KnE Life Sciences

The 2nd International Meeting of Public Health 2016
The 2nd International Meeting of Public Health 2016 with theme
"Public Health Perspective of Sustainable Development Goals:
The Challenges and Opportunities in Asia-Pacific Region"
Volume 2018

Conference Paper

Particulate Matter 10 and the Incidence of Acute Respiratory Infectionsin Children in an Industrial Stone-carving Area in South Sulawesi, Indonesia

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Abstract

Stone carving, which is a common craft industry throughout Allakuang village, has the potential to produce particulate matter 10 (PM_{10}) during the cutting and grinding of stone. This can result in air pollution in the workplace, as well as in the homes of local residents. PM_{10} is a risk factor for acute respiratory infections (ARIs) in children. This study aimed to determine the association between exposure to dust PM_{10} inside homes and the incidence of acute respiratory infections (ARI) in children. This was a cross-sectional study conducted in Allakuang village, Maritengngae subdistrict, Sidrap, South Sulawesi, Indonesia and consisted of 101 children. ARI cases were based on a doctor's diagnosis. The concentration of PM_{10} in the workplace was assessed using a Haz-Dust EPAM 5000 monitor. Chi-square analysis and multiple logistic regression tests were conducted. The concentration of PM_{10} was significantly associated with the incidence of ARIs (2.6; 1.1-6.1). The results of the multivariate analysis showed that children living in homes with PM_{10} concentrations that exceeded accepted limits had a 3.5 times higher risk of ARIs after adjusting for smoking behavior of family members. The significant association between the PM_{10} concentration and incidence of ARIs in children found in this study points to the need to control stone dust in the stone carving craft industry to prevent indoor air pollution of homes close to the industrial area.

Keywords: PM10, acute respiratory infection, children, craft stone carving

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Received: 21 January 2018
Accepted: 8 April 2018
Published: 17 May 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the 2nd International Meeting of Public Health 2016 Conference Committee.

How to cite this article: Haeranah Ahmad, Ririn Arminsih Wulandari, Zakianis, Yulia Khairina Ashar, and Fajrin Nur Azizah, (2018), "Particulate Matter 10 and the Incidence of Acute Respiratory Infectionsin Children in an Industrial Stone-CarvingArea in South Sulawesi, Indonesia" in *The 2nd International Meeting of Public Health 2016 with theme "Public Health Perspective of Sustainable Development Goals: The Challenges and Opportunities in Asia-Pacific Region"*, KnE Life Sciences, pages 492–501. DOI 10.18502/kls.v4i4.2311

1. INTRODUCTION

Rapid industrial development in Indonesia has had positive impacts, such as improved economic conditions. However, it has also had negative impacts, including air pollution caused by emissions from industries. Air pollution caused by particulate matter, especially PM_{10} is commonly the result of burning activities, road traffic (emissions from vehicles and surface friction), and industrial activities [14].

As defined by the EPA (2016), PM_{10} refers to coarse inhalable particles larger than 2.5 micrometers and smaller than 10 micrometers. Due to its small size, PM_{10} can readily be inhaled and enter the respiratory tract through the nose and throat before reaching the lungs [19]. PM_{10} respirable and a good predictor of health [6]. Among children, PM_{10} exposure can cause acute respiratory infection (ARIs) and cardiovascular disorders, sometimes culminating in death. For people with asthma or a history of allergies, exposure to PM_{10} can result in decreased lung function and inflammation, resulting in respiratory disorders and chronic bronchitis [13].

According to the World Lung Foundation (2016), ACIs are the leading global killer of children under 5 years, with pneumonia alone responsible for almost 1.6 million deaths annually. Major (2010) reported that ACIs were the third main cause of death worldwide, after heart disease and strokes, and that they were the main factor responsible for mortality in low- and middle-income countries. In Indonesia, ARIs are a prevalent public health problem [5]. According to the Sidrap Health Agency, ARIs ranked number one among 10 prevalent diseases in 2011–2015.

The Sidrap district, which is located in the northern area of Makassar city, is a well-known stone-carving craft center. The center of the stone-carving craft is Allakuang village in the sub-district of Maritengngae, Sidrap district, which has a very large distribution area covering the entire Southern Sulawesi region. The stone-carving industry exploits natural resources and uses traditional methods (mortar and pestle) to produce gravestones. It is an informal industry, which contributes to significant air pollution.

Stone carving is the primary source of income for Allakuang villagers, and most houses are located within 50 m of a stone-carving workshop. Most of the villagers' houses are of stilt-type construction, in which the top part serves as the family's home, and the bottom part is used for stone carving. In most cases, the bottom part is a semi-permanent structure made from zinc or board wall. Due to the proximity of the residents to the stone-carving areas and the nature of the building construction, the residents are continually exposed to stone dust produced by cutting, shaping, and grinding processes. Furthermore, as these home industries operate at all hours, the residents are continually exposed to dust.

Infants and children inhale and retain larger amounts of air pollutants per unit of body weight than adults, and the air intake of a resting infant is twice that of an adult. In addition, immature lungs have a limited metabolic capacity to cope with exposure to air pollutants [17]. Most 7 to 12 year olds in Allakuang village spend large amounts of time indoors after returning from school because of the dense dust produced by stone-carving activities.

The focus of this research was primary school students aged 7–12 years because they are at greater risk than adults from exposure to the harmful effects of air pollutants [10]. Given the high level of exposure of children to dust in the crowded living conditions of the stone-carving industrial area of Allakuang village and the high reported number of ARI cases, this study aimed to analyze the correlation between PM_{10} exposure and the incidence of ARIs after adjusting for potential confounders, such as temperature, humidity, lighting, floor type, ceiling condition, wall type, kitchen location, ventilation, occupant density, use of insect repellent, cooking fuel, and smoking behavior.

2. METHODS

This research utilizeda cross-sectional design. The study population consisted of all children aged 7–12 years living close to stone-carving activities in Allakuang village whose parents agreed to their involvement in the study. The total population sampling method was used. In total, 101 children participated in the study.

The independent variable in this research was thePM_{10} concentration inside the children's homes, and the dependent variable was the incidence of ARIs. The potential confounders were temperature, humidity, lighting, floor types, ceiling condition, wall type, kitchen location, ventilation, occupant density, use of insect repellent, cooking fuel, and smoking behavior.

Primary data were collected by direct measurements, personal observations, clinical examinations, and interviews. The diagnosis of ARI was based on a clinical examination by a medical doctor. The PM_{10} concentration was measured using a Haz-DustEPAM 5000monitor. Temperature and humidity were measured using a thermoshygrometer. Lighting was measured by a lux meter, and ventilation was determined using a gauge. Data on floor type, ceiling condition, and kitchen location were based on personal observations. Data on occupant density, use of insect repellent, cooking fuel, and smoking behavior were obtained from the participants' mothers using a questionnaire form. The data were collected during June–July 2016. The data were analyzed using chi-square and multiple logistic regression analyses.

3. RESULTS

The results of the correlation analysis of the association between environmental factors, housing conditions, and children's habits showed that the PM_{10} concentration, occupant density, and smoking behavior of the family were correlated with the incidence of ARIs. The correlation between the PM concentration and ARI incidence was statistically significant. Children living in homes where the PM_{10} concentration exceeded recommended levels had a 2.6 times higher risk of ARIs than children living in homes where the PM_{10} met requirements (Table 1).

The association between occupant density and the incidence of ARIs was statistically significant, as shown by the results of the correlation analysis. Children living in homes where the occupant density did not comply with standards had a 4.8 times higher risk of ARIs than children living in homes where the occupant density met recommended guidelines. The results of the correlation analysis also revealed a significant association between the smoking behavior of the family and the childhood incidence of ARIs. Children living in homes in which one family member was a smoker had a 12.6 times higher risk of ARIs than children living in homes in which none of the family member smoked (Table 1).

Table 1: Results of the correlation analysis between environmental factors, including housing conditions, and the incidence of ARIs in children.

Variable	Acute Respiratory Infection				Total		OR (95% CI)	p value
	Yes		No					
	n	%	n	%	n	%		
PM_{10} concentration								
>70 μg/m	17	53.1	15	46.9	32	100	2.6 (1.09-6.14)	0.05
≤ 70 μg/m	21	30.4	48	69.6	69	100		
Humidity								
<40% or >60%	11	55.0	9	45.0	20	100	2.4 (0.90-6.61)	0.12
40–60%	27	33.3	54	66.7	81	100		
Temperature								
≥ 34° C	18	34.0	35	66.0	53	100	0.72 (0.32-1,61)	0.55
< 34° C	20	41.7	28	58.3	48	100		
Lighting								

Variable	Acute Respiratory Infection				Total		OR (95% CI)	p value
	Yes		No					
	n	%	n	%	n	%		
<60 lux or >120 lux	18	39.1	28	60.9	46	100	1.1 (0.50-2.52)	0.94
60–120 lux	20	36.4	35	63.6	55	100		
Floor type								
Not standard	29	33.7	57	66.3	86	100	0.3 (0.11-1.05)	0.09
Standard	9	60.0	6	40.0	15	100		
Ceiling construction								
Poor	6	42.9	8	57.1	14	100	1.3 (0.41-4.05)	0.89
Good	32	36.8	55	63.2	87	100		
Wall type								
Not standard	31	36.5	54	63.5	85	100	0.7 (0.25-2.18)	0.79
Standard	7	43.8	9	56.2	16	100		
Ventilation								
Standard	36	39.6	55	60.4	91	100	2.6 (0.53-13.04)	0.31
Not standard	2	20.0	8	80.0	10	100		
Occupant density								
Exceeded limits	37	80.4	9	19.6	46	100	4.8 (1.93-11.77)	0.001
Within limits	25	46.3	29	53.7	54	100		
Use of insect repellent								
Mosquito coils	27	39.1	42	60.9	69	100	1.2 (0.51-2.95)	0.81
Other types of insect repellent	11	34.4	21	65.6	21	100		
Cooking fuels								
Firewood/kerosene	1	33.3	2	66.7	3	100	0.8 (0.07-9.41)	1.00
Gas/electric stove	25	55.6	20	44.4	45	100		
Smoking behavior								
Family member smokes	37	44.0	47	56.0	84	100	12.6 (1.60-99.4)	0.007
No family member smokes	1	5.9	16	94.1	17	100		
Kitchen location								
Not separate from another room	2	20.0	8	80.0	10	100	0.4 (0.07-1.90)	0.31
Separate	36	39.6	55	60.4	91	100		

Based on the results of the multiple logistic regression analysis, children living in houses in which the PM_{10} concentration did not meet standards had a 3.5 times higher risk of ARIs, after adjusting for family members' smoking behavior.

Table 2: Results of the correlation analysis between the PM_{10} concentration and incidence of ARIs in children.

Impaired lung function	Coef.	OR	*P* Value	95% CI
PM_{10} concentration	1.245	3.5	0.011	1.33-9.05
Smoking behavior	2.837	17.1	0.009	2.05-142.4
_constant	-3.453	0.62	0.032	

4. Discussion

The PM_{10} concentrations measured in the houses of 78 children varied from 20μg/m^3 to 158μg/m^3 and the average was 62.76 μg/m^3. Thus, the average PM_{10} concentration did not exceed the threshold (>70 μg/m^3) stipulated under government regulations (Peraturan Menteri Kesehatan Republik Indonesia Nomor 1077/Menkes/per/v/2011). However, thePM_{10} levels exceeded the threshold in 24 (30.8%) houses. Most of these houses were located closer than 50 m to a stone-carving site. Some of the houses also functioned not only as homes but also as sites for stone carving. In addition, many houses did not meet building construction standards. Furthermore, the proximity of the living quarters of these homes to the stone-carving areas meant that stone dust particulates from cutting, shaping, and grinding processes were transported into the houses. In the children's homes, dust covered the floors, and the air around the houses was dense with dust.

The results of the present study revealed a significant correlation between the PM_{10} concentration and incidence of ARIs. PM_{10} particulates range in size from 0.1μmto 10 μm (US EPA 2004). These particulates facilitate the inhalation of viruses (0.1–1 μm), bacteria (0.5–5 μm), chemical substances, and other materials, which gain entry to both branches of the bronchivia the nasal passage (US EPA 2004). The findings of the present study are in agreement with those reported in a study of children younger then15 years in Turkey in which the authors demonstrated a significant correlation between PM_{10} exposure and hospital admissions for asthma and other respiratory diseases [15]. Dockery and Pope (1994) analyzed epidemiological data on children and estimated a mean increase of 3% and 0.7% in the prevalence of lower (LWRD) and upper (UPRD) respiratory diseases for every increase of 10 μg/m^3 in PM_{10}, respectively. Another study reported a 3.7% and 5.1% rise in UPRD and LWRD, respectively, per 10-μg/m^3 increase in PM_{10} [11]. Lindawaty (2010) reported that children younger than 5 years in homes where the PM_{10} concentration exceeded70 μg/m^3 had a 5.73 times higher risk of ARIs than those living in homes that met PM_{10} concentration standards.

Large numbers of occupants in a house require more space, especially bedrooms. Occupant density affects the health of household members, with overcrowded conditions leading to a lack of oxygen and facilitating the transmission of infections to other members [1]. In Allakuang village, 80.4% of children live in houses where the occupant density exceeds standards. The results of the present study showed that children living in such houses had a 4.8 times higher risk of ARIs as compared to children living in houses in which the occupant density met standards.

The present study found a significant correlation between smoking behavior of family members and the incidence of ARIs in children. This result can be explained by the findings of a previous report, which stated that cigarette smoke can cause persistent irritation of the respiratory tract, resulting in increased vulnerability to various diseases [18]. A previous study reported that passive smokers (i.e., nonsmokers exposed to second-hand smoke from smokers) were at risk of smoke-related diseases, including lung cancer, respiratory tract infections, allergic syndrome, chronic lung disease, and chest pain [7]. The findings of the present study are in line with those of research conducted by Gertrudis (2010) and Rahayu (2011). Rahayu (2011) showed that exposure to cigarette smoke in the home was associated with a 40.5 times higher risk of ARIs as compared to homes without cigarette smoke. In the present study, most of the children had a family member who smoked inside the house.

In the present study, based on the results of a bivariate analysis, the risk of ARIs among children was 2.6 times higher when the PM_{10} concentration inside the children's homes exceeded the threshold. After adjusting for smoking behavior of a family member, this risk was 3.5 times higher, revealing that smoking behavior of family members can increase the risk of ARIs associated with PM_{10} levels.

5. CONCLUSION

The PM_{10} concentration showed a significant correlation with the incidence of ARIs in children living in close proximity to a stone-carving industrial area in Allakuang village. Children living in houses where the PM_{10} concentration did not comply with standards had a 3.5 times higher of ARIs after adjusting for smoking behavior of family members. The findings indicate that smoking behavior of family members can further exacerbate the risk of ARIs associated with the PM_{10} concentration. The increased level of indoor air pollution (a high concentration of PM_{10} in the house and cigarette smoke) may result in impaired respiration, especially among children who spend most of their time inside.

As shown by the findings in this study, the living conditions were very unhealthy in many houses, with dust dispersed throughout the house during the day. The residents made some efforts, such as sweeping the floor sand washing them regularly with a wet mop, to remove the dust. However, such efforts do not combat the risk posed by PM_{10} because of its small size (10 μm) and aerodynamic nature. A better solution would be to minimize the dust from the pollutant source in the workplace. This could be done by applying wet methods, for example, channeling water through a hose attached to the grinder. The latter has been proven to reduce dust produced by cutting, shaping, and grinding processes. Wet filters or scrubbers/wet collectors could also be employed to clean the contaminated air by spraying water from the top. In addition, the dust concentration inside the workplace could be controlled by installing dust enclosures and a local exhaust ventilation system, including dust filters to catch the dust generated during the production process.

ACKNOWLEDGEMENTS

We would like to acknowledge the support of our research sponsor the Directorate of Research and Community Service, University of Indonesia and the assistance received under the Grant Proposal for International Indexed Publication for a Student Research Paper (Grant) No: 1977/UN2.RI2/HKP.05.00/2016. We also thank all the individuals who provided technical support for this research, especially those in the Department of Machine, Faculty of Engineering, University of Indonesia.

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