Predictive MERRA-2 aerosol diagnostic model for oral, oropharyngeal and laryngeal cancer caused by air pollution in Thai population

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A B S T R A C T

Introduction: Head and neck cancers were generally characterized with many possible causes. Exposure to outdoor particulate matter affected multiple organ systems but it was unknown whether which species in PM was an association with cancer incidence.

Objectives: The study aimed to examine the oral- oropharyngeal- laryngeal cancer incidence and accumulated air pollution-related cancers in the spatial patterns.

Methods: Observational study was conducted, and the Poisson log-linear models were used which were analyzed on subgroups-specific incidence rates by national references of Thailand and NASA’s database of aerosol diagnostics model (MERRA-2).

Results: With a significant influence on increasing of 1 μg/m³ black carbon, organic carbon, Dust-PM2.5 and SO4 were associated with increased cancer risk in 1.433 times (95%CI: 1.215–1.690), 1.272 times (95%CI: 1.139–1.420), 3.640 times (95%CI: 2.011–6.589), and 1.704 times (95%CI: 1.334–2.177), respectively.

Conclusion: This study indicated that oral-oropharyngeal-laryngeal cancer incidence could worsen because of adverse air pollution conditions. These issues should be addressed and the importance of the monitoring procedure for dust-PM2.5, sulfate, black carbon, and organic carbon should be emphasized.

1. Introduction

Thailand is increasingly facing environmental pollution, particularly air pollution. The concentration of PM2.5 across the Thailand capital city of Bangkok was also caused by vehicular exhausts and biomass burning [1]. A similar problem demonstrated in the Northern and the Northeastern regions [2,3]. Diesel exhaust was the primary contributor of carbonaceous aerosols at exceeding levels during weekdays [4]. Atmospheric particulate matter in the southern is region composed of organic carbon, elemental carbon, water-soluble ionic species, and polycyclic aromatic hydrocarbons (PAHs). The average concentration of SO4 was the major ionic components [5]. It was also found that the five main air pollution types were sulfur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO), ozone gas (O3), and dust particles up to 10 μm (PM10) [6]. These pollutants were found higher than normal limits within various regions of Thailand [7]. Diurnal variation of outdoor air pollution was the main result of human activities. The morning peak corresponding to road traffic emitted more particles at ground level, whereas the emissions from the burning of biomass and agricultural crop also influenced the accumulation of aerosol particles at higher atmospheric layer [8].

Multiple primary malignancies are a group of major diseases that were then affected [9–11]. Moreover, air pollution has a direct impact on both respiratory and cardiovascular diseases and the population morbidity rate [12]. Besides, increasing the amount of PM2.5 in the atmosphere contributes to higher population mortality [13,14]. Furthermore, toxic aerosol elements in the air such as sulfur dioxide [15] and nickel [16] worsen the mortality rates. The amount and time of exposure to these substances also lead to higher mortality rates [17]. The pollutant is not only prevalent in chronic diseases, but also has a direct impact on acute respiratory diseases [10,18]. The higher level of trace gaseous species and PM in haze episode significantly affected the requirement of the medical treatment [19].

The exposure of hazardous substances from air pollution to the body system would be harmful and may cause malignancies. Skin contact can cause skin cancer [20]. The presence of pollutants in food is a risk factor.
for tumors in the gastrointestinal tract [21]. Both the respiratory and gastrointestinal tract share a common pathway that is exposed to pollutants from air and food and has a direct impact on the occurrence of head and neck cancer [22–24]. Plants and vegetables grown from soil contaminated with heavy metals often lead to acute and chronic toxicity in humans [21,25]. The same goes for the contamination of water which was recognized as, “The cycle of food and drinking water” [25,26]. Moreover, chemical particles in the atmosphere would contaminate the entire food chain [27]. PAHs have been detected in various types of food, including soybean. Thai soybean products have unique fingerprints of PAHs. Fortunately, the level was within the acceptable range [28].

Inhaling carcinogenic pollutants from the air and chronic smoking are strongly associated with malignancies arising from oropharynx and laryngopharynx that are considered as a part of head and neck cancers [29–32]. These referenced the primary cause more than any others that could lead to head and neck cancer. Unfortunately, many people have overlooked the possibilities of air pollution on malignancies [33].

Satellite-related technology provides many advantages. The high-resolution technology of satellites can be utilized to substitute air, water environment, and ground quality indication. NASA scientists can track aerial pollution trends for decades in various regions globally [34]. However, the association between these aerial pollution regions and population health has not yet been explored.

Spatial epidemiology is statistical science for analyzing the relationship between areas with incidences or mortalities from diseases. It also emphasizes the explanation and determination of geographic patterns and their relationship between diseases and various risk factors involved. Various regions have linked and analyzed the risk of disease [35–37] which leads to the optimal protection approach to provide a link for future medical scientists/ researchers who would like to evaluate the findings on pollution via satellite-related technology. This present study, therefore, examined the relation between oral, oropharyngeal and laryngeal cancer and the associated risks and accumulated pollution in various areas of Thailand, using the satellites to explore the number of toxic substances especially aerosols in ambient air.

2. Materials and methods

Observational research was performed on the study of.

(i) Assessing oral, oropharyngeal and laryngeal cancer incidence rates of 30,720 eligible patients. We collected data of oral, oropharyngeal and laryngeal carcinoma from the Strategy and Planning Division, Ministry of Public Health’s database between January 1, 2017, and December 31, 2017 based on ICD-10 coding. The data displayed the incidence rates in 77 provinces (per 100,000 population) (Table 1). Thailand is located between the coordinates of 5.77434 latitudes to 20.43353 and longitudes of 97.96852–105.22908 [38]. Within the territory, Bangkok is the capital city. Thailand map representation of any kind of data was applied by Quantum Geographic Information System (QGIS) software [39].

(ii) An environmental database

The database was collected from the Modern-Era Retrospective Analysis for Research and Applications version 2 (MERRA-2) by NASA’s Global Modeling and Assimilation Office (GMAO). The quantity of each of aerosol components (aerosol diagnostics model) was analyzed (Black Carbon Surface Mass Concentration or black carbon, Dust Surface Mass Concentration – PM2.5 or mineral dust, Organic Carbon Surface Mass Concentration or organic carbon, Sea Salt Surface Mass Concentration or sea-salt and SO4 Surface Mass Concentration or SO4). The presence of ambient air quality with details of both horizontal and vertical grids from 2010 to 2016 was computed on a cubed-sphere grid and the analysis algorithm model was attributed by controlling the variable for moisture used in recent versions of Gridpoint Statistical Interpolation analysis system (GSI) [40]. Highlights of the MERRA-2 system performed detailed data analysis every 3 h. This data was utilized as the accumulated dose for each substance.

(iii) Carcinogenic risks associated with air quality

An investigation of spatial epidemiology associations for the relative risk of air quality and incidence rates of oral, oropharyngeal and laryngeal cancer in Thailand was conducted. The analysis correlations were separately analyzed by provinces.

2.1. Data processing and analysis

1. The spatial patterns were characterized by their influence between place - air quality in accumulated dose and burden of the diseases- location was examined. The analysis was used to detect which substance risk factors most correlated with cancer cases throughout the year by the Poisson log-linear model. The correlation between the incidence rate ratios of cancer and the accumulated surface mass concentration of each substance was performed to confirm their spatial correlation.

2. It is expected that different substances may become hybridizing various interactions to organ targets. The air quality profile from MERRA-2 of accumulated surface mass concentration was analyzed by the individual risk, except for the sea salt. The incidence rate ratio of oral, oropharyngeal and laryngeal cancer was estimated. This subsequent procedure was to compare the incidence rate ratio by each province. The low incidence rate area was used as comparable base with other provinces for estimation of the high-risk area.

2.2. Ethics approval and consent to participate

Data were obtained from two public domains that were opened for the public to use for noncommercial purposes. None of the variables or data used in this study allowed the identification of individuals. Confidentiality in this study was considered together with the privacy consideration, where relevant. The obligation to protect and promote the non-disclosure of information imparted in a relationship of trust lies at the core of the concept of confidentiality. The study was reviewed and approved by the Khon Kaen University Ethics Committee for Human Research (HE611183).

3. Results

Dust particles in our atmosphere are recognized by the suspension particles of solids and liquids in the air by the MERRA-2 system. These systems are necessary for performing the elements of the different tasks required such as black carbon, organic carbon, dust-PM2.5, SO4, and sea salt. The advantages of this system include a reanalysis and near-real-time climate analysis. The variables were chosen to evaluate the aerosol diagnostic series with ambient air quality from 2010 to 2016 (Table 1).

This study determined the average black carbon, organic carbon, sea salt, dust-PM2.5, and sulfate to be 8.211 μg/m3 (interquartile range [IQR]: 5.777 ± 10.058), 49.566 μg/m3 (interquartile range [IQR]: 47.318 ± 59.660), 119.374 μg/m3 (interquartile range [IQR]: 84.577 ± 180.296), 14.368 μg/m3 (interquartile range [IQR]: 12.343 ± 16.369), and 26.112 μg/m3 (interquartile range [IQR]: 22.842 ± 31.770), respectively.

The number of new cases of cancer (cancer incidence) was 31,859 per 100,000 people per year (based on 2017 cases). Fig. 1 displays the incidence rate of oral, oropharyngeal and laryngeal cancer in selected regions by spatial distribution as a scale for the various locations. The incidence rates were mostly concentrated in some provinces of the Northern, Northeastern, Southern and the Central regions of Thailand.
The results of this study indicated the largest percentage of cancer incidence in three provinces. For research purposes, the distribution of pollution intensity in Thailand between 2010 and 2016 is presented in Figs. 2 and 3. They demonstrate the natural arrangement of the geographical distribution in accumulated dose which estimate the exposure of Dust-PM$_{2.5}$, Black Carbon, Organic Carbon, and Sulfate Surface Mass Concentration across the different provinces. The maps were adjusted on an identical grid thus enabling a quantitative comparison between them. The correlation between these maps was relatively low (light color), emitted small amounts of pollution and dark color for large amounts of high pollution. Organic carbon and dust-PM$_{2.5}$ in a grid resolution of $0.50 \times 0.6250$ and 72 hybrid-eta levels from the surface to 0.01hPa were displayed more clustered pattern with higher values in the Northern, Northeastern and the Central regions, whereas black carbon and sulfate were densely compacted in the Northeastern and the Central regions of Thailand. The visual and geographical analysis of the map system revealed overall information of ambient air quality and the incidences of cancer. Results from the analysis showed that 12 of the 77 provinces had highest accumulated concentration level of dust-PM$_{2.5}$, indicating a poorest degree of...
collinearity among certain predictors within census categories. Whereas, sulfate, organic carbon, and black carbon were found highest in 7, 5, and 1 province, respectively.

The risk-exceedance probabilities were shown in Table 2. Dust-PM2.5 showed strong associations with cancer risk. Minor associated risk reduced in SO\(_4\), black carbon, and organic carbon, respectively. A significant influence on increasing of 1 \(\mu g/m^3\) Dust-PM2.5, SO\(_4\) black carbon, and organic carbon were associated with increased cancer risk in 3.640 times (95%CI: 2.011–6.589), 1.704 times (95%CI: 1.334–2.177), 1.433 times (95%CI: 1.215–1.690), and 1.272 times (95% CI: 1.139–1.420), respectively.

4. Discussion

The measurement of ambient air quality is a standard procedure used to measure various substances in the atmosphere such as carbon monoxide, lead, nitrogen dioxide, ozone, sulfur dioxide, and PM which contain various sizes of dust and moisture particles. PM10 is inhalable particles approximately 10 micrometers in circumference or smaller. PM2.5 is a tiny inhalable particle, generally 2.5 micrometers in circumference or smaller. Ground stations were built for collecting polluted data to a variety of users and monitoring. So far as reasonably practicable, there was insufficient station in each country. For instance, some technocrats were the choice to change the procedures with high capacity of data collection. This present study focused on the process of gathering and analyzing data by the Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) manufactured by NASA’s Global Modeling and Assimilation Office (GMAO). These methods are advantageous for understanding risk factors involving geographic locations that were affected by the incidences of oral, oropharyngeal, and laryngeal cancer in Thailand from various locations in 2017. The definite effect-time of more than 5 years of exposure to air pollution was shown to increase mortality of respiratory disease, lung cancer, colon cancer and cardiovascular disease [41–43]. The developed design of this study is also possible to confirm with the cancer association regarding risk factors in various areas for more than 5 years of exposure; pollution detection in general. A common method of assessment for air pollution is using a continuous ambient air monitoring ground station. However, some provinces in Thailand provide insufficient data for effective measurements [44]. For this reason, MERRA-2 models may be a tool that can monitor all areas simultaneously. Quality information between two resources, the MERRA-2 PM2.5 was underestimated compared with ground measurements, partly due to the bias in the MERRA-2 Aerosol Optical Depth (AOD) assimilation [45]. On the other hand, gathering pollution data by the ground station was suitable for local monitoring and too difficult to elaborate all areas or for large scale. Most installations required expensive equipment and complex units [46] which is why air quality monitoring throughout the country by MERRA-2 would be the most appropriate measurement method.

Our results are consistent among the cancer studies with the strong link between air quality and oral- oropharyngeal- laryngeal cancer development. However, based on our analysis such an approach is inhibited by considerable problems with data availability. Specific of some datasets such as individual-level risk factors, uncertainties in exposure, lifestyle, occupation risks, smoking habits, underlying diseases, and genetic predisposition were not collected. We designed the common methods for studying relationships between the spatially non-random cancer incidence rates and spatial patterns of the accumulated long-term exposure to air pollutants, and manipulated the data attributed availability by a Bayesian hierarchical regression modeling framework.

To our knowledge, this is the first study to investigate the relevance of specific chemical components of PM substances and upper aerodigestive tract cancers using advanced technological data recorders. The study site (Fig. 1), Northern and Northeastern, shows the dense location of cancer incidence (dark pink). In comparison with the accumulated pollutants, Dust-PM2.5 showed the same direction in color tone which
explains the higher correlation than other pollutants. Agriculture was the principal occupation in Northern and Northeastern of Thailand. Major crops were rice, corn, and sugarcane. After harvesting, they burned the grass to quickly prepare the farmland for the next sowing. It contributed to smog \cite{47,48}. Dust-PM2.5 was the most potentially carcinogenic correlation, followed by sulfate, black carbon, and organic carbon, respectively. There is an excess risk of cancer incidence in areas with high aerosol levels. There were some of the important local-level characterizations of violence dynamics, which are complicated by spatio-temporal scales of variation in influencing factors that drive diversity of the cancer incidence.

Uncertainties in the perception of their complex effects limit our knowledge about PM composition to health affected. Understanding of factorization of composition in PM was linked to identify and quantify the types of PM sources. The information of influences in geographic regions to specific sources of PM was essential in future efforts to reduce levels of aerosol pollutants and the overall burden on cancer. A significant influence on increasing of 1 μg/m3 Dust-PM2.5 was associated with increased cancer risk in 3.6 times, whereas black carbon, organic carbon, and SO4 were associated with increased cancer risk in 1.2–1.7 times. This determined that not only the concentration of PM affects the organ system but the amount of each composition could influence in varying degree.

Epidemiologic studies over the past 40 years displayed the effect of the general ambient air pollution; the burning of fossil fuels from automobiles and industrial plants releases emissions throughout the day resulted in significantly higher rates of lung cancer \cite{49}. It is also possible that prolonged exposure (many years) can promote the rate of cancer \cite{50} and the examination of miRNAs discovered that it is associated with non-small cell lung cancer \cite{51}. Ambient Air is not only a single toxic aerosol substance with many forms. According to studies in rodents which indicated the atmosphere with ozone (O3), or nitrogen dioxide (NO2) was related to inflammation in the respiratory tract and lung function \cite{52,53}. Research gathered from several countries displayed risk factors that cause lung cancer as a result of pollution such as black smoke concentration, NO2, PM2.5, PM10, and SO2 \cite{54–58}. The next generation of pollutants-driven disease prediction models will be most focused on the interaction of each chemical pollutant with another in PM or even another aerosol to cancer effects.

In the matter of head and neck cancer, the instances of the disease differ in various areas, such as oral cancer found in India, nasopharyngeal cancer discovered in Hong Kong, pharyngeal and laryngeal cancers distributed worldwide. The primary contributing factors that appear to increase the risk of cancer are smoking, drinking, and betel nut chewing \cite{59}. It is important to note that Thailand’s national anti-smoking campaign affected the behavior trends. Prevalence of smoking in Thailand dropped from 42.1% in 2010 to 38.8% in 2016 \cite{60}. The highest prevalence of smoking was recorded from the Northeast and the South regions \cite{61}. However, the incidence of tongue and oral, oropharyngeal cancer in males increased between 2013 and 2015 \cite{62}. This reversal tendency of primary risk and cancer prevalence could be attributed to risk factors. Future studies, therefore, should assess correlation, including synergistic effects between each intrinsic and extrinsic cancer risk which may impact future policy measures for cancer prevention strategies. A study regarding the impact of pollution on these group’s cancers is also less common compared to lung cancer \cite{49–51}. If we think about the path that the air passes through the lungs, these factors will have the same impact. Negative environmental impacts are more dangerous than most people conceive. However, some studies found that PM10 and pollution are directly related to the occurrence of laryngeal cancers as well as lung cancer \cite{63,64}. In this regard, it is similar to passive smoking. These factors are commonly neglected \cite{65}. PM is harmful in the atmosphere with the ability to affect both lung cancer and laryngeal cancer \cite{66}. Primary factors that affect the high level of aerosol in Thailand, mainly due to the rising population problems and lack of pollution control such as automobiles, industrial plants, and agricultural practices that focus on burning to harvest or preparation for the next season. This research, coupled with these precious air quality monitoring technologies, is a step and opportunity for better air quality in Thailand.

5. Conclusion

From obvious relationships between oral, oropharyngeal, and laryngeal cancer with ambient air quality based on the MERRA-2 model, environmental factor detectors, NASA’s technology, play a vital part in the management of health. This study indicated that oral, oropharyngeal, and laryngeal cancer incidence could worsen because of adverse air pollution conditions. These issues should be addressed and the importance of the monitoring procedure for dust-PM2.5, sulfate, black carbon, and organic carbon should be emphasized. It is also important to limit chronic exposure to air pollution as much as possible, the changes will provide everyone with quality living.

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CRediT authorship contribution statement

Kriangsak Jenwitheesuk: Conceptualization, Methodology, Writing – review & editing. Udomlack Peansukwech: Conceptualization, Visualization, Methodology, Software, Data curation, Writing – review & editing. Kamonwan Jenwitheesuk: Conceptualization, Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Authors’ contributions

All authors conceived and planned the project. UP performed the analytic calculations and performed the numerical simulations. KJ and KI took the lead in writing the manuscript. All authors provided critical feedback and help.
Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.toxrep.2022.04.015.

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