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Local $PM_{2.5}$ and O_3 Ambient Air Quality Targets Setting Study in Lishui, China

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Abstract: 2021 will be the first year of China's 14th Five-year period, and all cities have been working on making new local environmental protection plans. To further improve air quality, reduce smog, and control ozone pollution, many cities intend to set more stringent local air quality targets than the national requirements. However, how to set a reasonable and attainable air quality targets is very important because the targets have impacts not only on the welfare of local residents, but also on the local economy. This work presents a comprehensive approach to set reasonable local air quality targets. This approach has been applied to determine $PM_{2.5}$ and O_3 ambient concentration targets for Lishui city in its 14th Five-year Environmental Protection Plan. In this study, five years monitoring data of $PM_{2.5}$ and O_3 from year 2014 to 2018 in Lishui was collected and analyzed to assess the status quo and trends of its air quality. Then the concentration distribution of $PM_{2.5}$ and O_3 in Lishui surrounding cities and counties in Zhejiang Province were also analyzed and the possible impacts on Lishui city were evaluated. Moreover, $PM_{2.5}$ and O_3 air quality standards in other developed countries were reviewed and compared with Chinese current standards to assist the setting of appropriate ambient air quality targets. Based on the analysis, three-year sliding average concentration of $PM_{2.5}$ and O_3 are included in Lishui's annual air quality targets for the first time, and different air quality targets are set for both the whole city and each specific area of Lishui city.

Keywords: $PM_{2.5}$, O_3, Ambient Air Quality Target, Annual Average Concentration

1. Introduction

With the rapid development of China's economy, Chinese cities have been suffering severe air pollution in the past decades. In 2013, Chinese State Council issued the "Action plan for the prevention and control of air pollution", referred to "Atmospheric Ten Articles"[1]. Since then, Chinese governments at all levels have taken unprecedented strong measures on air pollution control, and air quality in key areas of China has improved remarkably. China's Ministry of Ecology and Environment announced in 2018 that all of the 45 key tasks identified in the State Council's "Atmospheric Ten Articles" have been completed on schedule [2].

Zhejiang province is one of the most economically developed provinces in China. Located in the southwest of Zhejiang province, Lishui city is the largest prefecture city in land area, which includes one municipal district: Liandu, seven counties: Qingtian, Jinyun county, Suichang, Songyang, Yunhe, Qingyuan, Jingning, and one county-level city: Longquan city. Its land covers 17,275 km^2, with a resident population of 2,186,000 in 2017. In 2018, Lishui's urban air quality ranked the first in Zhejiang province and the 5th among 169 cities in China.

To further improve air quality, reduce smog, and control ozone pollution, Lishui city intend to set more stringent local air quality targets than the national requirements in its 14th Five-year Environmental Protection Plan. However, how to set a reasonable and attainable air quality targets is very important because the targets have impacts not only on the welfare of local residents, but also on the local economy. In addition, different air quality levels in different areas of Lishui city should be considered when setting the air quality targets.

2. Analysis and Setting of Local $PM_{2.5}$ Ambient Air Quality Target

2.1. Comparison of $PM_{2.5}$ Standards in Different Countries

China's current air quality standards were set in 2012, implemented in some areas in 2013 and made mandatory nationwide in 2016 [3]. There are two types of national air quality standards. Primary standards (Level 1) set limits for Class I ambient air function area, which includes nature reserve, scenic spots and other areas in need of special protection. Secondary standards (Level II) set limits for Class II ambient air function area, which includes residential areas, commercial traffic mixed areas, cultural areas, industrial areas and rural areas. Same as China, the National Ambient Air Quality Standards (NAAQS) in U.S. also have two types of national air quality standards [4]. However, NAAQS standards are set for different protection objects, but not for different ambient air function areas. There's no ambient function area classification in NAAQS. Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings [5].

A comparison of $PM_{2.5}$ ambient standards between China and other five developed countries and regions in the world is shown in Table 1. It can be observed in Table 1 that the national $PM_{2.5}$ secondary standards, which almost all cities in China shall obey, are much more lenient than those in the listed five developed countries and regions. In addition, different from China's one-year average standard, both the U.S. and E.U. are using 3-year sliding average concentration index [6]. The three-year "sliding average concentration index" of $PM_{2.5}$ refers to the arithmetic average of the average $PM_{2.5}$ concentration in three consecutive natural years. Considering that the change of meteorological conditions has a certain influence on the air quality, this index can weaken the influence of inter-annual fluctuation of meteorological conditions to some extent.

Table 1. *Comparison of $PM_{2.5}$ standards between China and other countries.*

Country	Standards (μg/m^3)	Averaging time	Criteria for compliance
China [3]	15 (Level I) 35 (Level II)	Annual	Annual Average
	35 (Level I) 75 (Level II)	24-hour	95th percentile in a year
United States [4]	12 (Level I)	Annual	3-year average
	15 (Level II)	Annual	3-year average
	35 (Level I & II)	24-hour	98th percentile in 3 years
European Union [6]	25	Annual	No exceedance allowed
	20	Annual	3-year average
Australia [7]	8	Annual	No exceedance allowed
	25	24-hour	No exceedance allowed
	7	Annual	Year 2025 target
	20	24-hour	Year 2025 target
Japan [8]	15	Annual	Annual Average
	35	24-hour	the 98th percentile in 1 years
Singapore [9]	12	Annual	Year 2020 target
	37	24-hour	Year 2020 target

2.2. Status Qu and Interannual Variation of $PM_{2.5}$ Concentration in Lishui City

It is essential to understand the status qu and the change trend of Lishui's $PM_{2.5}$ ambient air quality before setting a new $PM_{2.5}$ ambient air quality targets. As Table 2 shows, $PM_{2.5}$ ambient concentration in all of the nine counties (cities and districts) of Lishui in year 2018 are lower than the corresponding national standards. The average annual concentration in Lishui city is 25μg/m^3, which is 28.6% lower than the Level II national standard (i.e., 35μg/m^3).

Table 2. *$PM_{2.5}$ Ambient air quality in Lishui in 2018.*

City	Annual average concentration (μg/m^3)	Daily concentration (95th percentile)	Exceed limits or not
Liandu	28	61	No
Qingtian	26	55	No
Jinyun	25	52	No
Suichang	25	51	No
Songyang	28	56	No
Yunhe	23	48	No
Qingyuan	26	54	No
Jingning	23	51	No
Longquan	21	44	No
Average	25	52	No

In this study, Spearman rank relational coefficient method was adopted to assess the air quality variation trends in the nine counties (cities and districts). The Spearman rank relational coefficient was calculated by using Equation 1.

$$r_s = 1 - \frac{6}{n(n^2-1)} \sum_{j=1}^{n} (X_j - Y_j)^2 \quad (1)$$

According to China's "Technical regulation for ambient air quality assessment (HJ663-2013)" [10], to evaluate the change trend, at least five years monitoring data from national network points shall be used. In addition, for 5 years evaluation period, only if the absolute Spearman rank coefficient (r_s) is greater than 0.9000 (the critical value), the change trend is statistically significant. The positive value of r_s indicates an upward trend, while the negative value indicates a downward trend. If the absolute value of the rank correlation coefficient is less than or equal to the critical value, it indicates that there's no obvious change.

In this study, five years monitoring data from nine secondary monitoring stations in Lishui were collected and analyzed. The variation and spacial distribution of annual average concentration of $PM_{2.5}$ in nine areas of Lishui city over the past five years (2014-2018) is shown in Table 3 and Figure 1. From Table 3, we can see that $PM_{2.5}$ annual average concentration in five of nine areas of Lishui city and the citywide average value in year 2014 exceeded the national secondary standard, while from year 2016 to 2018, no exceedance of $PM_{2.5}$ annual average concentration was observed in any of the nine areas.

According to the analysis of rank relational coefficients, the citywide r_s during the past five years is -1.000 with a decline rate of 35.9%, which indicates an obvious downward trend of $PM_{2.5}$ annual average concentration in the whole city. In terms of each individual area, the r_s for six of nine counties (cities and districts) during the past five years are negative and their absolute value are greater than the critical value (0.9000). The r_s for Songyang county and Jingning county are equal to -0.9000. Although the r_s for Qingyuan county is only -0.667, lower than the critical value, there's no exceedance from 2014 to 2018, and the average $PM_{2.5}$ concentration in the past five years is the second lowest. The downward trend of $PM_{2.5}$ annual average concentration in each area and the whole city can also be shown clearly in Figure 1.

Table 3. *$PM_{2.5}$ annual average concentration in all counties (cities and districts) of Lishui city from year 2014-2018 (Unit: $\mu g/m^3$).*

Area	Year2014	Year 2015	Year 2016	Year 2017	Year 2018	Variation (%)	Correlation
Liandu	44	38	33	33	28	-36.3	-0.975
Long-quan	32	25	24	23	21	-34.3	-1.000
Suichang	42	35	34	29	25	-40.5	-1.000
Qingtian	40	35	31	30	26	-35.0	-1.000
Yunhe	35	29	27	27	23	-34.2	-0.975
Qingyuan	33	27	24	26	26	-21.2	-0.667
Jinyun	43	39	35	31	25	-41.9	-1.000
Song-yang	46	36	33	34	28	-39.1	-0.900
Jingning	38	31	29	30	23	-39.5	-0.900
Average	39	33	30	29	25	-35.9	-1.000

In terms of regional distribution, the relatively high $PM_{2.5}$ concentration in 2014 was mainly distributed in the northwest, central and northeast of Lishui, including Liandu district, Songyang county, Jinyun county and Suichang county, with the highest concentration of 46μg/m^3 in Songyang county. By 2018, relatively high $PM_{2.5}$ concentrations were mainly distributed in the central part of Lishui, with the highest concentrations of 28μg/m^3 in Liandu district and Jinyun county.

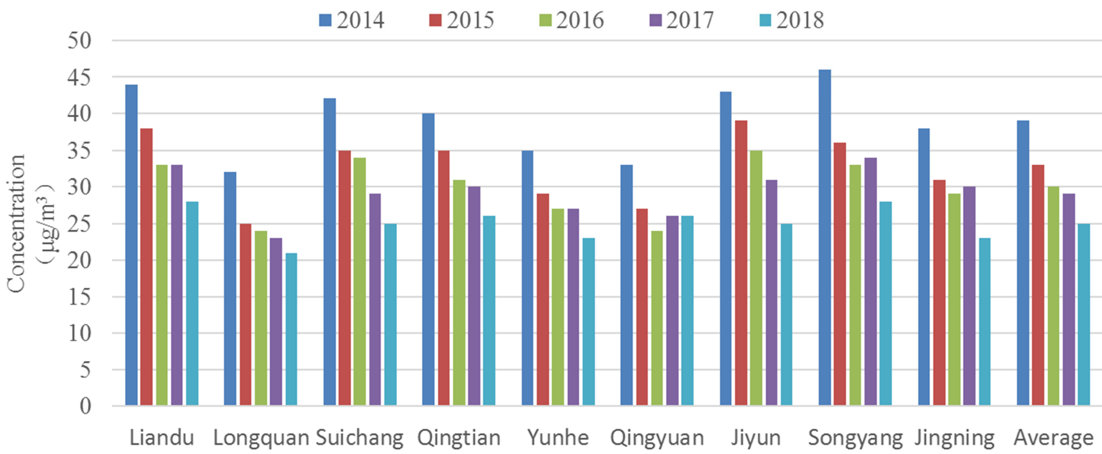

Figure 1. *$PM_{2.5}$ concentration interannual variation in all counties (cities and districts) of Lishui city from year 2014-2018.*

2.3. $PM_{2.5}$ Regional Impacts from Outside Lishui

It is well known that ambient $PM_{2.5}$ concentration are not only influenced by local emission sources, but also by long distance transport. Therefore, regional impacts on Lishui's $PM_{2.5}$ air quality should not be ignored when attempting to set a new target.

In this study, the monitoring data from 69 monitoring stations in Zhejiang province in 2018 were collected and analyzed. The spacial distribution of annual average $PM_{2.5}$ concentration in Zhejiang province in year 2018 is shown in Figure 2. In 2018, the annual average concentration range of $PM_{2.5}$ in 69 cities above the county level were between 21 ~ 42 μg/m^3, with the annual average concentration of 31 μg/m^3. According to Figure 2, the relatively high concentration of $PM_{2.5}$ is in the central and northern areas of Zhejiang and the Jinqu basin, while the relatively low concentration is mainly in the mountainous areas in Southern Zhejiang, East Zhejiang and islands in southeast Zhejiang. Located in southwest in Zhejiang, annual average $PM_{2.5}$ concentration in Lishui city in 2018 is apparently lower than that in most of Lishui's surrounding areas.

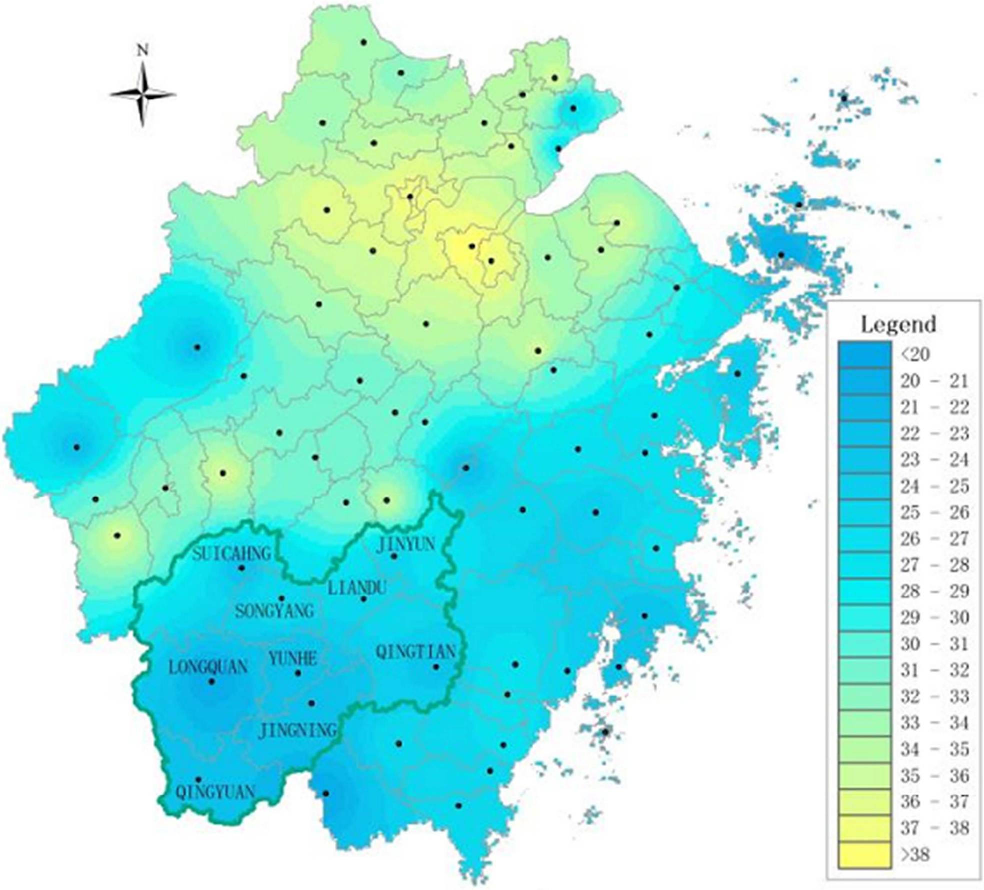

Figure 2. *Annual average $PM_{2.5}$ concentration distribution in Zhejiang province.*

In addition, $PM_{2.5}$ air quality conditions in ten counties and cities around Lishui city in 2018 were also analyzed. In the surrounding counties and cities, only $PM_{2.5}$ annual average concentration in Taishun county and Kaihua county were lower than Lishui's average value, which is 25μg/m^3. The average annual concentration of $PM_{2.5}$ in Wenzhou, Yongjia and Xianju is around 30μg/m^3; that of $PM_{2.5}$ in Jinhua and Quzhou is higher than 30 μg/m^3 but lower than the national secondary standard (35 μg/m^3); and Wuyi, Longyou and Jiangshan's $PM_{2.5}$ concentration even exceeded 35 μg/m^3. The details are shown in Table 4.

Table 4. *$PM_{2.5}$ ambient air quality in cities at the county level or above surrounding Lishui in 2018.*

City	Annual average concentration	Daily concentration (95th percentile)	Exceeds limits or not
Wenzhou	30	60	No
Yongjia	28	54	No
Taishun	21	40	No
Jinhua	34	72	No
Wuyi	36	78	Yes
Quzhou	33	73	No
Kaihua	23	46	No
Longyou	37	74	Yes
Jiangshan	36	74	Yes
Xianju	27	62	No

Obviously higher $PM_{2.5}$ concentrations in most of the surrounding areas of Lishui city will put pressure on the further improvement of Lishui's $PM_{2.5}$ air quality. However, according to the 2018 annual report of Zhejiang province's air quality [11], the annual average $PM_{2.5}$ concentration in the province decreased significantly year by year from 2013 to 2018, and this trend is expected to continue if strict controls on emissions continue. Therefore, it can be expected that the impacts of long-distance transport of $PM_{2.5}$ from the surrounding areas on Lishui city will also decrease in the future.

2.4. Setting $PM_{2.5}$ Ambient Air Quality Target During the 14th "Five-year" Period in Lishui City

According to the analysis above, $PM_{2.5}$ annual average concentration in the whole city in 2018 was 25μg/m^3, which is 28.6% lower than the national secondary standard, and over the past five years, the concentration of $PM_{2.5}$ has steadily declined year by year. In aspect of spatial distribution, almost 45% of the areas in Lishui city (i.e., four of nine counties) had an annual $PM_{2.5}$ concentration higher than 25μg/m^3, with the highest of 28μg/m^3 in Liandu district (the downtown area), and Songyang county. In addition, since $PM_{2.5}$ concentrations in most surrounding areas (i.e., eight of the ten counties) were higher than that in Lishui, the negative impacts caused by long distance transport of $PM_{2.5}$ on Lishui city should also be considered when setting a new $PM_{2.5}$ targets for the whole area. On the other hand, compared with the international air quality standards of developed countries and regions, the current annual $PM_{2.5}$ concentration in the E.U. is 25μg/m^3, which indicates that the use of 25μg/m^3 as the new target of $PM_{2.5}$ in Lishui is advanced. Therefore, setting $PM_{2.5}$ annual average concentration of 25μg/m^3 as the new target in the 14th Five-year period for the whole city is reasonable and attainable.

For specific counties (cities and districts) in Lishui city, 5 out of 9 districts and counties in Lishui in 2018 had the annual $PM_{2.5}$ concentration of less than or equal to 25μg/m^3. In order to further improve their local air quality, stricter air quality standards should be introduced to these areas. From the point of view of air quality standards development and progress history, it took the U.S. 15 years to reduce its three-year sliding average concentration of $PM_{2.5}$ from 15 μg/m^3 to 12 μg/m^3 (20% reduction) [12]. The E.U. requires its member states to reduce the three-year sliding average concentration of $PM_{2.5}$ by 20% (from 25μg/m^3 to 20 μg/m^3) over a 10-year period [13]. Therefore, a target of 23 μg/m^3 (i.e., 8% reduction) for these areas over the next 5 years (from 2021to 2025) is reasonable.

In addition, as mentioned above, the "three-year sliding average concentration index" of $PM_{2.5}$ adopted by the U.S. and E.U. can weaken the influence of inter-annual fluctuation of meteorological conditions to a certain extent. Although three-year sliding average concentration is more lenient than one-year average value, it can better reflect the environmental benefits brought by pollution control, and better meet the demand of current air quality evaluation. In China, according to the "2019 Action Plan for the prevention and control of pollution in Beijing" [14], Beijing has also included the "three-year sliding average concentration" of $PM_{2.5}$ to evaluate air quality in its 2019 annual air quality control target. Therefore, this study suggests that the three-year sliding average concentration of $PM_{2.5}$ should be included and used for setting the $PM_{2.5}$ control targets of specific counties in Lishui's during its 14th Five-year Environmental Plan. The $PM_{2.5}$ target of three-year sliding average concentration for Longquan county, Jingning county, Yunhe county, Suichang county and Qingtian are recommended to be 23 μg/m^3 and below, and the same index for Liandu district, Qingtian county, Qingyuan county and Songyang county are recommended to be 25μg/m^3 and below.

3. Analysis and Setting of Local O_3 Air Quality Target

3.1. Comparison of O_3 Standards in Different Countries

The current ozone air quality standards in China include daily maximum 8-hour mean and 1-hour average. A comparison of O_3 ambient standards between China and other five developed countries and regions in the world is shown in Table 5. The primary standard of daily maximum 8-hour average is 100 μg/m^3, which is the same as Singapore's 2020 standard and more stringent than the current standard in the United States and the European Union. The secondary standard of the daily maximum 8-hour mean value is 160 μg/m^3, which is more lenient than the 8-hour ozone standard of the United States and the European Union. However, the annual evaluation criteria for O_3 compliance are different between China and other countries, such as the U.S. and E.U. In China, 90th percentile of the daily maximum 8-hour sliding mean in each year is adopted, while 3-year average 4th highest daily maximum 8-hour rolling average is used in the U.S. and in E.U., no more than 25 days each year averaged over 3 years are allowed.

Table 5. *Comparison of $PM_{2.5}$ standards between China and other countries.*

Country	Standards (μg/m^3)	Averaging time	Criteria for compliance
China	100 (Level I) 160 (Level II)	daily maximum 8-hour	90th percentile of daily maximum 8-hour sliding average in a year
	160 (Level I) 200 (Level II)	1-hour	/
United States	140	daily maximum 8-hour	3-year average 4th highest daily maximum 8-hour rolling average
European Union	120	daily maximum 8-hour	Exceed no more than 25 days per year averaged over 3 years
	180	1-hour	Information threshold
	240	1-hour	Alert threshold
Australia	130	8-hour	Year 2025 target
	160	4-hour	No more than 1 day per year
	200	1-hour	No more than 1 day per year
Japan	0.06 ppm	1-hour	Maximum 1-hour concentration of photochemical oxidants
Singapore	100	8-hour	Year 2020 target

3.2. Status Qu and Interannual Variation of O_3 Concentration in Lishui City

It is essential to understand the status qu and the change trend of Lishui's O_3 ambient air quality before setting a new O_3 ambient air quality targets. As Table 6 shows, 90th percentile of the daily maximum 8-hour sliding mean of O_3 (hereinafter referred to as O_3 concentration) in all of the nine counties (cities and districts) of Lishui in year 2018 are lower than the seondary national standards. The average annual concentration in Lishui city is 118μg/m^3, which is 26.3% lower than the secondary national standard (i.e., 160μg/m^3).

Table 6. *O_3 Ambient concentration in Lishui in 2018.*

City	Daily maximum 8-hour average concentration (90th percentile)	Exceed limits or not
Liandu	135	No
Qingtian	125	No
Jinyun	112	No
Suichang	118	No
Songyang	119	No
Yunhe	112	No
Qingyuan	114	No
Jingning	102	No
Longquan	121	No
Average	118	No

The variation and spacial distribution of O_3 concentration in nine areas of Lishui city over the past five years (2014-2018) is shown in Table 7 and Figure 3. From Table 3, we can see that from year 2014 to 2018, O_3 concentration in all of the nine areas in Lishui city were lower than the primary national standard, which is 100μg/m^3. However, in 2018, compared with the previous four years, the O_3 concentration of all districts and counties in the city increased significantly, with an average rise rate of 57.3%. Among the nine counties and urban areas, Jingning county experienced the largest increase of 104%, with 52 μg/m^3 higher than that in 2014, while Yunhe county had the lowest increase of 31.8%, 27 μg/m^3 higher than that in 2014.

According to the analysis of rank relational coefficients, both citywide and county specific r_s during the past five years is positive and their absolute values are lower than the critical value (i.e., 0.9000), which indicates there's no obvious upward trend of O_3 ambient air concentration from 2014 to 2018. Only Yunhe county is an exception. Its r_s is 1.000 and higher than the critical value, which means the upward trend of O_3 ambient air concentration in this county is obvious.

Table 7. *90th percentile of the daily maximum 8-hour mean of O_3 in all counties (cities and districts) of Lishui city from year 2014-2018 (Unit: μg/m^3).*

Area	Year2014	Year 2015	Year 2016	Year 2017	Year 2018	Variation (%)	Correlation
Liandu	98	84	81	92	135	37.8	0.300
Long-quan	80	74	75	83	121	51.2	0.700
Suichang	86	62	76	100	118	37.2	0.700
Qingtian	66	61	62	71	125	89.4	0.700
Yunhe	85	86	78	75	112	31.8	1.000
Qingyuan	65	46	42	60	114	75.4	0.300
Jinyun	62	62	60	67	112	80.6	0.667
Song-yang	80	67	68	71	119	48.8	0.400
Jingning	50	39	35	57	102	104	0.600
Average	75	65	64	75	118	57.3	0.462

In terms of regional distribution, the relatively high O_3 concentration in 2014 was mainly distributed in the northwest and central region of Lishui, including Liandu district, Suichang county and Yunhe county, with the highest concentration of 98μg/m^3 in Liandu (Lishui's downtown area). By 2018, relatively high O_3 concentrations were mainly distributed in the north of Lishui, with the highest concentrations of 135μg/m^3 in Liandu district.

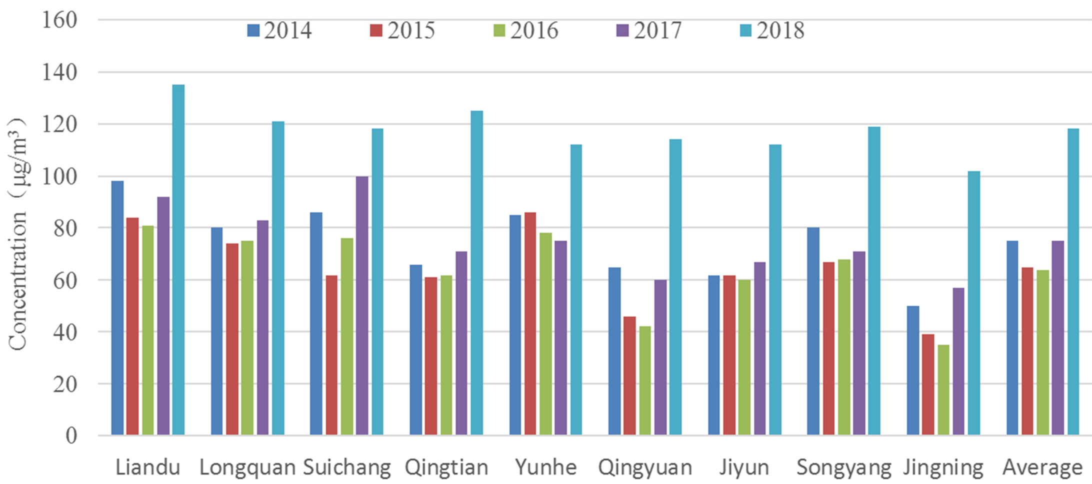

Figure 3. *O_3 concentration interannual variation in all counties (cities and districts) of Lishui city from year 2014-2018.*

3.3. O_3 Regional Impacts from Outside Lishui

Same as $PM_{2.5}$, considering pollutants' long distance transport, O_3 concentration is also influenced by emission sources outside of Lishui. The spacial distribution of O_3 concentration in Zhejiang province in year 2018 is shown in Figure 4. In 2018, the 90th percentile of the maximum 8-hour average ambient air concentration of O_3 in 69 cities above the county level were between 96 ~ 189 μg/m^3, with the average of 142 μg/m^3. Among them, O_3 concentration in 55 cities are lower than or equal to the national secondary standard, accounting for 79.7% of the total. According to Figure 4, the relatively high concentration of O_3 is in the central and northern areas of Zhejiang, while the relatively low concentration is mainly in the mountainous areas in southwestern Zhejiang. Located in southwest of Zhejiang, O_3 concentration in Lishui city in 2018 is apparently lower than that in most of Lishui's surrounding areas.

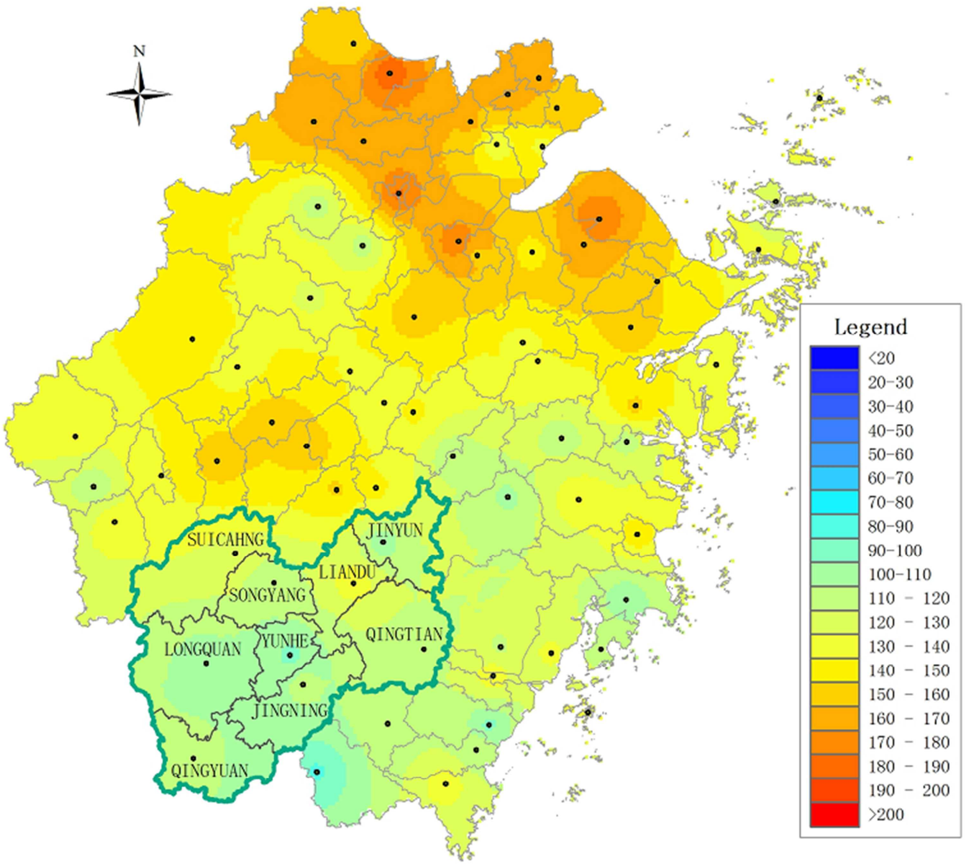

Figure 4. *90th percentile of the daily maximum 8-hour mean of O_3 concentration distribution in Zhejiang province.*

In addition, O_3 air quality conditions in ten counties and cities around Lishui city in 2018 were also analyzed. In the surrounding counties and cities, only O_3 concentration in Taishun county and Kaihua county were lower than Lishui's average value (i.e., 118μg/m^3). And two of the ten cities' O_3 concentrations even exceeded the secondary national standards. The details are shown in Table 8.

Table 8. *O_3 ambient air quality in cities at the county level or above surrounding Lishui in 2018.*

City	Daily maximum 8-hour average concentration (90th percentile)	Exceed limits or not
Wenzhou	141	No
Yongjia	132	No
Taishun	96	No
Jinhua	165	Yes
Wuyi	162	Yes
Quzhou	152	No
Kaihua	115	No
Longyou	128	No
Jiangshan	130	No
Xianju	132	No

According to the 2018 annual report of Zhejiang province's air quality, from 2013 to 2018, while the concentration of other pollutants decreased year by year in all districts and counties of Zhejiang province, the concentration of O_3 was rising. The number of pollution days with O_3 as the primary pollutant was the largest, accounting for 59.1% of the total pollution days. It has surpassed $PM_{2.5}$ as the primary pollutant in heavy pollution weather. The O_3 concentration in the ambient air of various cities fluctuated and rised, and the frequency that O_3 concentration exceeded the standard is higher than that of other pollutants. Obviously higher O_3 ambient concentrations in most of the surrounding areas of Lishui city will put pressure on the further improvement of Lishui's O_3 concentration, and the increase of regional O_3 concentration in the whole province in 2018 is also an important reason for affecting the increase of O_3 concentration in Lishui.

3.4. Setting O_3 Ambient Air Quality Target During the 14^{th} "Five-year" Period in Lishui City

According to the analysis above, O_3 concentration in the whole area of Lishui city did not show an obvious trend of increase during the five-year period, except that O_3 concentration in 2018 in each area increased obviously than that before. The reasons for the increase of O_3 concentration in 2018 are complicated. Different from particulate pollution, O_3 is not directly discharged from the sources, but is a product of secondary transformation. VOCs and NO_x are the main precursors of O_3 [15]. Therefore, to control O_3 concentration, VOCs and NO_x emission control must be coordinated. NO_x mainly comes from fossil fuel combustion and vehicle exhaust emissions, etc. VOCs comes from a wider range of sources, including industrial emissions, vehicle exhausts, domestic pollution sources and natural sources. In recent years, the NO_x emissions in Lishui is decreasing year by year (from 11,358 tons in 2014 to 4,206 tons in 2017), and the concentration of NO_2 in the air is also decreasing. However, it is difficult to reduce VOCs pollution due to its complex sources and large amount of fugitive emissions. Meanwhile there is a complex relationship between the concentration of VOCs and NO_x (i.e., the precursors) and O_3 (i.e., the photochemical product). The ozone concentration increases with the increase of VOCs, while the decrease of NO_x concentration may lead to the increase of O_3 concentration without effective control of VOCs concentration. In addition, due to the continuous decrease of particle concentration in recent years, the light radiation enhances, which is conducive to the generation of O_3 by photochemical reaction. Meanwhile, the formation of O_3 needs a certain period of time. Considering pollutants' long distance transport and dispersion in atmosphere, O_3 concentration in Lishui is also affected by external sources.

Due to the complicated formation mechanism of ozone, and the difficulty of controlling the emission of ozone precursors, the prevention and control of ozone pollution in Lishui city are facing a severe situation. Although the ambient air quality in Lishui is the best in Zhejiang province, it is not appropriate to set a more stringent O_3 target than its current level. In this study, it is recommended to set the 90^{th} percentile of the maximum 8-hour daily O_3 concentration in the whole area during the "14th Five-year" period to be 140 $\mu g/m^3$, which is the same as the current U.S. zone standard.

For specific counties (cities and districts) in Lishui city, 6 out of 9 districts and counties in Lishui in 2018 had the O_3 concentration of less than $120 \mu g/m^3$. In order to further improve their local air quality, this study suggests that the 3-year average daily maximum 8-hour rolling average concentration of O_3 to be included and used for setting O_3 control targets for specific counties in Lishui's during its 14^{th} Five-year Environmental Protection Plan. The O_3 target of three-year sliding average concentration for Jinyun county, Songyang county, Qingyuan county, Jingning county, Suichang county and Yunhe county are recommended to be 120 $\mu g/m^3$ and below, and the same index for Liandu district, Longquan city and Qingtian county are recommended to be $140 \mu g/m^3$ and below.

4. Conclusion

This work presents a comprehensive approach to set reasonable local air quality targets. Firstly, we assessed the status quo and trends of Lishui's air quality by analyzing its five-year monitoring data of $PM_{2.5}$ and O_3 from year 2014 to 2018. Then the possible impacts on Lishui from its surrounding cities and counties in Zhejiang Province were evaluated. Moreover, $PM_{2.5}$ and O_3 air quality standards in other developed countries were reviewed and compared with Chinese current standards to assist the setting of appropriate ambient air quality targets. Based on the analysis, three-year sliding average concentration of $PM_{2.5}$ and O_3 are introduced into Lishui's annual air quality targets for the first time, and different air quality targets are set for specific areas of Lishui city.

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