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TRACING THE RECENT CHANGE OF FINE DUST DENSITY IN SEOUL VIA STATISTICAL REASONING

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ABSTRACT

The global economy shrank sharply in the first half of 2020 mainly due to COVID-19 pandemic and countries' tight control of their people's movement. Our previous study (Chang and Lee 2021) presents that the monthly average concentration of fine dust in Seoul has improved significantly in the first half of 2020 compared to before the coronavirus. However, as the economic activities of countries, including China and Republic of Korea, gradually resumed in the second half of 2020, some changes in air quality around the world, including Republic of Korea, have been observed. Although the Government of Republic of Korea has recently implemented the second seasonal fine dust management system to reduce the intensity and frequency of fine dust by taking stronger emission reduction and management from December 2020, our analysis suggests that the differences of the monthly average concentration of ultrafine dust in Seoul during the period from October 2020 to March 2021 and that from October 2019 to March 2020 are not statistically significant. We also make some brief comments on the implications of our findings.

KEY WORDS: Particulate matter (PM), Air pollution before/after the coronavirus, Statistical significance

INTRODUCTION

The global economy shrank sharply in the first half of 2020 mainly due to COVID-19 pandemic and countries' tight control of their people's movement. Our previous study (Chang and Lee, 2021) presents that the monthly average concentration of fine dust in Seoul has improved significantly in the first half of 2020 compared to before the coronavirus. However, as the economic activities of countries, including China and Republic of Korea, gradually resumed in the second half of 2020, some changes in air quality around the world, including Republic of Korea, have been observed (see Material and Methods - Review of Related Works). Although the Government of Republic of Korea has recently implemented the second seasonal fine dust management system to reduce the intensity and frequency of fine dust by taking stronger emission reduction and management from December 2020, our analysis suggests that the differences of the monthly average concentration of ultrafine dust in Seoul during the period from October 2020 to March 2021 and that from October 2019 to March 2020 are not statistically significant. Our method has the advantage of providing statistically valid and reliable results compared to the simple average rate of change compared with that of the previous year, which is available in a report by the Ministry of Environment in Republic of Korea. We also make some brief comments on the implications of our findings.

The rest of this article is organized as follows: In Material and Methods, we summarize the review of related works, and their implications and limitations. In Results, we compare the differences of the monthly average concentration of ultrafine dust in Seoul during the period from October 2020 to March 2021 and that from October 2019 to March 2020 in Seoul. In Discussion, we discuss the implications of the results, including brief comments on the implications of our findings.

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MATERIAL AND METHODS - REVIEW OF RELATED WORKS

Known statistics in AirKorea and Meteorological Agency in Republic of Korea

According to the Ministry of Environment in the Republic of Korea, the fine dust warning system is designed to reduce the damage caused by fine dust by promptly notifying the public of the occurrence of high concentration and taking action. A special mayor, metropolitan mayor, special autonomous mayor, provincial governor, or special autonomous provincial governor can issue PM2.5/PM10 warning alarm (including alarm) if the environmental standards are violated and fine dust air pollution is deemed to cause serious harm to the health, property or growth of animals and plants.

Environmental standards for fine dust in Republic of Korea

- Fine dust (PM-10): Annual average value less than 50μg/m³, 24-hour average value less than 100μg/m³
- Ultrafine dust (PM-2.5): Annual average value less than 15μg/m³, 24 hour average value less than 35μg/m³

According to AirKorea and the report in the Meteorological Agency in the Republic of Korea, we have the following tables (Tables 1-3):

Remark 1. In Table 3, the number of days of yellow dust is defined as the number of days that the yellow dust was reported, and dust concentration is the PM10 mass concentration observed with a floating dust analyzer (PM10) (Report in Meteorological Agency in the Republic of Korea, 2010-2021).

Implications: As can be seen in Tables 1-3, most of the PM2.5/PM10 warning alarms in Seoul were issued in January, February, March, October, November and December. We also note that most yellow dust days in Seoul are during the spring, autumn, and winter seasons. We thus make statistical comparisons of two data sets: (i) monthly average concentration of fine dust in Seoul during the period from October 2020 to March 2021 and (ii) monthly average concentration of fine dust in Seoul during the period from October 2019 to March 2020.

Review of articles which present some changes in air quality around the world

As the movement restrictions which continued for a long time after Corona 19 were lifted and economic activities resumed in the second half of 2020, some changes in air quality around the world including China and Republic of Korea, have been observed (see supplementary materials for details). Some references are summarized as follows: Earth photo

Table 1. The number of PM2.5 caution alarm (including alarm) in Seoul (from Jan 1, 2018 to March 31, 2021)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2021	0	3	4	NA	NA	NA	NA	NA	NA	NA	NA	NA
2020	0	3	0	0	0	0	0	0	0	0	1	1
2019	6	4	5	0	1	0	0	0	0	0	0	1

Table 2. The number of PM10 caution alarm (including alarm) in Seoul (from Jan 1, 2018 to March 31, 2021)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2021	1	0	3	NA	NA	NA	NA	NA	NA	NA	NA	NA
2020	0	1	0	1	1	0	0	0	0	1	0	0
2019	1	0	1	2	0	0	0	0	0	2	1	1
2018	1	1	0	3	0	0	0	0	0	0	1	0

Table 3. The number of yellow dust days by season in Seoul (Report in Meteorological Agency in the Republic of Korea, 2010-2021)

Year	Spring (Mar-May)	Summer (June-Aug)	Autumn (Sept-Nov)	Winter (Dec-next Feb)
2021	5	NA	NA	NA
2020	2	0	3	2
Last 5 years	3.6	0.0	2.2	0.8
Last 10 years	4.6	0.0	1.3	1.2

of National Aeronautics and Space Administration (NASA) compared the average concentration of nitrogen dioxide (NO_2) in Wuhan from February 10 to 25, 2020, and from April 20 to May 12, 2020. This was revealed through the 'NASA Earth Observatory' website. According to NASA, air pollution in Wuhan and other Chinese metropolitan areas has deteriorated significantly over the past three months (NASA Earth Observatory, 2020). NO_2 is a harmful pollutant mainly emitted in the process of burning fossil fuels such as petroleum and coal in automobiles, power plants, and factories (NASA Earth Observatory, 2020). It reacts with sunlight near the surface and turns into ozone (O_3), which is harmful to health, and is also a causative agent of fine dust and acid rain (NASA Earth Observatory, 2020). According to the European Space Agency (ESA), the air pollution levels in China are bouncing back to their pre-pandemic levels as restrictions loosen (ESA, 2021). According to the report released by Forbes, as some countries emerged from strict Covid-19 lockdowns, air pollution saw a significant surge: New York, Los Angeles, Beijing, Melbourne, Madrid, and Cape Town saw a double-digit increase in PM2.5 levels since lockdown ended, according to an analysis by global workplace specialist Instant Offices (Report in Forbes, 2020). As life slowly returns to normal around the world, the comparison of air quality across 15 major cities suggests that, while some are still benefitting from cleaner air, others have seen pollution upsurge (Report in Forbes, 2020). Major industrial facilities in India resumed operations, after the COVID-19 blockade was lifted (Economic Times, 2020). In this connection, see articles in Economic Times (2020), Environment News in National Geographic (2020), Economictimes.indiatimes.com (2021), and Thehindu, India (2021). According to the report released by Energy Clean Air Center in Helsinki, the concentrations of fine dust, nitrogen dioxide, sulfur dioxide, and greenhouse gases in China hit the bottom in early March 2020 and then restored to their original state in early May, 2020. In the second half of 2020, as China declared a de facto 'corona victory', the plant utilization rate in China mostly recovered to before the Covid-19 crisis, and vehicle operation surged as the interregional blockade was lifted (Arirang Institute, 2020). Due to air pollution in Beijing on the 15 March, 2021, outdoor activities, such as kindergarten and physical education classes in elementary, middle and high schools, stopped (Global Times, 2021). In this connection, see CNN news (CNN, March 15, 2021) and Financial Times (Financial Times, March 20, 2021). China's National Air Pollution Prevention Alliance Center issued a serious air pollution warning to at least 54 northern cities, including Beijing (Beijing Air Pollution: Real-time Air Quality Index (AQI), Global Times 2021).

In recent years, along with the corona spread problem, air pollution has become one of the major social issues in Republic of Korea (Korea Herald, 2021): On March 29, 2021, thick yellow dust originating from China's inner Mongolia swept through most of the Republic of Korea on 29 March, prompting the Ministry of Environment (ME) to issue a nationwide warning (Korea Herald, 2021, Seoul Air Pollution: Real-time Air Quality Index (AQI)). On March 26, 2021, the greater Seoul area was blanketed by extraordinarily heavy concentrations of locally generated ultrafine particles (Korea Herald, 2021, Seoul Air Pollution: Real-time Air Quality Index (AQI)). On March 16, in 2021, almost all of the Republic of Korea was blanketed by a massive yellow dust storm originating from the inland deserts in northern China (Korea Herald, 2021, Seoul Air Pollution: Real-time Air Quality Index (AQI)). See Supplementary report for details on the summary of recent news on the fine dust air pollution around the world including Seoul.

Implications: As mentioned in the introduction, as the economic activities of countries gradually resumed in the second half of 2020, some changes in air quality around the world, including China and Republic of Korea, have been observed. Readers are referred to OECD report (OECD, 2021), World Health Orgnization, and World Air Quality report (2021) for details on the seriousness of air pollution and particulate matter.

Known statistics in the Ministry of Environment in Republic of Korea

The Ministry of Environment (ME) in the Republic of Korea released the analysis results on the ultrafine dust situation and major implementation results in December 2020, the first month of the implementation of the second fine dust seasonal management system (December 1, 2020-March 31, 2021). The Fine Dust Seasonal Management System is a system to alleviate the intensity and frequency of occurrence of high-density fine dust and reduce damage to public health through stronger emission reduction and management measures than usual. It may be remarked that the government of Republic of Korea first introduced and implemented the fine dust seasonal management system from December 2019 to March 2020, and is implementing the secondary fine dust seasonal management system from December 2020. See report (2020-2021) in ME in Republic of Korea for details.

- The monthly average concentration of ultrafine dust in December 2020

According to ME, the monthly average concentration of ultrafine dust (PM2.5) in the first month of the second seasonal management system was shown to have improved overall compared to the past. The monthly average concentration of ultrafine dust nationwide for one month, in December 2020, was 24g/m³. It was about 8% reduction compared to 26g/m³in December 2019. The monthly average concentration in December 2020 improved by about 11% compared to 27g/m³ in December 2019. The number of good days with the national average daily average ultrafine dust concentration of 15g/m³ or less was 10 days. It was an increase of four days compared to December 2019, and the number of bad days with a daily average of 36g/m³ or more was five days: a decrease of two days compared to December 2019.

- The monthly average concentration of ultrafine dust in February 2021.

The ME issued the 'Attention' stage of the PM2.5 crisis alarm in six regions (Seoul, Incheon, Gyeonggi, Chungnam, Chungbuk, and Sejong) from 06:00 on February 14th, 2021. It was announced on February 13 that the emergency reduction measures will be implemented.

- The monthly average concentration of ultrafine dust in March 2021

The ME issued PM2.5/PM10 caution alarms in Seoul at a high frequency due to thick yellow dust originating from China's inner Mongolia, and ultrafine particles. See Tables 1-3 in Material and Methods for details.

Implications: The Ministry of Environment's results in the Republic of Korea are based on average comparison, which is a simple method and easy to understand. But they do not give us detailed information about whether the difference is statistically significant. The method presented in this paper is not the average comparison that is available in the report by the Ministry of Environment in the Republic of Korea, and it has the advantage of providing statistically valid and reliable results. See Results and Discussion for details.

RESULTS

We make statistical comparison of two data sets: (i) the monthly average concentration of PM10 and PM2.5 in Seoul during the period from October 2020 to March 2021, (ii) the monthly average concentration of PM10 and PM2.5 in Seoul during the period from October 2019 to March 2020.

Known Statistics in AirKorea and AirVisual: Tables 4-5

We present the monthly average concentrations of PM10 and PM2.5 in Seoul during the period from October 2020 to March 2021 and that from October 2019 to March 2020 in Tables 4 and 5 (AirKorea, Seoul Metropolitan Air Quality Information):

Table 4. The monthly average concentrations of PM10 in Seoul during the period from October 2020 and March 2021 and that from October 2019 and March 2020 (unit: μg/m³)

	Year 2019	Year 2020
Oct	31	33
Nov	40	42
Dec	41	42
	Year 2020	Year 2021
Jan	42	38
Feb	41	48
Mar	45	67

Table 5. The monthly average concentration of PM2.5 in Seoul during the period from October 2020 and March 2021 and that from October 2019 and March 2020 (unit: μg/m³)

	Year 2019	Year 2020
Oct	15	17
Nov	20	24
Dec	28	27
	Year 2020	Year 2021
Jan	29	21
Feb	28	29
Mar	25	32

Statistical reasoning and analysis

We present statistical comparisons between data during the period from October 2020 to March 2021 and data during the period from October 2019 to March 2020 based on statistical reasoning and comparison. The following hypotheses are set for the monthly average concentration of PM10 in Seoul:

H_0 (Null hypothesis): Monthly average concentration of fine dust (PM10) in Seoul from October 2020 to March 2021 ≥ monthly average concentration of fine dust (PM10) in Seoul from October 2019 to March 2020

H_1 (Alternative hypothesis): Monthly average concentration of fine dust (PM10) in Seoul from October 2020 to March 2021 < monthly average concentration of fine dust (PM10) in Seoul from October 2019 to March 2020

Since two time series are correlated, and each month's data is paired with each other, a pairwise test was used to compare the differences between the two populations (Chang and Lee 2020). Under the assumption that the null hypothesis is true, the monthly average concentrations of PM10 in Seoul are compared between two periods mentioned above.

The following is the result of the pairwise comparison test (significant level of test = 0.01) using Excel (2016):

Remark 2. As you can see from Table 6, we have important observations:

Observation 1.

- Sample variance of monthly average concentration of PM10 from Oct 2019 to Mar 2020 = 22.4
- Sample variance of monthly average concentration of PM10 from Oct 2020 to Mar 2021 = 140.8

That is, there is a large difference in variance between the two data sets. Such large difference is mainly due to the existence of the high level of monthly average concentration of PM10 in March, 2021 (see Table 4).

Observation 2.

It is noted that two time series are correlated (see Pearson's correlation coefficient in Table 6).

Observation 3

As can be seen from Table 6, the monthly average concentration (45) of PM10 during the period from Oct 2020 to Mar 2021 is greater than that (40) of PM10 during the period from Oct 2019 to Mar 2020.

Remark 3. Consequences, conclusion and interpretation

As can be seen from Table 4, Table 6 and three observations mentioned above, we have the following conclusion: Although there is one month (January) when the monthly average concentration of fine dust decreased (see Table 4), the large increase in fine dust concentration in March exerted a greater influence in our statistical reasoning, leading to a reasonable conclusion that the null hypothesis was not rejected. That is, the null hypothesis that the two population groups have the same mean is not rejected because the p-value is 0.11658845, which is greater than 0.01 significance level. There is not enough evidence that the monthly average concentration of fine dust (PM10) in Seoul in Seoul in 2020 was less than that in Seoul in and the reliability of this conclusion is 0.99.

We carry out a similar analysis, and obtain the following table for the monthly average concentration of PM2.5 in Seoul:

As can be seen from table 7, the null hypothesis that the two population groups have the same mean is not rejected because the p-value is 0.353167005, which is greater than the 0.01 significance level. The

Table 6. Pairwise comparison test result (significance level = 0.01)
- Comparison period: Oct 2019 to Mar 2020 vs Oct 2020 to Mar 2021
t-test results
Pairwise comparison test

	Concentration of PM10 Oct 2019 to Mar 2020	Concentration of PM10 Oct 2020 to Mar 2021
Average	40	45
Sample variance	22.4	140.8
No. of observations	6	6
Pearson's correlation coefficient	0.726498675	
Difference between two means	0	
d.f.	5	
t statistics	-1.355815361	
P(T<=t) one-sided	0.11658845	
t statistics	3.364929997	
P(T<=t) two-sided	0.233176901	
t statistics two-sided	4.032142983	

Table 7. Pairwise comparison test result (significance level = 0.01)
- Comparison period: Oct 2019 to Mar 2020 vs Oct 2020 to Mar 2021
t-test results
Pairwise comparison test

	Concentration of PM2.5 Oct 2019 to Mar 2020	Concentration of PM2.5 Oct 2020 to Mar 2021
Average	24.16666667	25
Sample variance	30.96666667	30
No. of observations	6	6
Pearson's correlation coefficient	0.570875482	
Difference between two means	0	
d.f.	5	
t statistics	-0.399043442	
P(T<=t) one-sided	0.353167005	
t statistics	3.364929997	
P(T<=t) two-sided	0.70633401	
t statistics two-sided	4.032142983	

assertion of the alternative hypothesis that the monthly average concentration of PM2.5 in Seoul from Oct 2020 to Mar 2021 is less than that of Seoul from Oct 2019 to Mar 2020 is not statistically significant, and the reliability of this conclusion is 0.99.

DISCUSSION

In this article, we compared the differences of the monthly average concentration of ultrafine dust in Seoul during the period from October 2020 to March 2021 and that from October 2019 to March 2020 via statistical reasoning. According to our analysis (with significance level = 0.01), there is not enough evidence that the differences of the monthly average concentration of ultrafine dust in Seoul during the period from October 2020 to March 2021 and that from October 2019 to March 2020 are statistically significant.

We make supplementary comments on our conclusion based on the data observed from October 2020 and March 2021: As stated in Section 2, high frequencies and intensities of fine dust (especially during March, 2021) naturally affect the key statistics in our statistical reasoning, and lead to the rational conclusion: The differences of the monthly average concentration of ultrafine dust in Seoul during the period from October 2020 to March 2021 and that from October 2019 to March 2020 are not statistically significant. Note that our analysis is based on the fine dust statistics in Seoul from October 2020 and March 2021, and our conclusion is valid only for the period from October 2020 to March 2021. The analytical method presented in this paper is not just the average rate of change compared with that of the previous year that is available from the Ministry of Education in the Republic of Korea, and it has the advantage of providing statistically valid and reliable results.

Based on the results, we have drawn the following suggestions:

- It is desirable to highlight and present the percent decrease of fine dust in each city (e.g., Seoul, Yeongdong, Baekryeong island, etc), rather than that of fine dust in Republic of Korea.

For example, according to the report in ME in Republic of Korea, it was announced with emphasis that the percent decrease of the reduction of fine dust in the whole country (Republic of Korea) on December 2020 was about 8% (26μg/m³ → 24μg/m³) (Report in Ministry of Environment, Republic of Korea, 2020). But the percent decrease of the reduction of fine dust in Seoul on December 2020 was about 3.6% (28μg/m³ → 27μg/m³). If we are in the situation where the variability of the percent decrease of fine dust in each city is very high, the presentation of the reduction of fine dust for the whole country may not be informative.

- It is desirable that we use the average percent decrease with other metrics (such as the method and results in our articles).

As a method of comparing two data sets, the average rate of change compared with that of the previous year is used widely because of its simplicity. But the average rate of change compared with that of the previous year does not tell the whole story. For example, if there is a large difference in variance between the two data sets and/or correlation exists between them, its usage is limited. In such a situation, it is preferable to use it with other metrics (such as the method and results in our article) to get more information on the data sets (see Results for details).

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REFERENCES

AirKorea, https://www.airkorea.or.kr/eng

AirVisual, https://www.airvisual.com

Arirang Institute, September, 2020, China declares vitory over Coronavirus, Available online: http://www.ariranginstitute.org/new-blog/2020/9/8/china-declares-victory-over-coronavirus

Atmospheric environment report (2010-2021), Ministry of Environment, Republic of Korea. Available online: http://www.me.go.kr/home/web/index.do?menuId=12

Air Quality Information in Seoul Metropolitan City, Air policy Quality Division, Seoul, Available online: https://cleanair.seoul.go.kr/statistics/dayAverage (in Korean)

Beijing Air Pollution: Real-time Air Quality Index (AQI), https://aqicn.org/city/beijing/kr/

Centre for Research and Energy and Clean Air Report, 2021 Available online: https://energyandcleanair.org/publications/

Chang S.H. and Lee S., 2020, Air pollution assessment via statistical reasoning and its implications: a case study of Baekryeong island in Republic of Korea, *Pollution Research* 39(1): 1-11.

Chang S.H. and Lee S., 2021, Note on the comparison of air pollution in Seoul before coronavirus (BC; Before COVID-19) and after coronavirus (AC; After COVID-19) via statistical reasoning, *Indian Journal of Econmics & Business*, Vol. 20(1): 1-11.

CNN news, March 15, 2021, Beijing chokes on yellow dust during biggest sandstorm in almost a decade, Available online: https://edition.cnn.com/2021/03/15/asia/beijing-sandstorm-decade-intl-hnk/index.html

Economic Times, April 16, 2020, India to restart industry engine from April 20, Available online: https://economictimes.indiatimes.com/news/politics-and-nation/india-to-restart-industry-engine-from-april-20/articleshow/75169485.cms?from=mdr

Economictimes.indiatimes.com, Delhi's air quailty enters 'very poor category', Available online: https://m.economictimes.com/news/politics-and-nation/delhi-engulfed-in-smog-air-quality-enters-very-poor-category/articleshow/79163595.cms

European Space Agency (ESA), March 15, 2021, Air pollution returnning to pre-COVID levles: Available online: https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Air_pollution_returning_to_pre-COVID_levels

Financial Times, March 20, 2021, China suffers relapse to era of poor air quality, Available online: https://www.ft.com/content/80953219-7ca5-417e-82e8-13256fd3d2b3

Forbes, September 23, 2020, Some cities see air pollution surge after Covid lockdowns, Available online: https://www.forbes.com/sites/davekeating/2020/09/23/some-cities-see-air-pollution-surge-after-covid-lockdowns/?sh=659974036ce3

Global Times, March 28, 2021, Air quality worsens as sandstorm hits Beijing, northern provinces, Available online: https://www.globaltimes.cn/page/202103/1219628.shtml

Global Times, March 24, 2021, Sand, dust main causes of Beijing's 20 polluted days since February:experts, Available online: https://www.globaltimes.cn/page/202103/1219345.shtml

Global Times, March 17, 2021, Changing wind sweeps dust back into Beijing; may take 3 days for sand to fully subside, Available online: https://www.globaltimes.cn/page/202103/1218702.shtml

Global Times, March 15, 2021, Blue sky returns after Beijing hit by largest sandstorm in a decade, Available online: https://www.globaltimes.cn/page/202103/1218423.shtml

Korea Herald, Mar 29, 2021, S. Korea suffocated by worst yellow dust storm in a decade, , March 29, Available online: http://www.koreaherald.com/view.php?ud=20210329001156

Korea Herald, Mar 29, 2021, Yellow dust crisis looms, Available online: http://www.koreaherald.com/view.php?ud=20210329000719

Korea Herald, Mar 16, 2021, Almost all of S. Korea shrounded with yellow dust blowing in from China, Available online: http://www.koreaherald.com/view.php?ud=20210316000213

Korea Herald, Mar 13, 2021, Photo News, Seoul covered in hazy fine dust, Available online http://www.koreaherald.com/view.php?ud=20210311000891

Korea Herald, Mar 26, 2021, Ultrafine dust density soars to 'very bad' level in greater Seoul, Korea Herald, Available online : http://www01.koreaherald.com/view.php?ud=20210326000664

Ministry of Environment Report, Republic of Korea, Available online: http://eng.me.go.kr/eng/web/main.do

NASA Earth Observatory, Febraury 10-May 12, 2020, Nitrogen dioxide levels rebound in China, Earth

Observatory, National Aeronautics and Space Administration (NASA), Available online: https://earthobservatory.nasa.gov/images/146741/nitrogen-dioxide-levels-rebound-in-china

Nilanjana Bhowmick, November 14, 2020, In New Delhi, burning season make air even more dangerouns. Can anything be done?, Environment News in National Geographic, Available online:
https://www.nationalgeographic.com/environment/article/new-delhi-burning-season-makes-air-even-more-dangerous-can-anything-be-done

Organisation for Economic Cooperation and Develpment (OECD) Report, 2021, Air pollution effects, Available online: https://www.oecd-ilibrary.org/environment/air-pollution-effects/indicator/english_573e3faf-en

Seoul Air Pollution: Real-time Air Quality Index (AQI), https://aqicn.org/city/seoul

Supplementary material of this paper - some references which present news on fine dust air pollution around the world (Jan 2020-Mar 2021). Available online: https://drive.google.com/drive/folders/1WKE5SExHNuWiTEvP4Sgd8vGAGKLSLAtY?usp=sharing

Thehindu, India, Oct 22, 2020, Air pollution now biggest health risk in India, say report
https://www.thehindu.com/news/cities/Delhi/air-pollution-now-biggest-health-risk-in-india-says-report/article32912916.ece

World Air Quality Report- IQAir, Region & City PM2.5 rankings, 2020

World Health Orgnization, Air pollution, Available online: https://www.who.int/health-topics/air-pollution#tab=tab_1