НАУКА ЗЕМЛИ

AIR POLLUTION ASSESSMENT OF DONG NAI PROVINCE (VIETNAM) BASED ON GIS AND INTERPOLATION ALGORITHMS

Nguyen T.Hung[1],
Kosinova I.Ivanobna[2],
Nguyen D.Long[3]
[1]Vietnamese National University of Forestry, Ha Noi, 1000, Viet Nam
[2]Voronezh State University, Voronezh, 394018, Russia
[3]Center for Information Resources and Environment Technology under the Department of Natural Resources and Environment of Ba Ria - Vung Tau Province, Vung Tau, 78000, Vietnam.

ABSTRACT

Air pollution is a global problem. Interpolation algorithm the inverse distance weight can be used to determine the distribution of pollution in space, helping managers to issue environmental warnings. Studies have shown that the atmosphere is polluted by dust and concentrations of NO_2, SO_2, and CO, in industrial zones and urban areas. The AQI dust index and AQI CO are very high during the dry season (AQI= 100-300) and lower during the rainy season (AQI<100). This shows that air pollution in the dry season is very high and dangerous to human health.

Keywords: Pollution; Atmosphere; Dust; SO_2; NO_2; CO; Dong Nai.

INTRODUCTION

Air pollution can be defined as any atmospheric condition in which certain substances are present in concentrations that may have undesirable consequences for people and the environment. Air pollution is often concentrated in densely populated urban areas, especially in developing countries where environmental regulations are relatively inactive or absent [Ostachuk et all, 2008]. However, even in densely populated areas of developed countries there is an unhealthy level of pollution [Michelozzi et all, 1998]. In developing and poor countries, traditional biomass burning is the main source of air pollution; Traditional biomass includes wood, agricultural waste and manure. It is estimated that air pollution in cities annually leads to the death of 1.3 million people worldwide [World Health Organization, 2018a]. According to a report by the World Health Organization ambient (outdoor) air pollution in both cities and rural areas was estimated to cause 4.2 million premature deaths worldwide per year in 2016 [World Health Organization, 2018 a], People living in low- and middle-income countries disproportionately experience the burden of outdoor air pollution with 91% (of the 4.2 million premature deaths) occurring in low- and middle-income countries, and the greatest burden in the WHO South-East Asia and Western Pacific regions [World Health Organization, (2016, 2018a)]. A sobering report released by the International Energy Agency says air pollution has become a major public health crisis leading to around 6.5 million deaths each year, with “many of its root causes and cures” found in the energy industry [The new york time, 2016]. Air pollution is the main cause of poisoning for millions of children under the age of 15 years, and the destruction of their lives leads to the death of about six hundred thousand children a year [Reuters, 2018]. Some researchers in Europe have found that exposure to ultrafine dust particles can increase blood pressure in children [Pieters et all, 2016]. In developing countries, children under 5 are considered to be the most vulnerable part of the population due to air pollution [World Health Organization, 2018b].

India is a country with the highest mortality rate due to air pollution [The new york time, 2017]. China is considered the world's largest manufucturing hub, so the problem of pollution is very serious. The estimated number of deaths due to air pollution in China is about 500000 people per year [The telegraph, 2014]. From 2002 to 2011, the incidence of lung cancer in Beijing almost doubled. While smoking remains the main cause of lung cancer in China, the number of smokers is decreasing, while the incidence of lung cancer is increasing [Shuo L. Et all, 2018]. There is a positive correlation between mortality rate from pneumonia and air pollution from vehicle emissions [Zhe M. Et all, 2018]. In Europe, the number of people who die each year due to air pollution ranges from 430000 to 800000 [News, 2016]. In the UK, nitrogen dioxide causes 23500 premature deaths every year [Support The Guardian, (2008, 2017)]. Danish epidemiologists have found an increased risk of lung cancer in patients living in areas with high levels of nitrous oxide. They also found a link between air pollution and other types of cancer, including cervical cancer and brain cancer [Raaschou-Nielsen et all, 2011].

Dong Nai is a province with a large number of huge industrial parks, a large flow of vehicles and a high population density in urban areas. The amount of CO emitted in 2018 is about 18 tons/hour, SO_2 - about 3.4 tons/hour, NO_x - about 1.5 tons/day. Air pollution caused by transport in urban areas accounts about 70% which is significant proportion. The main emissions from transport activities are SO_2, NOx & CO [Dinh Quoc Thai, 2018].

MATERIALS AND METHODS

Automatic air monitoring data was collected at 80 monitoring stations (Fig. 2.1). Indicators collected include dust (TPS), NO2, CO, SO2, wind speed,wind direction, temperature, air humidity. We collected data for 3 rainy months (August, September, October); for 4 dry months (December, January, March and April).

Use the air quality index (AQI) and total pollution index (TPI) to assess the air quality of the environment. AQI and TPI are calculated according to formula 2.1 and 2.2 [Tran Hong Ha, 2013; Kosinova Irina I, 2014].

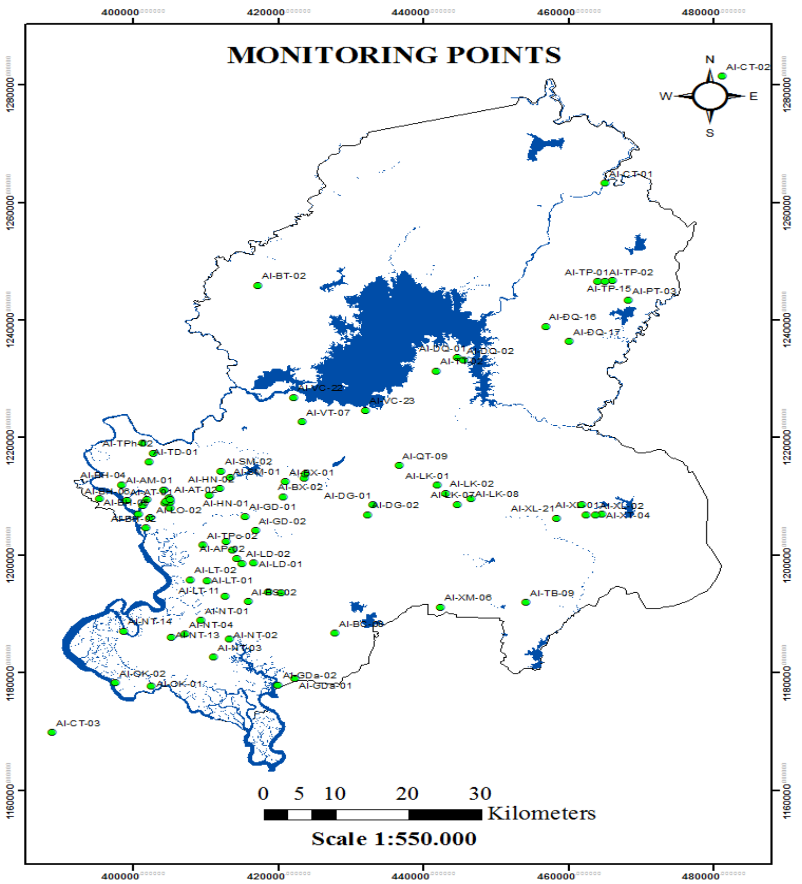


Figure 2.1 Monitoring points

$$AQI_i^{24h} = \frac{C_i^{24h}}{S_i^{24h}} \quad (2.1)$$

$$TPI = \sum_{k=1}^{n} AQI - \log_2 n \quad (2.2).$$

C_i^{24h} : The average concentration of substance i.

S_i^{24h} : Permissible environmental standards of substance i

n: Number of pollutants

Table 3.1.

Limits of basic parameters in air [Tran Hong Ha, 2013; Kosinova Irina I, 2014]

Parameter	Standard ($\mu g/m^3$)	AQI value	Air quality	TPI	Rank
Dust (TPS)	140	0-0.50	Good	-3≤*<-1	Natural background
SO_2	50	0.51-1.00	Medium	-1≤*<0	Technogenic background
NO_x	40	1.01-2.00	Bad	0≤*<2	Environmental standard
CO	5000	2.01-3.00	Very bad	2≤*<4	Environmental risk
		> 3.00	Dangerous	4≤*<8	Compensated crisis
				*>16	Disaster

Use the IDW (Inverse Distance Weighting) interpolation algorithm in Arcgis to interpolate pollution values in the study area. In IDW algorithm, interpolation points are determined by averaging the values of the monitoring points in the vicinity. The monitoring points have a greater degree of influence on the interpolation points closer to it than the interpolation points far from it, meaning that there is a greater weight of influence. The value of interpolation points is determined by formula (2.3) [Nazila K., 2012]:

$$Z_0 = \frac{\sum_{i=1}^{N} Z_1 d_1^{-n}}{\sum_{i=1}^{N} d_i^{-n}} \tag{2.3}$$

Z_0 : The estimation value of variable z in point i
Z_i : Sample value in point i.
d_1: The distance of sample point to estimated point
N: A coefficient that determines weigh based on a distance.

* Evaluate the accuracy of the interpolation results: Use the correlation coefficients R^2 and the NSI index (NashSutcliffe) to estimate the accuracy of the interpolation results (formula 2.4 & 2.5) [Krause P. et all, 2005; Nash, J. E. and Sutcliffe, 1970].

$$R^2 = \left(\frac{\sum_i^n (O_i - \bar{O})(P_i - \bar{P})}{\sqrt{\sum_i^n (O_i - \bar{O})^2} \sqrt{\sum_i^n (P_i - \bar{P})^2}} \right)^2 \quad (2.4) \quad NSI = 1 - \frac{\sum_{i=1}^n (O_i - P_i)^2}{\sum_{i=1}^n (O_i - \bar{O})^2} \quad (2.5)$$

O_i is the ith actual measured value.
$\bar{O}$ is the actual measured average value.
P_i is the predicted value.
$\bar{P}$ is the average predicted value.
n is the number of calculated values.

RESULTS

The assessment of air pollution was carried out on the basis of zoning, including the industrial zone, the solid waste treatment zone, the traffic zone and the urban population. Evaluation criteria include total dust (TPS), SO_2, NO_2 and CO.

According to data collected, during the dry months (December, January, March and April), the average temperature was 32° C, the wind speed is very low 0.2-1.0 m/s and the wind direction is northeast. The average humidity was 62%. During the rainy season (August, September, October) the average temperature was 30° C, the wind speed at the time of data collection was low, from 0.2-1 m/s, the south-westerly wind direction, the average humidity was 68%. Since the wind speed in the data collection process was rather low (0.2–1 m/s), the humidity and temperature between the dry and rainy seasons are relatively balanced. On the other hand, the terrain is quite flat (80% of the area is flat), so the influence of external factors, such as topography, wind, temperature and humidity is negligible.

AQI dust index

The general characteristic of dust content in the air is that the dry season always has higher dust content than the rainy season. The AQI index for dust in industrial areas is shown in chart 3.1, which shows that in most industrial zones in the province it exceeds the allowable level. The dry season has the highest level of pollution, since in march, april, december, almost everywhere, AQI exceeded 200-300 compared with the permissible level. The AQI of An Phuoc industrial zone (AI-AP-02) reached a very high level (AQI = 406) in december. This makes the air around this area polluted at a dangerous level. Another feature that is easy to see is that in large industrial areas, such as the industrial zone of Bien Hoa 1, Bien Hoa 2, Nhon Trach, Amata, the level of dust pollution is much higher than in small industrial zones, such as Song May and Tan Phu. This suggests that dust emissions into the air from large industrial areas should be controlled more closely. During the rainy season, dust pollution levels are lower than during the dry months, since most of the dust is washed away by rainwater. However, it is within 50-100% of the allowed level.

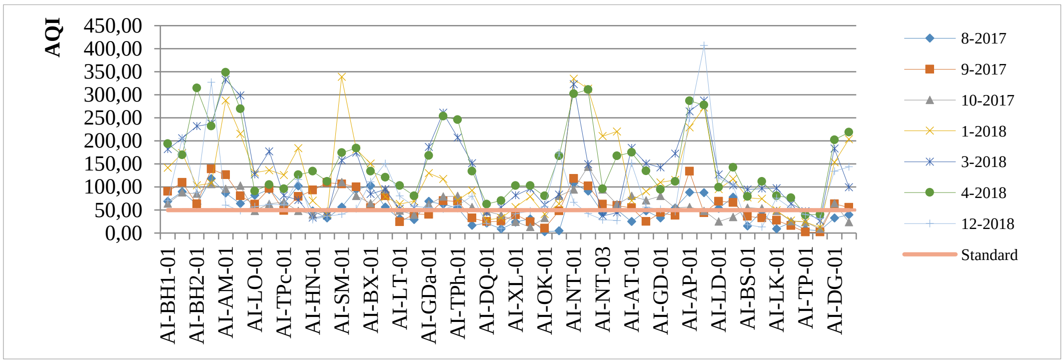


Chart 3.1 AQI Index of dust in industrial areas by months of the year

The average AQI index of dust in the solid waste treatment areas in Dong Nai province (chart 3.2) shows that in the Bien Hoa solid waste treatment area (AI-TD-01), the dust AQI index is rather high in January (AQI = 222). In addition, the AQI dust index in December at the solid waste treatment site in Phu Tan (AI-PT-03) was 204.3. This is a high level of pollution. Negative effects on human health.

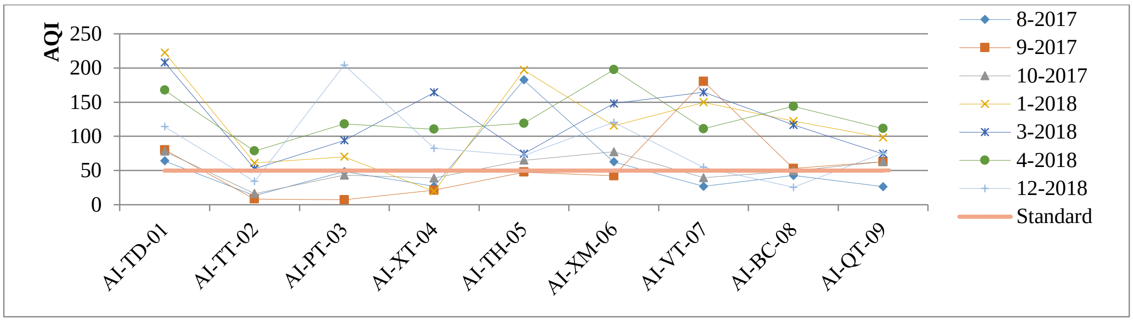


Chart 3.2 AQI Dust index in solid waste disposal areas by months of the year

The dust index AQI in traffic areas and urban areas is also quite high and exceeds the permissible level (AQI> 50). The dust content is particularly high in January at the locations of sources AI-BH-03 and AI-VC-22; AI-VC-23. In January and April (AQI index exceeds 300). However, in the rainy season, the dust index AQI is quite good (<50), the air quality in residential areas at this time is good and does not affect human health.

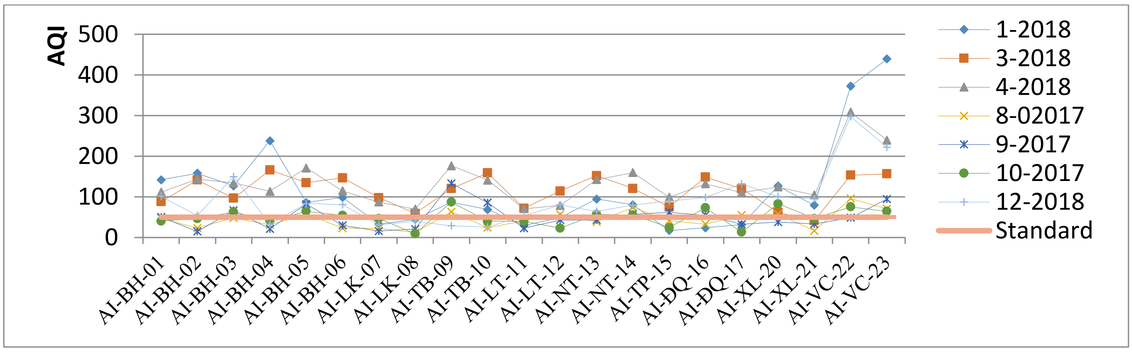


Chart 3.3 AQI dust index in urban residential areas by months of the year

AQI CO index

Based on chart 3.4, the AQI CO index in industrial areas exceeds the permissible level (> 100) and affects human health. Especially in march, an unusually high CO index (AQI = 446) is observed in the Bau Xeo area (AI-BX-01). For most of the points in january-march and april, the CO index exceeded the AQI from 150-250 in large areas.

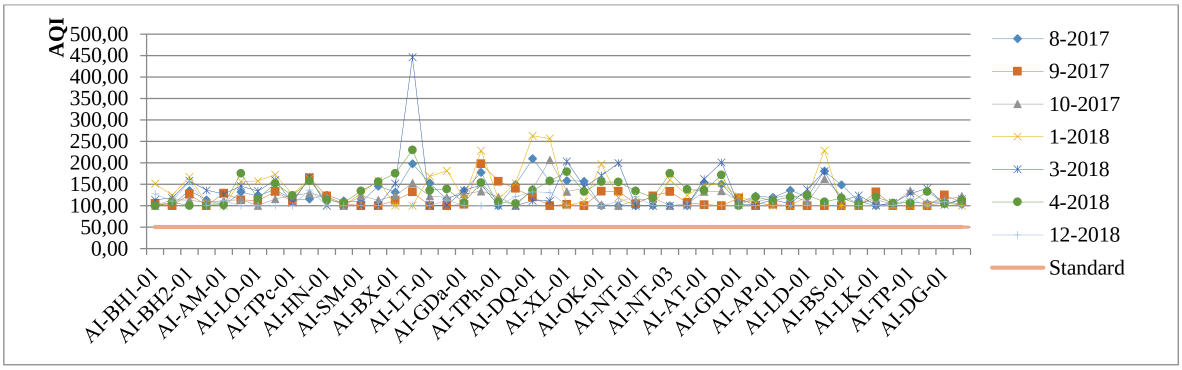


Chart 3.4 CO AQI index in industrial areas by months of the year

In general, the AQI CO index in the field of solid waste treatment in Dong Nai province is above the allowable level and exceeds 100. This is an average level of air quality that causes sensitivity to human health. Especially in January, very high AQI levels were noted at points AI-XM-06 and AI-VT-07 (AQI> 300). These are two areas that show that the amount of CO in this area is very dangerous for human health.

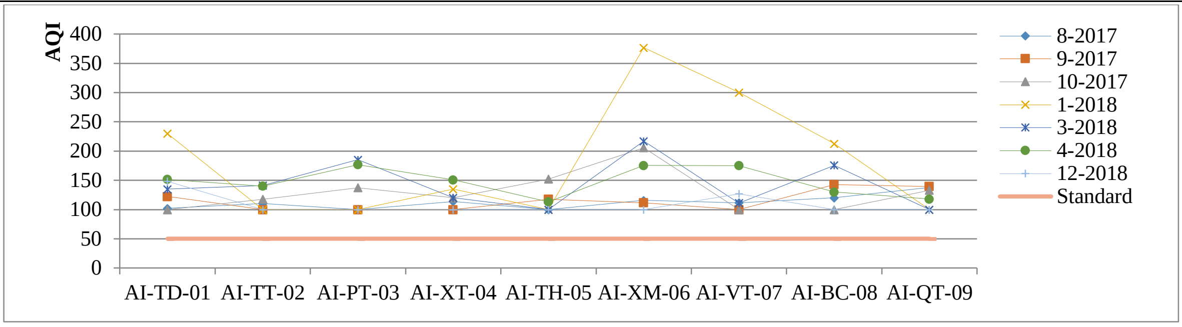


Chart 3.5 AQI index index in solid waste disposal areas by months of the year

Based on chart 3.6, the AQI CO index is exceeded in residential areas (>100), which affects human health. In Bien Hoa, the AQI CO index in March reached 450, and in January, the AQI CO index rose to 260. Most of the months of the rainy season have a lower AQI CO index, fluctuating in the range of 100-200.

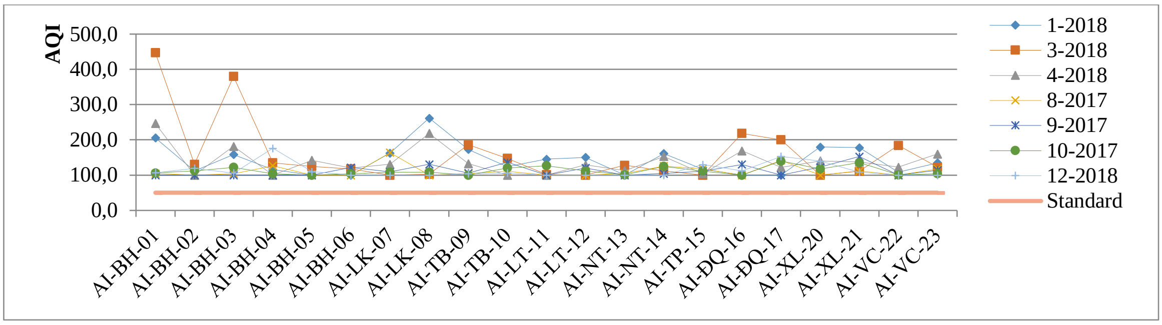


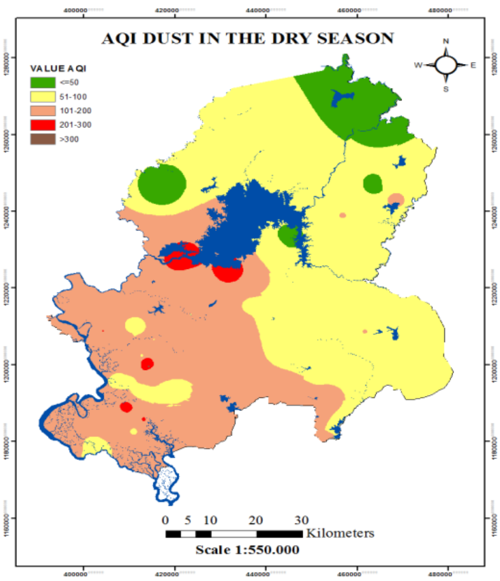
Chart 3.6 AQI CO index in urban residential areas by months of the year

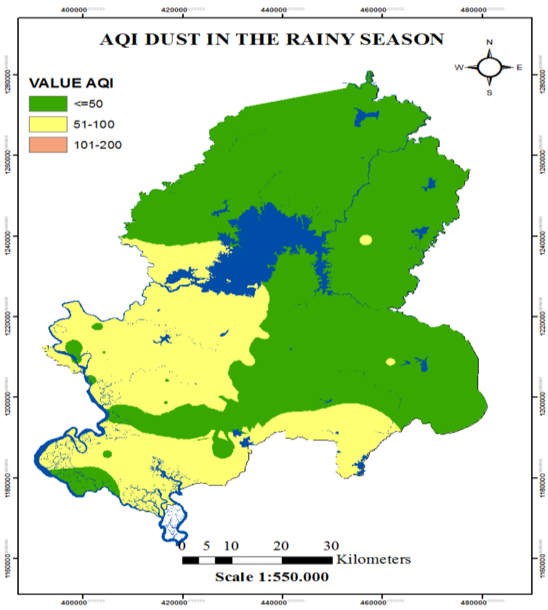
AQI-index of SO_2 and NO_2

According to the results of data analysis, the level of pollution of SO_2 and NO_2 in the study area is very low, within acceptable limits (AQI <50; TPI <0.5). Therefore, in this report we mention only two substances with a high level of contamination: dust and CO. However, on the total pollution index map, these pollution factors will be calculated.

As a result of the research, it was found that air pollution in Dong Nai province is mainly due to pollution by CO and CO. The main area of pollution is the air around large industrial areas, followed by urban residential areas and transportation, and, finally, landfills for solid waste. Maximum pollution is recorded during the dry months, mainly in January and March. The level of pollution at this time is considered harmful to human health. This is also consistent with the report of Dong Nai department of health about the number of patients suffering from respiratory diseases in the dry season accounting for 70% of patients in the year [Nguyen Trong Hai, 2018].

Space distribution of air pollution based on IDW interpolation





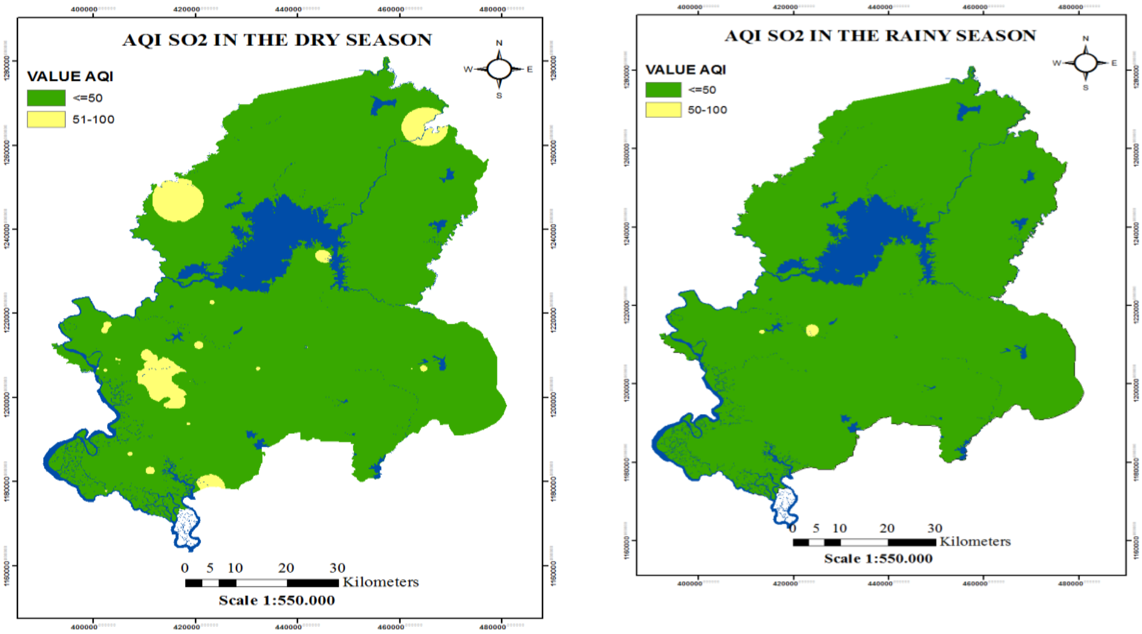
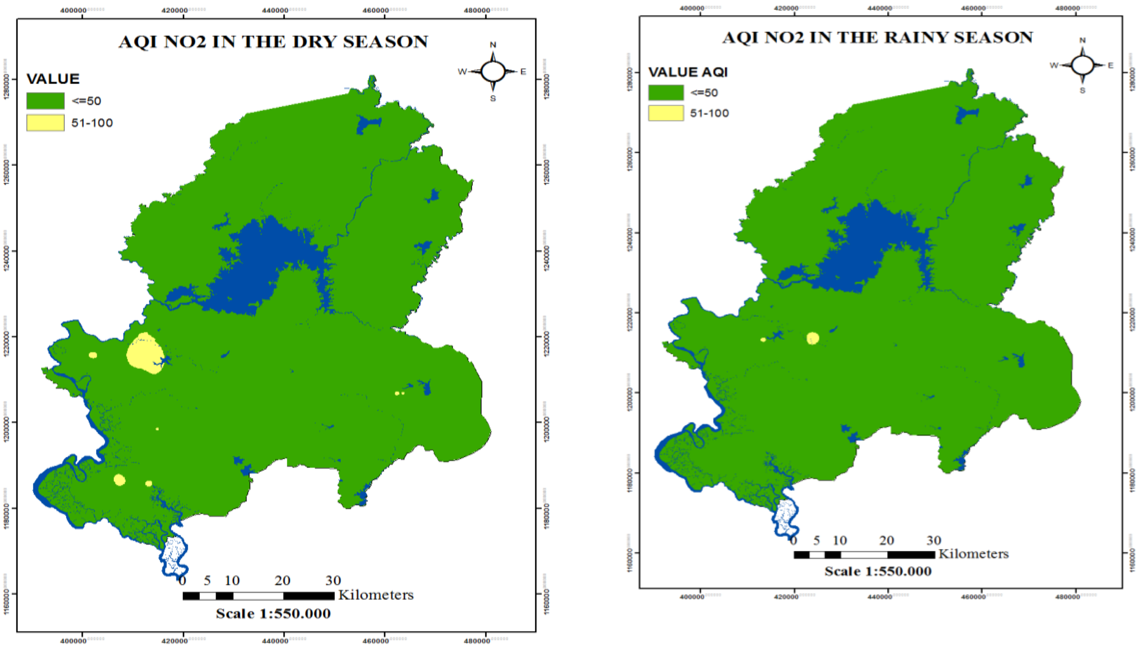


Figure 3.1 Distribution of air pollution by dust and SO_2



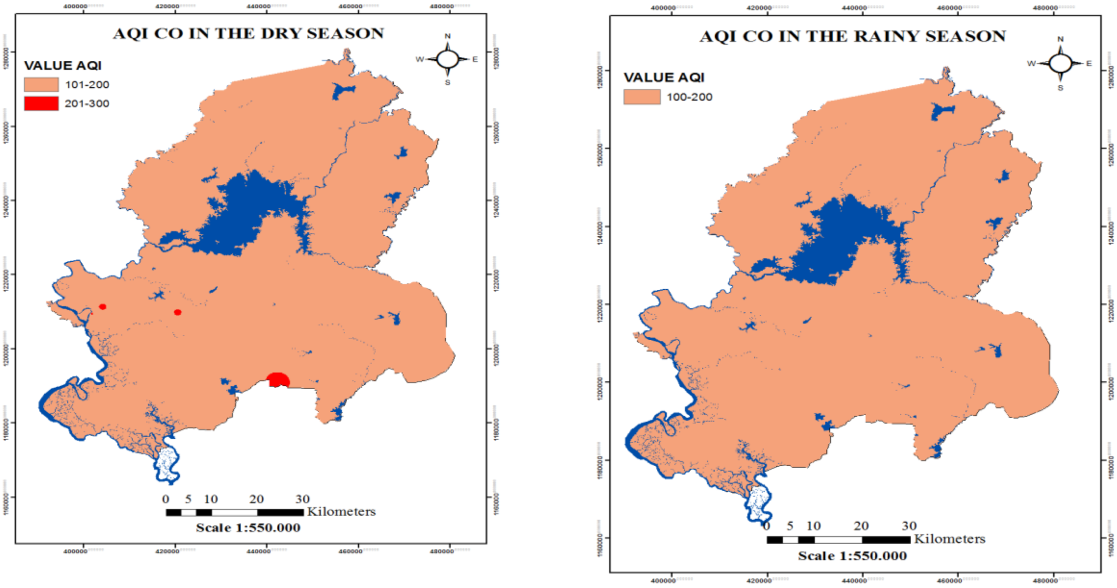


Figure 3.2 Figure 3.1 Distribution of air pollution by NO_2 and CO

As shown in figure 3.1 & 3.2, air pollution is mainly due to dust and CO. The territory polluted by dust is mainly located in the southern and western regions. The dry season has a level of pollution, and the area of pollution is distributed more widely than the rainy season. This is quite consistent with the distribution of territories. The northern and eastern areas are agricultural production areas and have a large national park, a fairly fresh air. In the west and south, there are many industrial parks and urban areas, so the level of pollution is higher. From that, it can be seen that the source of air pollution is mainly from industrial and urban waste gas.

Based on the results of the interpolation, the project calculates the NSI index and correlation coefficient to estimate the accuracy by the interpolation method (Table 3.1). The NSI and R^2 indices are quite high (R^2, NSI> 0.7), especially these indices are very high when interpolating SO_2 and NO_2 (R^2, NSI > 0.85).

Table 3.1

Correlation analysis results

	Correlation Coefficients (Rainy Season)				Correlation Coefficients (Dry Season)			
	Dust	SO_2	NO_2	CO	Dust	SO_2	NO_2	CO
NSI Index	0.73	0.86	0.87	0.95	0.70	0.88	0.82	0.89
Coefficient R^2	0.75	0.88	0.91	0.97	0.73	0.90	0.84	0.91

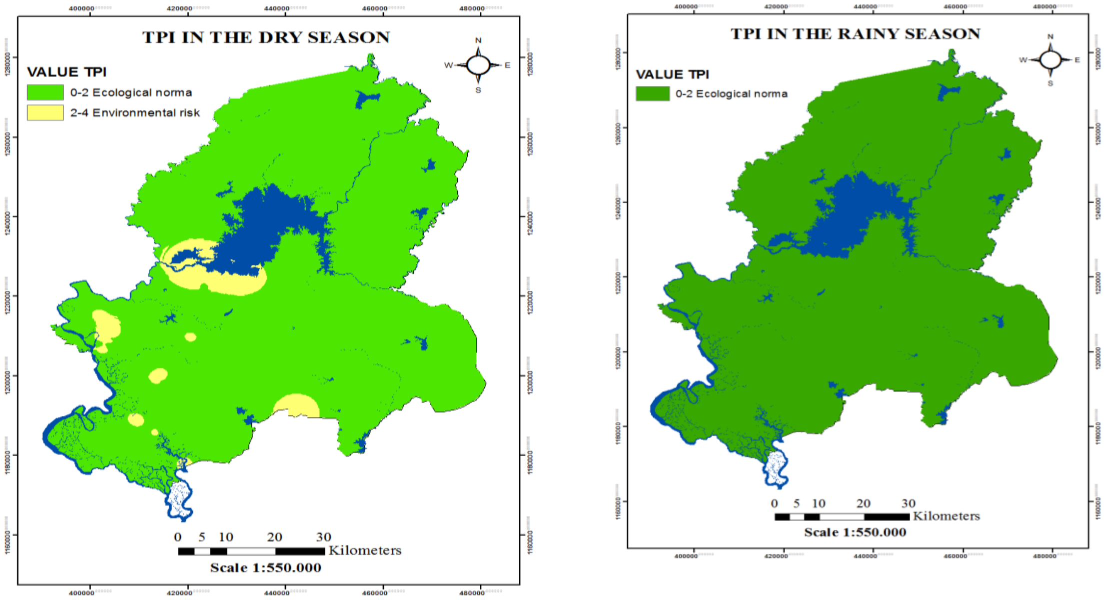


Figure 3.3 Integral interpolation model of air pollution

According to Figure 3.3, it can be seen that air quality in most areas is at an environmental standard level. In the dry season in the south and west there is a small part, the level of pollution is at environmental risk, this is a place for industrial and urban areas. In the northern and eastern regions during the dry season, the quality of the environment is still in an ecological norm, since the area has a national park and is agricultural production.

CONCLUSION

According to research results, it can be determined that in the dry season air pollution is due to the concentration of dust and CO in the air. The level of pollution is quite high AQI from 100-300, this is a dangerous level for human health. The location of pollution is mainly concentrated in the south-western part of the study area, where there are many large and populated industrial parks. Air pollution of SO_2 and NO_2 is almost not detected, the content of these two gases is low, within acceptable limits. During the rainy season, the level of pollution is below the allowable limit due to the process of self-purification of air from rainwater.

The test results of the accuracy of interpolation are quite high (R^2, NSI> 0.7), indicating the possibility of using the IDW interpolation algorithm in the assessment of air pollution in the study area is acceptable. This interpolation algorithm can be applied to forecast air pollution areas.

References

Dinh Quoc Thai (2018). Report on socio-economic development in 2018. Dong Nai, pp 25-35. (in Vietnamese)

Kosinova Irina I. and Fonova Svetlana I. (2014). Comprehensive assessment of the geosphere of vital activity of the population of the Lipetsk industrial district. Voronezh: Voronezh State University.

Krause P., Boyle D. P., and Base F. (2005). Comparison of different efficiency criteria for hydrological model assessment. Advances in Geosciences, (5), pp. 89–97.

Michelozzi P., Forastiere F., Fusco D., Perucci C. A., Ostro B., Ancona C., Pallotti G. (1998). Air Pollution and Daily Mortality in Rome, Italy. Occupational and Environmental Medicine, 55 (9), pp. 605–10. doi:10.1136/oem.55.9.605. JSTOR 27730990. PMC 1757645. PMID 9861182.

Nguyen Trong Hai (2018). Report the situation of infection in 2018. Dong Nai Department of Health, pp 75-86. (in Vietnamese)

News (2016). Car emissions: taking tests out of the lab and onto the road. [online] Available at: http://www.europarl.europa.eu/news/en/headlines/society/20160222STO15305/car-emissions-taking-tests-out-of-the-lab-and-onto-the-road. [Accessed 8 Apr. 2019].

Nazila K., Mohammad H., Ebrahim P., Davood N. and Hadi C. (2012). Comparison of Different Interpolation Methods for Investigating Spatial Variability of Rainfall Erosivity Index. Polish Journal of Environmental Studies, 21(6), pp.1659-1666.

Nash J. E. and Sutcliffe J. V. (1970). River flow forecasting through conceptual models, Part I - A discussion of principles. Journal of Hydrology, pp. 282–290.

Ostachuk A., Evelson P., Martin S., Dawidowski L., Yakisich J.S., Tasat D.R. (2008). Age-related lung cell response to urban Buenos Aires air particle soluble fraction. Environmental Research, 107 (2), pp. 170–177. doi:10.1016/j.envres.2008.01.007. PMID 18313661.

Pieters N, Koppen G., Van Poppel M., De Prins S., Cox B., Dons E., Nelen V., Int Panis L., Plusquin M., Schoeters G., Nawrot TS., (2015). Blood Pressure and Same-Day Exposure to Air Pollution at School: Associations with Nano-Sized to Coarse PM in Children. Environmental Health Perspectives, 123 (7), pp. 737–42. doi:10.1289/ehp.1408121. PMC 4492263. PMID 25756964.

Reuters, (2018). WHO says air pollution kills 600,000 children every year. [online] Available at: https://www.reuters.com/article/us-health-airpollution-children/who-says-air-pollution-kills-600000-children-every-year-idUSKCN1N3261. [Accessed 8 Apr. 2019].

Shuo L., Lei Y., Yannan Y., Huichao L., Jing T.,Sijia L., Ning W. and Jiafu J. (2018). Cancer incidence in Beijing, 2014. Chinese journal of cancer research. 30(1), pp. 13–20. doi: 10.21147/j.issn.1000-9604.2018.01.02.

Support The Guardian, (2017). London breaches annual air pollution limit for 2017 in just five days. [online] Available at: https://www.theguardian.com/environment/2017/jan/06/london-breaches-toxic-air-pollution-limit-for-2017-in-just-five-days. [Accessed 8 Apr. 2019].

Support The Guardian, (2008). Study links traffic pollution to thousands of deaths. [online] Available at: https://www.theguardian.com/society/2008/apr/15/health. [Accessed 4 Apr. 2019].

The telegraph, (2014). China's 'airpocalypse' kills 350,000 to 500,000 each year. [online] Available at: https://www.telegraph.co.uk/news/worldnews/asia/china/10555816/Chinas-airpocalypse-kills-350000-to-500000-each-year.html. [Accessed 8 Apr. 2019].

The new york time (2017). India's Air Pollution Rivals China's as World's Deadliest. [online] Available at: https://www.nytimes.com/2017/02/14/world/asia/indias-air-pollution-rivals-china-as-worlds-deadliest.html. [Accessed 8 Apr. 2019].

The new york time, (2016). Study Links 6.5 Million Deaths Each Year to Air Pollution. [online] Available at: https://www.nytimes.com/2016/06/27/business/energy-environment/study-links-6-5-million-deaths-each-year-to-air-pollution.html. [Accessed 8 Apr. 2019].

Tran Hong Ha (2013). National Technical Regulation on Ambient Air Quality. Ministry of Natural Resources and Environment, pp 1-3. (in Vietnamese)

Raaschou-Nielsen O., Andersen Z. J., Hvidberg M., Jensen S. S., Ketzel M., Sorensen M., Tjonneland

A. (2011). Air pollution from traffic and cancer incidence: a Danish cohort study. Environmental Health, 10, pp. 67. doi:10.1186/1476-069X-10-67. PMC 3157417. PMID 21771295.

World Health Organization, (2018a). Ambient (outdoor) air quality and health. [online] Available at: https://www.who.int/en/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health. [Accessed 8 Apr. 2019].

World Health Organization, (2018b). Air pollution and child health. [online] Available at: https://apps.who.int/iris/bitstream/handle/10665/275545/WHO-CED-PHE-18.01-eng.pdf?ua=1. [Accessed 8 Apr. 2019].

World Health Organization, (2016). Ambient air pollution: A global assessment of exposure and burden of disease. [online] Available at: https://www.who.int/phe/publications/air-pollution-global-assessment/en/. [Accessed 8 Apr. 2019].

Zhe M., Qiuli F., Lifang Z., Danni L., Guangming M., Lizhi W., Peiwei X., Zhifang W.,Xuejiao P., Zhijian C., Xiaofeng W., and Xiaoming L. (2018). Acute effects of air pollution on respiratory disease mortalities and outpatients in Southeastern China. Scientific Reports. (8) pp. 3461.

MONITOR CHANGES IN THE QUALITY OF DONG NAI RIVER WATER DURING THE SEASONS

Nguyen Thanh Hung[1],
Kosinova Irina Ivanobna[2]
[1]Vietnamese National University of Forestry, Ha Noi, 1000, Viet Nam
[2]Voronezh State University, Voronezh, 394018, Russia

ABSTRACT

The method of using WQI index to assess water pollution is used by many researchers. values of BOD5, COD, N-NH4, P-PO4, TSS, turbidity, total coliform, DO, pH, were used to calculate WQI index. Based on the value of WQI obtained, water quality is assessed in the study area. The method of determining WQI is based on the guidelines of the Ministry of Natural Resources and Environment of Vietnam. The results determine the extent and distribution of surface water pollution in the study area. At heavy polluted water levels (WQI≤25), pollutants are mainly caused by Coliform and Turbidity. At a lower level of pollution, water is only used for waterway purposes with pollution of many factors including turbidity, coliform, TSS, COD, DO, N-NH4. At the level of water only for agricultural usage, there are factors causing pollution. At the water level for drinking water, additional cleaning is required, the order of pollution decreases in the order of COD> Turbidity> DO> BOD5.

Keywords: Water pollution, WQI, Surface water, Dong Nai River, water quality.

Introduction

Water is an important component for the existence of flora and fauna in the biosphere (Kakar et al., 2010). Two-thirds of the earth's area is covered by water. This is an extremely valuable resource for people. However, people are not really aware of the value of this resource. One way or another, they are polluting the water more and more seriously with domestic waste, industrial and urban wastewater (Mahmood, 2006). The river plays a major role in assimilating or carrying industrial and urban wastewater (Stroomberg et al., 1995; Ward and Elliot, 1995). The river forms the main water supply for drinking, irrigation and industrial purposes. Agricultural, industrial, domestic and urban wastes can penetrate river and lake water through leachate, runoff, wastewater and dry deposition (Biney and Christopher 1991; Okoye et al. 1991). Water pollution not only affects water quality, but also threatens human health, economic development and social prosperity. According to World Health Organization (WHO), about 80% of all human diseases are caused by water (WHO, 2004). Concentrations of pollutants in which the system has led to bioaccumulation of toxic metals and serious environmental problems, threatening aquatic organisms and human health (Sasmaz et al., 2008).

The use of contaminated water in large city surroundings for growing vegetables is a common habit. Although it is considered a rich source of organic matter and plant nutrients, it also contains enough soluble salts and metals such as iron, manganese, copper, zinc, etc. Water is used to irrigate crops for a long time, these metals can accumulate in the soil and that could be toxic to plants and also cause soil degradation (Perveen et al., 2006). A variety of contaminants including toxic metals, especially copper and zinc are reported to be ubiquitous in rivers and reservoirs and are detrimental to aquatic organisms (Olsson, 1998). Monitoring of surface water pollution is meaningful in the context of human health is increasingly affected because of polluted water.

Dong Nai province is a province with many industrial parks and residential areas with high density (1060 people/ km^2). Therefore, the amount of wastewater discharged into the environment is huge. According to the statistical report of Dong Nai Department of Natural Resources and Environment, the total amount of industrial wastewater in the province is about 129,000 m^3/day. The total amount of domestic wastewater is about 190,000 m^3/day, particularly in Bien Hoa City, about 80,000 m^3/day. Wastewater flow of medical facilities is about 5,076 m^3/day (environmental report of Dong Nai, 2015). Therefore, the current study is an attempt to monitor the water quality of Dong Nai River (Vietnam).

Materials and methods

21 samples of river water were collected. Sampling locations were scattered along the length of the river, especially the river section through Bien Hoa