APPLICATION OF GIS TECHNIQUE AND BENMAP MODEL FOR STUDYING IMPACTS AIR POLLUTION ON PUBLIC HEALTH: A CASE OF HO CHI MINH CITY, VIETNAM

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ABSTRACT

Vietnam's urban areas have faced serious environmental pollution issues, including: water pollution, municipal waste and air pollution. Air in Ho Chi Minh city is polluted by $PM_{2.5}$ (particle matter with a diameter is less than 2.5 µm, so-called $PM_{2.5}$), O_3, CO, NO_2 and TSP which greatly affects public health. Ho Chi Minh City (HCMC) had 8,640,000 inhabitants with a total of 7,339,552 motorcycles and 637,323 automobiles. There are about 2,807 factories releasing air emissions, 2,061,957 households and 5,096 restaurants in the city. A comprehensive study is required to evaluate the impacts of air pollution levels on public health in this city. The aim of this study is to: (i) Application GIS technique to distribute air pollution concentration, population and public health diseases in the city and (ii) Then apply BENMAP theory model to calculate the mortality rate from three causes, namely Ischemic Heart Disease (IHD), cardiopulmonary, and lung cancer due to air pollution. The results showed that the annual average concentrations of NO_2 were higher than the standard of Vietnam National Technical Regulation on Ambient Air Quality (QCVN 05: 2013 40 µg/m3) and World Health Organization (WHO) (40 µg/m3). The annual average concentrations of $PM_{2.5}$ were 23 µg/m3 and were also much higher than the WHO (10 µg/m3) standard by about 2.3 times. $PM_{2.5}$ was found to be responsible for about 1136 deaths, while the number of mortalities from exposure to NO_2 and SO_2 was 172 and 89 deaths, respectively.

Keywords: *GIS Technique; health impacts; Air pollution; BENMAP model; Ho Chi Minh City*

1. INTRODUCTION

According to the National Environmental Status Report, Vietnam is facing an increase in air pollution, especially in megacities such as Hanoi or Ho Chi Minh City (HCMC). HCMC is the largest city in Vietnam with its position as the political, economic, scientific and cultural center of the country. Rapid urbanization rate leads to increased traffic pressure to meet the transportation demand of 8.6 million people in the city. HCMC has the highest number of vehicles in the country, accounting for about 9 million private vehicles in April 2017, up 5.4% compared to 2016 while public transport systems and the infrastructure has not met the rapid demand. In addition, HCMC has 2800 factories having chimneys to release air pollutants (including 19 manufacturing and industrial zones, 30 industrial clusters on an area of 1,900 ha, and numerous factories and enterprises located separately around the city). All activities including transportation, industry, construction, domestic cooking, etc could cause serious air environment problems. Monitoring data collected between 2012 and 2016 indicated that levels

of particulate matter (PM) and noise in urban areas including HCMC remained high in the last 5 years. Nearly 80% of total suspended particulate (TSP) samples exceeded the National technical regulation in ambient air quality (Vietnamese Standard QCVN 05:2013) in this period, especially at the high traffic density, industrial and crowded resident areas. NO_x and CO concentrations at the traffic area also exceeded the QCVN 05:2013 in this period. HCMC has 27% days exceed the standard of $PM_{2.5}$ in 2016-2017. These high pollutant concentrations were associated with an increase in the risk of human health in HCMC (Bang, 2017, Ly et., 2019). Air pollution event on 22 Sep. 2019 showed that the number of patients admitted for respiratory diseases at the Saigon General Hospital in District 1 has increased by 5-10 percent compared to normal days, it was even overloaded and all doctors and nurses had to work around the clock.

It is an urgent need to study the impacts of air pollution on public health in Ho Chi Minh City. Therefore, the research on "Application of GIS technique and BENMAP model for studying impacts air pollution on public health: a case of Ho Chi Minh City, Vietnam" was carried out. The aim of this study is: (i) Application GIS technique to distribute air pollution concentration, population, and public health diseases in the city and (ii) Then apply BENMAP theory model to calculate the mortality rate from three causes, namely Ischemic Heart Disease (IHD), cardiopulmonary, and lung cancer due to air pollution.

2. MATERIALS AND METHODS

The effects of air pollution on health have been studied and proven on a global scale. Generally, the health effect from air quality can be estimated by using an impact function relating to the levels of air pollution change, the exposure population, the baseline incidence rate and the relative risk coefficient from an epidemiological study. This impact function can be described as the following formula (equation 1) and Figure 1:

$$\Delta Y = Y_0 (1 - e^{-\beta \Delta PM}) Pop \quad (1)$$

Where Y_0 is the death rate baseline in the study area (%); β - the effect estimate calculated by relative Risk – RR relating to the specific change in pollutant concentration and can be found in the cohort studies; ΔPM- the air quality change (increase or decrease) in pollutant concentration (µg/m3 or ppb); and Pop- the exposed population in the study area (people). This study presents these parameters as a map layer, including: the pollutant concentration data which is the output of the CTM model for yearly-average of $PM_{2.5}$, NO_2 and SO_2 at cell resolution; the number of exposed people collected from the Statistic Office of HCMC for the year of 2017; the relative risk coefficients for each parameter are obtained from the report of Health Effects Institute by Daniel Krewski and colleagues (Table 1) (Krewski et al., 2009); and the death rate baseline is from Vietnamese A6 mortality reporting system (A6 system).

The study of Krewski has been carried out for 18 years, involving approximately 360,000 participants residing around the USA in 1980 and increasing up to around 500,000 people in 2000. These people were fully tracked for the levels of $PM_{2.5}$ exposure and their status is also recorded on their diseases and mortality. The RR value in Table 2 shows that $PM_{2.5}$ was strongly associated with the death due to lung cancer and IDH with the RR is higher than those of the other pollutants. Meanwhile, there is the weaker association between the disease and the mass of the larger size of particles, as well as with the concentration of SO_2.

Table 1. The relative risk of pollutants and selected cause of deaths

Pollutants	*Cause of deaths*	*Incremental Change*	*Risk Factor*
$PM_{2.5}$	Cardio-pulmonary	10 µg/m^3	**1.09** (1.06–1.12)
	Lung cancer		**1.11** (1.11–1.20)
	IHD		**1.15** (1.04–1.18)
NO_2	Cardio-pulmonary	10 ppb	**1.01** (1.00–1.02)
	Lung cancer		**1.01** (0.97–1.01)
	IHD		**1.02** (1.00–1.03)
SO_2	Cardio-pulmonary	5 ppb	**1.02** (1.01–1.03)
	Lung cancer		**1.00** (0.98–1.02)
	IHD		**1.04** (1.02–1.05)

Source: Krewski et al., 2009

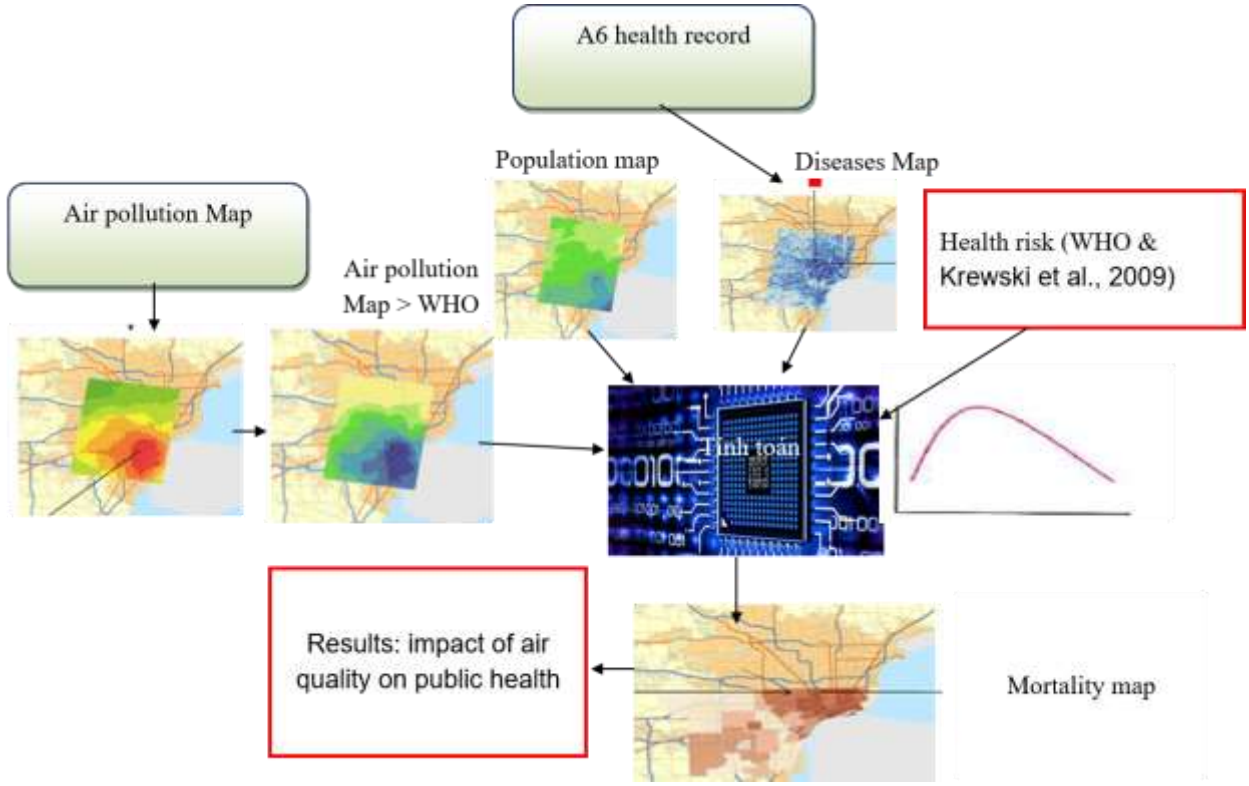


Figure 1. Methodology to studying impacts air pollution on public health

For mortality baseline incident rate in HCMC, the total number of deaths were gathered from the Ministry of Public Health in the form of the Vietnamese A6 mortality reporting system. This is a data set built from 1992 to record the death from the commune level, aggregated then and posted to the central level. Health storage system A6 in Vietnam recorded relatively full (94%) the number of deaths and correctly classified the top 3 causes of death (accounting for 66% of total deaths) which is related to the circulatory system, cancer and trauma. The mortality data for three main causes of death such as IHD, cardio-pulmonary and

lung cancer.

As recorded from the A6 health system of Ho Chi Minh City, there were about 6,630 deaths per year related to cardiopulmonary disease (accounting for 30.05% of total deaths), 3,314 deaths due to IHD (accounting for 15.02% of total deaths) and 437 deaths from lung cancer (accounting for 2.00% of total deaths).

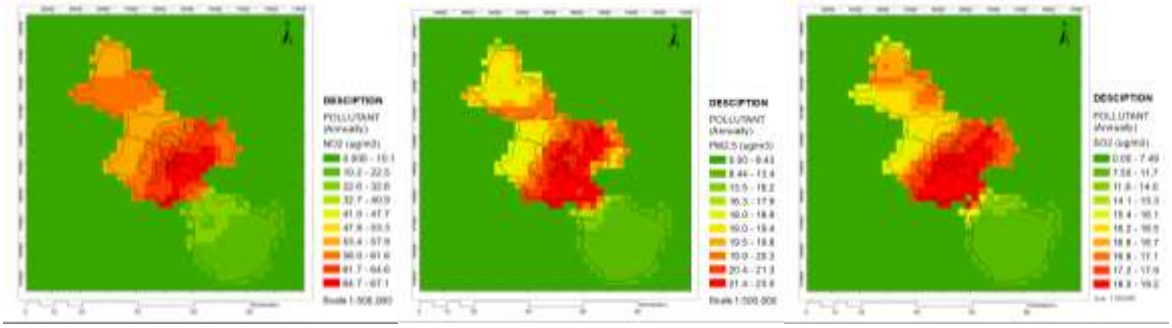
Air emission inventory

A comprehensive emission inventory in HCMC in 2019 was conducted by following the top-down and bottom-up approaches. The estimation of the emission of different types of sources including the line, point, area, and biogenic source was conducted. Traffic sources accounted for the largest emissions for almost all pollutants. Motorcycles were the dominant emission source of all pollutants for on-road sources, accounting for 35.3%, 91.4%, 65.4%, 70.4%, 99.4% and 79.9% of the total line sources emissions for NO_x, CO, SO_x, NMVOC, CH_4 and $PM_{2.5}$, respectively.

3. RESULTS AND DICUSSIONS

The air quality model used in this study is the Chemical Transport Model (CTM). The model was developed by CSIRO and detailed description model by the document of The Centre for Australian Weather and Climate Research (Cope, 2009). For simulations that require complex chemical transformation, CSIRO developed an enhanced version of TAPM referred to as TAPM-CTM (Cope, 2009). The advances of TAPM-CTM compared to TAPM were analyzed thoroughly in the study of Bang, 2018 (Bang, 2019) in which the prognostic model provides the meteorological fields that drive dispersion of emissions and pollutant concentrations CTM.

The results in Figure 2 also show that the annual average concentrations of NO_2 was 67.1 µg/m3, higher than QCVN 05: 2013 (40 µg/m3). In contrast, the annual levels of PM2.5 was 23 µg/m3, levels of SO_2 was 19.2 µg/m3 which is lower than QCVN 05: 2013 (25 µg/m3 and 50 µg/m3). The average annual concentration of $PM_{2.5}$ in HCMC is lower than QCVN 05: 2013 (25 µg/m3). However, the $PM_{2.5}$ levels in most areas in the city were about two times higher than WHO recommendations (10 µg/m3), with the exception of some areas in the south of the city (Can Gio District). The highest concentration was in District 4 and District where there are many ports and activities. These results were relatively similar to the $PM_{2.5}$ pattern observed by using continous monitoring in the period of 2011-2015.



(a) (b) (c)

Figure 2. Air pollution dispersion map for (a) NO_2, (b) $PM_{2.5}$, (c) SO_2 annually in HCMC

The total mortality cases are found to be 1396 for three diseases (lung cancer, cardio-pulmonary and IHD) due to $PM_{2.5}$, SO_2, and NO_2 pollutant levels. $PM_{2.5}$ has the highest impact in terms of mortality with a total of 1.136 deaths, followed by NO_2 with 172 cases and 89 cases by SO_2. The number of deaths from $PM_{2.5}$ accounts for 81% of total mortality among 3 pollutants ($PM_{2.5}$, SO_2, and NO_2). The second-largest impact is NO_2 accounting about 12.2 % and the third pollutant is SO_2 about 6.3%. This result of highest death due to $PM_{2.5}$ is consistent with the air quality monitoring data done by the HCMC environmental monitoring center (the $PM_{2.5}$ is usually higher than QCVN 05:2013) and consistent with the results of $PM_{2.5}$ air quality modeling in this study (the annual average concentrations of $PM_{2.5}$ is much higher than WHO (10 µg/m3) about 2.3 time). $PM_{2.5}$ is responsible for the largest number of mortality from cardio-pulmonary disease with 715 cases, followed by NO_2 with 83 cases, and finally SO_2 with 43 cases.

4. CONCLUSION

This research paper has presented the preliminary study about the application of GIS technique to distribute air pollution concentration, population and public health diseases in the city application BENMAP theory model to calculate the mortality rate from three causes, namely Ischemic Heart Disease (IHD), cardiopulmonary, and lung cancer due to air pollution. Air pollution has high impacts on public health in HCMC. The total mortality cases are found to be 1396 for three diseases (lung cancer, cardio-pulmonary and IHD) due to population exposure to the combination of $PM_{2.5}$, SO_2, and NO_2 pollutant levels. Among these air pollutants, $PM_{2.5}$ has the highest impact in terms of mortality with a total of 1.136 mortality, followed by NO_2 with 172 cases and 89 cases by SO_2. HCMC's government should develop measures to reduce air pollution as soon as possible to protect human health.

5. REFERENCES:

Bang. Q. HO, Vu Hoang Ngoc Khue, Nguyen Thoai Tam, Kristofer Lasko, 2017. *Air pollution emission inventory and air quality modeling for Can Tho City, Mekong Delta, Vietnam.* Air Quality, Atmosphere & Health, pp 1–13.

Ly Thi Mai Luong, Tran Ngoc Dang, Nguyen Thi Thanh Huong, Dung Phung, Long K Tran, Do Van Dung, Phong K Thai, 2019. *Particulate air pollution in Ho Chi Minh city and risk of hospital admission for acute lower respiratory infection (ALRI) among young children.* Environ Pollution Journal. doi: 10.1016/j.envpol.2019.113424. Epub 2019 Oct 18.

Krewski, D., Jerrett, M., Burnett, R. T., Ma, R., Hughes, E., Shi, Y., ... & Thun, M. J., 2009. *Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality (No. 140)*. Boston, MA: Health Effects Institute.

Cope, M., Lee, S., 2009. *Chemical transport model – user manual CAWCR Technical Report No. 016.*

Bang, H.Q., Hiep, N.D., Khue, V., Hien, T.T., 2018. *Photochemical smog modelling using the air pollution chemical transport model (TAPM-CTM) in Ho Chi Minh city, Vietnam*. Environmental Modeling & Assessment Springer International Publishing: 1-16.

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