sustainability

MDPI

Article

A New Study on Air Quality Standards: Air Quality Measurement and Evaluation for Jiangsu Province Based on Six Major Air Pollutants

Xueyan Liu [1] **and Xiaolong Gao** [2,*]

[1] School of Economics, Fudan University, Shanghai 200433, China; liuxueyan_fd@126.com
[2] School of Business, East China University of Science and Technology, Shanghai 200237, China
* Correspondence: cnxiaolong@126.com; Tel.: +86-21-6425-3583

Received: 27 August 2018; Accepted: 30 September 2018; Published: 5 October 2018

check for updates

Abstract: China's current Air Quality Index (AQI) system only considers one air pollutant which has the highest concentration value. In order to comprehensively evaluate the urban air quality of Jiangsu Province, this paper has studied the air quality of 13 cities in that province from April 2015 to March 2018 based on an expanded AQI system that includes six major air pollutants. After expanding the existing air quality evaluation standards of China, this paper has calculated the air quality evaluation scores of cities in Jiangsu Province based on the six major air pollutants by using the improved Fuzzy Comprehensive Evaluation Model. This paper has further analyzed the effectiveness of air pollution control policies in Jiangsu Province and its different cities during the study period. The findings are as follows: there are distinct differences in air quality for different cities in Jiangsu Province; except for coastal cities such as Nantong, Yancheng and Lianyungang, the southern cities of Jiangsu generally have better air quality than the northern cities. The causes of these differences include not only natural factors such as geographical location and wind direction, but also economic factors and energy structure. In addition, air pollution control policies have achieved significant results in Nantong, Changzhou, Wuxi, Yangzhou, Suzhou, Yancheng, Zhenjiang, Tai'an and Lianyungang. Among them, Nantong has seen the biggest improvement, 20.28%; Changzhou and Wuxi have improved their air quality by more than 10%, while Yangzhou, Suzhou, and Yancheng have improved their air quality by more than 5%. However, the air quality of Nanjing, Huai'an, Xuzhou, and Suqian has worsened by different degrees compared that of the last period within the beginning period, during which Suqian's air quality has declined by 20.07% and Xuzhou's by 16.32%.

Keywords: air quality; air quality evaluation standards; AQI; Jiangsu province; fuzzy comprehensive evaluation

1. Introduction

Since the reform and opening-up of China, with the rapid expansion in the size of its economy, its ecological environment, especially air quality, has been facing serious threats [1–6]. Increasing energy consumption, the energy structure over-relying on primary energy sources (such as coal) with low conversion efficiency and high pollution emissions, as well as the lack of environmental awareness, have all contributed to the severe deterioration in China's air quality [7–12]. In recent years, China has experienced frequent heavy pollution weathers, especially in the eastern coastal region. The devastating, long-lasting, and wide-ranging smog and haze phenomenon is typical proof of the deterioration in air quality. Apart from its negative impact on traffic, the growing problem of air pollution has also caused great loss to normal people's daily life, health [13,14], and the operation and production of enterprises, which has drawn great attention from the academic community [15–19].

As the most economically developed province in the eastern coastal areas of China, Jiangsu Province has also been seriously plagued by air pollution problems in recent years. According to the “Jiangsu Province Environmental Bulletin” published by the Jiangsu Provincial Environmental Protection Department every year, although the air quality of Jiangsu has improved since 2013, none of its 13 cities has reached the Level II Air Quality Standards stated in China’s “Ambient Air Quality Standards (GB3095-2012)” on air pollutants’ annual average concentration limits since 2013 (see Table 1 below) [20]. Moreover, the annual average concentration of NO_2 and O_3 rebounded in 2017, and the province’s air quality compliance rate decreased by 2.2% in that year [21].

Table 1. Annual Average Concentration of Major Air Pollutants and Air Quality Compliance Rate of Jiangsu Province (2013–2017).

	2013	2014	2015	2016	2017
$PM_{2.5}$ (μg/m^3)	73	66	58	51	49
PM_{10} (μg/m^3)	115	106	96	86	81
SO_2 (μg/m^3)	35	29	25	21	16
NO_2 (μg/m^3)	41	39	37	37	39
CO (mg/m^3)	2.1	1.7	1.7	1.7	1.5
O_3 (μg/m^3)	139	154	167	165	177
Air Quality Compliance Rate in Jiangsu (%)	60.3	64.2	66.8	70.2	68.0
Number of Cities in Jiangsu that Reached Level II Air Quality Standards	0	0	0	0	0

Therefore, although the official statistics of Jiangsu Province’s air quality compliance rate have improved in recent years [20], it is worth studying how to objectively evaluate the air quality and policy effectiveness in Jiangsu Province, given that the emissions of major air pollutants are still increasing [22].

In recent years, the academic community has also carried out various explorations on the measurement and evaluation of Jiangsu Province’s air quality. Wang et al. (2016) used the Logarithmic Mean Divisia Index (LMDI) to analyze the driving factors of SO_2 emissions in Jiangsu Province, and found that energy intensity is the main reason for the increase. They believe that the government needs to determine specific emission reduction targets and policy initiatives according to the actual energy structure of different cities [23]. Ge et al. (2017) used the Projection Pursuit Cluster (PPC) Model to analyze the Social Vulnerability for Air Pollution of the Yangtze River Delta (YRD) region represented by Jiangsu Province. By calculating the Social Vulnerability Index (SVI), they concluded that Jiangsu’s SVI was higher than that of Shanghai [24]. He et al. (2018) studied the impact of various factors including the industrial structure, energy consumption structure, and energy efficiency on air quality in Jiangsu Province from 2006 to 2015, and further explored the impact of relevant policies on energy consumption and air quality. Their study showed that every 1% optimization of the industrial structure in Jiangsu Province would result in an improvement of 0.0054% in the Air Quality Index [25]. Zhang et al. (2017) analyzed the spatial distribution of acid rain using the recent data of acid rain and urban pollutant emissions in the eastern coastal areas. They concluded that since 2009, the increase of $NH_4{}^+$ and Ca^{2+} has led to an increase in the number of haze days in Jiangsu, and that the long-distance spread of pollutants and alkaline pollutants are key drivers of acid rain and haze problems [26]. Xu et al. (2017) used the Structural Decomposition Analysis (SDA) method to decompose the factors behind the increase of CO_2 emissions in Jiangsu Province. They pointed out that the economic growth of Jiangsu Province has generally contributed to the increase of CO_2 emissions, and that the transfers-out and investment effects are the main reason for the increase of CO_2 emissions [27]. Chen et al. (2017) studied the relations between short-term ozone exposure and daily total mortality using a generalized additive model and univariate random-effects meta-analysis. By studying seven cities in Jiangsu Province from 2013 to 2014, they concluded that there was a significant correlation between premature total mortality and short-term ozone exposure [28]. Wang et al. (2017) divided the factors reducing air pollution into three stages: source prevention, process control, and end-of-pipe treatment based on index decomposition analysis and a whole process treatment perspective. After studying the treatment of energy-related SO_2 emissions in 13 cities of Jiangsu Province, they divided these cities into

4 types: the leading type, process-dependent type, end-dependent type, and lagging type. They also found that the development pattern of "Pollute First, Govern Later" still has not fundamentally changed for Jiangsu Province [29].

The above research on the air quality of cities in Jiangsu were still based on the existing air quality measurement standards of China, and most of them only considered 1–2 major pollutants such as $PM_{2.5}$ and PM_{10}. However, using only China's current national air quality standards—Ambient Air Quality Standards (GB3095-2012) and the Technical Regulation on Ambient Air Quality Index (HJ 633-2012)—it is difficult to make a comprehensive and objective assessment on the air quality of Jiangsu Province in recent years. This is because, first of all, China's current air quality assessment standards essentially only involve one type of pollutant (the pollutant with the highest concentration on the day), so it is difficult to fully reflect the overall air quality [30,31]. Secondly, China's current standards are only based on the average concentration value of each pollutant within a certain period of time, so it is difficult to reflect the extreme concentration values of the pollutant and its fluctuations in that period. Finally, the above standards were established in 2012, which set the upper limit of the "24-h average $PM_{2.5}$" as 500 [30,31]. However, this limit can no longer adapt to the reality because currently, the actual PM2.5 concentration values of many cities in China were far exceeding this upper limit (i.e., off the charts) [32]. Under such circumstances, the current assessment of China's air quality is often simplified into vertical and horizontal comparisons of the $PM_{2.5}$ statistics of different regions.

Therefore, based on above research, and drawing on the research of Cannistraro et al. (2016) [33], this paper has constructed a comprehensive air quality evaluation system that encompasses the six major pollutants (SO_2, NO_2, CO, PM_{10}, $PM_{2.5}$ and O_3) [30,31] covered in China's national routine monitoring and air quality assessment. Based on the statistics of the six air pollutants in cities of Jiangsu Province from April 2015 to March 2018, this paper has also utilized the Fuzzy Comprehensive Evaluation Model in order to measure and evaluate the air quality of various cities in Jiangsu Province, and to enrich the existing academic literature on Jiangsu Province's air quality. Scholars have adopted new approaches to the evaluation of air quality in Jiangsu in recent years. Cao et al. (2018) studied the air pollution caused by the exhaust gas from inland ships in the Jiangsu section of the Beijing-Hangzhou Grand Canal. Their results indicated that dry cargo ships are the most important air pollution sources in the Jiangsu section of the Grand Canal, while ships with a gross tonnage between 200 and 600 tons had the largest exhaust gas emissions [34]. Yang et al. (2018) derived the Variogram Model using the daily average concentration data of PM2.5 in the southern part of Jiangsu Province in 2014, and generated the distribution information maps of pollutants in the southern area of Jiangsu with help of the spatiotemporal ordinary kriging (STOK) technology. Their results showed that in 2014, about 29.3% of the area in southern Jiangsu was polluted by PM2.5, which also showed a spatial trend of the PM2.5 pollutants declining from the west to the east of southern Jiangsu [35]. This paper decided to calculate and evaluate the air quality of Jiangsu by Fuzzy Comprehensive Evaluation Model. Compared with other methods, the Fuzzy Comprehensive Evaluation Model describes the air quality level of evaluation with the membership function, and can evaluate the parameters in the model, which makes the results as close as possible to objective fact [36,37]. Moreover, this paper improves the original model in order to better evaluate the air quality of Jiangsu on the basis of six pollutants (please refer to Part 2).

The structure of this paper is as follows: Part 2 introduces the research methods used; Part 3 lists the calculation results; Part 4 analyzes the air quality of various cities of Jiangsu Province since April 2015; Part 5 summarizes the findings in this paper and provides corresponding policy recommendations.

2. Methodology and Data

2.1. Improved Fuzzy Comprehensive Evaluation Model

The air quality evaluation system constructed in this paper includes six major air pollutants: SO_2, NO_2, CO, PM_{10}, $PM_{2.5}$, and O_3. In this complex system, the evaluation of the air quality of each city in Jiangsu Province is determined by these six pollutants. Therefore, in the calculation of air quality evaluation scores, we first need to calculate the evaluation score of each pollutant, and then obtain the overall air quality evaluation result of that city based on the evaluation scores of each pollutant. In the actual evaluation process, in order to deal with the uncertainties of a complex systems containing six major pollutants of SO_2, NO_2, CO, PM_{10}, $PM_{2.5}$, and O_3, this paper has made a few improvements to the Fuzzy Comprehensive Evaluation Model commonly used in academic circles [38–42] in order to reduce the uncertainty of this evaluation system. The specific steps are as follows:

A city's air quality evaluation object P. $U = \{u_1, u_2, \cdots, u_n\}$ represents a set of pollutant indicators related to this evaluation object P. For each pollutant, there is a Rating Set $V = \{v_1, v_2, \cdots, v_m\}$. After making a fuzzy evaluation on the Rating Set of each pollutant in U, this paper has obtained (1) the fuzzy evaluation matrix about n factors:

$$R = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_4 \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \tag{1}$$

where r_{ij} is determined by the membership function. The calculation steps are as follows. Equations (2)–(4):

(1) Rating Level 1:

$$r_{i1}(r_i) = \begin{cases} 0 & r_i \geq v_{i2} \\ -\frac{r_i - v_{i2}}{v_{i2} - v_{i1}} & v_{i1} < r_i < v_{i2} \\ 1 & r_i \leq v_{i1} \end{cases} \tag{2}$$

(2) Rating Level j:

$$r_{ij}(r_i) = \begin{cases} 0 & r_i \leq v_{ij-1}, r_i \geq v_{ij+1} \\ \frac{r_i - v_{ij-1}}{v_{ij} - v_{ij-1}} & v_{ij-1} < r_i < v_{ij} \\ -\frac{r_i - v_{ij+1}}{v_{ij+1} - v_{ij}} & v_{ij-1} < r_i < v_{ij+1} \end{cases} \tag{3}$$

(3) Rating Level n:

$$r_{in}(r_i) = \begin{cases} 0 & r_i \leq v_{in} \\ \frac{r_i - v_{in-1}}{r_{in} - v_{in-1}} & v_{in-1} < r_i < v_{in} \\ 1 & r_i \geq v_{in} \end{cases} \tag{4}$$

The element r_{ij} in the above matrix represents the fuzzy membership degree of the factor u_i with regard to the rating v_i, that is, a fuzzy relationship from U to V; thus, the determined (U, V, R) constitutes a Fuzzy Comprehensive Evaluation Model.

In order to calculate the comprehensive evaluation value of different cities' air quality, it is also necessary to determine the weight of each factor. Since the degree of harm of the six pollutants has not yet been uniformly quantified, we weigh all pollutants equally in the calculation. Let the weights be $W = \{w_1, w_2, \cdots, w_n\}$, which denotes the weight of each indicator, and satisfies the condition

$\sum_{i=1}^{n} w_i = 1$. By using the matrix and vector algorithm, this paper can obtain Fuzzy Evaluation Set B with the following Equation (5):

$$B = W \times R^T = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \times [w_1, w_2, \cdots, w_n]^T = [b_1, b_2, \cdots, b_m] \quad (5)$$

Finally, based on the principle of maximum membership degree, this paper can obtain a comprehensive evaluation value of different cities' air quality by analyzing the Fuzzy Evaluation Vector B: in this Fuzzy Evaluation Set $B = (b_1, b_2, \cdots, b_m)$, let b_i be the membership degree of Level v_i to this Fuzzy Evaluation Set B. Let $M = max(b_1, b_2, \cdots, b_m)$, M's value represent the Fuzzy Comprehensive Evaluation Score of the evaluation object, i.e., the comprehensive evaluation value of the air quality of the city. Ranging from 0 to 1, the larger the M's value, the better air quality of the city; the smaller the M's value, the worse the air quality.

2.2. Data Sources

In February 2015, the Jiangsu Provincial People's Congress officially published the "Regulations on the Prevention and Control of Air Pollution in Jiangsu Province", which was officially implemented from March 2015 [43]. As the first local regulation reviewed and approved by the Jiangsu Provincial People's Congress since 2001, this regulation has gone through four rounds of review, which was a record in the local legislation of Jiangsu Province [22]. This regulation strictly stipulates the acquisition and disclosure of air pollution monitoring data, the development and publication of the heavy-pollution industrial projects list, as well as the enforcement actions including rectification, production restriction, production suspension, and closure, which provided effective local regulatory guidance on air pollution control to different cities of Jiangsu Province [43]. In March 2018, the second meeting of the Standing Committee of the 13th People's Congress of Jiangsu Province adopted a resolution to formally amend the regulations [44].

This paper has selected April 2015 to March 2018 as the study period, which was after the regulations were first implemented but before the amendment took place in order to analyze the influence and effectiveness of this regulation based on the six major air pollutants. This paper's calculation is based on the monthly air quality and pollutant monitoring data published by the Data Center of China's Ministry of Environmental Protection and China's National Environmental Monitoring Center, covering the monthly average concentration data of six major pollutants, i.e., $PM_{2.5}$, PM_{10}, CO, NO_2, O_3, and SO_2 [45,46].

3. Results

By adopting the Fuzzy Optimization Theory introduced in Part 2.1, this paper has calculated the air quality evaluation results for 13 cities in Jiangsu Province from April 2015 to March 2018 based on the aforementioned air pollutant data (as shown in Tables 2–5 and Figures 1–4 below).

Table 2. Air Quality Evaluation Score of Cities in Jiangsu Province (April 2015–December 2015).

	April 2015	May 2015	June 2015	July 2015	August 2015	September 2015	October 2015	November 2015	December 2015
Nanjing	0.5078	0.4561	0.4464	0.5025	0.4522	0.4712	0.4796	0.5141	0.5031
Nantong	0.5023	0.5110	0.4219	0.4226	0.4595	0.4774	0.4991	0.5425	0.5281
Suqian	0.5671	0.5598	0.4169	0.5073	0.5027	0.5209	0.4746	0.4360	0.4499
Changzhou	0.4251	0.4412	0.5918	0.4965	0.5023	0.4711	0.5129	0.5460	0.4783
Xuzhou	0.4354	0.3811	0.4156	0.5256	0.5413	0.5015	0.4517	0.4554	0.4719
Yangzhou	0.4622	0.4152	0.4165	0.4605	0.4659	0.4731	0.5067	0.5417	0.5522
Wuxi	0.4409	0.4820	0.4952	0.4847	0.4541	0.4278	0.5235	0.5389	0.4879
Tai'an	0.5000	0.4869	0.3814	0.4362	0.4872	0.4746	0.4466	0.5039	0.5069
Huai'an	0.5363	0.5268	0.4034	0.5267	0.5125	0.5612	0.5049	0.5295	0.4825
Yancheng	0.5172	0.5781	0.4812	0.5224	0.5149	0.5674	0.5297	0.5416	0.5152
Suzhou	0.4939	0.4987	0.5106	0.4928	0.4620	0.4509	0.5419	0.5614	0.5243
Lianyungang	0.5527	0.5319	0.4431	0.4999	0.5145	0.5087	0.5427	0.5195	0.4630
Zhenjiang	0.4478	0.4901	0.3907	0.4126	0.4321	0.4375	0.5113	0.5202	0.5232

Table 3. Air Quality Evaluation Score of Cities in Jiangsu Province (January 2016–September 2016).

	January 2016	February 2016	March 2016	April 2016	May 2016	June 2016	July 2016	August 2016	September 2016
Nanjing	0.5017	0.5163	0.4603	0.5163	0.4329	0.4763	0.4889	0.3910	0.4528
Nantong	0.5490	0.5354	0.5671	0.4766	0.4709	0.4742	0.4229	0.5417	0.5318
Suqian	0.4550	0.4272	0.4795	0.5459	0.6062	0.5217	0.5450	0.5195	0.5080
Changzhou	0.5114	0.4952	0.4439	0.4836	0.4601	0.4782	0.4688	0.4450	0.4958
Xuzhou	0.4226	0.4517	0.4518	0.4337	0.4692	0.4708	0.5016	0.4610	0.4870
Yangzhou	0.5316	0.5409	0.4953	0.5111	0.4650	0.5004	0.4484	0.5064	0.5171
Wuxi	0.5212	0.5380	0.4838	0.4485	0.4538	0.5090	0.4596	0.4541	0.4975
Tai'an	0.5124	0.4549	0.4397	0.4915	0.4743	0.4753	0.4302	0.5111	0.4970
Huai'an	0.4966	0.4833	0.4704	0.4948	0.5083	0.4862	0.5006	0.5470	0.5037
Yancheng	0.5021	0.5167	0.5509	0.5418	0.5691	0.5510	0.5927	0.6346	0.5506
Suzhou	0.5570	0.5409	0.5577	0.5176	0.4904	0.4983	0.4752	0.4927	0.5089
Lianyungang	0.4655	0.5381	0.5253	0.4592	0.5008	0.4927	0.5721	0.5498	0.4982
Zhenjiang	0.5190	0.4876	0.4867	0.5554	0.5202	0.5281	0.4402	0.4188	0.4846

Table 4. Air Quality Evaluation Score of Cities in Jiangsu Province (October 2016–June 2017).

	October 2016	November 2016	December 2016	January 2017	February 2017	March 2017	April 2017	May 2017	June 2017
Nanjing	0.4996	0.5976	0.5778	0.5359	0.5573	0.5393	0.5328	0.5593	0.4724
Nantong	0.5831	0.5627	0.6058	0.6149	0.5783	0.5556	0.4985	0.5737	0.4972
Suqian	0.5225	0.5059	0.5055	0.4737	0.4633	0.5306	0.5044	0.4556	0.4465
Changzhou	0.5355	0.5471	0.5404	0.5477	0.5160	0.5265	0.5196	0.5768	0.4594
Xuzhou	0.3773	0.4003	0.3694	0.3725	0.4045	0.4091	0.4556	0.3653	0.3874
Yangzhou	0.5447	0.4927	0.5354	0.5100	0.4575	0.4707	0.4835	0.5255	0.4291
Wuxi	0.4925	0.5243	0.5466	0.5630	0.5632	0.5453	0.5096	0.5667	0.4786
Tai'an	0.5403	0.4616	0.5403	0.5231	0.4827	0.5140	0.4887	0.5428	0.4628
Huai'an	0.5623	0.5181	0.5180	0.5148	0.4980	0.5200	0.4773	0.5208	0.4634
Yancheng	0.5602	0.5527	0.5951	0.5432	0.5130	0.5170	0.5319	0.6203	0.5707
Suzhou	0.5074	0.5637	0.5360	0.5926	0.5615	0.5358	0.4805	0.5951	0.5641
Lianyungang	0.5097	0.4891	0.5521	0.5265	0.5374	0.5189	0.5390	0.5645	0.5893
Zhenjiang	0.5719	0.5598	0.5724	0.5352	0.4760	0.4841	0.5111	0.5376	0.4572

Table 5. Air Quality Evaluation Score of Cities in Jiangsu Province (July 2017–March 2018).

	July 2017	August 2017	September 2017	October 2017	November 2017	December 2017	January 2018	February 2018	March 2018
Nanjing	0.4905	0.5343	0.5277	0.5377	0.5249	0.4723	0.4189	0.4983	0.4879
Nantong	0.3523	0.4103	0.4970	0.6436	0.5820	0.5737	0.6621	0.6210	0.6042
Suqian	0.5265	0.4668	0.5104	0.4812	0.4841	0.4722	0.3686	0.4575	0.4533
Changzhou	0.4253	0.4587	0.4998	0.5359	0.5206	0.4471	0.4539	0.4987	0.4882
Xuzhou	0.4723	0.4301	0.4060	0.3263	0.3928	0.3759	0.3133	0.3469	0.3644
Yangzhou	0.3598	0.4609	0.5262	0.5650	0.4818	0.5013	0.5240	0.5274	0.5033
Wuxi	0.4320	0.4637	0.4931	0.5254	0.5136	0.4806	0.4867	0.5063	0.5002
Tai'an	0.4414	0.5191	0.5353	0.5949	0.5144	0.5005	0.5201	0.5450	0.5189
Huai'an	0.5172	0.5342	0.5391	0.4978	0.4988	0.4858	0.4860	0.4933	0.4925
Yancheng	0.5404	0.5642	0.5101	0.6055	0.5517	0.5234	0.5637	0.5700	0.5521
Suzhou	0.4595	0.4800	0.5303	0.5579	0.5500	0.5039	0.5270	0.5393	0.5340
Lianyungang	0.6237	0.5682	0.5865	0.5468	0.5778	0.5896	0.5184	0.5559	0.5639
Zhenjiang	0.4094	0.4624	0.4674	0.5283	0.4669	0.4650	0.4612	0.4900	0.4700

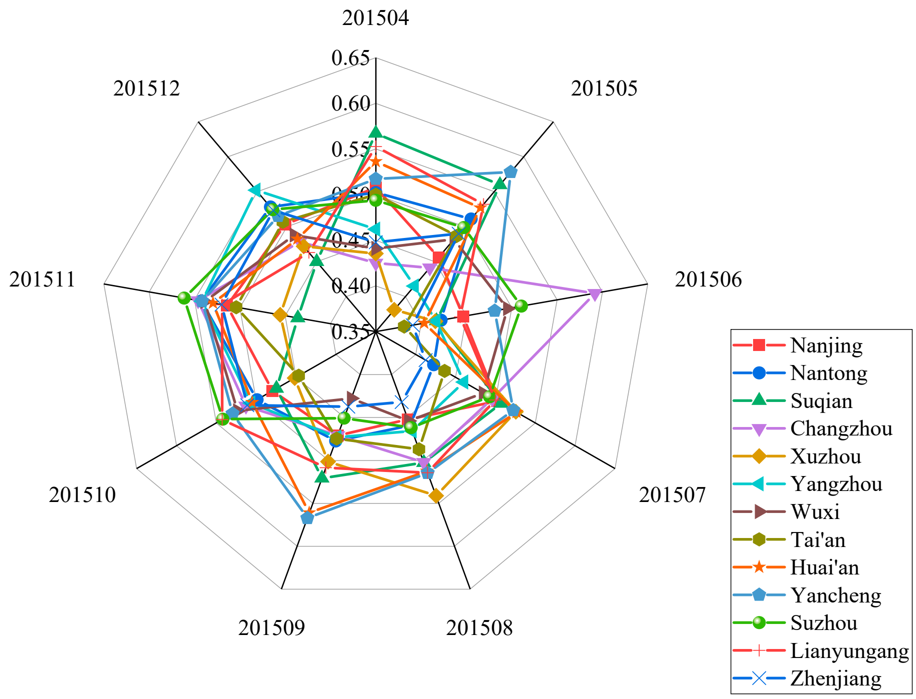

Figure 1. Air Quality Evaluation Score of 13 Cities in Jiangsu Province (April 2015–December 2015).

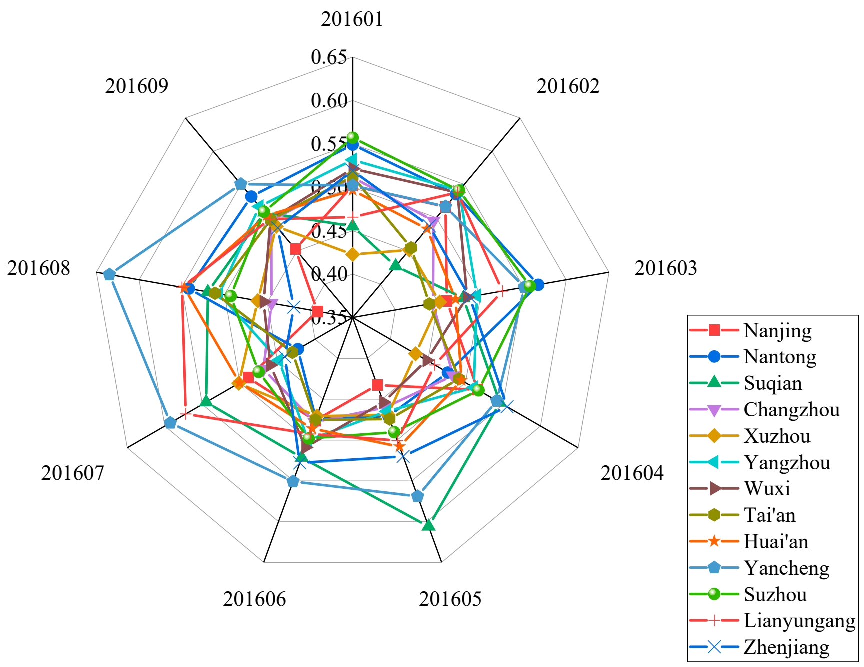

Figure 2. Air Quality Evaluation Score of 13 Cities in Jiangsu Province (January 2016–September 2016).

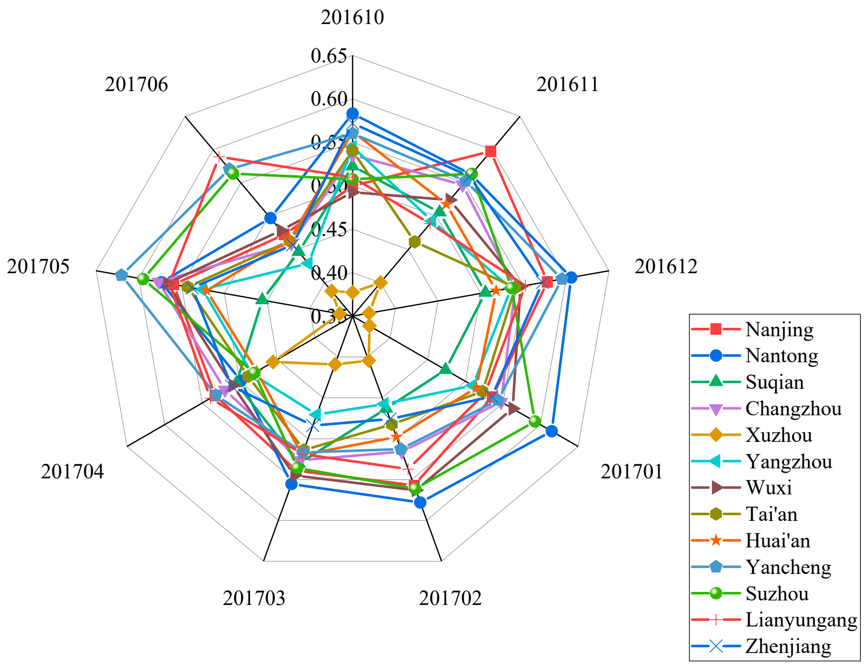

Figure 3. Air Quality Evaluation Score of 13 Cities in Jiangsu Province (October 2016–June 2017).

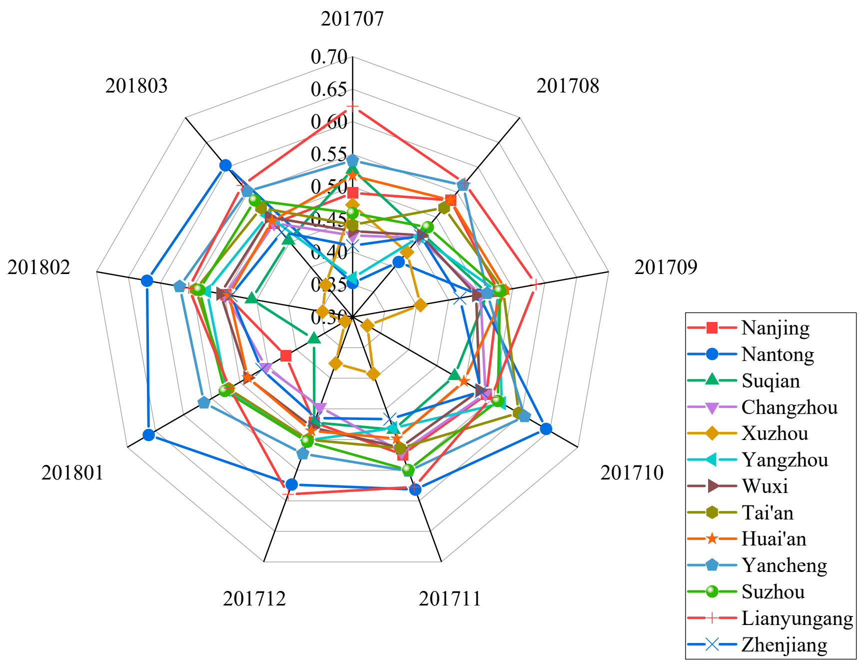

Figure 4. Air Quality Evaluation Score of 13 Cities in Jiangsu Province (July 2017–March 2018).

4. Discussions

Based on the air quality evaluation scores of various cities in Jiangsu Province from April 2015 to March 2018, this paper concludes that:

(1) Although none of the cities in Jiangsu Province has reached the Level II Air Quality Standards stated in China's "Ambient Air Quality Standards (GB3095-2012)" on air pollutants' annual average concentration limits within the study period [20,30], the lowest air quality evaluation score in the study period was that of Xuzhou in January, 2018 (0.3133), which was much higher than 0. Moreover, most cities' air quality scores ranged between 0.4–0.6 in the study period, which indicates that the overall air quality of Jiangsu cities was quite good. This is also why the Chinese central government, especially

the Ministry of Environmental Protection, didn't enforce intensified air pollution control policies (such as those on the Beijing-Tianjin-Hebei region) on Jiangsu Province.

(2) However, there are still some concerns regarding the air quality of cities in Jiangsu Province, such as:

- Although the air quality of the three coastal cities, Jiangsu-Nantong, Yancheng, and Lianyungang, was quite good during the study period—especially Nantong, whose air quality score has ranked top one among all Jiangsu cities for 5 months during the six months from October 2017 to March 2018—there have been large seasonal fluctuations in these cities' air quality. Taking Nantong as an example, according to the statistics of Jiangsu Provincial Academy of Environmental Science, in terms of the pollution sources of the six major air pollutants, local pollution sources accounted for 51%–73% (average 62%). In terms of the types of the pollution sources, coal burning accounts for the largest proportion, 26%; mobile pollution sources account for 24%; industrial pollution sources account for 23%, dust pollution accounts for 18%; other "scattered pollution" sources account for 9% [47]. Therefore, although Nantong has adopted a series of control measures in order to improve air quality, including the 39 so-called "strictest in history" relocation (or closure) projects targeting heavy pollution companies that were completed by the end of 2017 [48], its air quality during summers is still quite poor due to the impact of mobile pollution sources and dust pollution, resulting in significant fluctuations in air quality. In addition, although Yancheng's air quality ranked top among Jiangsu cities for four consecutive years according to official statistics, taking all the six major air pollutants into consideration, Yancheng's air quality has also experienced large fluctuations during the study period. Taking the factors of geographical location and wind direction into account, the air pollution in these three cities is greatly affected by the wind in offshore waters. Because of stronger winds in southern Jiangsu compared with the northern regions, the air quality of Nantong, which is located in the south, is generally better than that of Yancheng and Lianyungang in the north. Due to the clear seasonal pattern in wind direction in coastal areas of Jiangsu Province (east to southeast during spring and summer, and northerly winds in autumn and winter) and stronger winds during winter compared with that of summer [49], the air pollutants would linger for a long time above these three cities in summertime due to weaker east and southeast wind than in winter, resulting in worse air quality during summer than in winter.
- There is a clear difference in the air quality of different cities in Jiangsu Province; except for coastal cities, the air quality of southern cities in Jiangsu is generally better than that of the northern cities. During the study period, the air quality of southern cities (such as Suzhou, Wuxi and Changzhou) is generally better than the northern cities (represented by Xuzhou, Suqian and Huai'an). The reasons for this are, on the one hand, Suzhou, Wuxi, and Changzhou enjoy better economic condition and are less dependent on heavy-pollution energy sources such as coal. On the other hand, these cities have adopted low-carbon and energy-saving policies. Taking Suzhou as an example, it successfully decreased the energy consumption per unit of industrial production to 0.917 tons of standard coal per 10,000 yuan in 2010, and its total energy consumption per unit of GDP has also dropped from 1.043 tons of standard coal per 10,000 yuan of GDP in 2005 to 0.824 in 2010, with an average annual decrease of 4.87% [50], which has laid a good foundation for further implementation of air pollution control policies. In the above comparison, the GDP values are inflation-adjusted. While looking at the northern cities of Jiangsu Province, Xuzhou has long relied on coal resources, and there were once more than 250 coal mines in the city. As of 2017, 70% of the mountains in Xuzhou have suffered severe damage, and there are, in total, 381,900 mu of coal mining subsidence land in the city [51], which has not only caused serious air pollution, but has also caused severe damage to land resources. From 2010 to 2015, in the energy consumption structure of industrial companies of Suqian City, coal has taken a proportion of over 70%. In 2016, industrial smoke and dust emissions mainly from coal burning accounted for 46% of the city's total exhaust gas emissions [52]. Hua'an's average annual standard coal consumption

has increased by nearly 10% since 2008, and coal has taken the largest proportion in its energy structure, almost reaching 65% in 2015 [53].

(3) During the study period, the cities adopted a series of air pollution control policies based on the "Regulations on the Prevention and Control of Air Pollution in Jiangsu Province". These policies have shown different effects in different cities with regard to the changes in air quality evaluation scores. More specifically:

- Despite differences in effectiveness, the air pollution control policies have achieved improvements in the nine cities, i.e., Nantong, Changzhou, Wuxi, Yangzhou, Suzhou, Yancheng, Zhenjiang, Tai'an, and Lianyungang. Among them, Nantong's air quality has seen an improvement of 20.28% when comparing that of the ending period (March 2018) to that of April 2015, when the air pollution control policies were first implemented. Changzhou and Wuxi have improved their air quality by more than 10%, while Yangzhou, Suzhou, and Yancheng have improved theirs by more than 5%. These cities have all initiated their own pollution control policies with local characteristics based on the "Regulations on the Prevention and Control of Air Pollution in Jiangsu Province". For example, Nantong has actively promoted the relocation of heavily polluting companies out of its main urban zones, carried out pilot projects for the ultra-low emission transformation of coal-fired power plants, and upgraded the standards for smoke and dust emissions from cement industries and coal-fired boilers [48]. By the end of 2017, the relocation and transformation of all heavily polluting companies in Nantong's central urban area (Chongchuan District) has been completed [54]. Wuxi City has shut down three coal-fired power plants in its urban area, completed the rectification of more than 1200 small coal-fired boilers in its main urban area and subordinate counties, and implemented ultra-low emission transformation for eight large coal-fired power units in the city [55]. Suzhou and Yancheng have also formulated and implemented their annual work plan for air pollution prevention and control based on the "Regulations on the Prevention and Control of Air Pollution in Jiangsu Province", as well as the characteristics of their own pollutants and industrial structure [56,57], which has achieved remarkable results. Meanwhile, although Yangzhou's air quality has improved by 8.89% at the ending period compared with that of the beginning period, there has been clear decline since May 2017. According to the official environmental quality report issued by Yangzhou Municipal Government, the proportion of days with good air quality in Yangzhou City from January to September 2017 was 59.7%, down 12.2 percentage points year-on-year; meanwhile, the indicators on $PM_{2.5}$, PM_{10}, O_3, and NO_2 have all exceeded the standards by varying degrees [58]. The reason behind is that although Yangzhou has formulated the annual work plan for air pollution prevention and control, the implementation of the work plan has not been detailed enough since the end of 2016, resulting in a decline in air quality in 2017. After realizing this problem, Yangzhou local government revised and approved the "Yangzhou City Heavy Air Pollution Early Warning and Emergency Plan" in October 2017, included 31 high-emissions companies in the municipal-level key emission monitoring list, and incorporated the heavy air pollution warning and emergency response into the environmental performance evaluation of the CPC and local government leaders under a system of responsibility and accountability [59]. In December 2017, the provincial-level inspection team for air pollution prevention and control set up by the Jiangsu Provincial Environmental Protection Department officially started their one-month on-site inspection of Yangzhou [60]. As such, Yangzhou's air quality has shown clear improvements since January 2018.
- The air quality of Nanjing, Huai'an, Xuzhou and Suqian has shown different degrees of decline when comparing their ending score with the beginning score. Among them, Suqian's air quality has declined by 20.07%, and Xuzhou's by almost 20% (16.32%). The reason for this is that, on the one hand, for historical and geographical reasons, these cities rely more on coal burning in terms of energy structure and have more heavy-pollution companies. Taking Nanjing as an example, in the study on pollution sources of key monitoring cities for air pollution prevention

and control completed by China's Ministry of Environmental Protection in 2015, the primary pollution source of Beijing, Hangzhou, Guangzhou, and Shenzhen is motor vehicles, while that of Nanjing and Shijiazhuang is coal burning. The biggest consumers of coal in Nanjing are the four high-energy-consumption industries of electricity, steel, petrochemicals, and cement. From 2015 to 2016, Nanjing's total coal consumption exceeded 35 million tons, its sulfur dioxide emissions per unit of GDP ranked top one among sub-provincial cities, and its average chemical oxygen demand (COD) emissions ranked second [61]. As discussed above, the energy structure of Xuzhou, Suqian, and Huai'an also relies heavily on coal combustion. A major action to control air pollution by Xuzhou is to gradually transform the mining area into ecological parks, such as the ecological restoration project of coal mining subsidence areas around Pan'an Lake in the Jiawang District which was completed in 2017. This was the comprehensive project with the largest individual investment in Jiangsu Province since the establishment of People's Republic of China, covering 17,400 mu [62]. In addition, the fluctuations and decline in these cities' air quality is also partly due to the dust and smog spread from northern China since October 2017. With the cold air in northern China moving southward, the dust and smog in northern China has intensified the air pollution in these four non-coastal cities in northern Jiangsu, especially in 2018 [63–66].

5. Conclusions

This paper has studied the air quality of 13 cities in Jiangsu Province from April 2015 to March 2018 based on an expanded AQI system of six major air pollutants. After expanding the existing air quality evaluation standards of China, this paper has calculated the air quality evaluation scores of various cities in Jiangsu based on the six major air pollutants by using the improved Fuzzy Comprehensive Evaluation Model. This paper has further analyzed the effectiveness of air pollution control policies in Jiangsu Province and its different cities during the study period. The conclusions are: there are distinct differences in air quality of different cities in Jiangsu Province; except for the coastal cities such as Nantong, Yancheng and Lianyungang, the southern cities of Jiangsu generally have better air quality than the northern cities. Apart from natural factors such as geographical location, economic conditions and energy structures are also important causes of this situation. In addition, air pollution control policies have achieved significant results in the cities of Nantong, Changzhou, Wuxi, Yangzhou, Suzhou, Yancheng, Zhenjiang, Tai'an, and Lianyungang. Among them, Nantong has achieved the biggest improvement, i.e., 20.28%; Changzhou and Wuxi have improved their air quality by more than 10%, while Yangzhou, Suzhou and Yancheng have improved theirs by more than 5%. However, the air quality of Nanjing, Huai'an, Xuzhou, and Suqian has declined by different degrees when comparing that of the last period with the beginning period: Suqian's air quality has declined by 20.07%, while Xuzhou's has declined by 16.32%.

Based on above findings, this paper provides the following policy recommendations in order to further improve air pollution control of Jiangsu Province.

(1) Fundamentally change the energy structure of Jiangsu cities that are overly-reliant on coal combustion (especially the northern cities) with the latest revision and implementation of the "Regulations on the Prevention and Control of Air Pollution in Jiangsu Province" in April 2018 [44]. Establish long-term treatment measures against air pollution through industry upgrade and technological advancement in order to achieve a long-term and stabilized pollution control performance as well as to minimize the cyclical fluctuations of air quality, and ensure the sustainability in air pollution control.

(2) Take advantage of the trend of regional economic integration of the YRD region and integrate the formulation and implementation of air pollution control policies in Jiangsu Province. Since 2015, there haven't been many integrated measures for air pollution control by Jiangsu Province except the "Regulations on the Prevention and Control of Air Pollution in Jiangsu Province". Therefore, under the overall trend of regional economic integration in the YRD region, it is suggested that Jiangsu Province further improve the information sharing and decision-making

mechanism for air pollution control and treatment among its different cities by using various air pollution control programs such as the "Yangtze River Delta Regional Air Quality Improvement and Treatment Program (2017–2020)" [67], "Key Emphasis in the Cooperation of Yangtze River Delta Regional Air Pollution Prevention and Control (2018)" [68], etc. and by learning from the successful experience of Shanghai, Anhui, and other provinces, in order to fully realize the integration of air pollution control policies in the province.

(3) It is necessary to fully consider the local differences in air pollution of various cities of Jiangsu Province, and make targeted pollution control policies based on coordinated work and different characteristics of each city's air pollution sources and industrial structure. For northern cities such as Xuzhou, Suqian and Huai'an, it is necessary to change the energy structure which is overly-reliant on coal, to strictly restrict the number of new coal mining and coal-fired plants construction projects, and to prohibit various types of loose coal combustion while accelerating the development of clean energy. For cities such as Suzhou, Wuxi, and Changzhou, it is necessary to further improve and optimize the public transportation system, and strictly control the number of motor vehicles in order to curb the growth of mobile pollution sources.

Author Contributions: X.L. organized the whole research and designed the methodology. As the correspondence author, X.G. analyzed the data and results. He also drew the final figures. X.L. and X.G. approved this final version of manuscript together.

Funding: This research received no external funding.

Acknowledgments: X.L. and X.G. acknowledge the Special Issue "Air Quality Assessment Standards and Sustainable Development in Developing Countries" of *Sustainability*.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Guo, D.; Yu, J.; Ban, M. Security-Constrained Unit Commitment Considering Differentiated Regional Air Pollutant Intensity. *Sustainability* **2018**, *10*, 1433. [CrossRef]
2. Han, L.; Zhou, W.; Li, W. Growing Urbanization and the Impact on Fine Particulate Matter (PM2.5) Dynamics. *Sustainability* **2018**, *10*, 1696. [CrossRef]
3. Sun, Z.; An, C.; Sun, H. Regional Differences in Energy and Environmental Performance: An Empirical Study of 283 Cities in China. *Sustainability* **2018**, *10*, 2303. [CrossRef]
4. Yang, W.; Li, L. Energy Efficiency, Ownership Structure, and Sustainable Development: Evidence from China. *Sustainability* **2017**, *9*, 912. [CrossRef]
5. Yang, W.X.; Li, L.G. Analysis of Total Factor Efficiency of Water Resource and Energy in China: A Study Based on DEA-SBM Model. *Sustainability* **2017**, *9*, 1316. [CrossRef]
6. Yang, W.; Li, L. Efficiency Evaluation and Policy Analysis of Industrial Wastewater Control in China. *Energies* **2017**, *10*, 1201. [CrossRef]
7. Yang, W.X.; Li, L.G. Efficiency evaluation of industrial waste gas control in China: A study based on data envelopment analysis (DEA) model. *J. Clean. Prod.* **2018**, *179*, 1–11. [CrossRef]
8. Wu, D.; Ma, X.; Zhang, S. Integrating synergistic effects of air pollution control technologies: More cost-effective approach in the coal-fired sector in China. *J. Clean. Prod.* **2018**, *199*, 1035–1042. [CrossRef]
9. Wang, B.; Liu, Y.; Li, Z.; Li, Z. Association of indoor air pollution from coal combustion with influenza-like illness in housewives. *Environ. Pollut.* **2016**, *216*, 646–652. [CrossRef] [PubMed]
10. Li, L.G.; Yang, W.X. Total Factor Efficiency Study on China's Industrial Coal Input and Wastewater Control with Dual Target Variables. *Sustainability* **2018**, *10*, 2121. [CrossRef]
11. Guo, X.; Guo, X.; Yuan, J. Impact Analysis of Air Pollutant Emission Policies on Thermal Coal Supply Chain Enterprises in China. *Sustainability* **2015**, *7*, 75–95. [CrossRef]
12. Zhao, H.; Ma, W.; Dong, H.; Jiang, P. Analysis of Co-Effects on Air Pollutants and CO_2 Emissions Generated by End-of-Pipe Measures of Pollution Control in China's Coal-Fired Power Plants. *Sustainability* **2017**, *9*, 499. [CrossRef]
13. Bai, R.; Lam, J.C.K.; Li, V.O.K. A review on health cost accounting of air pollution in China. *Environ. Int.* **2018**, *120*, 279–294. [CrossRef] [PubMed]

14. Tian, Y.; Liu, H.; Liang, T.; Xiang, X.; Li, M.; Juan, J.; Song, J.; Cao, Y.; Wang, X.; Chen, L.; et al. Ambient air pollution and daily hospital admissions: A nationwide study in 218 Chinese cities. *Environ. Pollut.* **2018**, *242*, 1042–1049. [CrossRef] [PubMed]
15. Liu, M.; Huang, Y.; Ma, Z.; Jin, Z.; Liu, X.; Wang, H.; Liu, Y.; Wang, J.; Jantunen, M.; Bi, J.; et al. Spatial and temporal trends in the mortality burden of air pollution in China: 2004–2012. *Environ. Int.* **2017**, *98*, 75–81. [CrossRef] [PubMed]
16. Chen, X.; Shao, S.; Tian, Z.; Xie, Z.; Yin, P. Impacts of air pollution and its spatial spillover effect on public health based on China's big data sample. *J. Clean. Prod.* **2017**, *142*, 915–925. [CrossRef]
17. Yang, T.; Liu, W. Does air pollution affect public health and health inequality? Empirical evidence from China. *J. Clean. Prod.* **2018**. [CrossRef]
18. Yang, B.; Qian, Z.; Li, S.; Fan, S.; Chen, G.; Syberg, K.M.; Xian, H.; Wang, S.; Ma, H.; Chen, D.; et al. Long-term exposure to ambient air pollution (including PM1) and metabolic syndrome: The 33 Communities Chinese Health Study (33CCHS). *Environ. Res.* **2018**, *164*, 204–211. [CrossRef] [PubMed]
19. Zhu, Y.; Tao, S.; Sun, J.; Wang, X.; Li, X.; Tsang, D.C.W.; Zhu, L.; Shen, G.; Huang, H.; Cai, C.; et al. Multimedia modeling of the PAH concentration and distribution in the Yangtze River Delta and human health risk assessment. *Sci. Total Environ.* **2019**, *647*, 962–972. [CrossRef] [PubMed]
20. Environmental Protection Department of Jiangsu Province. *Jiangsu Province Environmental Status Bulletin, 2013–2017*; Environmental Protection Department of Jiangsu Province: Nanjing, China, 2018.
21. Environmental Protection Department of Jiangsu Province. *Jiangsu Province Environmental Status Bulletin, 2017*; Environmental Protection Department of Jiangsu Province: Nanjing, China, 2018.
22. Dai, J. *Research on the Effects of Financial and Tax Subsidy Policy on the Atmospheric Haze Governance in Jiangsu Province*; Nanjing University of Science and Technology: Nanjing, China, 2017.
23. Wang, Y.; Wang, Q.; Hang, Y. Driving Factors of SO2 Emissions in 13 Cities, Jiangsu, China. *Energy Procedia* **2016**, *88*, 182–186. [CrossRef]
24. Ge, Y.; Zhang, H.; Dou, W.; Chen, W.; Liu, N.; Wang, Y.; Shi, Y.; Rao, W. Mapping Social Vulnerability to Air Pollution: A Case Study of the Yangtze River Delta Region, China. *Sustainability* **2017**, *9*, 109. [CrossRef]
25. He, L.; Zhong, Z.; Yin, F.; Wang, D. Impact of Energy Consumption on Air Quality in Jiangsu Province of China. *Sustainability* **2018**, *10*, 94. [CrossRef]
26. Zhang, G.; Liu, D.; He, X.; Yu, D.; Pu, M. Acid rain in Jiangsu province, eastern China: Tempo-spatial variations features and analysis. *Atmos. Pollut. Res.* **2017**, *8*, 1031–1043. [CrossRef]
27. Xu, S.; Zhang, L.; Liu, Y.; Zhang, W.; He, Z.; Long, R.; Chen, H. Determination of the factors that influence increments in CO2 emissions in Jiangsu, China using the SDA method. *J. Clean. Prod.* **2017**, *142*, 3061–3074. [CrossRef]
28. Chen, K.; Zhou, L.; Chen, X.; Bi, J.; Kinney, P.L. Acute effect of ozone exposure on daily mortality in seven cities of Jiangsu Province, China: No clear evidence for threshold. *Environ. Res.* **2017**, *155*, 235–241. [CrossRef] [PubMed]
29. Wang, Q.; Wang, Y.; Zhou, P.; Wei, H. Whole process decomposition of energy-related SO_2 in Jiangsu Province, China. *Appl. Energy* **2017**, *194*, 679–687. [CrossRef]
30. Ministry of Environmental Protection of the People's Republic of China. *Ambient Air Quality Standards: GB3095-2012*; China Environmental Science Press: Beijing, China, 2012.
31. Ministry of Environmental Protection of the People's Republic of China. *Technical Regulation on Ambient Air Quality Index (on Trial): HJ 633-2012*; China Environmental Science Press: Beijing, China, 2012.
32. Xinhuanet. Hebei's Air Quality "Burst" and PM2.5 Index in Shijiazhuang Is Over 1000. Available online: http://www.xinhuanet.com/local/2016-12/19/c_129411383.htm (accessed on 21 April 2018).
33. Cannistraro, G.; Cannistraro, M.; Cannistraro, A.; Galvagno, A.; Engineer, F. Analysis of air pollution in the urban center of four cities Sicilian. *Int. J. Heat Technol.* **2016**, *34*, S219–S225. [CrossRef]
34. Cao, Y.; Wang, X.; Yin, C.; Xu, W.; Shi, W.; Qian, G.; Xun, Z. Inland Vessels Emission Inventory and the emission characteristics of the Beijing-Hangzhou Grand Canal in Jiangsu province. *Process Saf. Environ. Prot.* **2018**, *113*, 498–506. [CrossRef]
35. Yang, Y.; Christakos, G.; Yang, X.; He, J. Spatiotemporal characterization and mapping of PM2.5 concentrations in southern Jiangsu Province, China. *Environ. Pollut.* **2018**, *234*, 794–803. [CrossRef] [PubMed]
36. Loh, H.S.; Zhou, Q.; Thai, V.V.; Wong, Y.D.; Yuen, K.F. Fuzzy comprehensive evaluation of port-centric supply chain disruption threats. *Ocean Coast. Manag.* **2017**, *148*, 53–62. [CrossRef]

37. Wang, M.; Niu, D. Research on project post-evaluation of wind power based on improved ANP and fuzzy comprehensive evaluation model of trapezoid subordinate function improved by interval number. *Renew. Energy* **2019**, *132*, 255–265. [CrossRef]
38. Chen, C.; Qi, M.; Kong, X.; Huang, G.; Li, Y. Air pollutant and CO2 emissions mitigation in urban energy systems through a fuzzy possibilistic programming method under uncertainty. *J. Clean. Prod.* **2018**, *192*, 115–137. [CrossRef]
39. Debnath, J.; Majumder, D.; Biswas, A. Air quality assessment using weighted interval type-2 fuzzy inference system. *Ecol. Inform.* **2018**, *46*, 133–146. [CrossRef]
40. D'Urso, P.; Massari, R.; Cappelli, C.; Giovanni, L. De Autoregressive metric-based trimmed fuzzy clustering with an application to PM10 time series. *Chemom. Intell. Lab. Syst.* **2017**, *161*, 15–26. [CrossRef]
41. Wang, J.; Li, H.; Lu, H. Application of a novel early warning system based on fuzzy time series in urban air quality forecasting in China. *Appl. Soft Comput.* **2018**, *71*, 783–799. [CrossRef]
42. Xu, Y.; Du, P.; Wang, J. Research and application of a hybrid model based on dynamic fuzzy synthetic evaluation for establishing air quality forecasting and early warning system: A case study in China. *Environ. Pollut.* **2017**, *223*, 435–448. [CrossRef] [PubMed]
43. The Twelfth People's Congress of Jiangsu Province. *Air Pollution Prevention Ordinance of Jiangsu Province*; The Twelfth People's Congress of Jiangsu Province: Nanjing, China, 2015.
44. The Thirteenth People's Congress of Jiangsu Province. *Decision on Modifying 16 Local Regulations, including the Air Pollution Prevention Ordinance of Jiangsu Province*; The Twelfth People's Congress of Jiangsu Province: Nanjing, China, 2018.
45. China's National Environmental Monitoring Center. The City Air Quality Publishing Platform. Available online: http://106.37.208.233:20035/ (accessed on 17 July 2018).
46. Data Center of China's Ministry of Environmental Protection. Concentration of Main Pollutants in the PRD Region, 2015–2018. Available online: http://datacenter.sepa.gov.cn/ (accessed on 17 July 2018).
47. Jiangsu Provincial Academy of Environmental Science. *Air Pollution Source List and Air Pollutant Source Analysis Project for Nantong*; Jangsu Provincial Academy of Environmental Science: Nanjing, China, 2015.
48. Nantong Municipal Government. Notice on Printing and Distributing the 2017 Work Plan for Air Pollution Prevention and Control in Nantong. Available online: http://www.nantong.gov.cn//ntsrmzf/szfbwj/content/5ca1e69c-7fa1-4f8c-b74c-6df435090b3d.html (accessed on 26 August 2018).
49. Gao, X.; Zheng, Y.; Wang, J.; Cao, B. Temporal and Spatial Distribution Characteristics of Wind Elements in the Offshore Area of Jiangsu Province. *China Water Transp.* **2015**, *15*, 193–195.
50. Suzhou Municipal Government. Notice on Printing and Distributing the Low Carbon Development Plan of Suzhou. Available online: http://www.zfxxgk.suzhou.gov.cn/sxqzf/szsrmzf/201403/t20140314_366113.html (accessed on 26 August 2018).
51. Department of Land and Resources of Jiangsu Province. Reply to Recommendation No. 3062 of the First Session of the 13th National People's Congress of Jiangsu Province. Available online: http://www.jsmlr.gov.cn/gtxxgk/nrglIndex.action?type=2&messageID=2c90825464622937016464aefa0a0158 (accessed on 26 August 2018).
52. Wu, J.; Sun, D. Thoughts on the Prevention and Control of Environmental Air Pollution in Suqian City. *J. Green Sci. Technol.* **2016**, *4*, 61–62.
53. Shang, Z.; Gong, S. Characteristics of Industrial Energy Consumption and Carbon Emissions in Huai'an. *Territ. Nat. Resour. Study* **2016**, *6*, 75–79.
54. Nantong Municipal Government. Notice on Printing and Distributing the 2018 Work Plan for Air Pollution Prevention and Control in Nantong. Available online: http://www.nantong.gov.cn/ntsrmzf/szfbwj/content/074b86c9-f6a6-4fbd-9613-6ace39c4c45e.html (accessed on 26 August 2018).
55. Wuxi Municipal Government. *The Annual Air Pollution Prevention and Control Plan of Wuxi*; Wuxi Municipal Government: Wuxi, China, 2017.
56. Suzhou Municipal Government. Notice on Printing and Distributing the 2016 Annual Work Task Plan for the Prevention and Control of Air Pollution in Suzhou. Available online: http://www.zfxxgk.suzhou.gov.cn/sxqzf/szsrmzf/201702/t20170204_840900.html (accessed on 26 August 2018).
57. Yancheng Municipal Government. The 2016 Environmental Status Bulletin of Yancheng. Available online: http://www.jsychb.gov.cn/2017/ggtz_0605/5821.html (accessed on 26 August 2018).

58. Yangzhou Municipal Government. *The Environmental Quality Report of Yangzhou City in the Third Quarter of 2017*; Yangzhou Municipal Government: Yangzhou, China, 2017.
59. Yangzhou Municipal Government. *Heavy Pollution Warning and Contingency Plan for Air Pollution of Yangzhou City (Revised in September 2017)*; Yangzhou Municipal Government: Yangzhou, China, 2017.
60. Yangzhou Environmental Protection Bureau. The provincial air pollution inspection group entered Yangzhou. Available online: http://hbj.yangzhou.gov.cn/yzhbjceshi/gzdt/2017-12/12/content_8ea24c0f73404e5680453543c7071ed3.shtml (accessed on 21 April 2018).
61. CPC Jiangsu Provincial Committee. The Ministry of Environmental Protection Announced the Source of Air Pollution in the Nine Cities: The Primary Source of Pollution in Nanjing Is Coal. Available online: http://www.zgjssw.gov.cn/shixianchuanzhen/nanjing/201504/t2086578.shtml (accessed on 26 August 2018).
62. Yao, X. Pan'an Lake in Jiawang District of Xuzhou is transformed into a large garden by coal mining subsidence area. *People's Dly, 15 December 2017*. p. 14. Available online: http://js.people.com.cn/n2/2017/1215/c360304-31034826.html (accessed on 21 April 2018).
63. China Jiangsu Website. Results of Air Pollution Prevention Special Action on 2018 New Year's Day in Nanjing. Available online: http://jsnews.jschina.com.cn/jsyw/201801/t20180101_1311491.shtml (accessed on 21 April 2018).
64. Cannistraro, G.; Cannistraro, M.; Cannistraro, A.; Galvagno, A.; Trovato, G.; Engineer, F. Reducing the Demand of Energy Cooling in the CED, 'Centers of Processing Data', with Use of Free-Cooling Systems. *Int. J. Heat Technol.* **2016**, *34*, 498–502. [CrossRef]
65. Piccolo, A.; Siclari, R.; Rando, F.; Cannistraro, M. Comparative performance of thermoacoustic heat exchangers with different pore geometries in oscillatory flow. implementation of experimental techniques. *Appl. Sci.* **2017**, *7*, 784. [CrossRef]
66. Cannistraro, M.; Castelluccio, M.E.; Germanò, D. New sol-gel deposition technique in the Smart-Windows–Computation of possible applications of Smart-Windows in buildings. *J. Build. Eng.* **2018**, *19*, 295–301. [CrossRef]
67. The Air Pollution Prevention and Control Coordination Group of the YRD Region. *Further Plan for Deepening the Air Quality Improvement Work of the YRD Region (2017–2020)*; The Air Pollution Prevention and Control Coordination Group of the YRD Region: Suzhou, China, 2017.
68. The Air Pollution Prevention and Control Coordination Group of the YRD Region. *Priorities in Air Pollution Prevention and Control Coordination Work of the YRD Region (2018)*; The Air Pollution Prevention and Control Coordination Group of the YRD Region: Suzhou, China, 2018.

© 2018 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).