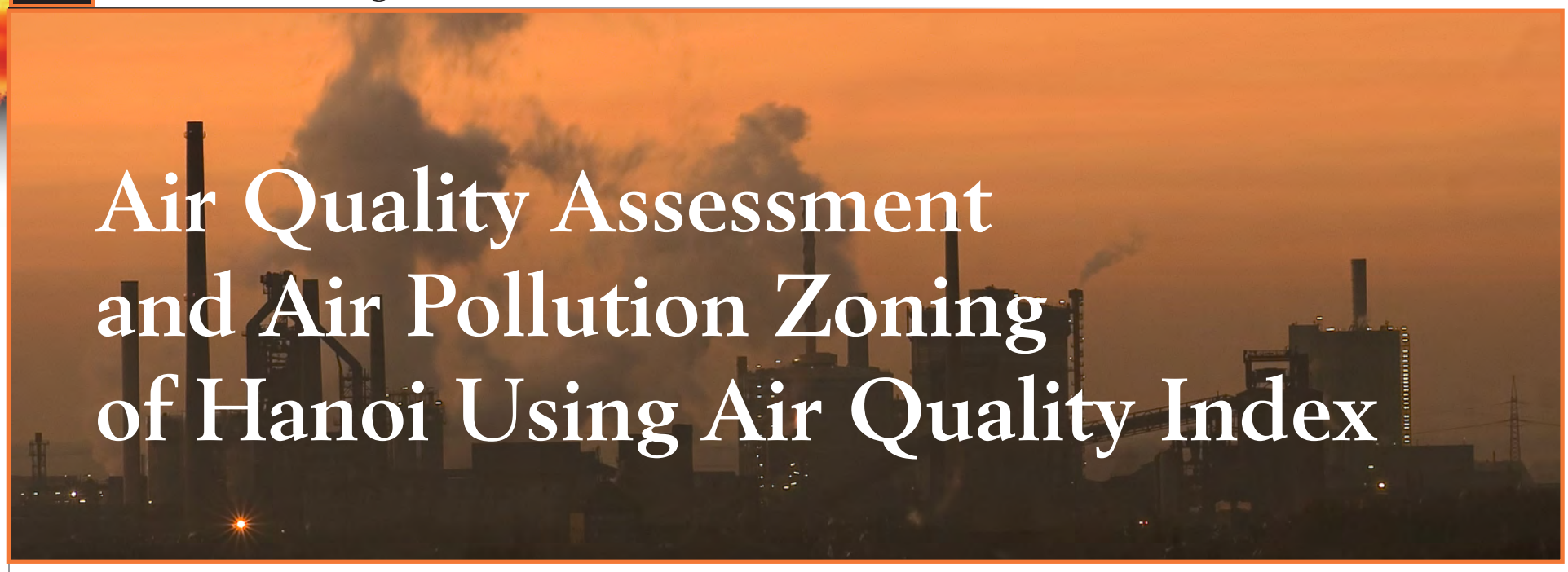

Air Quality Assessment and Air Pollution Zoning of Hanoi Using Air Quality Index

Pollution control is an important task in environmental management. Pollution and ambient air quality often vary over space and time. In many countries, the zoning of pollution or the quality of the ambient environment is often conducted on the basis of a defined period of time, about 5 to 10 years. It often uses two approaches to assess pollution or environmental quality of the ambient air. The first approach is using a dispersion model in combination with a geographic information system (GIS) to calculate environmental pollution. This approach requires a full description of all emission sources of environmental pollution and full parameters of weather conditions, terrain etc. of the study area. The second approach involves the synthesis, analysis and statistics of real environment monitoring data. This method requires a complete system of ambient environmental monitoring stations covering the study area. This approach is based on the concept of the Air Quality Index (AQI).

This study presents results of zoning air quality based on the second approach and AQI application. Therefore, GIS technology and software computing air quality index AQUIS are applied.

"This paper presents the methodology and results of the AQI-based air pollution assessment. For this purpose, the approach was built to fit Hanoi's actual state based on the AQI model and AQUIS."

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Introduction

The development of models for assessing and forecasting air quality has been widely applied in air environment pollution control recently. Many studies have been conducted in foreign countries and in Vietnam to develop the AQI for comprehensive assessment of ambient air quality. The AQI research has been conducted for the purpose of developing a model to forecast daily AQI and to serve as a basis for decision-making processes. The US Environmental Protection Agency (USEPA) has used various AQI applications for different criteria with pollutants such as $PM_{2.5}$, PM_5, PM_{10}, sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO). In work which studies AQI index based on the daily relative risk of daily mortality associated with short-term exposure of common air pollutants6, parameters used for the calculation include SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3 and CO. Another piece of research[7] studies the comparison of Revised Air Quality Index (RAQI) and Pollution Standards Index (PSI) with AQI. The authors use parameters such as PM_{10}, $PM_{2.5}$, SO_2, CO and NO_2 for calculating RAQI. A further study[8] has developed an aggregate Air Quality Index to assess air pollution in Mediterranean urban areas and analyse potential health impacts. The pollution parameters used to calculate the AQI include CO, SO_2, NO_2, O_3, PM_{10}. In India, the AQI developed by USEPA is used to give different criteria. The sub-index and breakpoint concentrations in the formula, however, are made with Indian National Ambient Air Quality Standard.

Zoning of air pollution for a city or province has been the subject of many research projects in Vietnam. Work by Pham Ngoc Dang[3,4] investigates all sources of industrial waste in Hanoi with information about location, coordinates of plants and factories, fuel consumption, flue size, emission volumes, climate conditions and uses the Gauss -Sutton – Pasquill model to calculate and zone air quality in Hanoi.

In 2011, the Vietnam Environment Administration announced the AQI calculation method[5] under the Decision 878/QD-TCMT. This method, however, does not pay attention to the importance of each involved substance. In this research, the authors set up a coefficient of importance (weight coefficient) for each pollutant considered. In addition, it requires the use of automated calculating tool with results displayed on GIS platform to apply the AQI calculating method.

This research is done with a goal of assessing air quality assessment and zoning air pollution in Hanoi using AQI.

Methodology

Approach

To conduct this study, authors have developed database and proprietary software named AQUIS (Air Quality Index Software) to manage data, and algorithms to calculate and zone air pollution. AQUIS has been developed on a basis of the approach presented in a study on integration of environmental databases, mathematical models and GIS[1,2]. AQUIS consists of an ambient air monitoring data management module, a GIS processing module, mathematical models, simulation calculation result displays, and reporting and statistics modules.

Used AQI Methods

AQI is also an index that assesses air pollution. So AQI formula helps determine levels of air pollution. Firstly, AQI for each pollutant is identified with the following formula:

$$AQI_i = \frac{1}{n}\sum \frac{C_{i,j}}{C_{i,0}} \times AQI_{conventional} \quad (1)$$

In which, $C_{i,j}$ - is the annual or daily average concentration of pollutant *i* - is the monitoring results at location *j* within study range; *j = 1,2,3... n*. The formula (2) is used to calculate the annual average AQI for pollutants *i*, in which, $C_{i,0}$ is the concentration of allowed standard of pollutant i, corresponding to Vietnamese standard allowing annual average concentration of 50 µg/m³ for SO_2, 40 µg/m³ for NO_x and 140 µg/m³ for TSP (total suspended dust). $AQI_{conventional}$ is the conventional air quality index, corresponding to $C_i = C_{i,0}$, depending on the individual country. In the US, for example, $AQI_{conventional} = 100$. According to research results in Nguyen Thi Thanh Tram, (2011), the estimated

$AQI_{conventional}$ for Vietnam is 100.

Air quality monitoring results for the national and local environmental monitoring systems show only 4 out of 7 basic parameters of pollutants which are defined in Vietnamese standards, including SO_2, CO, NO_2, TSP. Such parameters as PM_{10}, O_3 and P_b are neither regularly observed nor monitored in urban areas and the transport sector. Data of such parameters cannot be taken into account to determine criteria for zoning pollution across the country. The development of pollution zoning criteria in Vietnam at present uses 4 basic parameters.

This study applies the following formula to calculate the annual average AQI for SO_2, CO, NO_2 and TSP:

$$AQI(NO_2) = \frac{1}{n}\sum_{j=1}^{n}\frac{\frac{1}{p}\sum_{k=1}^{p}C_{j,k}(NO_2)}{C_0(NO_2)}\times 100; AQI(TSP) = \frac{1}{n}\sum_{j=1}^{n}\frac{\frac{1}{p}\sum_{k=1}^{p}C_{j,k}(TSP)}{C_0(TSP)}\times 100 \quad (2)$$

$$AQI(NO_2) = \frac{1}{n}\sum_{j=1}^{n}\frac{\frac{1}{p}\sum_{k=1}^{p}C_{j,k}(NO_2)}{C_0(NO_2)}\times 100; AQI(TSP) = \frac{1}{n}\sum_{j=1}^{n}\frac{\frac{1}{p}\sum_{k=1}^{p}C_{j,k}(TSP)}{C_0(TSP)}\times 100$$

In which, *j* is the number of monitoring locations in selected areas, *j = 1,2,..., n; k* is the number of annual observations, *k = 1, 2,..., p;* $C_{\sigma_{(i)}}$ is the allowed maximum annual average concentration pollutant *I* according to the national environmental standard/regulations, including: C_0 (SO_2), C_0 (CO), C_0 (NO_2), C_0 (TSP) with respective value of 50 µg/m³, 3000 µg/m³, 40 µg/m³ and 140 µg/m³. AQUIS has integrated the AQI calculation method studied in *Modelling on air quality assessment based on Air Quality Index (AQI) in accordance with the conditions of Vietnam*[11]*:*

- The method without weight coefficients of AQI_0 as follows:

$$AQI(NO_2) = \frac{1}{n}\sum_{j=1}^{n}\frac{\frac{1}{p}\sum_{k=1}^{p}C_{j,k}(NO_2)}{C_0(NO_2)}\times 100; AQI(TSP) = \frac{1}{n}\sum_{j=1}^{n}\frac{\frac{1}{p}\sum_{k=1}^{p}C_{j,k}(TSP)}{C_0(TSP)}\times 100 \quad (3)$$

- AQI_0 total is defined with weight coefficients as follows:

$$AQI(NO_2) = \frac{1}{n}\sum_{j=1}^{n}\frac{\frac{1}{p}\sum_{k=1}^{p}C_{j,k}(NO_2)}{C_0(NO_2)}\times 100; AQI(TSP) = \frac{1}{n}\sum_{j=1}^{n}\frac{\frac{1}{p}\sum_{k=1}^{p}C_{j,k}(TSP)}{C_0(TSP)}\times 100 \quad (4)$$

Calculation Result Display Module

Based on air quality monitoring data and AQI modeling, AQUIS allows calculation of AQI of the study area. AQUIS outputs are in two forms including direct results superimposed on digital map layers and ArcGis shape file maps, which will be further processed with the ArcGIS software and maps and pollution zoning maps then will be decorated with MapInfo *(Figure 1)*.

Figure 1. Steps of AQUIS operation

Used Data

The authors have collected most of the air monitoring data at Hanoi from 2006 to 2010, with 4 measurement parameters (TSP, SO_2, NO_2 and CO) with 6 periods in a year (2 months per period), but only AQI in 2010 will be used for air pollution zoning for Hanoi City. To develop air quality evaluation modelling and air pollution zoning software in Hanoi, the authors used administrative maps of Hanoi to show monitoring sites of industrial parks and complexes, urban/residential areas, and craft villages *(Figure 2)*.

Classification of Monitoring Types

Air quality monitoring data of Hanoi is classified according to the following monitoring types including industrial parks, residential areas, urban areas, and industrial complexes and craft villages. The number of monitoring sites for each monitoring type is shown in Table 1.Since 2010 Hanoi authorities have uniformed urban and residential areas. The city's network of monitoring sites is large enough to provide a good basis for pollution zoning with AQI.

Table 1. Total number of air quality monitoring sites for each monitoring type

TYPES	2010
Industrial Park	136
Urban Area	115
Industrial Complex	88
Craft Village	87
Residential Area	153
TOTAL	579

Results and Discussion

Air pollution calculation and zoning results according to the total air quality index (AQI_0) are presented in Figure 3 - Figure 5.

Figure 2. Maps of air monitoring sites in Hanoi, 2010.

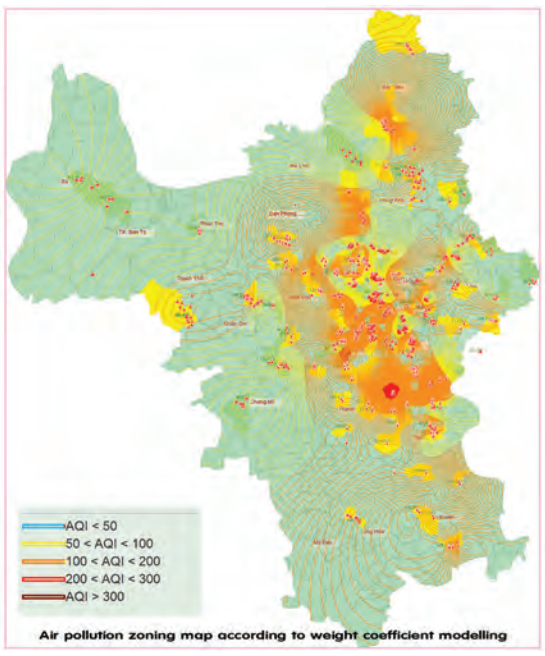

Figure 3. Air pollution zoning map according to weight coefficient modelling.

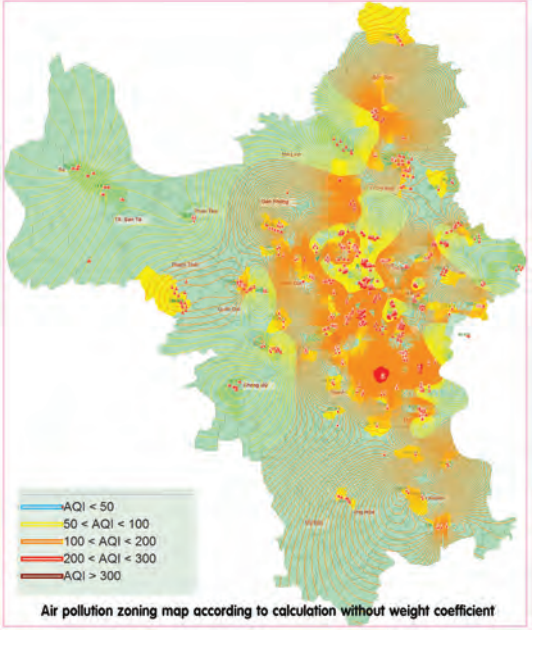

Figure 4. Air pollution zoning map according to calculation without weight coefficient.

Air Monitoring

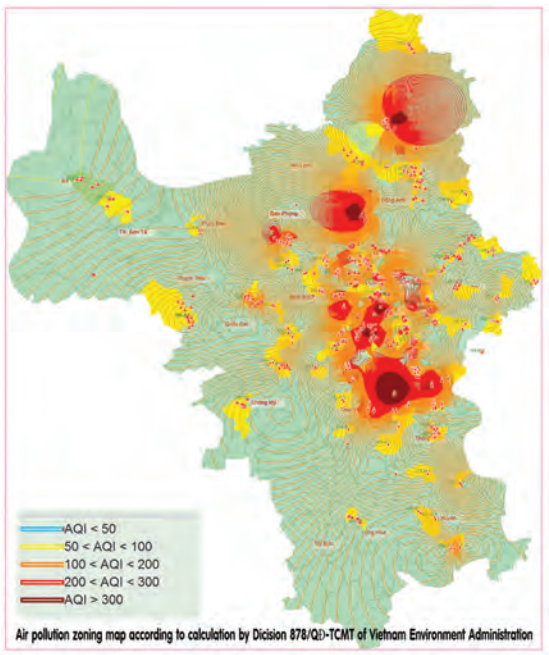

Figure 5.Air pollution zoning map according to calculation by Vietnam Environment Administration (VEA).

AQI values calculated both with and without weight coefficient show little difference. Using weight coefficient provides AQI values higher than the method without weight coefficient by between 1.5% and 8%, depending on the monitoring sites. Owing to a relatively large AQI-based zoning range, the number of monitoring sites located in good air quality and air pollution areas, however, does not vary much. Meanwhile AQI calculated by the VEA is much is higher. AQI of most of the monitoring sites calculated by the VEA's method is around 30-70% are higher than that of the weight coefficient method. The highest difference reached over 250%. This is consistent with the above mentioned analysis as the VEA's method selecting max value of monitoring data, making AQI higher than reality. The pollution zoning map calculated by the VEA's method shows many areas in orange, red, and even brown.

Comparison of results of monitoring data values and permitted national technical regulation values:

SO_2 pollution: The 2010 monitoring data from the VEA and the North Inland Environmental Monitoring and Analysis Station showed most of the collected data is lower than permitted values. At most monitoring sites according to the VEA's data, SO_2 concentrations are below the permitted standards. However, during the first monitoring period in 2010, many sites had SO_2 levels exceeding the permitted standards.

CO pollution: the 2010 environmental monitoring data by the VEA shows that measured CO concentrations from different monitoring periods, and from most monitoring sites in Hanoi, have not exceed the permitted national technical regulation values yet. CO concentrations at the Noi Bai Airport area during the first monitoring period (late April and early May) were highest but yet to exceed the permitted standards. The monitoring data by the North Inland Environmental Monitoring and Analys Station shows similar results; CO concentrations at all monitoring sites have not exceeded the permitted standards.

NO_2 pollution: the 2010 environmental monitoring data by the VEA indicates that NO_2 concentrations at all monitoring sites have not exceeded the permitted standards yet. Similarly, the monitoring data by the Environmental Monitoring and Analyzing Station shows that NO_2 concentrations were below the permitted national technical regulation values. The results of this analysis also coincides with the single calculation AQI for each parameter analysed above.

TSP pollution: the 2010 environmental monitoring data by the VEA shows that TPS concentrations in many monitoring periods at monitoring sites (25/35 observations in 7 monitoring sites) have exceeded the permitted standards. There were monitoring periods when TSP concentrations were in excess of the permitted standards by more than 5 times. One of the causes of suddenly high TPS concentrations is that the monitoring takes place in late November and early December when Hanoi witnesses dry weather and TSP pollution levels are higher than normal.

Conclusion

This paper presents the methodology and results of the AQI-based air pollution assessment. For this purpose, the approach was built to fit Hanoi's actual state based on the AQI model and AQUIS. The following results can be drawn from the study's results:

AQI-based software for calculating and assessing ambient air quality in Hanoi is a convenient tool, allowing managers and researchers to save time on calculating and mapping the air quality status of Hanoi, so as to propose timely control measures. Air pollution mapping is a simple and intuitive tool for conveying timely air pollution warnings to communities, helping people and concerned agencies monitor air pollution, raising community awareness on controlling and preventing violations of law in order to improve the environmental air quality.

AQI calculation with weight coefficient formula is appropriate in current conditions of Vietnam. Although AQI value calculated with a weight coefficient formula is not much different from the formula without weight coefficient, it shows the impact of each air pollutant on humans and organisms in the environment.

According to the calculation results, Hanoi's air was polluted in 2010. Pollution levels of some places at some times were higher than national technical regulation values. Some areas are heavily TSP polluted and many places are TSP polluted to a lesser extent. Hanoi was NO_2 unpolluted but some areas were polluted with CO and SO_2.

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