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The Influence of Air Pollution on Disease and Related Health Problems in Northern Thailand

(Pengaruh Pencemaran Udara terhadap Penyakit dan Masalah Berkaitan Kesihatan di Utara Thailand)

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ABSTRACT

Air pollution is a significant health risk factor. Long-term exposure to ambient air pollution has a significant impact on chronic respiratory illnesses and diseases related to health problems. The aim of this study was to investigate the association between air pollution, respiratory diseases and diseases related to health in Northern Thailand. The daily mean concentrations of PM_{10} and $PM_{2.5}$, including meteorological condition data from 2015 to 2020, were measured and recorded by Pollution Control Department (PCD), Ministry of Natural Resources and Environment, Thailand. The daily cumulative number of respiratory diseases and related health problems data from 2015 to 2020 was measured and recorded by Information and Communication Technology Centre, Ministry of Public Health, Thailand. The daily mean concentrations of PM_{10} and $PM_{2.5}$ were positively associated with CO, NO_2, SO_2, O_3, circulatory system (I00-I99), respiratory system (J00-J99.8), eye (H10-H19.8), rash and other nonspecific skin eruption (R21), and neoplasms (C00-D48). After adjusting for confounding factors, the multiple linear regression analysis revealed that the escalating daily mean PM_{10} concentrations were connected to the increasing daily mean $PM_{2.5}$ concentrations. This indicates that providing health education programmes and pollution protection, as well as policymakers and legislation, is required for better health.

Keywords: Air pollution; meteorological conditions; PM_{10}; $PM_{2.5}$; respiratory diseases

ABSTRAK

Pencemaran udara adalah faktor risiko kesihatan yang utama. Pendedahan jangka panjang kepada pencemaran udara persekitaran memberi impak yang besar kepada penyakit pernafasan kronik dan penyakit yang berkaitan dengan masalah kesihatan. Matlamat kajian ini adalah untuk mengkaji perkaitan antara pencemaran udara, penyakit pernafasan dan penyakit yang berkaitan dengan kesihatan di Utara Thailand. Purata kepekatan harian PM_{10} dan $PM_{2.5}$, termasuk data keadaan meteorologi dari 2015 hingga 2020, diukur dan direkodkan oleh Jabatan Kawalan Pencemaran (PCD), Kementerian Sumber Asli dan Alam Sekitar, Thailand. Bilangan kumulatif harian penyakit pernafasan dan data masalah kesihatan yang berkaitan dari 2015 hingga 2020 telah diukur dan direkodkan oleh Pusat Teknologi Maklumat dan Komunikasi, Kementerian Kesihatan Awam, Thailand. Purata kepekatan harian PM_{10} dan $PM_{2.5}$ dikaitkan secara positif dengan CO, NO_2, SO_2, O_3, sistem peredaran darah (I00-I99), sistem pernafasan (J00-J99.8), mata (H10-H19.8), ruam dan letusan kulit tidak khusus lain (R21) dan neoplasma (C00-D48). Selepas melaraskan faktor yang mengelirukan, analisis regresi linear berganda mendedahkan bahawa purata kepekatan PM_{10} harian yang semakin meningkat dikaitkan dengan peningkatan purata kepekatan $PM_{2.5}$ harian. Ini menunjukkan bahawa penyediaan program pendidikan kesihatan dan perlindungan pencemaran, serta penggubalan dasar dan perundangan, diperlukan untuk jaminan kesihatan yang lebih baik.

Kata kunci: Keadaan meteorologi; pencemaran udara; penyakit pernafasan; PM_{10}; $PM_{2.5}$

INTRODUCTION

Air pollution is caused by emissions from both human activities and natural sources, such as vehicle and industrial emissions, agricultural residue burning, biomass burning emissions and forest fires, along with the transboundary effect of air pollution from neighbouring countries (Boogaard et al. 2019; Manisalidis et al. 2020; Mueller et al. 2020; Thongtip et al. 2020; WHO 2018). In 2016, the World Health Organization (WHO) expressed alarm about ambient (outdoor air pollution) in both urban and rural regions, estimating that it was responsible for 4.2 million premature deaths worldwide (WHO 2018).

Long-term exposure to air pollutants including PM_{10} (particles with diameter smaller than 10 micrometres), $PM_{2.5}$ (particles with diameter smaller than 2.5 micrometres), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and ozone (O_3) are major environmental factors causing diseases such as cardiovascular disease, chronic obstructive pulmonary disease (COPD), asthma, lung cancer, affecting morbidity and mortality worldwide (Jiang et al. 2016; Manisalidis et al. 2020; Mueller et al. 2020; Ramakreshnan et al. 2018; Sweileh et al. 2018). Moreover, in 2016, the WHO reported that outdoor air pollution caused 58 percent of ischemic heart disease, 18 percent of COPD and acute lower respiratory infections, and 6 percent of lung cancer-related premature deaths (WHO 2018).

Many several studies have focused on PM_{10} and $PM_{2.5}$, especially when $PM_{2.5}$ penetrates deeply into the lower respiratory, lung, and circulatory system (Lee et al. 2020; Xing et al. 2016). The organic components of $PM_{2.5}$ can cause lung inflammation response, increase free radical production or the reactive oxygen species (ROS), break the antioxidant balance, and cause oxidative stress, including causing lung function damage which results in adverse effects on the lower respiratory system (Lee et al. 2020; Pothirat et al. 2019; Thongtip et al. 2020; Wu et al. 2018). Previous studies have confirmed that air pollution can lead to increased chronic and respiratory diseases (Kantipudi et al. 2016; Manisalidis et al. 2020; Xing et al. 2016).

The consequences of air pollution can be damaging to the human body, and PM_{10} and $PM_{2.5}$ may be responsible for some of these health problems (Lee et al. 2020; Xing et al. 2016). In Thailand, the most common air pollutants are PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, and O_3 which are caused by burning agriculture residues, forest fires, and transboundary haze in rural and border areas (Paoin et al. 2021; Vichit-Vadakan & Vajanapoom 2011). Furthermore, because of the daily cumulative number of lower chronic and respiratory diseases, air pollution might lead to an increase in hospital admissions and outpatient visits (Vichit-Vadakan & Vajanapoom 2011). Therefore, this study is aimed at examining the association between air pollution and respiratory diseases and related health problems in Northern Thailand.

MATERIALS AND METHODS

STUDY AREA

The daily air pollution and meteorological condition data of four air quality monitoring stations have been examined in Chiang Mai, Chiang Rai, Mae Hong Son, and Nan Province between January 2015 and December 2020. The locations of the study areas were Chiang Mai (Latitude 18°50'26.3"N Longitude 98°58'10.7"E, Chiang Mai Provincial Government Centre), Chiang Rai (Latitude 19°54'33.0"N Longitude 99°49'25.2"E, Provincial Office of Natural Resources and Environment), Mae Hong Son (Latitude 19°18'14.9"N Longitude 97°58'18.4"E, Provincial Office of Natural Resources and Environment) and Nan Province (Latitude 19°34'33.9"N Longitude 101°04'53.5"E, Chaloemprakiat Hospital), Northern Thailand.

DATA COLLECTION

The daily air pollution and meteorological condition data of PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, O_3, WS, WD, Temp., RH, and rain in four air quality monitoring stations in Chiang Mai, Chiang Rai, Mae Hong Son, and Nan Province between January 2015 and December 2020 were measured and recorded by PCD, Ministry of Natural Resources and Environment, Thailand. The daily mean PM_{10} concentrations of the National Ambient Air Quality Standards (NAAQS) and World Health Organization (WHO) standards were 150 and 45 $\mu g/m^3$, respectively. In part of daily mean $PM_{2.5}$ concentrations of NAAQS and WHO standards were 35 and 15 $\mu g/m^3$, respectively (EPA 2021; WHO 2021).

Between January 2015 and December 2020, the Information and Communication Technology Centre, Ministry of Health, Thailand, recorded daily cases data in Chiang Mai, Chiang Rai, Mae Hong Son, and Nan Provinces, which coded all the daily cases using the tenth revision of the International Classification of Diseases (ICD-10) such as circulatory system (I00-I99), respiratory system (J00-J99.8), skin and subcutaneous tissue (L00-L99), eye (H10-H19.8), rash and other nonspecific skin eruption (R21), and neoplasms (C00-D48).

STATISTICAL ANALYSIS

The data was analysed by using mean, and standard deviation values. Kruskal Wallis test were analyzed to find a difference in the association between parameters of air pollution and meteorological conditions, respiratory diseases and related health problems, four air quality monitoring stations, and years during 2015-2020. The link between air pollution and lower respiratory diseases and related health problems was investigated using Spearman's rank correlation coefficient. Additionally, the association between daily mean PM_{10} concentrations and the daily mean $PM_{2.5}$ concentrations during 2015-2020 were analysed by using multiple linear regression analysis.

ETHICAL CONSIDERATIONS

The study was approved by the Research Ethics Committee of University of Phayao, Thailand (No. 1.1/009/64).

RESULTS

CHARACTERISTICS OF AIR POLLUTION AND METEOROLOGICAL CONDITIONS DURING 2015-2020

The results showed that difference in the relationship between four air quality monitoring stations and PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, O_3, WS, WD, temp, RH, and rain. The highest annual concentrations of PM_{10} in Chiang Rai Province in the year 2019 and Chiang Mai Province in the year 2020 were 46.88±41.04 and 44.92±43.11 μg/m^3, respectively. The highest annual concentrations of $PM_{2.5}$ in Chiang Rai Province in the year 2019 and Mae Hong Son Province in the year 2020 were 32.61±35.71 and 32.35±46.02 μg/m^3, respectively. In Mae Hong Son Province, the lowest annual PM_{10} concentrations in 2019 and 2020 were 40.88±49.18 and 40.42±49.96 μg/m^3, respectively. In Nan Province, the lowest annual $PM_{2.5}$ values in 2019 were 29.58±35.49 and in 2020 were 26.79±36.56 μg/m^3 (Table 1).

TABLE 1. Characteristics of air pollution and meteorological condition during 2015-2020

Parameter	The annual mean of air pollution and meteorological conditions, mean±SD						*p*-value
	2015	2016	2017	2018	2019	2020	
PM_{10}, μg/m^3							
Chiang Mai	40.30±44.31	42.33±40.62	34.43±26.41	37.89±27.61	46.83±43.50	44.92±43.11	
Chiang Rai	43.10±47.60	43.95±42.43	33.23±21.43	37.19±22.70	46.88±41.04	42.17±41.36	<0.001[a*]
Mae Hong Son	49.48±55.69	41.74±44.49	35.23±36.51	34.08±35.17	40.88±49.18	40.42±49.96	
Nan	15.14±5.06	36.21±42.62	25.85±16.27	29.94±19.41	43.27±42.46	44.85±42.98	
$PM_{2.5}$, μg/m^3							
Chiang Mai	6.78±4.28	23.69±26.32	23.63±18.02	20.63±18.04	32.36±36.82	30.66±37.29	
Chiang Rai	-	-	-	20.39±14.92	32.61±35.71	30.02±35.72	<0.001[a*]
Mae Hong Son	-	-	-	8.72±3.82	31.03±43.17	32.35±46.02	
Nan	6.78±4.28	23.74±32.03	16.56±12.41	17.32±16.42	29.58±35.49	26.79±36.56	
CO, ppm							
Chiang Mai	0.46±0.25	0.49±0.25	-	-	-	-	
Chiang Rai	0.47±0.23	0.41±0.24	0.72±0.31	0.66±0.24	0.65±0.33	0.43±0.29	<0.001[a*]
Mae Hong Son	0.59±0.46	0.43±0.19	0.57±0.33	0.69±0.39	0.68±0.35	0.75±0.38	
Nan	0.13±0.09	0.31±0.34	0.22±0.12	0.26±0.19	0.34±0.29	0.18±0.25	
NO_2, ppb							
Chiang Mai	10.18±5.62	9.35±7.16	8.39±4.01	5.82±3.34	9.10±4.46	8.27±5.40	
Chiang Rai	-	-	-	4.73±1.38	7.75±4.28	4.66±3.35	<0.001[a*]
Mae Hong Son	-	-	-	2.26±0.63	4.48±3.71	4.51±3.68	
Nan	0.54±0.51	1.29±1.16	1.24±1.10	1.90±1.57	2.76±1.75	2.91±2.22	
SO_2, ppb							
Chiang Mai	1.33±1.32	0.81±0.82	0.78±0.57	0.90±0.86	0.60±0.63	0.38±0.46	
Chiang Rai	-	-	-	-	-	-	<0.003[a*]
Mae Hong Son	-	-	-	-	-	-	
Nan	0.34±0.44	0.70±0.73	1.18±0.49	1.36±0.58	0.70±0.52	0.72±0.67	

O_3, ppb							
Chiang Mai	19.47±9.89	19.25±11.67	18.02±10.67	21.36±13.15	24.57±12.15	20.34±11.55	
Chiang Rai	20.63±10.05	18.71±10.78	16.99±11.33	18.84±9.57	24.64±11.14	17.50±9.89	<0.001[a*]
Mae Hong Son	22.82±10.84	17.07±11.19	17.78±10.29	23.35±17.69	20.14±12.40	17.23±11.31	
Nan	9.62±4.97	16.52±10.89	15.52±8.86	14.75±9.63	22.05±10.46	20.25±10.04	
Temp., ^{0}C							
Chiang Mai	25.17±4.19	24.83±3.79	24.75±3.16	24.56±2.83	25.60±3.52	25.70±3.33	
Chiang Rai	24.77±3.06	23.81±3.61	22.72±2.86	23.40±2.85	25.71±3.50	25.51±3.03	<0.001[a*]
Mae Hong Son	23.23±5.38	25.09±2.44	26.68±2.36	25.90±2.18	26.18±3.37	26.84±3.34	
Nan	23.99±2.41	23.63±3.72	23.49±2.91	23.22±2.83	24.05±3.62	23.93±3.25	
RH, %							
Chiang Mai	75.88±11.74	74.40±12.24	75.44±12.61	77.00±11.01	69.71±14.41	68.56±15.21	
Chiang Rai	79.52±9.30	77.65±10.96	82.11±9.19	83.05±6.63	71.25±12.41	70.18±13.75	<0.001[a*]
Mae Hong Son	74.27±11.74	72.25±10.40	69.08±11.79	73.32±12.51	68.88±15.08	65.73±16.44	
Nan	85.52±4.82	78.53±10.09	79.79±8.46	80.22±6.79	73.77±14.65	74.76±12.10	
Rain, mm							
Chiang Mai	0.22±0.86	0.24±0.85	0.17±0.41	0.15±0.36	0.10±0.31	0.10±0.31	
Chiang Rai	0.44±1.48	0.56±1.57	0.25±0.50	0.23±0.44	0.11±0.31	0.13±0.38	<0.001[a*]
Mae Hong Son	0.19±0.47	0.15±0.36	0.17±0.44	0.14±0.37	0.11±0.34	0.11±0.32	
Nan	0.15±0.37	0.13±0.32	0.14±0.33	0.14±0.35	0.10±0.33	0.08±0.26	

Presented as Kruskal Wallis test; * p-value<0.01; a = difference in the association between parameters and four air quality monitoring stations

THE DAILY MEAN OF PM_{10} AND $PM_{2.5}$ CONCENTRATIONS DURING 2015-2020

The daily mean PM_{10} concentrations were compared to the NAAQS standard (150 µg/m^3) and the World Health Organization (WHO) standard (45 µg/m^3) between 2015 and 2020. Figure 1 shows a comparison of $PM_{2.5}$ values from 2015 to 2020 with the NAAQS standard (35 µg/m^3) and the WHO standard (15 µg/m^3) (EPA 2021; WHO 2021).

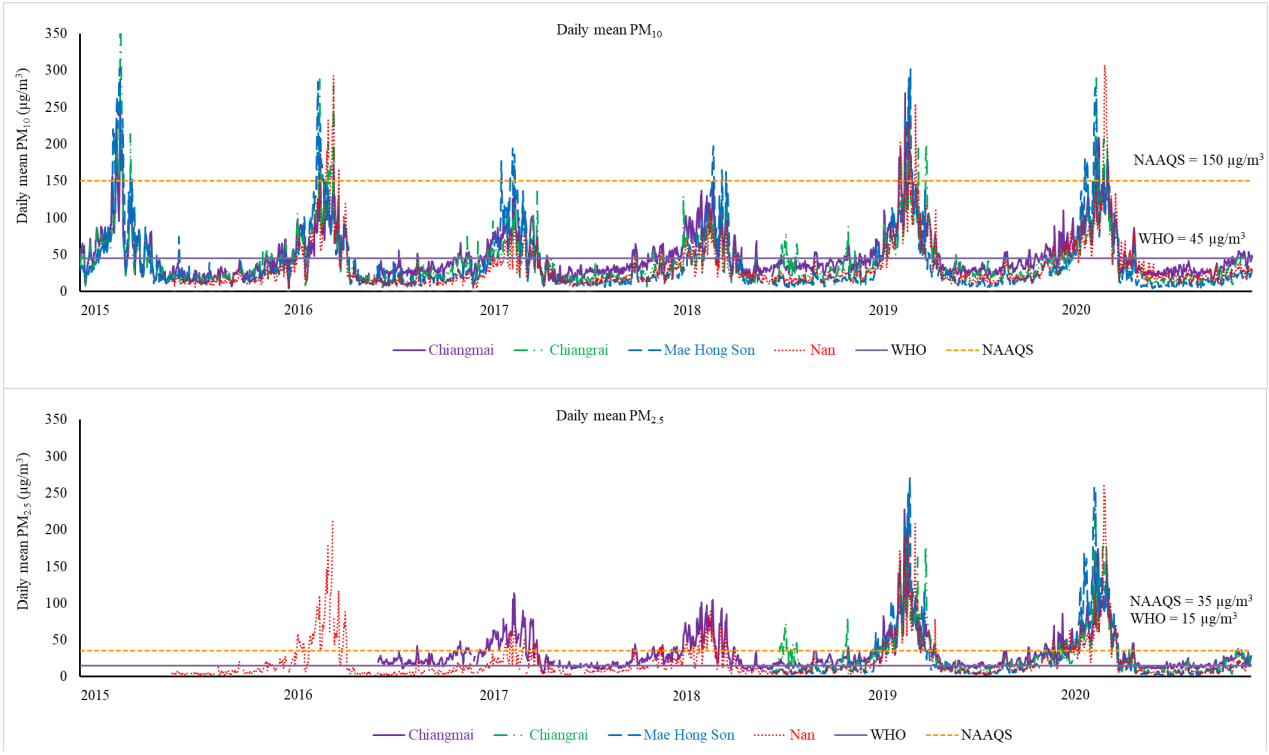

FIGURE 1. The daily mean of PM_{10} and $PM_{2.5}$ concentrations during 2015-2020

CHARACTERISTICS OF RESPIRATORY DISEASES AND RELATED HEALTH PROBLEMS DURING 2015-2020

The results showed that difference in the relationship between four air quality monitoring stations and I00-I99, J00-J99.8, L00-L99, H10-H19.8, R21, and C00-D48. The annual cumulative number of I00-I99, J00-J99.8, L00-L99, H10-H19.8 and C00-D48 in Chiang Mai Province during 2015-2020 was higher than in Chiang Rai, Mae Hong Son and Nan Province, except R21 during 2016-2020. The annual cumulative number of I00-I99, J00-J99.8, L00-L99, H10-H19.8, and C00-D48 in Mae Hon Song Province during 2015-2020 were lower than in Chiang Rai, Mae Hong Son and Nan Province, while the lowest annual cumulative number of R21 was in Nan Province (Table 2).

TABLE 2. Characteristics of respiratory diseases and related health problrms during 2015-2020

Parameter	The annual cumulative number of respiratory diseases and related health problems, mean±SD						*p*-value
	2015	2016	2017	2018	2019	2020	
I00-I99							
Chiang Mai	3411.08± 2202.48	3746.78±2353.70	3932.39± 2496.04	4108.25± 2632.16	4209.55±2728.36	4200.03±2724.54	<0.001[a*]
Chiang Rai	2352.01±1609.83	2507.34±1685.86	2543.87±1728.15	2562.76±1732.70	2686.00±1829.89	2877.53±1958.45	
Mae Hong Son	294.11±206.42	351.02±241.19	375.39±265.09	407.89±284.60	388.28±276.07	408.67±292.07	
Nan	923.20±566.26	996.15±614.90	1064.02±661.87	1110.45±697.14	1110.41±705.24	1107.79±712.84	
J00-J99.8							
Chiang Mai	2386.08±992.42	2580.80±1030.05	2321.19±926.49	2187.73±892.175	2262.71±987.43	1664.10±1016.07	<0.001[a*]
Chiang Rai	1685.93±745.23	1804.24±762.16	1607.71±688.45	1582.26±668.85	1574.99±714.60	1220.88±831.98	
Mae Hong Son	472.82±199.23	503.75±224.3875	441.50±187.73	452.95±190.47	431.49±191.41	338.20±201.43	
Nan	684.28±274.73	699.47±294.58	668.02±281.38	651.32±277.10	620.34±265.13	465.26±284.45	
L00-L99							
Chiang Mai	601.99±279.31	608.58±283.08	587.96±274.20	584.08±271.66	608.85±298.70	532.66±259.76	<0.001[a*]
Chiang Rai	431.19±214.98	447.81±216.53	412.35±192.46	386.92±181.70	417.65±211.97	393.73±217.13	
Mae Hong Son	102.31±47.81	97.14±43.10	95.56±43.56	94.58±45.54	89.32±42.78	84.19±43.08	
Nan	198.99±86.58	203.05±88.67	192.42±83.25	193.40±85.37	207.79±97.56	167.96±75.85	
H10-H19.8							
Chiang Mai	163.94±78.31	176.43±83.74	176.23±86.55	172.64±84.77	178.35±90.39	152.61±80.18	<0.001[a*]
Chiang Rai	131.69±68.19	138.06±68.74	140.09±70.52	136.33±67.24	143.59±75.01	122.42±67.78	
Mae Hong Son	25.11±12.46	26.51±13.70	26.00±13.54	26.75±13.22	26.28±13.28	23.25±12.85	
Nan	59.96±29.59	63.02±30.33	62.26±29.80	64.90±31.38	63.02±31.34	54.30±27.55	
R21							
Chiang Mai	88.44±42.06	89.50±42.32	78.20±35.89	72.56±32.28	74.88±33.56	64.36±28.94	<0.001[a*]
Chiang Rai	88.27±50.91	92.33±51.21	89.15±49.39	93.05±50.88	92.26±50.69	83.83±47.31	
Mae Hong Son	18.96±10.01	19.36±9.95	18.24±9.46	19.25±9.81	20.48±10.36	19.85±11.18	
Nan	17.02±9.12	15.08±7.79	14.01±6.70	16.59±8.05	18.78±9.58	13.91±7.27	
C00-D48							
Chiang Mai	332.59±243.47	406.41±271.10	436.67±295.73	477.21±334.40	584.97±419.00	568.94±408.38	
Chiang Rai	130.00±95.36	139.14±93.55	141.33±95.94	139.02±94.24	187.93±127.85	206.05±139.11	<0.001[a*]
Mae Hong Son	9.86±6.29	12.37±8.07	15.88±9.85	15.71±10.29	17.45±11.43	19.27±12.87	
Nan	52.39±31.31	59.00±35.56	64.83±39.77	71.52±44.60	74.88±46.81	77.77±49.48	

Presented as Kruskal Wallis test; * *p*-value<0.01; a = difference in the association between respiratory diseases, diseases related to health problems and four air quality monitoring stations

SPEARMAN'S RANK CORRELATION COEFFICIENT OF AIR POLLUTION, RESPIRATORY DISEASES AND RELATED HEALTH PROBLEMS DURING 2015-2020

Spearman's rank correlation coefficient analysis showed that the daily mean concentrations of PM_{10} during 2015-2020 was positively associated with respiratory diseases and related health problems in Chiang Mai Province (I00-I99, J00-J99.8, H10-H19.8 and C00-D48), Chiang Rai Province (I00-I99 and J00-J99.8), Mae Hong Son Province (J00-J99.8), and Nan Province (I00-I99 and C00-D48), but negatively associated with respiratory diseases and related health problems in Chiang Mai Province and Chiang Rai Province (L00-L99 and R21), Mae Hong Son Province (L00-L99 and C00-D48), and Nan Province (L00-L99). In addition, the daily mean concentrations of $PM_{2.5}$ during 2015-2020 was positively associated with respiratory diseases in Chiang Mai Province and Nan Province (I00-I99, and J00-J99.8), and Chiang Rai Province and Mae Hong Son Province (J00-J99.8), but negatively associated with respiratory diseases and related health problems in Chiang Mai Province, Chiang Rai Province, and Nan Province (L00-L99, and R21), Mae Hong Son Province (L00-L99, H10-H19.8, R2 and C00-D48) (Table 3).

TABLE 3. Spearman's rank correlation coefficient of air pollution, respiratory diseases and related health problems during 2015-2020

Respiratory diseases and related health problems	Air pollution					
	PM_{10}	$PM_{2.5}$	CO	NO_2	SO_2	O_3
I00-I99						
Chiang Mai	0.167***	0.115***	0.097*	0.177***	-0.024	0.064**
Chiang Rai	0.107***	-0.034	0.049*	0.072*	-	0.069**
Mae Hong Son	0.021	0.002	0.113***	0.140***	-	-0.031
Nan	0.175***	0.156***	0.108***	0.155***	0.061**	0.098***
J00-J99.8						
Chiang Mai	0.156***	0.172***	0.015	0.307***	0.186***	-0.005
Chiang Rai	0.173***	0.244***	0.184***	0.349***	-	0.067**
Mae Hong Son	0.097***	0.128***	0.065**	0.221***	-	-0.033
Nan	0.005	0.079**	0.071**	-0.061**	0.032	-0.084***
L00-L99						
Chiang Mai	-0.183***	-0.238***	-0.057	-0.047*	-0.009	-0.238***
Chiang Rai	-0.193***	-0.243***	-0.200***	-0.107**	-	-0.129***
Mae Hong Son	-0.194***	-0.277***	-0.174***	-0.086*	-	-0.203***
Nan	-0.166***	-0.202***	0.000	-0.143***	-0.112***	-0.135***
H10-H19.8						
Chiang Mai	0.054***	0.006	0.067	0.107***	0.052**	-0.014
Chiang Rai	0.025	-0.010	0.016	0.086*	-	0.054*
Mae Hong Son	-0.011	-0.099**	-0.020	0.051	-	-0.009
Nan	0.005	-0.010	0.088***	-0.013	-0.027	-0.027
R21						
Chiang Mai	-0.107***	-0.126***	-0.021	0.034	0.064**	-0.152***
Chiang Rai	-0.111***	-0.150***	-0.098***	-0.025	-	-0.031
Mae Hong Son	-0.043	-0.068*	-0.041	0.049	-	-0.023
Nan	-0.015	-0.060**	0.101***	0.009	-0.083***	0.007
C00-D48						
Chiang Mai	0.057**	-0.019	0.032	0.081***	-0.090***	-0.004
Chiang Rai	0.015	-0.025	-0.013	-0.025	-	0.002
Mae Hong Son	-0.087***	-0.090**	0.097***	0.066*	-	-0.087***
Nan	0.074**	0.036	0.016	0.106***	0.031	-0.004

Presented as Spearman's rank correlation coefficient; *p-value <0.05; **p-value <0.01; ***p-value<0.001

ASSOCIATION OF THE DAILY MEAN PM_{10} CONCENTRATION AND THE DAILY MEAN $PM_{2.5}$ CONCENTRATION DURING 2015-2020 USING MULTIPLE LINEAR REGRESSION ANALYSIS

The multiple linear regression analysis showed that the increasing daily mean concentration of PM_{10} during 2015-2020 was associated with the increasing daily mean concentration of $PM_{2.5}$ after adjustment for confounding factors (Table 4).

TABLE 4. Association of the daily mean PM_{10} concentrations and the daily mean $PM_{2.5}$ concentrations during 2015-2020 using multiple linear regression analysis

Associated factors	B	SE	*p*-value
Chiang Mai Province[a]	0.818	0.006	<0.001*
Chiang Rai Province[b]	0.850	0.008	<0.001*
Mae Hong Son Province[b]	0.927	0.006	<0.001*
Nan Province[c]	0.834	0.005	<0.001*

*p <0.01

[a]Adjust with NO_2, SO_2, O_3, WS, WD, temp, RH, rain, I00-I99, J00-J99.8, L00-L99, H10-H19.8, C00-D48, and R21

[b]Adjust with CO, NO_2, O_3, WS, WD, temp, RH, rain, I00-I99, J00-J99.8, L00-L99, H10-H19.8, C00-D48, and R21

[c]Adjust with CO, NO_2, SO_2, O_3, WS, WD, temp, RH, rain, I00-I99, J00-J99.8, L00-L99, H10-H19.8, C00-D48, and R21

DISCUSSION

Long-term exposure to air pollution is associated with chronic and respiratory diseases such as COPD, asthma, pulmonary insufficiency, cardiovascular disease, and lung cancer due to smaller particle size, especially $PM_{2.5}$, which can penetrate deeply into the lung and cause lung function damage (Lee et al. 2020; Manisalidis et al. 2020; Ramakreshnan et al. 2018; Xing et al. 2016). The results showed that differences between air quality monitoring stations during 2015-2020, and PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, O_3, WS, WD, temp, RH, and rain. Previous research has discovered differences in particulate matter (PM) concentrations in different cities and monitoring station, as well as varying levels of economic growth, which are emitted directly from sources such as industry, agriculture, and transportation (Yang et al. 2020; Zhang & Cao 2015; Zhao et al. 2019).

The annual concentrations of PM_{10} in Chiang Mai, Chiang Rai, Mae Hong Son, and Nan Province during 2019-2020 were higher than the standard of World Health Organization (WHO) standard (15 μg/m^3), while the annual concentrations of $PM_{2.5}$ in Chiang Mai, Chiang Rai, Mae Hong Son, and Nan Province during 2019-2020 were higher than the standard of the NAAQS standard (12 μg/m^3) and WHO standard (5 μg/m^3) as shown in Table 1 (EPA 2021; WHO 2021). Previous studies showed that the high concentrations of PM_{10} and $PM_{2.5}$ have become the main cause of the haze problem, which is usually caused by agricultural burning, forest fires, biomass open burning, and the transboundary effect of air pollution from neighbouring countries in Chiang Mai Province, Chiang Rai Province, and Mae Hong Son Province (Arunrat et al. 2018; Kim Oanh & Leelasakultum 2011; Kliengchuay et al. 2018; Wiriya et al. 2013). Moreover, the study has confirmed that the PM_{10} concentrations in Northern Thailand were high throughout the burning season (Mueller et al. 2020; Wiriya et al. 2013). The highest concentration of PM_{10} is seen during dry season in the upper north of Thailand (Kim Oanh & Leelasakultum 2011; Kliengchuay et al. 2021, 2018; Wiriya et al. 2013).

In addition, the findings showed discrepancies across air quality monitoring stations from 2015 to 2020, as well as I00-I99, J00-J99.8, L00-L99, H10-H19.8, R21, and C00-D48. The daily mean concentrations of PM_{10} and $PM_{2.5}$ during 2015-2020 was positively associated with CO, NO_2, SO_2, O_3, I00-I99, J00-J99.8, L00-L99, H10-H19.8, R21, and C00-D48, while the daily mean concentrations of PM_{10} was positively associated with $PM_{2.5}$. Previous research has discovered a link between air pollution mass concentrations, meteorological conditions, and chronic lower respiratory diseases (Anderson et al. 2012; Kliengchuay et al. 2018; Mueller et al. 2020;

Ramakreshnan et al. 2018; Requia et al. 2018). The highest cumulative number of I00-I99, J00-J99.8, L00-L99, H10-H19.8 and C00-D48 in Chiang Mai Province was measured during 2015-2020, while the highest cumulative number of R21 in Chiang Rai Province was measured from 2016 to 2020. The lowest annual cumulative number of I00-I99, J00-J99.8, L00-L99, H10-H19.8 and C00-D48 in Mae Hong Son Province was measured during 2015-2020, while the lowest annual cumulative number of R21 were Nan Province. Previous studies have found a significant correlation between the increasing respiratory diseases and air pollution such as bronchitis, upper respiratory tract infection, COPD, asthma, and lung disease (Anderson et al. 2012; Jiang et al. 2016; Requia et al. 2018; Ma et al. 2020; Mueller et al. 2020; Xie et al. 2020). Other risk factors for chronic respiratory disorders include tobacco use, indoor air pollution, outdoor air pollution, unhealthy diet, allergies, and non-modifiable risk (age and heredity), as well as environmental and occupational exposures (Cruz 2007; Gakidou et al. 2017; Li et al. 2020).

The results showed that the daily mean concentrations of PM_{10} and $PM_{2.5}$ during 2015-2020 was associated with respiratory diseases and related health problems in Chiang Mai Province, Chiang Rai Province, Mae Hong Son Province, and Nan Province). Exposure to PM_{10} has been linked to chronic respiratory disorders, cerebrovascular disease, and cardiovascular outpatient visits, according to studies (Anderson et al. 2012; Mueller et al. 2020). Researchers conclude that exposures to $PM_{2.5}$ have been positively associated with chronic respiratory diseases, cardiovascular and cerebrovascular disease, since PM can cause direct damage to the respiratory system (reduced lung function, asthma and COPD) and circulatory system, as well as higher morbidity and mortality (Anderson et al. 2012; Requia et al. 2018). Therefore, it is necessary to reduce biomass burning pollution (Mueller et al. 2020). Education and behavioural modification measures, as well as policymakers and legislation, should be offered for better health (Anderson et al. 2012).

The multiple linear regression analysis showed that an increasing daily mean concentration of PM_{10} during 2015-2020 is significantly associated with an increasing daily mean concentration of $PM_{2.5}$, after adjustment for confounding variables. Previous research has found a link between daily mean PM_{10} and $PM_{2.5}$ concentrations and daily mortality and respiratory mortality (Chae et al. 2021; Guo et al. 2014; Kim et al. 2017; Liu et al. 2019; Mueller et al. 2020).

Conclusion

The daily mean concentrations of PM_{10} and $PM_{2.5}$ were positively associated with CO, NO_2, SO_2, O_3, I00-I99, J00-J99.8, H10-H19.8, R21, and C00-D48. Moreover, an increasing daily mean concentration of PM_{10} was linked with an increasing daily mean concentration of $PM_{2.5}$ after adjustment for confounding variables. This indicates that PM was associated with repiratory diseases and related health problems, but the difference in particulate matter (PM) concentrations air pollutants depends on several factors including different economic development, different cities, different monitoring station, sources of air pollution (industry, agriculture, and transportation), anthropogenic emissions, and meteorological conditions. Importantly, the literature review showed that the haze problem in Northern Thailand may be affected by the high concentrations of PM_{10} and $PM_{2.5}$ during the dry season, which is usually caused by agricultural burning, forest fires, and the transboundary effect of air pollution from neighbouring countries especially, biomass open burning. Therefore, it is necessary to reduce biomass burning pollution during the dry season. Further studies are needed to provide health education programs and behaviour change interventions for better health including providing policymakers and legislation.

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