Effects of Traffic-Related Outdoor Air Pollution on Respiratory Illness and Mortality in Children, Taking Into Account Indoor Air Pollution, in Indonesia

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Objective: To evaluate the effects of outdoor air pollution, taking into account indoor air pollution, in Indonesia. **Methods:** The subjects were 15,242 children from 2002 to 2003 Indonesia Demographic and Health Survey. The odds ratios and their confidence intervals for adverse health effects were estimated. **Results:** Proximity increased the prevalence of acute respiratory infection both in urban and rural areas after adjusting for indoor air pollution. In urban areas, the prevalence of acute upper respiratory infection increased by 1.012 (95% confidence intervals: 1.005 to 1.019) per 2 km proximity to a major road. Adjusted odds ratios tended to be higher in the high indoor air pollution group. **Conclusion:** Exposure to traffic-related outdoor air pollution would increase adverse health effects after adjusting for indoor air pollution. Furthermore, indoor air pollution could exacerbate the effects of outdoor air pollution.

Air pollution causes ~800,000 deaths worldwide each year,[1] predominantly in developing countries.[1] Approximately two thirds of these deaths are in Asian countries,[2] where mortality due to acute respiratory infection in children is particularly high.[1,2] Thus, the impact of air pollution on the health of children is considered substantial. For this reason, some countries have begun efforts to reduce emissions from specific sources; for example, lead has been removed from gasoline and sulfur levels in fuel are controlled.[2] Despite these countermeasures, the level of outdoor air pollution is still increasing owing to industrialization and urbanization.[3,4]

To evaluate the current situation, epidemiological assessments of adverse health effects of exposure to outdoor air pollutants in Asia are needed. Nevertheless, most studies have been conducted in North America and Europe,[4–6] and there have been few assessments of the health effects of outdoor air pollution in Asia.[7–9] Asian countries may differ from other countries in terms of the nature of air pollution, the conditions and magnitude of exposure to pollution, health status, lifestyle, indoor air pollution, and socioeconomic status. In particular, indoor air pollution is ubiquitous and a serious concern in developing countries in Asia. Indeed, previous studies consistently showed that indoor air pollution increases the risk of acute respiratory infection in children.[2,10–14] Thus, evaluations of the health effects of outdoor air pollution taking into account indoor air pollution are required for Asian countries.[15]

We made an epidemiologic evaluation of the effects of outdoor air pollution on the prevalence of respiratory illness in children less than 5 years old, infant mortality, neonatal mortality, and miscarriage and stillbirth in Indonesia using data from the Indonesia Demographic and Health Survey (IDHS). Furthermore, we examined how the effects changed when we took into account indoor air pollution.

MATERIALS AND METHODS

Study Area and Participants

This study is based on 79,791 birth records from the 2002 to 2003 IDHS, which was a nationally representative cross-sectional sample survey performed by Badan Pusat Statistik–Statistics Indonesia. The 2002–2003 IDHS fieldwork was performed from October 2002 to April 2003 in selected areas in 26 of the 30 provinces in Indonesia (Fig. 1). Owing to security concerns, four provinces were excluded: Nanggroe Aceh Darussalam, Maluku, North Maluku, and Papua.[16] The 2002–2003 IDHS samples were selected using a stratified two-stage design. First, 1592 census blocks, each comprising approximately 80 households, were selected from the 26 provinces. In rural areas, before selecting census blocks, subdistricts were selected according to the number of households. In the second stage, 25 households were randomly selected from each of the selected census blocks.[16] Each household was then investigated.

The IDHS collected demographic, socioeconomic, and health information from each household via three questionnaires: the Household Questionnaire, the Women's Questionnaire for ever-married women aged 15 to 49 years, and the Men's Questionnaire for currently married men aged 15 to 54 years. In total, 29,996 ever-married women aged 15 to 49 years were identified in the target area, and complete interviews were obtained with 29,483 (98%) of them. On the basis of the Women's Questionnaire, 79,791 birth records, which we used in this study, were created in the IDHS.

In this study, as shown in Fig. 2, we selected 16,026 single births from 1998 to 2003 from the birth records and excluded 784 births that lacked global positioning system (GPS) information for exposure assessment. We thus targeted 15,242 births.

Measurement of Exposure

As an indicator of outdoor air pollution for participants (births), we measured the distances from households to major roads. In the survey, location information (latitude and longitude) of the village or settlement of the household was gathered by a trained interviewer using a GPS. Among the 1516 GPS points available in the 2002–2003 IDHS, 1315 points could be assigned to the households in this study. One GPS point represented 12 households on average (a maximum of 34, minimum of 1, and standard deviation [SD] = 5.1). To protect the

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This study was supported by the Yakumo Foundation for Environmental Science.

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DOI: 10.1097/JOM.0b013e3181d44e3f

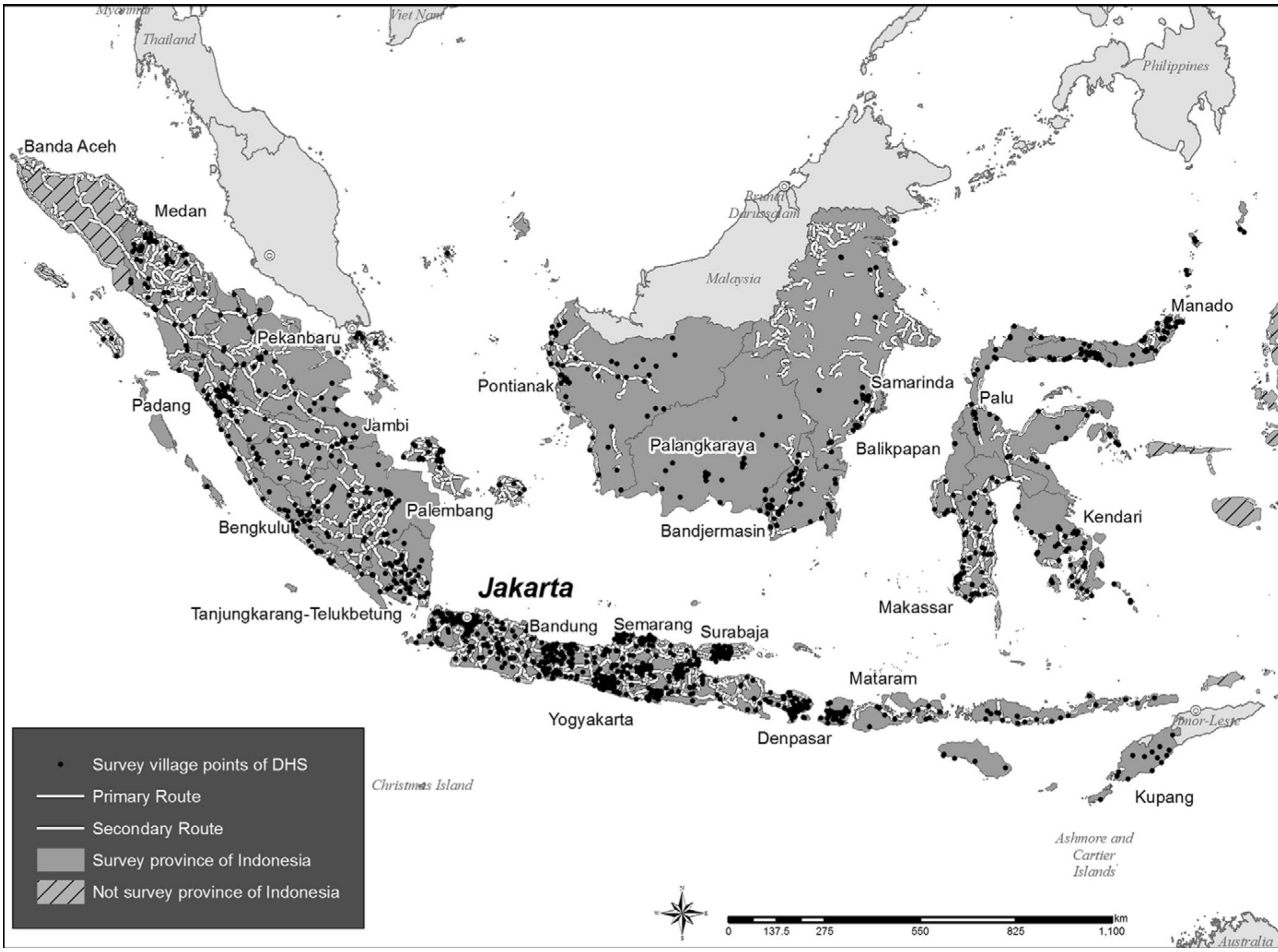

FIGURE 1. Map of Indonesia indicating major roads and the survey points for the IDHS 2002–2003.

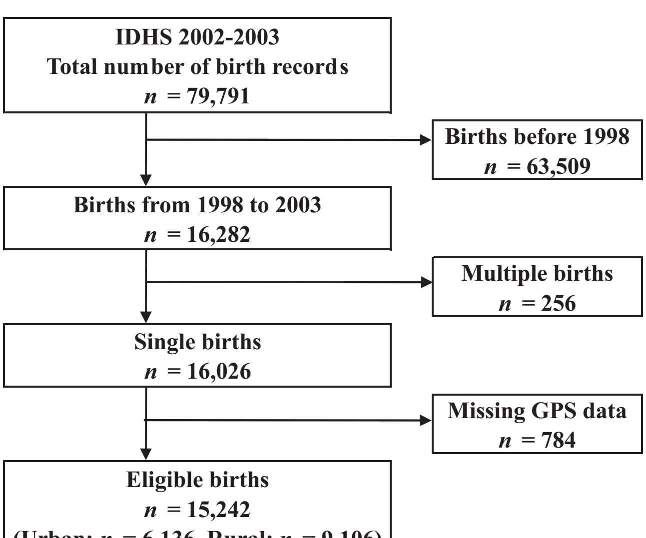

FIGURE 2. A selection of eligible births from the IDHS birth records.

privacy of respondents, offsets were employed. The offsets ranged 0 to 2 km in urban areas and 0 to 5 km in rural areas. Furthermore, in rural areas, a 10 km offset was applied to every 100th village. Because the maximum offset in the urban areas was 2 km, we adopted a 2 km increase in proximity as the exposure indicator. Nevertheless, as Zhou and Levy[17] described, air pollution from roads declines to near background levels within a distance of 500 m (ie, the zone of influence is less than 500 m), and we thus adopted a 500 m increase in proximity in the sensitivity analysis.

Information on major roads was obtained from the International Steering Committee for Global Mapping (ISCGM) of Indonesia, who released the information on 27 September 2007. The ISCGM provides digital geographic information for 70 countries with standardized specifications; for example, information on transportation, drainage, and political boundaries with 1 km resolution.[18] Major roads, which we considered in this study, are primary and secondary routes as defined by the ISCGM. According to the Global Roads Data Project, primary routes connect important cities and secondary routes connect important towns.[19]

Measurement of Health Outcomes

To evaluate the effects of outdoor air pollution on the prevalence of respiratory illness and mortality in children, we considered five health outcomes: 1) symptoms of coughing within the last 2 weeks indicating acute upper respiratory infection (AURI), 2) short and rapid breathing within the last 2 weeks indicating acute lower respiratory infection (ALRI), 3) infant mortality, 4) neonatal mortality, and 5) stillbirth including miscarriage. All health outcomes were ascertained from the Woman's Questionnaire in the IDHS. AURI was determined by the question "Q#467 Has (NAME) had an illness with a cough at any time in the last 2 weeks?," ALRI by "Q#468 When (NAME) was ill with a cough, did she/he breathe faster than usual with short, rapid breaths?," infant (younger than 1 year old) mortality and neonatal (less than 28 days old) mortality by "Q#220 How old was (NAME) when he/she died?," and stillbirth by "Q#229 Have you ever had a pregnancy that miscarried, was aborted, or ended in stillbirth?"

Measurement of Covariates

Our covariate sets include variables that have been previously recognized as predictors of the above health outcomes: indoor air pollution, baby's sex, mother's age, mother's current smoking of cigarettes or a pipe or other consumption of tobacco, and mother's number of years of education as an indicator of socioeconomic status. All covariate data were ascertained from the self-reported questionnaires.

We used the type of cooking fuel as an indicator of indoor air pollution. Previous studies showed that the type of cooking fuel is a good predictor of the indoor air pollution level in households.[10,11,14,20,21] On the basis of the results of previous studies,[2,10,11] we categorized the types of cooking fuel into high and low indoor air pollution groups. The high indoor air pollution group comprised coal/lignite, charcoal, firewood/straw, and dung, whereas the low pollution group comprised electricity, liquid petroleum gas/natural gas, biogas, and kerosene.

Statistical Analysis

We analyzed urban and rural areas separately because levels of outdoor and indoor air pollution and socioeconomic status are different for these areas in developing countries.[2] In the IDHS, urban areas were defined as large cities (capital cities and cities with populations >1 million), small cities (populations >50,000), and towns (other urban areas), whereas rural areas were defined as the remaining areas.[16]

We descriptively analyzed the participants (the targeted births) separately for urban and rural areas. We then used linear generalized estimating equation (GEE) models that use a logistic link to investigate the associations between proximity to a major road as a continuous variable and health outcomes, and estimated the crude and adjusted odds ratios (ORs) and their confidence intervals (CIs) per 2 km proximity. In the GEE models, we took account of correlations among villages using exchangeable correlation structures. In the model, we adjusted for indoor air pollution, baby's sex, mother's age, mother's current smoking, and mother's number of years of education.

To determine whether the effect of outdoor air pollution (proximity to a major road) is influenced by indoor air pollution, we stratified the participants for high and low indoor air pollution groups. We then estimated the adjusted ORs by adjusting for other confounders in each stratum. A test of interaction based on a multiplicative model was conducted by including multiplicative terms for interaction between the proximity and indoor air pollution in the model.

We conducted three sensitivity analyses in this study. First, as mentioned above, we adopted a 500 m increase in proximity as the exposure indicator. Second, instead of considering correlations among villages, we considered correlations among mothers using exchangeable correlation structures in the GEE models because children were also nested by mothers. Finally, instead of using the mother's number of years of education, we used the partner's occupation type to indicate socioeconomic status, and estimated the adjusted ORs for all health outcomes. There were eight categories of partner's occupation in the IDHS: professional/technical workers, clerical workers, sales workers, agricultural workers, services workers, skilled manual workers, unskilled manual workers, did not work, and do not know (Table 1). All CIs were estimated at the 95% confidence level. SPSS software (SPSS Japan Inc., version 17.0J) was used in the analysis.

TABLE 1. Demographic Characteristics of the Participants and Their Parents

	Urban	Rural
Demographic characteristics		
Single birth [no.]	6,136	9,106
Mean age of participants [year (SD)]	2.0 (1.4)	1.9 (1.4)
Child sex [no. (%)]*		
Male	3,149 (51)	4,723 (52)
Female	2,987 (49)	4,383 (48)
Estimated mean distance [km (SD)]	5.6 (21.7)	17.3 (40.2)
Type of cooking fuel [no. (%)]*		
High group (coal/lignite, charcoal, firewood/straw)	774 (13)	6,265 (71)
Low group (electricity, LPG/natural gas, kerosene)	5,217 (87)	2,616 (29)
Mean age of mothers [year (SD)]	29.5 (6.0)	28.8 (6.4)
Mother's smoking [no. (%)]		
Nonsmoker	6,041 (99)	9,098 (99)
Current smoker	89 (1)	123 (1)
Mean of mother's education [year (SD)]	9.5 (4)	6.7 (4)
Partner's occupation [no. (%)]*		
Professional, technical workers	789 (13)	485 (5)
Clerical workers	499 (8)	196 (2)
Sales workers	1,217 (20)	683 (7)
Agricultural workers	593 (10)	5,483 (60)
Services workers	959 (16)	607 (7)
Skilled manual workers	696 (11)	500 (6)
Unskilled manual workers	1,193 (20)	994 (11)
Did not work	169 (3)	146 (2)
Don't know	10 (0)	3 (0)
Health outcome		
Acute upper respiratory infection [no. (%)]*		
Yes	1,563 (27)	2,227 (26)
No	4,275 (70)	6,308 (74)
Acute lower respiratory infection [no. (%)]*		
Yes	462 (8)	801 (9)
No	5,343 (87)	7,684 (91)
Neonatal mortality [no. (%)]*	103 (2)	182 (2)
Infant mortality [no. (%)]*	153 (3)	382 (4)
Miscarriage and stillbirth [no. (%)]*	728 (12)	855 (9)

*The total number of subjects and percentages may not sum correctly owing to rounding and missing data.

The percentage is obtained by dividing the number of participants by the total number of births, separating for urban and rural areas.

Participants are single births during 1998–2003 in the 2000–2003 Indonesia Demographic and Health Survey separated for urban and rural areas.

No. indicates number.

RESULTS

The baseline characteristics of participants and their parents separated for urban and rural areas are shown in Table 1. The mean age among children was 2.0 years (SD = 1.4) in urban areas and 1.9 years (SD = 1.4) in rural areas. Regarding the distance to a major road as an indicator of outdoor air pollution, participants in urban areas lived closer to major roads than did participants in rural areas. Regarding the type of cooking fuel as an indicator of indoor air pollution, 71% of participants in rural areas were exposed to high levels of indoor air pollution, whereas 13% were in urban areas. Regarding the health outcomes, the prevalence of ALRI and infant mortality in rural areas was higher than that in urban areas.

The crude and adjusted ORs per 2 km proximity to a major road as an indicator of outdoor air pollution for health outcomes are given in Table 2 for urban areas and in Table 3 for rural areas. We also give the crude and adjusted ORs for types of cooking fuel as an indicator of indoor air pollution in Tables 2 and 3.

According to the adjusted ORs for urban areas (Table 2), proximity to a major road had significant or marginally significant adverse effects in terms of AURI (OR = 1.012, 95% CI = 1.005 to 1.019), ALRI (OR = 1.007, 95% CI = 0.997 to 1.018), infant mortality (OR = 1.007, 95% CI = 0.993 to 1.020), and stillbirth (OR = 1.006, 95% CI = 0.993 to 1.020). In other words, the prevalence of AURI increased by a factor of 1.012 per 2 km proximity. In contrast, indoor air pollution had the most significant adverse effect in terms of infant mortality (OR = 1.465, 95% CI = 0.920 to 2.331).

In rural areas (Table 3), proximity to a major road significantly or marginally increased the prevalence of AURI (OR = 1.004, 95% CI = 0.999 to 1.009), ALRI (OR = 1.007, 95% CI = 1.001 to 1.014), and stillbirth (OR = 1.006, 95% CI = 1.000 to 1.012). Regarding indoor air pollution, the type of cooking fuel had a significant effect on infant mortality (OR = 1.305, 95% CI = 1.003 to 1.698), as was the case in urban areas.

Adjusted ORs per 2 km proximity to a major road stratified by high and low indoor air pollution groups are shown in Fig. 3. The adjusted ORs for ALRI (P = 0.05) and infant mortality (P = 0.01) were higher in the high indoor air pollution group than in the low indoor air pollution group.

In the first sensitivity analysis, because a 500 m increase in proximity was a quarter of the original exposure indicator, the magnitude of the adjusted ORs decreased (one-quarter power of the exponential), but the qualitative associations did not change. In addition, when we took account of correlations among mothers using exchangeable correlation structures in the GEE models, the results did not change substantially. Finally, the outcomes did not change when we used the partner's occupation type instead of the mother's number of years of education to indicate the socioeconomic status.

TABLE 2. Crude and Adjusted ORs for Proximity to a Major Road and Indoor Air Pollution for Health Outcomes in Urban Areas

Health Outcome	Outdoor Air Pollution Proximity to a Major Road OR* (95% CIs)	Indoor Air Pollution Type of Cooking Fuel OR† (95% CIs)
AURI		
Crude	1.012 (1.005–1.020)	0.791 (0.638–0.979)
Adjusted	1.012‡ (1.005–1.019)	0.739§ (0.593–0.921)
ALRI		
Crude	1.007 (0.996–1.018)	1.048 (0.758–1.447)
Adjusted	1.007‡ (0.997–1.018)	0.933§ (0.667–1.304)
Neonatal mortality		
Crude	0.998 (0.985–1.011)	1.495 (0.910–2.455)
Adjusted	1.000‡ (0.986–1.013)	1.291§ (0.746–2.235)
Infant mortality		
Crude	1.004 (0.991–1.017)	1.739 (1.129–2.677)
Adjusted	1.007‡ (0.993–1.020)	1.465§ (0.920–2.331)
Stillbirth		
Crude	1.007 (0.996–1.019)	0.612 (0.445–0.842)
Adjusted	1.006‡ (0.993–1.020)	0.555§ (0.398–0.774)

*Proximity to major road was treated as a continuous variable and ORs were estimated per 2 km proximity to a major road.

†ORs for high indoor air pollution group were estimated by comparing with the low indoor air pollution group.

‡Adjusted for indoor air pollution (type of cooking fuel), mother's age, mother's smoking, baby's sex, and mother's education.

§Adjusted for outdoor air pollution (proximity to a major road), mother's age, mother's smoking, baby's sex, and mother's education.

TABLE 3. Crude and Adjusted ORs for Proximity to a Major Road and Indoor Air Pollution for Health Outcomes in Rural Areas

Health Outcome	Outdoor Air Pollution Proximity to a Major Road OR* (95% CIs)	Indoor Air Pollution Type of Cooking Fuel OR† (95% CIs)
AURI		
Crude	1.004 (0.999–1.009)	1.075 (0.946–1.222)
Adjusted	1.004‡ (0.999–1.009)	1.080§ (0.944–1.236)
ALRI		
Crude	1.007 (1.000–1.013)	1.130 (0.936–1.365)
Adjusted	1.007‡ (1.001–1.014)	1.094§ (0.895–1.338)
Neonatal mortality		
Crude	1.000 (0.989–1.010)	1.188 (0.829–1.701)
Adjusted	1.000‡ (0.989–1.011)	1.054§ (0.723–1.535)
Infant mortality		
Crude	0.999 (0.993–1.005)	1.508 (1.174–1.936)
Adjusted	1.000‡ (0.994–1.007)	1.305§ (1.003–1.698)
Stillbirth		
Crude	1.006 (1.001–1.012)	0.903 (0.751–1.085)
Adjusted	1.006‡ (1.000–1.012)	0.897§ (0.738–1.092)

*Proximity to major road was treated as a continuous variable and ORs were estimated per 2 km proximity to a major road.

†ORs for high indoor air pollution group were estimated by comparing with the low indoor air pollution group.

‡Adjusted for indoor air pollution (type of cooking fuel), mother's age, mother's smoking, baby's sex, and mother's education.

§Adjusted for outdoor air pollution (proximity to a major road), mother's age, mother's smoking, baby's sex, and mother's education.

DISCUSSION

We used a large-scale nationally representative data set and evaluated the health effects of traffic-related outdoor air pollution, taking into account indoor air pollution, in Indonesia. We found traffic-related pollution increased occurrences of respiratory illnesses in children, specifically AURI and ALRI, and stillbirth in both urban and rural areas, even after taking into account indoor air pollution. In addition, indoor air pollution had a positive adverse effect on infant mortality. Furthermore, our result suggested that indoor air pollution exacerbated the risks of ALRI and infant mortality due to outdoor air pollution.

Our results show that proximity to a major road increased adverse health effects for children after adjusting for indoor air pollution. Previous studies in Western countries that considered proximity to roads also found adverse health effects due to outdoor air pollution in terms of both mortality and morbidity. For example, Ciccone et al[22] showed that participants who lived within 100 m of a major road manifested bronchitis (OR = 1.74, 95% CI = 1.24 to

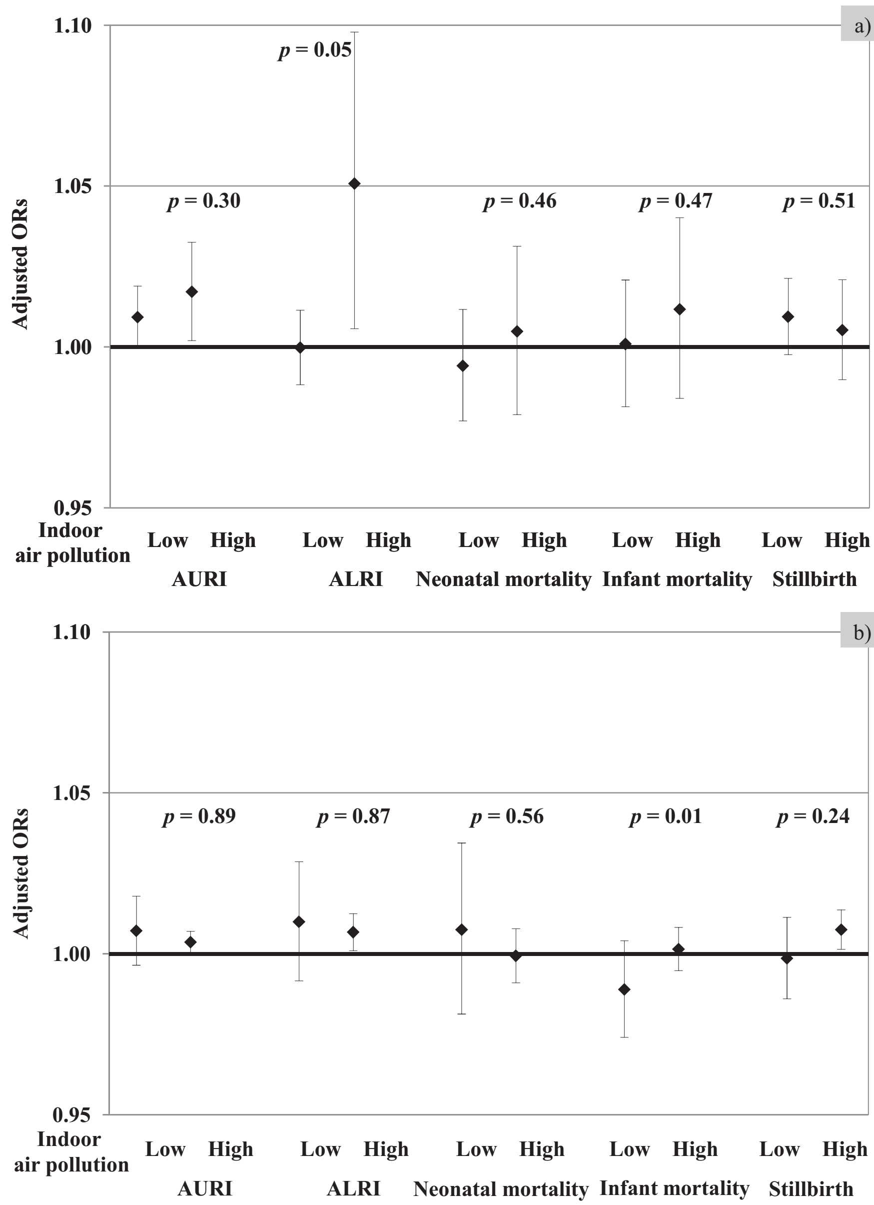

FIGURE 3. Adjusted ORs per 2 km proximity to a major road stratified by indoor air pollution. a, Urban area. b, Rural area. The *P*-value is for the interaction between proximity to a major road and indoor air pollution (type of cooking fuel).

2.30) and pneumonia (OR = 1.86, 95% CI = 1.26 to 2.73) more frequently than other participants did. Nevertheless, epidemiologic studies of outdoor air pollution in Western countries have generally not considered indoor pollution or total exposure.[2] Therefore, the present findings indicate stronger adverse effects of outdoor air pollution with the adjustment for indoor air pollution, which contributes to the total exposure to air pollution in developing countries in Asia.

Our study presents adverse health effects of indoor air pollution that are consistent with the results of previous studies.[11,14,21,23] Furthermore, the adverse effect of outdoor air pollution in terms of ALRI or infant mortality was exacerbated by indoor air pollution as shown in Fig. 3. As far as we know, this is the first study to examine the effect of indoor air pollution on the health effects of outdoor air pollution in developing countries in Asia. Because we found only 2 of the 10 candidate interactions were significant, it might be difficult to generalize this finding. These results, however, highlight the necessity of an environmental health strategy that deals with both outdoor and indoor air pollution in Asian countries.

In this study, a 2 km increase in proximity to a major road was used as an indicator of outdoor air pollution (ie, a proximity model) because of the problem of offsetting. Nevertheless, we found the same tendency when we adopted a 500 m increase in proximity. In recent studies, several exposure models such as the interpolation model,[24] proximity model,[25] dispersion model,[26] and land-use regression model[27–31] have been developed to estimate individual exposure. Among them, the land-use regression model has been used successfully in predicting the concentration of individual pollutants using existing variables such as land use, traffic intensity, and other relevant information within the framework of a geographic information system. Although this model can be used for Asian countries, it requires additional information such as the concentration of outdoor air pollution, population, and traffic intensity, and hence we used the proximity model in this study. To minimize exposure misclassification, more sophisticated modeling should be conducted in future studies.

There are several limitations in this study. First, the road information in this study was released by the ISCGM in September 2007. Although the exact time of the creation of road information in Indonesia was not obtained, the road information was originally based on Landsat satellite imagery for the year 2000.[19] Thus, substantial changes in road information between 2000 and 2007 have not been considered.

Second, as described previously, offsets of the GPS in the IDHS may induce exposure misclassification. Nevertheless, these exposure misclassifications would be nondifferential, and the net effect would tend toward null.[32]

Third, we only adjusted for the mother's education as an indicator of the socioeconomic status. Indeed, a previous study showed an association between the mother's education and mortality in children less than 5 years old in Indonesia.[33] In the sensitivity analysis, we adjusted for the partner's occupation as an indicator of socioeconomic status instead of the mother's education, but the adjusted ORs did not change substantially. Although it is difficult to measure and adjust for socioeconomic status comprehensively, the present results cannot be explained by socioeconomic status or other potential confounders.

Finally, the IDHS fieldwork was performed from October 2002 to April 2003. Thus, there is the possibility of disease misclassification of respiratory illness due to the interview date. Nevertheless, these misclassifications would be nondifferential, and the net effect would tend toward null.

In many Asian countries, outdoor air pollution has a large impact on public health. Therefore, air pollution epidemiological studies that examine Asian-specific problems (eg, indoor air pollution and socioeconomic status) should be conducted simultaneously. Large-scale nationally representative datasets such as the IDHS or ISCGM global map used in this study encourage such studies.

CONCLUSIONS

This study suggests that exposure to traffic-related outdoor air pollution increases the prevalence of respiratory illness in children and miscarriage and stillbirth taking into account indoor air pollution. The present findings provide additional evidence that indoor air pollution could exacerbate the risk of adverse health effects due to outdoor air pollution.

ACKNOWLEDGMENT

The software used in this study was supported by the Higher Education Grant Program of ESRI Japan Corp.

REFERENCES

1. WHO. *The World Health Report 2002: Reducing Risks, Promoting Healthy Life.* Geneva: World Health Organization; 2002.
2. HEI International Scientific Oversight Committee of HEI Public Health and Air Pollution in Asia Program. *Health Effects of Outdoor Air Pollution in Developing Countries of Asia: A Literature Review. Special Report 15.* Boston, MA: Health Effects Institute; 2004.
3. Air Pollution in the Megacities of Asia Project. *Benchmarking Urban Air Quality Management and Practice in Major and Mega Cities of Asia*. Seoul, Korea: AMPA; 2002.
4. WHO Regional Office for Europe. *Air Quality Guidelines. Global Update 2005. Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide*. Copenhagen, Denmark: WHO Regional Office for Europe; 2006.
5. Hoek G, Brunekreef B, Goldbohm S, Fischer P, van den Brandt PA. Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. *Lancet*. 2002;360:1203–1209.
6. Pope CA III, Burnett RT, Thun MJ, et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *JAMA*. 2002;287:1132–1141.
7. Kan H, London SJ, Chen G, et al. Season, sex, age, and education as modifiers of the effects of outdoor air pollution on daily mortality in Shanghai, China: The Public Health and Air Pollution in Asia (PAPA) Study. *Environ Health Perspect*. 2008;116:1183–1188.
8. Tan WC, Ng TP. COPD in Asia: where East meets West. *Chest*. 2008;133: 517–527.
9. Yorifuji T, Kashima S, Tsuda T, et al. Long-term exposure to traffic-related air pollution and mortality in Shizuoka, Japan. *Occup Environ Med.* 2009; Sep 22. [Epub ahead of print.] doi:10.1136/oem.2008.045542.
10. Mishra V, Retherford RD, Smith KR. Cooking smoke and tobacco smoke as risk factors for stillbirth. *Int J Environ Health Res*. 2005;15:397–410.
11. Smith KR, Samet JM, Romieu I, Bruce N. Indoor air pollution in developing countries and acute lower respiratory infections in children. *Thorax*. 2000; 55:518–532.
12. Surjadi C. Respiratory diseases of mothers and children and environmental factors among households in Jakarta. *Environ Urban*. 1993;5:78–86.
13. Bruce N, Perez-Padilla R, Albalak R. Indoor air pollution in developing countries: a major environmental and public health challenge. *Bull World Health Organ*. 2000;78:1078–1092.
14. Fullerton DG, Bruce N, Gordon SB. Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. *Trans R Soc Trop Med Hyg*. 2008;102:843–851.
15. Romieu I, Samet JM, Smith KR, Bruce N. Outdoor air pollution and acute respiratory infections among children in developing countries. *J Occup Environ Med*. 2002;44:640–649.
16. BPS and ORC Macro. *Indonesia Demographic and Health Survey 2002–2003.* Calverton, MD: BPS and ORC Macro; 2003.
17. Zhou Y, Levy JI. Factors influencing the spatial extent of mobile source air pollution impacts: a meta-analysis. *BMC Public Health*. 2007;7:89.
18. International Steering Committee for Global Mapping (ISCGM). Global Map Version 1.3 Specifications. 2007. Available at: http://www.iscgm.org/. Accessed May 25, 2009.
19. ICSU-CODATA Global Roads Data Development Working Group. *A Strategy for Developing an Improved Global Roads Data Set*. 2007. Available at: http://www.codata.org/taskgroups/WGlobalroads/index.html. Accessed May 25, 2009.
20. Mishra V, Retherford RD. Does biofuel smoke contribute to anaemia and stunting in early childhood? *Int J Epidemiol*. 2007;36:117–129.
21. Smith-Sivertsen T, Diaz E, Pope D, et al. Effect of reducing indoor air pollution on women's respiratory symptoms and lung function: the RESPIRE randomized trial, Guatemala. *Am J Epidemiol.* 2009;170:211–220.
22. Ciccone G, Forastiere F, Agabiti N, et al. Road traffic and adverse respiratory effects in children. SIDRIA Collaborative Group. *Occup Environ Med.* 1998;55:771–778.
23. Smith KR, Mehta S, Maeusezahl-Feuz M. Indoor smoke from household solid fuels. In: Ezzati AL, Rodgers A, Vander Hoorn S, Murray C, eds. *Comparative quantification of health risks: global and regional burden of disease due to selected major risk factors.* Geneva, Switzerland: WHO; 2004:1435–1493.
24. Jerrett M, Burnett R, Kanaroglou P, et al. A GIS—environmental justice analysis of particulate air pollution in Hamilton, Canada. *Environ Plan A*. 2001;33:955–973.
25. Jerrett M, Arain A, Kanaroglou P, et al. A review and evaluation of intraurban air pollution exposure models. *J Expo Anal Environ Epidemiol*. 2005;15:185–204.
26. Liu LJ, Curjuric I, Keidel D, et al; SAPALDIA team. Characterization of source-specific air pollution exposure for a large population-based Swiss cohort (SAPALDIA). *Environ Health Perspect*. 2007;115:1638–1645.
27. Brauer M, Hoek G, van Vliet P, et al. Estimating long-term average particulate air pollution concentrations: application of traffic indicators and geographic information systems. *Epidemiology*. 2003;14:228–239.
28. Henderson SB, Beckerman B, Jerrett M, Brauer M. Application of land use regression to estimate long-term concentrations of traffic-related nitrogen oxides and fine particulate matter. *Environ Sci Technol*. 2007;41:2422–2428.
29. Morgenstern V, Zutavern A, Cyrys J, et al. Respiratory health and individual estimated exposure to traffic-related air pollutants in a cohort of young children. *Occup Environ Med*. 2007;64:8–16.
30. Ross Z, Jerrett M, Ito K, Tempalski B, Thurston GD. A land use regression for predicting fine particulate matter concentrations in the New York City region. *Atmos Environ*. 2007;41:2255–2269.
31. Ryan PH, LeMasters GK. A review of land-use regression models for characterizing intraurban air pollution exposure. *Inhal Toxicol.* 2007; 19(Suppl 1):127–133.
32. Rothman KJ, Greenland S, Lash Timothy L. *Modern Epidemiology.* Philadelphia, PA: Lippincott, Williams, & Wilkins; 2008.
33. Houweling TA, Kunst AE, Borsboom G, Mackenbach JP. Mortality inequalities in times of economic growth: time trends in socioeconomic and regional inequalities in under 5 mortality in Indonesia, 1982–1997. *J Epidemiol Community Health*. 2006;60:62–68.