Assessment of the air quality and public health impact for proposing an air quality management plan in Ben Tre province, Vietnam

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Abstract

This work proposes a plan for air quality management in Ben Tre province (Vietnam) based on conducting the assessment of the current status and evolution of air quality in Ben Tre province using AERMOD dispersion model with monitoring and surveying data. The results of the assessment and forecast of the current status of air quality by 2030 show that transportation is the main source of air pollution in Ben Tre province. The emission rate is relatively high, but in general, it still meets air quality standards. The results of the actual survey in households and simulations by the AirQ+ model on the impact of air pollution on public health show that air pollution has a negative impact on public health with a high risk of respiratory and cardiovascular diseases. The management and treatment of air pollution in the province are well-concerned, coordinated, and implemented by management agencies. After considering the effectiveness analysis of environmental protection, this study has analyzed and proposed priority solutions for the implementation of the air quality management plan in the province until 2025 and proposed content and priority for the implementation of the plan in the period of 2022 – 2025.

Keywords: AERMOD, air quality, management plan, public health

1. Introduction

Recently, Ben Tre province (Vietnam) has made great strides in terms of economic development, particularly in the development of traditional craft villages. As a result, pressures on natural resources and the environment are also increasing. Air pollution is one of the most significant problems pertaining to the environment and natural resources in the Ben Tre province that has been identified in recent years. In 2021 – 2025, a major focus of Ben Tre province has been on mobilizing and effectively utilizing resources in order to develop infrastructure, processing and manufacturing industries, renewable energy, logistics, seaport, and rural and urban residential areas. Ben Tre province is to be developed towards the east in accordance with Resolution No. 04-NQ/TU dated January 29, 2021, as well as to ensure social security for the population and to become a fairly developed province under the country's overall development. In which, Ben Tre deploys the construction of grade I city and grade III, IV, and V urban centers. In addition, for sustainable development, the People's Committee of Ben Tre province (PCBT) has issued the Ben Tre Green Project to raise awareness throughout the system of authorities, businesses, and people together to build Ben Tre province into a "Green destination, worth living" by 2030 (People's Committee of Ben Tre Province (PCBT), 2021).

However, the development of industry and services is also the cause of air pollution in Ben Tre province, reducing the quality of the urban environment, especially with bad impacts on human health. In order to assess the current status of the environment, the monitoring of environmental quality is needed to carry out the tasks to effectively improve and control air pollution. It is important in order to take the initiative in the environmental protection plan and the development plan of specific action programs for each industry in the province. At the same time, comply with the Law on Environmental Protection in 2020, Decision No. 1973/QD-TTg on National Plan on air quality management for the period 2021 – 2025, Directive No. 03/CT-TTg on strengthening control of air pollution, Document No. 3051/BTNMT-CTMT on providing technical guidance for the formulation of provincial air quality management plan, the implementation of the assessment of the current status and development of an air quality management plan in Ben Tre province is necessary. The goal of strengthening air quality management through the action plans on controlling emission sources and monitoring ambient air quality was set to improve air quality, ensure public health, and raise awareness and responsibility of organizations and individuals. Hence, this study was conducted to propose a plan for air quality management in Ben Tre province based on the assessment of the current status and evolution of air quality environment management in Ben Tre province. In addition to the current status of air quality, the health impact of air pollution and effectiveness analysis of environmental protection solutions were also conducted as the basis for determining the objectives of the Ben Tre Provincial Air Quality Management Plan.

To study the current state of air quality, the AMS/EPA Regulatory Model (AERMOD) is suitable for conducting air pollution dispersion modeling from the availability of input data in Ben Tre province. In addition, the AERMOD model has been developed by the US Meteorological Agency and the US Environmental Protection Agency (USEPA) since 1991 and was officially used in 2005 after 14 years of research and improvement. Also, the AERMOD model is capable of applying to rural, urban, flat, and complex areas and various types of waste sources such as point sources, road sources, and area sources. The simulation results are in the form of 2D and 3D spatial images, helping users to easily see the impacts of emissions on the survey site (United States Environmental Protection Agency - USEPA, 2022). Furthermore, it is widely applied in many studies, such as in Vietnam and other countries. For example, Ho *et al.* (2022) developed an air pollution dispersion model based on the AERMOD model to study the effects of air pollution in Tan Tao Industrial Park, Ho Chi Minh City, Vietnam on its surrounding environment. In addition, Tran *et al.* (2022) conducted an assessment of the impact of thermal power plant stack emissions on Quang Ninh's ambient air using the AERMOD modeling system. In other countries, for instance, Lowshan in Qazvin provinces of Iran, Farivar Ghaziani *et al.* (2021) conducted AERMOD dispersion modeling to investigate the air quality of Lowshan is acceptable under the ambient air quality standards and confirmed the accuracy of results by NO_2 field measurements. In other cases, the AERMOD dispersion model was used to assess the air pollutant dispersion for specific locations or such as the study of Kanabkaew *et al.* (2014) for landfills in Nakhon Si Thammarat, Surat Thani, and Trang Provinces of Thailand and thermal power plants in Ho Chi Minh City's areas, Vietnam by Vu *et al.* (2022).

For the assessment of health impact from air pollution, the AirQ+ tool which integrates a dose-response function can be used to evaluate levels of health effects for some air pollutants and also the changes in health effects along with pollution levels change. The AirQ+ model can quantify the health impacts by processing data on pollutants $PM_{2,5}$, PM_{10}, NO_2, $O_{3,}$ and black carbon with considering different health effects related to mortality and morbidity in either or both acute and chronic conditions. The estimates generated by AirQ+

are the starting point for developing or adapting policies and measures to protect human health (Mudu *et al.*, 2016).

Lastly, the effectiveness of the air quality management proposed solutions were identified, analyzed, and evaluated for implementation in the Air Quality Management Plan of Ben Tre province from 2022 through 2025. It contained several solutions for air quality management divided into management, technical, economic, propaganda, education, capacity building, and awareness of air quality management.

2. Materials and Methods

2.1. Site study: Ben Tre province

In order to gain more understanding of the current state of air quality and environmental management in Ben Tre province (Figure 1), a survey was carried out with 326 questionnaires. The number of questionnaires is determined based on the actual scope, objects (industries, fields, emission sources), and the number of production facilities/factories, businesses, and management agencies. Especially, it includes surveying 183 households in 09 districts and cities in Ben Tre province (with a random sampling method to optimize the accuracy level and the number of survey samples to ensure statistical significance). Households selected for the survey are those with domestic cooking activities, waste burning (open burning form), spraying pesticides, and utilizing fertilizers. Emission data collected from the survey are summarized altogether with data collected at PCBT for emissions inventory.

Besides, it was also used to study the current state of environment management, environment protection, and complaints about air pollution issues from residents together with 54 questionnaires at direct management agencies and departments and 89 emission-generating enterprises and factories in Ben Tre province. The information on the coordination of the management agencies, identification of the current state of the environment, complaints about local air environment issues, and knowledge on air environment protection was collected in the survey. Then, survey data were processed with SPSS software to test the impact of air pollution on people's lives. Reliability analysis and scale testing are based on the analysis of Cronbach's Alpha coefficient (Hair *et al.*, 1998) and exploratory factor analysis.

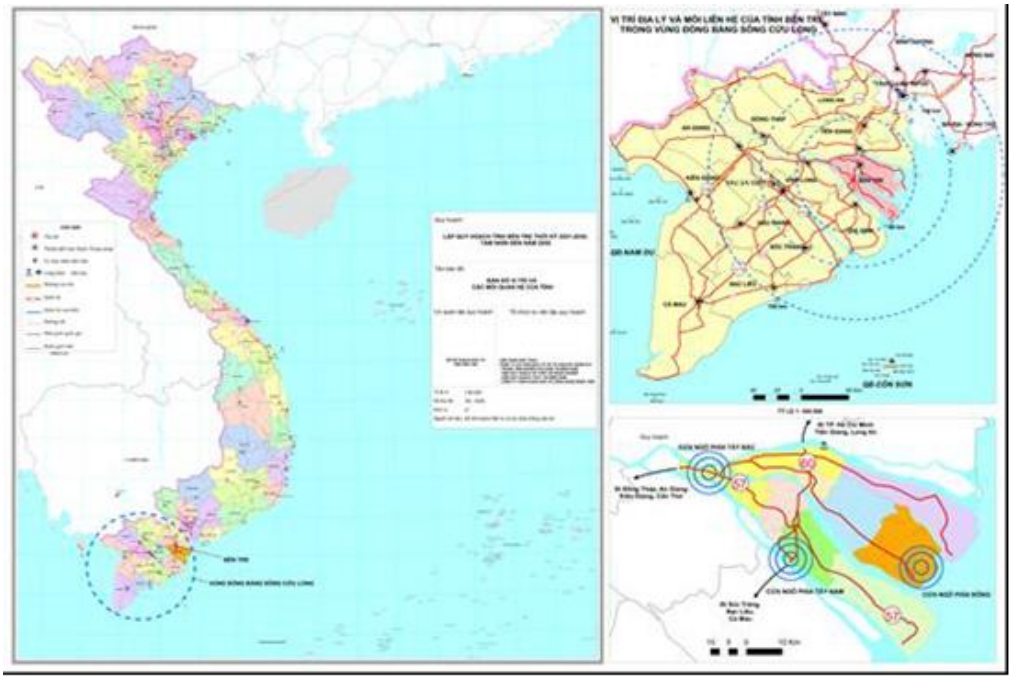


Fig. 1. Location of Ben Tre province (Vietnam)

2.2. The assessment of the current status of air quality in Ben Tre province

This study conducted an emission inventory to identify the main emission sources of Ben Tre province. The emission inventory methods are applied both top-down and bottom-up approaches for different types of emission sources. In the top-down approach, a simple emission inventory was utilized to quickly assess emissions from point sources including waste incinerators, crematoriums, biochar kilns, coconut jelly production facilities, craft villages, industrial parks, and others. It was based on the information related to the operation of the emission source (for example, the amount of fuel consumed or the amount of finished product) and emission factor which is the average emission volume of a pollutant per unit of fuel consumed or per unit of finished product. The emission factor can be uncontrolled or controlled by assuming whether it applied any emission control technologies. The emission level is determined according to the following formula:

$$E = A \times EF \qquad (1)$$

In which, E namely is the emission rate; A is related to the object's activities and emission sources and EF stands for emission factor. Emission factors can be referred from the information provided in USEPA Document AP-42 including manufacturing industries and agricultural fields (United States Environmental Protection Agency - USEPA, 2009), emission from fuels (United States Environmental Protection Agency - USEPA), and dust with emission factors for several different dimensions. Therefore, it is necessary to consider the maximum possibility of using emission factors with high accuracy and reliability following the requirements of AP-42 along with other scientific documents at the time of making the inventory.

On the other hand, the bottom-up approach focused on mobile source emission inventory with two main groups, which are road motor vehicles (e.g., cars, commercial vehicles, public buses, or motorcycles) and other mobile vehicles (e.g., boats, ships, trains, agricultural machinery, or heavy-duty vehicles). In addition, this method also conducts emission inventory for the area sources. The emission level of pollutant (i) in the exhaust gas of road motor vehicles using fuel type (j) is determined by the following formula:

$$E_{ij} = FC_j \times EF_{ij} \qquad (2)$$

In which, E_{ij} is namely emission level of pollutant (i) from fuel type (j) of the vehicle under consideration, FC_j is fuel consumption mass (j), and F_{ij} is the emission coefficient of air pollutant (i) due to using fuel (j) of the vehicle under consideration. Emission coefficients of road motor vehicles refer to the document of the European Environment Agency - EMEP/EEA (European Environment Agency (EEA), 2019) and other studies published results in Vietnam. According to the EU EPA, coarse particles which are bigger than 2.5 µm are generally negligible in the emissions of mobile sources, then it is considered typically PM2.5 dust. Therefore, the dust emission inventory results for mobile sources are aggregated into the parameter of PM2.5. For other mobile vehicles, emission inventory was collected for water transport, agricultural machines, and construction vehicles in addition to their maximum power, load factor, and hours of operation according to Document AP-42 (Beardsley and Lindhjem, 1998; EPA (Environmental Protection Agency), 2010).

In the case of emissions inventory for the area sources which are open burning, daily cooking activities, and others such as pesticides, livestock husbandry, and aquaculture, the applied method has defined the scope by referring to USEPA (2001) then followed by considering with the activity level of the source (such as production rate or consumption rate referred to Document AP-42 (United States Environmental Protection Agency (EPA)), EMEP/CORINAIR document (European Environment Agency (EEA), 2016), and emission inventory guidebook (European Environment Agency (EEA), 2016). Furthermore, both top-down and bottom-up approaches can be combined to apply for different types of emission sources in the same emission inventory program. It can be simply put as the baseline requirement on vehicle type and fuel consumption. Aggregated fuel consumption data by industry is considered the baseline requirement. The uncontrolled emission factors for each type of fuel used are collected to calculate emissions. Total emissions for each type of pollutant and fuel type are calculated based on the simple method with following formula:

$$Em_{i,j} = \sum_j Fc_j \times EF_{i,j} \qquad (3)$$

In which, j stands for vehicle type, $Em_{i,j}$ indicates the emission of pollutant i from vehicle type j, Fc_j is related to fuel consumption of vehicle type j, and $EF_{i,j}$ still is the emission factor of pollutant i for vehicle type j. However, in some cases, the simple method is said to overestimate emissions, as it does not take into account the implementation of catalytic converters and other technologies to reduce emissions from vehicles and traffic. Therefore, a more detailed and complicated method was used to calculate the emission by looking at the performance data for each vehicle type and the appropriate emission factors. Data on emission factor, number of vehicles and distance traveled per vehicle should be provided specifically for each vehicle type and class to apply in the detailed method for emission level with the following formula:

$$Em_{i,j,r} = Nv_j \times Mv_{j,r} \times e_{i,j,r} \qquad (4)$$

In which, j, r stands for vehicle type j and road type r (urban, rural), $Em_{i,j,r}$ is emissions of pollutant i generated in the reference year by vehicle type j driven on road type r, and the number of vehicles, Nv_j, in class j in circulation in the reference year that have annual mileage per vehicle, $Mv_{j,r}$, for vehicles which are driven on road type r of vehicle type j corresponding to their average base emission factor $e_{i,j,r}$. Emissions inventory for road vehicle motor vehicles takes into account emissions per vehicle mileage or emissions per mass of fuel. The simple approach is suitable for better spatial distribution and useful in identifying specific groups (i.e. heavy or light diesel engines). The complicated method of calculating emissions per fuel mass requires far fewer variables than the first method and can eliminate dependence on engine size. However, fuel consumption statistics cause greater uncertainty than the total distance driven. To calculate emissions from traffic activities, this study used the ABC EIM Excel Workbook as a tool to implement emission estimation methods. This Workbook adapts the format of the Global Atmospheric Pollution Forum Air Pollutants Emission Inventory Manual (European Environment Agency (EEA), 2006) and the IPCC Guidelines (Shrestha *et al.*, 2013).

2.3. The investigation of the contribution percentage of different emission sources in the air environment in Ben Tre province

In order to assess the current state of air quality in Ben Tre province, the inventory data on the contribution ratio of different emission sources in the air environment is investigated based on survey data from emissions and using AERMOD. The AERMOD is an atmospheric dispersion model with a variety of applications in rural and urban areas with either flat or complex surfaces and with many types of waste sources such as point, mobile, and area sources (Akula Venkatram, 2008).

The AERMOD model was specifically designed to support the regulatory program of the United States Environmental Protection Agency (USEPA). The model is an integrated system consisting of three modules including a dispersion model (AERMIC), a meteorological tool (AERMET), and a terrain tool (AERMAP). Specifically, the AERMIC module is designed for short-range (up to 50 km) dispersion of air pollutants emitted from industrial sources. Whereas AERMET processes surface meteorological data on different layers, it then calculates the necessary atmospheric characteristics such as turbulent air, altitude, friction velocity, and surface heat flux (United States Environmental Protection Agency - USEPA, 2022). Then, AERMAP represents a physical relationship between topographic features and air pollution cloud activity. It generates terrain data and provides information that allows dispersion models to simulate the effects of smoke trails when exposed to hilly surfaces. From AERMET and AERMAP modules, AERMOD will give simulation results in the form of 2D and 3D spatial images and output through Google Earth, helping users easily see the impacts of emissions on the survey area (Figure 2).

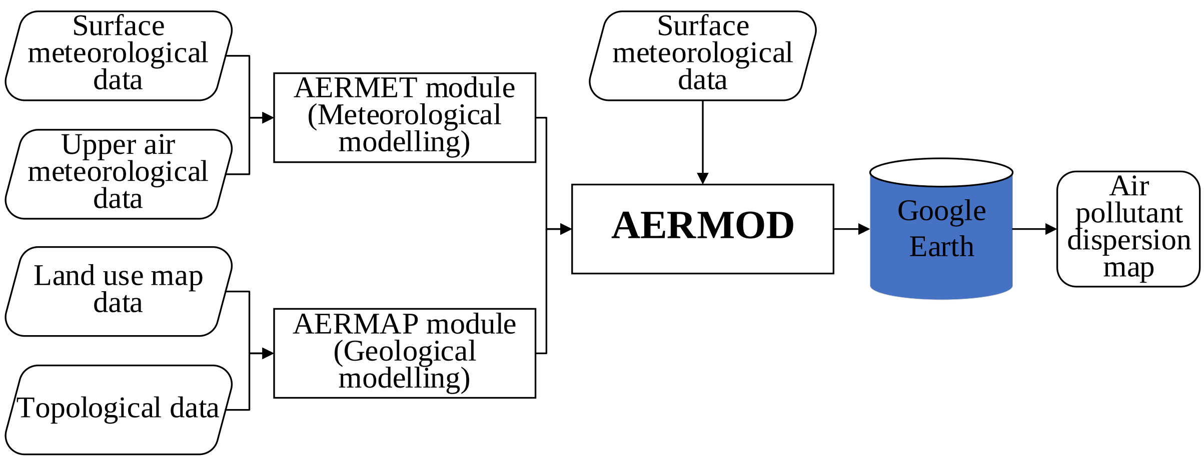


Fig. 2. Schematic flowchart of the AERMOD model. Source: United States Environmental Protection Agency - USEPA (2022)

The results of applying the AERMOD dispersion model will show the results of air quality changes as the map with the air pollutants concentration at the scale of 1:10,000 over the area of Ben Tre province within the timelines according to the assessment scenarios. The applicability, accuracy, and reliability of the AERMOD model are evaluated and verified by the comparison of actual air quality monitoring data with the modeling results of the air quality assessment. Currently, the Department of Natural Resources and Environment of Ben Tre province (BTDONRE) collaborates with other relevant departments to monitor the air quality around urban and rural areas, craft villages, and industrial zones/clusters. Other emission sources include solid waste treatment facilities, incinerators, and mobile sources at 27 monitoring points within Ben Tre province (Ben Tre Department of Natural Resources and Environment (BTDONRE), 2021). In case there is a significant difference between the observed data and the model data, model correction should be performed. Detailed steps to implement the AERMOD model are shown in **Figure 3**. The observed and simulated concentration values of basic parameters in the surrounding air then were used to evaluate and compare with the limit values according to the National Technical Regulation on Ambient Air Quality (i.e., QCVN 05:2013/BTNMT and QCVN 06:2009/BTNMT).

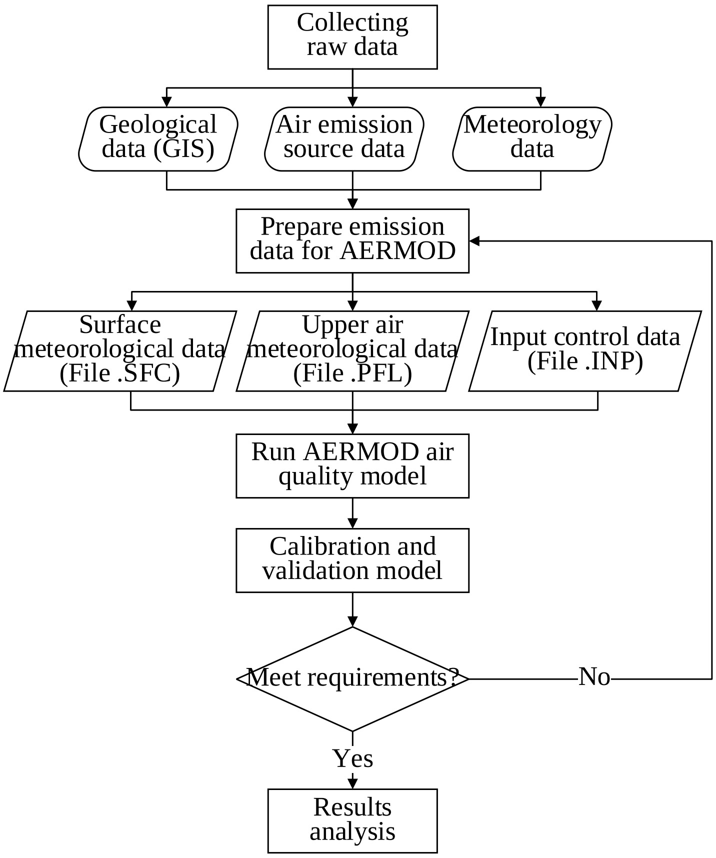


Fig. 3. Flowchart of AERMOD dispersion model

2.4. The assessment of air pollution effects on public health in Ben Tre province in the period of 2022 – 2025

Polluted air greatly affects human health, especially the respiratory system. Many studies have shown that living in a polluted air environment, human health is reduced, specifically lung function, causing asthma, and bronchitis (Dondi *et al.*, 2023; Squillacioti *et al.*, 2020; Almetwally *et al.*, 2020; Lee *et al.*, 2021; Bui *et al.*, 2020; Hung *et al.*, 2021). More serious cases can be cancer, cardiovascular disease, and reduced life expectancy. It also causes acute effects, sometimes even death (Vu *et al.*, 2022).

The most sensitive community groups to air pollution are the elderly, pregnant women and children under 15 years old, who often have to work outdoors, and those with diseases, lung and cardiovascular diseases. The degree of impact on each person depends on health, concentration, level of pollution, and time of exposure to the polluted environment. These subjects are prone to respiratory and cardiovascular diseases, mainly due to their weak immune systems. Especially for children under 5 years old, children's immune systems and lungs are developing, with each breath, children will take in more air than adults. So when the air is toxic, children will inhale more toxic gases than adults (Rees, 2017). Older people are more susceptible to diseases and infection because their immune systems weaken over time. In addition, they also tend to get sick more often and the consequences of each illness are worse (Bonita *et al.*, 2006).

This study proposes the application of the AirQ+ model to assess the correlation between air quality and human health. With the World Health Organization (WHO) guidelines on the AirQ+ model, the assessment of the effects of air pollution on public health used the monitoring data of air environment and the surveying data on patients at hospitals in Ben Tre province according to statistics of ICD-10 (Department of Medical Examination and Treatment - Ministry of Health). The survey data were collected from 183 households in order to assess the air quality in the area of Ben Tre province. A survey was conducted using questionnaires and in-depth interviews with people living within the residential communities to determine the actual status of environmental quality and environmental issues within the area of Ben Tre province. In addition, the air quality monitoring data in Ben Tre province is taken from the BTDONRE between 2017 and 2021. For surveying data on several patients hospitalized due to respiratory and cardiovascular diseases living in Ben Tre province, it was collected at hospitals according to ICD-10 with the consent of WHO. Lastly, the annual average population data of Ben Tre province is collected according to the Statistical Yearbook of Ben Tre province. The procedure of air pollution impacts on public health in Ben Tre province is shown in Figure 4. Expected outputs showed the short-term impact of each parameter PM_{10} and NO_2 on respiratory and cardiovascular diseases. Specifically, it is possible to calculate the number of cases where respiratory and cardiovascular diseases can be avoided according to the given scenarios.

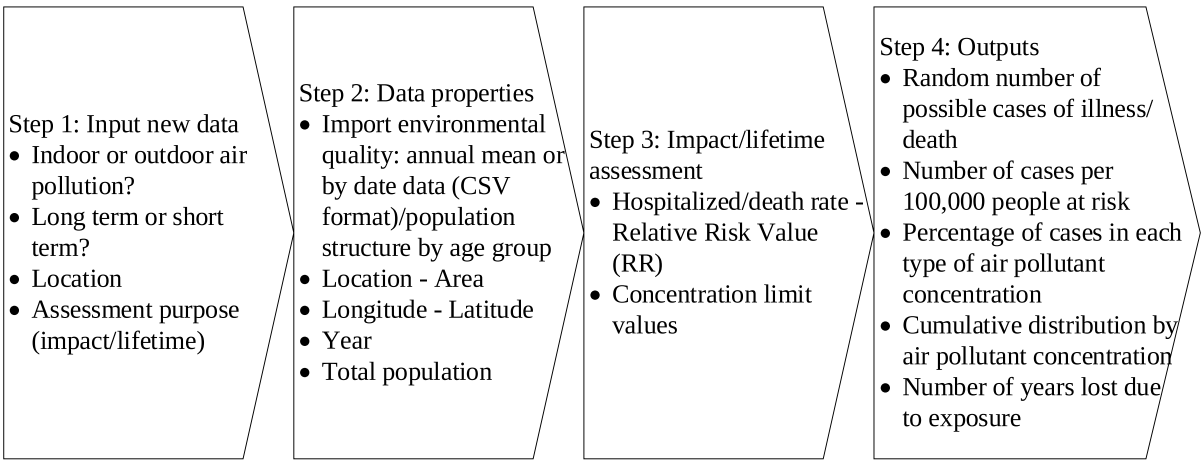


Fig. 4. Steps to run the AirQ+ model

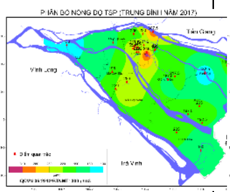
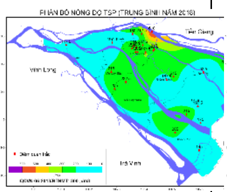
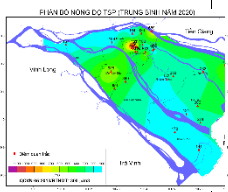
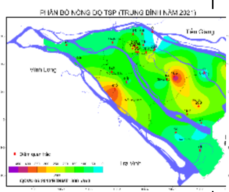
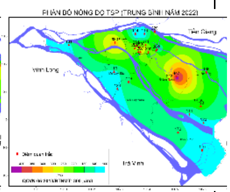
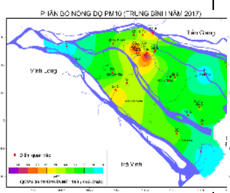
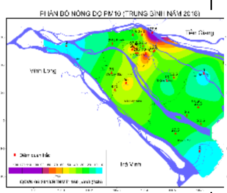
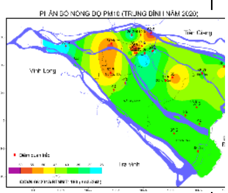
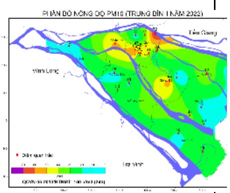
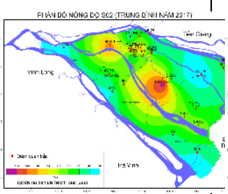
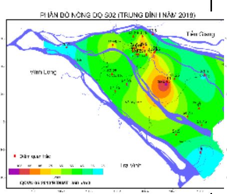
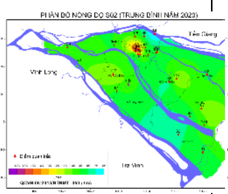
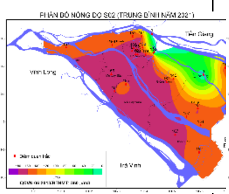
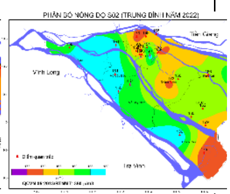
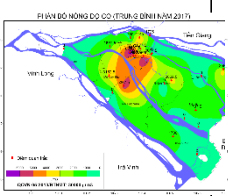
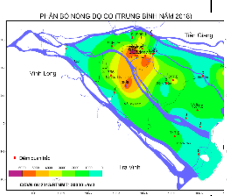
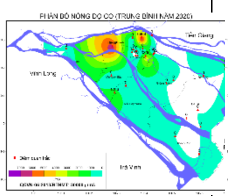
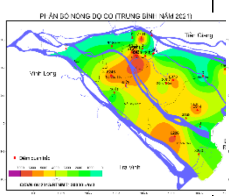
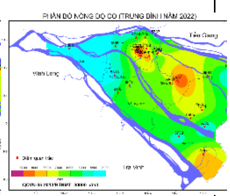
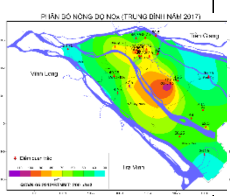
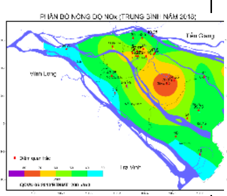
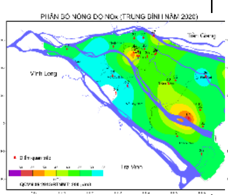
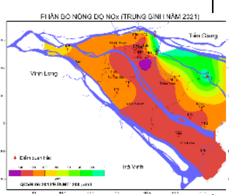
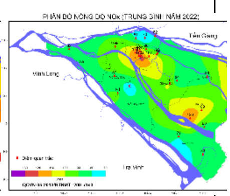
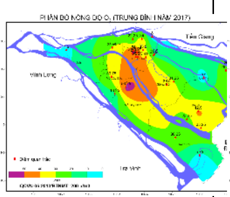
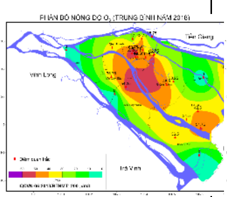
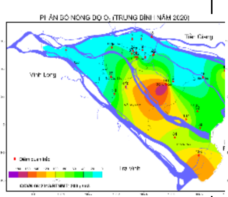
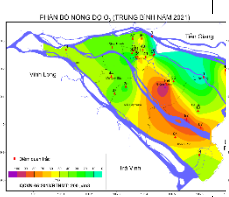
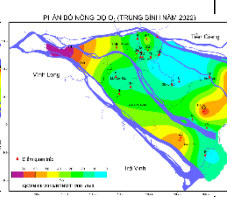
3. Results and discussion

3.1. Current status of air quality in Ben Tre province: Determination and assessment of important emission sources

Several types of emissions are commonly detected in Ben Tre province, including emissions from the biochar kiln in the craft village in Giong Trom district, odors from landfills, and emissions from seafood production and processing facilities. The amount of dust, CO, CO_2, SO_2, and NO_x emitted during the production process is quite high. Industrial production activities in Ben Tre province are considered one of the causes of air pollution. Industries in Ben Tre province are very diverse and the composition of emissions into the environment is also divergent. The exhaust gas treatment equipment of enterprises in the industrial zone is installed and operated regularly as committed in the EIA report. There are still some businesses that discharge exhaust gas beyond the permitted standards in the process of operating treatment equipment. Despite this, ambient air as well as the surrounding air environment of industrial zones continues to be controlled, with air quality parameters and noise levels within the permitted limits outlined in QCVN 05:2013/BTNMT and QCVN 26:2010/BTNMT. On the other hand, a significant amount of exhaust gas, smoke, and odors persist for a long time in residential areas, particularly as a result of the manufacturing of biochar from coconut shells. There are nearly 45 factories of biochar production in Giong Trom, a district that has been developing this industry for a long time. Most of them emit emissions with very high CO concentrations that cause serious environmental pollution.

From 2017 to 2021, the BTDONRE has conducted periodic air environment monitoring around urban and rural areas, craft villages, industrial zones/parks, and other emission sources including solid waste treatment facilities, garbage incinerators, and mobile sources at 27 monitoring sites. Due to the epidemic situation in 2019, Ben Tre province only conducted 01 measurement, so it is not possible to assess the current situation of air pollution in 2019. With a total of 17 monitoring data sets (four times per year but only one set in 2019), selected parameters such as total suspended particle (TSP), fine dust (PM_{10}), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), nitrogen dioxide (NO_2), and ozone (O_3) were collected. In addition, to ensure a better assessment of the current situation and forecast the evolution of air quality, this study conducted monitoring of the surrounding air environment 03 times in 2022 (01 time/month) at 41 monitoring points with the parameters such as SO_2, CO, NO_2, O_3, TSP, PM_{10}, $PM_{2,5}$, and Pb. Interpolated results of observed and monitoring data were mapped in contour lines and overlapped with GIS data of Ben Tre province (as shown in Table 1**).**

Table 1. Current status of the air environment according to monitoring data in Ben Tre province in 2017 - 2022

	2017	**2018**	**2020**	**2021**	**2022**
TSP					
PM_{10}					
SO_2					
CO					
NO_2					
O_3					

The highest TSP concentration was recorded at the Rach Mieu bridge area (affected by activities of My Tho city's urban area and high traffic activities on the bridge) and moved to around Mo Cay and Giong Trom districts from 2020 onward. All TSP concentrations exceeded QCVN 05:2013/BTNMT with a recorded value range from 345 $\mu g/m^3$ to more than 1,000 $\mu g/m^3$ between 2017 – 2022. The highest TSP recorded in My Tho city and area of Rach Mieu bridge with 95 $\mu g/m^3$, 127 g/m^3, 60 $\mu g/m^3$, and 70 $\mu g/m^3$. On the other hand, PM_{10}, SO_2, CO, NO_2, NO_2, and O_3 hourly average concentration in the whole province is below QCVN 05:2013/BTNMT.

The highest SO_2 and NO_2 concentrations were recorded at the landfill site of Giong Trom district with respectively recorded values of 117 $\mu g/m^3$ and 107 $\mu g/m^3$ in 2017, 183 $\mu g/m^{3,}$ and 79 $\mu g/m^3$ in 2018. Between 2020 – 2022, the highest SO_2 concentration ranging from 110 – 183 $\mu g/m^3$ was recorded at different locations within the urban area, particularly in Mo Cay Nam district. Whereas, the highest NO_2 concentration recorded in the same year with SO_2 showed concentrated in the area around Ba Tri district with a concentration from 61 to 140 $\mu g/m^3$. As for other pollution parameters, the highest CO concentration from 6,600 to 8,500 $\mu g/m^3$ was recorded in Chon Thanh, Mo Cay Bac, Giong Trom districts, and other urban areas of Ben Tre province and the highest O_3 concentration from approximately 50 to 181 $\mu g/m^3$ was recorded in Mo Cay town, Giong Trom, and Tan Phu districts between 2017 – 2022.

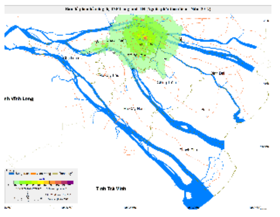
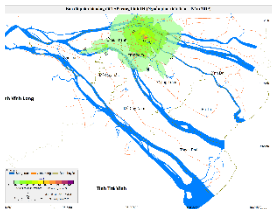
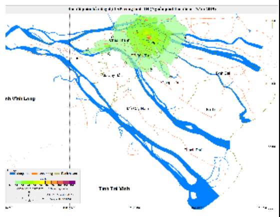
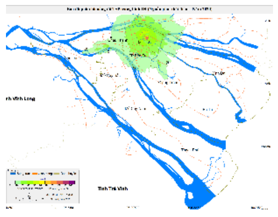
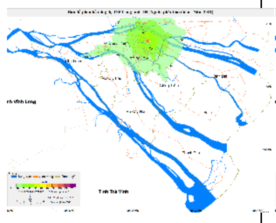
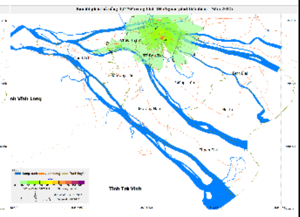
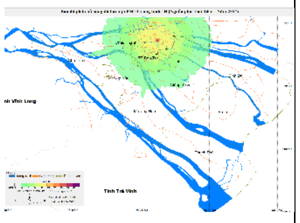
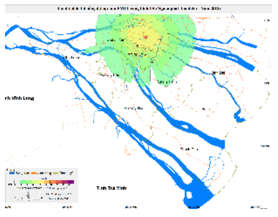
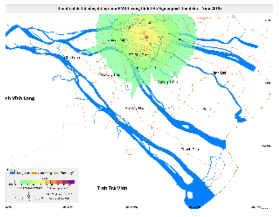
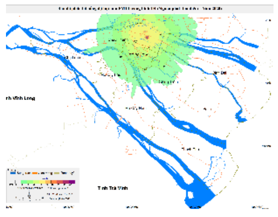
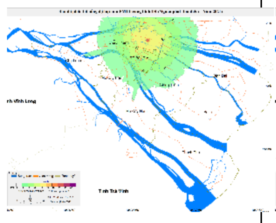
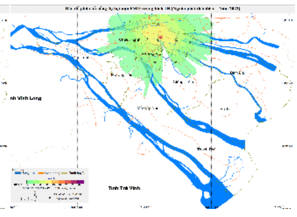
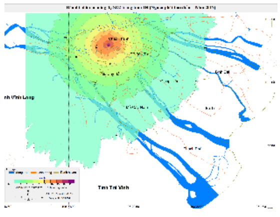
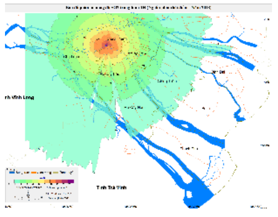
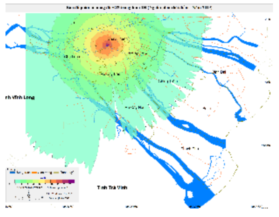
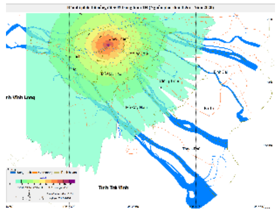
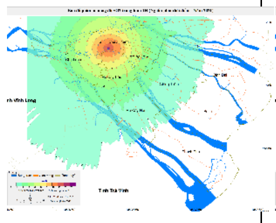
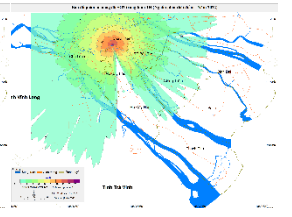
3.2. Assessment results of air quality changes in Ben Tre province by AERMOD dispersion model

The AERMOD model is implemented with input data from the beginning of 2017 to August of 2022 at 08 periodic air environment monitoring sites in Ben Tre province. The selected sites represent areas with high traffic density in urban areas and industrial zones. After the input data is established, the AERMOD model is executed for each year and showed output results of the annual average content distribution of air pollution parameters including TSP, PM_{10}, NO_2, CO, and SO_2. Since the parameters of emission sources are assumed to be fixed, the spatial distribution of emissions depends mainly on atmospheric conditions. Assessment results are presented in Table 2 for point sources and in Table 3 for area and mobile sources.

In Table 2, the results of emissions from point sources in Ben Tre province showed most of the highest concentrations recorded around industrial areas (Giao Long and An Hiep industrial parks) except CO which was influenced by biochar production around Phong Nam commune, Giong Trom district. All the highest recorded values showed much lower than the limit outlined by QCVN 05:2013/BTNMT. In addition to Table 3, the AERMOD model is executed to simulate and provide the results of the current distribution of air pollutants generated by road vehicles in 2022. The selected main roads including National Highway 60, 57, 57B, and 57C showed all the highest concentrations along highways, especially the area in Chau Thanh district (National Highway 60, 57B, and 57C) although all simulated values are still lower than QCVN 05:2013/BTNMT. For stimulated results in other related domestic activities, the highest results showed in the residential area of Ben Tre City but still lower than the limit values. In addition, all concerned air pollutant emissions related to domestic cooking activities showed insignificant value due to short time emission, in particular, SO_2 and NO_2 concentration resulted in less than 3 – 4 $\mu g/m^3$.

Thus, in order to assess the impact of emissions caused by transport, this study proposed a scenario of a 10% increase in the number of vehicles per year. By calculating the input emissions of the model with the aforementioned assumption, the distribution of air pollutants through transport was calculated with the current meteorological conditions for the future scenario in 2030 in Ben Tre province. Calculation results presented in Table 3 show that the highest average concentrations are still recorded along highways. All of the simulated results showed an increase compared to those in 2023 but most of them are still lower than QCVN 05:2013/BTNMT except for NO_2.

Table 2. The analysis results of the current air quality with point source emissions by the AERMOD dispersion model

	2017	**2018**	**2019**	**2020**	**2021**	**2022**
TSP						
PM_{10}						
SO_2						

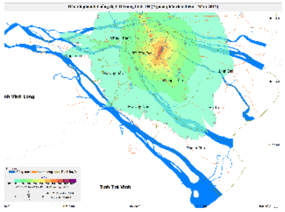
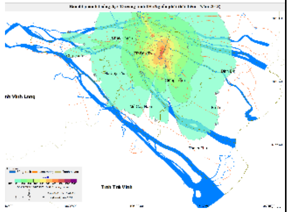
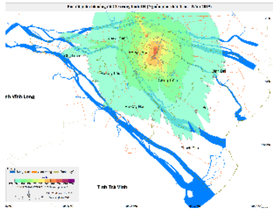
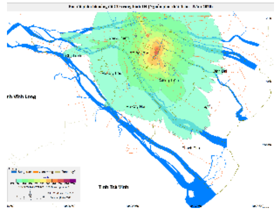
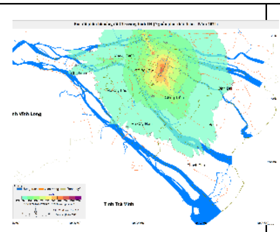
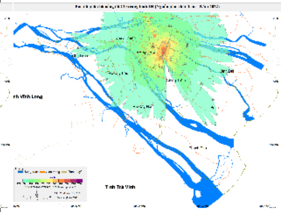
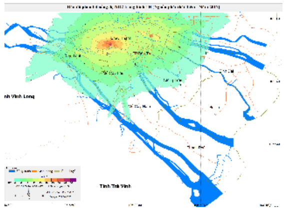
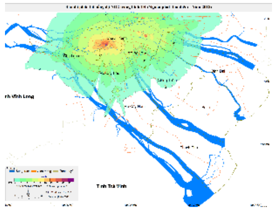
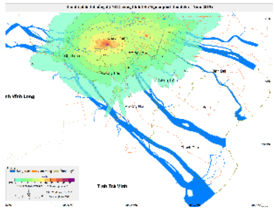
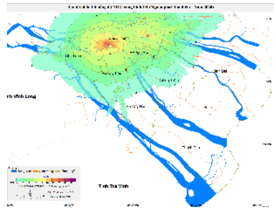
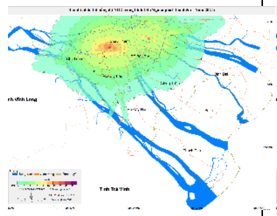
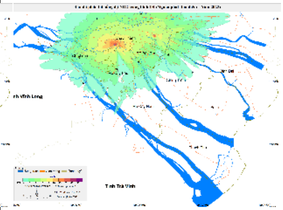
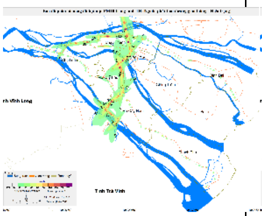
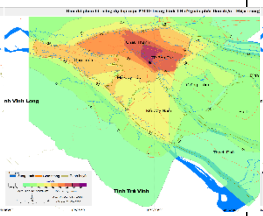
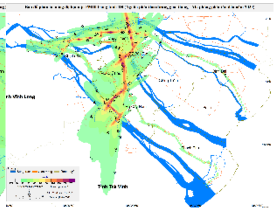
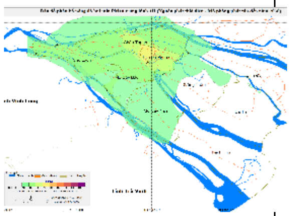
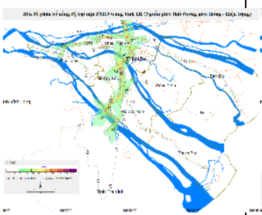
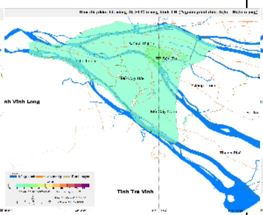
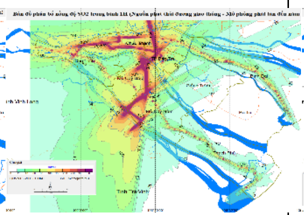
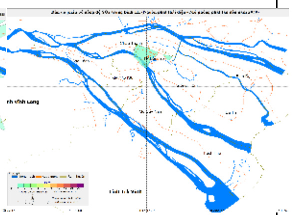
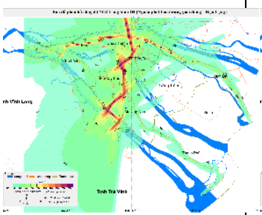
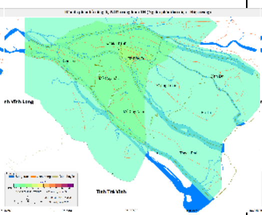
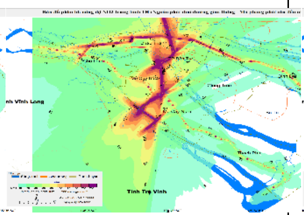
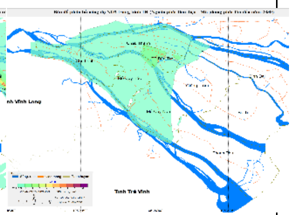
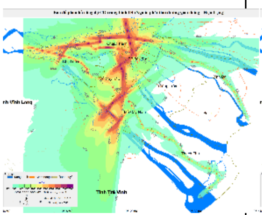
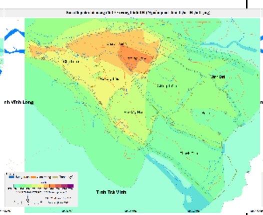
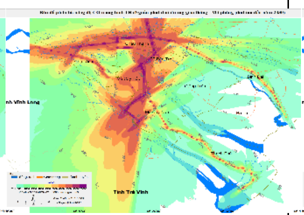
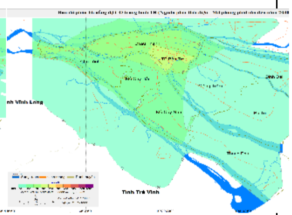
NO_2					 
CO					 

Table 3. The analysis results of the current air quality with area source and mobile source emissions by the AERMOD dispersion model

	2022		2030	
	Transportation	**Household activities**	**Transportation**	**Household activities**
PM_{10}				
SO_2				
NO_2				
CO				

According to the research of Phuc (2018) in “Research on energy/electricity demand based on household living standards”, the use of electricity in cooking is increasing so the demand for other fuels in this field will decrease. It was estimated that by 2030 the demand for fuels in cooking is reduced to half. Hence, the results of calculating the level of PM_{10}, CO, SO_2, and NO_2 presented in Table 3 are not significant.

The validation of the AERMOD model was investigated with real data ranging from 0 to less than 50%. The majority error is from 15 to 25%. In which, the calculated data is often lower than the actual measured data, especially since the calculation error in urban areas is larger than those in suburban and rural areas. So, through a comparison of actual measurements and calculations, it can be seen that the simulated AERMOD dispersion model is relatively consistent with reality. Errors in some locations are still large, which can be explained by the fact that the number of emission sources and types of air pollution have not been fully enumerated. In fact, many types of emission sources cannot be fully identified such as mechanical workshops or restaurants that use open coal burning. For the model to be able to simulate more accurately, it is necessary to continue to add information about different and more detailed emission sources.

3.3. The main impact assessment results from the AirQ+ model considering public health in Ben Tre province

To assess the impact of air pollution on people's health in Ben Tre province, this study used the air quality limit value according to WHO – Air Quality Guidelines (WHO AQG) (WHO, 2006) (PM_{10} = 20 µg/m^3). Considering the impact of PM_{10} together with the respiratory disease when running the AirQ+ model, it shows that in 2017 an estimated number of respiratory disease cases 301,657 when PM_{10} values exceeded 20 g/m^3, accounting for 5.89% of hospital admissions due to actual respiratory cases. The number of cases with the highest likelihood of respiratory diseases is 624,239 cases, accounting for 11.42% in 2020, although the number of patients with respiratory diseases in 2020 is lower than in 2017 – 2019. Therefore, it can be seen that the possibility of respiratory diseases is largely caused by the pollution concentration in PM_{10}. In the case of cardiovascular disease, the highest likely number of cases from 2017 to 2020 was 488,690 cases (2020) with an average annual PM_{10} concentration of 54 µg/m^3, estimated percentage of the disease at 8.94%.

The estimated incidence of respiratory diseases with NO_2 concentrations exceeding 40 µg/m^3 (WHO, 2006) showed that the estimated number of people suffering from respiratory diseases in 2017 was 75,810 cases, accounting for 3.44% of the cases likely to be hospitalized at the concentration value of 59.63 µg/m^3. In 2021, the number of cases with the highest probability of respiratory disease is 320,081 cases, accounting for 13.66%. The reason is that

2021 has the highest average NO_2 concentration with an average concentration of 122.32 $\mu g/m^3$. Besides, the actual number of local patients with respiratory disease has steadily decreased over the years, which shows that the ability to control the disease locally is very good. However, the problem of air pollution has increased over the years, increasing the likelihood of respiratory diseases and affecting the health of local people. The highest number of cardiovascular disease cases assessed with NO_2 content from 2017 to 2021 in 613,766 cases, accounting for 13.66% in 2021. Although the actual number of patients with cardiovascular disease in the locality over the years tends to decrease, it can be seen that the health of people is greatly affected by the surrounding air environment. Thus, the AirQ+ model shows the trend of the impact of air quality on the public health of people living in Ben Tre province in the period 2017 - 2022 quite clearly in terms of frequency and extent of the effect.

3.4. Proposed plan for air environmental management in Ben Tre province

This study proposed an air environment management plan in Ben Tre province to increase the effectiveness and efficiency of air quality management in line with the socio-economic development plan and development goals of “Green” Ben Tre. Also, it will be contributed to the implementation of the National Plan on air quality management for the period of 2021 - 2025.

The proposed plan listed several detailed goals as follows. First, the year 2023 should complete the treatment of environmental pollution in the biochar production area in the province. Secondly, it should communicate widely and continuously about ambient air quality to the people by deploying dynamic monitoring of air quality for urban areas such as Ben Tre city and Giao Long Industrial Park, Chau Thanh district. Then, ensuring effective management of emission sources by the end of 2024 to ensure over 90% of factories that will install monitoring equipment sending online data to BTDONRE is the next target. The third goals are to provide dust pollution control and effectively implement solutions to reduce pollution at emission sources arising from residential activities, construction, craft villages, and open landfills. Lastly, it needs to apply measures to reduce dust emissions on main and inter-provincial roads to ensure under-limit values according to QCVN 05:2013/BTNMT on ambient air quality. Currently, there are several solutions were applied. Specifically, to solve the environmental pollution caused by biochar production, which is expensive and not effective, the PCBT promulgates a document directing the control and prevention of new production of biochar that does not guarantee environmental treatment and the roadmap to the end of 2023.

For other future goals, by 2025, the capacity for environmental protection will be improved at all levels. The people's awareness of environmental protection will be raised, which can build a responsible society, take action to protect the environment, control sources of discharge, solve pollution problems, and gradually build a green - clean - beautiful environment in Ben Tre province.

4. Conclusions

This work studied the current status and development of an air quality management plan in Ben Tre province for the period 2022 - 2025. In general, the province's air quality has not changed much through 03 monitoring periods, the air pollution parameters are very low compared to QCVN 05:2013/BTNMT. However, the TSP at certain times and in areas such as Giong Trom district showed signs of heavy pollution caused by the heavy operation of transport and the production of sintering coal. The results of the assessment and forecast of the current state of air quality by 2030 show that the main sources of air pollution in Ben Tre province are mainly urban traffic activities with CO_2 emissions. The emission level is relatively high, but in general, it still meets QCVN 05:2013/BTNMT. The highest concentration of pollution occurs on National Highway 60 and 57B (Chau Thanh district). The results of the actual survey in households and simulations by the AirQ+ model on the impact of air pollution on public health show that air pollution has a negative impact on people's health. The higher the exposure, the higher the risk of respiratory and cardiovascular diseases. The management and treatment of air pollution in the province are well-concerned, coordinated, and implemented by management agencies. This study also proposed priority solutions for the implementation of the air quality management plan in the province until 2025. The plan is required to identify urgent issues related to the air environment in the province, and on that basis, to propose orientations and solutions to protect the air environment towards the goal of sustainable development.

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