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RISK ASSESSMENT OF UPPER RESPIRATORY HEALTH PROBLEMS AMONG WORKERS EXPOSED TO BIOGAS RESIDUES AT PALM OIL PLANTS IN SABAH, MALAYSIA.

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ABSTRACT

Objective: A cross-sectional study was carried out on the respiratory effects of biogas plant environment exposure in palm oil mills. The aim of this study was to determine whether respiratory health effects were more common among workers in biogas plant environment. **Methods:** Workers from 19 palm oil mills in Sabah with biogas plants were compared between the exposed and unexposed of the biogas plant environment. The workers were assessed with a questionnaire, physical examination, spirometry and oximetry tests. Then, the data obtained were analysed using the Statistical Package for the Social Sciences (SPSS) version 22. **Result:** Pearson Chi-square analysis (p =0.019, x^2 =5.51) showed there was a significant relationship between the biogas plant environment exposure and lung function test (LFT) with risk estimates (OR = 1.96, 95% CI 1.12, 3.45). The exposed group showed a higher proportion of abnormal lung function test in comparison with the unexposed group. **Conclusion:** In conclusion, workers in biogas plants environment have two times higher odds of having abnormal lung function test. Thus, the findings from this study can be used in the future planning by execution the optimal control measures as efforts to reduce the risk of respiratory-related disease in the biogas plant environment.

Keywords: biogas exposure, respiratory health effects, lung function test, biogas plant

1. Introduction

A biogas plant are a building that comprised of biomass, heating and gas system which utilized animal excrements, plant biomass, wastes, and sediment from wastewater to generate a biogas (Barnert, Piesik, & Śliwiński, 2014). There was an increasing trend up to five times of the accidents occurred in the biogas sector from the period from 2007 to 2011. Examples of accidents occurred including fire, explosion and release of raw biogas from the digester. Accidents leading to asphyxiation caused by access in confined space also have been reported (Moreno, Papasidero, Scarponi, Guglielmi, & Cozzani, 2015).

Bioaerosols consists of airborne biological particles, microbial fragments, and constituents of cells which consist of bacteria, fungi, pollens, particulate matter (PM_{10}), and by-products of cells. Workers in the biogas plant environment always exposed to very high levels of bioaerosols microorganisms as well as toxic gas (Douwes, 2003). Previous studies by Bünger, Schappler-scheele, Hilgers, & Hallier (2007), Douwes (2003), Radon (2003), van Kampen et al. (2012), and Wery (2014) have reported that workers at agriculture sector, composting and waste management also experiencing to occupational exposure to bioaerosols which contain high level of bacteria or fungi.

This could potentially triggered allergies, infections and respiratory diseases. The main toxic gas in biogas is hydrogen sulphide gas. It can cause fatalities with concentration exceeded 500 ppm. The gas odour's discernment diminish at concentrations ranging from 150-250 ppm, which elevate the risk of high-level exposure since the gas cannot be identified via its odour (Jones, 2014). The acute effects of exposure to hydrogen sulphide are well recognised, but accurate exposure response data is limited to acutely lethal effects, even in animal studies. Nevertheless, there is limited scientific documentation of the impact of biogas at biogas plants concerning spirometry outcomes and self-reported respiratory health outcomes.

The objective of this study was to determine the difference between respiratory health effects of workers in the biogas exposed group and workers in the control group. This study will be a significant endeavour in promoting good safety and health work environment in the biogas plant workplace and motivations of its employees. Furthermore, this study will be beneficial to the employers of biogas plants in planning strategic management when they are required to manage biogas plant risk scenarios mainly in proper good prevention and control related to the risks emerged.

2. Materials and Method

2.1. Study population

The study was performed at 19 sites of palm oil mills with biogas plants in Sabah and it involved 200 employees. From the total of 200 workers, 110 workers were from biogas plants, while for the comparative group, 90 respondents were workers in other areas than the biogas plant but in the same premise of palm oil mills with the biogas plant workers.

2.2. Data collection and instrumentation

The collection of data were held from June to November 2016. An interviews with participants were conducted to determine their health status particularly related to the respiratory health. The questions were referred to a checklist from the Occupational Health Section, Department of Occupational Safety and Health Sabah. Besides, it was referred from other questionnaires with similar studies. The questionnaire was pretested with a nearby cement industry, which was considered as a respiratory health problem issue. The study population also underwent a standard respiratory exam, including pulse oximetry.

The instrumentation used in this study was a spirometer. Spirometry assessments were conducted by the researchers using a MIR Spirobank II 910575 Spirometer according to the American Thoracic Society protocol (American Heart Association, 2015), set to the Knudson-predicted values (Knudson, Slatin, Lebowitz, & Burrows, 1976). Before the lung function test was performed to the respondents, their physical characteristics were measured, i.e., body weight and height, body mass index (BMI), pulse rate, and arterial oxygen saturation (SpO2). The two measurements that is vital in the interpretation of spirometry results are the forced vital capacity (FVC) and the forced expiratory volume in one second (FEV1). FVC is a measurement of lung size (in litres) which depicts the volume of air in the lungs that can be exhaled following a deep inhalation. While FEV1 is a measure of how much air can be exhaled in one second following a deep inhalation. The FEV1/ FVC ratio is a number representing the percentage of the lung size (FVC) that can be exhaled in one second. According to the American Thoracic Society protocol (American Heart Association, 2015), the respondents need to blow three times and only the highest reading is recorded.

2.3. Quality assurance and quality control

To ensure the data accuracy, quality assurance and quality control are important. Pre-testing of the questionnaire was carried out to gauge the respondents and to ensure a better understanding of the terms of study. The lung function test was carried out by the researchers. Therefore, before the instrument was used, the researchers were trained by a competent person and referred to the standard operating procedures (SOP) as produced by the manufacturer before starting a measurement.

2.4. Data analysis

Statistical Package for the Social Sciences (SPSS) version 22 software package was utilised to analyse the data collected in this study. Frequencies represented categorical data and means or medians for continuous data. For determination of the association of respiratory disease, a data comparisons between two groups were done (exposed and unexposed). All the variables were analysed using the Shapiro-Wilk test (Chernick & Friis, 2003), with the application of square-foot transformations, where necessary, to transform for normality. Descriptive statistics were calculated (e.g., means, 95% confidence intervals, percentiles, etc.). For univariable analyses, standard unpaired t-tests, testing for equal variance according to Levene's test, and chi- square tests were applied to compare variables between the biogas and referent groups (significance at $p \leq 0.05$). A chi-square ($\chi 2$)-test was performed in a 2 X 2 table and was used for comparing the variables among the two categorical groups. Odds Ratio (OR) and its 95% confidence interval (95% CI) were determined to assess the association between respiratory disease symptoms and occupational health.

3. Results and Discussion

According to Table 1 in the result section, there were no significant difference between the exposed and unexposed groups for the variables (age, education level and work experience). This explained that the participants in this study were having similar characteristics. The median age of the exposed group was 32 years old and it was almost like the unexposed group (33 years).

There were four major groups of ethnicities with the biggest number in respondents and the rest had a small number of ethnic groups that were categorised under others. Both groups of workers were categorised with a high percentage in the Bugis ethnic group, followed by Malay, Kadazan-Dusun, and Bajau. Most of them were married for both groups (69% and 78%) and had secondary education level (55% and 47%). For the exposed group, the respondents' weight was an average of 63.71 kg and height of 164.85 cm with a mean of BMI 23.46 kg/m2. It was significantly different to the unexposed group's weight and BMI. The median duration of employment for the exposed group was 4 years and it was dissimilar to the unexposed group (5 years). Having a well matched respondents is important to identify the relationship of biogas plant environment and workers' health status. A prior study that has noted the risk evaluation conducted on untreated biogas identified a potential health hazard originating from the following compounds: hydrogen sulphide, benzene, acetaldehyde, formaldehyde, chromium, and some organochlorinated compounds, such as vinyl chloride, trichloroethylene, tetrachloroethylene, tetrachloromethane, and 1-4 dichlorobenzene (Naja et al., 2011). In addition, according to Pietrangeli et al. (2013), there is a high exposure to inhalable bacterial and fungal spores in the surrounding air of workplace area environment. It is come from the large amounts of agricultural feedstocks handled in the biogas plant. Experimental and epidemiological studies have supported that these exposures are causing hypersensitivity pneumonitis, asthma, deteriorate lung function, airway inflammation, respiratory and organic dust toxic syndrome (Douwes, 2003).

An oximetry test was performed for both groups of workers and it showed that there was no significant difference between them. The two types of measurement used were pulse rate and an estimate of arterial oxygen saturation (SpO2). The mean pulse rates of the exposed and unexposed workers were 75.68 bpm and 76.96 bpm, respectively. There was also no significant difference for SpO2 between the exposed and unexposed workers ($p>0.05$). The smoking habits of the workers were compared, and it showed no significant difference between the biogas exposed and control groups ($p>0.05$).

Prevalence of reported symptoms of respiratory disease during the last 12 months. Workers were asked about their health status of the respiratory system for the last 12 months as part of the questionnaire. Table 2 shows that there were ten symptoms identified regarding respiratory disease symptoms from mucosal membranes to abdominal. It is apparent from this table that the exposed workers had a higher proportion with six out of ten symptoms as compared to the unexposed workers. Shortness of breath and abdominal pain were the significant differences between the exposed and unexposed workers when the significance level was set at $p<0.05$. The rest of the reported symptoms were almost similar for both groups. Overall, there was no significant difference of respiratory disease symptoms between the exposed and unexposed groups of workers.

In this current study, it was found that there was no significant difference between biogas exposure and unexposed in terms of respiratory symptoms such as eye irritation, congested nose, chronic cough, wheezing of breathing, and chest discomfort. The findings between the exposed and unexposed groups were generally very similar, even though some differences were indicated.

This study has few limitations. The self-reported symptoms by the participants may be subject to self-enhancing bias (i.e., participants have tendency to increase the reported symptoms due to their awareness to the fact that they are exposed). Another issue is the recall bias particularly during subjective questionnaires. Thus, in this study, a detailed and comprehensive questionnaires was used to minimise this bias. However, it quite impossible to control this especially in subjective data. Thus, a standardised questionnaires were used for all participants in both groups to minimise the effect. Other studies similar to respiratory symptoms were health effects from chronic low-level exposure to hydrogen sulfide (Legator, Singleton, Morris, & Philips, 2001), Kenyan farm women's biogas exposure (Dohoo, Guernsey, Critchley, & Vanleeuwen, 2012), and studies of the population in Rotorua city, New Zealand, which has the largest population exposed with geothermal sources, to relatively high ambient levels of H_2S (Bates, Garrett, Crane, & Balmes, 2013).

However, there were significant differences between biogas exposure and in exposure in shortness of breath and abdominal pain. Studies of health risks in employees working in the sewage treatment plants suggested that gastrointestinal tract symptoms are more common among employees at sewage treatment plants than among control employees (Thorn & Kerekes, 2001). In contrast with these results, other studies found no significant difference in the prevalence of gastrointestinal symptoms; nonetheless, the results indicated that all respiratory symptom prevalence, except dyspnoea, were significantly higher in the exposed group of municipal household waste collection as compared to the control group (Yang et al., 2001).

Each participant subjected to a respiratory assessment after they have been interviewed. Table 3 summarises the result of the lung function test for biogas exposed and unexposed groups. In the spirometry results, the individual's obtained value was compared with the reference value. The results are only considered as normal when the FVC and FEV1 values are within 80% of the reference value.

While 70% is the normal value for the FEV1/FVC ratio. A lower measured values compared to the reference value indicated a severe lung abnormality. The biogas plant workers had an abnormal result of 60%, while the control workers had 43%. There was a significant difference between the exposed and unexposed workers. In univariate analyses, the abnormal results of the lung function test (LFT) indicated two times a greater risk for workers in biogas plants as compared to the unexposed group. As shown in Figure 1, each category of respondents was split into detail abnormal categories, namely mild, moderate, and severe. Even though the exposed workers had a higher proportion of abnormal results, the percentage of workers who had mild and severe LFT was higher in unexposed workers as compared to exposed workers. The abnormal category also found similar findings and there was no statistical difference.

Results in Table 3, the proportion abnormal result in LFT of biogas plant workers was higher than the control subjects. Numerous studies have investigated the respiratory health effects of exposure to H_2S and endotoxin. Low asthma prevalence had been indicated in 1,206 farmers in comparison to 727 urban subjects as been reported by past studies in relation to the effect of H_2S and endotoxin to the respiratory health (Eduard, Omenaas, Bakke, Douwes, & Heederik, 2004). Similarly, a strong inverse relationship between endotoxin exposure and sensitisation has been described for 162 pig farmers (Portengen, Preller, Tielen, Doekes, & Heederik, 2005). Exposure to H_2S may be associated with at least a short-term increase in the need for anti-asthmatic drugs in the adult population (Carlsen, Zoëga, Valdimarsdóttir, Gíslason, & Hrafnkelsson, 2012). All these previous studies demonstrated the relation between H_2S and bioaerosol exposure and the respiratory health status of workers, suggesting that exposure to biogas may lead to respiratory disease. However, this result contradicts to a previous study in Germany, where the number of participants that had LFT readings (indicate of COPD) were found zero. In addition, no significant differences were observed in lung function between organic dust exposed and unexposed participants (van Kampen et al., 2012).

A safe and healthy work culture is a cornerstone in making safer and healthier workplaces through a strategic programme to prevent accidents and occupational diseases (MOHR, 2016). Therefore, the prevention of respiratory disease depends on prior knowledge of risks and the means to minimise or eliminate the hazards. Prevention based on toxic gas or bioaerosol reduction at the source would be more reliable and effective. The best practice must be considered in engineering control especially by installing safety devices or safety features. There are various options of instruments for safety devices proposed by various companies. It is important for employers to invest some money for a better future. The health human capital investment not only affects the health level of residents, but also plays a decisive role on the impact of economic growth (Tang & Huang, 2016). To the best of the researchers' knowledge, the current study is the first to demonstrate associations between biogas exposure and health-related outcomes outside occupational settings.

Table 1: Socio-demographic and physical characteristic of respondents

Socio-demography parameters	Frequency (%)[+] Mean ± SD[#] Median (IQR)[x]		Z-statistic[a] / X^2-statistic[b] / t-statistic[c]	p-value
	Exposed (n=110)	Unexposed (n=90)		
Age (years)[x]	32 (15)	33 (13)	-1.48	0.139
Ethnic[+]				
• Malay	15 (13.6)	25 (27.8)		
• Kadazan-Dusun	9 (8.2)	5 (5.6)		
• Bajau	15 (13.6)	4 (4.4)	0.49	0.482
• Bugis	47 (42.7)	34 (37.8)		
• Others	24 (21.8)	21 (24.4)		
Marital status[+]				
• Single	32 (29.1)	18 (20.0)		
• Married	76 (69.1)	70 (77.8)	2.19	0.335
• Widow	2 (1.8)	2 (2.2)		
Education level[+]				
• Primary	22 (20.0)	14 (15.6)		
• Secondary	60 (54.5)	42 (46.7)	3.57	0.168
• Tertiary	28 (25.5)	34 (37.7)		
Employment duration (year)[x]	4 (5)	5 (6)	-2.63	0.090
Weight (kg)[#]	63.71 ± 12.72	70.07 ± 12.00	-3.61	<0.001*
Height (cm)[#]	164.85 ± 6.71	164.44 ± 7.60	0.40	0.692
BMI (kg/m^2)[#]	23.46 ± 4.37	25.88 ± 3.88	-4.10	<0.001*
Pulse rate (bpm)[#]	75.68 ± 14.98	76.96 ± 12.62	-0.64	0.522
SpO_2 (%)[x]	98 (1)	98 (1)	-1.78	0.075
Smoking habit[+]				
• Never	46 (41.8)	34 (37.8)		
• Ex-smoker	18 (16.4)	10 (11.1)	2.11	0.349
• Current	46 (41.8)	46 (51.1)		

N = 200,
[a] Mann-Whitney Test was applied, [b] Pearson Chi-square Test was applied, [c] Independent t-Test was applied
** Significant at p<0.05*
BMI: body mass index
SpO_2: estimate of arterial oxygen saturation

Table 2: Frequency of symptoms from mucosal membranes or airways to abdominal

Variables	Frequency (%)		X^2-statistic[a]	p-value
	Exposed (n=110)	Unexposed (n=90)		
Eye irritation				
• Yes	18 (16.4)	18 (20.0)	0.44	0.505
• No	92 (83.6)	72 (80.0)		
Nose or throat congested				
• Yes	19 (17.3)	14 (15.6)	0.11	0.745
• No	91 (82.7)	76 (84.4)		
Chronic cough				
• Yes	2 (1.8)	3 (3.3)	0.47	0.495
• No	108 (98.2)	87 (96.7)		
Shortness breath				
• Yes	12 (10.9)	2 (2.2)	5.74	0.017*
• No	98 (89.1)	88 (97.8)		
Wheezing				
• Yes	5 (4.5)	7 (7.8)	0.92	0.338
• No	105 (95.5)	83 (92.2)		
Chest discomfort				
• Yes	17 (15.5)	9 (10.0)	1.30	0.254
• No	93 (84.5)	81 (90.0)		
Abdominal pain				
• Yes	24 (21.8)	9 (10.0)	5.01	0.025*
• No	86 (78.2)	81 (90.0)		
Vomiting / queasiness				
• Yes	23 (20.9)	16 (17.8)	0.31	0.578
• No	87 (79.1)	74 (82.2)		
Headache / dizziness				
• Yes	81 (73.6)	59 (65.6)	1.54	0.215
• No	29 (26.4)	31 (34.4)		
High fever				
• Yes	46 (41.8)	39 (43.3)	0.05	0.829
• No	64 (58.2)	51 (56.7)		

N=200
[a] Pearson Chi-square Test
** Significance at p<0.05*

Table 3: Lung function test results

Outcomes	Frequency (%) Exposed (n=110)	Frequency (%) Unexposed (n=90)	OR (95% CI)	X^2-statistic[a]	p-value
Lung function test					
• Abnormal	66 (60.0)	39 (43.3)	1.96 (1.12, 3.45)	5.51	0.019*
• Normal	44 (40.0)	51 (56.7)			

N=200
[a] Pearson Chi-square Test
** Significance at p<0.05*

4. Conclusion

This study provided evidence that biogas exposure is associated with LFT results (normal or abnormal) among biogas plants workers in palm oil mills. In conclusion, there was a higher proportion of abnormal lung function test result in the exposed group as compared to workers in the unexposed group. The workers in biogas plants were two times at higher odds of having an abnormal lung function test result as compared to those in the unexposed group. Hence, the results of this assessment shall be used in planning and implementing the optimal control measures to minimise the risk of respiratory disease in biogas plant environment exposure. For future study recommendations, more numbers of participants having well-functioning biogas plants for a longer period should be consider to determine the consequences of biogas exposure toward the respiratory health in palm oil mill workers.

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