

Research and Analysis on Annual Absorption of Sulfur Dioxide per Unit Area by Different Types of Forest Lands in Dapeng New District, Shenzhen

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Abstract The absorption of air pollutants is an indicator for studying the value of forest land. It plays an important role in compiling resource balance sheets by studying the absorption of air pollutants by forest land. This paper focused on sulfur dioxide, an air pollutant. Through on-site air sample collection and laboratory testing, using the calculation method of the UFORE model issued by the US Forestry Administration, the annual absorption data of sulfur dioxide in different forest lands in Dapeng New Area were obtained. The results showed that there was not much difference in the absorption capacity of sulfur dioxide among the three types of forest lands in the new area: shrubland, broad-leaved forest, and artificial forest. The amount of sulfur dioxide absorbed per unit area ranged from 11.80 to 13.62 kg/(hm² · a). However, coniferous forests had a lower absorption capacity for sulfur dioxide, with an absorption per unit area of 5.39 kg/(hm² · a).

Key words UFORE model; Ecosystem service; Forest land; Annual absorption; Sulfur dioxide

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With the continuous development of society, people's demands for living environment are increasing, but the problem of environmental pollution has not decreased. Urban air pollution is one of the increasingly serious environmental crises facing humanity. Due to the development of industry and transportation, and the extensive use of coal and oil, various toxic and harmful substances such as smoke, sulfur dioxide, nitrogen oxides, etc. are polluting the air environment in cities. At present, China has adopted many policies to address the deterioration of air quality, such as promoting the use of new energy vehicles, restricting the mining of coal with high sulfur and high ash, and other measures, which have achieved good results in improving urban air quality. At present, people's requirements for living environment are constantly increasing. In response, the Central Committee of the Communist Party of China and the State Council have officially issued the *Opinions on Accelerating the Construction of Ecological Civilization*, which clearly proposes to prepare a natural resource balance sheet and accelerate the construction of ecological civilization. At

present, Dapeng New Area is a pilot demonstration area for national ecological civilization construction. It plays an important role in compiling resource balance sheets by understanding the ability of forest land to absorb air pollutants.

In this regard, focusing on sulfur dioxide, an air pollutant, the absorption of pollutants by different forest lands is estimated in this paper. At present, the methods for evaluating the pollutant absorption function of forests are relatively mature, mainly using market value method or shadow engineering method. Their values are quantified by calculating the treatment cost of pollutants absorbed by forests, laying the foundation for natural resource asset accounting and balance sheet preparation work^[1].

1 Data and methods

1.1 Research content In this paper, a calculation method based on the UFORE model issued by the United States Forestry Administration was adopted. The data on sulfur dioxide concentration in different types of forest lands in Dapeng New Area were obtained through on-site data collection and laboratory testing. The purification rate of sulfur dioxide was calculated, and then multiplied by the vegetation area to obtain the absorption amount of the pollutant in a certain type of land, which can directly characterize the amount of sulfur dioxide absorbed by forest land and provide a data basis for calculating the value accounting of sulfur dioxide in the air regulated by forest lands.

1.2 Technical route In this paper, air samples from broad-leaved forests, coniferous forests, shrubs, and artificial forests in the Qiniang Mountain, the Honghua Mountain, the Paiya Moun-

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tain, the Bijia Mountain, and the central corridor of Dapeng New Area were first collected. Then, the concentration of sulfur dioxide in the air was determined by formaldehyde absorption – pararosaniline spectrophotometry. Based on the sulfur dioxide deposition rate provided by other research papers, the annual absorption of sulfur dioxide per unit area of each forest land can be calculated using the UFORE model issued by the US Forestry Administration. Dapeng New Area is located in Shenzhen, Guangdong Province, with excellent geographical conditions. It has not only a long coastline resource, but also abundant biological resources. Specifically, there are two large bays in the east and west of Dapeng New Area, namely Daya Bay and Dapeng Bay. The area is home to 9 national level protected plants and 40 provincial-level protected terrestrial spine animals. Dapeng New Area covers nearly half of the total area, mostly mountainous, with complex and variable terrain, forming small-scale basins, low-lying valleys, and intricate mountain ridge systems. The area accounts for about 17% of the land area in Shenzhen City. The forest resources in the new area are extremely abundant, with a coverage rate of up to 7/9 of the entire area. There are a wide variety of terrestrial vertebrates and wild plants, with 218 and 1 656 species respectively, accounting for 26.3% and 26.4% of the total in Guangdong Province. At the same time, they account for 44.8% and 70.0% of the total local animal and plant species in Shenzhen.

1.3 Data collection According to the content of this paper, it is necessary to obtain image map of Dapeng New Area, spatial distribution map of forest trees in Dapeng New Area, and air sulfur dioxide detection data from 20 forest sites in Dapeng New Area.

Based on the remote sensing image map and the interpreted distribution map of forest trees in Dapeng New Area, four testing sites including broad-leaved forest, coniferous forest, shrubland, and artificial forest were established in each testing area, including the Qiniang Mountain, the Honghua Mountain, the Paiya Mountain, the Bijia Mountain, and the central corridor, and investigation was conducted by combining with forest plot. There were a total of 5 regions and 20 plots, and sulfur dioxide in the air at each sampling point was measured.

The survey was conducted in two sampling periods, spanning spring and summer. The first sampling was conducted in early to mid March 2021, and the second sampling was conducted in mid to late July 2021.

1.4 Calculation method of UFORE model The calculation of data mainly referred to the calculation method of the UFORE model issued by the United States Forestry Administration. The amount of pollutants absorbed by trees is related to the concentration and deposition rate of pollutants. As long as the pollutant purification rate is multiplied by the area of the study zone, the amount of pollutants purified within a year can be estimated^[9]. The calculation formula for pollutant purification rate is as follows:

$$F = Vd \times C \quad (1)$$

where F is pollutant purification rate [$\text{g}/(\text{cm}^2 \cdot \text{s})$]; Vd is sedimentation rate (cm/s); C is concentration of atmospheric pollutants (g/m^3).

Among them, the data of atmospheric pollutant concentration C came from on-site monitoring results, and Vd came from the deposition rate of sulfur dioxide in Zhang Yan's research paper (Table 1). The vegetation types in this paper were different from those in Table 1, so corresponding adjustments were made. The main corresponding relationships are as follows: coniferous forests correspond to coniferous forests, broad-leaved forests and artificial forests correspond to tropical rainforests that are relatively close, and shrubs correspond to grasslands that are relatively close. Overall, the difference in atmospheric dry deposition rates between different forests is not significant, so it has little impact on the results.

Table 1 Regional mean of atmospheric dry deposition rates of different species on typical underlying surfaces^[10] cm/s

No.	Underlying surface	Deposition rate of sulfur dioxide
1	Farmland	0.25
2	Grassland	0.40
3	Deciduous forest	0.16
4	Coniferous forest	0.16
5	Water surface	0.70
6	Desert	0.10
7	Tundra, frozen soil	0.29
8	Tropical rainforest	0.36
9	Steppe	0.34
10	Whole country	0.35 ± 0.004

2 Investigation results and analysis of sulfur dioxide absorption in forest land

2.1 Sulfur dioxide concentration in each forest land Through on-site sample collection from 20 forest lands and laboratory analysis of the collected samples, the sulfur dioxide concentration data in the air of various types of forest lands were obtained (Table 2 – 3).

2.2 Annual absorption of pollutants per unit area in forest land Based on the sampling data of survey sites during March 11 – 17, 2018 and September 24 – 30, 2018, the calculation formula of UFORE model can be applied to calculate the annual absorption of sulfur dioxide per unit area in forest land, and the results were shown as Table 4.

2.3 Comparative analysis of calculation results with other research findings In order to verify the scientificity and comparability of the results, based on a large number of literature reviews, the research results of relevant scholars in Guangzhou, which has a high degree of similarity with Shenzhen's forest composition, climate temperature, ecological environment, socio-economic factors, *etc.*, were selected for comparative analysis. The comparison results were shown as Table 5.

Table 2 Measurement results of sulfur dioxide concentration in each forest land in spring (March 11 – 17, 2018)

No.	Site	Quadrat type	Coordinate	Sulfur dioxide concentration// mg/m ³
1	Bijia Mountain	Shrub 2	22°39.6790' N, 114°27.4429' E	0.009
2		Broad-leaved forest 3	22°38.1191' N, 114°26.1910' E	0.011
3		Coniferous forest 1	22°38'25.91" N, 114°26'0.56" E	0.013
4	Paiya Mountain	Artificial forest 2	22°38.3593' N, 114°28.8698' E	0.010
5		Shrub 2	22°39'4.79" N, 114°33'52.06" E	0.013
6		Broad-leaved forest 1	22°38'58.60" N, 114°31'43.82" E	0.013
7		Coniferous forest 2	22°36'9.36" N, 114°31'40.66" E	0.009
8	Central corridor	Artificial forest 1	22°38'47.29" N, 114°30'45.11" E	0.013
9		Shrub 1	22°35'22.43" N, 114°26'50.84" E	0.013
10		Broad-leaved forest 2	22°34'11.41" N, 114°27'50.33" E	0.009
11		Coniferous forest 3	22°35'3.68" N, 114°27'41.83" E	0.011
12	Honghua Mountain	Artificial forest 1	22°33'9.29" N, 114°29'53.03" E	0.009
13		Shrub 1	22°31'21.80" N, 114°29'40.67" E	0.009
14		Broad-leaved forest 3	22°31'16.60" N, 114°29'37.13" E	0.014
15		Coniferous forest 1	22°30'4.82" N, 114°31'52.34" E	0.015
16	Qiniang Mountain	Artificial forest 2	22°29'48.60" N, 114°32'6.25" E	0.009
17		Shrub 1	22°32'13.99" N, 114°35'33.97" E	0.011
18		Broad-leaved forest 2	22°30'9.97" N, 114°35'28.97" E	0.014
19		Coniferous forest 1	22°29'47.98" N, 114°34'39.00" E	0.010
20		Artificial forest 3	22°29'42.00" N, 114°31'0.98" E	0.015

Table 3 Measurement results of sulfur dioxide concentration in each forest land in autumn (September 24 – 30, 2018)

No.	Site	Quadrat type	Coordinate	Sulfur dioxide concentration// mg/m ³
1	Bijia Mountain	Shrub 2	22°39.6790' N, 114°27.4429' E	0.015
2		Broad-leaved forest 3	22°38.1191' N, 114°26.1910' E	0.009
3		Coniferous forest 1	22°38'25.91" N, 114°26'0.56" E	0.014
4	Paiya Mountain	Artificial forest 2	22°38.3593' N, 114°28.8698' E	0.008
5		Shrub 2	22°39'4.79" N, 114°33'52.06" E	0.010
6		Broad-leaved forest 1	22°38'58.60" N, 114°31'43.82" E	0.008
7		Coniferous forest 2	22°36'9.36" N, 114°31'40.66" E	0.010
8	Central corridor	Artificial forest 1	22°38'47.29" N, 114°30'45.11" E	0.009
9		Shrub 1	22°35'22.43" N, 114°26'50.84" E	0.013
10		Broad-leaved forest 2	22°34'11.41" N, 114°27'50.33" E	0.011
11		Coniferous forest 3	22°35'3.68" N, 114°27'41.83" E	0.007
12	Honghua Mountain	Artificial forest 1	22°33'9.29" N, 114°29'53.03" E	0.012
13		Shrub 1	22°31'21.80" N, 114°29'40.67" E	0.006
14		Broad-leaved forest 3	22°31'16.60" N, 114°29'37.13" E	0.013
15		Coniferous forest 1	22°30'4.82" N, 114°31'52.34" E	0.009
16	Qiniang Mountain	Artificial forest 2	22°29'48.60" N, 114°32'6.25" E	0.012
17		Shrub 1	22°32'13.99" N, 114°35'33.97" E	0.009
18		Broad-leaved forest 2	22°30'9.97" N, 114°35'28.97" E	0.011
219		Coniferous forest 1	22°29'47.98" N, 114°34'39.00" E	0.008
20		Artificial forest 3	22°29'42.00" N, 114°31'0.98" E	0.007

At present, there was relatively little quantitative research on the absorption of pollutants in forest land, and only two cases were selected for comparison in this paper. By comparison, it was found that the sulfur dioxide absorption in the forest land in this paper was one order of magnitude lower than the reference values in other literature. The reason was due to differences in research areas and measurement methods. In the literature 1, the service functions of forest ecosystem in Guangzhou were evaluated based on the *Specifications for Assessment of Forest Ecosystem*

Services. In the literature 2, the sulfur content of ground leaves was calculated by using the nitric acid – potassium perchlorate digestion method, and then the annual absorption of sulfur dioxide per unit area in forest land was calculated. Due to historical industrial development, sulfur dioxide concentration in these two comparative study areas is higher. However, Dapeng New Area developed its industry relatively late, and its ecological environment is well preserved, with a forest coverage rate of 77%. Therefore, the air quality in Dapeng New Area is better than that

in Guangzhou, and the sulfur dioxide concentration in the air is lower than that in Guangzhou.

Table 4 The amount of sulfur dioxide absorbed per unit area in forest land

Type of forest land	Area	Sulfur dioxide concentration in the air mg/m ³	Sulfur dioxide deposition velocity cm/s	Annual absorption of sulfur dioxide kg/(hm ² ·a)
Shrub	Bijia Mountain	0.012 0	0.400	15.137
	Honghua Mountain	0.008 0	0.400	9.461
	Paiya Mountain	0.012 0	0.400	14.507
	Qiniang Mountain	0.010 0	0.400	12.614
	Central corridor	0.013 0	0.400	16.399
	Mean	0.011 0	0.400	13.624
Broad-leaved forest	Bijia Mountain	0.010 0	0.360	11.353
	Honghua Mountain	0.013 5	0.360	15.326
	Paiya Mountain	0.010 5	0.360	11.921
	Qiniang Mountain	0.012 5	0.360	14.191
	Central corridor	0.010 0	0.360	11.353
	Mean	0.011 6	0.360	12.829
Artificial forest	Bijia Mountain	0.009 0	0.360	10.218
	Honghua Mountain	0.011 0	0.360	11.921
	Paiya Mountain	0.011 0	0.360	12.488
	Qiniang Mountain	0.011 0	0.360	12.488
	Central corridor	0.011 0	0.360	11.921
	Mean	0.010 6	0.360	11.807
Coniferous forest	Bijia Mountain	0.014 0	0.160	6.812
	Honghua Mountain	0.009 0	0.160	4.541
	Paiya Mountain	0.010 0	0.160	4.793
	Qiniang Mountain	0.009 0	0.160	4.541
	Central corridor	0.012 0	0.160	6.055
	Mean	0.010 8	0.160	5.349

Table 5 Comparison of calculation results of sulfur dioxide absorption in forest land with other study results

Type of forest land	This paper	Literature one ^[11]	Literature two ^[12]
Shrub	13.624	–	258.214
Broad-leaved forest	12.829	88.650	112.244
Artificial forest	11.807	152.130	104.552
Coniferous forest	5.349	152.130	359.848

2.4 Comparative analysis of sulfur dioxide absorption in different forest lands Seen from Table 5, there was not much difference in the absorption capacity of sulfur dioxide among shrub, broad-leaved forest, and artificial forest. The annual absorption of sulfur dioxide per unit area ranged from 11.80 to 13.62 kg/(hm²·a). However, coniferous forests had a lower absorption capacity for sulfur dioxide, with an annual absorption of 5.39 kg/(hm²·a).

2.5 Comparative analysis of sulfur dioxide absorption by forest land in different regions The forest land of the Qiniang Mountain had a relatively high absorption of sulfur dioxide, with an annual absorption of 11.43 kg/(hm²·a). The forest land in the Bijia Mountain, central corridor, and the Honghua Mountain

had a relatively moderate absorption of sulfur dioxide, with values ranging from 10.88 to 10.95 kg/(hm²·a). The forest land in the Paiya Mountain had relatively less absorption of sulfur dioxide, with a value of 10.31 kg/(hm²·a).

3 Conclusions

In this paper, air samples were collected from broad-leaved forests, coniferous forests, shrubs, and artificial forests in the Qiniang Mountain, the Honghua Mountain, the Paiya Mountain, the Bijia Mountain, and central corridor of Dapeng New Area in spring and autumn of 2018. Through data analysis, the annual absorption of sulfur dioxide per unit area in each forest land was calculated. By analyzing the sulfur dioxide absorption of different forest lands and regions, the research results can be obtained as follows.

(1) There were differences in the absorption of sulfur dioxide among different forest lands. The four forest lands surveyed in this paper were shrub, broad-leaved forest, artificial forest, and coniferous forest in the order of sulfur dioxide absorption from high to low.

(2) Environmental factors such as altitude, latitude and longitude, temperature, and precipitation may all affect the amount of sulfur dioxide absorbed by forest land.

In summary, some suggestions for promoting the absorption of sulfur dioxide in forest land of Dapeng New Area are proposed: maintaining the current ecological environment status and strictly prohibiting deforestation.

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