PN-ACT-488

EAST-WEST CENTER WORKING PAPERS

EAST-WEST CENTER

Population Series

No. 91, July 1997

Effects of Cooking Smoke on Prevalence of Blindness in India

Vinod Mishra, Robert D. Retherford, and Kirk R. Smith

Vinod Mishra is a Visiting Fellow and **Robert D. Retherford** is a Senior Fellow in the Program on Population at the East-West Center. **Kirk R. Smith** is a Senior Fellow in the Program on Environment at the East-West Center and a Professor in the School of Public Health at the University of California at Berkeley.

East-West Center Working Papers: Population Series are an unreviewed and unedited prepublication series reporting on research in progress. Please direct orders and requests to the East-West Center's Publication Sales Office. Single copies are available at no charge by surface post while supplies last. Charges for additional copies are $1.00 each. Charges for airmail delivery are $1.50 each within the United States and its territories and $4.00 each elsewhere.

Established in 1969 as a unit of the East-West Center, the **Program on Population** conducts research and offers professional education focusing on population issues, with emphasis on the analysis of demographic and human-resource trends, their social and economic causes and consequences, and their policy implications in Asia, the Pacific, and the United States.

The Office of Population of the United States Agency for International Development (USAID) provided support for this publication under a cooperative agreement with the Program on Population of the East-West Center.

Please address correspondence to:

Vinod Mishra
Program on Population, East-West Center
1601 East-West Road, Honolulu, HI 96848, USA
Tel: (1-808) 944-7452; Fax: (1-808) 944-7490
E-mail: mishra@hawaii.edu

A

EFFECTS OF COOKING SMOKE ON PREVALENCE OF BLINDNESS IN INDIA

ABSTRACT

Objective. To measure the effect of cooking smoke from biomass fuels on prevalence of blindness among persons age 30 years and older in India.

Methods. Data are from India's 1992–93 National Family Health Survey, which is based on a nationally representative sample of 88,562 households comprising 514,827 individuals. Logistic regression is used to estimate the net effects of cooking smoke from biomass fuels (wood and dung) on prevalence of blindness after controlling for a number of potentially confounding variables.

Results. Persons living in households that primarily use biomass for cooking fuel have a considerably higher risk of developing partial or complete blindness than persons living in households that use cleaner fuels. These results hold even when the effects of kitchen availability, house type, crowding, age, gender, urban-rural residence, education, religion, caste/tribe, and geographic region are statistically controlled, and also when the analysis is done separately for men and women and for urban and rural areas.

Conclusions. Results indicate that use of biomass fuels for cooking substantially increases the risk of blindness.

INTRODUCTION

In developing countries, concentrations of health-threatening air pollutants tend to be highest indoors, where biomass fuels such as wood, animal dung, and crop residues are burned by many households for cooking and heating.[1] This is contrary to the common perception that air pollution is primarily an urban phenomenon associated with motor vehicles and industries. Biomass fuels are at the high end of the energy ladder in terms of air pollution, and at the low end in terms of combustion efficiency.[2] Biomass smoke contains many noxious components, including respirable particulates, carbon monoxide, nitrogen oxides, formaldehyde, and polyaromatic hydrocarbons such as benzo(a)pyrene.[3,4,5]

In India the principal biomass fuels are wood, crop residues, and dung cakes, which are the primary cooking fuels for at least three-quarters of Indian households.[6] Cooking is often done under poorly ventilated conditions, and about one-half of all households do not have a separate kitchen that would shield persons in other rooms from cooking smoke. Life in a typical Indian household revolves around the cooking area, and Indian women spend much of their time there. Cooking stoves in most households are nothing more than a pit, a U-shaped *chulha*, or three pieces of brick. Cooking under these conditions entails high levels of exposure to cooking smoke. In developing countries such as India, daily air pollution exposures from cooking with biomass typically exceed relevant health-based guidelines by factors of twenty or more.[2]

Anecdotal association of eye problems with cooking smoke is common, but few epidemiological studies seem to have been done.[3,4] The chief proximate cause of complete blindness worldwide is cataract, which accounts for at least 50 percent of prevalence.[7] Cataract is a progressive opacification of the lens and is known to be linked to oxidative damage that can be produced by heavy airborne pollution as well as other factors.[8] A case-control study of cataract patients and controls at a New Delhi ophthalmic clinic showed that, compared to home use of bottled cooking gas, low-quality cooking fuels (wood, dung) were significantly associated with three of the four major types of cataract (cortical, nuclear, and mixed), even after controlling for 56 physiologic, behavioral, environmental, and biochemical variables.[9] As far as we know, this is the only scientific study of the effects of cooking smoke on cataract in a human population. A number of studies indicate that tobacco smoke can cause cataract,[10] suggesting that cooking smoke might have a similar

effect. A connection between cataract and both wood smoke and tobacco smoke has also been observed in experimental studies of laboratory rats.[11,12]

Both blindness and cataract are major health problems in India. Cataract is an even more important cause of complete blindness in India than it is in the world as a whole. A number of studies have indicated that cataract accounts for more than 80 percent of complete blindness in the country.[13,14] Cataract accounts for nearly 1 percent of the total burden of disease in India. Cataract in India also accounts for approximately one-third of the global prevalence of cataract.[15] In the 1980s, the prevalence of complete blindness in India is estimated to have ranged between 0.5 and 0.7 percent.[13,14] In the early 1990s, according to India's 1992–93 National Family Health Survey (NFHS), 3 percent of the population suffered from blindness—2.6 percent from partial blindness and 0.4 percent from complete blindness. (The somewhat lower prevalence of complete blindness in the NFHS may be due partly to the fact that the NFHS did not include completely blind persons who were permanently institutionalized at the time of the survey.) These percentages translate into almost 30 million partially or completely blind people in the country. The risk of partial or complete blindness increases dramatically with age, reaching 16 percent for 60–69 year-olds and 23 percent for those over 70.[6]

Our study examines the relationship between use of biomass fuels for cooking and the prevalence of partial or complete blindness among persons age 30 years and older in India, after statistically controlling for the effects of several potentially confounding variables. The analysis is limited to persons age 30 and over because the effects of cooking smoke on blindness are long-term and cumulative, so that cooking smoke is not likely to result in blindness in children and young adults. As far as we know, ours is the first study to provide quantitative estimates of the effects of cooking smoke on the prevalence of blindness in a human population.

DATA AND METHODS

Data for this study come from India's 1992–93 National Family Health Survey (NFHS). The NFHS collected demographic, socioeconomic, and health information from a probability sample of 88,562 households covering a total of 514,827 persons. All parts of the country except Kashmir and

Sikkim are represented in the sample, which covers 99 percent of India's population. Details of sample design are found in the basic survey report.[6] For reasons just described, the analysis is limited to usual residents age 30 and over, who number 173,520 in the survey.

The NFHS included several questions about the current health status of each household member, including whether each member suffers from partial or complete blindness. Partial blindness is defined as blindness in one eye, partial cataract, night blindness, or other eye problem resulting in seriously impaired vision. In our analysis, blindness is represented by dummy variables for partial blindness, complete blindness, and blindness in general (partial or complete). These are the response variables in our statistical models.

Our indicator of exposure to cooking smoke is the type of fuel used for cooking. The NFHS used a nine-fold classification of cooking fuel: wood, dung cakes, charcoal, coal/coke/lignite, kerosene, electricity, liquefied petroleum gas, bio-gas, and a residual category of other fuels. Unfortunately, the NFHS did not include a separate category for crop residues, which are known to constitute the second largest category of biomass fuel after wood.[16] It is evident that in the NFHS most households using crop residues as their primary cooking fuel reported using wood, inasmuch as the proportion of households falling in the residual category of "other fuels" is only 2 percent.

Initially we grouped fuels into three categories—high-pollution fuels (wood and dung), medium-pollution fuels (charcoal, coal/coke/lignite, and kerosene), and low-pollution fuels (electricity, petroleum gas, and bio-gas). However, differences between medium-pollution fuels and low-pollution fuels in their effects on blindness turned out not to be statistically significant, so we regrouped fuels into just two categories—biomass fuels (wood and dung) and cleaner fuels (charcoal, coal/coke/lignite, kerosene, electricity, petroleum gas, and bio-gas). Households using "other fuels" are excluded from the analysis.

In terms of total pollution content, coal/coke/lignite are not very different from biomass fuels. However, in terms of exposure to cooking smoke, coal/coke/lignite may be regarded as cleaner fuels in the present context. In India, coal/coke/lignite are usually burned on portable stoves that are often started in open areas and then, once the fuels are burning cleanly, brought indoors for cooking. Most of the smoke from these fuels is released outdoors within the first few minutes after the fire is ignited. Wood, crop residues, and dung cakes, on the other hand, are usually burned on stoves that

cannot be lifted or transported. Moreover, fires from these fuels require more or less continual fuel-feeding, resulting in extended exposure to noxious indoor pollutants.

In our analysis, type of cooking fuel is represented by a dummy variable with value 1 for biomass fuels and 0 for cleaner fuels. This is our principal predictor variable.

The NFHS also collected information on various socioeconomic and demographic characteristics of households and individuals. Among these characteristics are availability of a separate room for cooking (i.e., a separate kitchen), housing type (indicating quality of construction), number of rooms in the house (from which the average number of persons per room in the household can be calculated as a measure of crowding), age, gender, urban-rural residence, education, religion, caste/tribe, and geographic region. These variables function as control variables in our analysis.

The rationale for including these variables as controls is the following: Availability of a separate kitchen controls to some extent for intensity of exposure to cooking smoke. It also helps to control for household economic status, for which we have no direct measure. (The NFHS did not collect income data.) Controlling for household economic status is important because it is an indirect indicator of nutrition and health as well as access to medical services that might prevent blindness. Housing type may control to some extent for how well ventilated the house is, and it is also correlated with household economic status. Housing type is dichotomized into *kachcha* (low-quality construction materials such as mud and thatch) and *pucca* or semi-*pucca* (at least some high-quality construction materials such as bricks, tiles, cement, and concrete). Average number of persons per room in the household controls for crowding, which may also be correlated with exposure to cooking smoke as well as household economic status.

Age is controlled because it has a large effect on the risk of blindness and is also correlated with intensity of exposure to cooking smoke. Gender is controlled mainly because women usually do the cooking and are therefore exposed more intensely to cooking smoke than men are. Urban-rural residence and education are controlled because they are correlated with type of cooking fuel and with household economic status. And they are especially correlated with access to and use of medical services which may prevent blindness. Religion and caste/tribe are included because they may capture cultural and life style differences that are correlated with type of cooking fuel and intensity of exposure to cooking smoke. Region is included to control for regional differences in

climate, topography, and local customs that may be correlated with both blindness and exposure to cooking smoke.

All variables, except age, education, religion, and geographic region, are dichotomous. Each dichotomous variable is represented by one dummy variable in the analysis. Age is grouped into five categories—30–39, 40–49, 50–59, 60–69, and 70 years or older—and is represented by four dummy variables, with 30–39 as the reference. Education has three categories represented by two dummy variables—one for medium education (literate but less than high school) and one for high education (high school or more), with illiterate as the reference category. Religion is also represented by two dummy variables—one for Hindu and one for "other religion," with Muslim as the reference category. Geographic region is represented by three dummy variables—one for north and northeast, one for central and eastern, and one for west, with south as the reference category.

The basic methodological approach in this study is logistic regression, with blindness (partial, complete, or either) as the response variable, cooking fuel type as the principal predictor variable, and the ten demographic and socioeconomic variables mentioned earlier as controls. The logistic regression analysis of partial blindness is conditional on not being completely blind at the time of the survey (i.e., completely blind persons are excluded from the analysis), and the logistic regression analysis of complete blindness is conditional on not being partially blind at the time of the survey (i.e., partially blind persons are excluded from the analysis). We also did the analysis using multinomial logit regression, which yields results similar to those obtained by conditional logit regression. (Odds ratios representing the effect of cooking fuel type agree to two decimal places.) We have opted to show the results obtained by conditional logit regression because this method allows easy calculation of confidence intervals for odds ratios.

We estimated our logistic regression models taking design effects due to clustering into account. We did so using the HLOGIT option in the STATA statistical computing package.[17]

The NFHS oversampled certain states and certain categories of households. Weights must be used to restore the representativeness of the sample. Results presented in this paper are based on the weighted data.[6]

RESULTS

Table 1 contains variable definitions and mean values in our sample of 173,520 persons age 30 and over. Mean values are presented separately for urban, rural, and total (i.e., urban and rural combined). The table shows that the overall prevalence of blindness (partial or complete) is in the neighborhood of 7 percent. The prevalence of partial blindness is about 10 times higher than the prevalence of complete blindness. Biomass fuels are used for cooking by about three-quarters of the population. By residence, the proportion using biomass fuels is almost three times higher in rural areas (93 percent) than in urban areas (32 percent). The means of the control variables relating to housing, education, and caste/tribe also differ considerably between urban and rural areas.

Effects of cooking fuel type on blindness

Figure 1 shows the effects of cooking fuel type on prevalence of blindness. The unadjusted and adjusted prevalence rates shown in the figure are predicted values derived by logistic regression and multiple classification analysis, which is a method for transforming regression results into simple bivariate tables which can be portrayed as bar graphs.[18] The unadjusted prevalence rates for a particular category of blindness (partial, complete, or either) are predicted from a logistic regression of blindness (1 if blind, 0 otherwise) on type of cooking fuel (1 if wood or dung, 0 otherwise). The adjusted prevalence rates are predicted from a logistic regression of blindness on type of cooking fuel and the ten control variables discussed earlier. In the calculation of adjusted prevalence rates, the control variables are held constant by setting them to their mean values in the underlying logistic regression. In the calculation of both unadjusted and adjusted prevalence rates, the value of the constant term in each underlying logistic regression is reset so that, with the predictor variable or variables set to their mean values, the prevalence rate predicted by the regression equals the observed prevalence rate in the sample for which the regression is run.

Figure 1 shows that unadjusted prevalence rates of partial and complete blindness are substantially higher among persons living in households using biomass fuels than among persons living in households using cleaner cooking fuels. Adjusting for control variables reduces these differences to some extent, but considerably more so for complete blindness than for partial blindness. The adjusted prevalence rates of partial blindness (per 100,000) are 7,206 among those using biomass fuels and 5,489 among those using cleaner fuels. The difference of 1,717 between

these two prevalence rates is large and statistically significant ($p<.0001$). On the other hand, the adjusted prevalence rates of complete blindness are 665 and 609 for the two cooking fuel categories, and the difference of 56 is small and not statistically significant ($p=.59$), although still in the expected direction. The finding that cooking smoke from biomass fuels has a larger effect on partial blindness than on complete blindness is perhaps not surprising, inasmuch as the effects of cooking smoke tend to be incremental. Complete blindness is more often caused by birth defects, birth trauma, childhood diseases, or accidents.

Effects of the control variables on blindness

The effects of the control variables on prevalence of blindness are also of interest and are summarized in Table 2, along with the effects of cooking fuel type already shown graphically in Figure 1. In Table 2, effects are measured by odds ratios, as estimated by logistic regression. (Table 2 and the adjusted bars in Figure 1 are based on the same logistic regression.) Odds ratios and their 95 percent confidence intervals are presented separately for partial blindness, complete blindness, and either (partial or complete). For any given predictor variable specified by a row label, the set of control variables consists of all the other predictor variables in the table. The discussion below focuses on the adjusted effects shown in the last column pertaining to the combined category of partial or complete blindness.

With other variables controlled, persons living in households with a separate kitchen have a lower risk of blindness (partial or complete) than persons living in households without a separate kitchen, as expected. Persons living in higher quality housing (*pucca* or semi-*pucca*) have a lower risk of blindness, also as expected. Surprisingly, crowding tends to reduce the risk of blindness, perhaps because persons living in more crowded conditions spend more time outside the house. It is also possible that cooking under more crowded conditions is more likely to be done in an open or partially open area. Older persons have a much higher risk of blindness, as expected. Women have a considerably higher risk of blindness than men, no doubt mainly because women are more exposed to cooking smoke. Women may also be less likely than men to obtain medical treatment for eye problems, and, because of gender discrimination, may be more likely to suffer from nutritional deficiencies related to blindness. Women also spend more time indoors than men, working on eye-straining jobs such as sewing, knitting, and picking stones from grains.

With other variables controlled, urban residents have a higher risk of blindness than rural residents. This effect, which is not statistically significant, is the reverse of what is found for unadjusted prevalence, which is considerably lower in urban areas than rural areas (see Table 1). It may be that after cooking fuel type and other socioeconomic and demographic variables are controlled, the reversal of direction of the effect of urban residence reflects higher levels of ambient air pollution and chemical pollution in urban areas.

More educated persons have a lower risk of blindness, as expected. Hindus have a higher risk of blindness than Muslims, who have a higher risk than persons in the residual category of other religions. However, the differences between Hindus and Muslims are not statistically significant. The low risk of blindness among persons of other religions may occur because of the higher socioeconomic status of this group, which entails better access to and more use of medical services. Persons who belong to scheduled castes and scheduled tribes have a higher risk of blindness than persons who belong to other castes, perhaps mainly because persons from scheduled castes and scheduled tribes have poorer access to medical care.

Regional differences are surprisingly large. The risk of blindness is highest in the west region, followed by the south region, the central and eastern region, and the north and northeast region. Large regional differentials are found for both partial blindness and complete blindness. The regional differentials indicate a geographical gradient in the prevalence of blindness that tends to rise from north and east to south and west, and this suggests that the prevalence of certain eye diseases may follow a similar gradient. However, we do not have any disease-specific evidence that bears on this conjecture.

In Table 2, the effects of the demographic and socioeconomic variables on partial blindness and complete blindness are rather similar to the effects of these variables on the combined category of partial or complete blindness.

Further analysis of gender differences and urban-rural differences in the prevalence of blindness

Because women tend to do the cooking and are much more exposed than men to cooking smoke, and because urban and rural environments are so different, we decided to repeat the above analysis separately for men and women and separately for urban residents and rural residents. Only the combined blindness category (partial or complete) is considered in these analyses.

Figure 2 shows adjusted prevalence of blindness (partial or complete) by type of cooking fuel separately for men and women. The methodology for estimating the adjusted prevalence levels in this figure is similar to that in Figure 1, discussed earlier. In the case of the two bars for males in Figure 2, the control variables are set to their mean values for males, and in the case of the two bars for females the control variables are set to their mean values for females. In this figure, the adjusted effect of cooking fuel type on prevalence of blindness is about the same for both men and women. For both men and women the effect is highly significant, with $p<.0001$ for men and $p=.001$ for women. The similar effect for men and women is surprising, because women are more exposed than men to cooking smoke. However, partial blindness may be less likely to be reported for women than for men, especially in households that use biomass fuels for cooking, and this may account for the estimated effect of cooking fuel type on blindness not being larger for women than for men.

Table 3 provides additional detail on adjusted effects of the control variables on the risk of blindness by gender, as measured by odds ratios. The effects of the control variables tend to be rather similar among men and women, except that the effects of education and region are substantially larger among women than among men, for reasons that are unclear.

Figure 3 shows adjusted prevalence of blindness (partial or complete) by type of cooking fuel separately for urban areas and rural areas. In the case of the two urban bars the control variables are set to their mean values in urban areas, and in the case of the two rural bars the control variables are set to their mean values in rural areas. The adjusted effect of cooking fuel type on prevalence of blindness is considerably larger in rural areas than in urban areas. The adjusted effects are significant for both urban areas ($p=.04$) and rural areas ($p<.0001$). The smaller effect in urban areas may occur because the availability and quality of medical services for prevention and treatment of eye problems is better in urban areas.

Adjusted effects of the control variables on the risk of blindness by urban-rural residence are shown in Table 4. The effects of the control variables, like the effect of cooking smoke itself, tend to be stronger among rural residents than among urban residents. Again the reason may be that the availability and quality of medical services for prevention and treatment of eye problems is better in urban areas. The effect of being Hindu, relative to being Muslim, is to increase blindness in rural areas, but to decrease it in urban areas. However, in urban areas the effect of being Hindu is not statistically significant.

Proportion of risk of blindness attributable to cooking smoke

It is also of interest to look at the proportion of the risk of blindness in the population that is attributable to smoke from biomass fuels relative to cleaner fuels. This measure, which is sometimes referred to as the "population attributable risk proportion,"[19] is defined here as

$$\frac{\text{(Prevalence in total population)} - \text{(Prevalence in unexposed group)}}{\text{(Prevalence in total population)}}$$

This measure is usually defined in terms of incidence, but here we define it in terms of prevalence since we do not have data on incidence.

In the present context, this measure can be interpreted as the proportionate reduction in prevalence of blindness in the population that would occur if everyone used cleaner fuels. Those using cleaner fuels are the unexposed group in the formula. If, hypothetically, everyone uses cleaner fuels, the mean values of the other predictor variables in the unexposed group must be the same as the mean values of the predictor variables in the total population. Therefore, adjusted values of prevalence, with control variables set to their mean values in the total population, must be used to estimate "prevalence in unexposed group" in the formula. Note that if the calculation is done separately for urban or rural, "total population" in the formula then refers to "total urban population" or "total rural population."

Applying the formula, we find that 18 percent of blindness (partial or complete) in the total population (urban plus rural) is attributable to cooking smoke from biomass fuels. This proportion is 6 percent in urban areas and 29 percent in rural areas. The proportion is much higher in rural areas

not only because the effect of biomass fuels on blindness (as measured, for example, by odds ratios) is higher in rural areas, but also because the proportion of households using biomass fuels is much higher in rural areas.

DISCUSSION

Results from this study indicate that exposure to cooking smoke (from biomass fuels compared with cleaner fuels) substantially increases the risk of blindness, especially partial blindness. The effect on partial blindness is large and highly statistically significant ($p<.0001$) even when the effects of a number of potentially confounding variables are statistically controlled by holding them constant. The effect on complete blindness is diminished and no longer statistically significant when potentially confounding variables are controlled.

We also did the analysis separately for men and women and separately for urban and rural areas. Here we examined partial and complete blindness as a combined category rather than separately. The effects of cooking smoke on this combined category of blindness were found to be large and statistically significant for each sex and for each residence category.

The true effects of biomass fuels on blindness are probably stronger than we have estimated, for three reasons. The first is that households in India typically use a combination of cooking fuels, whereas we have information only on the primary cooking fuel. Our estimated effects are attenuated to the extent that a mix of biomass fuels and cleaner fuels is used instead of biomass fuels alone. The second reason stems from our lack of information about the history of fuel use in the household, which is important because the effects of cooking smoke on blindness are cumulative over time. Previous shifts from biomass fuels to cleaner fuels tend to bias downwardly our estimates of effects. Our estimates of the effects of cooking smoke from biomass fuels on blindness would also be larger had we measured the effects of biomass fuels relative to a very clean fuel such as electricity instead of a residual category of other fuels that includes charcoal, coal/coke/lignite, kerosene, petroleum gas, and bio-gas as well as electricity.

Nevertheless, there are several factors that could affect the validity of our conclusions. Fuel type is not an ideal measure of exposure to smoke, and reports of blindness (especially partial

blindness) by household heads or other household informants are not as accurate as clinical measures of blindness. And although our set of control variables included several measures of socioeconomic status, which is correlated with access to and use of medical services, we were not able to control directly for extent of use of medical services in connection with eye problems, because the NFHS survey did not collect any information on this subject. The NFHS also did not collect any data on such behaviors as tobacco smoking, drinking, and exposure to hazardous conditions at work which might account for some of the variation in the prevalence of blindness. Nor did the survey collect any information on nutrition—e.g., on vitamin deficiencies relating to blindness. The survey also lacks information on frequency of severe diarrheal episodes. According to some but not all studies, a history of severe diarrheal episodes may be associated with cataract development, in part because of the detrimental effects of dehydration of ocular fluids.[20,21,22] We also lack information on extent of exposure to sunlight. The oxidizing effect of the ultraviolet component of sunlight is a known cause of cataract.[23]

The socioeconomic variables included as controls in our models are likely to capture much, but not all, of the effects of these missing variables on blindness. Future health surveys might consider including additional questions on these variables. Longitudinal intervention studies using epidemiological methods would be especially useful for untangling the effects of the various risk factors, although cross-sectional surveys such as the NFHS are also very useful because they typically cover much larger and more representative populations at a considerably lower cost per respondent.

Our findings indicate that the prevalence of blindness in India, and probably in many other developing countries as well, might be reduced substantially by lowering exposure to cooking smoke, especially from biomass fuels. Perhaps the most obvious long-run policy implication is that the government should promote a shift from biomass fuels to cleaner fuels, which would also have significant health benefits from reduced respiratory, cardiovascular, and perinatal problems. In the short run, however, such a shift may not be feasible for the large proportion of households who cannot afford more expensive cleaner fuels. Moreover, given current infrastructure and fuel availability, the government does not have the capacity to provide all households with cleaner fuels. A more feasible policy in the short run would be for the government to increase its efforts to educate the public about the adverse health effects of cooking smoke and to accelerate its improved

cookstove program by making available inexpensive biomass-burning stoves that are fuel-efficient, relatively smokeless, and equipped with flues or hoods designed to prevent the release of pollutants directly into the kitchen and other parts of the dwelling. For such programs to be effective, local needs and community participation should be given high priority. The government should also place greater emphasis on blindness prevention in its health programs, because blindness can often be prevented if detected and treated at an early stage.

ACKNOWLEDGMENTS

We are grateful to Ian Bailey, Tom Carlson, Norman Luther, Premlata Menon, F. DeWolfe Miller, and Sheila West for helpful comments, and to the United States Agency for International Development for funding this research.

REFERENCES

1. Smith KR. Indoor Air Pollution in India. *Natl Med J India.* 1996; 9(3):103–4.

2. Smith KR, Liu Y. Indoor Air Pollution in Developing Countries. *Epidemiol Lung Cancer.* 1994; 74:151–84.

3. WHO (World Health Organization). *Epidemiological, Social, and Technical Aspects of Indoor Air Pollution from Biomass Fuel: Report of a WHO Consultation June 1991.* Geneva: World Health Organization, 1992.

4. Smith KR. *Biofuels, Air Pollution, and Health: A Global Review.* New York: Plenum Press, 1987.

5. Smith KR. Fuel Combustion, Air Pollution Exposure, and Health: The Situation in Developing Countries. *Ann Rev Energy and Env.* 1993; 18:529–66.

6. IIPS (International Institute for Population Sciences). *National Family Health Survey (MCH and Family Planning): India, 1992–93.* Bombay: International Institute for Population Sciences, 1995.

7. Foster A. Worldwide Blindness, Increasing but Avoidable! *Sem Ophthalmol.* 1993; 8(3):166–70

8. Taylor A, Jacques PF, Epstein EM. Relations Among Aging, Antioxidant Status, and Cataract. *Am J Clin Nutr.* 1995; 62(suppl):1439S–47S.

9. Mohan M, Sperduto RD, Angra SK, et al. India-US Case Control Study of Age-Related Cataracts. *Arch Ophthalmol.* 1989; 107:670–6.

10. Hodge WG, Whitcher JP, Satariano W. Risk Factors of Age-related Cataracts. *Epidemiol Rev.* 1995; 17(2):336–46

11. Shalini VK, Luthra M, Srinivas L, et al. Oxidative Damage to the Eye Lens Caused by Cigarette Smoke and Fuel Smoke Condensates. *Indian J Biochem Biophys.* 1994; 31(4):261–6.

12. Rao CM, Qin C, Robison WG Jr, Zigler JS Jr. Effect of Smoke Condensate on the Physiological Integrity and Morphology of Organ Cultured Rat Lenses. *Curr Eye Res.* 1995; 14(4):295–301.

13. Venkataswamy G. Blindness control in India. *Sem Opthalmol.* 1993; 8(3):171-6.

14. Thylefors B, Negrel A-D, Pararajasegaram R, Dadzie KY. World Health Organization Programme for the Prevention of Blindness: Available Data on Blindness (update 1994). *Ophthalmic Epidemiol.* 1995; 2(1):5–39.

15. Murray CJL, Lopez AD, eds. *Global Burden of Disease.* Cambridge, MA: Harvard University Press, 1996.

16. Ravindranath NH, Hall DO. *Biomass, Energy, and Environment: A Developing Country Perspective from India.* Oxford, UK: Oxford University Press, 1995.

17. Stata Corporation. *Stata Reference Manual, Release 4, Volume Two.* College Station, Texas: Stata Press, 1995.

18. Retherford RD, Choe MK. *Statistical Models for Causal Analysis*. New York: John Wiley & Sons, Inc., 1993.

19. Mausner JS, Kramer S. *Epidemiology: An Introductory Text*. Philadelphia: W.B. Saunders Company, 1985.

20. Minassian DC, Mehra V, Jones BR. Dehydrational Crises from Severe Diarrhoea and Heatstroke and Risk of Cataract. *Lancet*. 1984; 1:751–3.

21. Minassian DC, Mehra V, Verrey J. Dehydrational Crises: A Major Risk Factor in Blinding Cataract. *Br J Ophthalmol*. 1989; 73(2):100–105.

22. Bhatnagar R, West KP Jr, Vitale S, Sommer A, Joshi S, Venkataswamy G. Risk of Cataract and History of Severe Diarrheal Disease in Southern India. *Arch Ophthalmol*. 1991; 109:696–9.

23. Evans J, Minassian DC. Epidemiology of Age-related Cataract. *Community Eye Health*. 1992; 9:2–6.

Table 1: Variable definitions and mean values[1] for persons age 30 years and older, India 1992-93

Variable name	Variable definition	Means		
		Urban	Rural	Total
	Response variables (mean values expressed per 100,000)			
PBLIND	Dummy variable, with value 1 if person suffers from partial blindness	5485	7153	6689
CBLIND	Dummy variable, with value 1 if person suffers from complete blindness	477	728	658
BLIND	Dummy variable, with value 1 if person suffers from partial or complete blindness	5911	7781	7262
	Predictor variables (mean values of dummy variables expressed as percentages)			
BIOMASS	Dummy variable, with value 1 if person lives in a household that uses wood or animal dung as its primary cooking fuel	32.1	93.1	75.8
KITCHEN	Dummy variable, with value 1 if person lives in household that has separate kitchen	67.9	54.1	57.9
PUCCA	Dummy variable, with value 1 if person lives in a *pucca* (high quality) or semi-*pucca* house[2]	84.1	41.8	53.6
CROWD	Dummy variable, with value 1 if three or more persons per room in the household	38.7	45.6	43.7
AGE40_49	Dummy variable, with value 1 if age 40-49	26.2	23.8	24.5
AGE50_59	Dummy variable, with value 1 if age 50-59	17.4	17.8	17.7
AGE60_69	Dummy variable, with value 1 if age 60-69	11.6	14.7	13.9
AGE70+	Dummy variable, with value 1 if age 70 years or older	6.8	8.7	8.2
FEMALE	Dummy variable, with value 1 if female	47.2	48.1	47.9
URBAN	Dummy variable, with value 1 if residence is urban	100.0	0.0	27.8
EDM	Dummy variable, with value 1 for literate people with less than a high school education	34.3	26.7	28.8
EDH	Dummy variable, with value 1 for people with at least high school education	33.7	8.7	15.6

(Table 1 continued)

Variable name	Variable definition	Means		
		Urban	Rural	Total
HINDU	Dummy variable, with value 1 if the person lives in a household whose head is Hindu	76.8	84.8	82.6
OTHREL	Dummy variable, with value 1 if the person lives in a household whose head is not Hindu or Muslim	8.0	5.7	6.3
SCST	Dummy variable, with value 1 if the person lives in a household whose head belongs to a scheduled caste (SC) or scheduled tribe (ST)[3]	11.4	23.6	20.2
NORTH	Dummy variable, with value 1 for people living in Jammu Region of Jammu & Kashmir, Himachal Pradesh, Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, or Tripura	2.6	5.0	4.4
CENTR	Dummy variable, with value 1 for people living in Haryana, Punjab, Delhi, Uttar Pradesh, Madhya Pradesh, Bihar, West Bengal, or Orissa	47.1	55.1	52.9
WEST	Dummy variable, with value 1 for people living in Maharashtra, Goa, Gujarat, or Rajasthan	25.0	18.2	20.1
n	Number of unweighted persons 30 years and older in the sample[4]	56351	117169	173520

Notes:
1. Mean values are based on the weighted sample.
2. The reference category is *kachcha*. *Kachcha* houses are made from mud, thatch or low-quality materials. *Pucca* houses are made from high-quality materials (such as bricks, tiles, cement, and concrete) throughout, including roof, walls, and floor. Semi-*pucca* houses are made from partly low-quality materials and partly high-quality materials.
3. Scheduled castes (SC) and scheduled tribes (ST) are those castes and tribes identified by the Government of India as socially and economically backward and in need of protection from social injustice and exploitation.
4. Actual sample size varies slightly for individual variables depending on the number of missing values.

Table 2: Adjusted effects of type of cooking fuel and other selected variables on the risk of blindness among persons age 30 years and older, India 1992-93

Variable	Partial blindness		Complete blindness		Partial or complete blindness	
	Odds Ratio	95% Confidence Interval	Odds Ratio	95% Confidence Interval	Odds Ratio	95% Confidence Interval
Cooking fuel type						
Biomass fuels	1.34	1.17, 1.53	1.09	0.79, 1.51	1.32	1.16, 1.50
Cleaner fuels†	1.00	--	1.00	--	1.00	--
Separate kitchen						
Yes	0.89	0.83, 0.95	0.81	0.67, 0.98	0.88	0.83, 0.94
No†	1.00	--	1.00	--	1.00	--
House type						
Kachcha†	1.00	--	1.00	--	1.00	--
Pucca or semi-*pucca*	0.90	0.83, 0.99	0.85	0.69, 1.04	0.90	0.83, 0.98
Crowding						
<3 persons per room†	1.00	--	1.00	--	1.00	--
≥3 persons per room	0.90	0.85, 0.97	1.13	0.95, 1.35	0.92	0.86, 0.98
Age						
30 - 39†	1.00	--	1.00	--	1.00	--
40 - 49	2.78	2.49, 3.10	1.99	1.36, 2.92	2.71	2.43, 3.02
50 - 59	5.43	4.86, 6.07	3.65	2.57, 5.18	5.28	4.74, 5.89
60 - 69	10.56	9.46, 11.80	8.89	6.46, 12.24	10.41	9.36, 11.59
70 +	16.96	15.06, 19.11	26.25	19.25, 35.79	17.75	15.82, 19.91
Gender						
Male†	1.00	--	1.00	--	1.00	--
Female	1.23	1.17, 1.30	1.35	1.15, 1.59	1.24	1.18, 1.31
Residence						
Urban	1.07	0.94, 1.23	0.89	0.66, 1.19	1.06	0.93, 1.21
Rural†	1.00	--	1.00	--	1.00	--
Education						
Illiterate†	1.00	--	1.00	--	1.00	--
Below high school	0.87	0.81, 0.93	0.65	0.52, 0.82	0.85	0.79, 0.91
High school & more	0.64	0.57, 0.73	0.93	0.66, 1.30	0.66	0.59, 0.75
Religion						
Hindu	1.08	0.94, 1.23	1.40	1.00, 1.96	1.10	0.96, 1.25
Muslim†	1.00	--	1.00	--	1.00	--
Other	0.78	0.64, 0.95	1.17	0.73, 1.88	0.80	0.66, 0.97
Caste						
SC/ST	1.09	1.01, 1.18	1.08	0.87, 1.36	1.09	1.01, 1.18
Other†	1.00	--	1.00	--	1.00	--
Geographic region						
North and northeast	0.26	0.21, 0.31	0.64	0.44, 0.94	0.28	0.23, 0.33
Central and eastern	0.69	0.60, 0.78	1.17	0.93, 1.48	0.71	0.63, 0.81
West	1.12	0.95, 1.31	1.41	1.07, 1.84	1.13	0.97, 1.32
South†	1.00	--	1.00	--	1.00	--
No. of unweighted cases	167992		159138		168888	

† Reference category

Note: For definition of variables see text and Table 1. Odds ratios are estimated by logistic regression. Confidence intervals take design effects due to clustering into account. For any given predictor variable specified by a row label, the set of control variables consists of all the other predictor variables in the table. Models are based on the weighted sample.

Table 3: Adjusted effects of type of cooking fuel and other selected variables on the risk of blindness (partial or complete) among persons age 30 years and older by gender, India 1992-93

Variable	Male		Female	
	Odds Ratio	95% Confidence Interval	Odds Ratio	95% Confidence Interval
Cooking fuel type				
Biomass fuels	1.31	1.12, 1.52	1.30	1.12, 1.50
Cleaner fuels†	1.00	--	1.00	--
Separate kitchen				
Yes	0.90	0.83, 0.98	0.87	0.80, 0.94
No†	1.00	--	1.00	--
House type				
Kachcha†	1.00	--	1.00	--
Pucca or semi-*pucca*	0.88	0.80, 0.97	0.92	0.84, 1.02
Crowding				
<3 persons per room†	1.00	--	1.00	--
≥3 persons per room	0.89	0.82, 0.97	0.94	0.87, 1.02
Age				
30 - 39†	1.00	--	1.00	--
40 - 49	2.78	2.37, 3.26	2.64	2.29, 3.05
50 - 59	5.54	4.75, 6.46	5.02	4.37, 5.77
60 - 69	10.75	9.24, 12.52	10.04	8.80, 11.46
70 +	19.38	16.58, 22.64	16.18	13.95, 18.75
Residence				
Urban	1.05	0.91, 1.21	1.07	0.93, 1.24
Rural†	1.00	--	1.00	--
Education				
Illiterate†	1.00	--	1.00	--
Below high school	0.91	0.83, 0.99	0.77	0.68, 0.86
High school & more	0.71	0.62, 0.82	0.54	0.43, 0.69
Religion				
Hindu	1.24	1.05, 1.46	1.00	0.87, 1.14
Muslim†	1.00	--	1.00	--
Other	0.82	0.64, 1.04	0.80	0.65, 0.99
Caste				
SC/ST	1.11	1.01, 1.22	1.07	0.98, 1.18
Other†	1.00	--	1.00	--
Geographic region				
North and northeast	0.28	0.23, 0.35	0.27	0.22, 0.34
Central and eastern	0.69	0.60, 0.80	0.72	0.63, 0.83
West	1.11	0.94, 1.32	1.14	0.96, 1.35
South†	1.00	--	1.00	--
No. of unweighted cases	87744		81144	

† Reference category

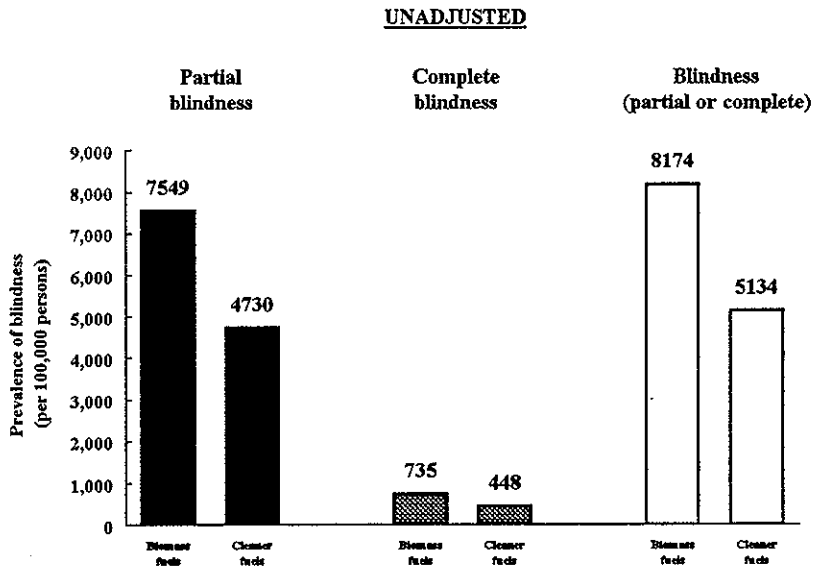
Note: For definition of variables see text and Table 1. Odds ratios are estimated by logistic regression. Confidence intervals take design effects due to clustering into account. For any given predictor variable specified by a row label, the set of control variables consists of all the other predictor variables in the table. Models are based on the weighted sample.

Table 4: Adjusted effects of type of cooking fuel and other selected variables on the risk of blindness (partial or complete) among persons age 30 years and older by residence, India 1992-93

Variable	Urban		Rural	
	Odds Ratio	95% Confidence Interval	Odds Ratio	95% Confidence Interval
Cooking fuel type				
Biomass fuels	1.22	1.01, 1.49	1.49	1.23, 1.80
Cleaner fuels†	1.00	--	1.00	--
Separate kitchen				
Yes	0.94	0.81, 1.09	0.87	0.81, 0.94
No†	1.00	--	1.00	--
House type				
Kachcha†	1.00	--	1.00	--
Pucca or semi-*pucca*	0.90	0.73, 1.10	0.90	0.82, 0.98
Crowding				
<3 persons per room†	1.00	--	1.00	--
≥3 persons per room	0.90	0.78, 1.05	0.92	0.86, 0.99
Age				
30 - 39†	1.00	--	1.00	--
40 - 49	2.29	1.91, 2.73	2.91	2.54, 3.32
50 - 59	4.00	3.29, 4.87	5.87	5.16, 6.68
60 - 69	7.76	6.40, 9.42	11.61	10.22, 13.20
70 +	12.63	10.09, 15.82	20.07	17.55, 22.95
Gender				
Male†	1.00	--	1.00	--
Female	1.26	1.15, 1.38	1.24	1.17, 1.31
Education				
Illiterate†	1.00	--	1.00	--
Below high school	0.89	0.78, 1.00	0.84	0.77, 0.92
High school & more	0.66	0.55, 0.79	0.65	0.55, 0.78
Religion				
Hindu	0.91	0.73, 1.14	1.20	1.03, 1.41
Muslim†	1.00	--	1.00	--
Other	0.62	0.46, 0.85	0.92	0.72, 1.16
Caste				
SC/ST	1.15	0.97, 1.38	1.08	0.99, 1.17
Other†	1.00	--	1.00	--
Geographic region				
North and northeast	0.43	0.33, 0.57	0.26	0.21, 0.31
Central and eastern	0.84	0.66, 1.06	0.68	0.58, 0.79
West	1.22	0.91, 1.64	1.11	0.92, 1.33
South†	1.00	--	1.00	--
No. of unweighted cases	55550		113338	

† Reference category

Note: For definition of variables see text and Table 1. Odds ratios are estimated by logistic regression. Confidence intervals take design effects due to clustering into account. For any given predictor variable specified by a row label, the set of control variables consists of all the other predictor variables in the table. Models are based on the weighted sample.



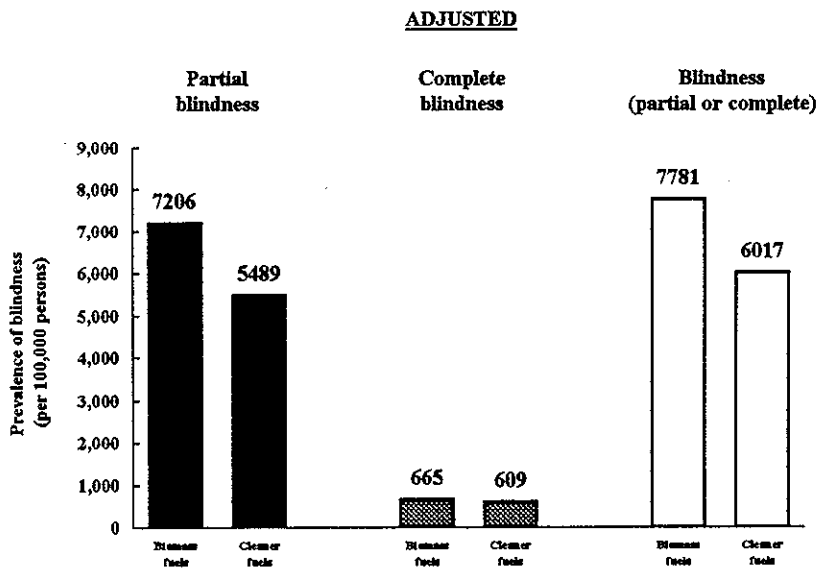


Figure 1: Unadjusted and adjusted prevalence of blindness by type of cooking fuel: persons age 30 years or older, India 1992-93

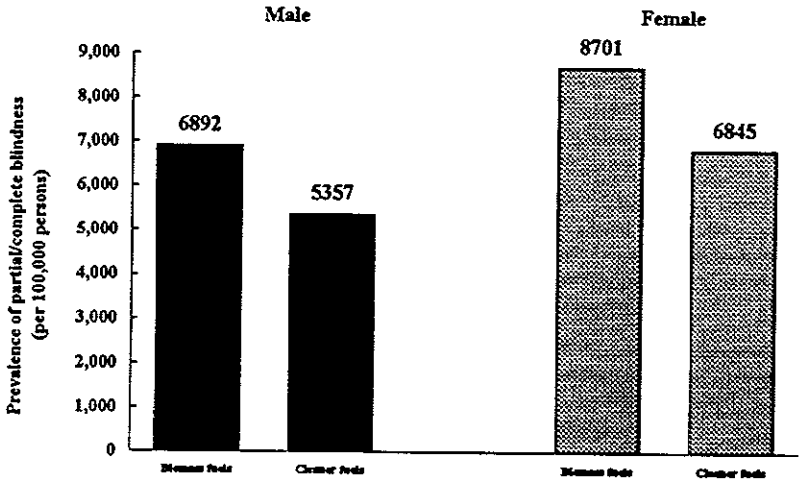


Figure 2: Adjusted prevalence of blindness (partial or complete) by type of cooking fuel and gender: persons age 30 years or older, India 1992-93

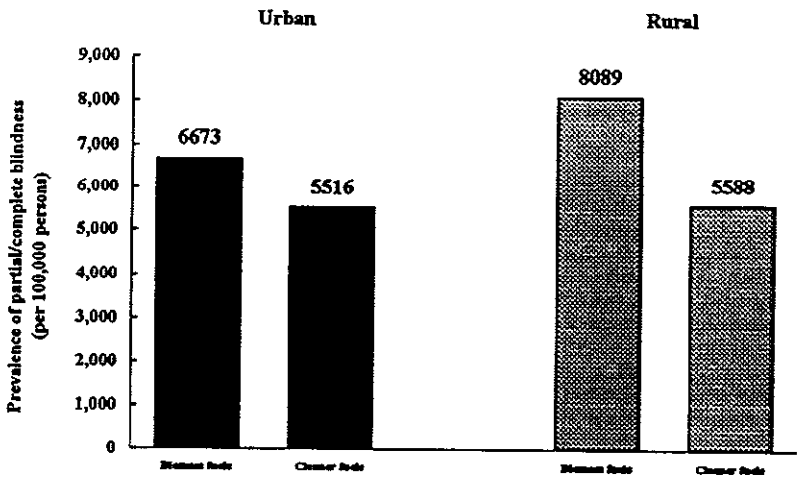


Figure 3: Adjusted prevalence of blindness (partial or complete) by type of cooking fuel and residence: persons age 30 years or older, India 1992-93