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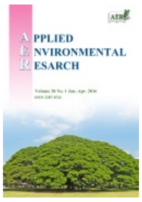

Relationship between Annual Average Concentration of Ambient PM_{10} and Out-patients with Respiratory Disease: Thailand Case Study

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Abstract

The objectives of this research were to identify (1) correlation between annual average concentration of ambient PM_{10} and prevalence of out-patients with respiratory diseases; (2) the relative risk and attributable proportion of out-patients with respiratory disease due to long-term exposure to ambient PM_{10}; and (3) the correlation between annual average concentration of ambient PM_{10} and the relative risk of out-patients with respiratory disease. Time-series data of annual average concentration of ambient PM_{10} and prevalence rate of out-patients with respiratory disease during an 11- year period (2004-2014) in the study area were obtained from the Pollution Control Department, Ministry of Natural Resources and Environment, and the Bureau of Policy and Strategy, Ministry of Public Health, respectively. To estimate the relationship, Pearson's product moment correlations between variables were calculated and significance testing of correlation coefficients were carried out. A retrospective cohort method was used to study the annual average concentration of ambient PM_{10} ratio, the relative risk and the attributable proportion. No association was found between the annual average concentration of ambient PM_{10} and the prevalence rate of out-patients with respiratory disease; however, there was a highly significant positive relationship between the annual average concentration of ambient PM_{10} ratio and the relative risk of out-patients with respiratory disease ($r = 0.852$, $df = 4$, $p < 0.05$). The relative risk of out-patients with respiratory disease due to exposure to the annual average concentration of ambient PM_{10} equal to or higher than 30 $\mu g/m^3$ varied within the range of 0.99 - 1.14, and the attributable proportion of out-patients with respiratory disease were about 10 % and 3 % attributed to exposure to the annual average concentration of ambient PM_{10} higher than 30 $\mu g\ m^{-3}$ and 40 $\mu g\ m^{-3}$, respectively.

Keywords: Air pollution; PM_{10}; Risk ratio; Particulate matter; Public health effect

Introduction

Particulate matter is a widespread air pollutant, consisting of a mixture of solid and liquid particles suspended in the air. Indicators describing particulate matter that are relevant to health refer to the mass concentration of particles with diameter of less than 10 μm (PM_{10}). Health effects resulting from short- and long-term exposure include respiratory and cardiovascular morbidity and mortality form cardiovascular and respiratory diseases [1]. The health impacts associated with concentrations of suspended particles include effects such as coughs, asthma, bronchitis, respiratory illness and mortality; exposure to particulate pollution contributes to the incidence and progress of chronic illnesses. The impacts include increased risk of influenza and exacerbation of asthma symptoms in children and in babies [2-3]. High PM_{10} levels in ambient air was found to be associated with restrictive, obstructive, and combined types of lung function deficits in children [4]. High levels of PM_{10} were also strongly associated with wheezing symptoms; respiratory symptoms were found to have a statistically significant positive association with airborne PM_{10} levels [5], and a strong statistical significant positive association was observed between PM_{10} levels and the prevalence of lower respiratory tract symptoms [6]. The effects of ambient PM_{10} on cause-specific respiratory disease mortality were strongest for pneumonia and increase in PM_{10} was associated with increase in mortality for total respiratory disease, chronic lower respiratory disease, and chronic obstructive pulmonary disease [7].

For long-term exposure to ambient PM_{10}, the annual mortality of adults would increase resulting from increase in annual concentration of PM_{10}. The average lifespan of residents would be prolonged, and premature deaths avoided if the annual PM_{10} concentration were reduced to below 20 $\mu g\ m^{-3}$, the WHO guideline value [1-8]. Prolonged exposure to particulate pollution increase risks of chronic bronchitis, chronic obstructive pulmonary disease and cardiovascular disease [3]. Further, during 1983-2013, respiratory system diseases always been the most common disease among out-patients in Thailand, with a prevalence rate in 2013 of 418.25 per 1,000 out-patients [9]. Therefore, the objective of this research was to elucidate the relationship between long-term exposure to annual average concentration of ambient PM_{10} and respiratory diseases among members of the public, and especially among out-patients with respiratory disease. The relative risk and the attributable proportion of out-patients with respiratory disease due to long term exposure to ambient PM_{10} were also studied. The correlation between the annual average concentration of ambient particulate matter with an aerodynamic diameter of less than 10 μm and the prevalence rate of outpatients with respiratory disease as well as correlation between the annual average concentration of ambient PM_{10} ratio and the relative risk of these patient were investigated in order to identify whether long-term exposure to ambient PM_{10} or annual average concentration of ambient PM_{10} affects the prevalence or relative risks of out-patients with respiratory disease.

Data analysis and methods

1) Data

Time-series data for 11 consecutive years (2004-2014) covering annual average concentrations of ambient PM_{10} were obtained from the Pollution Control Department, Ministry of Natural Resources and Environment [10]. Populations were selected for study in provinces with functioning ambient air monitoring stations and a prevalence of out-patients with respiratory diseases. Quota sampling was applied to identify sample sites in eight provinces of Thailand- Chiang Mai, Lampang, Khon Kaen, Nakhon Ratchasima, Nonthaburi, Chonburi, Songkhla, and Phuket. Data for annual average concentrations of ambient PM_{10} in the provinces with one ambient air monitoring station i.e. Khon Kaen, Nakhon Ratchasima, Songkhla, and Phuket derived from the Pollution Control Department were used and the average number of air samples analyzed for ambient PM_{10} concentration in one year at each province were 321 ± 12 (95 % CI) samples. For the others, four provinces that have more than one ambient air monitoring station i.e. Chiang Mai, Lampang, Nonthaburi, and Chonburi, the represented data of the annual average concentration of ambient PM_{10} of each year were the combined mean. The combined mean, which is the arithmetic mean of several sets of data combined into a single arithmetic mean for the combined datasets [11] was calculated from all stations located in that province. For each province at the year calculated, the combined mean was calculated by the equation of combined means as follows Eq. 1.

$$\sum xi\mu i \sum / xi, \ i = 1 - n \qquad \text{(Eq. 1)}$$

where i = number of station, x = number of samples analyzed for ambient PM_{10} concentration and μ = the annual average concentration of ambient PM_{10}.

The average number of samples analyzed for ambient PM_{10} concentration throughout the year at one ambient air monitoring station located in the provinces that have more than one ambient air monitoring station was 326 ± 7 (95 %CI) samples.

Data of the prevalence of out-patients with respiratory disease in the study area during the specific period of this research were collected from the Bureau of Policy and Strategy, Ministry of Public Health [12]. The prevalence, presented in per 1,000 persons per year was the period prevalence of the province, which was the number of people in a population who had visited as an out-patients with respiratory disease in the past year. The numerator was the number of existing cases, both newly and previously diagnosed, of out-patients with respiratory disease at a specified time and the denominator was the mid-interval or mid-year population [9-12]. During the study period, no data were available for the annual average concentration of ambient PM_{10} for one year in one province, therefore, the total number of the available data from eight provinces during 11 consecutive years were 87 pairs of variables.

2) A retrospective cohort method

A retrospective cohort study is an observational analytical epidemiology, used to quantify the association between exposure and outcomes that have already occurred [13]. For the retrospective cohort method, a cohort was grouped according to intensity of the causative factor i.e. the annual average concentration of ambient PM_{10}, and ambient PM_{10} annual average guidelines by WHO of 20 $\mu g\ m^{-3}$ [1], European Union of 40 $\mu g\ m^{-3}$ [3], and Thailand ambient PM_{10} annual average standard of 50 $\mu g\ m^{-3}$ [10] were the criteria for dividing independent variable into 4 groups. The independent variable or the intensity of the causative factor or the annual average concentration of ambient PM_{10} were divided into 4 groups (A, B, C, D) i.e. the range of the annual average concentration of ambient PM_{10} between 20-29.99 $\mu g\ m^{-3}$ (A), 30-39.99 $\mu g\ m^{-3}$ (B), 40-49.99 $\mu g\ m^{-3}$ (C) and 50-59.99 $\mu g\ m^{-3}$ (D), respectively. The annual average concentration of ambient PM_{10} ratio, the relative risk or the risk ratio as well as the attributable proportion of out-patients with respiratory disease were calculated according to the intensity of exposure to the causative factor - the annual average concentration of ambient PM_{10}, of a cohort. To calculate the ratio of annual average concentration of ambient PM_{10}, the numerator and the denominator were different categories of the annual average concentration of ambient PM_{10} such as mean of the annual average concentration of ambient PM_{10} representing the range of 20-29.99 µg m^{-3} (A), and 30-30.99 µg m^{-3} (B), respectively. The relative risk and the attributable proportion of out-patients with respiratory disease were also calculated according to grouping of a cohort exposed to different categories of the annual average concentration of ambient PM_{10}.

3) Statistical method

The Pearson's product moment correlation coefficient (*r*) was used to measure the strength of association between a pair of variables, to test the relationship between these variables and to test whether the association is greater than could be expected by chance [14]. Significance testing of the correlation coefficient was conducted and the coefficient of determination (r^2) as well as percentage of the variable having in common (R^2) were calculated. The correlation coefficient (*r*) is used in environmental research where the observer has no control over the variables and the coefficient of determination (r^2) offers a useful way to determine the importance of the correlation, by measuring the proportion of the variation in one variable that is explained by the variation in the other variable. If the Pearson's product moment correlation coefficient (*r*), a parametric test for measuring correlation, is +1 or –1, then the variation in both variables is perfectly matched. The nearer the correlation coefficient is to zero, the less correlation there is between the variables. Further, the coefficient of determination describes the proportion of the variable that the two variables have in common. It is calculated as the square of the value of r value (i.e. r^2), and multiplying this value by 100, called R^2, to express the percentage that the two variables have in common [15].

In this research, mathematical calculation and statistical analysis were performed using Microsoft Excel 2016 [16]. The Pearson's product moment correlation coefficient between the annual average concentration of ambient PM_{10} and the prevalence rate of out-patients with respiratory disease, and the correlation coefficient between the annual average concentration of ambient PM_{10} ratio and the relative risk of out-patients with respiratory disease were calculated. Then, the coefficient of determination (r^2) and percentage of the two variables having in common (R^2) were calculated. In addition, significant testing of the correlation coefficient takes the two-tailed form and critical tables for the correlation coefficient (*r*) are two tailed. Hypothesis testing was achieved by consulting the critical value of (*r*) with *n*-2 degrees of freedom. If the modulus of (*r*) is greater than the tabulated value for the specified *p* value (0.05), the null hypothesis i.e.: the correlation coefficient is zero: is rejected. And, the relationship $t = r\ [(n\text{-}2)^{1/2}]/(1\text{-}r^2)$, which transforms the correlation coefficient (*r*) to the value of *t* statistic was calculated to check significance of the correlation coefficient by using *t* statistic with level of significance for two-tail test at 0.05 *p* value [14-15]. A flowchart summarizing data analysis and methods is displayed in Figure 1.

Results and discussion

1) Relationship between the annual average concentration of ambient PM_{10} and the prevalence rate of out-patients with respiratory disease

Data of the annual average concentration of ambient PM_{10} and the prevalence rate of out-patients with respiratory disease in the eight studied provinces were plotted in time order, showing fluctuation over time as shown in Figure 2; additional data are provided in Table 1.

A series of the annual average concentration of ambient PM_{10} and a series of the prevalence rate of out-patients with respiratory disease in the study area over 11 consecutive years of the study period varied within the range of 18.00-77.40 µg m^{-3} and 253.63 - 594.76 per 1,000 persons per year, respectively.

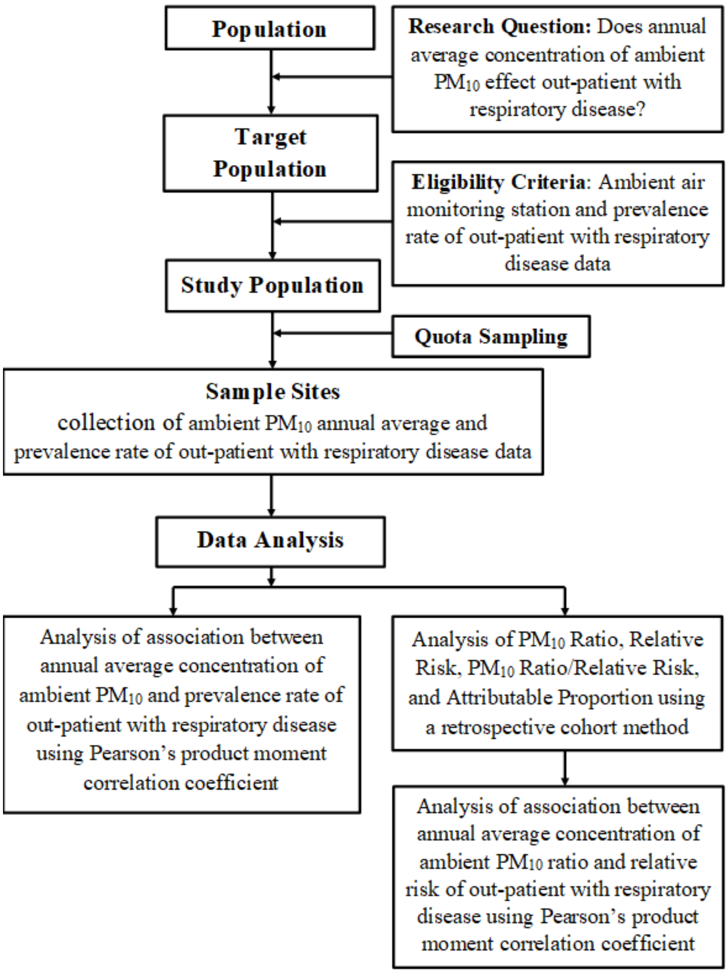

Figure 1 A flowchart summarizing data analysis and methods.

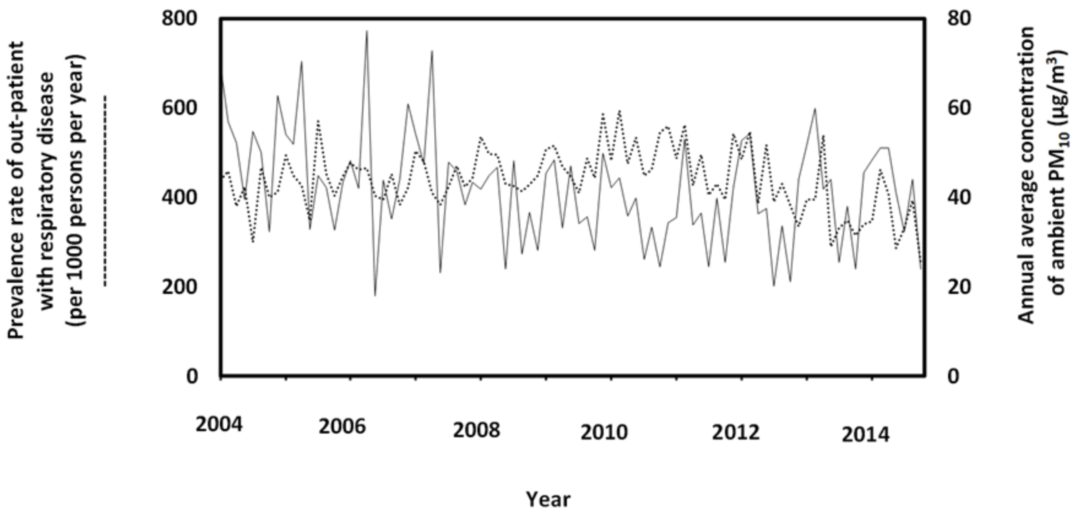

Figure 2 Time-series data of the annual average concentration of ambient PM_{10} and the prevalence rate of out-patients with respiratory disease of the eight studied provinces.

Table 1 The annual average concentration of ambient PM_{10} and the prevalence rate of out-patients with respiratory disease during 11 consecutive years of the eight studied provinces

Province	2004		2005		2006		2007	
	PM_{10}*	PR**	PM_{10}*	PR**	PM_{10}*	PR**	PM_{10}*	PR**
Chiang Mai	69.28	438.98	54.16	494.75	48.16	476.49	54.23	503.67
Lampang	56.88	459.00	51.87	448.49	42.09	462.85	47.54	480.20
Nakhon Ratchasima	52.30	380.42	70.50	426.82	77.40	465.37	72.80	411.03
Khon Kaen	39.50	424.14	32.90	348.54	18.00	403.11	23.10	383.01
Nonthaburi	54.67	300.13	44.83	571.48	43.86	395.47	47.96	423.47
Chonburi	49.99	466.41	42.25	451.79	35.12	452.77	45.94	469.96
Songkhla	32.30	400.37	32.60	403.75	44.10	384.00	38.30	422.93
Phuket	62.80	412.08	43.40	446.89	60.90	422.70	43.40	443.15
	2008		**2009**		**2010**		**2011**	
Chiang Mai	41.83	536.29	45.41	507.10	49.91	585.26	34.42	559.54
Lampang	44.90	497.49	48.46	515.08	42.27	482.50	35.46	487.54
Nakhon Ratchasima	46.70	496.47	n/a	552.51	44.30	594.76	53.00	562.80
Khon Kaen	23.90	430.88	33.20	468.75	35.80	475.98	33.90	427.72
Nonthaburi	48.20	425.24	47.13	447.86	39.86	533.80	36.53	496.02
Chonburi	27.34	413.56	34.15	410.03	26.19	448.81	24.52	404.71
Songkhla	36.70	429.20	35.60	487.79	33.30	461.93	39.80	430.17
Phuket	28.20	449.64	28.10	443.35	24.50	545.92	25.40	395.04
	2012		**2013**		**2014**			
Chiang Mai	42.15	543.08	43.98	335.41	45.48	339.73		
Lampang	52.81	486.06	51.72	394.55	48.39	347.19		
Nakhon Ratchasima	54.30	547.65	60.00	395.78	51.00	461.51		
Khon Kaen	36.30	387.18	41.95	538.59	51.00	407.58		
Nonthaburi	37.44	516.95	44.01	289.25	41.00	286.51		
Chonburi	20.08	390.03	25.49	332.45	32.26	331.67		
Songkhla	33.60	430.04	38.00	348.11	44.00	392.80		
Phuket	21.10	381.27	24.00	314.85	24.00	253.63		

Note: *Annual average concentration of ambient PM_{10} ($\mu g\ m^{-3}$)
**Prevalence rate of out-patients with respiratory disease (per 1,000 persons per year)

The scatter graph of the annual average concentration of ambient PM_{10} versus the prevalence rate of out-patients with respiratory disease were plotted as shown in Figure 3. The association between the annual average concentration of ambient PM_{10} and the prevalence rate of out-patients with respiratory disease shows Pearson's product moment correlation coefficient (r) = 0.191 then consult the table r values at $df = n\text{-}2 = 85$. The value of 0.191 is lesser than the $p < 0.05$ table value [14]. Therefore, there was no correlation between annual average concentration of ambient PM_{10} and the prevalence of out-patients with respiratory disease. In addition, significance testing of the correlation coefficient was conducted by using the t statistic; the value of the t statistic was calculated as 1.794, which is lower than the table value of t, $p < 0.05$ for $df = 85$, (two tailed) [14-15]. Thus, the t statistic also shows no evidence for association between the annual average concentration of ambient PM_{10}

and the prevalence rate of out-patients with respiratory disease. Therefore, the relationship analysis between the annual average concentration of ambient PM_{10} and the prevalence rate of out-patients with respiratory disease by using the Pearson's product moment correlation coefficient does not reveal any association between these two variables, and other methods such as analytical epidemiology, which can be used to quantify the association between exposure and outcomes [13] should therefore be applied.

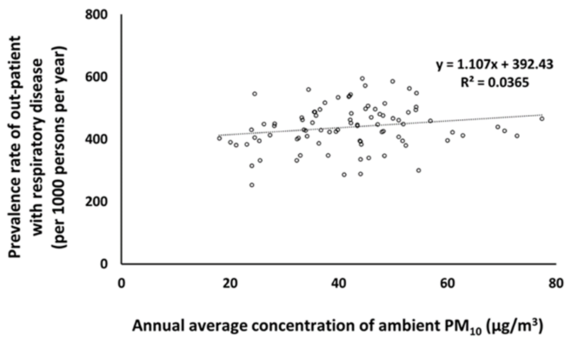

Figure 3 Scatter graph of annual average concentration of ambient PM_{10} and prevalence of out-patients with respiratory disease.

2) A cohort category, the relative risk and the attributable proportion of out-patients with respiratory disease

The intensity of exposure to the annual average concentration of ambient PM_{10} was used as a causative factor to form a group of cohorts as shown in Table 2. The independent variable or the cause was the annual average concentration of ambient PM_{10} and the dependent variable was the prevalence of out-patients with respiratory disease in a cohort group. According to different intensity of exposure to the annual average concentration of ambient PM_{10}, a cohort category was divided into 4 groups, which were equal to 79 groups of cohorts because data of the independent variable or the annual average concentration of ambient PM_{10} were not available for one point and out of analytical range for eight points e.g. the annual average concentration of ambient PM_{10} below 20 µg m^{-3} for one point and higher than 59.99 µg m^{-3} for seven points. Thus, there were 14, 23, 30, and 12 groups of cohorts exposed to the annual average concentration of ambient PM_{10} within the range of 20-29.99 µg m^{-3} (A), 30-39.99 µg m^{-3} (B), 40-49.99 µg m^{-3} (C), and 50-59.99 µg m^{-3} (D), respectively.

Table 2 A cohort category exposed to the annual average concentration of ambient PM_{10} and the prevalence rate of out-patients with respiratory disease within the cohorts

A cohort category	Range of PM_{10} concentration[a]	Number of cohort groups	Mean (95%CI) PM_{10}[b]	Mean (95%CI) Prevalence rate[c]
A	20-29.99	14	24.71 ± 1.19	399.08 ± 35.19
B	30-30.99	23	35.52 ± 0.97	440.65 ± 23.43
C	40-40.99	30	45.12 ± 0.91	454.43 ± 28.72
D	50-50.99	12	53.16 ± 0.95	453.88 ± 40.23

Note : [a] Range of annual average concentration of ambient PM_{10} (µg m^{-3})

[b] Mean (95%CI) representing the annual average concentration of ambient PM_{10} (µg m^{-3}) of a cohort category

[c] Mean (95%CI) representing the prevalence rate of out-patients with respiratory disease (per 1,000 persons per year) of a cohort category

A cohort was a group of people who were exposed to the causative factor i.e. the higher annual average concentration of ambient PM_{10}, while the comparison groups were another cohort of individuals exposed to the lower concentration of a causative factor. Results of a cohort case of the annual average concentration of ambient PM_{10} ratio, the relative risk, the ratio of the annual average concentration of ambient PM_{10} ratio to the relative risk and the attributable proportion are shown in Table 3. A ratio of the annual average concentration of ambient PM_{10} (PM_{10} Ratio in Table 3) is the relative magnitude of two quantities calculated as follows Eq. 2.

The relative risk or the risk ratio compares the risk of disease in the exposed group with the risk of disease in the comparison group, while the attributable proportion or the attributable risk percent is the amount of disease in the exposed group attributable to the exposure [13-17]. The relative risk and the attributable risk (%) in Table 3 are calculated as follows Eq. 3.

$$PM_{10}\,Ratio = \frac{\text{Mean representing the higher concentration interval of ambient } PM_{10} \text{ annual average}}{\text{Mean representing the lower concentration interval of ambient } PM_{10} \text{ annual average}} \quad \text{(Eq. 2)}$$

$$Relative\ Risk = \frac{\text{Risk of disease for the exposed group}}{\text{Risk of disease for the comparison group}}$$

$$Attributable\ risk(\%) = \frac{\text{Risk of disease for the exposed group - risk of disease for the comparison}}{\text{Risk of disease for the exposed group}} x\,100\% \quad \text{(Eq. 3)}$$

Where; Risk of disease for the exposed group equals the mean representing the prevalence rate of out-patients with respiratory disease of cohort groups exposed to the higher concentration interval of ambient PM_{10} annual average; and Risk of disease for the comparison group equals the mean representing the prevalence rate of out-patients with respiratory disease of cohort groups exposed to the lower concentration interval of ambient PM_{10} annual average.

Table 3 A cohort case of the annual average concentration of ambient PM_{10} ratio, the relative risk, the ratio of the annual average concentration of ambient PM_{10} ratio to the relative risk, and the attributable proportion or the attributable risk percent of out-patients with respiratory disease

Case[a]	PM_{10} Ratio[b]	Relative Risk	PM_{10} Ratio/Relative Risk [c]	Attributable Risk (%)
B/A	1.44	1.10	1.30	9.43
C/A	1.83	1.14	1.60	12.18
D/A	2.15	1.14	1.89	12.07
C/B	1.27	1.03	1.23	3.03
D/B	1.50	1.03	1.45	2.91
D/C	1.18	0.998	1.18	-0.12

Note : [a] A cohort case exposed to different categories of annual average concentrations of ambient PM_{10}

[b] The annual average concentration of ambient PM_{10} ratio

[c] The ratio of the annual average concentration of ambient PM_{10} ratio to the relative risk

3) Relationship between the annual average concentration of ambient PM_{10} ratio and the relative risk of out-patients with respiratory disease

The Pearson's product moment correlation coefficient was used to measure the strength of association between the annual average concentration of ambient PM_{10} ratio and the relative risk of out-patients with respiratory disease. The Pearson's correlation coefficient (r) was found to be 0.852, since n = 6, the degree of freedom, n-2 = 4 and, from table for the critical value of correlation coefficient for the 5 % level of significance, the value of the correlation coefficient is 0.811 [14]. Therefore, there is strong evidence for a positive correlation between the annual average concentration of ambient PM_{10} ratio and the relative risk of out-patients with respiratory disease ($r = 0.852$, $df = 4$, $p < 0.05$). Further, the t statistic was calculated as equal to 3.253. Since the 5 % critical value of t, $p < 0.05$, for $df = 4$, (two tailed) equal to 2.776 [14-15], thus the t statistic confirms a significant positive association between annual average concentration of ambient PM_{10} ratio and the relative risk of out-patients with respiratory disease.

Since the correlation coefficient (r) = 0.852, the coefficient of determination (r^2) = $(0.852)^2$ = 0.725 or R^2 = 72 % , which implies that the annual average concentration of ambient PM_{10} ratio and the relative risk of out-patients with respiratory disease having 72 % variation in common. This does not imply that the ratio of the annual average concentration of ambient PM_{10} directly influences the relative risk of out-patients with respiratory disease and other variables likely to be involved. Various factors such as composition of particles, population characteristic and other air pollutants are influencing human respiratory disease [2-18]. Thus, the ratio of the annual average concentration of PM_{10} ratio to the relative risk of out-patients with respiratory disease was calculated based on the assumption that all confounders affected respiratory disease were ignored. It was found that, on average, the ratio of the annual average concentration of ambient PM_{10} ratio to the relative risk of out-patients with respiratory disease was equal to 1: 1.4±0.2 (95 %CI). Therefore, it might be concluded that increasing annual average concentration of ambient PM_{10} for 1 time cause increasing in the relative risk of out-patients with respiratory disease for 1.4±0.2 (95 %CI) times if we ignored all confounders influencing respiratory disease.

The potential confounders that may influence the analysis of cohort study such as diet, smoking and socio-demographic factors [19], as well as central site measurement of ambient PM_{10} concentration, which are crucial in the study of health effect of air pollution [20] were not considered for this retrospective cohort epidemiology study. In addition, on average, results of the study found that change in annual average concentration of ambient PM_{10} of about 9.48±1.28 (95 %CI) μg m^{-3} generated a relative risk of 1.073±0.045 (95 %CI). Regarding the relative risk value, there had study from Khaniabadi et al. [21] showed health impact attributed to PM_{10} during 2014-2015 in Kermanshah City of Iran that a 10 μg m^{-3} change in PM_{10} generated a relative risk of 1.066.

The prevalence rate of out-patients with respiratory disease within a cohort category reflects the penetration of a respiratory disease within a population because the prevalence rate is the proportion of the population that has health condition at a point in time, reflecting the presence of disease in a population while the relative risk or risk ratio is the ratio of probability of an event occurring [13-17], for example, developing of a respiratory disease, in an exposed group to the probability of the event occurring in a comparison group. The relative risk or the risk ratio can be calculated for occurrence of respiratory illness between two cohort groups, that were the proportion of persons in a population or people who exposed to different intensity of the annual average concentration of ambient PM_{10}. The relative risk greater than 1.0 indicates an increased risk for the group on the numerator [13-17-22] - the exposure to the higher annual average concentration of ambient PM_{10}.

The relative risk of cohorts exposed to the annual average concentration of ambient PM_{10} equal to or higher than 30 μg m^{-3} when compared with the comparison groups i.e. the cohorts exposed to the annual average concentration of ambient PM_{10} 20-29.99 μg m^{-3} varied within the range of 1.10-1.14. A relative risk of 1.1 may seems so small, but the relative risk more than one has the usual meaning of increased risk [22], therefore, morbidity from respiratory disease is more likely to occur in populations exposed to annual average concentrations of ambient PM_{10} higher than 30 μg m^{-3}.

The results of the attributable proportion suggest that about 3-12 % of morbidity with respiratory disease among populations with long-term exposure to concentrations of ambient PM_{10} higher than 30 μg m^{-3} might be attributable to ambient PM_{10} pollution and the remaining 88-97 % of their morbidity with respiratory disease would have occurred. The attributable proportion or the attributable risk percent was used to measure public health impact [13-17] resulting from long term exposure to ambient PM_{10}, reflecting the burden that an exposure contributed to the frequency of disease in the population. The calculation of the attributable proportion assumes that the occurrence of out-patients with respiratory disease in those who exposed to the lower annual average concentration of ambient PM_{10} represents baseline or the expected risk for the disease. It further assumes that if the risk of respiratory disease in those who exposed to the higher annual average concentration of ambient PM_{10} is higher than the risk in those who exposed to the lower annual average concentration of ambient PM_{10}, the difference can be attributed to the exposure. Thus, the attributable proportion is the amount of disease in the exposed group attributable to the exposure. It presents the expected reduction in disease if the exposure could be removed [13-17]. Therefore, about 10 % and 3 % of out-patients with respiratory disease in those who exposed to annual average concentration of ambient PM_{10} higher than 30 μg m^{-3} and 40 μg m^{-3} attributable to their exposure. To understand the reason why, the attributable proportion of the annual average concentration of ambient PM_{10} higher than 30 μg m^{-3} (10 %) is higher than that of 40 μg m^{-3} (3 %) there might be from annual average concentration of ambient PM_{10} in the air higher than 40 μg m^{-3} is more polluted than that of 30 μg m^{-3}, thus confounding variables that can affect human respiratory system, such as other air pollutants and composition of particles might play an important role in addition to population characteristic [2-8], and further study of ambient PM_{10} concentration and respiratory health effect is necessary for a better understanding of the public health impact of ambient PM_{10} concentration.

For long-term exposure to ambient PM_{10}, increase in level of annual average concentration of ambient PM_{10} affects the respiratory system, and reduction in concentration of annual average concentration of ambient PM_{10} will bring respiratory health benefits to the public, following the study of Xie et al. [8], which concluded that for long-term exposure, reduction in concentration of PM_{10} would deliver health benefits. Since the annual average concentration of ambient PM_{10} suggested by WHO is 20 μg m^{-3} and there is no evidence of a safe level of exposure or a threshold below which no adverse health effect occur, relatively low concentrations of particulates generate a significant public health burden [1]. In addition, Remy et al. [23] reported that 5.5 % of the mortality was attributable to PM_{10} concentration higher than 20 μg m^{-3} and a reduction in concentration of annual mean PM_{10} to the level of 20 μg m^{-3} would lead to a substantial health benefit for the population. Thus, the annual standard of ambient PM_{10} concentration should be revised to protect the public from respiratory disease, especially for long term exposure. Further, evidence suggests that decreased levels of particulate air pollution following a sustained intervention can result in health benefits for the population. Interventions may range from regulatory measures, i.e. more stringent air quality standards and limits for industrial emissions, structural change such as reducing energy consumption based on combustion sources, changing modes of transport, land use planning as well as behavioral changes by individuals by using cleaner modes of transport or household energy sources [1].

Conclusion

This study found no association between the annual average concentration of ambient PM_{10} and the prevalence rate of out-patients with respiratory disease ($r = 0.191$, $df = 85$, $p < 0.05$). However, the study found a highly significant positive correlation between annual average concentration of ambient PM_{10} ratio and the relative risk of out-patients with respiratory disease ($r = 0.852$, $df = 4$, $p < 0.05$). The relative risk of out-patients with respiratory disease due to exposure to the annual average concentration of ambient PM_{10} equal to or higher than 30 μg m^{-3} compared with those exposed to the annual average concentration of ambient PM_{10} 20-29.99 μg m^{-3} varied within the range of 1.10-1.14 and changing in annual concentration of ambient PM_{10} of about 9.48 ± 1.28 (95 %CI) μg m^{-3} generated a relative risk of 1.073 ± 0.045 (95 %CI). An annual average concentration of ambient PM_{10} above 30 μg m^{-3} and 40 μg m^{-3} resulted in an attributable risk to respiratory system illness for the general public of about 10 %, and 3 %, respectively. Based on this research finding, it can be concluded that for long-term exposure, increase in level of ambient PM_{10} concentration above 30 μg m^{-3} adversely affects the human respiratory system. Reduction in the annual average concentration of ambient PM_{10} to below 30 μg m^{-3} will bring significant respiratory health benefits to the general public. Therefore, Thailand's minimum standard for ambient PM_{10} of 50 μg m^{-3} should be revised downwards.

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