AIR POLLUTION ASSESSMENT USING RS AND GIS IN HO CHI MINH CITY, VIET NAM: A CASE STUDY OF PERIOD 2015-2019 FOR SO₂ AND NO₂

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Abstract. Large urban areas are currently facing the problem of increasingly serious air pollution, which greatly affects human health and economic development. The sources of air pollution are mainly from industrial activities, transportation and human activities. Air pollutants data can be monitored and extracted from remote sensing images. This research aims to assess the level of NO₂ and SO₂ pollution in the air from data collected by OMI (Ozone Monitoring Instrument) on AURA satellite of A-Train group. Pollution levels of NO₂ and SO₂ will be calculated, assessed. Then, a map illustrating the trend of NO₂ and SO₂ in Ho Chi Minh City during the period of 2015-2019 will be made. The results of the study showed that NO₂ concentration varies significantly with the seasons, relatively high in the dry season reaching 70 (μg/m³) and decreasing in the rainy season. The concentration of SO₂ varies relatively evenly in the area and increases in industrial areas with concentrations ranging from 0.1 to 1.37 mg/m³. Therefore, it is necessary to speed up the rapid monitoring of air pollution in urban areas and large cities in order to get accurate, fast and timely air pollution information to have more appropriate and effective mitigation and prevention measures.

1. Introduction

Air pollution is a complex issue related to many fields as well as urban activities including construction, land use, transportation, community activities, industrial zone development, energy use, etc. The air pollutants include: oxides such as nitrogen oxides (NO, NO₂), nitrogen dioxide (NO₂), SO₂, CO, H₂S and halogen gases (chlorine, bromine, iodine); fluorine compounds; suspended substances, nitrates, sulfates, carbon molecules, aerosols, soot, smoke, fog, pollen; radioactive waste, temperature, noise ...Currently, air pollution in Ho Chi Minh City (HCMC) is significantly increasing in the dry season, especially on several main streets that are really busy in rush hours. This has been causing a big problem that most of the citizens of HCMC inhale a large amount of toxic emissions. In addition, HCMC’s top priorities are to deal with air pollution including reducing dust pollution in the manufacturing industry of building materials; SO₂ pollution from thermal power plants as well as the amount of CO₂ and SO₂ generated from residential activities in urban and rural areas. NO₂, SO₂ is...
mainly generated from industrial zones and large urban areas. Therefore, this research focuses on extracting these two substances to evaluate the pollution transmission and control air pollution. Researches in Vietnam many research used to RS techniques to show air pollution for many years. In 2018, Tran Quang Bao et al, this paper presents the results of remote sensing application for mapping of air quality in mining area in Luong Son district, Hoa Binh province. Using Landsat 8 data with a resolution of 30m in 3 periods: 2013, 2015 and 2017 to calculate vegetation indices, air pollution index (API). The level of air pollution increased gradually from 2015 in both scale and intensity, there was no sign of decline. The API of the Landsat satellite images over the years compared with the collected values at the monitoring stations was higher and was at a serious level. Air pollution has impacted the surrounding lives and health, as reflected in the survey results of people in three areas: far from mines, processing factories and transport routes. The study also showed that the area with high forest cover would have better air quality than the area where mining activities were conducted [1]. Nguyen Hai Hoa, Nguyen Thi Huong, 2017 using Landsat image to develop the distribution map of air pollution caused by mining activities in Hoanh Bo district, Quang Ninh province. Most of the dust concentration has increased from 2006 to 2010 because the mining industry has taken place extensively this period. The results also show that there is a relationship between vegetation cover and air quality, in which vegetation plays an important role in reducing air pollution and dust concentration from mining activities [2]. In 2014, Tran Thi Van et al, this study is the initial test proving that remote sensing can be seen as a useful, economical tool to help monitor the air environment in cities. Distribution of high concentrations of PM10 detected on intersections and traffic axes, industrial parks and construction sites [3].

In the world, there are related studies in the application of remote sensing techniques to evaluate NO2 and SO2 pollution, other air pollutants. In 2017, Shelly Nofriti et al argued that population activity which tends to centralized in certain area cause decrease in air quality due to exhaust gas from transportation vehicle. The increase of vehicle in Palembang gave the city air pollution potential. Transportation is the main source of air pollution in big city with 70% contribution. Exhaust gas from transport activity consist of 60% CO and 15% incomplete combustion of hydrocarbon such as NOx and Sox. The aim of research is to analyzed air quality in Palembang city [4]. In 2018, the study show impact of traffic-related air pollution on morbidity and mortality in Copenhagen Municipality and the health gain of reduced exposure. Nitrogen oxide concentration can serve as a proxy of exposure to traffic-related air pollution; The annual mean nitrogen oxide concentration is 19.6 μg/m³ in Copenhagen; One-year gain in life expectancy by lowering nitrogen oxide exposure to rural level [5]. In 2018, Kuang Xiao et al, most cities in China are experiencing severe air pollution due to rapid economic development and accelerated urbanization. Long-term air pollution data with high temporal and spatial resolutions are needed to support research into physical and chemical processes that affect air quality, and the corresponding health risks. The concentrations of PM10, PM2.5, NO2 and CO were highest in winter and lowest in summer; the highest SO2 concentration was also observed in winter and was lowest in autumn, whereas the O3 concentration peaked in summer [6].

2. Study area
Ho Chi Minh City lies in the transitional zone between the Southeast and the Mekong River Delta. The general topography has a lower form from North to South and from East to West. Ho Chi Minh City is located in the subequatorial monsoon tropics, so it has a steadily high temperature throughout the year and has two distinct rainy and dry seasons affecting the air environment. The rainy season is from May to November, the dry season from December to April next year. According to the observational documents of the Tan Son Nhat station in many years through the main meteorological factors show the following climatic characteristics of HCMC. Rainfall is average/year of 1,949 mm. The average number of rainy days per year is 159 days. About 90% of the annual rainfall is concentrated in rainy months; in which, June and September usually have the highest rainfall. Rainfall in February and March is very little and negligible. On the scale of the city space, rainfall is not evenly distributed,
tends to increase gradually along the southwest - northeast axis. Most of the central districts and the northern districts usually have higher rainfall than the southern and southwest districts.

Wind is influenced by two main wind direction, mainly monsoon West - Southwest and North - Northeast. The West-South wind from the Indian Ocean blows in the rainy season, from June to October, the average speed is 3.6 m/s and the wind is strongest in August, the average speed is 4.5 m/s. The North-Northeast wind blows from the East Sea in the dry season, from November to February, with an average speed of 2.4 m/s. Besides, there is trade wind blowing south-southeast direction from March to May with the average speed of 3.7 m/s.

![Figure 1](image_url)

**Figure 1.** The transportation system and industrial area mapping of Ho Chi Minh City

3. **Method and Data**

3.1. **Method**

The research extracted air pollution information from data collected by OMI (Ozone Monitoring Instrument) on AURA satellite of the A -Train group, OMI data covers a period of more than 10 years for the analysis of pollution trends. It is important to correlate emissions with urban and industrial sources of emissions, to determine the location of emission sources from the VNREDSAT data. From the data set, ICST developed calculation techniques from the RT model (radiation propagation technique) to analyze remote sensing image data and extract NO₂ and SO₂ pollution data [7].
3.2. Data
- Collect monthly OMI data set from 2015 to 2019 in Ho Chi Minh City and surrounding areas to analyze the laws of change and the impact of air pollutants.
- Data NO\textsubscript{2} and SO\textsubscript{2} were extracted from the 2 km resolution image showing air pollutants for the HCMC area (90 km x 110 km).
- Interpolate extracted data for the study area, then display it on map and statistic data.

4. Result and Discussion

4.1. Creating NO\textsubscript{2} concentration map
The concentration of NO\textsubscript{2} depends on time. According to National Technical Regulation on Ambient Air Quality, permissible maximum concentration 100 μg/m\textsuperscript{3}. As a result, the research shows that the concentration of NO\textsubscript{2} meets the regulation. Currently, the traditional method to estimate concentration of NO\textsubscript{2} is data acquisition from automatic air quality stations. The monitoring shows the annual concentration of NO\textsubscript{2} is higher than that of the previous year, especially along street areas of the city. However, as a matter of fact that the number of monitoring stations is not enough for mapping NO\textsubscript{2} concentration for the whole city. Therefore, the method of analyzing OMI data to create NO\textsubscript{2} concentration map is applied as a effective alternative.

Figure 3 shows a spatial distribution of NO\textsubscript{2} concentration in HCMC that is estimated by using OMI data from January to June 2019. The trend shows the concentration of NO\textsubscript{2} is highest in the city center in February and March in the dry season. Due to the impact of Southeast wind from March to May with the average speed of 3.7 m/s, NO\textsubscript{2} moves towards District 2, Thu Duc district and Nha Be district.

Around 90% of the annual rainfall is concentrated from May to November, of which the strongest is in August. On contrary, February and March have little rainfall. Moreover, the rainfall is unevenly distributed especially for the southwest-northeast axis. Additionally, the rainfall in the northern districts is higher than that in the southern and southwest districts. In combination with the influence of West-Southwest wind blowing from Indian Ocean in rainy season results in the transfer of NO\textsubscript{2} to southwest areas, Nha Be district, and the southern part of Binh Chanh district (Figure 4).

Figure 5 provides the information that the concentration of NO\textsubscript{2} increases in the city center during the dry season due to the influence of the North-Northeast wind blowing from the East Sea due from October to December 2019.
Figure 3. Trend of NO\textsubscript{2} concentration (January to June 2019) in study area
Figure 4. Trend of NO$_2$ concentration (July to September 2019) in study area

Figure 5. Trend of NO$_2$ concentration (October to December 2019) in study area

The 2019 results show that the concentration of NO$_2$ clearly fluctuates with seasons which is relatively high in the dry months (Figure 6) and lower in the rainy season (Figure 7).
Figure 6. Trend of NO₂ concentration in dry season

Figure 7. Trend of NO₂ concentration in rainy season

Figure 8 shows the change in average concentration of NO₂ in 2015-2019. Especially in 2018, the concentration exceeded 70 μg/m³ in January, February, November, December with the value of 74.2 μg/m³, 79.1 μg/m³, 82.7 μg/m³, 74.3 μg/m³, respectively.
Figure 8. Variation of mean concentration of NO\textsubscript{2} in 2015-2019 (μg/m\textsuperscript{3})

4.2. Creating SO\textsubscript{2} concentration map
In addition to other pollutants, the air environment in HCMC is also affected by SO\textsubscript{2} in industrial areas which use lots of fossil fuel and also along main roads in the city. As regulated, the concentration of SO\textsubscript{2} must be lower than 0.3 mg/m\textsuperscript{3}. According to the analysis of OMI data, there are several industrial parks having higher concentration of SO\textsubscript{2} than the standard. Besides, the concentration of SO\textsubscript{2} at main street areas are also higher than the standard with the value of 0.3 – 0.8 mg/m\textsuperscript{3}. Figure 9 shows the spatial distribution of monthly concentration of SO\textsubscript{2} in HCMC in 2018.

Figure 9. Trend of SO\textsubscript{2} concentration (2018) in study area
Figure 9 reveals that the variation of SO\textsubscript{2} is uneven between by seasons and by districts while the NO\textsubscript{2} variation is relatively even in HCMC. In August 2018, the change of SO\textsubscript{2} concentration in the West-South region is very high compared to the city center and the Northwest region. The concentration of SO\textsubscript{2} ranged from 0.03 to 0.65 mg/m\textsuperscript{3}, while in May, the concentration of SO\textsubscript{2} reached the value ranging from 0.1 to 1.98 mg/m\textsuperscript{3}.
Figure 10 shows that changes of SO$_2$ in the dry season between 2015, 2016 and 2017 are concentrated in most industrial zones with the higher value than the permitted standard (0.3 mg/m$^3$). The concentration of SO$_2$ reached 4.47 mg/m$^3$ and 3.4 mg/m$^3$ in June 2015 and January 2017, respectively. In the meantime, the concentration of SO$_2$ at main intersections in central areas are at the permitted standard. In general, the concentration of SO$_2$ in the city reaches the highest value in the dry season (January).

**Figure 10.** Trend of SO$_2$ concentration in January (2015-2018) in study area
5. Conclusion
The paper shows the results of extracting pollution levels of NO\textsubscript{2}, SO\textsubscript{2} from remote sensing images and develops solutions to map pollution trends over time. In addition, the data is analyzed to determine the locations of emission sources in order to forecast changes of pollutants to significantly contribute to the development of air quality management plans. The results show that the impacts of air pollutants are usually concentrated in the dry season (from January to March) and HCMC has a higher concentration of pollution in urban area, industrial area. In rainy season concentration of NO\textsubscript{2}, SO\textsubscript{2} is reduced. Therefore, the control and reduction of air pollution in urban areas of Ho Chi Minh City must be based on a series of synchronous solutions, including climate and weather characteristics.

References

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