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Measurement and Impact Assessment of PM_{10} in Ambient Air of BSCIC Bagerhat

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Abstract

The study measured the concentration of coarse particulate matter (PM_{10}) in the ambient air of Bangladesh Small and Cottage Industries Corporation (BSCIC) Bagerhat in order to evaluate its impact on workers' health. 14 known-volume air samples were obtained through Envirotech APM 541 PM10 Particulate Sampler. The short-term (6 hours) samples were taken from 9 industrial units in the winter season of October, 2015 to January, 2016. Simple gravimetric analysis showed large variations in concentrations in distinct industrial units. The minimum concentration was found 33.61 μ/m^3 in the outdoor premises of a coconut oil mill and the maximum was found 471.38 μ/m^3 in the house of a rice mill. The pollutant sources were detected as cabinless husking machines and soot from boilers and fryers. A questionnaire survey was conducted to evaluate the mostly occurring symptoms of Chronic Obstructive Pulmonary Diseases (COPD) and bronchoconstriction among workers. The highest prevalence of symptoms of bronchoconstriction (OR = 7.1; 95% CI = 2.3 - 21.9) was found among workers in rice mills and eye disturbances (OR = 2.7; 95% CI = 0.9 - 8.6) had the highest prevalence in coconut mills. Monitoring of air quality, providing personal respiratory prevention and improvement in machineries were required in the study area for a healthy environment.

Keywords

PM_{10}, BSCIC, Health Impact, Odds Ratio

1. Introduction

Bangladesh Small and Cottage Industries Corporation (BSCIC) has been contributing to the promotion and extension of micro to small & medium cottage industries yielding social and economic returns domestically [1]. BSCIC Bagerhat contains the largest clusters of paddy and coconut processing mills in Bangla-

desh along with a variety of agricultural enterprise. The inputs for seasonal post-harvest operations are raw agricultural products. All industrial processes are fueled by agricultural by-products and charcoal while they (total 79 estates in Bangladesh) unloose a variety of refuse that is potentially degrading the environment [2].

Agro-based industries are noted as one of the major stationary sources of air pollution in Bangladesh [3]. In BSCIC Bagerhat, agro-processes such as threshing, shelling, drying and husking are done without monitoring or evaluating the effects of great amount of grain dust produced. Rice husk, rice-bran, coconut-coir and charcoal may cause air pollution when processed or burnt in open and if not disposed of properly, it may create allergic reactions in workers [4].

Particulate matter is the major pollutant of concern internationally, as it is in Bangladesh [5]. In the major cities here, the concentration of particulate matter has been steadily increasing in recent years, with an annual average much higher than the prescribed World Health Organization (WHO) guidelines [3]. The health effects are mostly associated with inhalable particles in the range of 10μm Equivalent Aerodynamic Diameter (EAD) and less [6]. Varied concentrations of PM_{10} (225 $\mu g/m^3$ - 1600 $\mu g/m^3$) generated from bagasse-fired boilers; vehicular emission and road construction; animal confinements and fodders; soil tillage operations; silica and cotton dust influenced respiratory disturbances, *i.e.*, Chronic Obstructive Pulmonary Disease (COPD), chronic bronchitis, pneumonitis and excess risk of laryngeal cancer among workers [7] [8] [9] [10]. 25% increase in patients with COPD in winter season was found, enlisting its symptoms as frequent cough, shortness in breath and tightness in chest certifying dust and smoke as the causes for such ailments [11]. Also, when particulate matter lodged in the lungs, it caused chronic respiratory problems including emphysema, pneumonia, bronchitis, asthma and respiratory tuberculosis etc. [12]. Moreover, organic dust may contain pollen, fungal spores, fungal hyphae, mycotoxins, bacteria and endotoxins [13].

2. Materials and Methods

2.1. Site Selection

Occupational exposure to particulate matter in agro based industrial operations had scarcely come to focus in Bangladesh despite having an agro-based economy. Maximum PM_{10} concentration in a sugar mill in Kushtia was found 380.339 $\mu g/m^3$ [7]. Air quality monitoring in this sector is yet to strengthen. The workers are not conscious about the health effects of PM_{10}. In such circumstance, the largest agro industrial complex in Khulna division was chosen for the study.

2.2. Study Area

BSCIC is situated beside the Khulna-Bagerhat Sadar Road of Bagerhat District in the Division of Khulna in southwest Bangladesh. Small scale (production capacity around 700 kg/day) rice processing mills, coconut oil manufacturing mills,

tin processing mills, biscuit mills and pulse processing mills were chosen for air sampling. The study was conducted in November, 2015 to January 2016 with average temperature ranging from 23˚C to 19˚C. The general directions of the wind in winter are north-westerly over the western Bangladesh [3] and the wind speed varies between 2 km/h to 11 km/h [14]. The driest month is December with 8 mm monthly precipitation [14].

2.3. Status of Department of Environment (DoE) in BSCIC Bagerhat

Under the Environment Conservation Act (ECA), 1995 and the Environment Conservation Rules, 1997, agricultural product processing industries are listed in ORANGE-A Category [15]. An ECC (Environment Clearance Certificate) is needed for the initiation of all industrial activities and it is to be renewed every year afterward. The BSCIC Bagerhat administration record showed that, each of the mills had the initial ECC, but they were merely renewed and poorly monitored. DoE evaluated the SPM (Suspended Particulate Matter) concentrations along with noise level in industrial units, but did not measure inhalable particulate matter in any industry of BSCIC Bagerhat.

2.4. Methodology

The study was dealt through both quantitative and qualitative data collected primarily.

2.4.1. Air Sampling and Analysis for PM_{10} Estimation

14 air samples of known volume were taken by Envirotech APM 541 PM_{10} Particulate Sampler through short term sampling (6 hour) from purposively chosen stations. The known volumes of air sample were weighted in laboratory of Environment Science Discipline, Khulna University, Khulna −9208 by the simple gravimetric method to determine the PM_{10} concentrations (in $\mu g/m^3$) in samples and each concentration was calculated into 24 hour Time Weighted Average (TWA).

2.4.2. Evaluating Health Risk by Questionnaire Survey

Based on previous studies and documented eye and pulmonary disturbances due to exposure to PM10, a questionnaire was structured, adopting British Medical Research Council (BMRC) Questionnaire [16]. The key points had been on symptoms of eye irritation or inflammation, COPD (*i.e.*, shortness of breath, tightness in chest, arrhythmia) and bronchoconstriction (the occurrence of frequent cough *i.e.*, more than six times a day and more than 4 days out of the week; frequent phlegm *i.e.*, bringing up phlegm more than twice a day and more than 4 days a week and getting phlegm in the morning; and frequent sneezing while working). Simple random sampling technique had been applied and the sample size was adjusted [17] to screen 50 workers among 130 permanent employees (employment period minimum 6 days a week for one year). These 50

workers (21 in rice mills, 20 in coconut processing mills and 9 in other mills) were the exposed group to particulate matter emission. Another 50 people were chosen randomly as the unexposed group who were small businessmen, poultry owner, home makers and students living in the BSCIC residence (along the estate margin). They were selected as in the same age group as the exposed group.

MS Excel 2013 and IBM SPSS Statistics v21 software were used for drawing results from the study. Permission was granted to conduct the study from the estate manager of BSCIC, Bagerhat. Every participant was interviewed with his/her prior consent.

3. Results and Discussion

3.1. Sources of PM_{10} in the Study Area

Reconnaissance survey revealed that generation of coarse particles initiated from the unloading of raw agricultural products in the mill premises. Then they are threshed, boiled, dried, and carried into mill houses where they were husked, processed and packaged. Some of the raw products needed to be shelled out of coir and fried in the burners. The threshing, pressing and husking machinery in the mill houses were run by electricity or generators. These machines were built poorly and had no coverage or cabin to block husks from flying out. The boiling, frying and baking burners were run by biomass which mostly were agricultural by-products, *i.e.*, grain husks, straws, twigs and coconut shells. A few burners were fueled by charcoal. Workers upload charcoal and biomass into the burners by throwing them in and doing so they were exposed to a cloud of dust and soot around them. The mills each have stacks of only about 25 feet height emitting plume where it should be at least 50 feet, as suggested by DoE. The stacks being closer to ground may increase the risks of concentrated particulates in ambient air. The whole mill house remained in the dusty condition in the working time, *i.e.*, from 8 am to 12 am and from 2 pm to 6 pm due to poor ventilation.

3.2. Status of PM_{10} in Different Industrial Units

The rice and coconut processing mills each had two distinct working zones, indoor mill houses and outdoor drying premises, while the biscuit mill, tin mill, pulse processing mill and BSCIC office had single zone in each. The concentrations found in each zone varied widely and it is shown in Table 1.

3.3. Usage of Personal Protective Equipment (PPE)

The walk-through survey revealed that 52% of the total sample population was using only a piece of cloth as a mask or gloves. Interviews found out that 86% of the total of them is unaware of any health impact of the dusty environment they were working in and 12% stated that the PPE they were using were inefficient and insufficient. 5% of them felt it was uncomfortable to use masks and gloves due to the hot and humid weather.

Table 1. Concentration of PM_{10} in ambient air of distinct industries vs. National Ambient Air Quality Standard (NAAQS) for 24 hour Time Weighted Average (TWA).

Name of the Mill	Selected Zone	Concentration of PM_{10} ($\mu g/m^3$) for 24 hour TWA	NAAQS in Ambient air ($\mu g/m^3$) for 24 hour TWA
Papon Coconut Oil Mill	Premises	45.83	150
	Mill house	157.49	
Akash Coconut Oil Mill	Premises	33.61	
	Mill house	114.10	
Al-amin Rice Mill	Premises	78.32	
	Mill house	390	
Tila-Shila Rice Mill	Premises	82.42	
	Mill house	438.33	
Hossain Rice Mill	Premises	88.21	
	Mill house	471.38	
BSCIC Office Premises	-	86.49	
Pinky Pulse Processing Mill	-	108.46	
Adorsho Tin Mill	-	52.86	
Biscuit Mill	-	71.31	

3.4. Health Status of the Workers

Presented in Table 2, 40% and 42% of the sample population working in rice mills had trouble with their eyes while working in the mill houses and in the premise respectively. Moreover, 16% worker regularly felt shortness of breath during normal pace of activity and 23% of rice mill workers experienced allergic reaction from dust in the mill house.

On the other hand, the mostly occurred (in 40% of workers of mill house) disturbance among coconut oil mill workers was found to be eye irritation and inflammation as shown in Table 3.

Table 4 shows that 45% of people working in pulse processing, mill, tin processing mill, BSCIC office and biscuit mill had no disturbances in their health. Among the rest, 11% felt shortness of breath, 22% felt tightness in chest and 22% of them had arrhythmia.

In Figure 1, an overall comparison has been done to have a perception of health statuses of all workers.

Status of Bronchoconstriction among the Workers

Extracts of airborne grain dust are capable of muscle contraction and narrowing air of air-passage resulting in asthma-like syndrome [18].

65% of the rice mill workers had frequent sneezing which might have occurred from the entry of coarse particles in the upper trachea, as shown in Figure 2. They also have the most frequency of cough and phlegm.

Table 2. Disturbances in eye and respiratory health of workers in rice mills in percentages.

Zone	Eye Irritation/ Inflammation (%)	Shortness of Breath (%)	Tightness in chest (%)	Arrhythmia (%)	Dust Allergy (%)	No disturbance (%)
Premise	40	7	0	7	0	46
Mill House	42	16	0	0	23	19

Table 3. Disturbances in eye and respiratory health of workers in coconut oil mills in percentages.

Zone	Eye Irritation/ Inflammation (%)	Shortness of Breath (%)	Tightness in chest (%)	Arrhythmia (%)	Dust Allergy (%)	No disturbances (%)
Premise	35	15	0	11	0	39
Mill House	40	25	0	22	0	13

Table 4. Percentages of disturbances in eye and respiratory health of workers in biscuit mill, pulse processing mill, BSCIC office and tin mill.

Eye Irritation/ Inflammation (%)	Shortness of Breath (%)	Tightness in chest (%)	Arrythmia (%)	Dust Allergy (%)	No Disturbance (%)
0	11	22	22	0	45

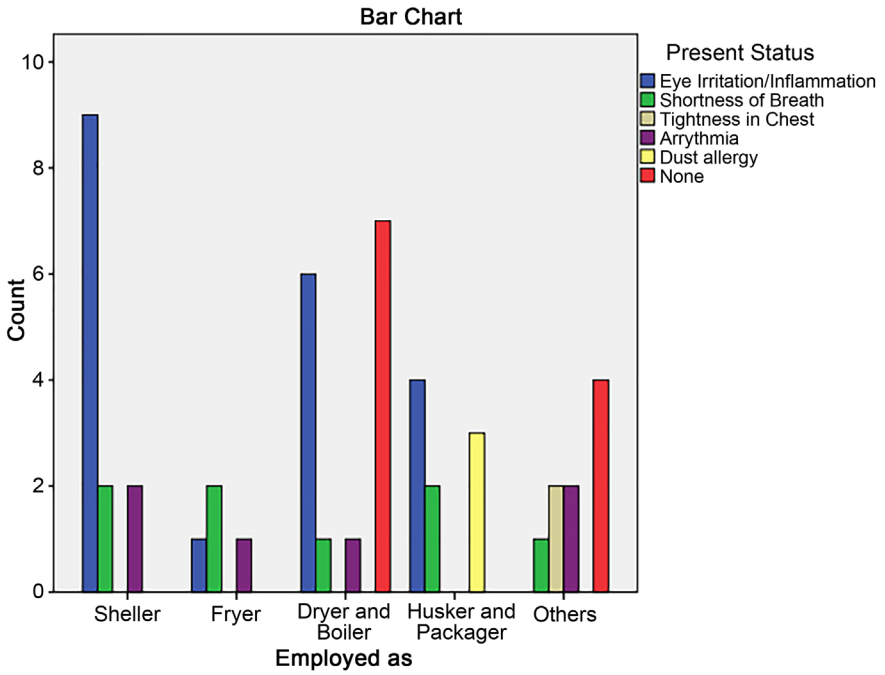

Figure 1. A comparison between health statuses of all workers in distinct mills.

3.5. Comparison of Health Status between the Exposed Workers and the Unexposed Group

Table 5 presents that the prevalence of respiratory symptoms and eye distur-

bance were higher among the exposed workers.

Table 6 depicts the differences in symptoms in workers in rice mills from the unexposed group which were significant for symptoms of bronchoconstriction (OR = 7.1; 95% CI = 2.3 - 21.9).

Meanwhile, the differences of symptoms in workers of coconut mills from the unexposed group were significant for eye irritation or inflammation (OR = 2.7; 95% CI = 0.9 - 8.6).

Agro-industries have extremely diverse zone and the contents of particulates depend on where, when and how the dust is produced. The outer premises had sufficient ventilating and dispersing opportunities unlike the mill house. PM_{10} concentrations were found much denser than the safe limit due to dust emissions

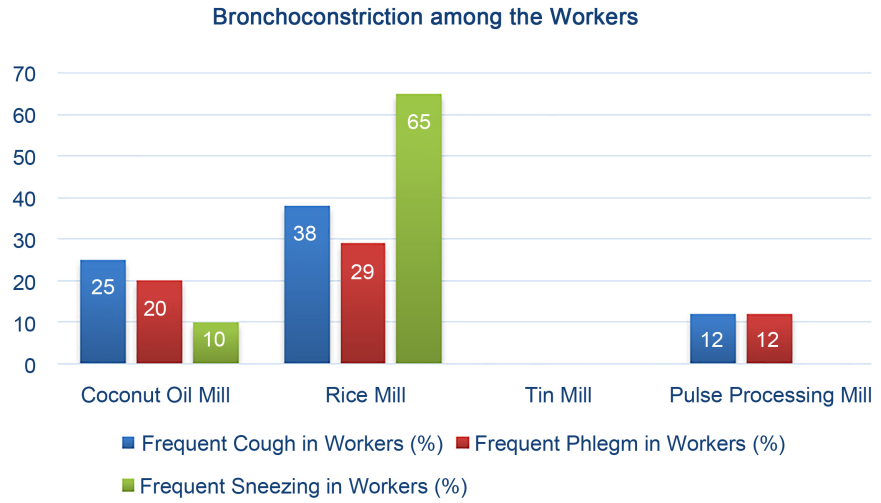

Figure 2. A comparison between bronchoconstriction in workers in distinct mills.

Table 5. Prevalence of eye disturbance and respiratory symptoms among workers in rice mills.

Symptoms associated with	Exposed (n = 21)	Unexposed (n = 50)	OR (95% CI)*
Eye irritation or inflammation	9	10	3.0 (0.9 - 9.1)
COPD	7	9	2.3 (0.7 - 7.3)
Bronchoconstriction	14	11	7.1 (2.3 - 21.9)

*Odds ratio (95% confidence interval).

Table 6. Prevalence of eye disturbance and respiratory symptoms among workers in coconut mills.

Symptoms associated with	Exposed (n = 20)	Unexposed (n = 50)	OR (95% CI)*
Eye irritation or inflammation	8	10	2.7 (0.9 - 8.6)
COPD	6	9	1.9 (0.6 - 6.3)
Bronchoconstriction	6	11	1.5 (0.5 - 4.824)

*Odds ratio (95% confidence interval).

from husking and packaging machines in the closed hall of rice mills. In a study, enclosed-cabin threshing and husking machines were suggested for such context [8]. The odds ratio for symptoms of bronchoconstriction (OR = 7.1; 95% CI = 2.3 - 21.9) indicated that the odds of getting bronchoconstriction are 7.1 times higher among the workers in rice mills than the people unexposed to PM_{10} emission.

Eye disturbances (OR = 2.7; 95% CI = 0.9 - 8.6) had the highest occurrences in coconut mills, though the concentrations of PM_{10} were within the standard. However, it could occur due to the cumulative effect of stack gas emission from coconut fryers fueled by biomass with charcoal soot from burners. Visibility impairment due to brown cloud from PM_{10} emission has been documented [19]. The agro laborers had very vague knowledge about consequences of chronic PM_{10} exposure. A study [20] among 588 agro-workers revealed that 75% of them were not very concerned about respiratory health risks related to their profession.

Threshold limits or exposure limits for mineral or organic PM concentrations do not exist yet due to the difficulties to characterize the PMs found in the agricultural products. The technology used is not advanced and engineering controls are very weak in agro-industrial facilities, resulting in the excess amount of dust [21].

4. Conclusion

BSCIC, Bagerhat is the largest diversified agro-industrial complex of the Southeast Bangladesh. The investigation was conducted to evaluate PM_{10} concentration and the effect of its chronic exposure in the workers. PM_{10} concentrations found in rice mill houses exceeded the threshold limit of the standard. The highest percentages of symptoms of COPD and bronchoconstriction were found in the mill house workers there. The monitoring system of DoE was found ineffective in the area. The BSCIC, Bagerhat authority should supply the workers with dust masks for personal prevention along with providing technical improvements such as water sprinkling system and closed or covered outlets in machinery. Occupational exposure to dust in the agro-industries should be an important area of interest.

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