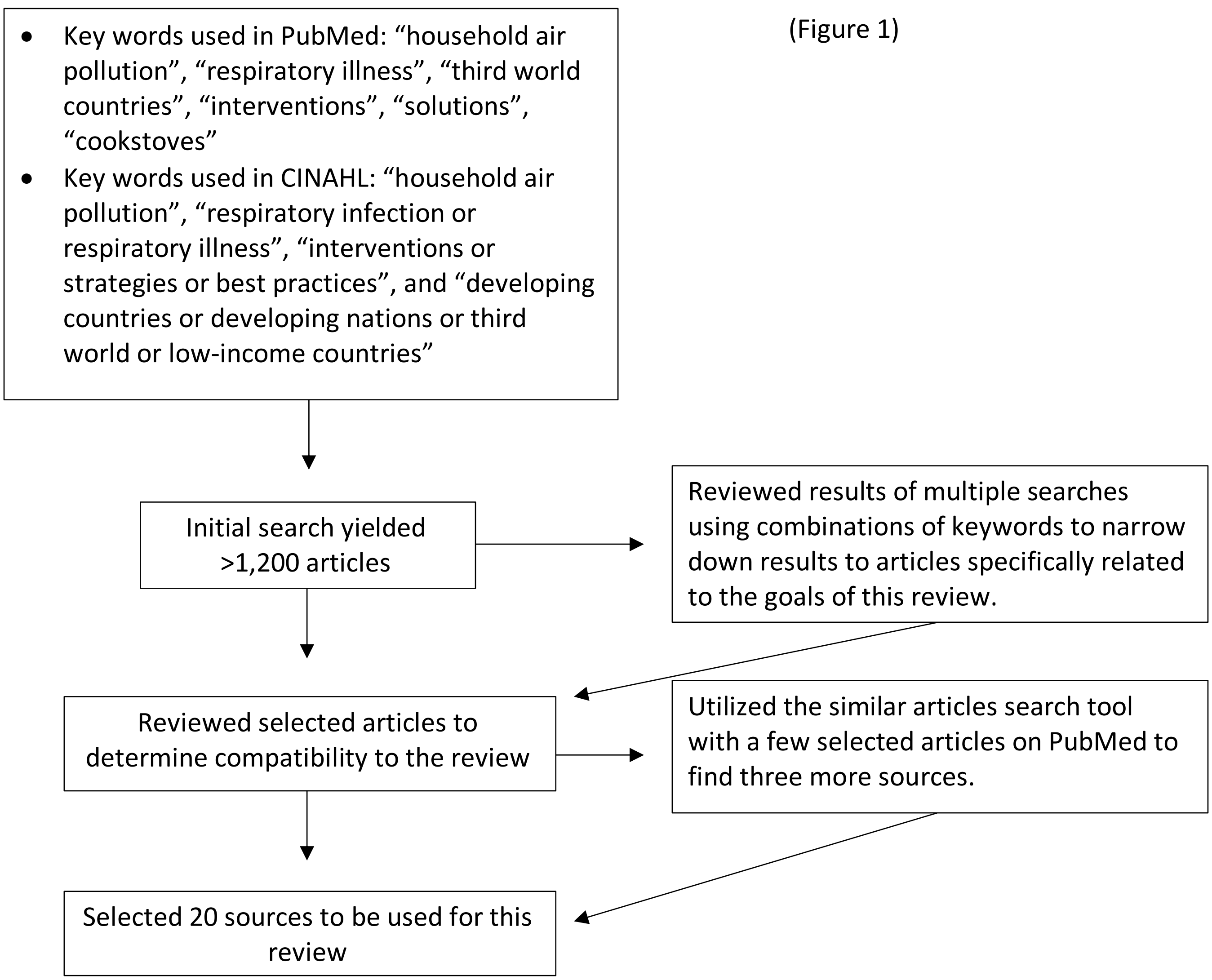
burning biomass fuel sources. Another study, called RESPIRE, found evidence that participants with higher rates of exposure to HAP had an increased prevalence of COPD when compared to other populations with less exposure (Siddharthan et al., 2018). The adverse effects of HAP are seen most regularly in individuals who spend a majority of their time either cooking or around the cookstoves; these at-risk individuals tend to include women and children. “Women often have the highest risk of exposure due to their involvement in the cooking process. Children are also often close to their mothers and therefore can be exposed to HAP from a young age” (Simkovich et al., 2019). The results of the assessments in a community-based cross-sectional study with the purpose of evaluating the rate of occurrence of childhood acute-lower respiratory infection (ALRI), showed that the prevalence of ALRI shows that the occurrence is 19.2%, 20% for female and 18.4% for males. When prevalence by age was identified, children less than one year old showed 21.9%, children at the age of one showed 19.7%, 18% for children at the age of two, and 16% for three-year-old children (Adane et al., 2020).

Methods

For this review, sources have been accessed from two databases, PubMed and CINAHL. The search strategy on PubMed consisted of five keyword searches including the phrases “household air pollution”, “respiratory illness”, “third world countries”, “interventions”, “solutions”, and “cookstoves”. Each search contained the keyword “household air pollution” and at least one, or several, of the additional key words using the “and” feature on the database. In the PubMed database, the similar articles search tool was utilized to find more sources relatable to this review. When conducting searches in the CINAHL, or EBSCO Host, database, the key phrases searched mirrored the searches in PubMed. The key words used

included “household air pollution”, “respiratory infection or respiratory illness”, “interventions or strategies or best practices”, and “developing countries or developing nations or third world or low-income countries”. There were two distinctive searches done using the CINAHL database which yielded seven sources. Figure 1 shows the selection process of articles utilized in this review. The inclusion criteria utilized in the searches, for both databases, included peer reviewed articles, English language, full text articles available, and the majority are primary sources.

(Figure 1)



Results

Adane et al. (2020) conducted a community-based cross-sectional study with the purpose of evaluating the rate of occurrence of childhood acute-lower respiratory infection (ALRI) among children in homes using biomass fuels in Northwest Ethiopia as the major fuel source for cooking. The study was conducted in a low-income rural community of the MECHA Health and Demographic Surveillance System (MHDSS), which is a research center utilized by Bahir Dar University, and consists of three climate zones called the highlands, midlands, and lowlands. The area also contains ten sub-districts, Kebeles, three of which are urban and seven are rural. The study isolated 65,086 people in 20,631 households with children below the age of four comprising 13.3% of the population (Adane et al., 2020). The study was conducted with the intention of evaluating the effect of the improved Injera stove on the prevention of community-acquired childhood ALRI. The study population included households with children under the age of four and data was collected prior to their fifth birthdays. The sampling technique for participants was a cluster method in the 132 small villages, or “gots”. Out of the 132 small villages, 100 were randomly selected to represent the total population while all eligible households were included within the included clusters. The MHDSS records were utilized to identify households with children under the age of four; the youngest child from each eligible household was selected to be included in the study. According the Adane et al. (2020), the outcome variable of the study was to “classify community-acquired childhood ALRI status (yes or no)” by using the WHO Integrated Management of Childhood Illness (IMCI)-pneumonia definition. The IMCI definition of pneumonia is “a child with cough or difficult breathing who has fast breathing and no general danger signs, no chest indrawing and no stridor when calm”

according to the World Health Organization's Handbook IMCI: Integrated Management of childhood Illness. The classification table for cough or breathing difficulty from the IMCI Handbook is shown in Figure 2. The revised classification and treatment of childhood pneumonia from the WHO is shown in Figure 3. The occurrence of community ALRI was assessed by nurses conducting interviews with the mothers or guardian of the children; the questions asked inquired about signs and symptoms of childhood ALRI/pneumonia in the two weeks prior to the interview. The nurses also conducted physical assessments of the children using the IMCI pneumonia algorism. The predictor variables were placed into five categories; socio-demographic, ventilation, technology, behavioral, and other potential variables (Adane et al., 2020). The variables were evaluated through interviews with the children's caregivers, as well as, questionnaires that assessed four features of household ventilation, three aspects of household cooking technology, five behavioral factors, and four other variables (Adane et al., 2020). Data collection for this study was conducted in May of 2018 by local nurses trained to conduct interviews and questionnaires with the guardians of the selected children. The data collection questionnaire assessed "household location, socio-demographic, index child health, main cooking quarter characteristics, cooking pattern and alternative sources of household air pollution" (Adane et al., 2020). The socio-demographics characteristic results showed that, out of a total of 5830 children within the 100 clusters, 51.7% were male, 92.7% of the guardians were married, 79.1% of the caretakers did not have a formal education and 66.8% were farmers, and 34.7% of the children living in homes with up to five occupants (Adane et al., 2020). The cooking related characteristics of the household questionnaire resulted in showing that 94.5% of the homes utilized traditional "Injera" baking stoves, 92.1% used cooking stoves

(Adane et al., 2020). All participating households utilized biomass fuels; 80% used wood/shrub/straw, 14.4% used charcoal, and 5.6% used cow dung. In addition to cooking activities, 95.8% of the households participated in additional indoor, and 38.1% outdoor, burning ceremonies, such as coffee ceremonies, incense use, local alcohol (areqi), making, trash burning, and charcoal production (Adane et al., 2020). The findings for factors associated with childhood acute respiratory infection were evaluated by a logistic regression model and narrative description of the results. It was found that the female gender had a higher risk for developing ALRI and the odds of ALRI development decrease by 41% as the child reaches age three when compared to a one-year-old (Adane et al., 2020). When the factors related to household ventilation were analyzed, it was found that children living in homes with a chimney had decreased odds of childhood ALRI when compared to homes without chimney ventilation; the presence of eaves and four or more rooms in the home also showed a decrease risk for ALRI in childhood (Adane et al., 2020). The cooking technology used in the home, specifically traditional or improved cookstove, showed an association with decreased odds for childhood ALRI; children living in homes with an improved cooking stove saw a 57% decrease in risk compared to household with a traditional cookstove (Adane et al., 2020). The results of the behavioral factors associated with childhood ALRI showed that children who spent more time near the stove while it was in use showed an increase in the odds when compared to children who do not spend time nearby; the presence of an indoor and/or outdoor burning ceremony also contributes to an increased risk for childhood ALRI. Households that prepared three to four meals a day also saw an increase in the odds of childhood ALRI when compared to cooking once or less a day. Children who were breastfeed for six months showed a decreased risk, while

children who were exposed to secondary smoking increased the risk for childhood ALRI (Adane et al., 2020).

EXAMPLE 4: CLASSIFICATION TABLE FOR COUGH OR DIFFICULT BREATHING

SIGNS	CLASSIFY AS	IDENTIFY TREATMENT (Urgent pre-referral treatments are in bold print.)
• Any general danger sign or • Chest indrawing or • Stridor in calm child.	SEVERE PNEUMONIA OR VERY SEVERE DISEASE	➤ **Give first dose of an appropriate antibiotic.** ➤ **Refer URGENTLY to hospital.**
• Fast breathing	PNEUMONIA	➤ Give an appropriate oral antibiotic for 5 days. ➤ Soothe the throat and relieve the cough with a safe remedy. ➤ Advise mother when to return immediately. ➤ Follow-up in 2 days.
No signs of pneumonia or very severe disease.	NO PNEUMONIA: COUCH OR COLD	➤ If coughing more than 30 days, refer for assessment. ➤ Soothe the throat and relieve the cough with a safe remedy. ➤ Advise mother when to return immediately. ➤ Follow-up in 5 days if not improving.

(Figure 2) Classification table for cough or difficult breathing

World Health Organization, Handbook IMCI: Integrated Management of Childhood Illness

(retrieved by citation, Adane et al., 2020)

Rumchev et al. 2017 conducted a study with the intention of assessing the impact of social, housing, and indoor environmental conditions on the respiratory health of mothers and children in the southern Indian city of Tirupur. The hope for this study was to identify important information that could be used to influence interventions in the future. The identified study population was two hundred and fifty homes located in the smaller communities of Tirupur, South India. The city is located in the Coimbatore District of Tamil Nadu State. Our of the 250 households identified, 170 agreed to participate in the first stage of the study, the questionnaire; out of the 170, 80 agreed to allow indoor air quality monitoring to be performed

and signed an informed consent document. Data collection for the study was done in two stages; the first stage included a standardized health and housing survey completed by interview, the second stage completed the indoor air quality monitoring. The respiratory health survey was relational to the participants' demographic and housing factors and health status; the survey was drawn from a standardized questionnaire on indoor air quality (IAQ) and health of the American Thoracic Society that had been used in other studies with success. The questionnaire was altered to better fit the population by altering some questions to reflect the local lifestyle and setting and translating it to Tamil, the local dialect. The altered questionnaire was pre-tested on ten families to ensure proper understanding and appropriateness. The questionnaire itself consisted of three sections. Section one was meant to collect demographic information including age and gender, and health status data including the presence of a cough, wheeze, and breathlessness in the mothers and children in the previous six months. Section two addressed household factors and activities of the families, specifically focused on cooking and indoor smoking. The third section utilized questions regarding socioeconomic status, including number of children, the parents' educational level, and the household income. The second stage of the study, quality air quality monitoring, "involved a quantitative assessment of indoor concentrations of CO and $PM_{2.5}$" (Rumchev et al., 2017). Within the 80 households who consented to assessment, measurements were taken from the kitchen area for about four hours including the time spent cooking. The equipment utilized was a DustTrak Aerosol Monitor model 8520 was placed one meter above the ground and monitored for fine particles ($PM_{2.5}$); this monitoring system had a flow rate of 1.7 L/min and was calibrated using the 37 mm filter, in addition to the annual factory calibration, at selected site locations to determine the

gravimetric concentration which created a custom calibration that was utilized at all measurement sites (Rumchev et al., 2017). The levels of CO were assessed using a Dräeger pump, model 21/31, with the limit of detection of the tube set to 2.47 mg/m^3 and range of detection set to 2.47 to 74 mg/m^3 (Rumchev et al., 2017). Additional indoor parameters, temperature and humidity, were measured by Tiny tag-Ultra Data Loggers with built-in sensors (Rumchev et al., 2017). The statistical analysis for the study saw respiratory symptoms for mothers and children as the main outcome and were recoded as binary variables, specifically 0 refers to no symptoms while 1 means symptoms were present. "Upper respiratory symptoms were defined as runny nose and coughs, whereas lower respiratory symptoms were defined as wheeze, shortness of breath, asthma, chest pain, and bronchitis" (Rumchev et al., 2017). Factors such as demographics, kitchen characteristics, domestic environmental conditions (smoking), and indoor pollution were considered independent/exposure variables and were recoded into categorical or binary variables with greater than two levels by Rumchev et al. 2017. The study considered family income, the mothers' level of education, and parents' occupations to be indicators for socioeconomic status. Descriptive statistics were performed for the outcome and independent variables. Cross-tabulations and chi-squares tests were bivariate analyses conducted to assess unadjusted correlations between the independent/exposure variables and respiratory symptoms as outcome variables (Rumchev et al., 2017). Due to the study being cross-sectional with health outcomes that commonly occur, a multivariable Poisson regression (MPR) analysis with robust variance estimation was considered applicable to address the adjusted association between, first, respiratory symptoms and characteristics of the participating homes, kitchen tasks and environmental condition, controlling for demographic

factors, socioeconomic status, and smoking, and, secondly, between respiratory symptoms and indoor air pollution as shown by $PM_{2.5}$ and CO, also controlled for demographic factors, socioeconomic status, and smoking and including the humidity and temperature. Multivariable modelling was done in two stages, complete and reduced. The complete modelling included all socioeconomic status variables, household factors, and indoor environmental conditions. The reduced modelling only included variables determined to be significantly correspondent to the health outcomes in the univariate analysis with $p < 0.1$, as reported by Rumchev et al. 2017. The study reports crude and adjusted prevalence rations and their 95% confidence interval, as well as, the crude prevalence ratio when associations are significant but unaltered for confounders, demographic factors, socioeconomic status, smoking, relative humidity, and indoor temperature. “Only variables still significantly ($p < 0.05$ or $p < 0.1$) associated with mothers’ and children’s respiratory symptoms after controlling for confounders in the final model are reported as adjusted prevalence rations (APR)” (Rumchev et al., 2017). The study also inspected the relationship of household factors, socioeconomic status, and indoor air quality. “Independent *t*-test or one-way ANOVA were used to investigate the difference between groups. Multivariable linear regression (MLR) analysis with a backward elimination approach was conducted to examine the effect of household characteristics, kitchen activities and domestic environment conditions on indoor air pollution concentrations, controlling for socioeconomic status” (Rumchev et al., 2017). The results of the demographic characteristics and socioeconomic status questionnaire conducted by Rumchev et al. 2017 in the 170 homes showed that the mothers ranged between 19 and 45 years of age, the children were aged between 1 and 15 years; 52% of the families had two or three children, 23% had only one, and

27% had more than three. Out of the mothers, 98% had primary education, 2% had a secondary education, and one person had a university degree. Out of the 170 homes, 82% had a total family income of less than 1000 Indian rupees per month and 18% earned within the range of 1000-3000 rupees per month; the poverty cutoff was 1000 rupees per month. The study also reported that 141 (83%) of the homes had one or two rooms; 74 (43%) had mud floors, 96 (56%) had cement floors, and no homes had carpet floors. There was a kitchen or stove in 119 (70%) of the homes. A majority, 120 (71%) of the kitchen roofs were covered by tiles; thatch, or coconut leaves, covered 40 (24%), asbestos covered 4 (7%) and iron sheets covered 3 (2%). The most commonly used fuel source was biomass, which was used in 125 (74%) homes; the next most common fuel source was liquid petroleum gas (LPG), used by 28 (16%) homes, and 17 (10%) homes used kerosene. No households utilized coal or electricity to cook. No mothers reported smoking, but 78 (46%) fathers smoked; 38% of the households permitted their guests to smoke indoors. The second stage of the study had 80 families consent to indoor air quality monitoring measuring exposure to $PM_{2.5}$ and CO. According to Rumchev et al. 2017, the mean concentration of $PM_{2.5}$ was 3.80 mg/m^3 while the median concentration was 1.18 mg/m^3 with a range of 0.04 mg/mg^3 to 83.84 mg/m^3. These results show that all monitored households exceeded the WHO guideline value of 0.025 mg/m^3; 80% of the homes were subject to ten times the guideline of $PM_{2.5}$ concentrations. It is interesting to report that 83% of the households were within the WHO 8-h CO guideline of 10 mg/m^3 with a highest recorded concentration of 50 mg/m^3. Rumchev et al. 2017 state the median concentration of CO to be 2.47 mg/m^3 and the mean to be 4.63 mg/m^3; the range for CO was 2.47 mg/m^3 to 50 mg/m^3. The mean temperature recorded in the homes was 30°C, with a range of 24°C to 43°C, and the

mean relative humidity was 52%, with a range of 33% to 82%; both of these recorded values surpass the ASHRAE guideline values of 21°C to 26°C for temperature and 30% to 70% for relative humidity. The study reviews associations between household characteristics and indoor concentrations of $PM_{2.5}$ and CO by interpreting the results of the univariate analysis through independent sample *t* test. The analysis revealed that homes who primarily utilized biomass fuels for cooking were exposed to significantly (p <0.01) increased concentrations of $PM_{2.5}$ with a median of 1.32 mg/m^3, compared to 0.16 mg/m^3 in homes that used LPG or other fuel sources. Homes with tiles covering the kitchen roof saw a significantly lower (p = 0.037) median value of $PM_{2.5}$ concentration of 0.875 mg/m^3 when compared to kitchens covered by thatch, asbestos, or iron, which had a concentration of 1.415 mg/m^3. Occupants of low-income households also saw significantly higher levels of $PM_{2.5}$ exposure (p < 0.05) with a concentration of 1.30 mg/m^3 when compared to a concentration of 0.51 mg/m^3 in higher income homes. In homes where the windows were closed while cooking occurred, there was a significant (p < 0.05) increase in concentration of $PM_{2.5}$, 1.36 mg/m^3, when compared to cooking with open windows, 0.45 mg/m^3. Smoke free households saw a significantly lower (p <0.05) concentrations of $PM_{2.5}$, 1.12 mg/m^3, than those who allowed smoking, 2 mg/m^3. The MLR analysis supported the relationship between fuel type and $PM_{2.5}$ concentration; the use of firewood significantly (p = 0.006) increased the $PM_{2.5}$ concentration by 1.368 mg/m^3. Nearly half of the participating households 46 (57%) had CO concentrations below 2.47 mg/m^3. Rumchev et al. 2017 report that all participating mothers communicated having at least one respiratory symptom with the most common being wheeze (53%), then cough (43%); 34% of the children reported a cough, 23% a runny nose, and 17% a wheeze. The study also reported

that the socioeconomic status characteristic that had the greatest health impact was household income. The Poisson regression analysis showed that women in households making less than 1000 rupees per month were more likely to see a higher prevalence of cough, wheeze, shortness of breath, and chest pain. Respiratory symptoms were impacted by the house characteristic; such as, smoking indoors, the use of a biomass fuel, amount of time spent cooking, source of lighting, and floor and wall coverings. Low income and the allowance of indoor smoking contributed to the adverse health effects seen in children and is consistent with that of the mothers. "Children who lived in smoking households were almost five times more likely to experience hay fever and two times more likely to have a cough compared to those who lived in a smoke free house" (Rumchev et al., 2017). Children that stay close to their mothers during cooking were more likely to face respiratory symptoms and, for every additional hour spent in the kitchen, the prevalence of hay fever was increased nearly two times. A study that was conducted by Kilabuko et al. (2007) also addressed air pollution, specifically PM_{10}, NO_2, and CO, in three microenvironments around the selected households. The microenvironments included the kitchen (separated into three additional categories depending on location, indoor, separate house, and outdoor), living room, and the outdoor areas of 100 randomly selected homes in the Nianjema village in Bagamoyo, Tanzania; however, only 83 homes were eligible for monitoring. The kitchen microenvironments were tested for PM_{10} before and after cooking occurred and the living room and outdoor area concentrations were measured in a similar manner; however, CO and NO_2 measurements were recorded for the kitchen and outdoor areas only. CO data was collected for all 83 homes, but, due to equipment malfunction, PM_{10} data was only available for 75 homes and 64 homes for

NO_2 monitoring. This study also utilized a questionnaire to gather health related information from the participants regarding acute respiratory infection (ARI); people were identified to have experienced ARI if they had a cough and rapid breathing. All homes identified wood, a biomass fuel, as their main source fuel. The results of the study showed that PM_{10} concentrations were seven times higher during cooking (29.0 to 2656.0 μg/m^3) than they were when the stove was not being utilized in the kitchens (9.4 to 611.3 μg/m^3) (Kilabuko et al., 2007). The mean NO_2 concentration was higher in the kitchens (31.8ppb) than it was outdoors (6.8ppb); the mean CO concentration was 15ppm, which was not drastically different from other kitchen locations. The study found that the prevalence of ARI seen in both the cooks and children under 5 years of age was 54%; the rest of the family saw a prevalence of 17%. The unadjusted odds ratio conducted in this study revealed that the main cooks of the family and the children under 5 in the household were six times more likely to experience an ARI then the men and women who did not cook (Kilabuko et al., 2007). The results of this study, when compared to the results of the study conducted by Rumchev et al. (2017), support the evidence that women and children who are close to the cookstoves have an increased risk of developing negative respiratory health outcomes due to the exposure to toxins omitted by biomass fuel sources. A third report also identified the increase in HAP being associated with negative health outcomes. This review identifies indoor air pollution and related health problems in Ethiopia. “Mothers, children, and the elderly who traditionally spend much of their time in the place where cooking takes place are exposed to the most PM2.5” (Tefera et al., 2016). The report also identifies NO_2 levels and CO levels to exceed recommended values, and that charcoal is the most commonly used fuel

source in Ethiopia. The review also identifies that exposure to indoor air pollution exposure can be linked to acute respiratory disorders in children (Tefera et al., 2016).

Another study, conducted by Siddharthan et al. 2018, was published in the American Thoracic Society, American Journal of Respiratory and Critical Care Medicine; this study had the objective of analyzing the relationship between exposure to household air pollution and chronic obstructive pulmonary disease (COPD) outcomes in thirteen low- and middle-income countries. The study consisted of pooled data from five population-based studies from six countries and 13 locations in Latin America, Sub-Saharan Africa, and Southeast Asia. The data was collected from previous studies sponsored by MIH/NHLBI and UnitedHealth Chronic Disease Initiative, the Fogarty International Center of the NIH, and the FRESH AIR (Free Respiratory Evaluation and Smoke Exposure Reduction by Primary Health Care Integrated Groups) Study Group. The studies included had to meet the criteria of four sets of data: adults aged 18 years or older; a site found in a World Bank-defined low-middle income country within the selected networks; performed a population-based study; and utilized post-bronchodilator spirometry in subjects with an obstruction, and be cooperative with contributing data to the pooled analysis. Data for this study was extracted from the PRISA (Pulmonary Risk in South America) study which was overseen by the Institute for Clinical Effectiveness and Health Policy at two Argentinian sites (Marcos Paz and Bariloche), one site in Chile (Temuco), and one in Uruguay (Canelones). The data also came from the CRONICAS Cohort Study that took place in Peru and was run by the CRONICAS Centre of Excellence for Chronic Diseases at Universidad Peruana Cayetano Heredia and John Hopkins University. Another source of data was a longitudinal study in Bangladesh

directed by the Centre for Control of Chronic Diseases at the International Centre for Diarrheal Disease Research, Bangladesh (icddr,b). The Link (Lung Function Study in Nakaseke and Uganda) and the FRESH AIR Uganda study were included in the data analysis, they were conducted by the Makerere Lung Institute. The included studies were identified as follows: “both PRISA and CRONICAS studies are prospective longitudinal studies with multiple years of follow-up that started n 2010. icddr,b conducted a longitudinal study from 2011 to 2012. LINK is an ongoing longitudinal study with baseline data collected in 2015. FRESH AIR Uganda is a cross-sectional study conducted in 2012 in rural Masindi” (Siddharthan et al., 2018). Siddharthan et al. 2018, identify that PRISA and CRONICAS utilized age and sex stratified random sampling as their study design, while the Bangladesh study utilized a simple random sampling of available census data at each site. The LINK study utilized a World Health Organization sampling technique, while the FREASH AIR study used a multilevel sampling approach. Siddharthan et al. 2018. Limited their data analysis to include study subjects aged 35-95 years to match reference equation age limitations; all studies utilized informed consent forms from the local and international ethics boards and mandated confidentiality training was given to field workers. All sites selected abided by the combined American Thoracic Society/European Respiratory Society guidelines when conducting and grading spirometry; PRISA, CRONICAS, LINK, and the Bangladesh study utilized comparable spirometry equipment while FRESH AIR utilized Pneumotrac spirometers. The PRISA and CRONICAS studies measured both pre- and post-bronchodilator FEVs, other studies only measured postbronchodilator readings on participants who were screened as positive for obstruction on prebronchodilator spirometry ($FEV_1/FVC \leq 0.7$ in FRESH AIR and Bangladesh, and $FEV_1/FVC \leq$ lower limit of normal in LINK). The definition of COPD used by

Siddharthan et al. 2018 was having a post-bronchodilator FEV_1/FVC *z*-score less than or equal to -1.64 SDs of the Global Lung Function Initiative mixed ethnic reference population. The GOLD strategy was used to define COPD severity, see figure 4. The study defined pack-years of smoking as the number of packs smoked per day multiplied by how many years the person had been smoking. Symptomatic COPD was characterized by a wheeze, cough, or phlegm at that time or within the last year. Restrictive spirometric pattern was defined as a prebronchodilator FVC *z*-score less than -1.64 and no spirometric evidence of COPD, daily smoking was defined as one or more cigarette per day, and HAP exposure was defined as the primary source in the home being a biomass fuel. Lung function reversibility was defined as the difference in post- and pre-bronchodilator FEVs greater than 200 ml and/or a percentage greater than 12%. Siddharthan et al. 2018 planned their biostatistical analysis the characterize the relationship between exposure to HAP and COPD; they conducted secondary analyses to interpret the correspondence between HAP exposure and COPD outcomes, specifically the severity and the associated respiratory symptoms, prebronchodilator FEVs, and the restrictive spriometric pattern and HAP exposure association. The primary analysis utilized multivariable alternating logistic regressions to show the relationship between HAP exposure and COPD, it was adjusted for the confounders of age, sex, daily smoking, body mass index, post-treatment tuberculosis, and secondary education. Alternating logistic regressions is a variant of general equations used to estimate where the relationship between pairs of subjects for a specific site is shown with a log odds ratio (OR) rather than correlations. In sensitivity analyses, the Mantel-Haenszel method was utilized to estimate unadjusted OR weighted by site, and multivariable random effects logistic regression to the findings were robust to the approach used to show

heterogeneity across settings. The study also looked for effect modification by sex, age (≥55 or <55), self-reported smoking, and secondary education. Adjusted OR estimates were used the calculate the population-attributable fraction (PAF) of COPD caused by HAP exposure using the Levin Formula, $PAF = \frac{p\times(OR-1)}{1+p\times(OR-1)}$ (Siddharthan et al., 2018). For the secondary analyses, multivariable random effects ordinal logistic regressions were used to assess the correlation between HAP exposure and COPD severity (none, mild, moderate, or severe/very severe) or symptomatic COPD (none, asymptomatic, and symptomatic) adjusted for previous confounders. Alternating logistic regressions were utilized to examine the relationship between exposure to HAP and either seeing a restrictive spirometric pattern or reversibility adjusted with the same confounders. Multivariable linear mixed-effects models with a random intercept by location was used to observe the relationship between HAP exposure and prebronchodilator FEVs accounting for an interaction with age and the previous confounders. A sensitivity analyses was performed using the GLI2012 Caucasian reference value to evaluate is the estimates were steady despite the chosen reference; pack-years smoking was used in place of daily smoking to eliminate the risk of residual confounding by not adjusting for frequency of exposure to smoking. The population characteristics for the study conducted by Siddharthan et al. 2018 included 13 sites that supplied data on 13.023 subjects, but only 12,396 met the criteria and were included in the complete data analysis. The percentages of the populations in each location are divided as follows: 58% from Latin America, 28% in Southeast Asia, and 14% in Sub-Saharan Africa. The average age of the study participants was 54.9 years, with a range of 44.2-59.6 years, with 48.5% being women. The total prevalence of exposure to HAP was 38% with no difference in COPD prevalence between the participants that were included and

excluded; but the excluded subjects had a higher rate of HAP exposure, were younger, and majority were women. Subjects reported a range of biomass use of 0.5% in Argentina to 99.6% in Uganda. Cigarette smoking on a daily basis ranged from 0.2% in Peru to 36.2% in Uganda. The overall occurrence of COPD was 8.8%, ranging from 1.7% in Kampala, Uganda to 15.5% in Masindi, Uganda. It was shown that men had a 10.3% prevalence of COPD vs. 7.2% in women; but there was a notable heterogeneity in the occurrence of COPD by sex throughout the sites, the prevalence of COPD ranged from 0% in Peru to 26.5% in Bangladesh. Men saw a higher rate of moderate to severe/very severe COPD than women with 53.4% vs. 39.8% for moderate and 19.3% vs.10.6% for severe/very severe and both seeing a P value < 0.001. When assessing site specific data, it was seen that daily smokers had an increased chance of having COPD than subjects who did not smoke. Subjects who were exposed to HAP had a higher prevalence of COPD than subjects with no exposure, 10.8% vs. 7.6% and a P value < 0.001. Participants who were in advanced age and exposed to HAP were at an increased risk of COPD than younger participants also exposed. It was also shown that subjects exposed to HAP had an increased risk of having more severe disease outcomes and having symptoms when compared to subjects with no exposure. It was found that women exposed to HAP had a stronger association to COPD than men who were also exposed; it was also shown that older participants, ≥ 55 years, had increased odds of developing COPD than the younger participants. Siddharthan et al. 2018 approximate that 13.5% of the COPD prevalence shown in the study was due to HAP exposure when compared to 12.4% due to daily smoking, 9.4% due to lower education, and 6.6% due to post-treatment pulmonary tuberculosis. In regards to HAP exposure and lung function, subjects with HAP exposure had lower prebronchodilator FEV_1, FVC, and FEV_1/FVC *z*-scores on average

at any age in contrast to unexposed subjects. All ages, with HAP exposure, showed a regularly lower prebronchodilator FEV_1 score than the participants without exposure; however, there were greater differences in FVC *z*-scores between subjects with and without exposure to HAP were increased in the younger subjects while the differences in FEV_1/FVC *z*-scores were increased in older subjects. Pointedly, subjects exposed to HAP saw a slightly lower adjusted prebronchodilator FEV_1 *z*-score than those with no exposure across all ages, with no relationship effect among HAP exposure and age. There was a decreased prebronchodilator FVC *z*-score at age 35 years but not at 60 years, and no variation in prebronchodilator FEV_1/FVC *z*-score at 35 years but a decreased FEV_1/FVC *z*-score at 60 years. It was found that subjects with HAP exposure had an increase likelihood to see lung function reversibility than those with no exposure at a younger age but not in the older years. Subjects exposed to HAP had a decreased occurrence of restrictive spirometric patterns than subjects with no exposure across all ages. This study utilized data from population-based cohorts to address the relationship between HAP exposure and COPD outcomes throughout thirteen low-middle income countries and found a positive correlation between exposure to HAP and COPD outcomes among 12,396 subjects; specifically, an increased prevalence and increased severity in both lung function and symptoms especially among women. “Our data suggest that HAP exposure is likely the leading population-attributable risk factor for COPD in out resource-poor settings, even above that of cigarette smoking” (Siddharthan et al., 2018). Another study, conducted by Van Vliet et al. (2019), supports the data found by Siddharthan et al. (2018) concerning the presence of respiratory symptoms and exposure to HAP. Siddharthan et al. (2018) defined COPD using postbronchodilator FEV_1/FVC *z*-scores and defined symptomatic COPD as the presence of a

wheeze, cough, or phlegm at the time of the study or within the year before. Van Vliet et al. (2019) does not specifically address the prevalence of COPD, but rather worked to assess the prevalence of respiratory symptoms, measured by continuous personal carbon monoxide (CO), in nonsmoking pregnant women in rural Ghana. The respiratory symptoms identified by this study are cough, wheeze, dyspnea, a combination of the previous three symptoms, phlegm (with a cough), and a clinic visit in the previous four weeks due to respiratory infection. Van Vliet et al. (2019) identified an association between personal CO levels and all identified symptoms, excluding dyspnea. These two studies correlate in the sense that they study similar respiratory symptoms, but one for a chronic respiratory disease (COPD) and the other for more acute respiratory infections. The fact that the acute respiratory symptoms that were correlated to increased CO exposure, in the women in Ghana, also were seen in chronic respiratory disease patients further indicates the relationship between household air pollution and developing long-term negative respiratory health outcomes.

Figure 4: Classification of COPD Severity – the GOLD Standard

TABLE 1. GRADING OF SEVERITY OF AIRFLOW LIMITATION IN COPD (BASED ON POST-BRONCHODILATOR FEV_1)

In patients with $FEV_1/FVC < 0.70$:		
GOLD 1:	Mild	$FEV_1 \geq 80\%$ predicted
GOLD 2:	Moderate	$50\% \leq FEV_1 < 80\%$ predicted
GOLD 3:	Severe	$30\% \leq FEV_1 < 50\%$ predicted
GOLD 4:	Very severe	$FEV_1 < 30\%$ predicted

Definition of abbreviation: COPD = chronic obstructive pulmonary disease; GOLD = Global Initiative for Chronic Obstructive Lung Disease.

(Vestbo et al., 2013) Found via citation from Siddharthan et al. 2018.

Table 1: Data Extracted from Articles for Review

Study	**Number of Subjects**	**Smoking**	**Fuel type**	**Prevalence of respiratory illness**
Adane et al. 2020	5,830 children <4 years in 100 clusters	Secondary smoking = 1.8% (104 households) Extra indoor burning event = 95.8% (5,583 households)	Wood/shrub/straw = 80.0% (4,662 households) Cow dung = 5.6% (328 households) Charcoal = 14.4% (840 households)	Childhood ALRI[1] status "yes" Female = 20% (564 children) Male = 18.4% (555 children) Total = 19.2 % 1119
Rumchev et al. 2017	170 households in demographic survey; 80 in indoor air quality monitoring	Smoking permitted in the home, including family and visitors = 68.3% (116 homes)	Biomass = 73.5% (125 homes) Liquid Petroleum Gas (LPG) = 26.5% (45 homes)	Respiratory symptoms in mothers: *upper respiratory* cough = 57.1% (97 women) *lower respiratory* wheeze = 53.5% (91) SOB[2] = 24.1% (41) ever had asthma = 0.6% (1) ever had bronchitis = 14.1% (24) chest pain = 35.9% (61) all = 0% (0) *other* ever had pneumonia = 4.1% (7) ever had emphysema = 100% (170) ever had TB[3] = 1.2% (2) ever had hay fever = 10.6% (18) respiratory symptoms in children: *upper respiratory* cough = 33.5% (57) runny nose = 22.9% (39) both = 15.3% (26) *lower respiratory* wheeze = 17.1% (29) ever had asthma = 1.8% (3) had both runny nose and cough = 1.2% (2) *other* ever had hay fever = 4.7% (8) ever had itchy rash = 7.1% (12) ever had eczema = 5.3% (9) ever had tonsillectomy = 1.8% (3)
Siddharthan et al. 2018	12,396 adults aged 25-95 years	Daily smokers = 12.1% (1,505 people)	Biomass as primary fuel source = 38.0% (4,714 people)	Overall prevalence of COPD = 8.8% Range = 1.7% in Kampala Uganda to 15.5% in Masindi, Uganda

1) ALRI = acute lower respiratory infection 2) SOB = shortness of breath 3) TB = tuberculosis

Discussion

One of the most commonly seen interventions being studied is the introduction of more efficient, clean fuel burning cookstoves; however, even though various studies have seen a decrease in emissions with improved cookstoves, they have been unable to prove that the reduction improves health outcomes. One study identifies previous research on upgraded cookstoves, “Little is known about how the determinants of improved cookstove adoption and sustained use, the role of individual perceptions of improved cookstoves as they are shaped and the perceived benefits and limitations of specific cookstove designs affect environmental exposures and health outcomes” (Klasen et al., 2013). Other interventions that should be considered in the case of addressing HAP and respiratory illness include alternate fuel sources being made available to the poor populations that are at a higher risk and supplying electricity to the same low-middle income countries who see increased exposure to HAP. An example of a community attempting to intervene is the Indian Government who, in 2018, kick started a program across poor communities to provide liquefied petroleum gas, electricity, vaccinations, health insurance and LED lights to address HAP related concerns (Clasen & Smith, 2019). The association seen between young children and increased exposure to toxic pollutants found in household pollution due to the use of biomass fuels should be considered a negative, modifiable health outcome and addressed accordingly. Naz et al. (2017) published an article in the Maternal and Child Health Journal that identifies the correlation between HAP exposure in children under five years of age and the increased mortality rates associated with the exposure. This article also identifies potential interventions that could be supportive for low to middle-income countries. The use of improved, cleaner fuel sources, such as LPG/natural gas, biofuel,

and electricity, could work to improve the amount of household air pollution the at-risk populations are exposed to and therefore improve their health outcomes. One barrier to implementing clean fuels is the cost of obtaining the sources for the poor families, but also the inability for the communities to support the intervention. Due to these barriers, such interventions would require extensive support for longer periods of time. (Naz et al., 2017). These barriers show the return of the most common intervention, improved cookstoves with improved ventilation, due to the more cost effective and easily supported nature of implementation. A case-control study conducted by Admasie et al. (2018) discusses the correlation between the use of unclean fuel and poorly ventilated homes and the increased odds of respiratory infection among children seen in the community of Wolaita-Sodo in Southern Ethiopia. This study defines unclean fuels as primarily biomass and charcoal, and defines the levels of ventilation as good, moderate, and poor. Good ventilation indicating a home with more than one door and one window, moderate being a home with only one door and one window, and poor as a home with one door and no windows (Admasie et al., 2018). It was shown that the exposure to unclean fuel contributed to the rate children with ARI when compared to children whose households utilize clean fuel, electricity, biogas, and LPG. The relationship to unclean fuel and ARI may be contributed to the particulate matter that is released into the air that compromises the ability of the lungs to combat bacterial infection (Admasie et al., 2018). The ventilation of the homes also contributed to the risk of children developing ARI; Admasie et al. (2018) state that the children who lived in homes with poor ventilation were four times more likely to develop ARI when compared to children in homes with good ventilation. Increasing the effectiveness of ventilation in homes could be a more

cost-effective intervention that is easily introduced and accepted by households in low to middle income countries to reduce the exposure to HAP by reducing the level of toxins in the air. A study conducted by Pilishivilli et al. (2016) implemented the use of six various improved cookstoves (ICS) and compared the amount of personal and kitchen $PM_{2.5}$ and CO concentrations compared to the traditional cookstoves (TCS) among 45 households in rural western Kenya. The study found a significant reduction in $PM_{2.5}$ was seen with the use of four out of six the ICSs in relation to the TSF, and a significant reduction in CO was seen with use of the three out of six ICSs. The study requested that participants utilize only the ICSs provided; however, 27% to 46% of the women reported continued use of the TCS in addition to the ICS (Pilishvilli et al., 2016). The continued use of the traditional cookstoves by the women shows that implementation of improved cookstoves needs to include proper education and assessment of the participants willingness to sustain the use of improved stoves. The strength of the evidence found in this review stems from the accredited peer-reviewed journals and databases utilized in the accumulation of literature. There are several potential gaps in the literature and studies surrounding the HAP and respiratory illness problem as well as the associated intervention options. There are several studies that identify specific at-risk individuals and households in a population and perform specific air function tests before, during, and after the traditional cookstoves are used. These studies involve a large ideal population; however, not all measurements are made in every identified household. For example, Rumchev et al. (2017) performed a study on a population of 170 households to participate. All 170 households completed a demographics survey, but only 80 families agreed to take part in the indoor quality monitoring to measure exposure to particulate matter and

carbon monoxide. The populations identified as at risk for HAP exposure and related adverse effects tend to be poor villages in third world countries that have not yet developed consistent use of clean fuel sources; these villages may have a limited number of households willing to participate in studies and it would be difficult to expand studies to include multiple villages and maintain the same requirements and control variables; but a larger population to study would be beneficial to problem identification and intervention analysis. Another barrier to thorough research for studies seeking to identify successful interventions for HAP is the acceptance of improved cookstove and continued use by the at-risk populations. An article published in CHEST Journal studies lung function in an at-risk population before and after the integration of an upgraded cookstove. The results of this study show that there was limited impact on lung function with the use of the improved stove, despite a reduction of the harmful toxins emitted by the traditional style. The authors identify a potential cause for limited lung function improvement; “Many households may not have switched fully to using the stove, and use may have diminished further over years of follow-up” (Guarnieri et al., 2015). This study also reveals the need for more long-term studies of intervention acceptance in trial studies, including the cultural response of the participants and their acceptance of upgraded, modern cookstoves. Cultural ideals may refrain participants in intervention studies from integrating new cooking techniques and fuel sources into their daily routines due to traditional practices and beliefs; an example of this barrier that needs to be further studied is seen in the study conducted by Pilishvilli et al. (2016). Another study conducted by Alam et al. (2016) in two rural Indian villages implemented a trial of five various improved cookstoves; they assessed the cultural characteristics, current practices, and preferences surrounding the use of cookstoves and the

acceptance of improved stoves in a field test. The results of the study help to identify key factors to consider prior to the implementation of improved cookstoves. The article suggests that the experience and education of HAP related adverse health effects may not be enough encouragement for the adoption of an ICS; however, the education of adverse effects seen in children and a tangible relief of respiratory symptoms may be a facilitating factor to precede acceptance. Alam et al. (2016) also identified cost effectiveness and time as valuable incentives to support implementation among the target population; it was found that cash incentives could be helpful to encourage promotion of improved cookstoves. It was also noteworthy to recognize the process of decision making in the household; men tend to supervise the finances of the household while elderly women, typically mothers-in-law may hold a different opinion that the main cook in the household; therefore, it is important to include all members of the home in education and decision-making processes. It may also be beneficial to include distinguished community members in the implementation process so that they may provide support and a positive influence for acceptance of the ICS program (Alam et al., 2016). Another study performed by Gemert et al. (2019) sought to discuss the idea "that implementation of improved cookstoves and heaters, imbedded in HAP awareness programmes and tailored to local context and needs, would result in higher acceptance, and enhanced and maintained respiratory health effects." The study included 610 participants from communities in Uganda, Vietnam, and Kyrgyzstan, three low to middle income locations. The baseline for all locations were reports of high rates of daily respiratory symptoms and symptoms while cooking. Once an improved cookstove was introduced, each location saw either a disappearance or reduction of respiratory symptoms. The implementation of the ICS comprised of several factors, the

households were provided education on HAP, then permitted to choose from three stoves to receive the one best suited to their needs. Gemert et al. (2019) refer to maintenance as the acceptability and long-term use of the ICS selected by the household; the results revealed a positive experience from the majority of the users, except for in Vietnam where the stoves were perceived as too small and the traditional stoves were used in conjuncture. Stove stacking, the use of multiple stove types, was seen in all three locations, but mainly in Vietnam (Gemert et al., 2019). These cultural implications and methods to boost acceptance of cookstove programs are considerations that should be intertwined in all efforts to introduce the effects of HAP and the health considerations surrounding exposure to low to middle income communities so that acceptance of new cookstoves and other interventions will be more likely. A study conducted by Bruce et al. (2013) identified the need for further research to continue to support the reduction of HAP in low to middle income countries. The study identifies the need for more data concerning the use of advanced combustion solid fuel stoves and the development of methods that succeed in reducing HAP levels to fall within WHO guidelines. "Research is urgently required on the performance and acceptability of more advanced stove designs (with and without chimneys), the role modern fuels can play in advancing access to clean household energy, and on the impacts of these interventions on child health outcomes with studies that incorporate thorough exposure assessment" (Bruce et al., 2013). Research associated to HAP could also be conducted utilizing longer follow up assessments to provide more data on the long-term effects of intervention implementation, after educational steps have been made to encourage the use of improved cookstoves and cultural practices have been considered. The use of biomass fuels by low to middle income countries around the world

contributes to the amount of household air pollution many people are exposed to throughout their lifetimes; the particles and toxins released by biomass fuel sources, like wood or animal dung, contributes to negative health outcomes. Specifically, acute respiratory illness and chronic disease development can be attributed to the exposure women and children see in households that utilize biomass fuel sources to cook, heat their homes, and other burning ceremonies. Nurses are a valuable asset in addressing the problem of HAP across the globe; they are able to identify problems and incorporate interventions into patient care and, in some cases, help to create legislature that can further address the issue on a larger scale. Nursing actions in the affected communities could address the barriers of cultural and educational acceptance of improved cookstoves or financial shortcomings seen in implementing clean fuel sources. With proper nursing education addressing HAP as a global concern, “nurses can be alerted to assessing patients, with cultural sensitivity, regarding diseases that result from chronic exposures to smoky fuels at the household level” (Thomas et al., 2012).

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