2020

World Air Quality Report

Region & City PM2.5 Ranking

IQAir

Contents

About this report

The 2020 World Air Quality Report analyzes PM2.5 data reported by ground-level monitoring stations around the world, as aggregated through IQAir's air quality information platform.

By comparing PM2.5 levels across the globe, IQAir strives to highlight a wide variety of air quality challenges as well as underscore the threat of human-caused air pollution.[1] Raising air pollution awareness empowers people to take action to improve air quality and reduce their personal exposure.

Only PM2.5 monitoring stations with high data availability have been included. Thus, the 2020 World Air Quality Report is based on a subset of the information provided on IQAir's online air quality information platform and covers 106 countries.

An interactive presentation of the report's dataset is available online, allowing further exploration of air quality across global regions and subregions.

1 An explanation of PM2.5 and its importance is provided on page 5.

Executive summary

Air pollution continues to present one of the world's biggest health hazards to people everywhere, contributing to about 7 million premature deaths annually.[2, 3] 600,000 of these deaths are children.[4] Compounding this staggering health crisis, air pollution is estimated to cost the global economy upwards of $2.9 trillion per year (3.3% of global GDP) due to fossil fuel emissions alone, while also contributing to a range of severe environmental problems.[5]

Air pollution contributes to about 7 million early deaths annually, while burdening the global economy upwards of $2.9 trillion per year.

As we learn more about air pollution, we see how it affects our lives. From mental health, Alzheimer's, and loss of vision to vulnerability to diseases such as COVID-19, 2020 brought another year of new insights into the extent to which air pollution can impact people's health and wellbeing.[6, 7, 8]

This report is based on the world's largest database of ground-based air pollution measurements, aggregating PM2.5 data published in real time from ground-based sensors throughout 2020. This data largely comes from governmental air monitoring stations as well as a growing network of non-governmental air quality monitors.

The data shows several trends:

- As in previous years, South and East Asian locations emerge as the most polluted globally. Bangladesh, China, India, and Pakistan share 49 of the 50 of the most polluted cities worldwide.
- The COVID-19 pandemic emerged as a major, exceptional factor influencing air quality during 2020. Termed by some the 'largest-scale experiment ever' into air quality, the temporary reduction in fossil fuel consumption caused by lockdowns around the world correlated with significant decreases in air pollution compared to previous years. 2020 saw a remarkable 65% of global cities experience air quality improvements from 2019, while 84% of countries saw improvements overall. Due to the circumstances of these improvements, pollutant concentrations are likely to rebound.
- Unfortunately, 2020 also witnessed several extreme air pollution events in the form of wildfires and dust storms linked to increasing global temperatures as part of climate change as well as agricultural practices. Record-breaking wildfires ravaged the United States, Australia, Siberia, and South America, while Indonesia and parts of Africa also experienced devastating agricultural fires. These events resulted in major air pollution spikes in these areas while also emitting copious greenhouse gases. While continuous contributions to air pollution globally stem from the burning of fossil fuels and industrialization, the mutual benefits of combating those who contribute to both climate change and air pollution are increasingly evident.

Air quality data is essential to quantify and understand air quality trends like these in our fast-changing world. The increase in short-term, fast-evolving air pollution emergencies, such as those caused by wildfires, has only increased the importance of access to real-time air quality data, to which only part of the world has access.

The 2020 World Air Quality Report includes data for 106 countries, up from 98 countries in 2019 and 69 countries in 2018.

Air quality awareness remains low in areas where real time monitoring is sparse but pollution levels may be high.

Despite significant gains in global air quality monitoring infrastructure, numerous cities and countries still lack the data necessary to guide important health decisions. Laser-based PM2.5 sensors, available at a fraction of the cost of governmental monitors, provide an opportunity to improve data granularity and allow non-governmental organizations and individuals to become air quality data contributors.

Where does the data come from?

This report only includes PM2.5 data that has been reported by ground-based monitoring stations in real time or close to real time. Data is sourced from both governmental monitoring stations as well as privately owned stations operated by individuals and organizations. Additionally, historical datasets provided by governments have been selectively added to fill gaps or add locations where available.

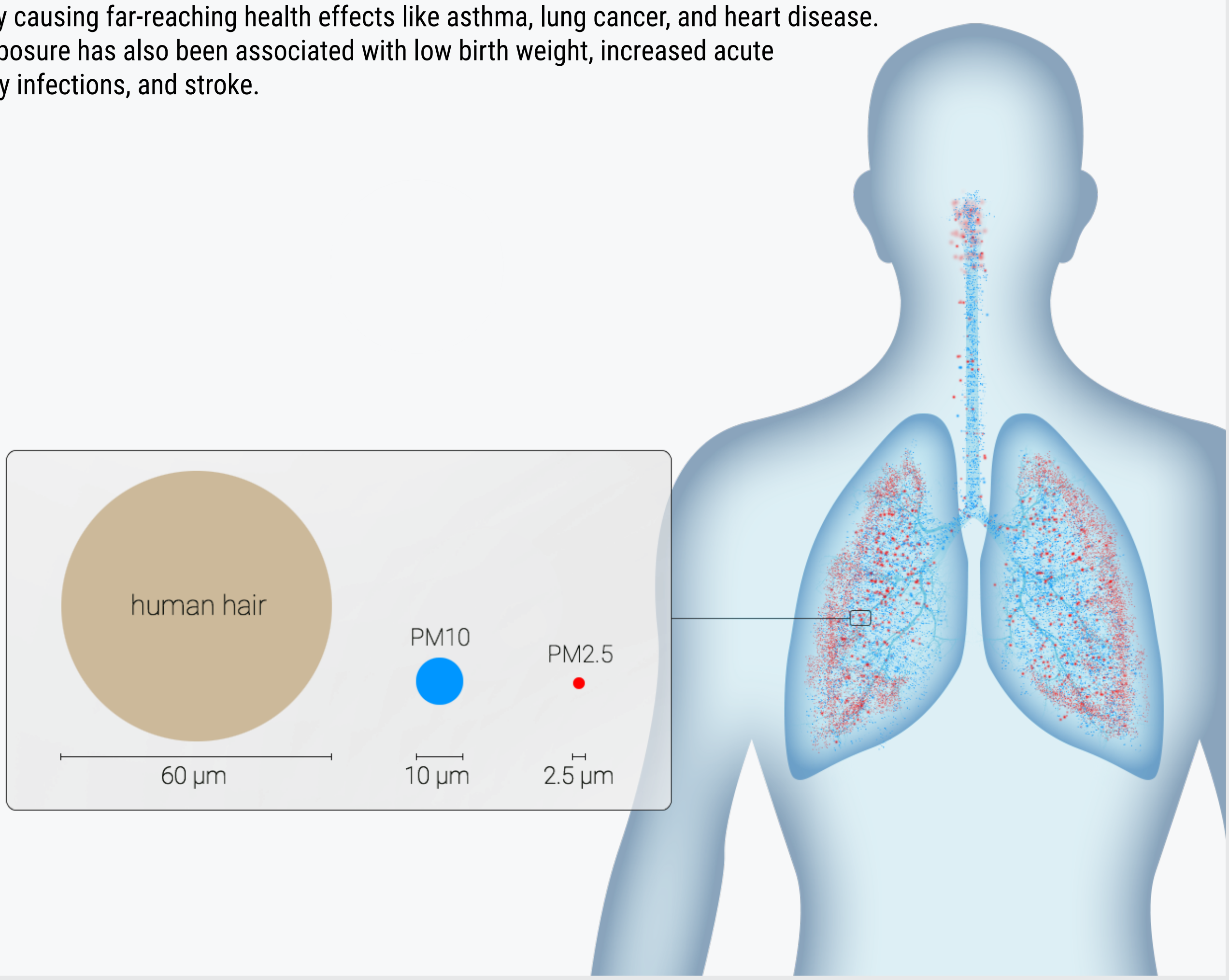
All PM2.5 data has been aggregated at a station level and then organized into settlements (hereafter referred to as cities). Depending on local population patterns and administrative structures, these can be cities, towns, villages, counties, or municipalities. The size and population density of cities thus varies.

Why PM2.5?

Among criteria pollutants commonly measured in real time, fine particulate matter (PM2.5) is currently understood to be the most harmful to human health due to its prevalence and far-reaching health risks. Exposure to PM2.5 has been linked to negative health effects like cardiovascular disease, respiratory illness, and premature mortality.

PM2.5 is defined as ambient airborne particulates that measure up to 2.5 microns in size. These particles include a range of chemical makeups and come from a range of sources. The most common human-made sources include fossil-fuel powered motor vehicles, power generation, industrial activity, agriculture and biomass burning.

The microscopic size of PM2.5 allows these particles to be absorbed deep into the bloodstream upon inhalation, potentially causing far-reaching health effects like asthma, lung cancer, and heart disease.
PM2.5 exposure has also been associated with low birth weight, increased acute respiratory infections, and stroke.



Data presentation

This report refers to two guidelines in order to correlate PM2.5 concentration values to a more relatable reference for health risk: the World Health Organization (WHO) Air Quality Guideline for annual PM2.5 exposure and the United States Air Quality Index (US AQI).[9, 10] The color key uses the US AQI standard, supplemented by the WHO guideline (in blue) for values under 10 µg/m^3.

WHO Air Quality Guideline

The WHO states that, while no level of PM2.5 exposure is free from adverse health effects, annual average exposure below 10 µg/m^3 minimizes risks.

WHO PM2.5 Target: 10 µg/m^3

United States Air Quality Index (US AQI)

This report uses the US Air Quality Index (AQI) to visualize PM2.5 levels that exceed the WHO target. The index translates daily pollutant concentrations into 6 categories ranging from “good” (green) to “hazardous” (maroon). This system has been adopted because it is widely used. However, adverse health effects can occur at any level of PM2.5 exposure, including those labeled as “good” by the US AQI. Moreover, while the US AQI is designed to communicate the hazards from short-term (24h) PM2.5 exposure, persistent long-term PM2.5 exposure at the same level is more dangerous.[11] Thus, the AQI category names for daily exposure do not capture the full severity of the annual mean pollution exposure.

US AQI Level			PM2.5 (µg/m^3)	Health Recommendation (for 24hr exposure)
	Good	0-50	0-12.0	Air quality is satisfactory and poses little or no risk.
	Moderate	51-100	12.1-35.4	Sensitive individuals should avoid outdoor activity as they may experience respiratory symptoms.
	Unhealthy for Sensitive Groups	101-150	35.5-55.4	General public and sensitive individuals in particular are at risk to experience irritation and respiratory problems.
	Unhealthy	151-200	55.5-150.4	Increased likelihood of adverse effects and aggravation to the heart and lungs among general public.
	Very Unhealthy	201-300	150.5-250.4	General public will be noticeably affected. Sensitive groups should restrict outdoor activities.
	Hazardous	301+	250.5+	General public is at high risk to experience strong irritations and adverse health effects. Everyone should avoid outdoor activities.

COVID-19, air pollution and health

In March 2020, COVID-19 was deemed a pandemic, resulting in widespread restrictions on economic activity and drastic changes in human behavior.[12] As billions sheltered in place for weeks at a time, transitioned to remote-work where possible, and limited movement to essential trips, dramatic air quality improvements were observed around the world in what has been described as an unprecedented air quality experiment.[13]

Between 7 and 33% of deaths from COVID-19 are attributable to long-term air pollution exposure.

While lockdown measures and changes in human behavior and the economy led to healthier air in 2020 (with improvements observed in 67% of global cities), these environmental health improvements were coupled with the spread of the deadly SARS-CoV-2 virus. A growing body of research suggests that people exposed to air pollution, particularly long-term air pollution, are more vulnerable to serious health impacts of COVID-19, which attacks people's respiratory and cardiovascular systems.

Globally, an early study estimated the proportion of deaths from COVID-19 attributable to long-term air pollution exposure from anthropogenic emissions to be between 7 and 33% of deaths.[14] These deaths may have been prevented by reducing human-made air pollution.

Links between PM2.5 and COVID-19

Several factors link PM2.5 pollution to increased COVID-19 vulnerability, including:

- **increased incidence of comorbidities:** chronic air pollution exposure increases the risk of respiratory and cardiovascular complications associated with more severe COVID-19 outcomes.
- **weakened lungs and autoimmune responses:** particle pollution triggers cellular inflammation and promotes the production of free radicals that induce cellular damage.[15]
- **increased virus susceptibility:** evidence suggests that particle pollution can stimulate a receptor (ACE-2) on cell surfaces and promotes uptake of the virus.[16]
- **increased virus transmission:** COVID-19 cases have been linked to greater levels of air pollution, a trend that may be attributed to air pollution extending the longevity of the viral particle load in the air.[17]

Impact of the COVID-19 pandemic on air quality

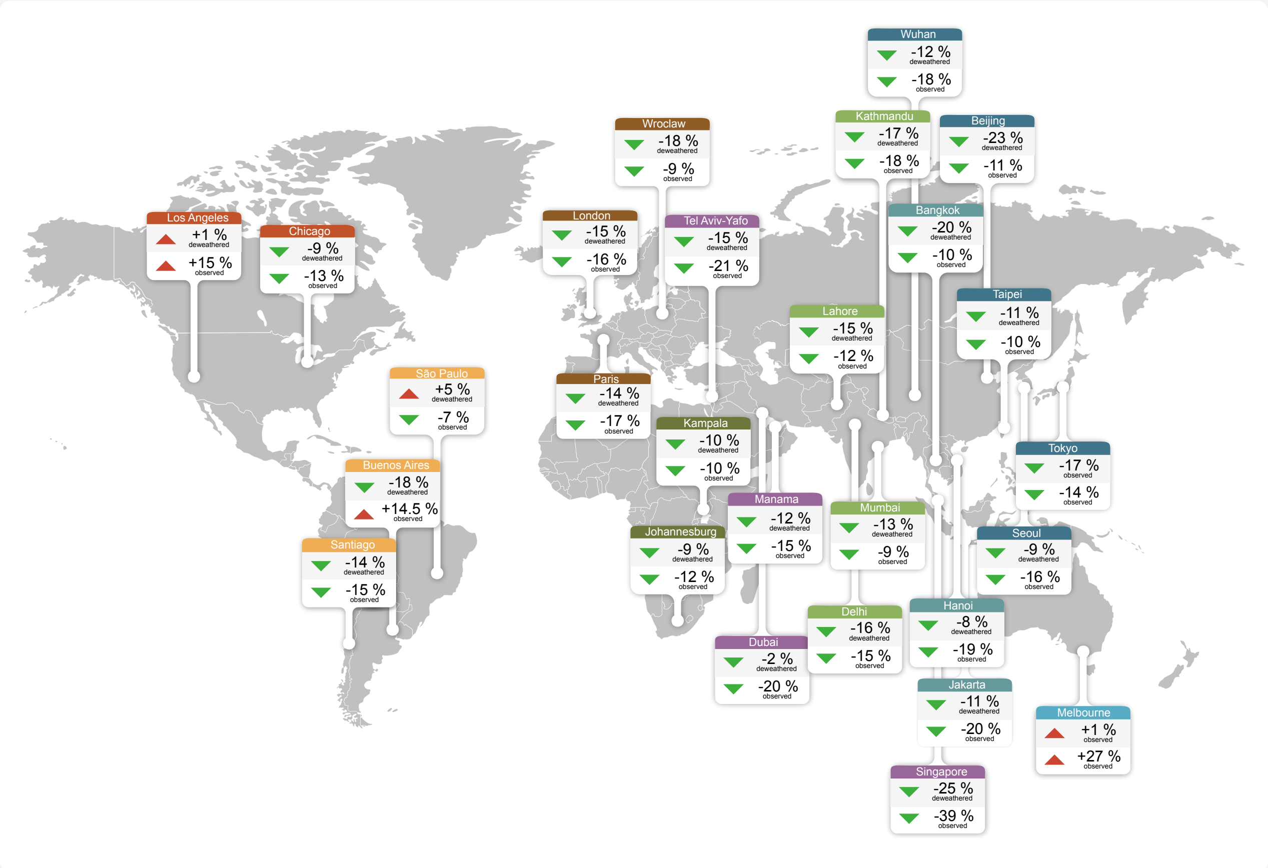
The connection between COVID-19 and air pollution has shone new light on the latter, especially as many locations have observed visibly cleaner air – revealing that air quality improvements are possible with urgent, collective action.[18]

However, human-related emissions from industry and transport that may have been slowed by COVID-related lockdowns are not the only factor influencing air pollution. Emissions aside, weather is the other main influence, affecting how air pollution gathers, disperses, and undergoes chemical reactions, impacting what we breathe.

To more clearly understand how human behavior changes and human-made emissions influenced air pollution during the COVID-19 pandemic in 2020, it is important to isolate other influencing factors, such as weather. To do this, The Centre for Research on Energy and Clean Air (CREA) has conducted a data analysis of our 2020 dataset by applying a "weather correction".[19] This method essentially links weather and air quality data at a given location and aims to correct for the effects of weather on air pollution, better isolating the impact of emissions on overall air quality. Data that has been corrected to eliminate the influence of weather is hereafter referred to as "de-weathered" data.

Observed and de-weathered changes in annual PM2.5

Many major cities across the world experienced reductions in annual PM2.5 levels in 2020 compared to 2019. The map shows de-weathered changes on top with observed changes below.



Map of observed and de-weathered PM2.5 reductions in select major cities

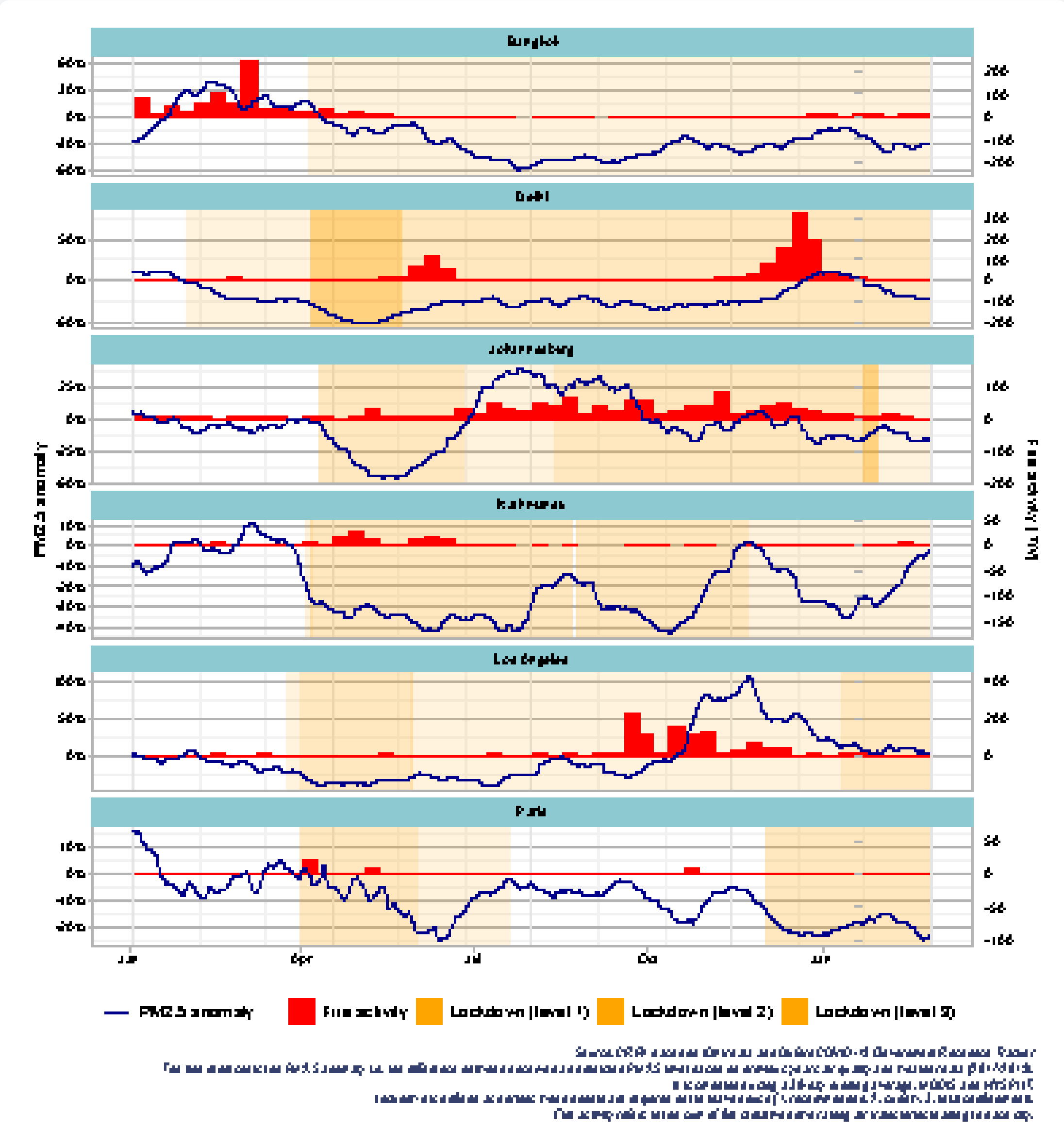
From the sample, Singapore (-25%), Beijing (-23%), and Bangkok (-20%) observed the greatest reductions in PM2.5 based on weather-corrected data from 2020 and the prior year. São Paulo (+5%), Los Angeles (+1%), and Melbourne (+1%) observed the greatest increases – all three were impacted by severe wildfire seasons, which greatly affected annual PM2.5 averages.

PM2.5 anomaly trends

To visualize PM2.5 trends over 2020, the difference between observed and weather-corrected PM2.5 levels has been graphed for 6 cities: Bangkok, Delhi, Johannesburg, Kathmandu, Los Angeles, and Paris.

The timing of lockdown measures in each city is indicated with different intensities of orange highlight (1: recommended; 2: curfew; 3: total confinement) to visualize the concurrence with lower air pollution levels.

Red bars on the graph represent the amount of smoke (e.g. wildfires, biomass burning) that may have impacted the city air quality in any given week. This fire activity index represents the sum of fire radiative power along air trajectories flowing into these cities, and is calculated using air trajectory simulations and satellite-based fire detection. The concurrence of fires with PM2.5 increases is very clear in cities like Bangkok, Delhi, Johannesburg, and Los Angeles.

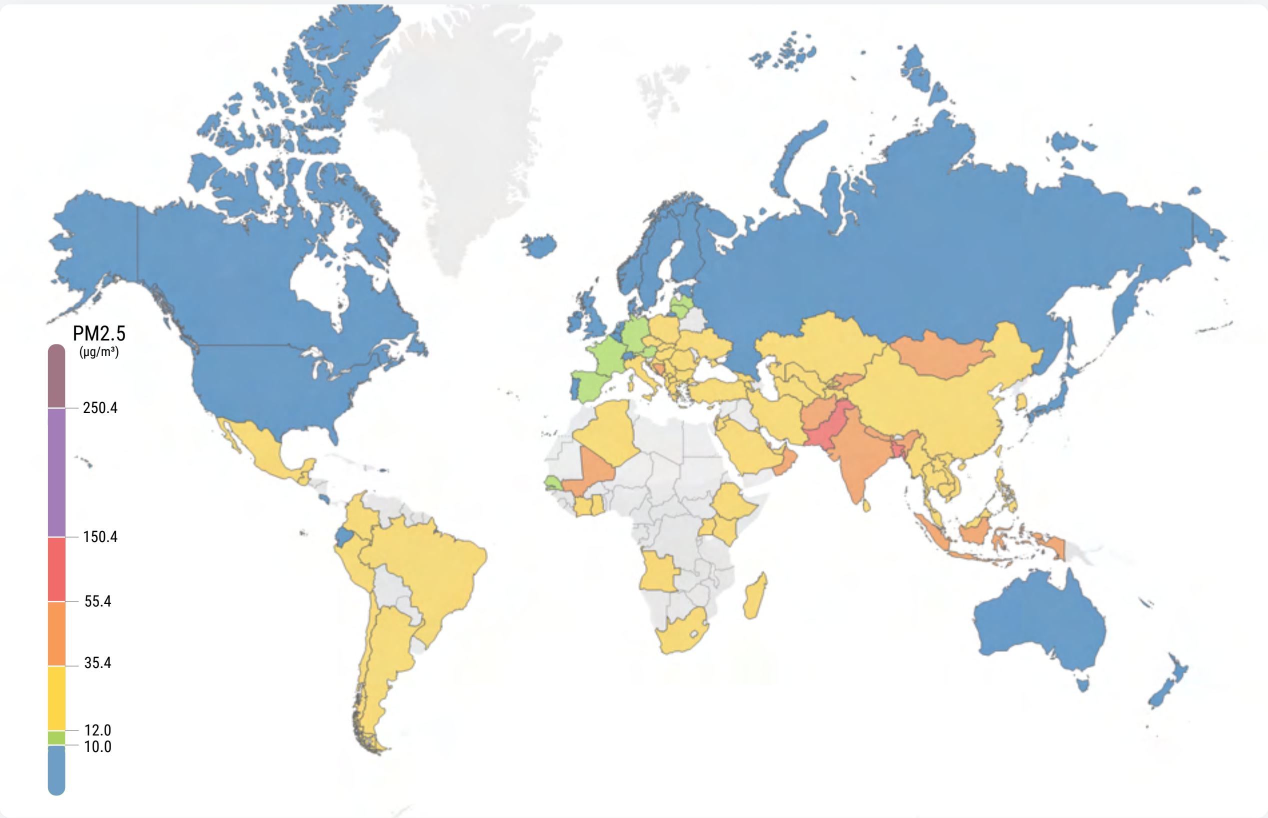


Negative trends (or anomalies) indicate that PM2.5 levels were lower than what would have been expected in these weather conditions, suggesting a decrease in PM2.5 emissions. Often, the most dramatic negative anomalies coincide with the city's first COVID-19 lockdown. Anomalies in Bangkok, Delhi, Johannesburg, Kathmandu, and Los Angeles nearly all reached -50% on a 30-day running average, meaning PM2.5 levels were almost halved for extended periods of time.

The correlation between more relaxed or lifted lockdown measures and neutralized PM2.5 anomalies indicates that PM2.5 air quality improvements are not currently sustainable in a post-COVID-19 world without significant changes to our energy mix or behaviors.

Global overview

Global Country/Region PM2.5 Exposure



Global map of estimated PM2.5 exposure by country/region in 2020

Countries and regions in East Asia, Southeast Asia and South Asia suffer from the highest annual average PM2.5 concentration weighted by population. Notably, the Africa region has least data representation, with a majority of countries greyed out as a result.

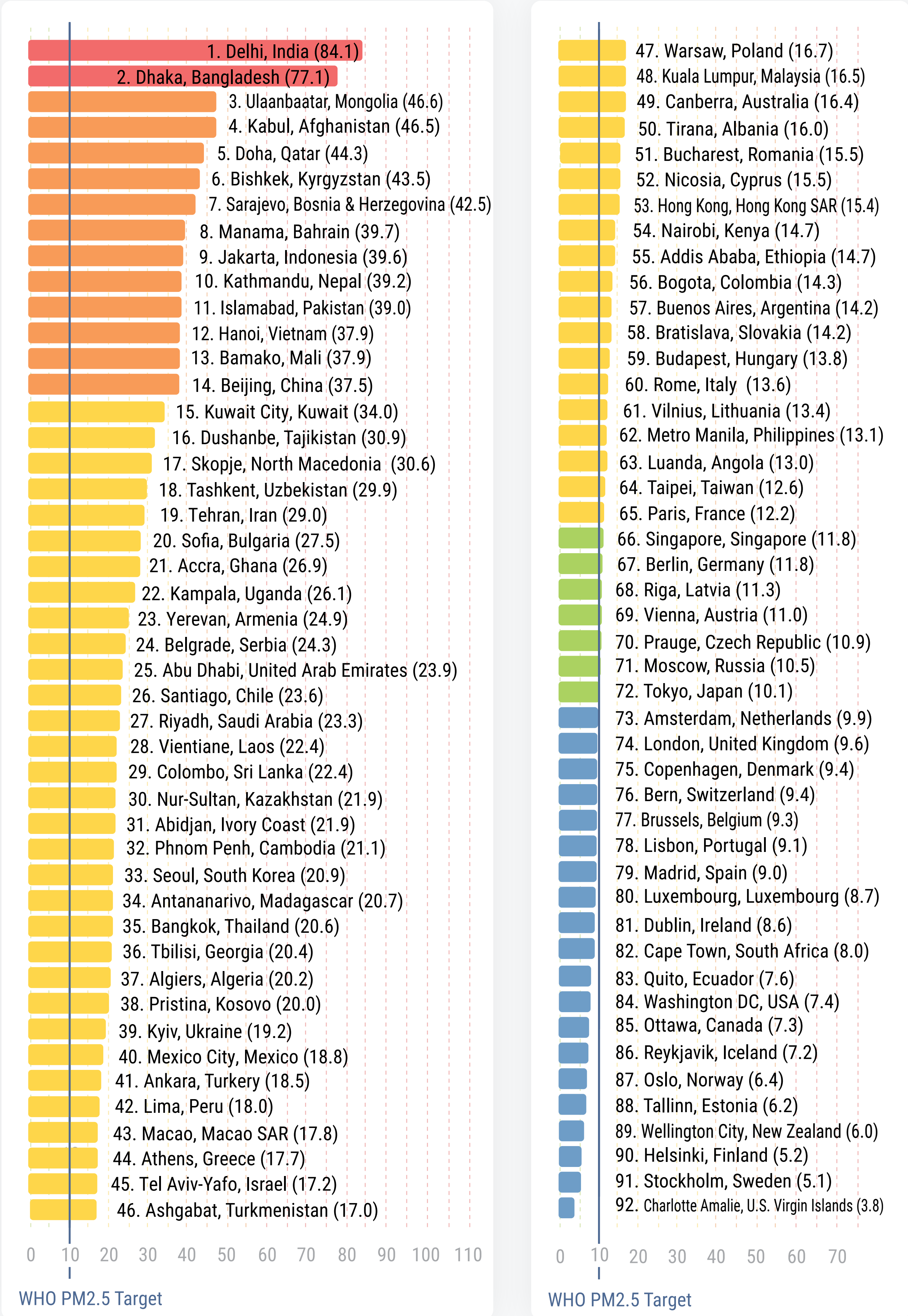
World country/region ranking

Arranged by annual average PM2.5 concentration (μg/m³), weighted by population based on the available data

1	Bangladesh	77.1
2	Pakistan	59.0
3	India	51.9
4	Mongolia	46.6
5	Afghanistan	46.5
6	Oman	44.4
7	Qatar	44.3
8	Kyrgyzstan	43.5
9	Indonesia	40.7
10	Bosnia Herzegovina	40.6
11	Bahrain	39.7
12	Nepal	39.2
13	Mali	37.9
14	China	34.7
15	Kuwait	34.0
16	Tajikistan	30.9
17	North Macedonia	30.6
18	Uzbekistan	29.9
19	Myanmar	29.4
20	UAE	29.2
21	Vietnam	28.1
22	Bulgaria	27.5
23	Iran	27.2
24	Ghana	26.9
25	Montenegro	26.1
26	Uganda	26.1
27	Armenia	24.9
28	Serbia	24.3
29	Saudi Arabia	23.3
30	Sri Lanka	22.4
31	Laos	22.4
32	Ivory Coast	21.9
33	Kazakhstan	21.9
34	Thailand	21.4
35	Croatia	21.2
36	Cambodia	21.1
37	Georgia	20.4
38	Algeria	20.2
39	Madagascar	20.0
40	Kosovo	20.0
41	South Korea	19.5
42	Chile	19.3
43	Ukraine	19.2
44	Guatemala	19.2
45	Mexico	18.9
46	Turkey	18.7
47	Italy	18.5
48	Greece	18.4
49	South Africa	18.0
50	Peru	17.9
51	Macao SAR	17.8
52	Turkmenistan	17.0
53	Poland	16.9
54	Israel	16.9
55	Albania	16.0
56	Cyprus	15.8
57	Romania	15.8
58	Malaysia	15.6
59	Colombia	15.6
60	Hong Kong SAR	15.4
61	Slovakia	15.3
62	Taiwan	15.0
63	Jordan	14.9
64	Ethiopia	14.7
65	Hungary	14.3
66	Argentina	14.2
67	Kenya	14.2
68	Brazil	14.2
69	Angola	13.0
70	Philippines	12.8
71	Czech Republic	12.3
72	Malta	11.8
73	Singapore	11.8
74	Lithuania	11.7
75	Latvia	11.3
76	Senegal	11.2
77	France	11.1
78	Austria	10.9
79	Curacao	10.5
80	Spain	10.4
81	Germany	10.2
82	Japan	9.8
83	Netherlands	9.7
84	USA	9.6
85	Denmark	9.4
86	Russia	9.4
87	Portugal	9.1
88	Luxembourg	9.0
89	Switzerland	9.0
90	Belgium	8.9
91	Ireland	8.6
92	United Kingdom	8.4
93	Costa Rica	8.2
94	Ecuador	7.6
95	Australia	7.6
96	Andorra	7.4
97	Canada	7.3
98	Iceland	7.2
99	New Zealand	7.0
100	Estonia	5.9
101	Norway	5.8
102	Finland	5.0
103	Sweden	5.0
104	U.S. Virgin Islands	3.7
105	New Caledonia	3.7
106	Puerto Rico	3.7

World capital city ranking

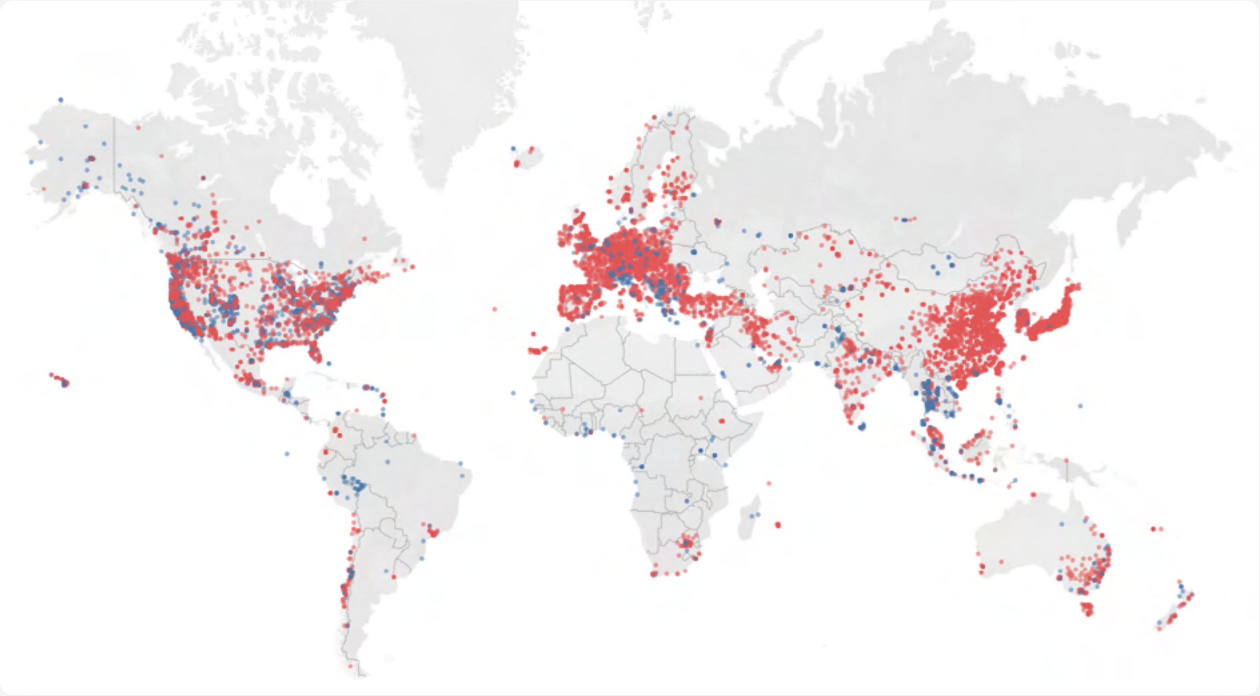
Arranged by annual average PM2.5 concentration (µg/m³)



Overview of public monitoring status

The availability of public air quality data varies considerably between cities and countries. China, Japan, and the United States have the most comprehensive government monitoring networks that publish continuous air quality data. Data is included in this report only if it achieved a set level of data availability, further explained on page 34.

The map below illustrates the unequal global distribution of PM2.5 air quality monitors that met data availability requirements for 2020.



Global distribution of PM2.5 air quality monitoring stations included in this report.
Red dots indicate government stations. Blue dots indicate data from independently operated air monitors.

Populated areas that lack air quality monitoring include vast regions on the African and South American continents. Higher-income countries tend to have more data availability and public access than lower-income countries.

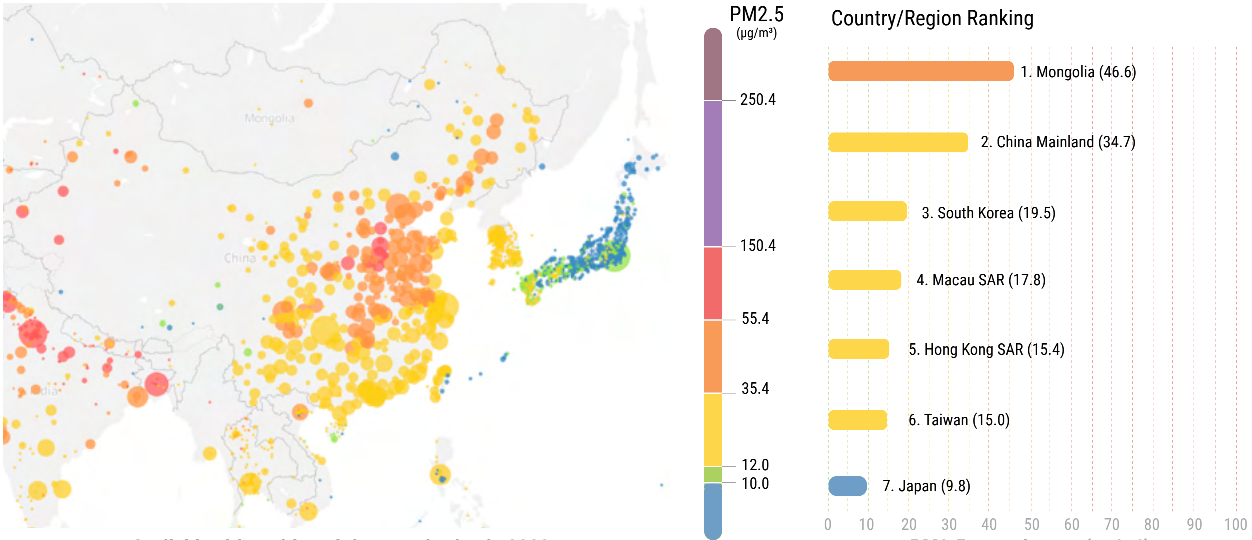
For areas that lack governmental real-time air quality monitoring, lower-cost PM2.5 sensors can offer an opportunity to accelerate access to air quality information, as they can be installed and managed with fewer resources.

This report includes both governmental data, typically provided by reference-grade monitors, and data from low-cost monitoring stations, all validated by IQAir's AirVisual platform artificial intelligence.

Community-contributed monitors provide the only real-time, public air quality data for Andorra, Angola, Cambodia, Latvia, Oman, Qatar, Senegal, U.S. Virgin Islands, and Ukraine.

EAST ASIA

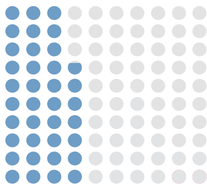
China Mainland | Hong Kong SAR | Japan | Macau SAR | Mongolia | South Korea | Taiwan

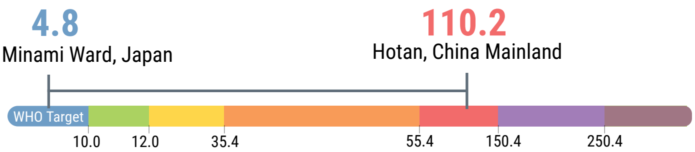


Available cities with real time monitoring in 2020

33.8%

Regional cities which met the WHO PM2.5 target in 2020





Range of annual mean PM2.5 (μg/m³) across regional cities

Most Polluted Regional Cities

Rank	City	2020 AVG
1	Hotan, China Mainland	110.2
2	Kashgar, China Mainland	81.0
3	Anyang, China Mainland	61.5
4	Puyang, China Mainland	59.3
5	Hebi, China Mainland	58.9
6	Handan, China Mainland	58.9
7	Aksu, China Mainland	58.4
8	Yuncheng, China Mainland	57.7
9	Shijiazhuang, China Mainland	57.6
10	Shihezi, China Mainland	57.5
11	Jiaozuo, China Mainland	56.2
12	Xingtai, China Mainland	55.9
13	Kaifeng, China Mainland	55.5
14	Luohe, China Mainland	55.4
15	Zaozhuang, China Mainland	54.8

Least Polluted Regional Cities

Rank	City	2020 AVG
1	Minami Ward, Japan	4.8
2	Obihiro, Japan	5.6
3	Minamiaizu, Japan	5.8
4	Otaru, Japan	5.9
5	Shimamoto, Japan	6.2
6	Minamiuonuma, Japan	6.2
7	Otofuke, Japan	6.2
8	Gero, Japan	6.2
9	Ngari, China Mainland	6.2
10	Toyono, Japan	6.7
11	Okinawa, Japan	6.7
12	Gojo, Japan	6.7
13	Shima, Japan	6.7
14	Ebina, Japan	6.7
15	Uchinada, Japan	6.7

SUMMARY

East Asia is estimated to carry the highest regional share of global outdoor air pollution-related deaths (37%).[20] Air pollution also costs 7.5% of this region's annual gross domestic product (GDP) in welfare losses.[21] While cities from this region comprise 42 of the 100 most polluted cities globally, PM2.5 concentrations are trending downward overall. This improvement is attributable to the considerable steps taken by East Asian countries to improve air quality monitoring and pollution control. In 2020, temporary measures established to reduce the spread of SARS-CoV-2 resulted in lowered transportation emissions and some reductions in manufacturing and industry, further reducing ambient PM2.5.

Air pollution sources vary across the region, but the most common PM2.5 sources include coal-based energy production, industrial activity, fossil-fuel based transportation, and domestic heating.

Hong Kong, Taiwan, Macao, and South Korea are additionally impacted by transboundary pollution from regional neighbors, as PM2.5 can travel large distances when carried by wind.[22]

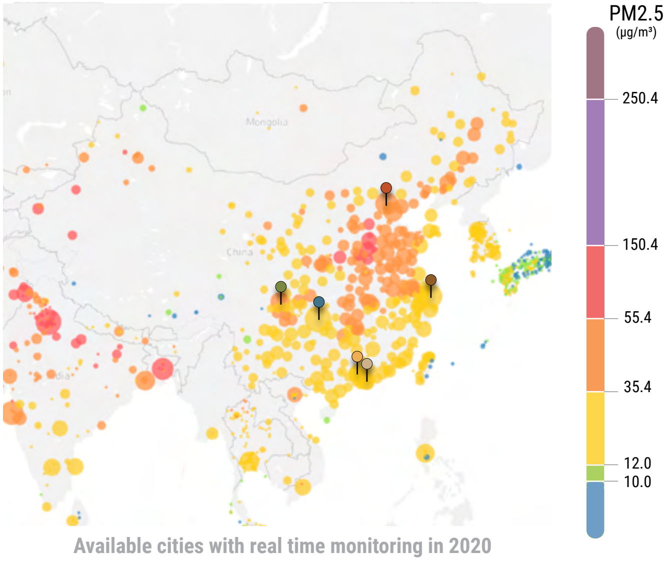
MONITORING STATUS

East Asia has a robust air quality monitoring network with some of the best global data coverage and availability. Data in this region is mostly provided by governments, with China, Japan, and South Korea hosting the largest governmental networks here.

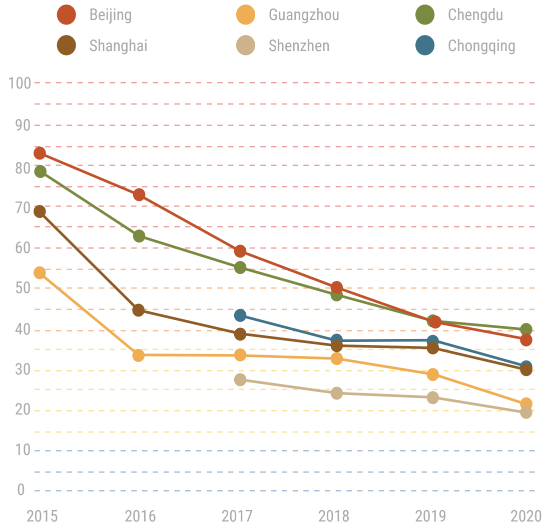
While China has the largest monitoring network in the region, Japan has the most granular network globally, with 30% fewer stations than China but distributed over a land area that is 25 times smaller.

Air quality monitoring in Mongolia is growing rapidly, largely due to non-governmental organizations and individuals whose community-deployed sensors now supply two-thirds of national data. Most stations here are concentrated in Ulaanbaatar, which has quickly become one of the most densely monitored cities globally with 40 stations, up from 8 stations in 2018.

CHINA MAINLAND



Available cities with real time monitoring in 2020



PM2.5 annual mean (µg/m³) over 6 years

PM2.5: µg/m³	2020 Annual AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Percent of days in 2020 ≥ 25 µg/m³
Beijing	37.5	63.3	62.5	34.7	31.3	35.3	30.7	35.8	25.1	21.9	41.1	38.9	30.2	57.7%
Shanghai	31.5	53.1	32.4	26.3	33.0	37.9	28.8	27.2	19.9	24.9	19.7	26.7	47.1	50.3%
Guangzhou	22.6	28.8	23.2	21.3	26.2	18.3	11.4	11.5	17.0	20.4	26.8	31.0	34.7	35.8%
Shenzhen	19.0	27.0	18.7	20.5	21.7	13.1	6.6	6.8	12.1	15.5	23.8	26.7	34.2	26.5%
Chengdu	40.5	67.5	51.3	40.7	39.0	40.5	28.8	21.9	22.8	23.9	30.1	56.4	62.9	67.2%
Chongqing	31.7	48.0	48.1	36.0	32.2	27.2	20.5	15.2	17.6	18.2	25.7	36.0	56.6	56.0%

PROGRESS

Overall, air quality in cities across China has been improving. In 2020, 86% of Chinese cities observed cleaner air than the previous year, and average pollution exposure by population fell 11%.

Long-term trends of improving air quality are attributable to China's comprehensive air pollution policy, updated every three years.[23] China's Air Pollution Action Plan for 2020 did not set tougher targets but rather included more cities in the scope, requiring them to meet annual targets of < 35 µg/m³ in 2020 or a minimum PM2.5 reduction of 18% from 2015 levels.

China notably became the earliest epicenter of COVID-19 in 2020 and mandated rigorous lockdown measures to limit its spread. From January to April 2020, mobility and industry were greatly limited, resulting in some of the cleanest air on record for this time period among key cities (including Wuhan and Beijing).[24]

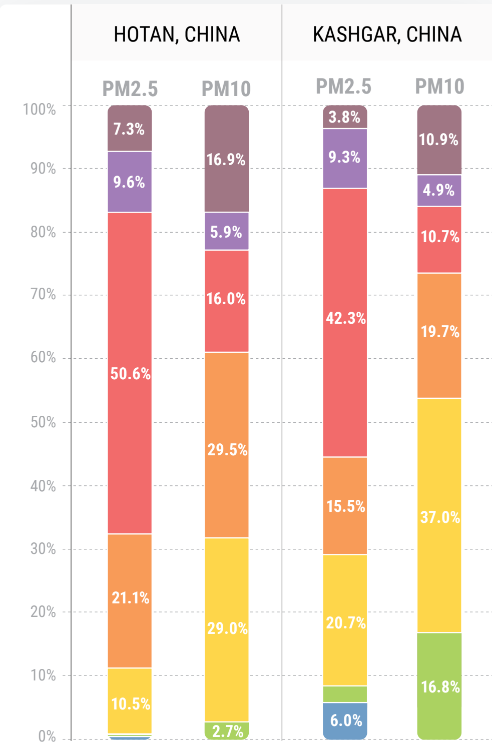
CHALLENGES

Only 2% of the 388 Chinese cities included in this report achieved the WHO annual PM2.5 target of < 10 µg/m³, while 61% of cities met China's national Grand II annual standard of < 35 µg/m³ (in line with the WHO interim target 1).

China remains the world's largest producer and consumer of coal, a principal contributor to PM2.5 pollution nationally.[25] Although China is achieving the largest growth of any country in renewable energies, these sources account for just 23% of China's energy consumption, while coal accounts for 58%.[26] China's thermal power plants are estimated to contribute up to 24% of PM, 39% of SO_2, and 52% of NO_X.[27] Petroleum and other liquids are the second-largest source of energy, significantly contributing to national PM2.5 pollution.

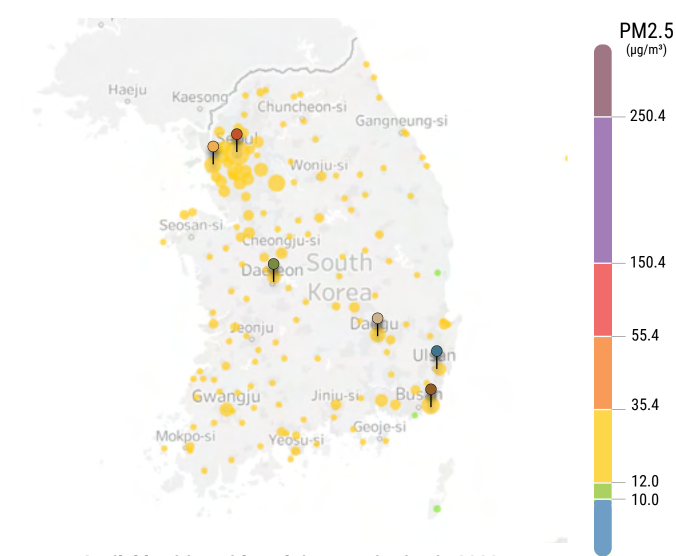
HIGHLIGHT: SANDSTORMS

During 2020, Xinjiang dominated China's most polluted cities, with 4 of China's top 10 located in this sand- and storm-prone province that has also seen rapid increases in coal and fossil fuel emissions. The oasis town of Hotan experienced the highest monthly PM2.5 pollution worldwide from March to June and was China's most polluted city from February to October. Dust storms in this region are typically most severe in the spring months of March and April due to weather patterns, although human influence in the form of land manipulation for agriculture and human-influenced climate change increasing the severity and frequency of droughts are also linked to more extreme dust storms.[28, 29] In parts of Xinjiang, dust and human-made pollution combine to create extreme pollution episodes.[30]

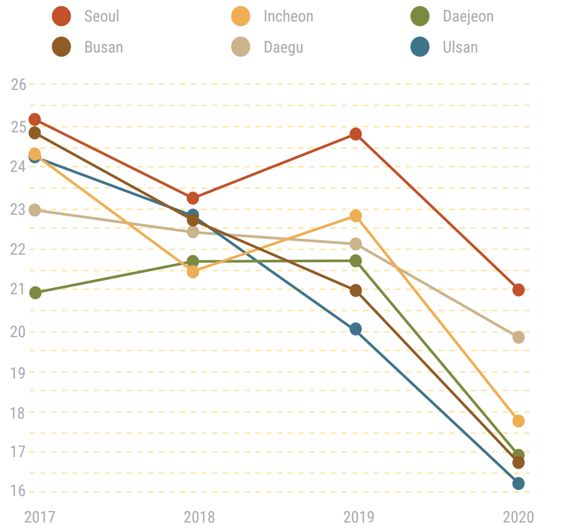


Annual hours spent in different AQI levels

SOUTH KOREA



Available cities with real time monitoring in 2020



PM2.5 annual mean (μg/m³) over 4 years

PM2.5: μg/m³	2020 Annual AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Percent of days in 2020 ≥ 25 μg/m³
Seoul	20.9	28.8	28.3	24.9	20.5	19.2	20.9	13.8	15.0	10.8	17.6	24.5	27.3	30.1%
Busan	16.7	20.5	21.9	16.0	16.6	17.1	14.8	10.0	18.3	12.5	14.7	16.7	21.0	15.6%
Incheon	17.7	26.9	22.2	20.7	16.2	14.8	16.9	12.2	13.7	9.7	14.9	20.4	23.8	20.5%
Daegu	19.8	26.7	25.8	20.3	18.0	19.2	19.7	13.6	15.9	14.4	17.5	23.0	24.1	25.7%
Daejeon	16.9	25.2	22.9	19.7	17.1	15.7	17.9	8.1	9.9	10.8	16.5	19.6	20.0	19.9%
Ulsan	16.3	19.1	19.2	16.4	16.6	18.3	18.2	10.5	16.3	12.9	14.4	16.0	18.2	15.8%

PROGRESS

Between 2019 and 2020, all cities in South Korea observed air quality improvements. On average, PM2.5 levels fell by 19% across South Korean cities. The country's cleaner air is partially attributable to temporary measures established to reduce the spread of the SARS-CoV-2 virus, which restricted some transportation and economic activity.

Coal comprises half of South Korea's energy mix and is a key contributor to ambient PM2.5.[31] In 2019, measures were put in place to mitigate the seasonal impact of coal on air quality from December through March, including temporarily capping or closing operations at coal-fired plants. 2020 marked the first year of that policy.

Between January and March, pollution levels were down 32% compared to the same time period in 2019. South Korea has also committed to achieving carbon neutrality by 2050, which could require all coal-fired power generation be replaced with renewable energy sources as soon as 2029.[32]

CHALLENGES

Despite continued year-over-year reductions in average ambient PM2.5, none of the included cities in South Korea met the WHO annual PM2.5 target of < 10 μg/m³, and only 5 of 60 cities met South Korea's annual PM2.5 guideline of < 15 μg/m³. Pollution levels exceeding the WHO standard are estimated to cost South Koreans an average of 1.4 years of life expectancy.[33]

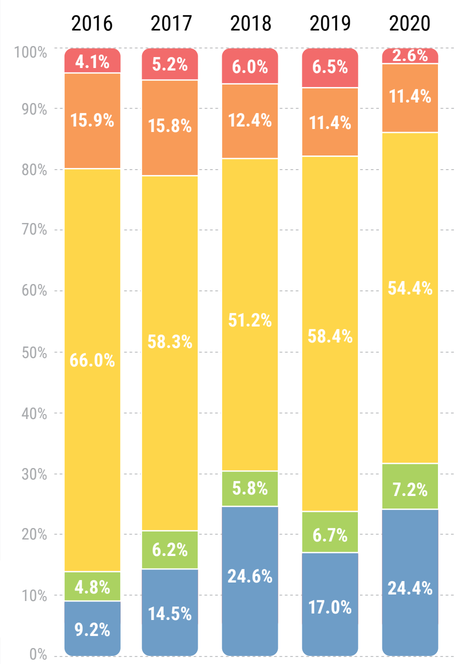
The northwestern provinces of Chungcheongnam-do and Gyeonggi-do exhibit the highest pollution levels in South Korea, claiming 15 of the country's 20 most polluted cities due to their coal-fired power production and manufacturing industries as well as heating and vehicular emissions.

While transboundary air pollution accounts for 30-50% of South Korea's ambient PM2.5, the remainder is from national anthropogenic sources. National sources can comply with WHO standard air quality through more stringent national policy and enforcement.[34]

HIGHLIGHT: SEOUL

Seoul's 15.7% reduction in annual average PM2.5 in 2020 follows years of little change to air quality levels. This reduction is likely attributable to changes in transport emissions as a result of lockdowns as well as new restrictions on coal-fired plants during the winter. The latter cut PM2.5 emissions from 60 coal-fired plants nationwide, from 8,781 tons in December 2018 to 3,527 tons in December 2020.[35]

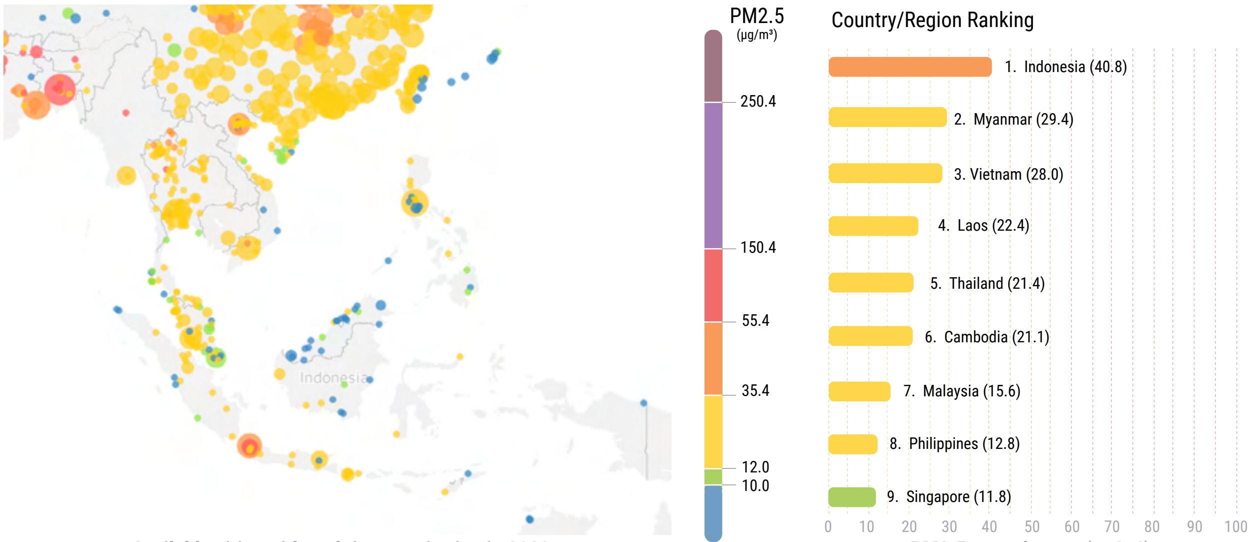
SEOUL, SOUTH KOREA



Annual hours spent in different PM2.5 pollution levels

SOUTHEAST ASIA

Cambodia | Indonesia | Laos | Malaysia | Myanmar | Philippines | Singapore | Thailand | Vietnam

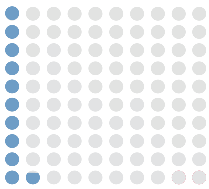


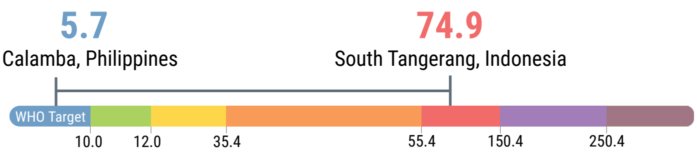
Available cities with real time monitoring in 2020

PM2.5 annual mean (μg/m³)

10.8%

Regional cities which met the WHO PM2.5 target in 2020





Range of annual mean PM2.5 (μg/m³) across regional cities

Most Polluted Regional Cities

Rank	City	2020 AVG
1	South Tangerang, Indonesia	74.9
2	Pai, Thailand	53.0
3	Bekasi, Indonesia	48.1
4	Chiang Saen, Thailand	43.7
5	Phan, Thailand	41.6
6	Saraphi, Thailand	40.5
7	Jakarta, Indonesia	39.6
8	Hanoi, Vietnam	37.9
9	San Kamphaeng, Thailand	37.8
10	Hang Dong, Thailand	36.8
11	Ben Cat, Vietnam	36.4
12	Chiang Rai, Thailand	36.3
13	Pong, Thailand	35.6
14	Si Samrong, Thailand	35.1
15	San Sai, Thailand	34.0

Least Polluted Regional Cities

Rank	City	2020 AVG
1	Calamba, Philippines	5.7
2	Palangkaraya, Indonesia	5.9
3	Kapit, Malaysia	6.4
4	Limbang, Malaysia	6.6
5	Tawau, Malaysia	6.7
6	Mukah, Malaysia	6.7
7	Kota Samarahan, Malaysia	7.2
8	Banjarmasin, Malaysia	7.3
9	Sarikei, Malaysia	7.3
10	Bongawan, Malaysia	7.6
11	Sri Aman, Malaysia	7.8
12	Tanjong Malim, Malaysia	7.9
13	Putatan, Malaysia	8.3
14	Shibu, Malaysia	8.4
15	Bandar Penawar, Malaysia	8.7

SUMMARY

Southeast Asia faces air pollution challenges largely stemming from rapid population growth and economic development. The region's energy demand has steeply increased as a result, with electricity demand increasing at around 6% per year.[36] The region mostly relies on fossil fuels for energy, with oil as the leading and coal the fastest-growing source.

PM2.5 emission sources in Southeast Asia vary by country and environment. In urban areas, dominant emission sources include construction, industry, and transportation.

In rural areas, a leading contributor to PM2.5 is open burning, an agricultural practice involving setting fire to stubble to clear land for next season's cultivation. Agricultural burning is estimated to contribute 5-30% of this region's total human-made emissions.[37] Although most countries in the region have policies against open burning, there is generally poor enforcement. The transboundary transport of air pollutants from open burning sites to neighboring countries is also a concern in the region, especially for Singapore and Malaysia – both experience seasonal air pollution as a result.

Southeast Asia is also susceptible to wildfires. Deforestation and agriculture have caused large land-use changes that exacerbate conditions in which fires spread both in forests and peatland.[38] However, the region experienced fewer fires in 2020 than in 2019 due to a wetter dry season.[39]

On a positive note, 70% of cities in Southeast Asia enjoyed improved air quality in 2020. However, cities in northern Thailand endured a severe agricultural burning season and comprised the largest portion of cities in the region that experienced worsened air quality in 2020.

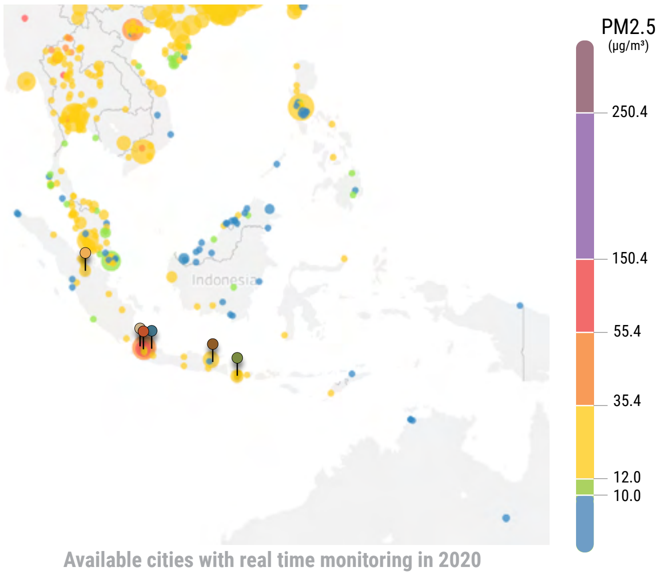
MONITORING STATUS

Despite the region's high air pollution burden, governmental monitoring in Southeast Asia is generally sparse. Roughly two-thirds of air quality monitoring infrastructure in the region is contributed by non-governmental organizations and individuals.

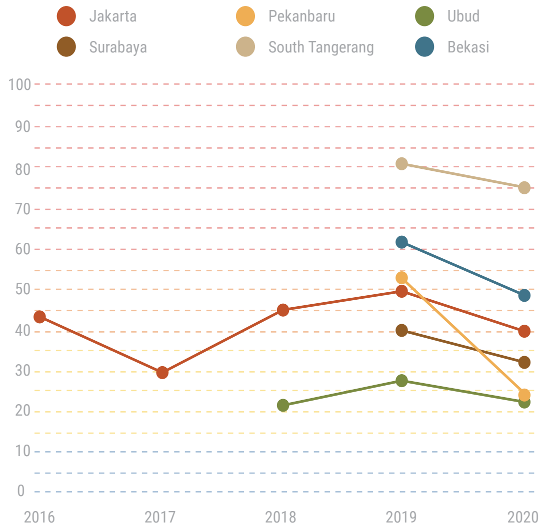
Thailand has the largest governmental network in the region (158 stations) as well as the largest network of non-governmental stations (424 locations). In the Philippines, there are a total of 55 government PM2.5 stations, the majority of which are located in the Manila metropolitan area (22 stations).

Only non-governmental data is available in Cambodia, Myanmar, and Laos.

INDONESIA



Available cities with real time monitoring in 2020



PM2.5 annual mean (μg/m³) over 5 years

PM2.5: μg/m³	2020 Annual AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Percent of days in 2020 ≥ 25 μg/m³
Jakarta	39.6	30.9	27.0	32.9	40.3	39.8	57.9	54.4	52.4	45.3	39.0	41.3	13.7	75.1%
Surabaya	33.4	35.6	29.5	40.7	34.8	30.7	36.0	37.1	30.8	28.1	31.3	37.8	28.9	71.0%
Bekasi	48.1	42.0	36.0	42.6	53.1	48.1	68.7	62.0	57.8	51.8	40.7	25.3	7.8	82.8%
South Tangerang	74.9	53.7	46.9	53.2	72.8	73.2	97.0	101.1	98.5	89.4	--	--	--	96.5%
Pekanbaru	24.2	25.6	31.5	34.4	29.3	23.8	27.3	25.0	23.1	16.7	18.9	15.6	19.3	40.4%
Ubud	22.2	23.2	25.5	26.8	30.6	23.6	21.7	23.1	19.9	16.3	16.0	16.7	19.7	32.5%

PROGRESS

From 2018 to 2019, every city in Indonesia with available data observed worsened air quality. In 2020, amid measures to contain the COVID-19 pandemic, annual mean PM2.5 concentrations in every city dropped compared to 2018.

However, the country's continued economic growth and rapid urbanization are likely to contribute to worsened air quality in the future unless government action is taken to further control emissions.

Public air quality awareness in Indonesia is on the rise. From 2016 to 2020, Indonesia's public real-time air quality monitoring network grew from a few monitors in Jakarta to 77 stations across 19 cities. Nearly half of these newly deployed air quality monitors are government-operated, while the remainder were contributed by non-governmental individuals and organizations.

CHALLENGES

Rapid urbanization and population growth have led to increases in new construction and energy demand. Indonesia's energy is mostly supplied by polluting fossil fuels, with oil and coal as significant contributors.[40]

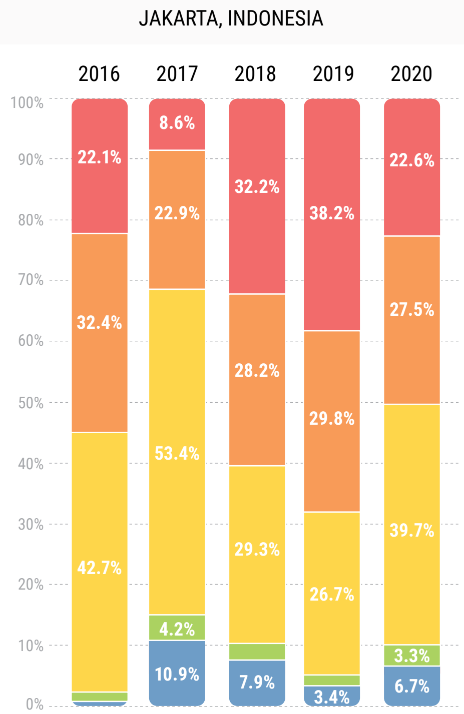
Major sources of Indonesia's air pollution include agricultural burning and wildfires. Agriculture drives this pollution in different ways:

- Many farmers are economically driven to agricultural burning of cropland, as it is a cheap and common method of preparing the land for the next harvest.
- Global demand for agricultural products, such as palm oil, drives deforestation and draining of land for agriculture, exacerbating conditions for large-scale forest and peat fires to spread.

Agricultural land change makes typically waterlogged peat more vulnerable to fires. Peat fires are particularly challenging to extinguish and cause very harmful types of air pollution.[41]

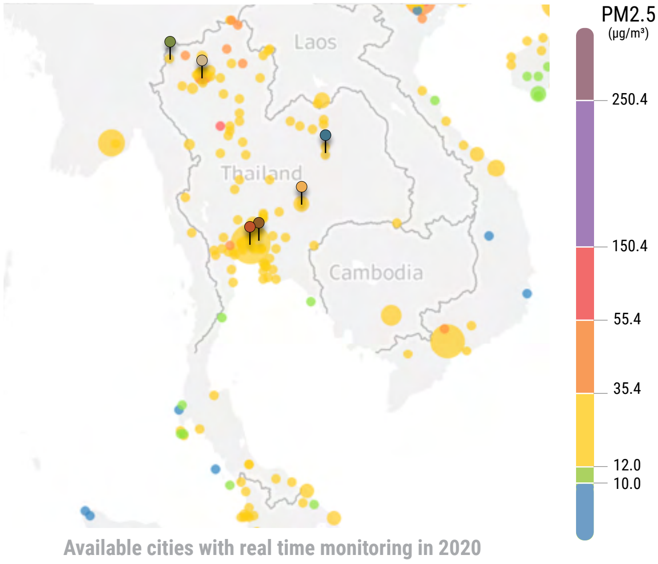
HIGHLIGHT: JAKARTA

To slow the spread of the SARS-CoV-2 virus, Jakarta implemented a large-scale social restriction policy on April 10 that closed offices, schools, and places of worship.[42] The restrictions lasted until June 5 and correlated with observed PM2.5 reductions of 12.8% in April and 31.7% in May as compared to the previous year.

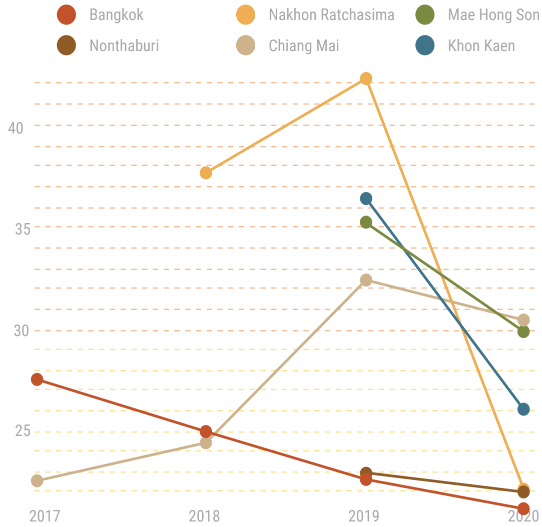


Annual hours spent in different PM2.5 pollution levels

THAILAND



Available cities with real time monitoring in 2020



PM2.5 annual mean (μg/m³) over 4 years

PM2.5: μg/m³	2020 Annual AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Percent of days in 2020 ≥ 25 μg/m³
Bangkok	20.6	44.7	43.8	22.2	20.3	12.3	6.9	7.7	9.2	8.9	16.9	24.1	30.4	28.7%
Nonthaburi	21.1	47.3	48.1	23.5	21.1	11.9	5.2	6.4	8.0	7.7	15.7	27.1	32.6	30.1%
Nakhon Ratchasima	21.6	41.5	43.4	40.5	27.8	17.2	7.5	7.8	9.1	8.4	10.9	21.5	24.4	34.7%
Chiang Mai	30.5	42.3	57.5	94.1	66.7	20.7	6.1	6.3	9.3	10.2	9.2	18.5	26.0	39.3%
Khon Kaen	26.1	41.4	44.6	49.5	36.7	24.5	11.4	12.5	12.9	14.1	17.2	27.1	33.3	46.4%
Mae Hong Son	29.7	29.8	87.3	129.1	73.0	17.2	4.8	3.6	4.5	5.0	7.0	11.2	17.6	29.8%

PROGRESS

From 2017 to 2020, Thailand's public air quality monitoring network has grown from 54 to 565 stations. While the Thai government provides the region's largest monitoring network, non-governmental contributors operate 73% of monitoring stations nationally. Engagement around this data has increased public awareness and promoted the importance of clean air and reduced pollution exposure.

Bangkok is home to 283 of Thailand's air quality monitoring stations, and non-governmental data contributors have helped provide Bangkok with the largest number of public PM2.5 stations globally. While recent improvements in air quality monitoring in Bangkok have coincided with air quality improvements, annual PM2.5 concentrations are still more than double the WHO annual pollution exposure target of 10 μg/m³.

CHALLENGES

In 2020, only one Thai city (Satun) was able to meet the WHO target for annual average PM2.5 concentration of < 10 μg/m³ and even the more lenient WHO Interim target-3 of < 15 μg/m³ was met by only 12 cities of 106. On average, Thai cities exceed WHO targets for daily PM2.5 exposure 31% of the year. Northern Thai cities exposed to smoke from agricultural burning carry the greatest pollution burden, with PM2.5 concentrations 2 to 5 times the WHO target.

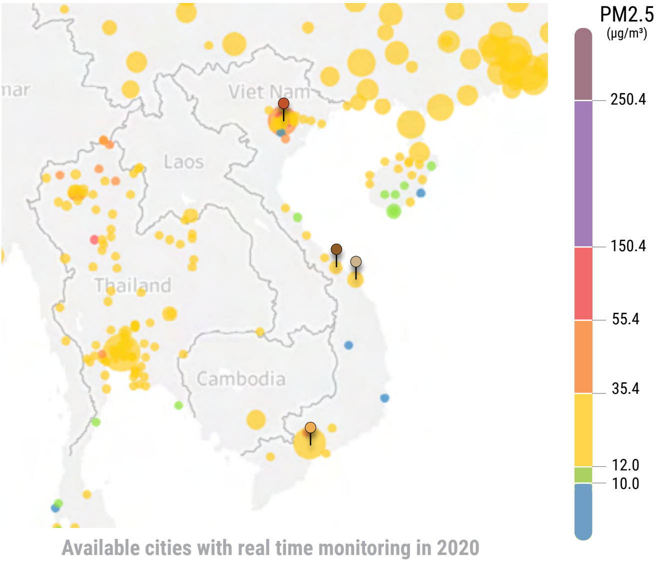
PM2.5 emissions from open burning practices occur primarily in Northern Thailand across Chiang Mai, Chiang Rai, and Mae Hong Son. However, southward wind transports pollution nationwide from January to March, increasing PM2.5 concentrations throughout the country. In 2020, the northern cities of Pai, Chiang Saen, and Phan experienced the most extreme pollution of the year (average of > 150 μg/m³) during March, correlating with widespread fires across Southeast Asia during the agricultural burning season.[43] Other sources of PM2.5, particularly in urban areas, include fuel-powered transport, industry, and construction.[44]

HIGHLIGHT: OPEN BURNING PRACTICES

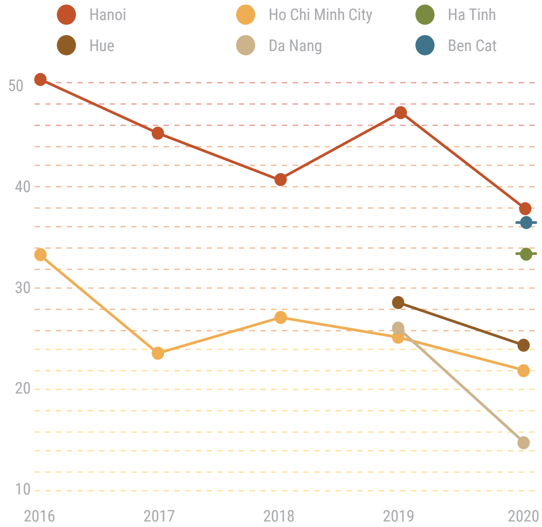
In Northern Thailand, air pollution is largely related to agricultural burning practices used in maize farming.[45] Maize's cash crop status has resulted in illegal land conversion of the forested areas as well as year-over-year increases in the land size area of satellite-observed burn scars in the Mekong Basin, from 14.7% in 2015 to 24.4% in 2019. During the peak burning season in March and April, air pollution averages "very unhealthy" levels as defined by the US AQI.

Map of acreage burned in 2020

VIETNAM



Available cities with real time monitoring in 2020



PM2.5 annual mean (µg/m³) over 5 years

PM2.5: µg/m³	2020 Annual AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Percent of days in 2020 ≥ 25 µg/m³
Hanoi	37.9	49.8	62.8	45.4	43.4	34.5	27.5	23.9	23.3	27.9	27.4	39.7	50.5	69.4%
Ho Chi Minh City	22.0	32.6	27.2	16.1	19.9	15.0	22.5	19.6	16.3	20.6	19.7	28.5	26.4	34.4%
Da Nang	14.8	18.6	17.5	18.4	13.8	13.7	12.2	11.2	9.4	13.4	12.8	18.7	17.8	6.6%
Hue	24.2	26.7	26.4	38.8	36.6	39.5	10.6	8.7	9.7	14.5	19.1	28.9	32.9	37.2%
Ha Tinh	33.4	43.7	46.1	51.3	47.7	31.2	10.1	11.8	9.9	20.5	25.5	43.5	60.5	55.2%
Ben Cat	36.4	47.7	42.9	33.2	31.5	31.1	38.2	39.4	27.1	--	--	41.0	31.2	77.0%

PROGRESS

Vietnam's air quality monitoring network nearly doubled between 2019 and 2020, growing from 54 monitoring stations across 4 cities to 90 stations across 24 cities. This achievement is attributable to gains in both governmental and non-governmental air quality monitoring, which contributed 67 and 51 stations, respectively.

In 2020, the average pollution exposure in Vietnam fell by 18% from 2019 levels. Strict measures to reduce the spread of SARS-CoV-2, including mass quarantines, a 1-month nationwide lockdown, and restrictions on mass gatherings and mobility, have contributed to an 8% reduction in PM2.5 in 2020, based on de-weathered data analysis in Hanoi.[46]

In 2019, Can Tho became the first Vietnamese city to join the worldwide BreatheLife Network and to commit to reaching WHO air quality guidelines for PM2.5 and other pollutants by 2030. With this commitment, Vietnam's 4th largest city set an air quality control precedent for other Vietnamese cities to follow.[47]

CHALLENGES

Air pollution remains a major environmental health threat in Vietnam. The WHO estimates that as many as 60,000 deaths in Vietnam were caused by air pollution in 2016.[48]

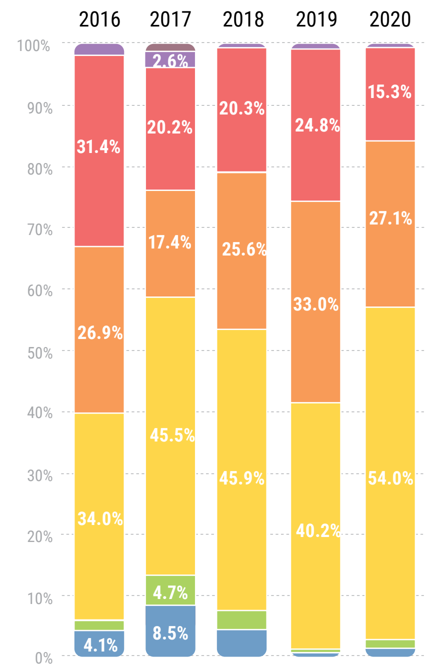
While gains in air quality monitoring have helped raise awareness, most cities still lack public real-time data. In rural areas, the impact of open burning rice straw and other biomasses for heating and cooking remains largely unmitigated.

Rapid urbanization and a growing economy also contribute to ambient PM2.5 levels. Without additional policy measures, PM2.5 concentrations in Vietnamese cities may increase as much as 20-30% by 2030.[49]

HIGHLIGHT: HANOI

Hanoi's average annual PM2.5 concentration improved in 2020 following 3 consecutive years of worsening conditions. Despite improvements, air quality within the capital remains nearly 4 times the WHO target for annual exposure (10 µg/m³), exceeding the air pollution levels of Beijing, China for the second consecutive year.

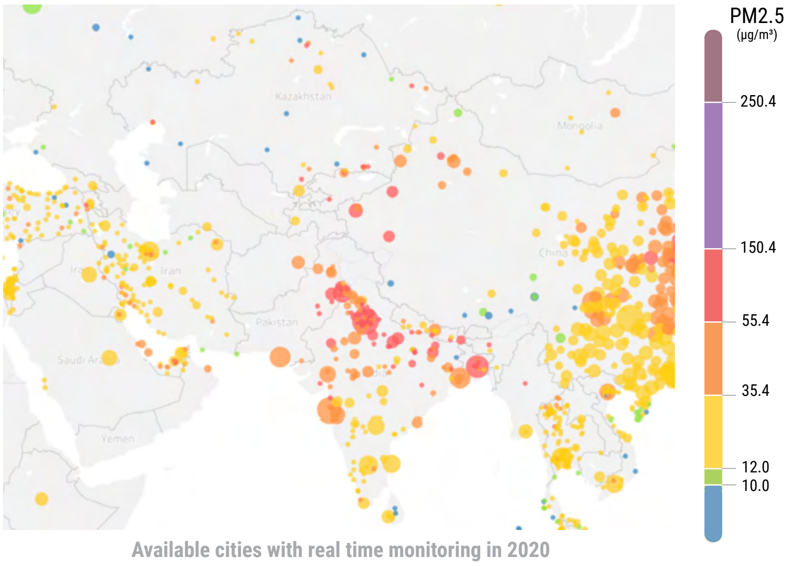
HANOI, VIETNAM



Annual hours spent in different PM2.5 pollution levels

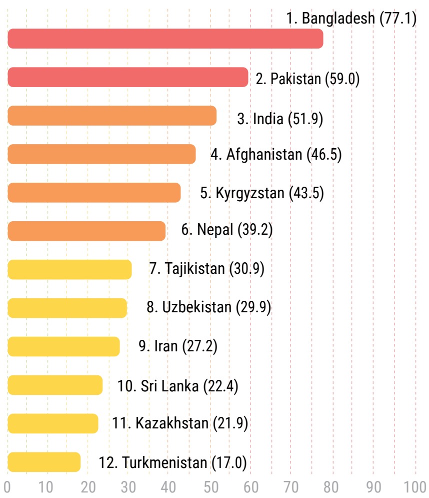
CENTRAL & SOUTH ASIA

Afghanistan | Bangladesh | India | Iran | Kazakhstan | Kyrgyzstan | Nepal | Pakistan | Sri Lanka
Tajikistan | Turkmenistan | Uzbekistan



Available cities with real time monitoring in 2020

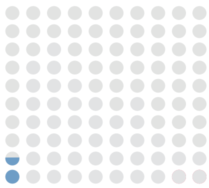
Country/Region Ranking



PM2.5 annual mean (μg/m³)

1.6%

Regional cities which met the WHO PM2.5 target in 2020



8.6 Digana, Sri Lanka

106.6 Ghaziabad, India

Range of annual mean PM2.5 (μg/m³) across regional cities

Most Polluted Regional Cities

Rank	City	2020 AVG
1	Ghaziabad, India	106.6
2	Bulandshahr, India	98.4
3	Bisrakh Jalalpur, India	96.0
4	Bhiwadi, India	95.5
5	Noida, India	94.3
6	Greater Noida, India	89.5
7	Kanpur, India	89.1
8	Lucknow, India	86.2
9	Delhi, India	84.1
10	Faridabad, India	83.3
11	Meerut, India	82.3
12	Jind, India	81.6
13	Hisar, India	81.1
14	Agra, India	80.2
15	Manikganj, Bangladesh	80.2

Least Polluted Regional Cities

Rank	City	2020 AVG
1	Digana, Sri Lanka	8.6
2	Sanandaj, Iran	9.6
3	Dambulla, Sri Lanka	9.8
4	Semnan, Iran	10.6
5	Ratnapura, Sri Lanka	12.9
6	Ashgabat, Turkmenistan	17.0
7	Satna, India	17.2
8	Mysuru, India	17.2
9	Tabriz, Iran	17.6
10	Arak, Iran	18.2
11	Yazd, Iran	18.5
12	Hamedan, Iran	18.8
13	Kochi, India	19.0
14	Meybod, Iran	19.2
15	Kerman, Iran	19.8

SUMMARY

South Asia has some of the world's worst air quality on record, with 37 of the world's 40 most polluted cities in 2020. An estimated 13-22% of deaths in this region are linked to the health effects of air pollution exposure, with associated estimated costs equating to 7.4% of the region's GDP.[50, 51]

India, Pakistan, and Bangladesh generally experience the worst air quality in this region, with 32%, 67%, and 80% of cities averaging a US AQI measurement of "Unhealthy" (> 55.5 μg/m³), respectively.

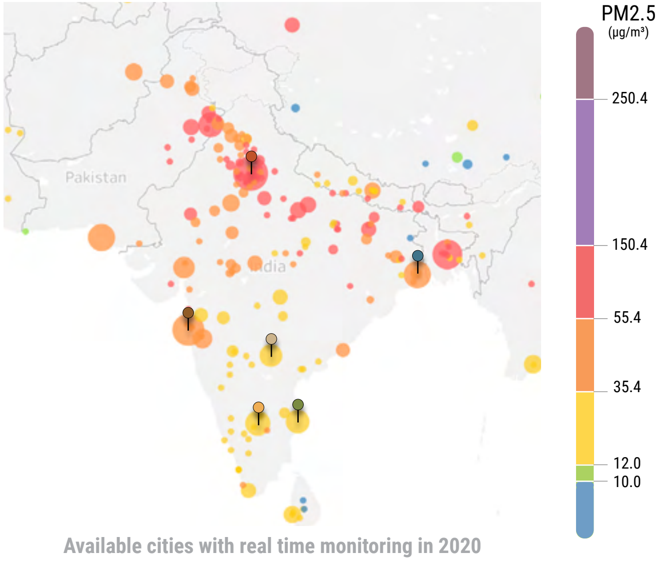
Several improvements in air quality were observed in the region during 2020. The 25 most polluted cities in this region with historical data demonstrated either reductions from 2019 PM2.5 levels or an overall downward trend over the past 4 years. In 2020, 5 of 7 capital cities observed reductions in PM2.5, with the greatest reductions seen in Kabul (-21%), Kathmandu (-18%) and Delhi (-15%). Meanwhile, Tehran (+12%) and Islamabad (+11%) experienced increases in 2020, and only 3 South Asian cities, located in Iran and Sri Lanka (Digana, Sanandaj and Dambulla), achieved WHO annual targets.

Key trends contributing to South Asia's air pollution include urbanization, economic growth, and industrialization. Common sources of air pollution include biomass burning (especially for cooking in rural areas), burning of fossil fuels, dust from construction and vehicles, and agricultural burning (which can cause transboundary air pollution issues within the region).[52]

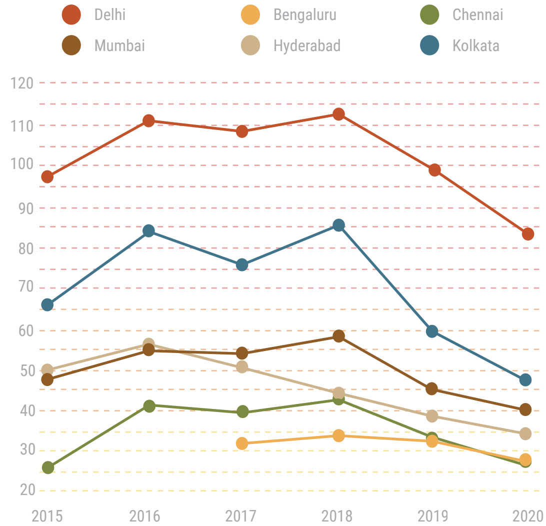
MONITORING STATUS

India, Iran, and Nepal are still the only South Asian countries with domestic government monitoring networks reporting real-time data to the public. However, data coverage from governmental networks and non-governmental low-cost sensor networks is growing. In 2020, 55 additional cities were monitored compared to 2019. Given the severity of air pollution within this region, more real-time monitoring is needed to enable more people to respond and protect their health.

INDIA



Available cities with real time monitoring in 2020



PM2.5 annual mean (μg/m³) over 6 years

PM2.5: μg/m³	2020 Annual AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Percent of days in 2020 ≥ 25 μg/m³
Delhi	84.1	128.1	99.8	54.8	53.6	55.2	52.5	42.0	35.5	58.9	128.0	143.6	157.3	90.2%
Mumbai	41.3	68.8	73.3	46.2	31.6	20.6	15.9	18.6	20.0	24.7	42.1	63.8	70.6	63.9%
Bengaluru	27.5	36.5	35.9	30.4	26.0	22.7	19.9	18.4	22.4	21.3	32.0	27.2	37.1	46.7%
Hyderabad	34.7	46.4	42.0	33.6	31.1	32.1	23.5	21.9	19.7	23.5	44.9	39.9	57.8	61.7%
Chennai	26.5	36.5	31.1	26.7	14.4	17.8	18.9	22.7	24.8	24.1	34.2	25.9	40.1	51.6%
Kolkata	46.6	79.9	66.9	47.2	29.3	26.2	24.8	24.7	26.3	27.9	38.9	65.7	101.3	49.2%

PROGRESS

India showed an overall improvement in several cities, with 63% reporting direct improvements over 2019 averages. All cities whose pollution levels increased in 2020 still show an overall downward trend from 2018 and earlier.

Progress is only marginally attributable to India's flagship National Clean Air Programme (NCAP) introduced in January 2019, which targets PM2.5 reductions between 20-30% in 122 selected cities by 2024 from a 2017 baseline. Officials cite the pandemic as part of the reason for the program's slow implementation.[53]

CHALLENGES

Despite widespread air quality improvements during 2019 and 2020, air pollution in India is still dangerously high. India continues to dominate annual PM2.5 rankings by city – 22 of the top 30 most polluted cities globally are located in India.

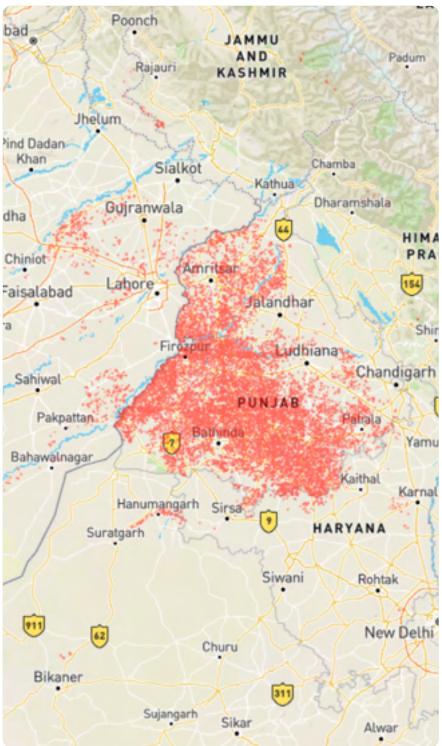
Major sources of India's air pollution include transportation, biomass burning for cooking, electricity generation, industry, construction, waste burning, and episodic agricultural burning. Transportation constitutes one of India's leading PM2.5 emission sources, responsible for emitting pollutants and resuspending road dust.[54]

Biomass cookstoves are the main source of indoor pollution nationally, particularly affecting women and children. While India promotes access to fuels which emit less particulate pollution like liquefied gas and increases the share of clean energy extending electricity access across the country, coal remains the major domestic source of India's energy supply.[55, 56]

HIGHLIGHT: AGRICULTURAL BURNING

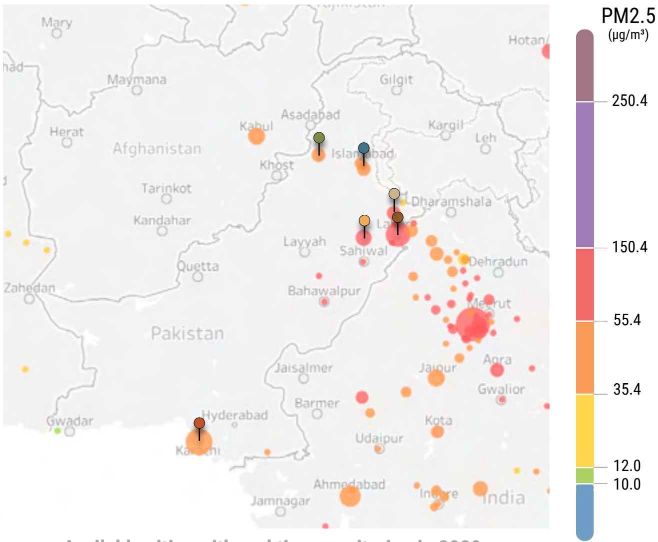
In India's Punjab and Haryana province, open burning practices have provided a means for quickly and affordably transitioning fields from the summer rice crop to the winter wheat crop.[57] During 2020, there was a record number of stubble-burning incidents in Punjab (76,537), increasing 46.5% over 2019.[58] In order to reduce agricultural burning, the government should provide viable alternative solutions.

Delhi, the world's second most populous city, is located southeast of India's agricultural breadbasket, where open burning is common. It is estimated that as much as 20 to 40% of Delhi's air pollution originates from Punjab farm fires.[59] During peak burning season, Delhi experienced average PM2.5 levels of 144 μg/m³ in November and 157 μg/m³ in December, exceeding the WHO's annual exposure guideline by more than 14 times.

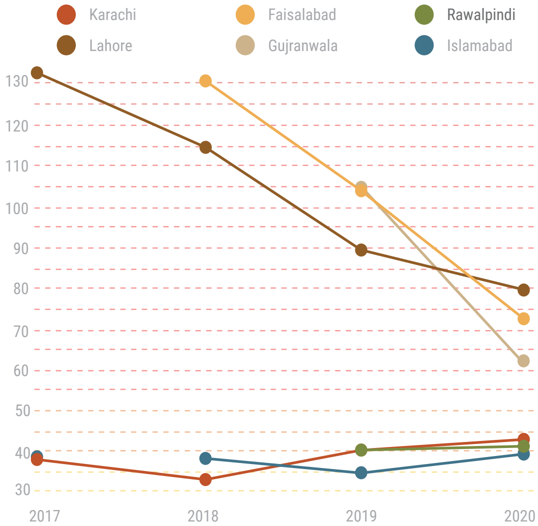


Map of acreage burned in 2020

PAKISTAN



Available cities with real time monitoring in 2020



PM2.5 annual mean (μg/m³) over 4 years

PM2.5: μg/m³	2019 Annual AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Percent of days in 2020 ≥ 25 μg/m³
Karachi	43.8	70.9	60.0	35.4	26.9	24.1	25.4	24.6	24.6	29.7	41.2	80.9	86.1	73.2%
Lahore	79.2	138.0	107.3	47.0	31.4	38.9	39.9	39.7	30.8	56.0	109.9	151.3	161.0	87.7%
Faisalabad	73.2	146.3	108.2	54.7	34.6	39.2	45.7	50.0	38.3	56.7	103.9	203.9	101.5	94.0%
Rawalpindi	42.4	55.9	55.5	26.2	18.4	14.1	24.0	29.2	22.8	35.0	51.1	82.9	93.7	65.0%
Gujranwala	62.1	86.6	104.4	35.6	22.4	30.7	49.8	46.6	32.4	57.0	98.6	118.0	--	81.4%
Islamabad	39.0	63.5	52.9	26.7	22.4	18.8	29.8	33.2	27.2	32.0	42.4	53.3	66.1	71.0%

PROGRESS

During 2020, 71% of Pakistan's cities reported decreased levels of PM2.5 from the previous year. Additionally, community-driven air monitoring networks continue to increase awareness of air pollution in the country.

There is no public access to data from the government network, but the Pakistan Environmental Protection Agency has implemented some measures to mitigate industrial emissions and plans to implement a monitoring network. It is not yet clear whether data from the monitoring network will be made public in real-time.[60]

CHALLENGES

Key drivers of air pollution in Pakistan include urbanization, rapid economic development, and industrialization. Major sources of Pakistan's air pollution include road transport emissions (both vehicle exhausts and road dust), domestic biomass burning, and industrial activity.[61]

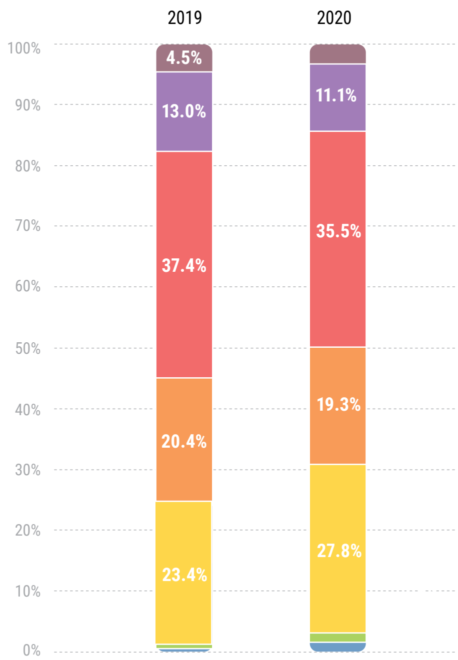
Pakistan also experiences air pollution from agricultural burning and shares transboundary pollution from this activity with India. More than 20% of deaths in Pakistan are attributable to the negative health impacts of air pollution exposure.[62]

While community-driven air quality monitoring networks are raising awareness of air pollution in Pakistan, more monitoring is needed to quantify this massive health hazard.

HIGHLIGHT: LAHORE

Lahore emerged as the world's 18th most polluted city during 2020 and 2nd most polluted megacity (following Delhi), exposing its over 11 million residents to hazardous PM2.5 levels. While highly urbanized Lahore faces year-round pollution sources, largely stemming from local transportation, industry (including solid-fuel powered brick kilns), and dust, Lahore experiences its highest pollution levels during winter months from October to February.[63] This winter peak can be partly attributed to not only temperature inversions and increased biomass burning for heat but also increased levels of agricultural burning in both Pakistan and India, during relatively stable winter conditions following the summer monsoon season.

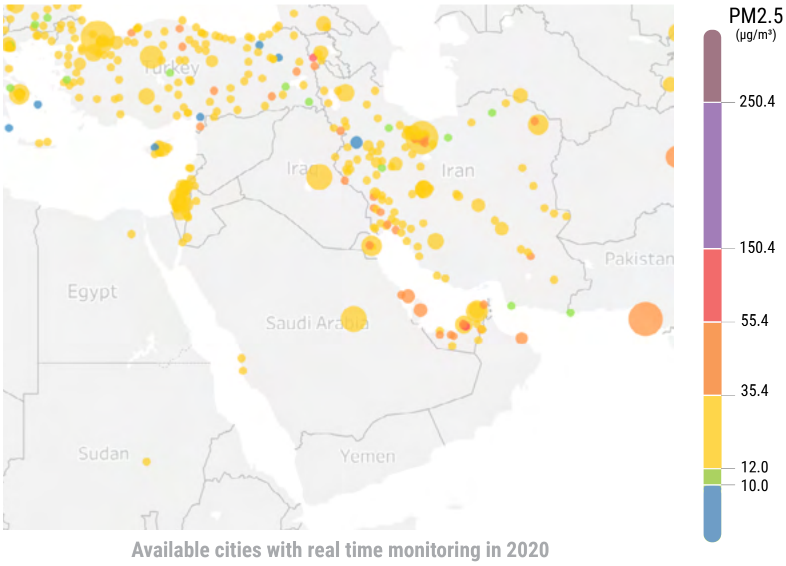
PM2.5-based Air Quality Index (AQI) in Lahore



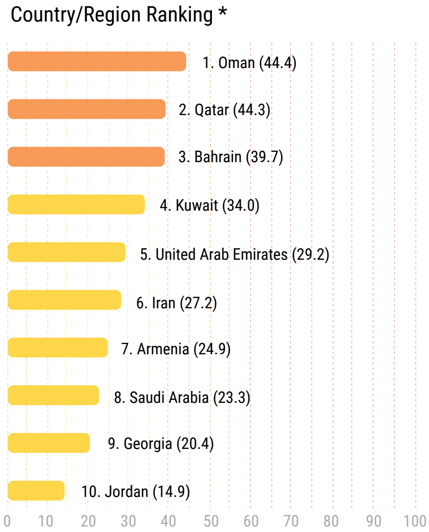
Annual hours spent in different PM2.5 pollution levels

WEST ASIA

Armenia | Bahrain | Georgia | Israel | Jordan | Kuwait | Oman | Qatar | Saudi Arabia | United Arab Emirates



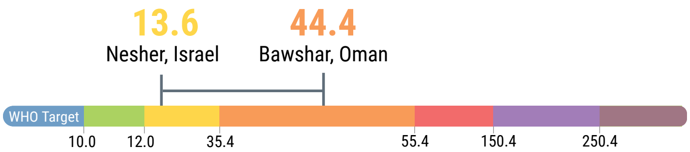
Available cities with real time monitoring in 2020



PM2.5 annual mean (μg/m³)

0%

Regional cities which met the WHO PM2.5 target in 2020 *



Range of annual mean PM2.5 (μg/m³) across regional cities

Most Polluted Regional Cities*

Rank	City	2020 AVG
1	Bawshar, Oman	44.4
2	Doha, Qatar	44.3
3	Manama, Bahrain	39.7
4	Dhahran, Saudi Arabia	36.6
5	Kuwait City, Kuwait	34.0
6	Salwa, Kuwait	33.3
7	Dubai, UAE	32.6
8	Rust'avi, Georgia	31.3
9	Sharjah, UAE	26.8
10	Yeghegnavan, Armenia	26.6
11	Yerevan, Armenia	24.9
12	Abu Dhabi, UAE	23.9
13	Riyadh, Saudi Arabia	23.3
14	Pardes Hanna-Karkur, Israel	21.5
15	Al `Abdalli, Jordan	20.5

Least Polluted Regional Cities *

Rank	City	2020 AVG
1	Nesher, Israel	13.6
2	Ein Tamar, Israel	14.1
3	Kutaisi, Georgia	14.4
4	Gvar'am, Israel	14.8
5	Al Quwayrah, Jordan	14.9
6	Kiryat Tiv'on, Israel	15.1
7	Gan Yavne, Israel	15.2
8	Yad Binyamin, Israel	15.3
9	Kiryat Ata, Israel	15.5
10	Ashkelon, Israel	15.6
11	Ashdod, Israel	15.8
12	Holon, Israel	15.9
13	Afula, Israel	15.9
14	Kiryat Malakhi, Israel	15.9
15	Sde Yoav, Israel	16.0

* Based on available data.

SUMMARY

Air pollution in West Asia originates from a combination of sources, including motor vehicles, fossil-fuel based energy production, industry, open waste burning, construction, and natural sources like sandstorms.[64]

Sandstorms are mostly seasonal, occurring more frequently from May to August when intense heat causes convective low-pressure systems to form and kick up significant amounts of dust. Sandstorms are estimated to account for 30% of the particle pollution on the Arabian Peninsula. Nearly half of premature deaths from air pollution in West Asia and North Africa are associated with sandstorms.[65, 66]

Cities in the southern and eastern regions of Western Asia tend to bear the highest PM2.5 concentrations. Doha (Qatar), Manama (Bahrain) and Kuwait City (Kuwait) are all located on the Persian Gulf coast and also rank among the top 5 most polluted cities in the region.

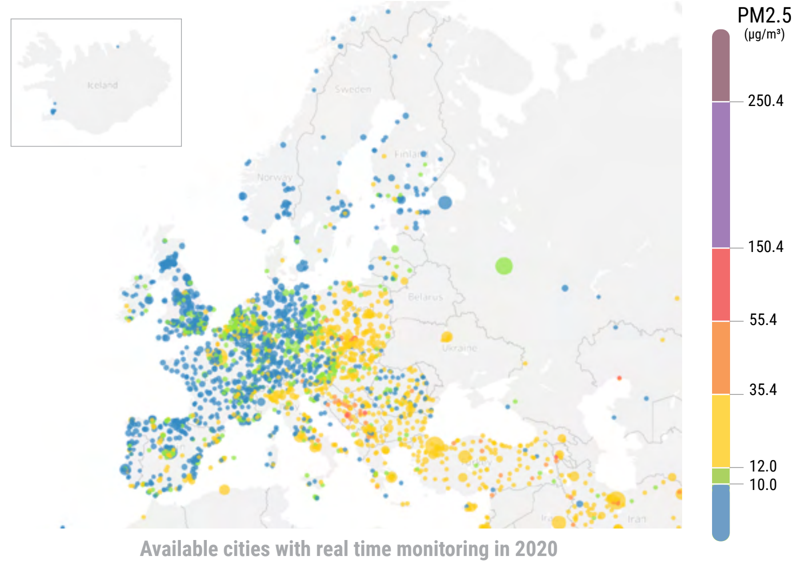
MONITORING STATUS

Air quality monitoring in West Asia is generally sparse. Numerous countries in the region lack government monitoring and are instead represented by U.S. State Department monitors or low-cost sensors from organizations and private individuals, including Armenia, Bahrain, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and Yemen.

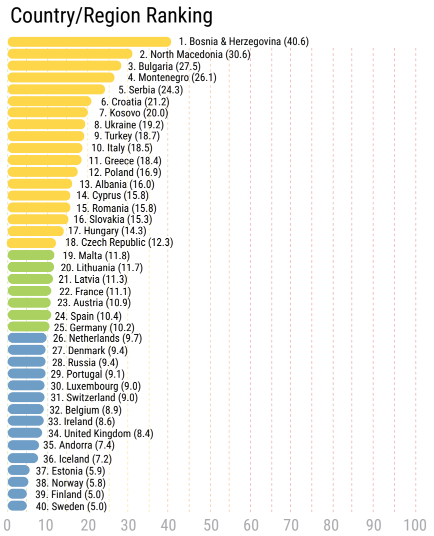
Israel, United Arab Emirates, Georgia, and Jordan have the largest governmental monitoring networks and experience some of the region's lowest PM2.5 levels.

EUROPE

Albania | Andorra | Austria | Bosnia and Herzegovina | Bulgaria | Croatia | Cyprus | Czech Republic | Denmark | Estonia | Finland | France
Germany | Greece | Hungary | Iceland | Ireland | Italy | Kosovo | Latvia | Lithuania | Luxembourg | Malta | Montenegro | Netherlands | North Macedonia
Norway | Poland | Portugal | Romania | Russia | Serbia | Slovakia | Spain | Sweden | Switzerland | Turkey | Ukraine | United Kingdom



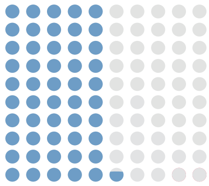
Available cities with real time monitoring in 2020

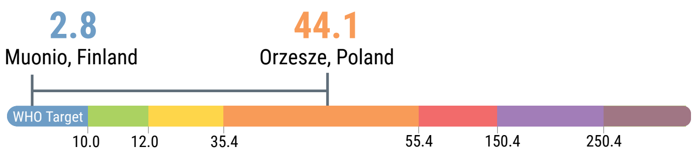


PM2.5 annual mean (µg/m³)

50.7%

Regional cities which met the WHO PM2.5 target in 2020





Range of annual mean PM2.5 (µg/m³) across regional cities

SUMMARY

Air pollution emissions across Europe have fallen considerably over past decades, but air pollution remains the continent's greatest environmental health risk.[67]

In 2020, about half of European cities exceed WHO targets for annual PM2.5, contributing to an estimated 50,000 premature deaths per year.[68] 18% of European cities are chronically polluted, experiencing 50 or more days where daily WHO targets (≥ 25.5 µg/m³) are breached.

PM2.5 concentrations tend to be more severe in Eastern and Southern Europe than in Western and Northern Europe. This trend is particularly pronounced in winter, when countries with a heavier reliance on coal-based energy and biomass burning for heating observe the largest seasonal fluctuations. Urban areas in Poland, Bosnia-Herzegovina, Serbia, and Turkey commonly experience two or more months during which average air quality is classified as "unhealthy" (≥ 55.5 µg/m³) by US AQI standards.

In early 2020, Siberian Taiga forest fires in Russia scorched 19 million hectares, an area larger than Greece. The resulting smoke produced prolonged periods of elevated air pollution in Siberia. While the fires had little direct impact on human well-being because they occurred in remote areas, their growing frequency poses severe risks to the environment and climate.

MONITORING STATUS

Governmental air quality monitoring and reporting in Europe is relatively pervasive. While Northern and Western Europe constitute the densest air quality monitoring networks with 818 cities covered, Eastern and Southern Europe are not far behind with 616 cities covered.

Air quality monitoring is common in major cities and urban areas, and less common in rural locations. To supplement government monitoring, individuals and organizations have contributed sensors to the network, notably within Greece, Denmark, Bosnia Herzegovina, Kosovo, and Russia, where these now provide 88%, 86%, 86%, 71% and 43% of live data respectively.

Most Polluted Regional Cities

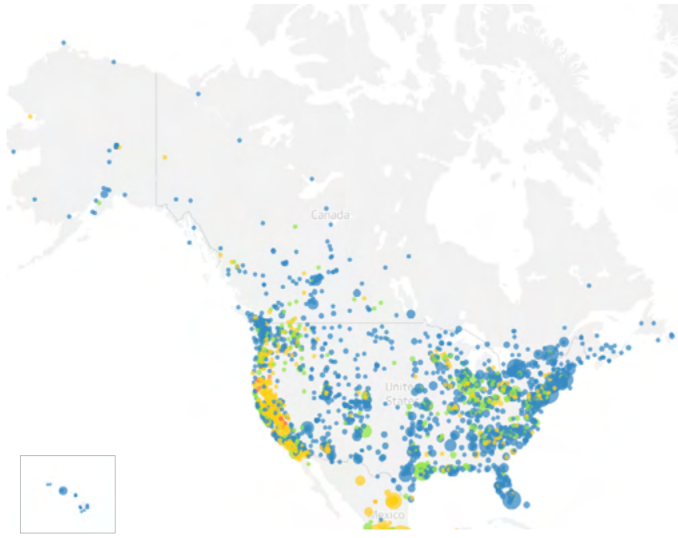
Rank	City	2020 AVG
1	Orzesze, Poland	44.1
2	Sarajevo, Bosnia & Herzegovina	42.5
3	Valjevo, Serbia	41.5
4	Lukavac, Bosnia & Herzegovina	37.7
5	Doboj, Bosnia & Herzegovina	37.6
6	Kosjeric, Serbia	36.7
7	Corum, Turkey	36.0
8	Zivinice, Bosnia & Herzegovina	34.6
9	Vushtrri, Kosovo	34.3
10	Erzurum, Turkey	34.2
11	Duzce, Turkey	33.3
12	Gaggiano, Italy	32.7
13	Tuzla, Bosnia & Herzegovina	32.1
14	Nis, Serbia	32.0
15	Ceglie Messapica, Italy	31.7

Least Polluted Regional Cities

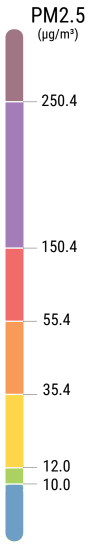
Rank	City	2020 AVG
1	Muonio, Finland	2.8
2	Korsholm, Finland	3.4
3	Bodo, Norway	3.4
4	Vaasa, Finland	3.4
5	Vladivostok, Russia	3.6
6	Midlothian, United Kingdom	3.8
7	Narvik, Norway	3.9
8	Velilla del Rio Carrion, Spain	3.9
9	Villalba de Guardo, Spain	3.9
10	Vielsalm, Belgium	4.2
11	Fundao, Portugal	4.2
12	Kohtla-Jaerve, Estonia	4.3
13	Kokkola, Finland	4.3
14	Kuopio, Finland	4.3
15	Husavik, Iceland	4.3

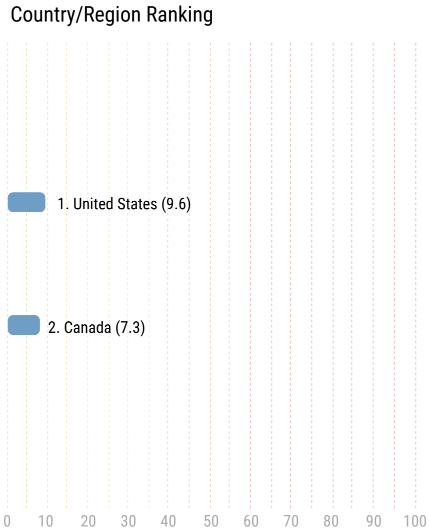
NORTHERN AMERICA

United States | Canada



Available cities with real time monitoring in 2020

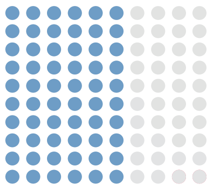




PM2.5 annual mean (μg/m³)

65.0%

Regional cities which met the WHO PM2.5 target in 2020



2.2 Waimea, HI, USA

37.8 Yosemite Lakes, CA, USA

Range of annual mean PM2.5 (μg/m³) across regional cities

Most Polluted Regional Cities*

Rank	City	2020 AVG
1	Yosemite Lakes, CA, USA	37.8
2	Springville, CA, USA	28.7
3	Susanville, CA, USA	26.2
4	Mammoth Lakes, CA, USA	25.6
5	Quincy, CA, USA	25.4
6	Reedley, CA, USA	24.1
7	Tulare, CA, USA	23.8
8	Visalia, CA, USA	23.5
9	Three Rivers, CA, USA	23.1
10	Clovis, CA, USA	22.8
11	Fresno, CA, USA	22.2
12	Oroville, CA, USA	22.1
13	Shafter, CA, USA	21.9
14	Orleans, CA, USA	20.8
15	La Grange, TX, USA	20.7

Least Polluted Regional Cities

Rank	City	2020 AVG
1	Waimea, HI, USA	2.2
2	Kailua Kona, HI, USA	2.6
3	Grand Portage, MN, USA	3.1
4	Ocean View, HI, USA	3.2
5	Bar Harbor, ME, USA	3.2
6	Pahala, HI, USA	3.3
7	Naalehu, HI, USA	3.4
8	St. Andrews, Canada	3.5
9	Hilo, HI, USA	3.5
10	Waikoloa Village, HI, USA	3.5
11	Dunn Center, ND, USA	3.5
12	Clyde, NC, USA	3.6
13	Fort Chipewyan, Canada	3.8
14	Honolulu, HI, USA	3.8
15	Kingston, Canada	3.9

*Based on available data of cities with populations >~5,000.

SUMMARY

Through air pollution monitoring and emission control, Northern America has decoupled air pollution from gains in gross domestic product (GDP) and energy consumption.[69] Despite long-term progress, 35% of regional cities still exceed the WHO target for annual PM2.5 exposure (10 μg/m³).

Human-made PM2.5 emissions are estimated to account for 200,000 premature U.S. deaths and 14,600 premature Canadian deaths.[70, 71] More integrated and ambitious pollution control plans as well as a rapid transition away from fossil fuels (consistent with climate change targets) are needed to reduce the regional health burden.

Human-made sources of PM2.5 emissions in Northern America include fossil-fuel based energy production, transport, and industry.

Wildfires are a dominant natural source, growing in frequency and severity in recent years largely attributed to human-induced climate change.[72] On days exceeding PM2.5 standards, wildfires are estimated to contribute as much as 70% of ambient PM2.5. However, certain regions continue to experience chronic poor air quality even in the absence of wildfires, mostly due to combustion of fossil fuels.

2020 was a record-breaking year for wildfires in Northern America by the total number of fires as well as acres burned.[73] Heavy smoke emissions from wildfires caused Northern America to be the only region in this report to experience increased pollution levels in 2020. Pollution levels increased despite a pandemic that resulted in reduced human-made emissions resulting from restricted economic activity and people's movement.

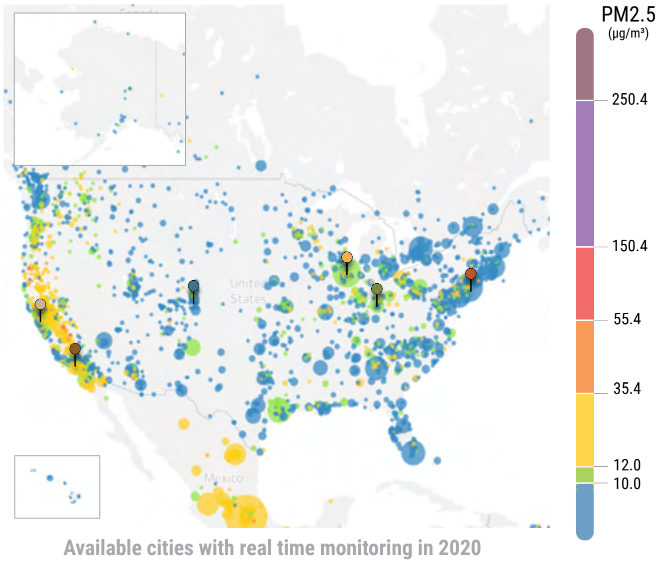
MONITORING STATUS

Northern America has the largest air quality monitoring network of all regions, with over 5,500 stations across 1,700 cities. 95% of these stations are based in the United States. The number of U.S. air quality monitoring stations is in large part due to crowd-sourced monitoring, with over 75% of the country's stations contributed by local organizations and individuals.

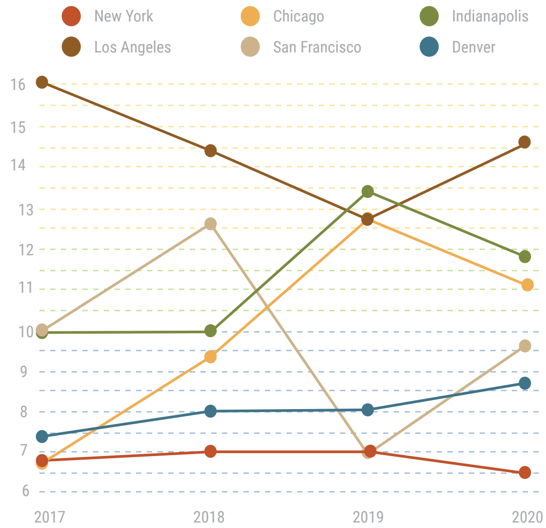
Los Angeles and San Francisco have the world's most granular city-wide networks, with 146 stations and 112 stations, respectively.

Canada has a monitoring network of 436 stations across 174 cities.

UNITED STATES



Available cities with real time monitoring in 2020



PM2.5 annual mean (µg/m³) over 4 years

PM2.5: µg/m³	2020 Annual AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Percent of days in 2020 ≥ 25 µg/m³
New York	6.5	9.1	8.1	5.6	4.6	4.2	5.7	7.4	7.0	5.3	4.9	7.5	8.0	0%
Los Angeles	14.6	17.3	13.0	5.6	8.8	10.1	10.2	13.9	15.5	26.3	24.9	17.0	12.4	13.1%
Chicago	11.1	15.6	11.9	11.9	10.9	8.0	10.0	10.9	9.2	7.9	8.1	12.0	16.4	5.5%
San Francisco	9.6	7.1	8.1	4.7	4.1	4.2	4.8	6.1	12.7	26.5	14.4	9.0	13.9	6.6%
Indianapolis	11.8	14.0	12.6	11.6	12.2	7.9	10.9	13.0	11.8	11.0	8.8	11.8	15.8	3.3%
Denver	8.7	6.6	7.6	6.2	5.6	5.6	6.0	6.6	16.6	15.9	12.9	6.9	8.0	4.1%

PROGRESS

For 5 decades, the Clean Air Act has contributed to reduced PM2.5 air pollution levels while the U.S. economy, population, and energy demands have grown.[74] Despite long-term success in reducing pollution levels, 2016 through 2018 observed a rebound, with PM2.5 levels increasing 5.5% during the two years. Rising and stagnated PM2.5 levels in cities across the United States are attributable to continued reliance on fossil fuels, the increased prevalence and severity of wildfires as well as a lack of enforcement of the Clean Air Act. This regression is estimated to have contributed to an additional 9,700 premature deaths in 2018 and an economic cost of $89 billion.

Thanks to contributions by many individuals and non-governmental organizations, the United States contain the largest number of air quality monitors in the world. In 2020, approximately 80% of national data comes from low-cost sensors, operated by individuals or non-governmental organizations. Some of these low-cost sensor networks have been made possible by government funding.

CHALLENGES

While gradual air quality improvements have saved lives, air pollution from fossil fuel combustion is estimated to have been responsible for an estimated 230,000 premature U.S. deaths in 2018 alone.[75] Notably, urban areas and the U.S. West face the highest PM2.5 concentrations overall and there is evidence that low-income and people of color face elevated exposure to PM2.5.[76]

In 2020, 38% of U.S. cities in the database did not meet the WHO target of 10 µg/m³ for annual mean PM2.5 concentration. This was a considerable increase from 2019, in which 21% of U.S. cities exceeded the WHO target. This increase in PM2.5 occurred despite the restrictions to fight the COVID-19 pandemic, which contributed to short-term PM2.5 reductions of 10-30%.

HIGHLIGHT: WILDFIRES

During 2020, extensive fires broke out across the west coast of America, estimated to be the region's most severe in 18 years. Because of devastating wildfires, during September 2020 numerous U.S. cities constituted a remarkable 77 of 100 of the world's most polluted cities for PM2.5 by monthly average. These were located in California (35), Oregon (35) and Washington (7).

Fire data for the state of California*

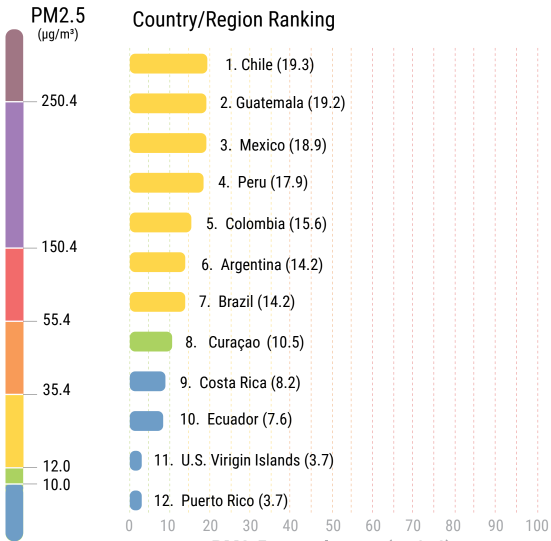
	Number of fires	Acres burned	Avg. acres/fire
2015	8,283	880,899	106.3
2016	6,954	669,534	96.3
2017	9,270	1,548,429	167.0
2018	7,948	1,975,086	248.5
2019	7,860	259,823	33.1
2020	9,917	4,257,863	429.3

Map of acreage burned in 2020

LATIN AMERICA & THE CARIBBEAN

Argentina | Brazil | Chile | Colombia | Costa Rica | Curaçao | Ecuador | Guatemala
Mexico | Peru | Puerto Rico | US Virgin Islands

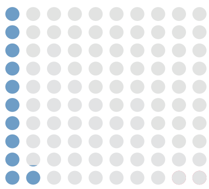

Available cities with real time monitoring in 2020

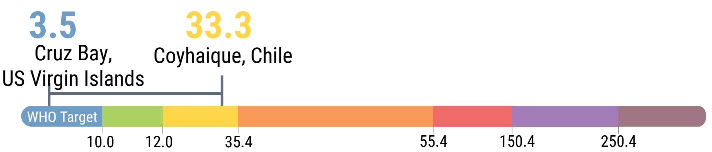


PM2.5 annual mean (μg/m³)

11.2%

Regional cities which met the WHO PM2.5 target in 2020





Range of annual mean PM2.5 (μg/m³) across regional cities

Most Polluted Regional Cities

Rank	City	2020 AVG
1	Coyhaique, Chile	33.3
2	Padre las Casas, Chile	28.6
3	Nacimiento, Chile	27.3
4	Toluca, Mexico	27.1
5	Tijuana, Mexico	26.1
6	Puebla, Mexico	24.6
7	Guadalajara, Mexico	24.5
8	Garcia, Mexico	23.9
9	Rancagua, Chile	23.8
10	Emiliano Zapata, Mexico	23.7
11	Santiago, Chile	23.6
12	Nezahualcóyotl, Mexico	23.3
13	Los Cerrillos, Chile	23.1
14	Minatitlan, Mexico	22.9
15	Juarez, Mexico	22.9

Least Polluted Regional Cities

Rank	City	2020 AVG
1	Cruz Bay, U.S. Virgin Islands	3.5
2	Camuy, Puerto Rico	3.7
3	San German, Puerto Rico	3.7
4	Charlotte Amalie, U.S. Virgin Islands	3.8
5	Punta Arenas, Chile	4.7
6	Puerto Baquerizo Moreno, Ecuador	4.9
7	Zacatecas, Mexico	5.4
8	Cuncumen, Chile	5.6
9	Tutamandahostel, Ecuador	5.9
10	Santiago de Queretaro, Mexico	6.3
11	Calama, Chile	6.6
12	Iztacalco, Mexico	7.0
13	Ribeirao Preto, Brazil	7.2
14	Sangolqui, Ecuador	7.5
15	Quito, Ecuador	7.6

SUMMARY

Latin America and the Caribbean face considerable air quality challenges as a result of rapid urbanization. As cities grow, so do their energy demands and transportation emissions, exacerbating regional PM2.5 levels. In 2020, more than 50% of cities in the region recorded more than 50 days of air quality exceeding the WHO's 24-hour guideline for PM2.5.

Lax regulations, outdated and inefficient vehicles and appliances, wildfires (particularly in Mexico), and biomass burning for domestic heating and cooking further contribute to high particle pollution levels in the region.

In Chile, major sources of PM2.5 air pollution include motor vehicles, marine aerosol, copper smelters, secondary sulfates, and soil dust.[78] Adding to those, widespread wood-burning for heating and cooking places several of its cities to the most polluted cities ranking for the Western Hemisphere. In winter, weather conditions can create a pollution-trapping effect (thermal inversion) that causes emitted pollution to stagnate and accumulate. While the Chilean government has promoted transitions to cleaner heating technologies, wood burning still contributes as much as 94% of PM2.5 emissions in some cities.[79] More should be done by the government to incentivize and transition the public to cleaner fuels.

MONITORING STATUS

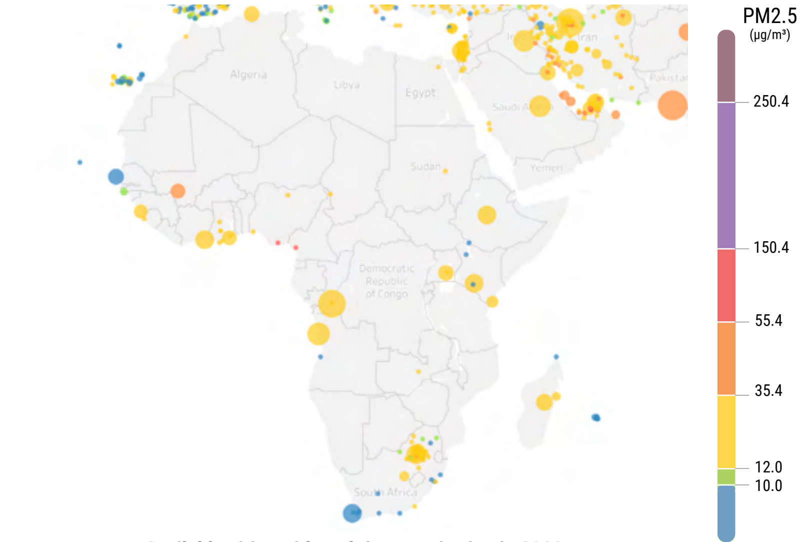
There is still little air quality monitoring in Latin America and the Caribbean. Only 170 cities across the region have public real-time data, despite 8% of the global population residing here. Monitoring stations are predominantly concentrated in the capital and major cities, and 70% of cities with monitoring data have less than 3 sensors within their administrative boundaries.

Mexico has the largest monitoring networks of any country in this region with over 200 monitors. Chile has the second largest monitoring network but has fewer than half the number of monitors as Mexico. Brazil's monitoring network remains limited to São Paulo and Acre, but is growing.

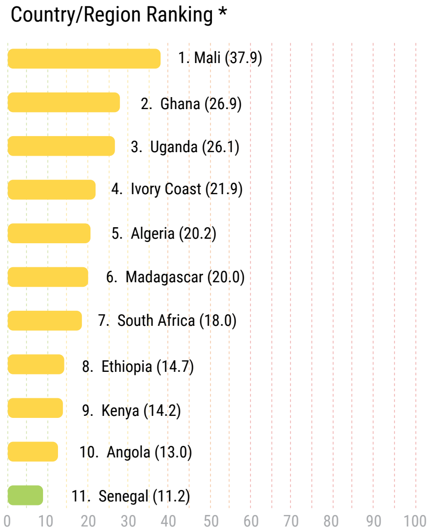
Guatemala, Honduras and Argentina all lack government monitoring. Stations within these countries are operated by local organizations and individuals.

AFRICA

Algeria | Angola | Ethiopia | Ghana | Ivory Coast | Kenya | Madagascar
Mali | Senegal | South Africa | Uganda



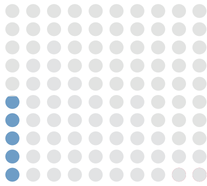
Available cities with real time monitoring in 2020

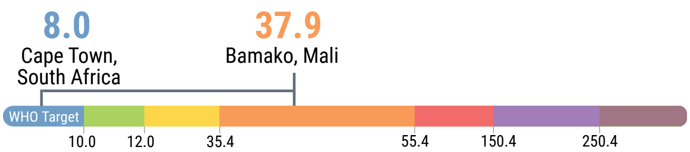


PM2.5 annual mean (µg/m³)

4.9%

Regional cities which met the WHO PM2.5 target in 2020





Range of annual mean PM2.5 (µg/m³) across regional cities

Most Polluted Regional Cities*

Rank	City	2020 AVG
1	Bamako, Mali	37.9
2	Sebokeng, South Africa	29.5
3	Accra, Ghana	26.9
4	Vereeniging, South Africa	26.5
5	Kampala, Uganda	26.1
6	Soshanguve, South Africa	26.0
7	Sasolburg, South Africa	25.6
8	Pretoria, South Africa	24.4
9	Springs, South Africa	24.4
10	Midstream, South Africa	23.3
11	Ga-Rankuwa, South Africa	22.5
12	Johannesburg, South Africa	22.3
13	Abidjan, Ivory Coast	21.9
14	Secunda, South Africa	21.8
15	Hartbeespoort, South Africa	20.8

Least Polluted Regional Cities*

Rank	City	2020 AVG
1	Cape Town, South Africa	8.0
2	Port Elizabeth, South Africa	9.0
3	Mokopane, South Africa	10.5
4	Ziguinchor, Senegal	11.2
5	Mahikeng, South Africa	11.3
6	Potchefstroom, South Africa	11.4
7	Phalaborwa, South Africa	12.0
8	Mombasa, Kenya	12.3
9	Lephalale, South Africa	12.8
10	Luanda, Angola	13.0
11	Bethlehem, South Africa	13.4
12	Hendrina, South Africa	13.5
13	East London, South Africa	13.6
14	Thabazimbi, South Africa	14.7
15	Addis Ababa, South Africa	14.7

SUMMARY

The severity of air pollution in Africa and its resulting health impact is difficult to quantify, as air quality data is limited. For most regional locations, insights must be inferred from satellite data. By this method, it is estimated that air pollution claims up to 780,000 African lives annually.[80]

PM2.5 sources vary considerably across this region, but commonly include pollutants produced from fossil fuels (such as coal and kerosene), waste, agricultural burning, emission-intense transportation, and windblown dust from the continent's deserts. The population of Africa is expected to double in the next 30 years, presenting challenges in balancing rapid growth, industrialization, and urbanization with clean air.[81]

NASA satellite data has exposed Africa as the 'fire continent.' An estimated 70% of global fires occur in the region.[82] While grassland fires are a major source of ambient PM2.5, they differ from those in Northern and Latin America. Since the fires primarily occur in the Savanna, where grass is able to replenish within a year, fires can occur year after year in the same location. According to available data, Bamako (Mali) is the most polluted city in the region with available data, with the highest frequency of "unhealthy" days per year (> 60%) in 2020 by a significant margin.

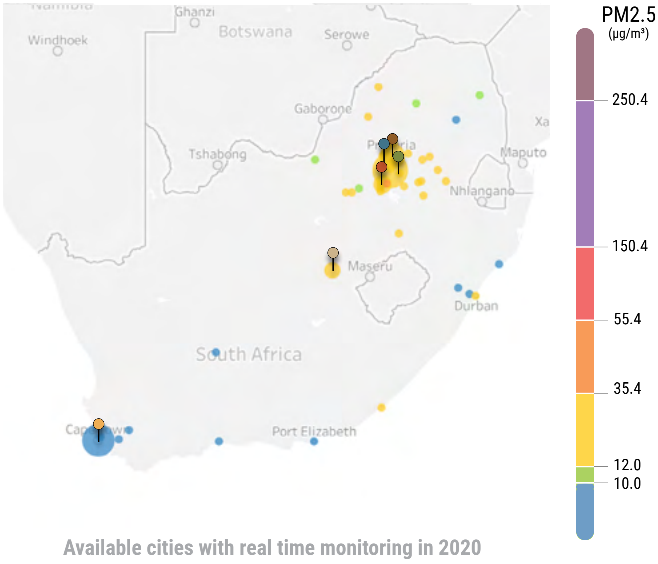
MONITORING STATUS

In 2020 alone, this region's air quality monitoring network grew across 5 new countries (Senegal, Mali, Ivory Coast, Madagascar, and Kenya) and 10 new cities. However, data in the region remains sparse. 41 African countries lack air quality monitoring data, leaving nearly a billion people without information necessary to make important health decisions.

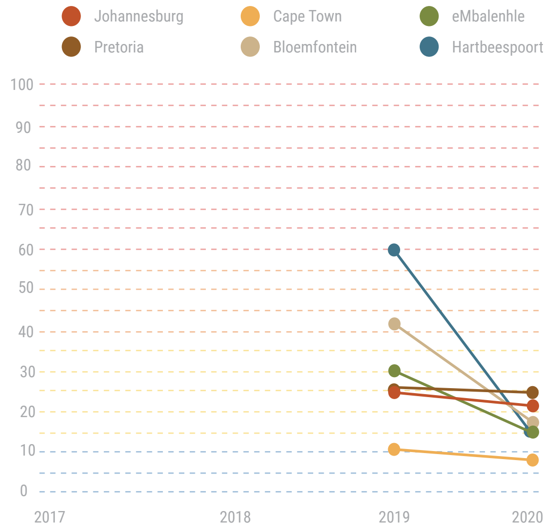
South Africa is the only African country with a public, real-time governmental air quality monitoring network. Data for every other country in the report is supplied by either U.S. State Department monitors or non-governmental monitors contributed by individuals and organizations.

Since air pollution data is sparse, public awareness of the problem remains low in the region.

SOUTH AFRICA



Available cities with real time monitoring in 2020



PM2.5 annual mean (µg/m³) over 4 years

PM2.5: µg/m³	2020 Annual AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Percent of days in 2020 ≥ 25 µg/m³
Johannesburg	22.3	15.7	17.0	16.4	12.8	28.8	45.9	41.6	25.4	20.5	17.5	14.2	13.8	29.8%
Cape Town	8.0	3.2	3.8	4.7	9.6	14.5	16.3	12.1	8.3	7.2	6.1	4.0	4.6	2.0%
Pretoria	24.4	18.0	27.1	27.3	21.3	30.5	39.7	40.4	27.9	20.1	17.2	14.4	12.2	42.7%
Bloemfontein	17.2	11.8	12.0	12.9	10.9	25.2	35.0	33.9	20.5	21.7	--	8.9	9.2	23.0%
eMbalenhle	15.6	13.1	13.3	8.4	10.1	17.8	17.8	26.1	24.1	19.1	13.7	11.9	10.4	15.6%
Hartbeespoort	20.8	5.0	14.0	13.2	11.6	25.0	37.5	43.5	24.0	16.0	14.4	12.3	12.0	25.9%

PROGRESS

On a positive note, 90% of cities in South Africa experienced improved air quality in 2020, as population weighted average PM2.5 exposure across South Africa fell by 3.6 µg/m³.

This reduction is attributable to measures taken to reduce the spread of SARS-CoV-2, namely reduced vehicular emissions as a result of shuttered businesses and facilities during lockdown periods and measures to protect the electricity power system from a total collapse (load shedding). In spite of the reduced energy demand, the state utility still had limited capacity and implemented load-shedding frequently, further contributing to the decline in emissions.

In 2019, environmental groups filed the first lawsuit against the South African government for its failure to address coal and industrial air pollution as well as provide a healthy environment – a right established in the nation's constitution.[83] This case aims to require the federal government to establish a more comprehensive and effective air pollution management plan.

CHALLENGES

Air quality levels across South Africa vary considerably by region. Southern and western coastal locations have the lowest PM2.5 concentrations, while interior cities to the north carry the highest pollution burden. In 2020, only 4.9% of South African cities met WHO targets for annual PM2.5 exposure.

A 2012 study estimated that 7.4% of all deaths in South Africa resulted from chronically high PM2.5 levels.[84] In 2020, PM2.5 pollution in Johannesburg, Pretoria, and Hartbeespoort exceeded WHO standards for daily pollution exposure (< 25 µg/m³) for more than a quarter of all days.

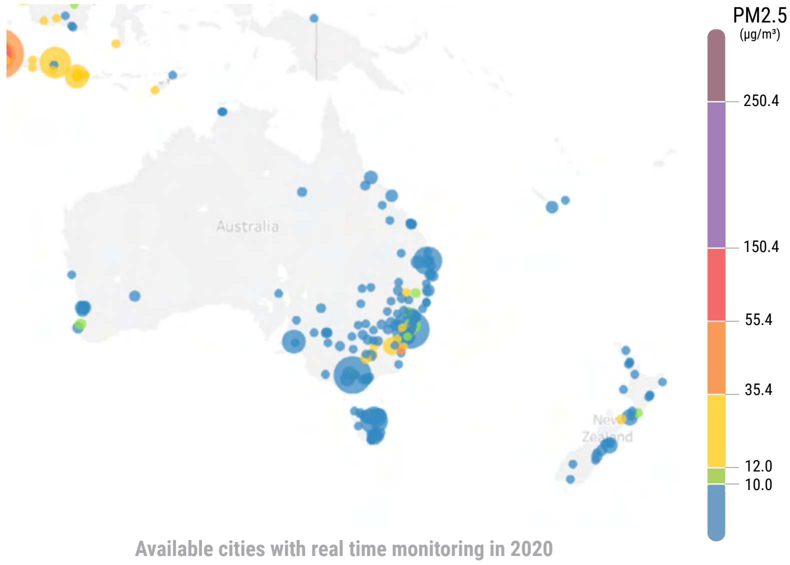
HIGHLIGHT: COAL-BASED ENERGY RELIANCE

South Africa's heavy reliance on coal-based energy and other fossil fuels, comprising 91% of the country's energy mix (one of the highest rates in the world), is a major source of ambient particle pollution.[85] Historically, the government has done little to regulate emissions from coal-fired plants, even as they fail to comply with comparatively loose emission standards.[86] In 2020, an environmental justice group (groundWork) successfully campaigned to prevent a newly proposed coal plant, while demand for exported coal has observed its third straight year of decline.[87] Between the landmark ruling and trends in the global marketplace, there is mounting pressure for the government to shift towards a greater share of renewable energy.

Map of acreage burned in 2020 (in red) & Coal-fired power plans (in black)

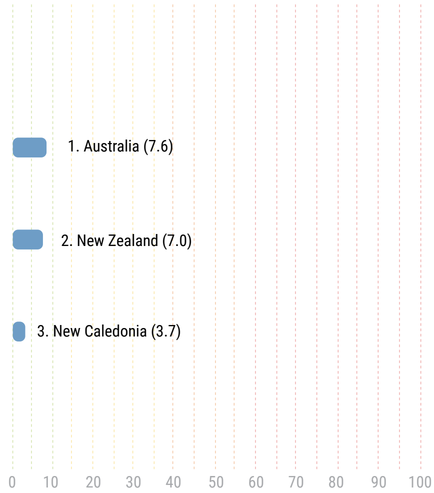
OCEANIA

Australia | New Caledonia | New Zealand

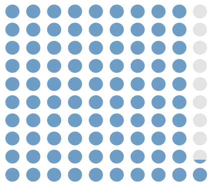


Available cities with real time monitoring in 2020

Country/Region Ranking

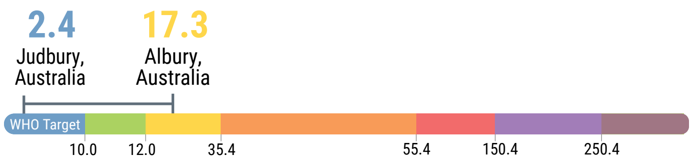


PM2.5 annual mean (μg/m³)



91.3%

Regional cities which met the WHO PM2.5 target in 2020



Range of annual mean PM2.5 (μg/m³) across regional cities

SUMMARY

Oceania is the world's cleanest region for annual mean air quality. However, this region is also susceptible to extreme short-term air pollution events, such as wildfires and dust storms. One of Australia's most devastating fire seasons on record lasted from June 2019 to March 2020. The severity of PM2.5 smoke from the fires peaked between December 2019 and January 2020, affecting the local population and travelling as far as New Zealand and even South America.[88]

Several cities in Australia and New Zealand also experienced heightened PM2.5 levels between May and August; this trend could partly be attributable to higher levels of heating and domestic solid fuel burning during winter.[89] Domestic wood heaters contribute around 50% of PM pollution during winter in Australia.[90]

In the region, 12 cities exceeded the WHO's annual target for PM2.5. The Australian cities of Albury, Canberra, Goulburn, and Wangaratta ranked as the most polluted cities in the region, experiencing PM2.5 levels in January over 10 times higher than the historical average for the month.

Population growth and climate change are both predicted to increase energy and transportation demands as well as intensify drier and hotter conditions, which may foster more intense wildfires and dust storms.

Most Polluted Regional Cities

Rank	City	2020 AVG
1	Albury, Australia	17.3
2	Canberra, Australia	16.4
3	Goulburn, Australia	13.3
4	Wangaratta, Australia	13.0
5	Wagga Wagga, Australia	12.4
6	Blenheim, New Zealand	12.3
7	Armidale, Australia	11.4
8	Churchill, Australia	11.4
9	Masterton, New Zealand	11.2
10	Latrobe, Australia	11.1
11	Beresfield, Australia	10.6
12	Muswellbrook, Australia	10.1
13	Geraldine, New Zealand	10.0
14	Kaiapoi, New Zealand	10.0
15	Orange, Australia	9.9

Least Polluted Regional Cities

Rank	City	2020 AVG
1	Judbury, Australia	2.4
2	St Helens, Australia	2.4
3	Broken Hill, Australia	2.5
4	Bourke, Australia	2.6
5	Emu River, Australia	2.6
6	Brewarrina, Australia	2.9
7	Ouyen, Australia	3.0
8	Dareton, Australia	3.1
9	Grafton, Australia	3.1
10	Fingal, Australia	3.1
11	Gretna, Australia	3.1
12	Mornington, Australia	3.2
13	Cygnet, Australia	3.3
14	Swan Hill, Australia	3.5
15	Cobar, Australia	3.6

MONITORING STATUS

Higher-income countries tend to have denser air quality monitoring networks. However, this trend does not hold for Australia and New Zealand, who are among the wealthiest in the world. This may be attributable to widely dispersed populations and relatively low levels of air pollution year-round.

Some emergency government stations were set up during the 2019/20 bushfires in Australia and have been retained as continuous monitors ever since, attesting to the importance of air quality data during fast-changing emergencies like wildfires.[91]

Of the region's 155 cities with air quality data coverage, 135 are located in Australia. Community-deployed sensors make up 60% of all air quality monitoring in Australia and 55% in New Zealand, significantly expanding the amount of local data available within Oceania.

Next Steps

What can governments do?

Reduce air pollution emissions

- Phase out coal-, gas-, and oil-based energy, as well as waste incinerator facilities.
- Expand clean energy, including the role of renewables like wind and solar.
- Transition government-funded transportation (vehicles, marine vessels, and airplanes) to cleaner energy.
- Introduce comprehensive and affordable public transport as well as safe walking and cycling infrastructure within cities.

Apply more stringent regulations on air pollution sources

- Implement increasingly stringent emission limits, with the goal of phasing out fossil fuels.
- Require the application of new technologies for improving energy efficiency and reducing emissions.
- Develop detailed and urgent strategies for the improvement of air quality which are backed up in law.

Expand government air quality monitoring

- Install public monitoring stations or provide funding support for such to operated by non-governmental organizations to increase the access to real-time air quality information.
- Tighten air quality limits to meet WHO recommendations for not only PM2.5 but also other toxic emissions, with the goal of drastically reducing and eventually eliminating human-made air pollution.

What can I do?

Reduce your pollution exposure

Even in polluted cities, it's possible to reduce your exposure to dirty air:

- Limit outdoor activities and wear a pollution mask during pollution events.
- Reduce polluted outdoor air from leaking indoors during high pollution events by closing doors and windows, and setting, and setting air conditioning (A/C) systems with fresh air intake to their recirculate mode. Use air purification systems where possible.*
- Follow real-time and forecast air quality information to stay prepared for pollution episodes.

**Ventilate indoor spaces by opening windows and A/C systems when air quality improves, even if temporary.*

Lower pollution emissions

Personal choices can help to reduce pollution emissions and improve air quality. Simple and effective means for contributing to a healthier environment include:

- Choose cleaner modes of transport (e.g., cycling, walking, public transport where available).
- Reducing personal energy consumption and waste.
- Helping to raise local air pollution awareness.
- Supporting local and national air quality initiatives.

Become an air quality data contributor

Growing access to public air quality data is a critical first step towards tackling the air pollution problem and mitigating its impact on public health. Accessible air quality data increases both public awareness and demand for action.

Making air quality data accessible empowers people to breath cleaner air.

While the year 2020 saw a significan increase in air quality monitoring stations, an alarming number of global cities are still unrepresented in terms of air quality monitoring. Many of these communities are expected to experience relatively high pollution levels.

Filling global air quality data gaps by way of increased governmental reference monitors and low-cost, non-governmental monitors is urgently needed to empower people everywhere to breathe cleaner air.

Low-cost air quality monitors allow individuals and organizations to contribute hyper-local PM2.5 data that empowers communities to take proactive steps to breathe cleaner air, while also providing researchers and policy advocates with the information they need to make healthy changes for a cleaner planet.

Visit https://www.iqair.com/air-quality-community to find out more.

Methodology

Data sources

All PM2.5 data included in this report was collected by ground-based monitoring stations. 66.6% of stations were operated by governmental agencies, while the remainder represented monitoring stations managed by citizens, communities, non-profit organizations and companies.

While most data was aggregated on an hourly basis as measurements were made publicly available, supplemental historical datasets have been included where possible to increase data coverage and completeness. Historical data from the European Environment Agency (EEA) has been included to provide a fuller dataset where possible in Europe.

Data validation

Both government and low-cost sensors are subject to data anomalies and inaccuracies as a result of sensor defects or temporary hyperlocal emissions near the sensor. In order to mitigate the prevalence and impact of data anomalies on the dataset, IQAir's cloud-based data validation system quarantines data outliers and cross-checks data with nearby sensors and future readings. Data that does not pass the anomaly detection process is discarded.

Data calibration

Low-cost PM2.5 sensors included in this report quantify PM2.5 concentration by sensing the amount of light scatter reflected from a laser beam. Since environmental conditions (including humidity and particle composition) can affect particle size, shape, density, and refractive index (how light is reflected), IQAir calibrates these measurements against government reference monitors, where available, by parameterizing the relationship between impacting variables and optimizing measurements within.

Data calculation

PM2.5 data included in this report is collected from individual monitoring stations. Clusters of stations are then organized into cities by geolocation.

City-level data

City-level data is calculated from the hourly median between stations in the same city. These hourly median values for a city are then used to calculate both the city's monthly and annual mean values, respectively.

Supplemental historical data has been included for locations that otherwise lack available data. Cities with data from both real-time aggregation and supplemental historical records use whichever offers the highest level of data availability over the year, followed by the highest number of stations providing measurements.

Country/region data

Average pollution exposure is calculated for countries and regions using data sampling. Available data is weighted by population in order to estimate average pollution exposure of the residents. As data granularity across countries and regions may vary, this method, while imperfect, can provide a broad global overview and context between countries and regions.

The following calculation is used to estimate a country's/region's average PM2.5 exposure based on the available data and weighted city-sample population:

$$\frac{\Sigma \text{ city mean PM2.5 } (\mu g/m^3) \times \text{City population}}{\text{Total regional population covered by available city data}}$$

Data availability

Only data that met both the report's "yearly availability" and "daily average availability" has been included.

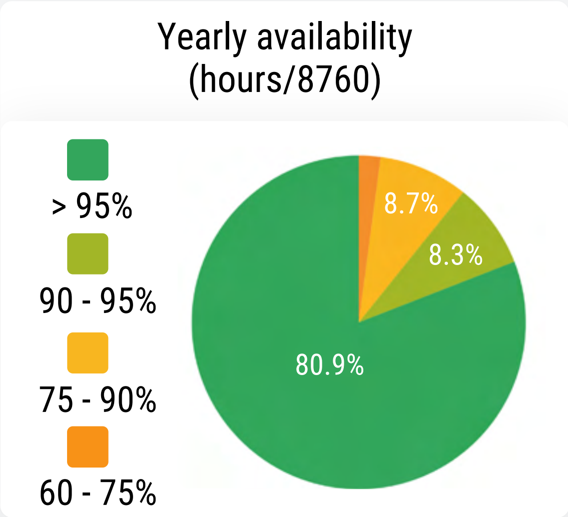
Yearly availability

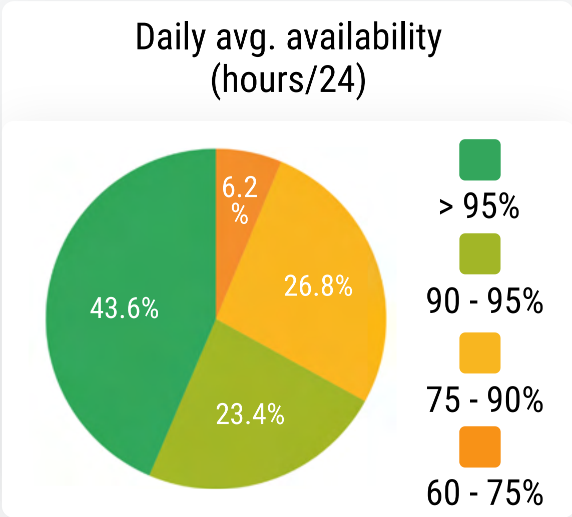
Yearly availability is defined as a percentage of hours of the year (out of 8760 total) that have data availability. For data to be included in this report, data had to have a yearly availability of > 60% (5256 hours of data per city).

Daily average availability

Daily average availability is the average percentage of hours of the day (out of 24 hours total) that have measurements available from those days with at least one reading from at least one station. Cities must have > 60% daily average availability (equivalent to a mean availability of > 14.5 hours of readings per day) to be included in the dataset.

A summary of this dataset's data availability for 2020 is provided below.





Disclaimer

This report includes PM2.5 data collected from global ground-based monitoring stations in 2020. Most of the included data has been aggregated by the IQAir platform in real time. Additional historical datasets have provided supplemental data from governmental sources where available.

Data presented in this report is limited to locations with ground-based monitoring stations. No estimated or satellite data has been included.

We invite feedback and active dialogue related to the information provided.

IQAir is politically independent. Graphs, maps, and content included in this report are intended to expand on the dataset and do not indicate any political stance. Regional maps have been created using OpenStreetMap.

FAQ

Why are some locations (city / country / region) not included in this ranking?

- The area lacks public, ground-based PM2.5 monitoring stations. The report only includes stations or cities where PM2.5 data is measured.
- The area lacks adequate calendar or daily data availability in 2020 to be representative.

Why does the data provided within this report differ from the data provided by my government?

- There are numerous air quality index systems. Often, countries use their own. In order to make direct data comparisons, PM2.5 concentrations in µg/m³ should be the basis.
- There are different ways to calculate city averages over an hour, day, month, and year. This report uses an hourly median value across all stations in a city. Outlier data can have an effect on averages calculated in different ways.
- Data aggregated by the IQAir platform may include more or less stations than provided by a government. For example, governments may have monitoring stations that are either not public or that IQAir did not collect. Alternatively, lower cost monitors provided by independent contributors may not be reflected by a governmental dataset.

Why is the report missing some locations that are available on the IQAir website?

- Monitoring stations may have only recently been added to the IQAir platform and, as a result, did not meet the data availability criteria for 2020.
- Some locations on the IQAir website do not report PM2.5 data. Only locations with PM2.5 data have been included in this report.
- For some global locations that lack ground-level real-time PM2.5 data, the IQAir AirVisual platform includes estimated PM2.5 values marked with an asterisk (*). Estimated data is not included in this report.

Where can I find the complete city ranking of all locations included in the report?

The full air quality data set of the world's most polluted cities has been provided in an interactive format on the IQAir website at https://www.iqair.com/world-most-polluted-cities. This ranking also includes monthly mean values and historical annual mean values.

How precise is the ranking?

The data included in the report is collected from a variety of monitors and data sources. All monitoring stations and collection methods have a degree of error. While the data is checked and validated, some uncertainty remains. For locations (city/country/region) that have similar PM2.5 concentrations, ranking positions should be considered to be indicative rather than absolute.

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About IQAir

IQAir is a Swiss-based air quality technology company that seeks to empower individuals, organizations and communities to breathe cleaner air through information, collaboration and technology solutions.

IQAir's AirVisual global air quality information platform aggregates, validates and calibrates air quality data from a wide variety of sources, including governments, private citizens and organizations. The platform supports the free integration of sensor data from a variety of low-cost sensor and monitoring devices.

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