Association between household air pollution and neonatal mortality: an analysis of Annual Health Survey results, India

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ABSTRACT

Background: In India, household air pollution (HAP) is one of the leading risk factors contributing to the national burden of disease. Estimates indicate that 7.6% of all deaths in children aged under 5 years in the country can be attributed to HAP. This analysis attempts to establish the association between HAP and neonatal mortality rate (NMR).

Methods: Secondary data from the Annual Health Survey, conducted in 284 districts of nine large states covering 1 404 337 live births, were analysed. The survey was carried out from July 2010 to March 2011 (reference period: January 2007 to December 2009). The primary outcome was NMR. The key exposure was the use of firewood/crop residues/cow dung as fuel. The covariates were: sociodemographic factors (place of residence, literacy status of mothers, proportion of women aged less than 18 years who were married, wealth index); health-system factors (three or more antenatal care visits made during pregnancy; institutional deliveries; proportion of neonates with a stay in the institution for less than 24 h; percentage of neonates who received a check-up within 24 h of birth); and behavioural factors (initiation of breast feeding within 1 h). Descriptive analysis, with district as the unit of analysis, was performed for rural and urban areas. Bivariate and multivariable linear regression analysis was carried out to investigate the association between HAP and NMR.

Results: The mean rural NMR was 42.4/1000 live births (standard deviation [SD] = 11.4/1000) and urban NMR was 33.1/1000 live births (SD=12.6/1000). The proportion of households with HAP was 92.2% in rural areas, compared to 40.8% in urban areas, and the difference was statistically significant (P < 0.001). HAP was found to be strongly associated with NMR after adjustment (β = 0.22; 95% confidence interval [CI] = 0.09 to 0.35) for urban and rural areas combined. For rural areas separately, the association was significant (β = 0.30; 95% CI = 0.13 to 0.45) after adjustment. In univariable analysis, the analysis showed a significant association in urban areas (β = 0.23; 95% CI = 0.12 to 2.34) but failed to demonstrate an association in multivariable analysis (β = 0.001; 95% CI = –0.15 to 0.15).

Conclusion: Secondary data from district level indicate that HAP is associated with NMR in rural areas, but not in urban areas in India.

Key words: developing countries, indoor air pollution, low birth weight, neonatal mortality
BACKGROUND

Globally, household air pollution (HAP) is the second-biggest environmental contributor to the burden of diseases, after unsafe water and sanitation. Around 2.7% of the global burden of diseases (in disability-adjusted life-years [DALYs]) was attributed to HAP in 2004. In India, it is estimated to be the leading risk factor contributing to the national burden of disease. It has become the second-largest risk factor for disease burden in India. It is estimated that 7.6% of all deaths in children aged under 5 years in the country can be attributed to HAP.

HAP is associated with increased risk for several acute and chronic health conditions, including acute respiratory infections, pneumonia, tuberculosis, chronic lung disease, cardiovascular disease, cataracts and cancers. Exposure is higher among women and children, since they spend more time near the domestic hearth. There is emerging evidence that HAP also increases the risk of adverse pregnancy outcomes; fetal mortality; low birth weight (LBW); preterm birth; small for gestational age; intrauterine growth retardation; and congenital anomalies. A study in rural Guatemala has shown that babies born to women using wood fuel were 63 g lighter (after adjustment for confounding) than those born to women using gas or electricity. An association between exposure to HAP and perinatal mortality (odds ratio (OR) = 1.5, after adjusting for other factors), has also been established. Exposure of infants of normal birth weight to HAP has been associated with respiratory mortality (OR = 1.40) and sudden infant death syndrome (OR = 1.26).

Many studies from India have explored the relationship between HAP and LBW and/or stillbirth. However, very few studies have attempted to establish the relationship of HAP with neonatal mortality. In a large representative sample from India, it was shown that mortality among 1–4 year olds was 50% higher among those exposed to HAP. Among neonates, the mortality rate was found to be almost eight times higher, according to an analysis of data from India’s National Family Health Survey (NFHS-3), collected in 2005–2006. The analysis revolved primarily around sociodemographic factors that can influence neonatal health.

Since 2005, multiple interventions have been added to the national programme (National Rural Health Mission [NRHM]) to increase access to skilled care for pregnant women and neonates. Implementation of integrated management of neonatal and childhood illnesses and home-based newborn care aims to increase the contact of neonates with the health system during this critical period of life. In addition, the Government schemes, Janani Suraksha Yojana and Janani Shishu Suraksha Karyakram, facilitate institutional deliveries and also influence neonatal health. At the same time, facility-based care has also been improved to take care of sick neonates. These programmatic interventions have a role in improving neonatal survival.

METHODS

Study setting

India is a union of 29 states and 7 union territories, with a huge range of socioeconomic characteristics. States are further divided into districts, each with a population of 1–2 million, which are further subdivided into blocks.

The study includes 284 districts of nine large states – Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, Rajasthan, Uttarakhand and Uttar Pradesh. These states constitute about 48% of the country’s population, 70% of infant deaths, 75% of deaths in children aged under 5 years and 62% of maternal deaths. The Government of India has classified these states as high-focus states, to receive focused attention and greater resource allocation in the health sector.

Study design

The study is an analysis of secondary data from a large population-based survey, the Annual Health Survey (AHS).

Data source

The AHS is the largest sample survey in the world. This is the first survey that records the district-level health outcomes in high-focus states, to provide critical inputs for public health programmes. The data are available in the public domain.

The AHS adopted one-stage stratified random sampling without replacement, except in the case of larger villages in rural areas, to select 20 694 villages and urban blocks. It surveyed about 18 million populations, 3.6 million households and 1 404 337 live births. The survey was carried out in all nine AHS states between July 2010 and March 2011 (reference period; January 2007 to December 2009). A total of 284 districts were covered in rural areas. In order to avoid unusual sampling fluctuations, estimates for urban areas were not available when the number of urban sampling units was less than six. Therefore, for most of the variables, data were available from 239 districts. All the variables were elicited during interviews of family members as part of the large survey. A brief description of the variables is given in Box 1.
Study variables

The key outcome variable was district-level NMR. The key exposure was the use of firewood/crop residues/cow dung as fuel. In the absence of individual-level data, the proportion of households using firewood/crop residues/cow dung as fuel was considered as a surrogate marker of the proportion of households with HAP. Data on households primarily using kerosene as their fuel, and the proportion of women who smoke were also available but since the values were very small, these were not considered as exposures. Instead, data on the proportion of the population who smoke was used to indicate exposure to second-hand smoke.

The following maternal and delivery care factors were considered as covariates: sociodemographic factors (place of residence, literacy status of mothers, proportion of women aged less than 18 years who were married, wealth index); health-system factors (three or more antenatal care [ANC] visits made during pregnancy, institutional deliveries, proportion of neonates with a stay in the institution of less than 24 h, percentage of neonates who received a check-up within 24 h of birth); and behavioural factors (initiation of breastfeeding within 1 h).

Box 1. Case definitions, measurements and calculations used in the AHS survey

- Neonatal mortality rate (NMR): The proportion of neonates who died within 28 days of birth out of 1000 live births in a district.
- Low birth weight (LBW): Birth weight below 2.5 kg. The information on birth weight was collected for all living children (for the last two outcomes of pregnancy resulting in live births) during the reference period. The percentage of children whose birth weight was taken and was less than 2.5 kg was considered.
- Household air pollution (HAP): The proportion of households using firewood/crop residues/cow dung as the main source of fuel was considered.
- Households using kerosene: The proportion of households using kerosene as the main source of fuel was considered.
- Wealth quintile: In the absence of income and expenditure measures of economic status, household wealth index has been constructed at state level for each of the states, using the assets possessed (structure of the house and the facilities available for use by the household). The households were ranked according to their individual Household Asset Score and then divided into five quintiles, with the same number of households in each quintile. For the present study, the proportion of households in the lowest 20% and highest 20% income quintile in each district, based on assets possessed, was calculated.
- Effective literacy rate: The proportion of the population in a district with the ability to read and write in any language, expressed as a percentage.
- Marriage below 18 years: This is the proportion of marriages among women taking place below the legal age, that is 18 years. These proportions were also based on marriages of the members of household (usual residents as in January 2010) taking place during 2007–2009. In addition, the percentage of currently married women aged 20–24 years who were married before the legal age was calculated.
- Three or more antenatal care (ANC) visits: This was elicited through a series of responses to questions from every married woman aged 15–49 years. The indicator, the percentage of mothers who received three or more ANC check-ups, is with reference to the last live/still birth during the reference period.
- Institutional delivery: Details were requested from every married woman aged 15–49 years. This indicator reflects the percentage of deliveries that took place in institutions (government or private) for the last live/still birth during the reference period.
- Breastfeeding within 1 h: This was assessed by asking mothers of all living children (for the last two outcomes of pregnancy resulting in live births during the reference period). The percentage of children breastfed within 1 h was calculated.
- Less than 24 h stay after delivery: This was elicited from every married woman aged 15–49 years for the last live/still birth during the reference period. This indicator reflects the percentage of women who stayed for less than 24 h in institutions after delivery. This has a direct bearing on the health of the mother and neonate.
- Neonates checked within 24 h of birth: This was elicited from mothers whose last outcome of pregnancy resulted in live birth during the reference period. The percentage of neonates who received a check-up within 24 h has been worked out. For institutional deliveries, if the baby remained in the institution for at least 24 h, it was presumed that the first check-up was done within 24 h.
- Proportion of people who smoke: This information was collected from usual residents aged 15 years and above. This reflects the proportion of habitual smokers (who smoke at least once every day).
Ethical issues

The study is based on the data available in the public domain.

Statistical analysis

The analysis was performed by considering all districts combined, and also stratified by place of residence (that is rural and urban). For the district-level analysis, the main outcome variable was district-level NMR. The analysis focused on exploring the relationship between district-level NMR and HAP in the nine high-focus states in India. Sociodemographic characteristics of the districts for both rural (284) and urban (239) areas have been presented. A simple linear regression analysis was used to study the relationship between the number of households using cooking fuel in rural areas, which is used as a proxy for HAP, and neonatal mortality. Correlation analysis was performed using Pearson’s correlation, and Spearman’s rank correlation, as appropriate. Subsequently, multiple regression models were developed to assess the effect of change in the district-level HAP on NMR when adjusting for sociodemographic variables. Multiple regression models were run for the total sample, as well as for urban and rural areas separately. Variables that had a strong correlation in bivariate analysis and seemed to be a plausible explanation for high NMR were considered in the models. All analyses were performed in STATA version 12 (StataCorp, College Station, Texas) and SPSS version 21.

RESULTS

The mean total NMR was 40.5/1000 live births (standard deviation [SD] = 11.28/1000), while that of rural and urban areas was 42.4/1000 (SD = 11.4/1000) and 33.1 (SD = 12.6/1000) live births, respectively. The proportion of LBW in rural areas was 28.1% (SD = 11.5%) compared to 25.5% (SD = 9.9%) in urban areas. The proportion of households with HAP was 92.2% (SD = 8.3%) in rural areas compared to 40.8% (SD = 15.9%) in urban areas, and the difference was statistically significant (P < 0.001). Other variables that varied greatly between urban and rural areas were the proportion of households using liquid petroleum gas/piped natural gas (LPG/PNG) as fuel; the proportion of households in the lowest 20% and highest 20% wealth quintiles; marriage below 18 years of age; the rate of institutional deliveries; and the effective literacy rate (see Table 1).

The bivariate analysis (table not shown) indicated that significant correlation exists between HAP and total NMR (r = 0.37, P < 0.001), as well as for rural (r = 0.36, P < 0.001) and urban areas (r = 0.29, P < 0.001) separately. Other variables that were significantly associated with total NMR include initiation of breast feeding within 1 h of delivery (r = –0.18); the proportion of households in the lowest 20% (r = 0.22) and highest 20% wealth quintile (r = –0.31); neonates checked within 24 h of birth (r = 0.24); three or more ANC check-ups during pregnancy (r = –0.13); and effective literacy rate (r = –0.21). Despite there being a significant correlation between NMR and the proportion of households using kerosene and LPG/PNG, these were excluded because the proportions were very low.

HAP was found to be strongly associated in both unadjusted and adjusted analysis for total (β = 0.22; 95% confidence interval [CI] = 0.09 to 0.35) and rural areas (β = 0.30; CI = 0.13 to 0.45) (see Table 2). The difference was greater for those households where neonates were checked within 24 h of delivery. The analysis showed a significant association in urban areas in univariable analysis (β = 0.23; 95% CI = 0.12 to 0.34) but failed to demonstrate an association in multivariable analysis (β = 0.001; 95% CI = –0.15 to 0.15).

DISCUSSION

The analysis from 284 districts indicates that a strong association exists between HAP and NMR, after adjusting for the proportion of households in the lowest and highest 20% wealth quintiles; the proportion of neonates checked within 24 h of birth; those who initiated breastfeeding after 1 h; the proportion of women who went for three or more ANC check-ups; the proportion of babies who stayed for less than 24 h in hospitals; and effective literacy rate. Adjusted analysis suggests that an association between HAP and NMR exists in rural areas but fails to demonstrate an association in urban areas.

There is limited evidence on the association of HAP and infant or neonatal mortality rates. Bassani et al. reported that child mortality (age 1–4 years) increased by 50% with exposure to HAP.25 In their analysis using data from NFHS-3, Epstein et al. concluded that exposure to HAP increased the risk of NMR by 7.5 times.24 The risk of death of neonates born in households using coal was more than 18 times higher than that for neonates in households primarily using gas.24

The strength of the evidence between the use of biomass as cooking fuel and neonatal mortality was found to be weak in a population-based cohort of more than 10 000 neonates in south India.26 However, the study documented a 21% increased risk of dying in the first 6 months of life.26

The present results are contrary to the findings provided on the basis of death estimates given by a United Nations report that stated that no neonatal or post-neonatal deaths were attributed to solid-fuel use.23 The present results show that neonatal mortality as a result of exposure to solid fuel is 4.2% in rural areas, 2.3% in urban areas and 3.0% in total.

The association between solid fuel combustion and LBW is established.26–28 The reported association (OR) was from 1.23 in a hospital-based study to as high as 18.54, as represented from an analysis of NFHS-3 data.29 There is also strong evidence that HAP is associated with stillbirths.3,4,21,26,30,31 Exposure to HAP has 50% more risk of stillbirths as reported in various studies from India.21,26,30 The current dataset did not report stillbirths. Low birth weight was reported for every district. This, too, was based on the records that were made available to the survey team. There was no report on the completeness of these data and hence this study did not attempt to establish an association between HAP and LBW.
Table 1: Baseline characteristics of the study districts

<table>
<thead>
<tr>
<th>District characteristics</th>
<th>Rural Number of districts</th>
<th>Rural Mean ± SD (range)</th>
<th>Urban Number of districts</th>
<th>Urban Mean ± SD (range)</th>
<th>Total Number of districts</th>
<th>Total Mean ± SD (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonatal mortality rate (per 1000 live births)</td>
<td>284</td>
<td>42.4 ± 11.4</td>
<td>201</td>
<td>33.1 ± 12.6</td>
<td>284</td>
<td>40.51 ± 11.3</td>
</tr>
<tr>
<td>Low birth weight (%)</td>
<td>284</td>
<td>28.1 ± 11.5</td>
<td>239</td>
<td>25.5 ± 9.9</td>
<td>284</td>
<td>25.0</td>
</tr>
<tr>
<td>Institutional delivery (%)</td>
<td>284</td>
<td>53.6 ± 19.0</td>
<td>239</td>
<td>73.1 ± 15.0</td>
<td>284</td>
<td>56.2 ± 18.6</td>
</tr>
<tr>
<td>Less than 24 h hospital stay (%)</td>
<td>284</td>
<td>50.4 ± 20.5</td>
<td>239</td>
<td>42.9 ± 20.6</td>
<td>284</td>
<td>49.0 ± 20.2</td>
</tr>
<tr>
<td>Neonates checked within 24 h after delivery (%)</td>
<td>284</td>
<td>62.0 ± 16.6</td>
<td>239</td>
<td>77.7 ± 11.9</td>
<td>284</td>
<td>64.3 ± 16.0</td>
</tr>
<tr>
<td>Breastfeeding within 1 h after delivery (%)</td>
<td>284</td>
<td>50.0 ± 21.1</td>
<td>239</td>
<td>52.2 ± 19.9</td>
<td>284</td>
<td>50.1 ± 20.6</td>
</tr>
<tr>
<td>Household air pollution (%)</td>
<td>284</td>
<td>92.2 ± 8.3</td>
<td>239</td>
<td>40.8 ± 15.9</td>
<td>284</td>
<td>85.9</td>
</tr>
<tr>
<td>Household use of LPG/PNG as fuel (%)</td>
<td>284</td>
<td>3.8</td>
<td>239</td>
<td>52.1 ± 15.7</td>
<td>284</td>
<td>9.8</td>
</tr>
<tr>
<td>Least wealth quintile (20%)</td>
<td>284</td>
<td>24.6 ± 11.9</td>
<td>284</td>
<td>3.7</td>
<td>284</td>
<td>21.37 ± 11.1</td>
</tr>
<tr>
<td>Marriage below 18 years (%)</td>
<td>284</td>
<td>12.7</td>
<td>284</td>
<td>3.9</td>
<td>284</td>
<td>11.2</td>
</tr>
<tr>
<td>Three or more antenatal care visits (%)</td>
<td>284</td>
<td>46.1 ± 20.7</td>
<td>284</td>
<td>53.9 ± 30.1</td>
<td>283</td>
<td>48.88 ± 20.7</td>
</tr>
<tr>
<td>Household use of kerosene as fuel (%)</td>
<td>284</td>
<td>0.1</td>
<td>284</td>
<td>1.4</td>
<td>284</td>
<td>0.4</td>
</tr>
<tr>
<td>Highest wealth quintile (20%)</td>
<td>284</td>
<td>9.7</td>
<td>284</td>
<td>50.8 ± 13.2</td>
<td>284</td>
<td>15.7</td>
</tr>
<tr>
<td>Effective literacy rate (%)</td>
<td>284</td>
<td>58.1 ± 9.6</td>
<td>284</td>
<td>77.6 ± 7.3</td>
<td>284</td>
<td>61.9 ± 9.6</td>
</tr>
<tr>
<td>Population who smoke (%)</td>
<td>284</td>
<td>11.4 ± 4.9</td>
<td>239</td>
<td>6.9 ± 3.3</td>
<td>284</td>
<td>10.4 ± 4.4</td>
</tr>
</tbody>
</table>


a Data pertain to the indicators of urban and rural population in 284 districts. Indicators for urban population were not available for a few districts.

b Median and interquartile range are presented.
In a meta-analysis of five studies, Pope et al. concluded that exposure to HAP is associated with 1.38 times higher risk of LBW and 51% higher risk of stillbirth. Assuming a 70% prevalence of solid fuel use, population-attributable risk for LBW and stillbirth were found to be 21% and 26.3% respectively. A more recent analysis from India, using district-level data, indicated that around 12% of stillbirths in India could be prevented by providing access to cleaner fuel, assuming a 70% exposure to HAP is associated with 1.38 times higher risk in nature. There is a possibility of selection bias, uncontrolled secondary data and also with a study design that is ecological in nature. There is a possibility of selection bias, uncontrolled confounding and misclassification of exposure and outcome. Errors could be introduced by variations in settings, type of exposure, study design, sampling techniques and factors such as random errors. Controlling for confounding factors in ecological studies is more difficult than in individual-based studies because of extra potential sources of bias due to aggregation of subjects into groups. Another limitation is that the present analysis is based on the data aggregated at the district level, since the researchers did not have access to individual-level data. It is, therefore, not possible to comment on the individual-level association between these variables. It may be unfair to over-interpret the magnitude of effect on NMR, yet a degree of consistency with other studies that have focused on smoking, use of biomass as fuel, and urban air pollution is appreciable.

Temporality is also established, since it can be presumed that exposure to HAP was present during pregnancy. Boy et al. reported a possibility that some women change fuel during the later part of pregnancy, which could result in a bias. This is unlikely in Indian settings where affordability of cleaner fuel is a challenge.

Moreover, the studies reported were based on data collected before 2006. After this period, with the advent of the NRHM, strengthening of health systems has been the focus and there have been dramatic improvements. Measures were instituted to improve the contact of neonates with community health workers within the first 24 h – the most critical period of life – and to promote deliveries in hospitals, to ensure skilled personnel are involved. These factors, which are known to influence NMR directly, were controlled during the analysis.

<table>
<thead>
<tr>
<th>Table 2: Association of neonatal mortality rate and explanatory variables: results of multivariable analysis</th>
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<tbody>
<tr>
<td>Explanatory variables</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>Household air pollution</td>
</tr>
<tr>
<td>Lowest wealth quintile (20%)</td>
</tr>
<tr>
<td>Highest wealth quintile (20%)</td>
</tr>
<tr>
<td>Neonates checked within 24 h after delivery</td>
</tr>
<tr>
<td>Breastfeeding within 1 h after delivery</td>
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<tr>
<td>Three or more antenatal care visits</td>
</tr>
<tr>
<td>Effective literacy rate</td>
</tr>
<tr>
<td>Institutional delivery</td>
</tr>
<tr>
<td>Less than 24 h hospital stay</td>
</tr>
</tbody>
</table>

CI: confidence interval.

*P < 0.05, **P < 0.001.
Sociodemographic factors take time to change and hence little difference was expected between the previous and the present analysis. Nevertheless, the fact that, despite these adjustments, HAP still continues to be predictive of neonatal mortality is a concern.

Other sources of environmental smoke and outdoor air pollution were not considered in the present analysis. Studies from developing countries have reported a decline in birth weight with exposure to second-hand smoke.26 Smoking was not considered as an exposure because, in India, active smoking is relatively rare in pregnancy as compared to tobacco chewing. Information on chewing tobacco was unavailable in the data captured. In the present study, the proportion of the population that smoke was considered as an indirect marker of exposure to second-hand smoke.

Despite the limitations, the analysis emphasizes and reiterates the contribution of HAP to neonatal well-being and warrants interventions. Globally, owing to the established linkages between HAP and health outcomes, many policies or interventions have been proposed to decrease HAP. In 2008, Dufo et al. outlined some of the policy interventions and argued their relevance in the context of reducing HAP and its impact on health outcomes, but did not directly link it to neonatal mortality.31 One method has been to subsidize cleaner fuel technologies, in most cases kerosene, but this option has a huge cost implication, with huge subsidy pressure on the governments; even at the subsidized prices, this is an expensive option for most low-income households. The improved cooking stove has become a particularly popular policy prescription, especially with recent evidence of its cost effectiveness and its potential to reduce HAP, as well as to improve health outcomes. The cost of using an intervention with improved cooking stoves can be as low as US$ 50 to US$ 100 per DALY saved.34 However, the impact of the alternative is dependent on the user’s ability to use it in an appropriate way. The third policy intervention, improving ventilation, is a recommendation of the Disease Control Priorities Project of the World Bank Group. However, if smoke exposure is the greatest threat in the immediate vicinity of the stove it is unclear whether improving ventilation in the kitchen as a whole will reduce the smoke exposure for the primary cook in the household, as recent studies have found no correlation between ventilation and smoke exposure.35 However, no matter what the policy intervention is, the final goal of policy or interventions should be to reduce exposure to HAP, while meeting domestic energy and cultural needs and improving safety, fuel efficiency and environmental protection, along with economic affordability.3 There is need for research in the areas of epidemiology, exposure assessment and intervention impact in the context of HAP, for better evidence-based decision-making.18

CONCLUSION

Secondary data from district level indicate that HAP is associated with NMR in the rural areas but not in urban areas in India. This association is maintained even after adjusting for programmatic factors that have increased access to services that can improve neonatal health. There is a need for a policy intervention to reduce exposure to HAP, while meeting domestic energy and cultural needs and improving safety, fuel efficiency and environmental protection, along with economic affordability.

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Contributorship: SBN planned the study, analysed the results and drafted the manuscript; SP analysed the data; JS contributed towards literature search and analysis; MC (Maulik Choksi) gave input on the technical content of the paper; MC (Monika Chauhan) conducted the literature search and reviewed articles; SZ and VKP provided guidance on drafting the paper. All the authors reviewed and finalized the manuscript.