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Workplace Environment and Health Effects of Ribbed Smoked Sheet Factory: A Case Study of Thung Yai Rubber Fund Cooperative

Supandee Maneelok[1], Peerapol Juntaro[2], Rattatammanoon Ainthong[2], Peerapol Kaoien[3] and Nantaporn Noosai[4*]

[1]Department of Occupational Health and Safety, Faculty of Health and Sports Science, Thaksin University, Phatthalung 93210, Thailand
[2]Department of Occupational Health and Safety, Faculty of Health and Sports Science, Thaksin University, Phatthalung 93210, Thailand
[3]Siam General Technology Co., Ltd., Trang 92140, Thailand
[4]Department of Civil and Environmental Engineering, Faculty of Engineering, Prince of Songkla University, Hat Yai, Songkhla 90112, Thailand
[*]E-mail : nantaporn.no@psu.ac.th

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Abstract

This study investigates environmental conditions and their impact on worker health within the Thung Yai Rubber Fund Cooperative, specifically focusing on the Ribbed Smoke Sheet factory. Working area temperature and wind velocity were systematically monitored at two locations using digital thermometers and anemometers, respectively. Air quality parameters, including total dust, carbon dioxide (CO_2), and oxygen (O_2) levels, were assessed using real-time monitoring equipment. A qualitative approach was adopted to evaluate adverse health effects experienced by workers, employing standardized questionnaires and comprehensive interviews. The results revealed significant health implications among workers exposed to total dust and an inappropriate working environment over the last three months. Specifically, 53.8% of workers experienced nose congestion and stuffy nose; 46.2% experienced a runny nose; 30.8% experienced sore eyes, itchy eyes, body rash, and body itching; 15.4% experienced red eyes; 38.5% experienced sore throat, coughing, mucus, and fatigue; 23.1% experienced difficulty breathing; and 7.7% experienced rapid heartbeat and wheezing. Furthermore, the study concluded that workplace temperatures exceeded prescribed standards, and oxygen concentration levels is slightly higher than Occupational Safety and Health Administration (OSHA) standards. These findings should provide the intervention to address hazardous working conditions, including regulating temperature to safeguard worker health and well-being. Continuous monitoring and enforcement of safety standards are imperative to prevent future respiratory ailments and ensure a safe working environment conducive to optimal productivity and employee welfare within the Thung Yai Rubber Fund Cooperative.

Keywords : workplace environment; health effects; ribbed smoked sheet; total dust; CO_2; O_2

Introduction

Rubber production occupies a central position in Thailand's economy, supporting livelihoods, driving economic growth, and shaping social development [1, 2]. However, concerns arise regarding air pollution emissions from rubber sheet processes, particularly from the Ribbed Smoked Sheet process. The air pollution stemming from this process poses significant challenges, particularly for workers within the facilities and surrounding communities [1, 3]. Air pollution from Ribbed Smoked Sheet (RSS) factories can have significant health impacts due to the emissions generated during the rubber drying and smoking processes [3]. Toxic compounds are released into the air at nearly every stage of rubber processing, where heat is applied to mold its shape or incorporate additives. Because rubber requires heat to soften and react with these additives, emissions occur throughout the process. Studies have shown that the rubber industry emits significant amounts of hazardous substances. These emissions have a harmful impact on human health, particularly on workers in the industry [4]. These emissions include particulate matter, volatile organic compounds (VOCs), carbon monoxide (CO), sulfur dioxide (SO_2), and polycyclic aromatic hydrocarbons (PAHs). The pollutants have significant health implications [1-5].

Regarding Particulate matter (PM), consisting of fine particles like soot and ash produced during the smoking process, can be deeply inhaled into the lungs, causing respiratory and cardiovascular problems. VOCs, including chemicals like benzene, toluene, and xylene, are released during rubber processing and contribute to air pollution, leading to health issues such as headaches, dizziness, and long-term effects like liver and kidney damage [6]. Carbon monoxide, a toxic gas generated by incomplete combustion during smoking, can cause symptoms ranging from headaches and dizziness to potentially fatal outcomes at high concentrations. Sulfur dioxide, produced from burning sulfur-containing materials, can irritate the respiratory system, exacerbating conditions like bronchitis and asthma. PAHs, which are released during the incomplete combustion of organic materials, are known carcinogens, with prolonged exposure increasing the risk of cancer, particularly lung cancer [4-9]. Regarding, Mitigation measures to address pollution in RSS factories include improving ventilation and filtration systems, which can effectively lower the concentration of harmful pollutants inside the facility and safeguard workers' health. Implementing emission control technologies, such as scrubbers and electrostatic precipitators, can significantly cut down on the pollutants released from the factory. Additionally, conducting regular health check-ups and continuous air quality monitoring are essential practices for the early detection and prevention of pollution-related health issues among workers and nearby residents.

According to Thitiworn et al. (2010) [7], the production of RSS leads to significant environmental pollution, affecting both ambient air quality and workplace conditions in factories. While previous research on the environmental impact of Thailand's rubber industry [1-3, 5-7] has primarily concentrated on greenhouse gas emissions [8-10], other harmful emissions such as SOx, NOx, PAHs, and particulate matter (PM) from the primary para-rubber industry have not been adequately studied. Additionally, the overall environmental burden from Ribbed Smoked Sheet process has not been comprehensively evaluated. Regarding previous study relating to pollution from the rubber process has focused on intermediate products and their transportation in Thailand [1]. However, the data on the environmental impacts in work place of Ribbed Smoked Sheet productions are crucial to understand the issue and take measures to reduce the environmental issues.

This study presents a comprehensive examination of air pollution and its health effects originating from a Ribbed Smoked Sheet factory. The research includes an in-depth analysis of the factory's ventilation system, recognizing its critical role in mitigating indoor air pollution and safeguarding worker health. The study aims to provide valuable insights into the complex interplay between industrial air pollution and worker health. Through a multidisciplinary approach encompassing environmental science, occupational health, and public policy, we endeavor to inform evidence-based interventions aimed at minimizing pollution-related health risks and fostering a healthier, more sustainable working environment within the Ribbed Smoked Sheet Factory and similar industrial settings.

Methodology

This investigation encompasses multiple facets crucial to understanding the dynamics of working conditions and their ramifications on worker health. The Ribbed Smoked Sheet (RSS) factory which is Thung Yai Rubber Fund Cooperative located in Trang Province, Thailand was designated as a study area. We scrutinize the study area of the factory to contextualize our analysis within the operational environment. This involves assessing factors such as layout (Figure 1), infrastructure, working area temperature, and wind velocity, which can influence pollution dispersion and exposure pathways [5]. Figure 1 showed the schematic of smoking room and collecting area where V, G and TD is velocity, gas and total dust collecting point, respectively. Additionally, the study focusses on characterizing the air pollutants emitted by the factory, particularly Total dust, CO_2 levels [1, 2, 5], and oxygen (O_2) concentrations. Moreover, the Pollution Exposure is examined to elucidate its potential health implications.

Monitoring of environmental parameters

The working area temperature and wind velocity at two locations in the Ribbed Smoked Sheet factory were monitored to understand environmental variations. The hot wire anemometer (Tesco, model 425) was strategically placed for temperature and wind velocity measurements, respectively. Air quality parameters, including total dust, carbon dioxide (CO_2), and oxygen (O_2) levels, were examined. Total dust (airborne particulate) as per NIOSH 0500 sampling method was measured using gravimetric technique with personal pump (Gilian, model GilAir Plus) at flow rate of 2 L/min for 8 hour and 37 mm PVC filter cassette. The air sampling pump was calibrated with Soap bubble technique. Real-time CO_2 and O_2 measurements were conducted with gas detector equipment (model AS8900) every 2-hour for 8 hours working time.

The data for each parameter were collected every 2 hours during the 8-hour working time, resulting in four data sets for each parameter. The averages and standard deviations of the measured parameters are illustrated in Tables 1 and 2.

Health Effects

The experienced Pollution Exposure is examined by workers in various roles and departments within the factory. Through personal exposure monitoring and health assessments, we seek to quantify the magnitude of pollution exposure and elucidate its potential health implications. Respiratory ailments, cardiovascular disorders, and other adverse health effects associated with prolonged exposure to industrial pollutants are of particular concern.

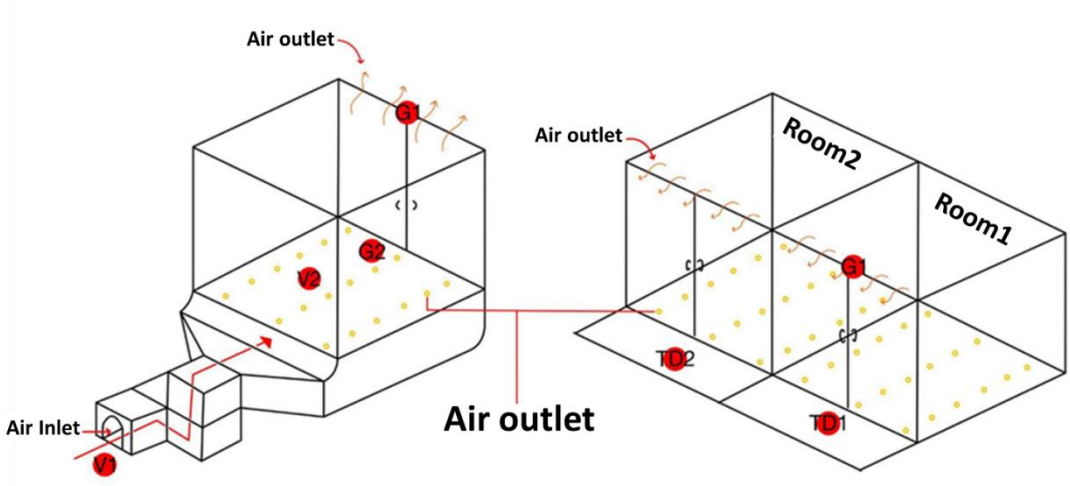


Figure 1 Schematic of Ribbed Smoked Sheet Room

A qualitative approach as questionnaire was employed to evaluate adverse health effects experienced by workers. The questionnaire was developed from the World Health Organization [11-12] and administered to collect health effects related to pollution exposure from work. The questionnaire presented factors including sociodemographic, medical history, symptoms, and perceived health effects related to work environment. Workers from various departments participated, providing informed consent. Comprehensive interviews were conducted to gather detailed insights into workers' health experiences concerning working conditions and air pollution exposure. The questionnaire was evaluated by three specialists, who focused on examining the Index of Congruence (IOC). The evaluation resulted in an IOC of 0.91 and a Cronbach's alpha coefficient of 0.87. The data analysis was conducted using descriptive statistics as frequency, mean, standard deviation, median, maximum, and minimum.

Results and Discussion

The environment of Thung Yai Rubber Fund Co-operative

By observation, it was noted that the environmental conditions, particularly within the working area of the Thung Yai Rubber Co-operative Development Fund, are excessively warm, humid, and stuffy, especially during rubber sheet smoking sessions. This is attributed to a poor ventilation system, characterized by limited natural ventilation, leading to inadequate air circulation within the building. The smoking rooms, totaling 11 in number, are constructed with steel doors and equipped with 8-24 drilled holes per room to facilitate smoke ventilation from the burning stoves situated outside the cooperative. The wind direction flowed upstream from holes to roof as can be seen the smoke direction in figure 2. However, the roof is not high so it caused the smoke still dispersion in the air around working area. The temperature during smoking sessions ranges from 55-60 degrees Celsius, spanning approximately 3 days and 3 nights, resulting in a substantial release of smoke particulates from the smoking rooms and subsequent accumulation within the cooperative building (See Figure 2).

Working environment and ventilation systems

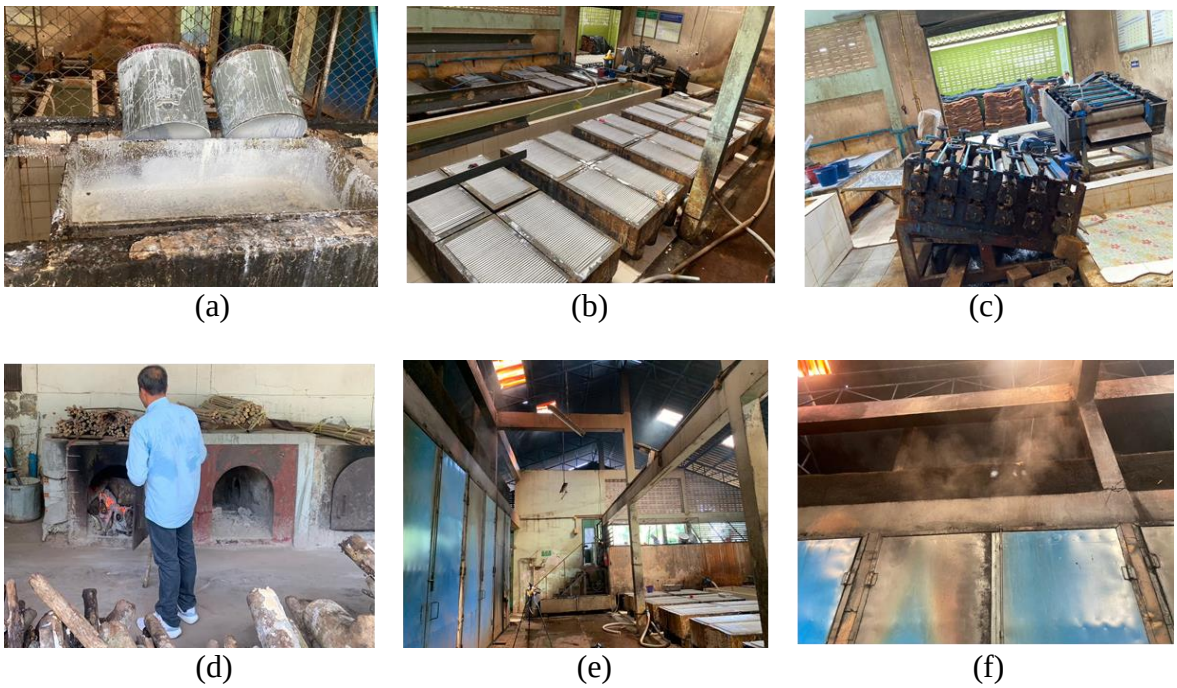
Monitoring studies of the working environment at the Thung Yai Rubber Fund Cooperative were conducted in two locations: working room no. 1 and no. 2. The results in Table 1 showed average wind speeds ($\overline{x}$) of 0.46 and 0.97, with standard deviations (S.D.) of 0.032 and 0.067, in room no. 1 and no. 2, respectively. The temperature measurements yielded average values ($\overline{x}$) of 66.7°C and 58.7°C, with standard deviations (S.D.) of 0.984 and 1.752, in room no. 1 and no. 2, respectively (See Table 1). The temperature in 2 rooms was not much difference.

Assessments of the ventilation system at Thung Yai Rubber Fund Cooperative were conducted at various locations within the building for total dust, carbon dioxide (CO_2), and oxygen (O_2). Total dust measurements were taken at two locations adjacent to the smoking rooms. The measured total dust levels were found to meet the Safety in Working with the Environment (Chemicals) standard (15 mg/m^3) from Ministry of Interior with readings of 8.3 mg/m^3 and 1.6 mg/m^3 at locations 1 and 2, respectively. It can be seen that total dust concentration at location 1 was found higher than location 2. This might be due to high temperature from wood burning in smoking room 1 lead air and particulate matter spreading in environment.

Indoor CO_2 concentrations are typically managed to address general Indoor Air Quality (IAQ) concerns, with recommended limits generally below 1000 ppmv [13]. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) recommends that indoor CO_2 levels should not exceed the local outdoor air concentration by more than around 650 ppm. ASHRAE Standard 62-2001 sets indoor air quality standards intended to be acceptable to occupants and to reduce the potential for adverse health effects. Moreover, the Occupational Safety and Health Administration (OSHA) has specific guidelines regarding oxygen levels in the workplace. OSHA's respiratory protection standard (29 CFR 1910.134) outlines these requirements, defining

the minimum acceptable oxygen concentration for general industry as 19.5% [14].

CO_2 and O_2 concentrations were assessed at seven different locations: smoking room no. 1, smoke release point from room no. 1, one meter away from the smoking room no. 1, smoking room no. 2, smoke release point from room no. 2, one meter away from the smoking room no. 2, and the rubber sheet squeezing area. CO_2 and O_2 concentration levels met the standards for all measured locations. The result of total dust, CO_2 and O_2 concentrations at working area location were shown in Table 2.



(a) (b) (c)

(d) (e) (f)

Figure 1 Rubber sheet production process and Working condition at Thung Yai Rubber Fund Cooperative; (a) Raw rubber loading, (b) Rubber slab formation, (c) Rubber sheet squeezing, (d) Wood burner, (e) Rubber sheet drying and (f) Particle matter and smoke from smoking room

Table 1 Temperature and wind velocity at 2 different smoking rooms

Parameter	$\bar{x}$	SD	Standard
Wind Velocity (m/s)			
Room 1	0.46	0.032	NA
Room 2	0.97	0.067	NA
Temperature (°C)			
Room 1	66.7	0.984	NA
Room 2	58.7	1.752	NA

Table 2 Total dust, CO_2 and O_2 concentrations at working area location

Parameter	Measured location	Measured Value	Standard
Total dust (mg/m^3)	Smoking room no.1	8.3	Regulations on Standards for Administration, Management and Operation of Safety, Occupational Health and Working Environment Regarding Heat, Light and Noise B.E. 2559
	Smoking room no.2	1.6	
CO_2 (ppm)	Smoking room no.1	515	ASHRAE Standard 62-2001
	Smoke release point from room no. 1	529	
	1.0 meter away from the smoking room no. 1	22	
	Smoking room no.2	505	
	Smoke release point from room no. 2	123	
	1.0 meter away from the smoking room no. 2	18	
	Rubber sheet squeezing area	10	
O_2 (%)	Smoking room no.1	20.1%	OSHA's respiratory protection standard (29 CFR 1910.134)
	Smoke release point from room no. 1	19.9%	
	1.0 meter away from the smoking room no. 1	20.9%	
	Smoking room no.2	20.2%	
	Smoke release point from room no. 2	20.9%	
	1.0 meter away from the smoking room no. 2	20.9%	
	Rubber sheet squeezing area	20.9%	

The result show difference in oxygen and CO_2 levels between Room No. 1 and Room No. 2. The CO_2 level was higher in Room No. 1, which is coherent with the lower oxygen level found there compared to Room No. 2. Thia can be attributed to several factors. Room No. 1 may have less effective ventilation, leading to inadequate fresh air exchange, which is critical in maintaining oxygen levels. Additionally, higher combustion activity in Room No. 1 could result in more significant oxygen consumption. The room's layout and airflow patterns might also contribute to localized oxygen depletion, particularly if air circulation is obstructed or uneven. Lastly, if Room No. 1 is closer to primary emission sources, this proximity could exacerbate oxygen depletion due to increased consumption of oxygen by combustion processes.

Worker health assessment

For the worker health assessment, there were a total of 13 workers participated in the study including 9 male workers and 4 female workers. Among them, one was under 20 years old, 4 workers were aged between 20-29, 1 worker was between 40-49, 4 workers were between 50-59, and 1 worker was over 60 years old. In terms of health conditions, it was found that 4 workers had chronic diseases (30.8%), while 9 workers did not (69.2%). Regarding respiratory diseases, 2 workers were affected

(15.4%), while 11 workers were not (84.6%). Concerning smoking frequency, 7 workers smoked (53.8%), while 6 workers did not (46.2%). As for exercise frequency, 6 workers exercised weekly (46.2%), while 7 workers did not (53.8%). In terms of personal protective equipment usage, 4 workers wore personal protective equipment (30.8%), while 9 workers did not (69.2%).

The assessment of adverse health effects experienced by workers exposed to total dust over the last three months is shown in Table 3. The study results revealed that 53.8% of workers experienced nose congestion and stuffy nose; 46.2% experienced runny nose; 30.8% experienced sore eyes, itchy eyes, body rash and body itching; 15.4% experienced red eyes; 38.5% experienced sore throat, coughing, mucus, and fatigue; 23.1% experienced difficult breathing; while 7.7% experienced rapid heartbeat and wheezing. None of the participants had experienced nosebleeds.

Table 3 Adverse health effects assessment

Adverse Health Effects	Worker	Percentage
1. Do you have symptoms of nasal congestion?		
Regularly	0	0
Often	1	7.7
Occasionally	5	38.5
Rarely	1	7.7
Never	6	46.2
total	**13**	**100**
2. Do you have a stuffy nose?		
Regularly	1	7.7
Often	2	15.4
Occasionally	3	23.1
Rarely	1	7.7
Never	6	46.2
total	**13**	**100**
3. Do you have symptoms of sore eyes?		
Regularly	0	0
Often	1	7.7
Occasionally	1	7.7
Rarely	2	15.2
Never	9	69.2
total	**13**	**100**
4. Do you have symptoms of itchy eyes?		
Regularly	0	0
Often	1	7.7
Occasionally	2	15.4
Rarely	1	7.7
Never	9	69.2
total	**13**	**100**
5. Do you have symptoms of red eyes?		
Regularly	1	7.7
Often	0	0
Occasionally	1	7.7
Rarely	0	0
Never	11	84.6
total	**13**	**100**

Adverse Health Effects	Worker	Percentage
6. Do you have symptoms of a sore throat?		
Regularly	0	0
Often	2	15.4
Occasionally	0	0
Rarely	3	23.1
Never	8	61.5
total	**13**	**100**
7. Do you have a runny nose?		
Regularly	0	0
Often	1	7.7
Occasionally	4	30.8
Rarely	1	7.7
Never	7	53.8
total	**13**	**100**
8. Do you have a rash appearing on your body?		
Regularly	1	7.7
Often	0	0
Occasionally	0	0
Rarely	3	23.1
Never	9	69.2
total	**13**	**100**
9. Do you have symptoms of itching on your body?		
Regularly	1	7.7
Often	0	0
Occasionally	0	0
Rarely	3	23.1
Never	9	69.2
total	**13**	**100**
10. Are you experiencing fatigue?		
Regularly	1	7.7
Often	1	7.7
Occasionally	1	7.7
Rarely	2	15.4
Never	8	61.5
total	**13**	**100**
11. Do you have symptoms of difficulty breathing?		
Regularly	0	0
Often	1	7.7
Occasionally	1	7.7
Rarely	1	7.7
Never	10	76.9
total	**13**	**100**
12. Do you have symptoms of coughing?"		
Regularly	0	0
Often	1	7.7
Occasionally	1	7.7
Rarely	3	23.1
Never	8	61.5
total	**13**	**100**

Adverse Health Effects	Worker	Percentage
13. Do you have symptoms of rapid heartbeat?		
Regularly	0	0
Often	0	0
Occasionally	1	7.7
Rarely	0	0
Never	12	92.3
total	**13**	**100**
14. Do you have symptoms of wheezing?		
Regularly	0	0
Often	0	0
Occasionally	0	0
Rarely	1	7.7
Never	12	92.3
total	**13**	**100**
15. Do you have mucus?		
Regularly	1	7.7
Often	1	7.7
Occasionally	1	7.7
Rarely	2	15.4
Never	8	61.5
total	**13**	**100**
16. Do you have nosebleeds?		
Regularly	0	0
Often	0	0
Occasionally	0	0
Rarely	0	0
Never	13	100
total	**13**	**100**

Conclusions

This study unveiled environmental conditions during the smoking room operating for RSS production for Thung Yai Rubber Co-operative Development Fund. The oxygen and carbon dioxide concentration level slightly exceeded the standard. The total dust was emitted from smoking room and its concentration is below the standard. Workers experienced health effects on nose congestion and stuffy nose, and a runny nose. The key findings underscore the pressing need for immediate intervention to address the working conditions identified in this study. Implementing measures to regulate temperature and improve carbon dioxide levels in the workplace is crucial to safeguarding the health and well-being of workers. Furthermore, ongoing monitoring and enforcement of safety standards are imperative to prevent future occurrences of respiratory ailments and ensure a safe working environment conducive to optimal productivity and employee welfare.

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