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Review

Air Quality and Lung Cancer in South Korea and Thailand: A comparative study.

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Abstract

Background: Air quality is deteriorating worldwide due to increase in environmental emissions. Outdoor air pollution was responsible for approximately 3.7 million deaths in the year 2012. The combination of indoor and outdoor air pollution is among the largest risks to human health worldwide which has not spared South Korea and Thailand.

Methods: A comparative cohort study on air quality and lung cancer between South Korea and Thailand was conducted nested on several data sources namely, World Health Organization particulate matter databases 2011, 2014, 2016; GLOBOCAN 2012, Numbeo, and World Health Disease Rankings databases. 7 cities in South Korea and 14 cities in Thailand were systematically sampled from WHO Air Pollution databases. We used multivariate computation and ANOVA in data analysis using IBM SPSS Statistics software version 21.

Results: The burden of lung cancer is more in South Korea than in Thailand. 95% CI of Air Quality Index (AQI) for South Korea ranged from 48.38 – 89.90 while that of Thailand ranged from 70.72 – 73.06. Air pollution 95% CI of the difference for South Korea ranged from 47.14 – 53.80 while that of Thailand ranged from 38.49 – 44.99 with ANOVA p-value of 0.000.

Conclusion: The burden of lung cancer as well as PM concentration is higher in South Korea than in Thailand. Although the overall quality of life is better in South Korea than in Thailand, lung cancer burden and air pollution is the opposite between the two countries.

Keywords: Air quality; Lung Cancer; Particulate Matter

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Introduction

Air quality landscape is deteriorating worldwide due to increasing environmental emissions such as motor vehicle exhaust gases, industrial discharges, coal smoke and indoor emissions from burning biomass among others[1]. Outdoor air pollution was responsible for the deaths of approximately 3.7 million people under the age of 60 in the year 2012. The combination of indoor and outdoor air pollution is among the largest risks to human health worldwide [1].

On the global scale, lung cancer is the leading cause of cancer deaths in men and the second leading cause of cancer deaths in women. Approximately 1.7 million deaths have been reported worldwide due to lung cancer in the year 2015 [2, 3]. In Asia, the burden of lung cancer is significantly large; South Central Asia reported the highest lung cancer mortality rates in men while the lowest rates have been reported among women in the same region [4-6]. The variations in the burden of lung cancer by country largely reflect differences in the degree of environmental exposures [7]. This is evident from many epidemiological studies that have been conducted to examine the extent of exposure and outcome. For instance, the burden of lung cancer is higher among Chinese women than women in many European Countries because of their high exposure to indoor air pollution from unventilated coal-fueled stoves and from cooking fumes [7-9].

The burden of lung cancer is also seen to increase in countries undergoing industrialization and urbanization due to high levels of ambient air pollution generated from increased motor vehicle exhaust gas fumes and industrial emissions among others [6, 7]. In this study, we hypothesized that the increase in environmental emissions would result into poor air quality and increase in the burden of lung cancer in South Korea and Thailand. This study therefore aimed at analyzing and comparing the air quality landscape and the burden of lung cancer between South Korea and Thailand which are two identical countries lying in the eastern and southern part of People's Republic of China respectively on the continent of Asia where the burden of lung disease is on the increase.

Materials and Methods

We conducted a comparative cohort study on air quality and lung cancer between South Korea and Thailand nested on several data sources namely, the databases of the World Health Organization Ambient Air Pollution (2011, 2014 and 2016), the global cancer database -GLOBOCAN 2012, the Number air quality database, and World Health Disease Rankings database.

Ambient air pollution (PM10) cohort data were extracted from the World Health Organization Ambient Air Pollution databases 2011, 2014 and 2016. These WHO databases are made up of annual submissions of particulate matter (PM10 and PM2.5) data from designated sampling sites by countries worldwide while data on lung cancer cases and deaths were extracted from GLOBOCAN 2012 database [3]. Data on all forms of cancer are transmitted to WHO and are integrated in the GLOBOCAN database. Cancer projections are also made based on the GLOBOCAN database. We further extracted data from Numbeo database for air quality assessment while the 'World Health Disease Rankings database [4] was used to determine demographic statistics.

We systematically sampled 7 cities in South Korea and 14 cities in Thailand from the World Health Organization Ambient Air Pollution databases 2011, 2014 and 2016 on PM10. These cities are contained in all the three databases thus giving us the air pollution cohort by city. The cohort of Air Quality Index from 2013 to 2016 was extracted from Nambeo database. We used multivariate computation and one way ANOVA in analyzing the cohort data using IBM SPSS Statistics software version 21.

Concerning data quality, we would like to mention that the GLOBOCAN database has almost all countries data on lung cancer burden while WHO ambient air pollution databases do not have all countries' data on both PM10 and P2.5. However, data for countries under study were available in the databases. World Health Disease Rankings database has almost all countries data while Numbeo database does not have data for all countries.

Results

In order to have a better understanding of the air quality landscape and lung cancer trends between South Korea and Thailand, we started by analyzing key demographic indicators such as population, birth rate, death rate, sex ratio, population growth, health life expectancy, unemployment and GDP per capita among other indicators in order to understand the quality of life between the two countries.

The population of South Korea stands at 50,924,172 and is ranked 28th in the world while that of Thailand stands at 68,200,824 and is ranked 21st in the world. The population growth rate of South Korea is 0.53% and is ranked 137th in the world while that of Thailand is 0.32% and is ranked 149th in the world.

INDICATORS	**SOUTH KOREA**		**THAILAND**	
	STATISTICS	**WORLD RANKING**	**STATISTICS**	**WORLD RANKING**
POPULATION TOTAL	50,924,172	28	68,200,824	21
SEX RATIO M / F	1.00	64	0.97	121
POPULATION 0-14	13.5 %	186	17.2 %	152
POPULATION 15-64	73.0 %	6	72.6 %	8
POPULATION 65 +	13.5 %	47	10.2 %	63
BIRTH RATE / 1000	8.40	188	11.10	157
DEATH RATE / 1000	5.80	152	7.90	88
FERTILITY RATE	1.25	191	1.51	168
INFANT MORTALITY	3.00	184	9.40	134
SEX RATIO AT BIRTH M / F	1.07	11	1.05	58
SEX RATIO UNDER 15 M / F	1.07	13	1.05	49
SEX RATIO 15-64 M / F	1.05	25	0.97	139
SEX RATIO 65 + M / F	0.71	142	0.78	100
NET MIGRATION	2.60	26	0.00	56
POPULATION GROWTH	0.53 %	137	0.32 %	149
LITERACY TOTAL	97.9 %	59	93.5 %	95
LITERACY MALE	N/D	N/D	96.6 %	59
LITERACY FEMALE	N/D	N/D	96.7 %	48
UNEMPLOYMENT	3.6 %	152	0.9 %	172
LIFE EXPECTANCY / BIRTH	82.3	11	74.9	71
HEALTHY LIFE EXPECTANCY	73.2	3	66.8	62
GDP PER CAPITA USD	$36,700	30	$16,100	75

Table 1: Demographic summary of South Korea and Thailand

*N/D Not determined.

South Korea has unemployment rate of 3.6%, ranked 152nd in the world while Thailand's unemployment rate is 0.9% and is ranked 172nd in the world. The GDP per capita in US Dollar terms is $36,700 for South Korea, ranked 30th in the world while Thailand's GDP per capita is $16,100 and is ranked 75th in the world. Table1 shows details of key demographic indicators and global rankings of South Korea and Thailand.

Lung cancer cases have been on an increase in both countries from the year 2012 to the year 2015 although South Korea reported more cases than Thailand in all age groups. In 2012, South Korea reported 22,873 lung cancer cases whereas Thailand reported 19,505 cases. In the year 2015, South Korea reported 25,800 lung cancer cases whereas Thailand reported 21,151 cases. There were more lung cancer cases among males than females in all age groups for both countries. Details of trends and demographic changes are shown in table 2.

SOUTH KOREA	**YEAR**	**AGE GROUP**	**MALE**	**FEMALE**	**BOTH SEXES**
	2012	All ages	15,724	7,149	22,873
		Ages < 65	4,703	2,731	7,434
		Ages >= 65	11,021	4,418	15,439
	2015	All ages	17,854	7,946	25,800
		Ages < 65	5,239	2,976	8,215
		Ages >= 65	12,615	4,970	17,585
		Demographic change			
		All ages	2,130	797	2,927
		Ages < 65	536	245	781
		Ages >= 65	1,594	552	2,146
THAILAND					
	2012	All ages	13,094	6,411	19,505
		Ages < 65	5,770	2,801	8,571
		Ages >= 65	7,324	3,610	10,934
	2015	All ages	14,252	6,899	21,151
		Ages < 65	6,298	3,039	9,337
		Ages >= 65	7,954	3,860	11,814
		Demographic change			
		All ages	1,158	488	1,646
		Ages < 65	528	238	766
		Ages >= 65	630	250	880

Table 2: Lung cancer cases in South Korea and Thailand in 2012 and 2015

Deaths due to lung cancer have also been on an increase in both countries from the year 2012 to the year 2015 although South Korea reported more deaths than Thailand in all age groups. In 2012, South Korea reported 17,848 lung cancer deaths whereas Thailand reported 17,669 deaths. In the year 2015, South Korea reported 20,318 lung cancer deaths whereas Thailand reported 19,158 deaths. There were more lung cancer deaths among males than females in all age groups for both countries. Table 3 shows details of trends and demographic changes.

SOUTH KOREA	YEAR	AGE GROUP	MALE	FEMALE	BOTH SEXES
	2012	All ages	12,783	5,065	17,848

		Ages < 65	3,163	990	4,153
		Ages >= 65	9,620	4,075	13,695
	2015	All ages	14,593	5,725	20,318
		Ages < 65	3,529	1,093	4,622
		Ages >= 65	11,064	4,632	15,696
		Demographic change			
		All ages	1,810	660	2,470
		Ages < 65	366	103	469
		Ages >= 65	1444	557	2,001
THAILAND					
	2012	All ages	11,854	5,815	17,669
		Ages < 65	5,185	2,549	7,734
		Ages >= 65	6,669	3,266	9,935
	2015	All ages			
		Ages < 65	12,889	6,269	19,158
		Ages >= 65	5,647	2,774	8,421
			7,242	3,495	10,737
		Demographic change			
		All ages	1,035	454	1,489
		Ages < 65	462	225	687
		Ages >= 65	573	229	802

Table 3: Lung cancer deaths in South Korea and Thailand in 2012 and 2015

Air Pollution Index for both countries was moderate from the year 2013 to the year 2015 although South Korea reported higher figures than Thailand. In 2016, South Korea Air Quality Index was good while that of Thailand remained moderate. 95% CI of this difference for South Korea ranged from 48.38 to 89.90 while that of Thailand ranged from 70.72 to 73.06. Table 4 shows results of both Pollution Index and Exponential Pollution Index for both countries.

YEAR	**SOUTH KOREA**		**THAILAND**	
	Pollution Index	**Exponential Pollution Index**	**Pollution Index**	**Exponential Pollution Index**
2013	75.57	140.38	72.12	127.24
2014	74.24	136.21	71.13	123.48
2015	77.11	140.95	72.81	126.72
2016	49.65	89.02	71.51	124.15

Table 4: Air Quality Index for South Korea and Thailand

*****API: 0-50 Good; 51-100 Moderate; 101-200 Unhealthy; 201-300 Very unhealthy; 301-500 Hazardous

The cohort of Mean Annual Particulate Matter (PM10) for seven cities of South Korea and fourteen cities of Thailand are shown in table 5. The results show that South Korean Cities reported higher concentration of PM10 than cities in Thailand during the study period.

COUNTRY	**CITIES**	**MEAN ANNUAL PARTICULATE MATTER (PM10)**			
SOUTH KOREA		**YEARS**			
		2007	**2010**	**2012**	**2014**
	Busan	68	49	-	48
	Daegu	64	51	-	45
	Daejeon	49	43	-	41
	Gwangju	52	45	-	41
	Incheon	54	55	-	49
	Seoul	64	49	-	46
	Ulsan	53	48	-	46
THAILAND					
	Bangkok	54	-	38	42
	Chiang Mai	42	-	42	46
	Chiang Rai	33	-	70	49
	Chon buri	27	-	21	32
	Khon Kaen	24	-	36	51
	Lampang	45	-	57	53
	Nakhon Ratchasima	47	-	55	51
	Nakhon Sawan	46	-	38	57
	Narathiwat	29	-	33	29
	Phuket	28	-	21	24
	Rayong	40	-	35	41
	Saraburi	59	-	66	57
	Songkhla	37	-	34	44
	Surat Thani	32	-	38	39

Table 5: Cohort of ambient air pollution by city in South Korea and Thailand

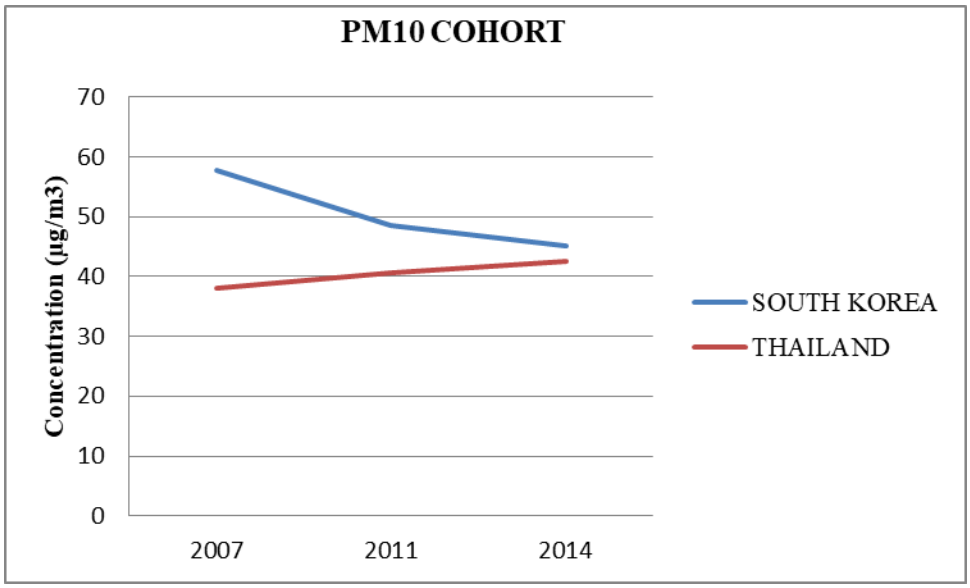

Figure1: PM10 Cohort for South Korea and Thailand

Figure 1 shows the trends of mean particulate matter of South Korea and Thailand. There was a decrease in the concentration of PM10 for South Korea and an increase in the trend for Thailand during the study period.

One way ANOVA showed that there was a significant difference between ambient air pollution trends in South Korea and Thailand from 2007 to 2014 with *p*-value of 0.000 ($p <= 0.05$). 95% CI of the difference for South Korea was 47.14 to 53.80 while that of Thailand was 38.49 to 44.99. Details of the Mean Annual PM10 cohort of the two countries are shown in table 6.

Country	**Mean PM10 Cohort**				***p*-value**
	Years				
	2007	**2010**	**2012**	**2014**	
South Korea	57.71	48.57	-	45.14	0.000
Thailand	38.07	-	40.67	42.53	

Table 6: Mean PM10 Cohort in South Korea and Thailand

*****results significant at $p < 0.05$

Discussion

Demographic statistics have indicated that Thailand (68,200,824) is more populated than South Korea (50,924,172) and that Death rate in Thailand (7.9) is higher than death rate in South Korea (5.8). Life expectancy at birth in South Korea (82.3) is higher than that of Thailand (74.9). However, this comparative cohort study has revealed that lung cancer morbidity in South Korea is higher than that of Thailand. A similar trend has also been observed where lung cancer mortality rate is higher in South Korea compared to Thailand. Although the overall death rate in Thailand is higher than that of South Korea, this study has revealed that lung cancer death rate is actually higher in South Korea than in Thailand.

Epidemiologic studies conducted on cancers have shown that lung cancer is the leading cause of cancer deaths in South Korea [10, 12]. Lung cancer mortality rate is higher in males compared to females .This study has revealed that the burden of lung

cancer in both South Korea and Thailand is higher among males than females despite the fact that both sexes live in the same environment. This is attributed to the fact that more men engage themselves in tobacco smoking compared to women in South Korea and Thailand [13-17].

With reference to the World Health Organization Air Quality Standards, this study has established that the pattern of air quality in South Korea changed from being "moderate" during the years 2013 – 2015 to "good" in the year 2016 while that of Thailand remained "moderate" throughout the study period. Air quality is compromised by air pollution which is a heterogeneous mixture of gases, liquids, and solid particles, which all may be hazardous to health [18].

The main constituents of air pollution along with particulate matter (PM) are; sulfur oxides (SO_2), carbon monoxide (CO), nitric oxides and ozone (O_3). However, many epidemiologic studies have pointed to PM exposure as being a risk factor for lung cancer as well as cardiorespiratory diseases, stroke and type 2 diabetes mellitus [18, 19]. High concentration of particulate matter (PM) can also be associated with increases in pneumonia and viral respiratory illness as well as oxidative stress, protein denaturation, mitochondrial perturbation, inflammation, nuclear uptake, neuronal tissue uptake, endothelial dysfunction, phagocytic function perturbation, neo-antigen generation, and DNA damage [20- 22].

The concentration of ambient air pollution (PM10) by cities in both South Korea and Thailand varies considerably. This study has established that cities in South Korea reported higher concentrations of particulate matter (PM10) than cities in Thailand. Although South Korean cities generally reported higher concentrations of particulate matter than cities in Thailand, there was a steady reduction in the concentration of particulate matter for South Korea from 2007 through to 2014 whereas Thailand's trend showed a slight steady increase in the concentration of particulate matter during the study period. . One way ANOVA showed that cities of these two countries' air pollution levels are not the same with *p*-value of 0.000 ($p <= 0.05$).

This comparative cohort study has also confirmed the outcome of many previous studies [23 – 38] about the association between long-term exposure to ambient air pollution and the burden of lung cancer. This study has established that South Korea has higher concentration of particulate matter as well as higher burden of lung cancer than Thailand which is on the lower side in terms of PM concentration and lung cancer burden.

Our study had some limitations; we could not assess lung cancer morbidity and mortality rate at city level as we did with PM10. Secondly, not all cities data are contained in the World Health Organization databases 2011, 2014 and 2016. Air quality index data were at national level and not city level.

In conclusion, the burden of lung cancer as well as PM concentration is higher in South Korea than in Thailand. One way ANOVA showed that cities of these two countries' air pollution levels are not the same with *p*-value of 0.000. Although the overall quality of life is better in South Korea than in Thailand, this is not the case with the burden of cancer and air pollution landscape between the two countries.

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Authors' contributions

MK designed the study; MK conducted the study; HS provided technical advice and model selection; MK wrote the paper. Both authors read and approved the final manuscript. The results reported here and the conclusions based on them are the sole responsibility of the authors. The authors assume full responsibility for analyses and interpretation of the data.

Competing interests

Authors declare that they have no competing interests.

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