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Assessment of PM_{10} Exposure Risk in Communities Downwind and Upwind of Stone Milling Plants in Northeastern Thailand

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Abstract

PM_{10} particles can be inhaled and absorbed into the bloodstream and lymphatic systems. However, there is a lack of information in Thailand regarding the release of dust from stone mill units and the potential health risks it poses to the surrounding community. The aim of this research is to assess the health risks associated with PM_{10} exposure for residents of communities surrounding stone milling plants in Northeastern Thailand. The study included a total of 225 households located both downwind and upwind of the stone milling plants. Data were gathered by the conduct of a questionnaire to the participants, as well as the collection of PM_{10} particulate matter in the specified area. The collection of PM_{10} was conducted following the established NIOSH method number 0600. The non-carcinogenic attributes of PM10 were analyzed based on the guidelines provided by the Environmental Protection Agency. A descriptive statistical analysis was performed on the collected data to determine various parameters such as frequency, percentage, average, maximum, and minimum values. The mean concentration of PM_{10} in the downwind community was 0.024796 mg/m^3 (S.D. = 0.0551), while in the upwind community it was 0.000232 mg/m^3 (S.D. = 0.0002). The community exhibited Hazard Quotient (HQ) values that were considered acceptable, along with lower exposure levels. However, the residents in the surrounding areas of the stone mill may be exposed to dust from a variety of sources, including transportation, construction, and the burning of agricultural material. The current study's findings are anticipated to provide important information to improve the understanding of PM_{10} exposure in populations living near stone milling plants.

INTRODUCTION

Respirable particulate matter (PM_{10}) refers to tiny particles in the air with a diameter of 10 µm or less. PM_{10} particles are inhaled through the respiratory tract and can either accumulate in the lungs or be absorbed into the bloodstream and lymphatic systems (Zychowski et al.,2019; Xinheng,2023; Izzotti et al., 2022). Particulate matter is influenced by multiple variables, including industrial operations, automobile emissions, biomass burning, and dust storms (Ryou et al., 2018; Cao et al., 2021). Particulate matter has a greater impact on Southeast Asia during the dry season, which normally ranges from May to October (Nakata et al., 2018). Several studies have shown that exposure to particulate matter has been recognized as a factor that leads to many health consequences, such as higher rates of hospitalizations,

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visits to the emergency department, reduced lung capacity, respiratory symptoms, exacerbated chronic respiratory (Chujit et al.,2020; Jabbar et al., 2022; Chomanee et al.,2020).

According to the stone mill's operation in Thailand, during the stone crushing process, stones of considerable dimensions, extracted from quarries and measuring between 200 and 300 mm, are reduced to smaller sizes suitable for various applications, typically ranging from 6 to 25 mm (Samarakoon et al., 2023). Most stone-crushing operations are typically situated in close proximity to densely populated regions. According to the 2020 Real-Time World Air Quality Index report, Thailand ranks third among the top 10 countries globally with the highest air pollution index, followed by India and China (World Air Quality Index, 2023). A previous studies reported that the average concentration of particulate matter in stone mills in Thailand during an eight-hour workday was 8.72 mg/m^3, with a range of 0.25–48.46 mg/m^3. These levels exceeded the criteria established by the Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) (Samana et al., 2023). The stone-mortar (particulate matter (PM_{10}), which contains crystalline silica) workers had an average daily dose (ADD) of 0.018 mg/kg-day for PM10 and 0.005 mg/kg-day for crystalline silica. The risk assessment conducted by the U.S. Environmental Protection Agency (U.S. EPA) determined that the hazard quotients (HQ) for PM10 and crystalline silica were 1.64 and 1.67, respectively. These values indicated the presence of health risks associated with exposure to these pollutants (Thongtip, 2019), and the study revealed that all stone mill locations did not comply with the accepted regulations. Hence, the industry's functioning impacted nearby educational institutions, communities, villages, tourist attractions, and archaeological sites (Dantrakul et al., 2012).

The Nam Yuen District, located in the Ubon Ratchathani Province of northeastern Thailand, is classified as a rural area in the country. Agriculturalists made up the majority of the community's population. During the rice farming season, several farmers in this region continue to burn rice stubble. Additionally, this district is located in close proximity to four stone mills. Based on the survey, all communities located within a 5-kilometer radius of stone mills that are categorized as medium-sized enterprise stone mills. The geographical area in Thailand undergoes three unique climatic periods, including a hot season (from February to May), a rainy season (from June to September), and a cold season (from October to January). In October, we gathered PM10 particles during a southwest to northeast wind flow. The wind speed ranged from approximately 10 to 25 kilometers per hour (Meteorological Department, 2023). Consequently, those residing in the vicinity have a greater chance of encountering small particulate matter from various sources in comparison to other populations.

The data revealed the number of patients suffering from air pollution. In 2023, Nam Yuen Hospital in Ubon Ratchathani Province had 4,879 cases in total, of which 793 and 732 patients suffered from chronic obstructive pulmonary disease and pneumonia, respectively (Ministry of Public Health, 2023). Currently, there is a scarcity of information in Thailand addressing the release of dust from stone mill units and its potential health risks to the surrounding community. This study aims to evaluate the health risks for people living in communities located upwind and downwind of the stone mill industry in rural areas of Thailand, specifically related to their exposure to particulate matter .

METHOD

This study is analytic cross-sectional research aimed at evaluating the risk of exposure to particles smaller than 10 micrometers, in accordance with the guidelines set by the United States Environmental Protection Agency (U.S.EPA), among communities located downwind and upwind of stone milling plants in Nam Yuen District, Ubon Ratchathani Province, Thailand.

Population and Sample

This study examined two different population groups consisted of the downwind group is a community located north of the stone mill. Ban Kaset Somboon in Bu Puei Subdistrict, Nam Yuen District, Ubon Ratchathani Province is located approximately 1.8 kilometers away from the stone mill, and there are a total of 220 dwellings and the upwind settlement, Ban Non Thong, is south of the stone mill in Si Wichian Subdistrict, Nam Yuen District, Ubon Ratchathani Province. The stone mill is located approximately 5 kilometers from this community. The upwind community comprises 104 dwellings.

The total number of residences located predominantly downwind, which amounts to 220 households, was selected to determine the sample size. Data were gathered from a sample of houses that are representative of the population, with one individual per family, using the following formula: $n=[x^2\ Np(1-p)]/[e^2\ (N-1)+x^2\ p(1-p)]$,

where n is the sample size, N is the number of residences located downwind (220 households), x^2 is the chi-square value at the given degrees of freedom (df) is 1, while the corresponding value at a 95 percent confidence level is 3.841, p is the proportion of the average level of PM10; based on the analysis of existing literature, the value of P is determined to be 0.5 (Kanjanasiranont et al., 2022), and e is the assignment of an estimate of 0.05 to the random errors. Then n = 120.81 households.

Therefore, there were a total of 121 households selected as downwind community for data collection by using accidental sampling. As for the upwind community, data were collected from representatives of all 104 households. The selected representatives worked in the designated village area, were at least eighteen years old, literate, able to answer the questionnaire independently , and the participants selected to answer the questionnaire were purposively chosen as household representatives who have resided in the household for the longest period, typically exceeding 10 years.

Research Tools

The research tools included, firstly, the questionnaire concerning the risk assessment of PM10 exposure between communities located downwind and upwind of the stone milling plants, which is divided into two parts and consists of Part 1. The modified questionnaire is designed to gather information using multiple-choice questions and value specifications. It covers several aspects, such as gender, age, weight, marital status, education level, duration of residence in the community, frequency of exposure, occupation, presence of congenital diseases, and the source of dust exposure. Part 2 of the questionnaire concerns system-related health problems and diseases. It employs a 3-level rating system to assess the frequency of symptoms: experience, sometimes, and without symptoms. And secondly, the equipment for gathering PM10 particulate matter in the area includes a personal air sample pump, which monitors the concentration of dust in the air at breathing levels, as well as an accuracy calibration set.

Research Tool Quality Assessment

The questionnaire was subjected to a content validity assessment by three experts who were lecturers from the College of Medicine and Public Health at Ubon Ratchathani University. These experts specialize in risk assessment, public health, and air pollution . After incorporating their suggestions, it was evaluated for the Index of Item Objective Congruence. It was observed that each item received a score between 0.67 and 1.

Data Collections

There were three steps for gathering the data, are as:

First, the questionnaire was obtained from 121 individuals residing in households located downwind of the stone mill and 104 respondents who were the representatives of every home upwind of the stone mill.

And secondly, five samples of PM_{10} particles were gathered from the community upwind and downwind of the stone milling plants, following the standard NIOSH collection method number 0600, which was employed to delineate the sampling methodology for respiratory PM10 (Centers of Disease Control and Prevention, 2003). The calibration of the aluminum cyclone sampler with a tarred 5-µm PVC membrane was performed using a bubble meter. Subsequently, the sampler was used to collect samples according to the previously specified procedure. An eight-hour sample collection was operated to cover and represent the measurement. The filter cartridge was affixed to the cassette holder and securely fastened to the tripod, ensuring it was positioned at a minimum height of 1.50 meters from the ground. Two blank filter papers were prepared for every ten samples. Samples were obtained at a rate of 2 liters per minute. After the sample was completed, the filter cartridge was detached by closing both sides, allowing air in and out. The following information was recorded and provided: the duration of the sample collection process, the temperature, relative humidity, atmospheric pressure, the kind of storage pump used, and the location where the samples were collected. Samples were ensured to be stored in suitable receptacles to avoid any potential loss, and thereafter, the samples were transported to the laboratory for analysis.

The last step was analyzed in a laboratory setting. To eliminate moisture, the filter paper was placed in a desicator for a duration of 16–24 hours. Then, one sheet of the filter paper was carefully removed at a time using forceps and positioned on a scale. The mass of the filter paper was determined and the measurement was provided. The concentration of PM_{10} particles was determiend using the following formula (Thongchom, 2021): $C=[(W_2-W_1) - (B_2-B_1)/V] \times 100$, where, C is the particulate concentration (mg/m^3), W_1 is the initial filter weight (mg), W2 is the final filter weight (mg), B_1 is the initial blank filter weight (mg), B_2 is the final blank filter weight (mg), and V is the air volume (m^3).

This study was approved by the Human Research Ethics Committee of Ubon Ratchathani University (code UBU-REC-140/2566).

Data Analysis

The data analysis included descriptive statistics were used to analyze general, dust exposure, and risk assessment data. Quantitative data are typically presented with measures such as the average, standard deviation (SD), maximum value, and minimum value. On the other hand, qualitative data are usually presented using frequency and percentage and the daily exposure to PM10 among the community upwind and downwind of the stone mill was assessed using the equation (Ihsan et al., 2023): I=(C×IR×ET×EF×ED)/(BW×AT), where I is the daily exposure (mg/kg/day), C is the concentration of PM10 (mg/m^3), IR is the average adult inhalation rate of 20 m^3/day (National Research Council (US) Committee on Risk Assessment of Hazardous Air Pollutants, 1994), ET is the exposure time (hours/day), EF is the exposure frequency (days/year), ED is the exposure duration (years), BW is the body weight (kilograms), and AT is the average time affected (365 days).

The risk level was computed using an equation based on non-cancerous effects using the equation (Widiana et al., 2019): HQ = I/RfC, where HQ is the Hazard Quotient, I is the daily exposure to PM_{10} (mg/kg/day), RfC is the reference dose is the estimated concentration or value of daily exposure to a non-carcinogenic risk agent that is deemed harmless, even with lifetime exposure (50 µg/m3) (Saju et al., 2023).

The Hazard Quotient (HQ) can be interpreted as follows: if HQ is higher than 1, it indicates a health risk that must be controlled. On the other hand, if HQ is equal to or less than 1, it indicates an acceptable degree of health risk (Ihsan et al., 2023).

RESULT AND DISCUSSION

The participants from the downwind community and the upwind community have the following respective characteristics: 54.4% and 67.3% are females; the average age is 32.3 (SD = 10.5) and 52 (SD = 12.4); 47.1% and 60.5% are single; 44.6% and 19.2% have graduated from secondary school; 81.0% and 58.7% have the occupation of a farmer; 91.7% and 56.7% do not have any congenital diseases; and 40.1% and 41.4% are exposed to particulates from burning agricultural manure activity (Table 1).

The top three symptoms reported by the community representatives were: clogged nose (64.4%), mucus-producing (63.1%), and itchy

Table 1. Demographic information of the participants (n=225)

Characteristics	Downwind community (n=121)		Upwind community (n=104)	
	n	percentage	n	percentage
Gender				
Male	55	45.5	34	32.7
Female	66	54.5	70	67.3
Age (Year)				
19-30	65	53.7	9	8.7
31-40	29	24.0	6	5.8
41-50	20	16.5	30	28.8
51-60	6	5.0	33	31.7
>60	1	0.8	26	25.0
Average (S.D.)	32.3(10.5)		52(12.4)	
Weight (Kg)				
Minimum - Maximum	31-80		39-132	
Average (S.D.)	52.5(8.9)		61.1(12.5)	
Marital Status				
Single	57	47.1	63	60.5
Married	46	38.0	27	26.0
Widowed, Divorced, Separated	18	14.9	14	13.5

Characteristics	Downwind Community (n=121)		Upwind Community (n=104)	
	n	percentage	n	percentage
Education Level				
Primary School	45	37.2	79	76.0
Secondary School	54	44.6	20	19.2
Bachelor's Degree	15	12.4	2	1.9
Postgraduate	2	1.7	1	1.0
None	5	4.1	2	1.9
Duration of Residence (Year)				
Minimum - Maximum	16 - 65		2 - 75	
Average (S.D.)	43.1 (10.5)		52 (15.8)	
Occupation				
Hired Laborer	13	10.7	27	26.0
Farmer	98	81.0	61	58.7
Government Officer	4	3.3	6	5.8
Merchant	6	5.0	8	7.6
Stone Mill Worker	-	-	2	1.9
Congenital Disease				
Yes	10	8.3	45	43.3
No	111	91.7	59	56.7
The Source of the Particulates that an Individual was Exposed to				
Burning Agricultural Manure	49	40.1	43	41.4
Vehicles	21	17.2	30	28.8
Construction	7	5.8	10	9.6
Stone Drilling	24	19.7	15	14.4
Manufacturing	20	17.2	6	5.8

body (42.7%). The individuals in the downwind community experienced the following symptoms: increased mucus production (88.4%), clogged nose (85.1%), coughed-up phlegm (62.0%), dry coughs (54.5%), itchy body (44.6%), and stinging or itching in their eyes (41.3%). People in the upwind community experienced the following symptoms: a clogged nose (41.8%), itchy body (40.4%), and excessive mucus production (33.7%) (Table 2).

Table 2. Community-reported percentage of symptoms (n=225)

Symptoms Percentage	Downwind Community (n=121)	Upwind Community (n=104)	Total in Percentage (n=225)
	Percentage	Percentage	
Mucous Membrane Symptoms			
Clogged Nose	85.1	41.8	64.4
Mucus-producing	88.4	33.7	63.1
Nasal Stinging	42.2	19.0	31.1
Nose Bleeding	16.5	10.6	13.8
Throat Stinging	21.5	17.3	19.6
Sibilant Voice	41.3	14.4	28.9

Symptoms Percentage	Downwind Community (n=121)	Upwind Community (n=104)	Tatal in Percentage (n=225)
	Percentage	Percentage	
Mucous Membrane Symptoms			
Dry cough	54.5	15.4	36.4
Cough up phlegm	62	15.4	40.4
Difficulty breathing	28.1	7.7	18.7
Shortness of breath	5	5.8	5.3
Skin System Symptoms			
Itchy body	44.6	40.4	42.7
Body rash	40.5	27.9	34.7
Eye Related Symptoms			
Ocular stinging or itching	41.3	18.3	30.7
Conjunctivitis	16.5	7.7	12.4
Tearing	62	18.3	41.8
Unable to see properly	17.4	14.4	16
General Symptoms			
Fainting	26.4	27.0	26.7
Dizziness	33.1	37.5	35.1

The amount of PM_{10} concentration in the environment in the upwind and downwind community areas surrounding the stone mill in Nam Yuen District, Ubon Ratchathani Province, indicated that the concentration of PM_{10} in downwind community areas during dry weather conditions, without any rainfall, has an average value of 0.024796 mg/m^3 (SD = 0.0551). The concentration of PM_{10} in upwind community areas during dry weather conditions has an average value of 0.000232 mg/m^3 (S.D. = 0.0002) (Table 3). The health risk assessment process involving data utilization is organized and shown in Table 4. The average daily PM10 exposure among people in the downwind community ranged from 0.06300 to 0.30520 mg/kg/day, while that among people in the upwind community ranged from 0.00057 to 0.00286 mg/kg/day.

The Hazard Quotient (HQ) for PM_{10} among people in the downwind community ranged from 1.26×10-3- 6.1×10-3, while that among people in the upwind community ranged from 1.1×10-5- 5.7×10-5. The Hazard Quotient is less than 1 in every population, both downwind and upwind of the stone milling plants. It is probable that during the sampling in the communities in October 2023, there was no rain on the day of sample collection. However, there was a storm in the northeastern part of Thailand at that time, which resulted in rain that month. As a result, the dispersion of PM_{10} particulates decreased. Nevertheless, Cichowicz et al.'s (2020) study discovered a correlation between greater particulate matter (PM_{10}) levels and decreased wind speeds. When we were gathering PM_{10} samples throughout the communities, that was in the month when the rain came. In addition, the wind speed in the area at that time ranged from 10 to 25 kilometers per hour, which produced humidity and led to the dispersion of PM_{10} in the vicinity. This is in accordance with a study conducted by Ramos-Contreras et al. (2023), where the average mass concentration of PM_{10} ranged from 37.0 µg/ m^3 to 45.7 µg/m3 between March 2017 and October 2017 (Ramos-Contreras et al., 2023). However, in contrary to the findings of Lewis et al. in 2023, it was observed that the level of PM10 exceeded 140 µg/m^3 during days when hourly measurements were taken (Lewis et al., 2023). Additionally, Usahanunth's 2021 study found that the dispersion of PM10 from the source to a nearby community close to the stone mill was 90 µg /m^3 (Usahanunth, 2021). This affected the calculation of the daily PM_{10} exposure for people residing in the communities both downwind and upwind of a stone mill. The daily average PM_{10}

exposure in the downwind community varied between 0.06300 and 0.30520 mg/kg/day, whereas in the upwind community, it ranged from 0.00057 to 0.00286 mg/kg/day.

Table 3. The ambient concentration of PM_{10} in the community environment

Area	PM_{10} (mg/m^3)					
	Sampler no. 1	Sampler no. 2	Sampler no. 3	Sampler no. 4	Sampler no. 5	Average
Downwind Community	0.0001	0.0001	0.00021	0.12344	0.00013	0.024796 (S.D. = 0.0551)
Upwind Community	0.00063	0.00011	0.00014	0.00013	0.00015	0.000232 (S.D. = 0.0002)

Table 4. Variables used for evaluating health risk

Variable	Downwind Community	Upwind Community	Unit
	Range of values (Minimum - Maximum)		
PM_{10} Concentration	0.10 - 123.44	0.11 - 0.63	$\mu g/m^3$
Body weight (BW)	31- 80	39 - 132	kilograms
Exposure duration (ED)	16 - 65	2 - 75	years
Exposure frequency (EF)	365	365	Days/year
Exposure time (ET)	8 - 24	7 - 24	Hours/day

Conversely, the individuals in the community revealed lower levels of exposure, and HQ values were considered acceptable. Nevertheless, each PM_{10} particle has a unique level of toxicity when it comes to regulation and the study of poisons, depending on the duration of exposure (Thongchom et al., 2021; Zychowski et al., 2019), and it is clear that people in the surrounding area may come into contact with dust from a variety of sources, such as the combustion of agricultural manure, vehicles, and construction activities. According to the U.S. Environmental Protection Agency (EPA) standard, the exposure calculation algorithm showed that the exposure time (measured in hours per day), exposure frequency (measured in days per year), and exposure duration (measured in years residing in the communities) directly influence the exposure score. The age of the participants correlates with the exposure duration, suggesting a prolonged stay in the community. However, because there are several elements related to the exposure score, there are no established criteria for a safe threshold for each factor. As a result, researchers decided to assess the entire exposure score for each individual. Consequently, individuals remain susceptible to adverse effects, encompassing both immediate and long-term conditions such as irritation of the mucous membranes, skin disorders, ocular symptoms, and general ailments (Roberts, 2020; Mueller et al., 2021). This aligns with the research that discovered the detrimental impacts of air pollution on individuals who are more susceptible (Lin et al., 2022; Manisalidis et al., 2020; Serafini et al., 2022). The results of the current study would offer useful information to enhance the comprehension of PM_{10} exposure in communities surrounding stone mill manufacturing, particularly in locations where information is limited. Additionally, it would provide an understanding of the health effects of such exposure on individuals residing in these areas. Additionally, it would encourage relevant agencies to promote suitable strategies to reduce the population's level of exposure.

This study had some limitations. The study design solely ascertained the risk level and did not establish risk factors or causal associations between the variables and the risk level. Furthermore, the climate has the potential to affect PM_{10} concentration. Hence, future studies should focus on investigating the relationship between risk fac-

tors and the gathering of particulate matter during the dry season.

CONCLUSION

The community demonstrated lower exposure levels and HQ values deemed acceptable. Nevertheless, it is apparent that people living in nearby areas can encounter dust generated from several sources, such as the incineration of agricultural materials, transportation, and construction operations. As a result, people are still susceptible to negative consequences, including both immediate and long-term diseases such as irritation of the mucous membranes, skin disorders, eye symptoms, and general illnesses. The findings of the current study would provide useful information to improve understanding of PM_{10} exposure in populations located near stone milling plants, especially in areas with limited information. Furthermore, it would provide insights into the health effects of such exposure on people who live in these regions. Furthermore, it would encourage relevant organizations to promote suitable strategies to reduce the population's levels of exposure.

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