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Effect of Coordinated Development between Urban Economy and Forestry on VOC Pollution Control Based on Statistical Analysis of Data

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With the development of economy and the acceleration of urbanization, the pollution of volatile organic compounds (VOCs) in the atmosphere is becoming increasingly obvious, drawing more and more attention of people. The development of urban forestry has the function of adsorbing and collecting VOCs, and the development of urban forestry has the cost effectiveness, with many kinds of benefits produced. Based on the statistical analysis of data, this study focuses on the effect of coordinated development between urban economy and forestry on VOC pollution control. It is found that the coordinated development between urban economy and forestry has made great contributions to the global VOC collection, and urban forestry has obvious functions of controlling, adsorbing and collecting VOCs. Taking residential areas as an example, the VOC concentration of residential areas with good coordinated development between urban economy and forestry tends to be fixed from the ninth month, while the VOC concentration of residential areas with uncoordinated development between urban economy and forestry continues to increase, keeping higher.

1. Introduction

Forestry is not only closely related to national economic construction, but also directly related to human living environment (Yang et al., 2015). Among the environmental problems, urban environmental problems are particularly prominent, urban population is dense, architecture, industry and commerce, and roads are concentrated, and human production and life discharge a large amount of wastes. Therefore, urban environment draws more and more attention from the people (Furlan and Kreutzweiser, 2015; Marino et al., 2017). In order to maintain a virtuous circle of urban environment, a great deal of urban forestry planning have been carried out in all regions to reduce environmental pollution to a certain extent and give full play to the beneficial characteristics of trees to reform, purify and beautify the environment (Li et al., 2018; Namour et al., 2016). The planning areas of urban forestry are small and scattered, with the characteristics of engineering afforestation, complex and diverse afforestation site conditions and microclimate types, and strong social public welfare, and the development of forestry is inseparable with the development of urban economy (Wang et al., 2017).

With the further expansion of economic development and the acceleration of urbanization process, the emission of volatile organic pollutants (VOC) in the atmospheric environment has become more and more serious, and the chemical composition of the pollutants has become more and more complicated, and the concentration has a greatly increasing trend. Major sources of VOCs include industrial source emissions, building coatings, motor vehicle exhaust, and the like (Wararena and Chuah, 2009; Tu and Ma, 2018). The coordinated development between urban economy and forestry can play a role in purifying and adsorbing VOCs, which is beneficial for reducing VOC pollution (Marttila and Klove, 2010). At present, the main methods of VOC sampling include container capture method, solid phase adsorption/solvent elution method, solid phase microextraction method, solid phase adsorption/thermal desorption method, etc. The common methods for VOC analysis include gas chromatography, high performance liquid chromatography, gas chromatography-mass spectrometry, fluorescence spectrophotometry, film introduction mass spectrometry and the like (Wei et al., 2017, Estrada et al., 2015). Based on statistical analysis of data, this study focuses on the effect of the

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coordinated development between urban economy and forestry on the purification, collection and control of VOC pollution, which has important guiding significance for improving the quality of urban atmospheric environment.

2. Study on VOC collection potential of urban forestry

VOC concentration in the atmosphere directly affects air quality and people's health. Cutting off VOC emission sources and increasing VOC collection capacity of land ecosystem are the main strategies to reduce VOC emission. Urban forestry ecosystem is a part of forest ecosystems, and urban forestry development significantly reduces VOC emissions resulting from industrial production and architectural decoration in cities (Copper et al., 2014). The collection of forest VOCs is cost-effective, and the large-scale development of forestry is an important strategy to deal with environmental pollution in China. In the past two decades, China has become the largest country in the world with the largest net increase in economic development and forestry, making great contributions to global economic growth and environmental pollution solutions. According to the statistical analysis of the data, Figure 1 shows the world's forest VOC collection reserves from 2002 to 2017, each state has made great efforts for the world's VOC purification; Figure 2 shows the dynamic changes of forest area and forest reserve in China and from 1983 to 2017, China's forest area doubled and forest reserve increased 1.6 times; Figures 3 and 4 respectively show the changes in forest area and forest reserve in China under the economic growth conditions, representing the change values of the benchmark scenario, the high-growth scenario and the medium-development scenario respectively. It can be seen that the forest area and forest reserve in China increase greatly in a positive linear manner in whatever scenario.

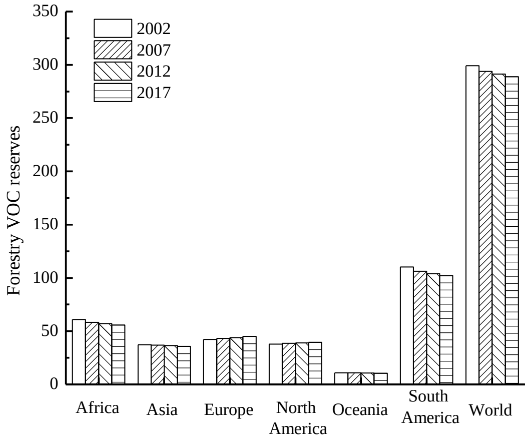

Figure 1. 2002-2017 world forestry VOC collection reserves

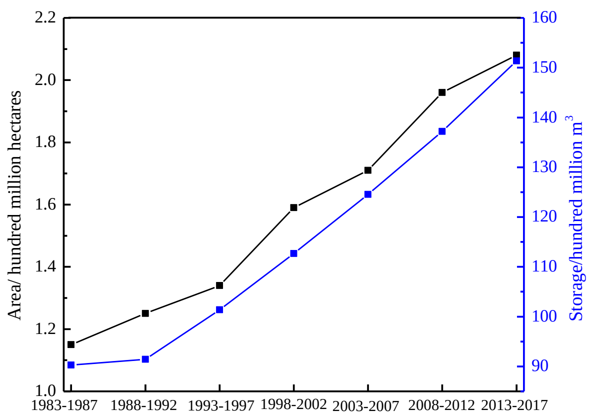

Figure 2. Dynamic changes of forestry area and forestry accumulation in China

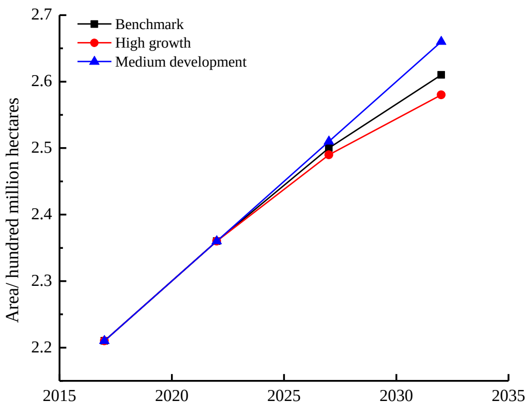

Figure 3. Changes in China's forestry area under conditions of economic growth

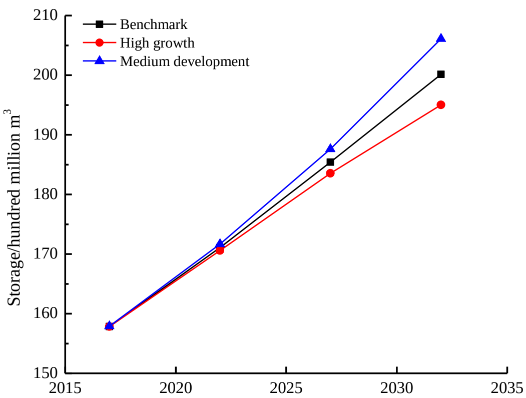

Figure 4. Changes in China's forestry accumulation under economic growth conditions

3. Collection and analysis of VOC samples

3.1 Experiment

The VOC components in the atmosphere are complex with lower content and usually exist on the order of μg/m^3. Therefore, the accurate collection and analysis of VOCs is directly related to the reliability of the determination results. In this collection test, Carbotrap 300 sampling tube is used to collect and analyze over 350 kinds of VOCs in air, and their linearity and precision are evaluated in detail. The sampling equipment includes sampler, standard flow corrector, sample adsorption tube and activation device. The adsorption tube used in the experiment has higher purity and higher adsorption efficiency of adsorbents and can be analyzed in full quantity. The analytical instrument uses a gas chromatography-mass spectrometer, a medium-sized capillary chromatography column, a thermal desorption concentration sampling device, and the like. The collected gas samples are matched with the standard mass spectra in the spectrum library, and the standard solutions configured are analytical pure or chromatographic pure reagents. Table 1 shows the general situation of the urban functional area and surrounding environment represented by each collection point. Hangzhou is selected as the collection area for this collection. The representative functional area includes cultural education area, commercial tourism area and commercial trade area.

Table 1: Each collection point represents the urban functional area and surrounding environment

Sampling point	Representative function area
Zhejiang University Huajiachi Campus	Cultural education area
Wushan Square	Commercial tourist area
Wulin Square	Commercial trade Zone
Hangzhou business school	Cultural education area
Epidemic prevention station	Commercial trade Zone

3.2 Results and discussion

Table 2: Mass concentration of each component in atmospheric VOC at each sampling point

Component mass concentration	Sampling point				
	Huajiachi	Epidemic prevention station	Wulin Square	Wushan Square	Business school
Alkane	30.5	48.2	41.2	30.5	35.2
Aromatic hydrocarbon	78.8	78.4	68.6	59.1	64.0
Olefins	20.5	58.6	54.3	39.5	19.7
Halogenated hydrocarbon	6.3	14.4	15.7	17.2	11.1
Naphthenic	13.5	15.2	14.3	10.9	12.7
Aldehyde	11.9	13.5	14.0	15.5	10.4
Alcohol	13.6	15.2	9.3	11.0	10.7
Ketone	11.3	19.1	17.7	11.8	9.5
Terpenoid	8.9	7.2	6.5	7.1	8.4
Total VOC	211.2	285.0	249.7	209.9	198.5

Table 3: Mass concentration of each component in VOC in Hangzhou and domestic and foreign typical polluted cities

Component mass concentration	City						
	Hamburg	Vienna	Sydney	Shi Jiazhuang	Nan Jing	Tai Wan	Hang Zhou
Olefins	21.3	25.1	19.9	54.4	54.1	114.1	40.5
Alkane	79.4	139.6	78.8	233.2	146.0	274.6	39.3
Arene	81.8	121.2	33.7	216.3	82.5	161.4	73.7
VOC	182.6	285.9	132.4	503.9	282.8	550.1	236.3

According to matching with standard mass spectra, it is found that more than 200 volatile organic compounds are matched, including aromatic hydrocarbon, alkane, cycloalkane, alkene, aldehyde, ketone, alcohol and so on. The analysis shows that the overall average mass concentration of VOCs in five places in Table 1 is 236.3 μg/m^3. The mass concentration of each component in atmospheric VOCs at each sampling point is shown in Table 2. Table 3 shows the mass concentration of VOCs in Hangzhou and typical polluted cities at home and abroad. The VOC concentration in Hangzhou is lower than that in Shijiazhuang and Nanjing, because

Hangzhou has better dustproof and forestry protection, which has the function of purifying, adsorbing and collecting VOC.

4. Analysis on the effect of coordinated development between urban economy and forestry on VOC pollution control

4.1 Sample collection and analysis

Urban economic development has led to more and more VOC emissions from urban building decoration and automobile exhaust. We need to conduct a control effect analysis based on the measured VOC concentration. Figure 5 shows the contribution rate of seven types of primary VOC emission sources in China in 2017, including fixed combustion sources, road movement sources, non-road movement sources, industrial process sources, solvent product use sources, fossil fuel distribution sources and other sources, in which the largest VOC emissions are fixed combustion sources and road movement sources. The fixed combustion sources are mainly biomass fuels, and the road movement sources are mainly diesel for motor vehicles. The sample collection is mainly based on the newly-built residential quarters in the city. The data of cities respectively with good and poor coordinated development between the urban economic and forestry in the assessment process are selected for statistical analysis. The sampling time is fixed at 45min and the flow rate is 120 mL/min.

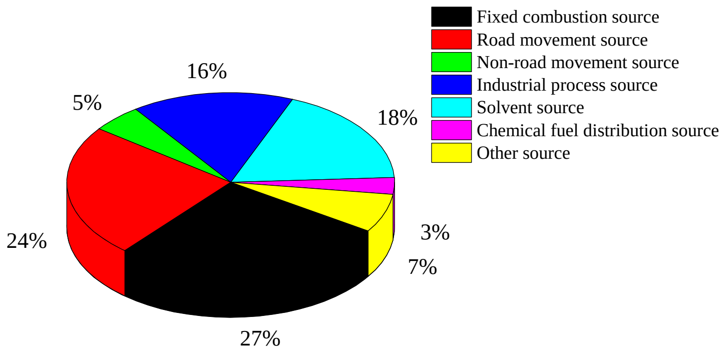

Figure 5: Contribution rate of China's seven types of primary VOC emission sources in 2017

4.2 Results and discussion

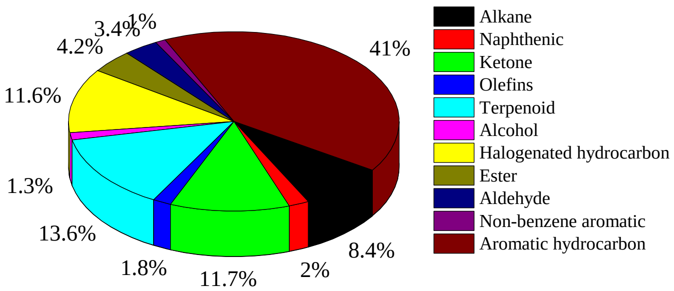

Figure 6: Percentage of each compound in VOC

According to the matching with the standard mass spectra, 265 VOC components are detected at selected detection points, mainly including aromatic hydrocarbon, alkane, naphthenic hydrocarbon and halogenated hydrocarbon. The percentage of each compound in VOCs is as shown in Figure 6, and the proportion of aromatic hydrocarbon is the largest, reaching 41%. Table 4 shows the results of quantitative detection of VOCs in residential areas with good coordinated development between urban economy and forestry, indicating that the variation range of VOC concentration is 24.8-1,423.6μg/m^3, and the average concentration is 248.3 μg/m^3; the average value of VOC concentration in residential areas with uncoordinated development between urban economy and forestry is 379.6 μg/m^3, which is obviously higher than that in residential areas with good coordinated development between urban economy and forestry, indicating that the coordinated development between urban economy and forestry have obvious effect of control, adsorption and collection on

VOCs. Figure 7 is a trend chart of VOC variation with the change in decoration interval and shows that with the increase of decoration time, the VOC concentration increases, and the VOC concentration value of residential quarters with coordinated development between urban economy and forestry tends to be a fixed value from the ninth month while that in residential areas with uncoordinated development between urban economy and forestry continues to increase, and the concentration value of VOCs is higher than that of residential areas with coordinated development between urban economy and forestry. Table 5 shows the average content of aromatic hydrocarbons in a residential quarter in Hangzhou. It can be seen that the concentration value of aromatic hydrocarbons in the residential quarters with good coordinated development between urban economy and forestry is smaller than that in the residential quarters with uncoordinated development between urban economy and forestry. Figure 8 shows the estimated level of VOC pollution in China from 2002 to 2017. It can be seen that urban forestry can play a role in purifying and adsorbing VOCs and the level of VOC pollution in areas with uncoordinated development between urban economy and forestry is increasing year by year.

Table 4: Quantitative detection results of VOCs in residential communities with coordinated development of urban economy and forestry μg/m³

Number	VOC	Average value	Standard deviation	Median	Minimum value	Maximum value
1	Alkane	23.0	33.0	9.2	0.7	195.0
2	Naphthenic hydrocarbon	6.7	11.7	2.8	1.2	57.6
3	Olefin	5.2	11.3	1.3	0.0	55.5
4	Alcohol	3.6	4.8	1.9	0.0	21.9
5	Ester	11.0	20.5	2.1	0.6	93.8
6	Aldehyde	10.4	10.7	5.1	0.8	49.3
7	Ketone	32.4	40.3	14.4	0.2	176.9
8	Terpenoid	39.9	50.8	17.3	3.7	234.4
9	Aromatic hydrocarbon	116.1	112.8	66.9	17.6	539.2
Total VOC		248.3	295.9	121	24.8	1423.6

Table 5: Average content of aromatics in military and civilian communities in Hangzhou μg/m3

Number		10	10	10	10	10	50
Time interval		1	3	9	18	36	Total average
Coordinated development of urban economy and forestry	Benzene	14.2	4.7	3.7	2.6	0.3	5.1
	Toluene	31.7	24.0	17.3	17.1	15.6	21.1
	Xylene	77.7	43.8	19.3	10.7	0.9	30.5
Urban economy and forestry development are not coordinated	Benzene	12.9	3.2	1.8	0.6	0	3.7
	Toluene	28.6	18.1	8.5	8.0	3.6	13.4
	Xylene	66.3	34.1	10.9	4.3	0.1	23.1

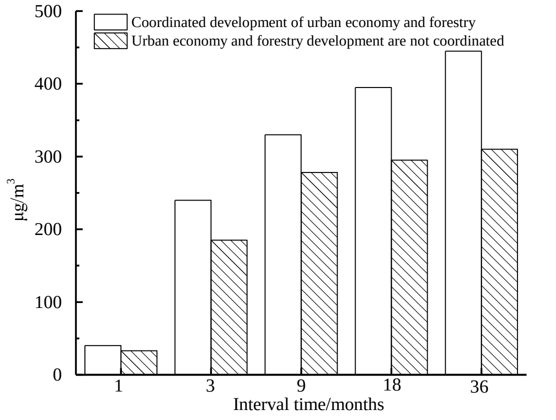

Figure 7: VOC change trend with decoration interval

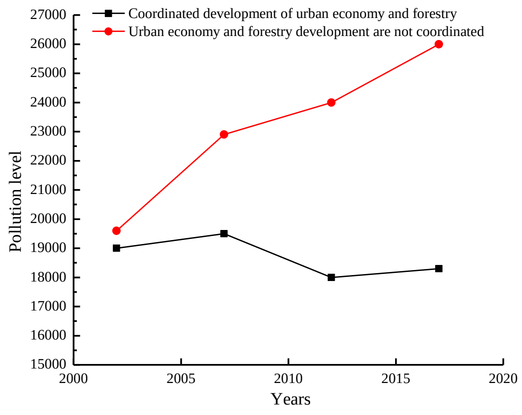

Figure 8: Estimated VOC pollution level in China from 2002 to 2017

5. Conclusions

Based on the statistical analysis of data, this study focuses on the effect of the coordinated development between urban economy and forestry on the purification, collection and control of VOC pollution, with the concrete conclusions as follows:

(1) According to the statistical analysis of the data, in the past 30 years, China's forestry area has doubled and forest reserve has increased 1.6 times. From the future forecast growth model, China's forestry area and forest reserve will have greatly increased in a positive linear manner by 2030.

(2) The coordinated development between urban economy and forestry has played a role in purifying, adsorbing and collecting VOCs. It is found from the experiment that the VOC pollution control effect in Hangzhou is obviously better than that in Shijiazhuang and Nanjing, among which the forestry collection plays a greater role.

(3) With the increase of decoration time, the concentration of VOCs in residential areas increases, but the value of VOC in residential areas with coordinated development between urban economy and forestry tends to be a fixed value from the ninth month, while the concentration of VOC in residential areas with uncoordinated development between urban economy and forestry continues to increase and the VOC concentration value is higher than that in residential areas with coordinated development between urban economy and forestry.

Reference

Cropper M. L., Jiang Y., Alberini A., Baur P., 2014, Getting cars off the road: the cost-effectiveness of an episodic pollution control program. Environmental & Resource Economics, 57(1), 117-143, DOI: 10.1007/s10640-013-9669-4

Estrada J. M., Bernal O. I., Flickinger M. C., Muñoz R., Deshusses M. A., 2015, Biocatalytic coatings for air pollution control: a proof of concept study on voc biodegradation, Biotechnology & Bioengineering, 112(2), 263-271, DOI: 10.1002/bit.25353

Furlan L., Kreutzweiser D., 2015, Alternatives to neonicotinoid insecticides for pest control: case studies in agriculture and forestry, Environmental Science & Pollution Research, 22(1), 135-147, DOI: 10.1007/s11356-014-3628-7

Li G., Wei W., Shao X., Nie L., Wang H., Yan X., 2018, A comprehensive classification method for voc emission sources to tackle air pollution based on voc species reactivity and emission amounts, Journal of Environmental Sciences, 67(5), 78-88, DOI: 10.1016/j.jes.2017.08.003

Marttila H., Klove B., 2010, Managing runoff, water quality and erosion in peatland forestry by peak runoff control, Ecological Engineering, 36(7), 900-911, DOI: 10.1016/j.ecoleng.2010.04.002

Namour P., Eschbach D., Schmitt L., Cournoyer, B., Moulin, B., Breil, P.f., 2016, Influence of instream geomorphic units on the spatial distribution of pollutants in suburban river sediments. Case of the Chaudanne (France), Instrumentation Mesure Metrologie, 15(3-4), 57-72, DOI: 10.3166/I2M.15.3-4.57-72

Oliva G., Zarra T., Naddeo V., Munoz R., Lebrero R., Angeles R., Belgiorno V., 2018, Comparative analysis of aops and biological processes for the control of vocs industrial emissions, Chemical Engineering Transactions, 68, 451-456, DOI: 10.3303/CET1868076

Tu J.Z., Ma D.L., 2018, A spatial economics perspective on convergence research of carbon emissions performance in China, International Journal of Heat and Technology, 36(3), 962-972, DOI: 10.18280/ijht.360324

Wang Y., Xue Y., Tian H., Gao J., Chen Y., Zhu C., 2017, Effectiveness of temporary control measures for lowering pm 2.5, pollution in beijing and the implications, Atmospheric Environment, 157, 75-83, DOI: 10.1016/j.atmosenv.2017.03.017

Warahena A. S., Chuah Y. K., 2009, Energy recovery efficiency and cost analysis of voc thermal oxidation pollution control technology, Journal of Taiyuan University of Technology, 43(15), 6101-6105, DOI: 10.1021/es900626e

Wei W., Li P., Wang H., Song M., 2017, Quantifying the effects of air pollution control policies: a case of shanxi province in china, Atmospheric Pollution Research, 9(3), 429-438, DOI: 10.1016/j.apr.2017.11.010

Yang J., Chang Y., Yan P., 2015, Ranking the suitability of common urban tree species for controlling pm 2.5, pollution, Atmospheric Pollution Research, 6(2), 267-277, DOI: 10.5094/APR.2015.031