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EFFECTS OF INDOOR AIR POLLUTION ON ACUTE RESPIRATORY ILLNESSES AMONGST CHILDREN LESS THAN 5 YEARS IN EASTERN PART OF INDIA: A HOSPITAL-BASED STUDY

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Background

Globally, Acute Respiratory Illness (ARI), along with diarrhoea, still remains a leading cause of mortality in under-5 children, as per recent estimates of World Health Organisation (WHO). Respiratory infections are also a significant contributor of hospital admissions in children of low- and middle- income countries. In spite of the interventions for prevention and control of pneumonia, under the Reproductive and Child Health (RCH) program since 1992, about 17.1% of under-5 mortality, 30-50% of outpatient department (OPD) attendance, and 20-40% of inpatient admissions in India, are due to ARIs. [1]

Indoor air pollution (IAP) is one of the major risk factors for pneumonia amongst children. It constitutes mainly of the following 2 sources:

Solid fuel: this can be biomass or coal; biomass fuel comprises of wood (uncompressed or charcoal), dung or crop residues. Combustion of solid fuels give rise to inorganic gases (eg. CO, NO^2, O^3 etc.), particulate matter (PM), hydrocarbons, oxygenated and chlorinated organic compounds and free radicals. Amongst these, PM less than 2.5 µm in diameter ($PM_{2.5}$) fuels, is one of the most hazardous pollutants emitted by solid fuels, especially in concentrations above 2.5 µg/m^3 (24 hour average), as per guidelines laid down by WHO.

Second-hand Smoke (SHS): This comprises of a mixture of mainstream smoke (smoke first inhaled by an active smoker and then exhaled) and side-streamed smoke (emitted between puffs). SHS is a complex mixture of vapour phase compounds (eg. benzene, vinyl chloride, acrolein etc.) and particulate phase chemicals (eg. alkaloids, nicotine and its derivatives, aromatic amines, polycyclic aromatic hydrocarbons etc.) and can be more carcinogenic than mainstream smoke.

Acute Respiratory Infections (ARIs) can be divided into acute upper respiratory infections (AURIs) involving the airways from the nostrils till the vocal cord in the larynx, and acute lower respiratory infections (ALRIs) involving the airways from trachea and bronchi to bronchioles and alveoli. ALRIs, mainly pneumonia, cause the majority of the ARI deaths and severe illness episodes in under-5 children. Risk factors of ALRIs include malnutrition, low birth weight (< 2500g), non-exclusive breastfeeding in the first 4 months, absence of measles immunisation within the first 12 months, IAP and overcrowding. [2] Unlike the adults, the children below 5 years have immature nasal structure and lesser immunity and hence more vulnerable to IAP. [1]

Although multiple studies have been conducted in India and worldwide, to assess the role of indoor smoke from biomass fuels in respiratory tract health of children, a study to assess the collective role of IAP from burning of solid fuels and SHS, has been lacking. Also, the role of overcrowding and accessibility of separate kitchen in the household has been ignored. Henceforth, this study has been undertaken to assess the role of IAP from various sources and overcrowding (based on room criteria), [3] in the causation of ARIs in under-5 children in the eastern region of India.

Objectives

Our study aims to identify the association of the following:

i) combustion of bio-mass fuel

ii) household with no separate kitchen

iii)overcrowding

iv)parental and household tobacco smoke exposure

with the causation of ARIs (in the Paediatric emergency department visits & indoor admissions due to pneumonia, bronchiolitis & croup).

Method

This is an observational cross-sectional study which included children above 28 days and below 5 years, with ARIs attending outpatient and in-patient department of College of Medicine and JNM Hospital, Kalyani, Nadia district, West Bengal. Children below 28 days and above 5 years of age and/or suffering from chronic illnesses like asthma, cystic fibrosis, and congenital heart defects or serious comorbidities like cerebral palsy was not included in this study. Study tenure was 1 year from December 2023 till November 2024. We used a bi-lingual questionnaire (Bengali and English) which was filled up by the parents (where applicable) or by the principal investigator.

Exposure variables

In our study, the exposure variable is indoor air pollution which was indirectly assessed by type of fuel used for cooking, facility of separate room as kitchen, cooking smoke removal mechanism and smoking behavior of family members of the same household.

Households using solid fuels produce more pollutants per cooking meal than those using liquid, gaseous and other cleaner fuels. [16]. Thus, the type of fuel used as a good indicator of indoor pollution. Following two groups created regarding household usage of fuels-(1) clean fuels are liquid petroleum gas (LPG), biogas, natural gas and electricity, (2) biomass fuels include coal, kerosene, wood, cow dung, straw/grass and others.

Information gathered regarding the presence of a separate room designated as kitchen (coded as 1) or not (coded as 0) and cooking smoke removal mechanism present (coded as 1) or not (coded as 0).

Also, in the study we enquired about the smoking behavior of the household members. Exposure to Smoking was indicated as 1 if any of the parents is a smoker, 2 if any other household member smokes inside the house and ’0’ all family members are non-smoker.

Confounding variables

Several socio-demographic variables were included as confounding factors that have a potential impact on the prevalence of respiratory illness.

The confounding variables of this study include age of child (categorized into infant 1-12 months, 13–36months and 37–59 months), sex of child (male, female), household crowding (<=3 persons per room, >3 persons per room).

Outcome variables

The outcome variables were the requirement of oxygen and management in PICU needed for the under-5 children with ARIs attended OPD and admitted in IPD during the study period.

Method of analysis

Descriptive statistics were carried out to understand the characteristics of study participants

Bivariate percentage distribution was estimated to assess the requirement of oxygen and admission in PICU among children by the key predictors and confounding variables and the differences were later tested by Pearson's chi-square statistic.

The outcome variables were requirement of oxygen and admission in PICU. The key predictors were type of cooking fuel used, presence of a separate kitchen, presence of a cooking gas removal system and the smoking behavior of parents and other family members. The confounding variables were age in months, sex and presence of overcrowding. The sample weight was used for the estimation of percentage distribution.

All the statistical analyses were performed using STATA version 14.0 (StataCorp LP, College Station, TX, USA).

Results

Participant characteristics: In child demographics, 75.3 % were infants (Figure 1a) and 69.4% children were male (Figure 1b).

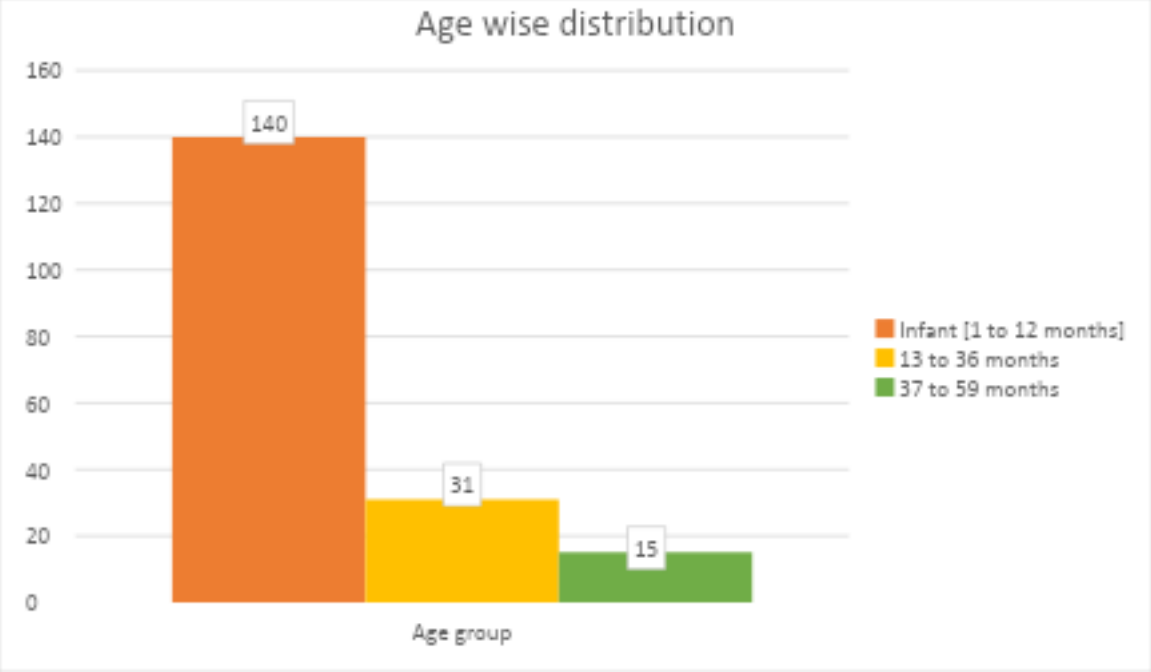

Figure 1a. Age wise distribution of study participants

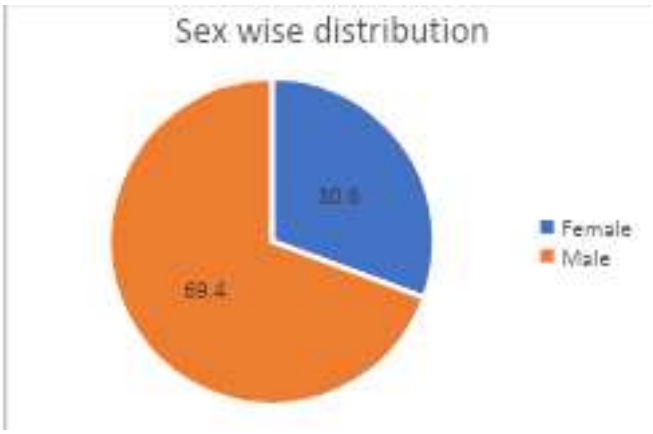

Figure 1b. Sex wise distribution of study participants

Out of the total 186 households, 43.01% used biomass fuels for cooking (Figure 2). Over half of the households, 55.38%, had a separate kitchen for cooking. More than two-thirds of households (81.2%) had no separate cooking gas emission systems.
Regarding smoking behavior, almost 3 out of every 5 families had members with smoking habits, and amongst all, half of the families had smoker parents.
Over half of the children participating in this study (54.3%) lived in crowded houses where more than 3 persons stayed together per room.

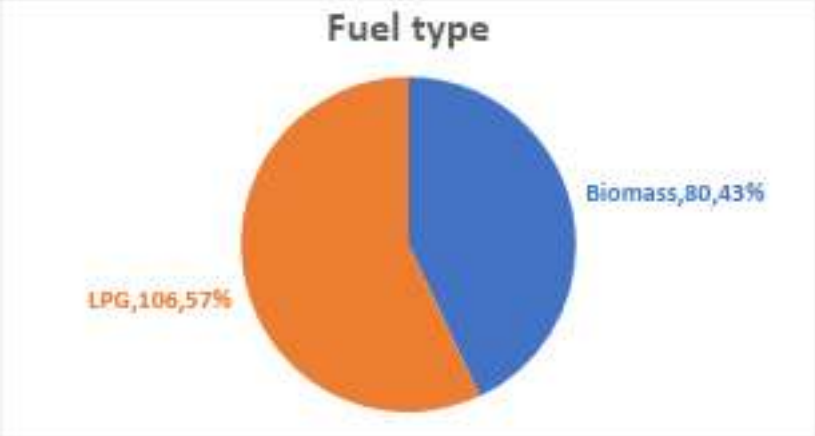

Figure 2. Distribution of type of fuels usage

Prevalence and severity of ARI among under-five children by explanatory variables
Out of the 186 children participating in this study, 63.98% children required oxygen at some point of their hospital stay, while 20.97% required PICU admissions.

The requirements of oxygen and PICU admission percentage was significantly higher among children living in households using biomass fuels compared to those living in households using cleaner fuels (38.7% vs 25.27%, p <0.0001) and (17.20% vs 3.76%, p<0.0001) respectively.

Under five children with ARI had less oxygen requirement and PICU admission for households having a separate kitchen facility compared to those who did not have it (26.34% vs 37.63%, p <0.001) and (7.53% vs 13.44%, p<0.006).

Children belonging to household having no separate cooking gas emission system had higher oxygen requirement and higher PICU admission rate (50.54% vs 8.06%, p <0.03) and (19.89% vs 1.08%, p <0.01) respectively; also, presence of smoker in the family was associated with higher oxygen

requirement (41.94% vs 22.04 %, p<0.03) and PICU admission rate (16.13% vs 4.88 %, p <0.01) as compared to families with no smoker.

Furthermore, the requirement of oxygen and PICU admission was slightly higher among under five children with ARI who stayed in overcrowded households as compared to children from houses with no overcrowding (39.25% vs. 24.73%, p<0.01) and (15.59% vs 5.38%, p <0.005). (Table 1)

Table no 1 : Percentage of O2 requirement and ICU requirement in ARI patients among under 5 children affected by indoor air pollution

Variables		**Sample Characteristics**		**O2 requirement**		**ICU requirement**	
Outcome Variables		**Frequency**	**Percentage**	**Percentage**	**P value**	**Percentage**	**P value**
Requirements of Oxygen							
	Yes	119	63.98				
	No	67	36.02				
Admission in PICU							
	YES	39	20.97				
	No	147	79.03				
Key Predictors							
Type of cooking fuel					<0.0001		<0.0001
	Biomass	80	43.01	38.70%		17.20%	
	Clean fuel	106	56.99	25.27 %		3.76 %	
Separate kitchen					<0.0001		0.006
	NO	83	44.62	37.63 %		13.44 %	
	YES	103	55.38	26.34%		7.53%	
Cooking gas removal system					0.0363		0.0141
	No	151	81.2	50.54%		19.89%	
	Yes	35	18.8	8.06%		1.08%	
Smoker					0.0369		0.0171
	Yes Parents	96	51.6	37.10%		15.05%	
	Yes others	13	7	4.84%		1.08%	

	Yes	109	58.6	41.94%		16.13%	
	NO	77	41.4	22.04 %		4.88 %	
Confounding Variables							
Age in months							
	1-12 months	140	75.3%				
	13 – 36 months	31	16.7%				
	37-60 months	15	8.1%				
Sex							
	Male	129	69.4				
	Female	57	30.6				
Overcrowding					0.0104		0.0048
	Yes	101	54.3	39.25%		15.59%	
	No	85	45.7	24.73%		5.38%	

The use of biomass fuels (OR [odds ratio]: 11.3, 95% CI [confidence interval]: 4.95 - 25.78), households having no separate kitchen (OR: 5.93, 95% CI: 2.93 -12.03), no mechanism for smoke removal (OR: 2.2, 95% CI: 1.05 - 4.64) and presence of smoking behavior of household members (OR: 2.21, 95% CI: 1.19 – 4.07) were associated with greater risk of oxygen requirement in patients of ARI among under-five children.

The use of biomass fuels (OR [odds ratio]: 9.43, 95% CI: 3.88 – 22.90), households having no separate kitchen (OR: 2.74, 95% CI: 1.32 -5.70), no mechanism for smoke removal (OR: 5.36, 95% CI: 1.23 – 23.40) and presence of smoking behavior of household members (OR: 2.87, 95% CI: 1.27 – 6.47) were associated with greater risk of admission in PICU among under-five ARI patients even after adjusting for age of child, sex of child and household crowding (Table No.2)

Table no 2 : Risk association between O2 requirement and ICU requirement with key predictors of indoor air pollution in ARI patients among under 5 children

			O_2 requirement	Room Air	Odds Ratio	95% CI
Fuel type	Wood	Exposed	72	8	11.3	4.95 to 25.78
	LPG	Non exposed	47	59		
Separate kitchen	NO	Exposed	70	13	5.93	2.93 to 12.03
	YES	non exposed	49	54		
Gas Emissions	No	Exposed	94	57	2.2	1.05 to 4.64
	Yes	Non exposed	15	20		

Overcrowding	YES	Exposed	73	28	2.21	1.20 to 4.06
	NO	Non exposed	46	39		
Smoker	Yes Parents	Exposed	69	27	2.21	1.19 to 4.07
	others		9	4		
	NO	Non exposed	41	36		
			Admitted in PICU	Not required PICU		
Fuel type	Wood	Exposed	32	48	9.43	3.88 to 22.90
	LPG	Non exposed	7	99		
Separate kitchen	NO	Exposed	25	58	2.74	1.32 to 5.70
	YES	non exposed	14	89		
Gas Emissions	No	Exposed	37	114	5.36	1.23 to 23.40
	Yes	Non exposed	2	33		
Overcrowding	YES	Exposed	29	72	3.02	1.37 to 6.64
	NO	Non exposed	10	75		
Smoker	Yes Parents		28	68		
	others		2	11		
	All smoker	Exposed	30	79	2.87	1.27 to 6.47
	NO	Non exposed	9	68		

Discussions

Multiple epidemiological studies have demonstrated the associations between ARI and IAP, but there has been heterogeneity in the estimations of these associations in both magnitude and consistency. A systematic review by Sumal Nandasena et al has shown the risk of ARI is almost three times higher in children exposed to solid biomass fuels as compared to non-exposed children. Children of the youngest age groups are most vulnerable [2]. In our study, 75.3% of children were in the age group of 0-1 year, corroborating with this finding. Also, almost half of the households (43.01%) were using solid biomass fuels for cooking. Younger children are more susceptible to IAP due to their physical characteristics of the upper respiratory tract. Also, they are more likely to stay with their mothers during cooking. In contrast, children above 3 years spend more time away from house and in outdoors and hence are less susceptible to IAP.

A study conducted in Uganda, by Katherine E Woolley et al, has shown an insignificant role of ventilation in household air pollution [4]. In contrast, our study revealed that both the prevalence and severity of ARI (measured as requirements for oxygen and PICU admissions) was significantly higher in children living households with no separate kitchen and having no separate cooking gas emission

systems. Resembling this finding, a study conducted in Afghanistan, by Jewel Rana et al, has shown an increased prevalence of ARI amongst children who were highly exposed to IAP (characterized by use of solid fuels and having no separate kitchen) [5].

Our study investigated the role of environmental tobacco smoke on ARI in under-5 children. The prevalence and severity of ARI was significantly higher in children belonging to families with at least 1 smoker. Mishra et al had shown positive effects of environmental tobacco smoke on ARI in young children [6]. Our study also noted a significant role of overcrowding in determining the severity of ARI. Studies like those conducted by S Ganesh Kumar et al in Puducherry, India [7], and Vinod K Ramani et al in urban slums of Gulbarga [8], similarly emphasized the significant role of overcrowding in prevalence of ARI.

The novelty of our study lies in the fact that we assessed the role of various exposure variables like use of biomass fuels, presence of second-hand smoke exposure, overcrowding, absence of separate kitchen and lack of ventilation in kitchen in determining the severity of ARI as assessed by requirements of oxygen and PICU admission at some point of the hospital stay in the IPD patients.

Few limitations of our research are that we failed to assess the influence of socio-economic factors like household wealth and education level of parents. There is also a significant role of exclusive breastfeeding in prevention of ARI in infants [9], which we failed to assess in our study.

Conclusions:

Under-5 children are more susceptible to IAP due to their physiological susceptibility and spending more time indoors. In developing countries, IAP is a modifiable risk factor of ARI. Hence, to reduce the global burden of ARI, as an important contributor of under-5 mortality and morbidity, urgent policy interventions are required to reduce the exposure to IAP, particularly among the impoverished groups. The government should ensure cleaner fuels for cooking, such as LPG and electricity, to minimize the risk of respiratory diseases amongst children. Further, stringent laws need to be implemented to reduce the second-hand smoke (SHS) exposure for under-5 children.

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