2021

World Air Quality Report

Region & City PM2.5 Ranking

IQAir®

Contents

About this report

This 2021 World Air Quality Report presents an overview of the state of global air quality in 2021. The report is based on PM2.5 air quality data from 6,475 cities in 117 countries, regions and territories around the world. The data used to create this report was generated by tens of thousands of regulatory and low-cost air quality monitoring stations operated by governments, non-profit organizations, research institutions, educational facilities, companies, and citizen scientists around the world.

The PM2.5 data presented here is reported in units of micrograms per cubic meter (μg/m^3) and utilizes the latest World Health Organization (WHO) annual PM2.5 air quality guideline and interim targets as a framework for data visualization.

The dataset used to generate this report was derived from the IQAir real-time online air quality monitoring platform, which aggregates, validates, calibrates, and harmonizes data from air quality monitoring stations around the globe.

Additional information on real-time and historic air quality conditions in cities, countries, and regions around the world is available on the IQAir website, with a ranking of annual air quality data for 6,475 cities and an **interactive global map of annual city concentrations**.

With these resources, IQAir endeavors to engage, educate, and inspire governments, researchers, NGOs, companies, and citizens to work together to improve air quality and create healthier communities and cities.

Executive summary

Air pollution is now considered to be the world's largest environmental health threat, accounting for seven million deaths around the world every year. Air pollution causes and aggravates many diseases, ranging from asthma to cancer, lung illnesses and heart disease.[1] The estimated daily economic cost of air pollution has been figured at $8 billion (USD), or 3 to 4% of the gross world product.[2]

Air pollution affects those that are most vulnerable the most. It is estimated that in 2021, the deaths of 40,000 children under the age of five were directly linked to PM2.5 air pollution. And in this age of COVID-19, researchers have found that exposure to PM2.5 increases both the risk of contracting the virus and of suffering more severe symptoms when infected, including death.[3]

In September 2021, the World Health Organization (WHO) released a timely and ambitious update to its global air quality guidelines, 15 years after the last update released in 2006. Acknowledging the significant impact of air pollution on global health, the WHO cut the recommended annual PM2.5 concentration by half, from 10 $\mu g/m^3$ down to 5 $\mu g/m^3$, with the ultimate goal of preventing millions of deaths.[4]

IQAir's annual World Air Quality Report aggregates and compares millions of PM2.5 measurements taken in thousands of locations around the world. The data is gathered over the course of the year from a combination of regulatory and non-regulatory ground-based air quality monitors. Although many areas around the world still lack access to publicly available air quality information, global air quality data continued to increase in 2021.

While the 2020 World Air Quality Report included data from 4,745 locations in 106 countries and regions, the 2021 report coverage expanded to 6,475 locations in 117 countries, territories, and regions. This is in part due to the increasing number of low-cost air quality sensors mostly operated by non-profit organizations, governments, and citizen scientists. The increased number of PM2.5 stations helps to create a more accurate picture of hyper-local air quality, and global air quality.

Where does the data come from?

While many other air quality reports and apps report air quality information based on satellite data, this report is generated exclusively from PM2.5 measurements obtained by ground-level monitoring stations. Air quality data was aggregated from regulatory monitoring stations operated by governments as well as privately-owned, non-regulatory stations operated by individuals, educational institutions, and non-profit organizations. Most data employed in the report was collected in real time. When available, supplementary year-end historical data sets were also included to provide the most timely and comprehensive global data analysis possible.

The data from individual stations were combined into "settlements," which can represent a city, town, village, county, or municipality depending on local population patterns and administrative structures. In this report, "settlements" will be hereafter referred to as cities. The data from cities are subsequently population weighted and aggregated to create a regional annual average and ranking.

Why PM2.5?

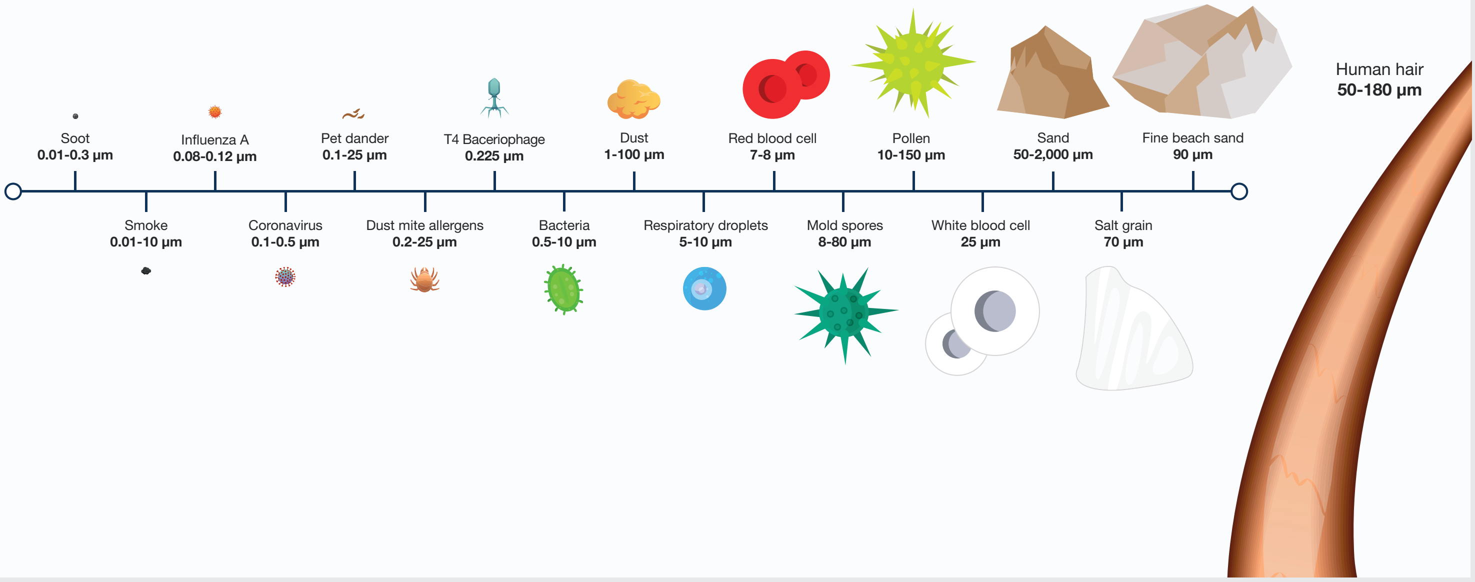
PM2.5 concentrations, in micrograms per cubic meter (μg/m³) were selected as the standard metric for this report. PM2.5, particulate matter consisting of fine aerosol particles measuring 2.5 microns or smaller in diameter, is one of six routinely measured criteria air pollutants and is commonly accepted as the most harmful to human health due to its prevalence in the environment and broad range of health effects.

PM2.5 is generated from many sources and can vary in chemical composition and physical characteristics. Common chemical constituents of PM2.5 include sulfates, nitrates, black carbon, and ammonium. The most common human-made sources include internal combustion engines, power generation, industrial processes, agricultural processes, construction, and residential wood and coal burning. The most common natural sources for PM2.5 are dust storms, sandstorms, and wildfires.

Particulate Size Matters: **Comparing sizes**

Small particles pose the greatest risk to human health. While the nose can filter most coarse particles, fine and ultrafine particles are inhaled deeper into the lungs where they can be deposited or even pass into the bloodstream.

Measurements indicate microns in diameter (μm).



2021 WHO air quality guidelines

There has long been a consensus in the public health and scientific communities of the causal relationship between air pollution exposure and adverse health effects. However, connecting the dots between physically measured air pollution levels, represented in this report as PM2.5 concentrations in micrograms per cubic meter (µg/m³), and the resulting exposure-related health risks requires additional context. In 1987, the World Health Organization (WHO) published its first report on global air quality guidelines.[5] The report documented findings of a comprehensive review and analysis of the available information from scientific studies linking air pollution levels and quantified risks of adverse health outcomes. The guidelines were crafted as a tool providing quantitative, evidence-based health information on the burden of disease caused by air pollution. The goal of the guidelines is to assist policymakers around the world in crafting air quality legislation and emissions standards to levels that meaningfully reduce the public health risks posed by air pollution. Since 1987, the guidelines have been periodically updated as new research has become available, and in September 2021,15 years after the last update was released in 2006, the WHO released the latest edition of the global air quality guidelines.[4]

How are the guidelines determined?

Work to produce the 2021 WHO global air quality guidelines began in 2016. WHO organizers administered the collaborative process by forming a global team of subject matter experts in fields including health effects of air pollution; air pollution emissions and atmospheric chemistry; health economics; vulnerable groups, equity, and human rights; policy implications; and methodology and guideline development. These experts worked together to review the available scientific information linking exposure to specific components of indoor and outdoor air pollution and adverse health effects. Once the information was compiled and assessed, the recommended guidelines were determined as the threshold pollutant concentration above which there is an increased potential for adverse health effects, independent of the microenvironment.

New research findings informing the 2021 WHO guidelines

Evidence compiled from the last 20 years of research has more clearly quantified the impact severity of air pollution on human health, a factor now known to have been previously significantly underestimated. A systematic study analyzing the global burden of disease conducted in 2019 found that air pollution, from both indoor and outdoor sources, accounted for approximately 12% of deaths that year, ranking it as the fourth major risk factor for global disease and mortality.[6] Results from the most recent studies quantifying the correlation between air pollution levels and adverse health risks have indicated that exposure to even low levels of air pollution can result in harmful health effects, concluding that there is no level at which exposure to PM2.5 could be deemed safe.[7,8,9]

2021 PM2.5 air quality guideline

Acknowledging the severity of the impact of air pollution on global health and the non-trivial risk of adverse effects present at low pollution concentrations, the recommended level for the 2021 PM2.5 annual guideline was cut by half, dropping the 2005 guideline level of 10 µg/m³ down to 5 µg/m³. In many areas of the world with exceedingly high air pollution concentrations, achieving this guideline level is not immediately feasible. For these cases, incremental step goals of 10, 15, 25, and 35 µg/m³ were recommended for use in guiding the creation of air pollution reduction plans in highly polluted regions capable of being accomplished in realistic timelines.

Data presentation

Data for this report is presented within the context of the WHO recommended annual air quality guideline levels and interim targets for PM2.5. These guidelines help to determine which cities and regions are most in danger from the health risks of PM2.5 in the hopes that they implement stricter policies to help lower those risks.

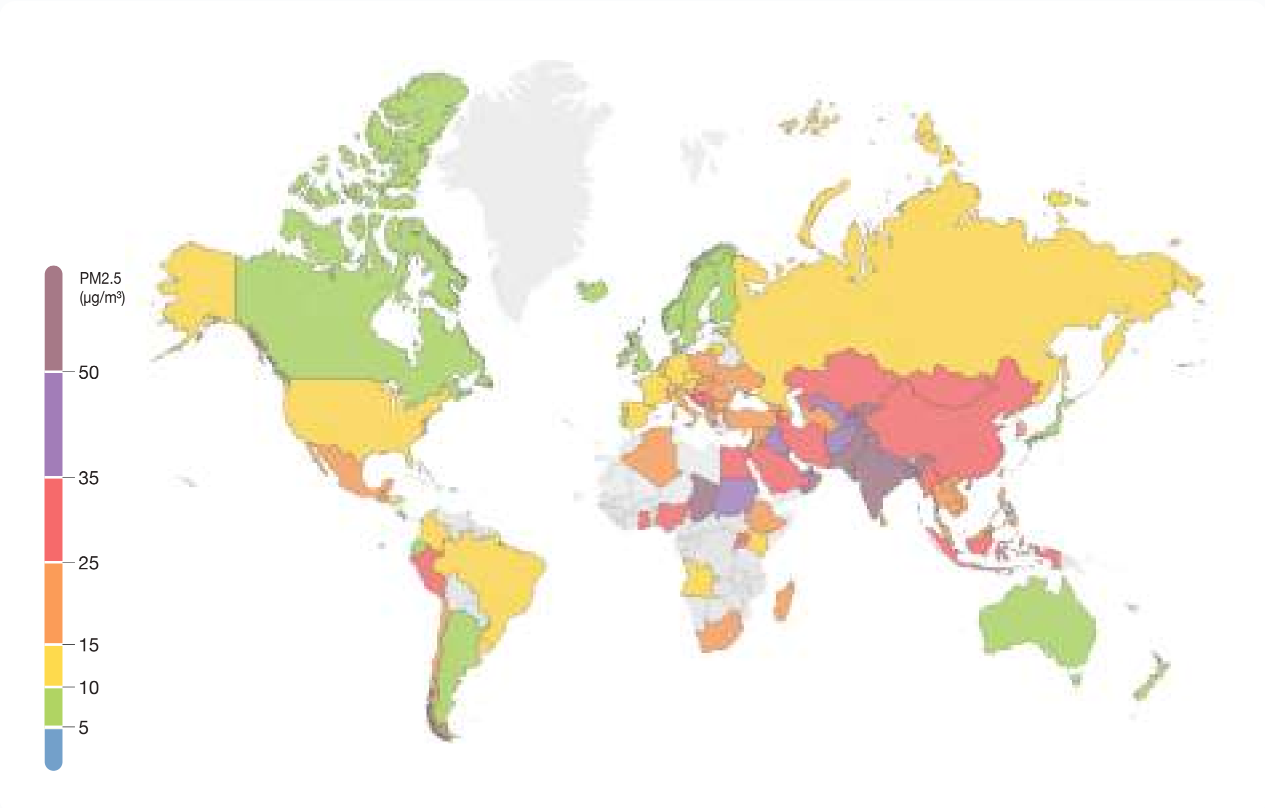
This report uses seven color bands to provide an easy identification of multiples of the 5 μg/m³ WHO PM2.5 guideline, and the interim target levels.

2021 World Air Quality Report visualization framework

Annual PM2.5 breakpoints based on 2021 WHO guideline and interim targets	PM2.5	Color code	WHO levels
Meets WHO PM2.5 guideline	0-5 (μg/m³)	Blue	Air quality guideline
Exceeds WHO PM2.5 guideline by 1 to 2 times	5.1-10 (μg/m³)	Green	Interim target 4
Exceeds WHO PM2.5 guideline by 2 to 3 times	10.1-15 (μg/m³)	Yellow	Interim target 3
Exceeds WHO PM2.5 guideline by 3 to 5 times	15.1-25 (μg/m³)	Orange	Interim target 2
Exceeds WHO PM2.5 guideline by 5 to 7 times	25.1-35 (μg/m³)	Red	Interim target 1
Exceeds WHO PM2.5 guideline by 7 to 10 times	35.1-50 (μg/m³)	Purple	Exceeds target levels
Exceeds WHO PM2.5 guideline by over 10 times	>50 (μg/m³)	Maroon	Exceeds target levels

While World Air Quality Reports from previous years utilized the U.S. AQI as a tool to communicate health risks associated with PM2.5 exposure, data visualization for this year's report is based on the WHO annual guideline value and interim targets. The U.S. AQI was calibrated to convey information about health risks associated with exposure to multiple pollutants over the period of a day.[10,11] The PM2.5 concentration values reported here are based on an averaging period of a year, rather than a single day. As such, it is deemed more appropriate to use the WHO annual guideline and interim target levels as a framework for data visualization.

2021 Global PM2.5 Map



2021 global map color coded by annual average PM2.5 concentration

Countries and regions in East Asia, Southeast Asia, and South Asia suffered from the highest annual average PM2.5 concentration weighted by population. Notably, the African continent had only 13 out of 54 countries with sufficient public air quality monitoring data, resulting in a majority of countries showing in gray. Additionally, the Latin America and Caribbean region also lacked sufficient monitoring.

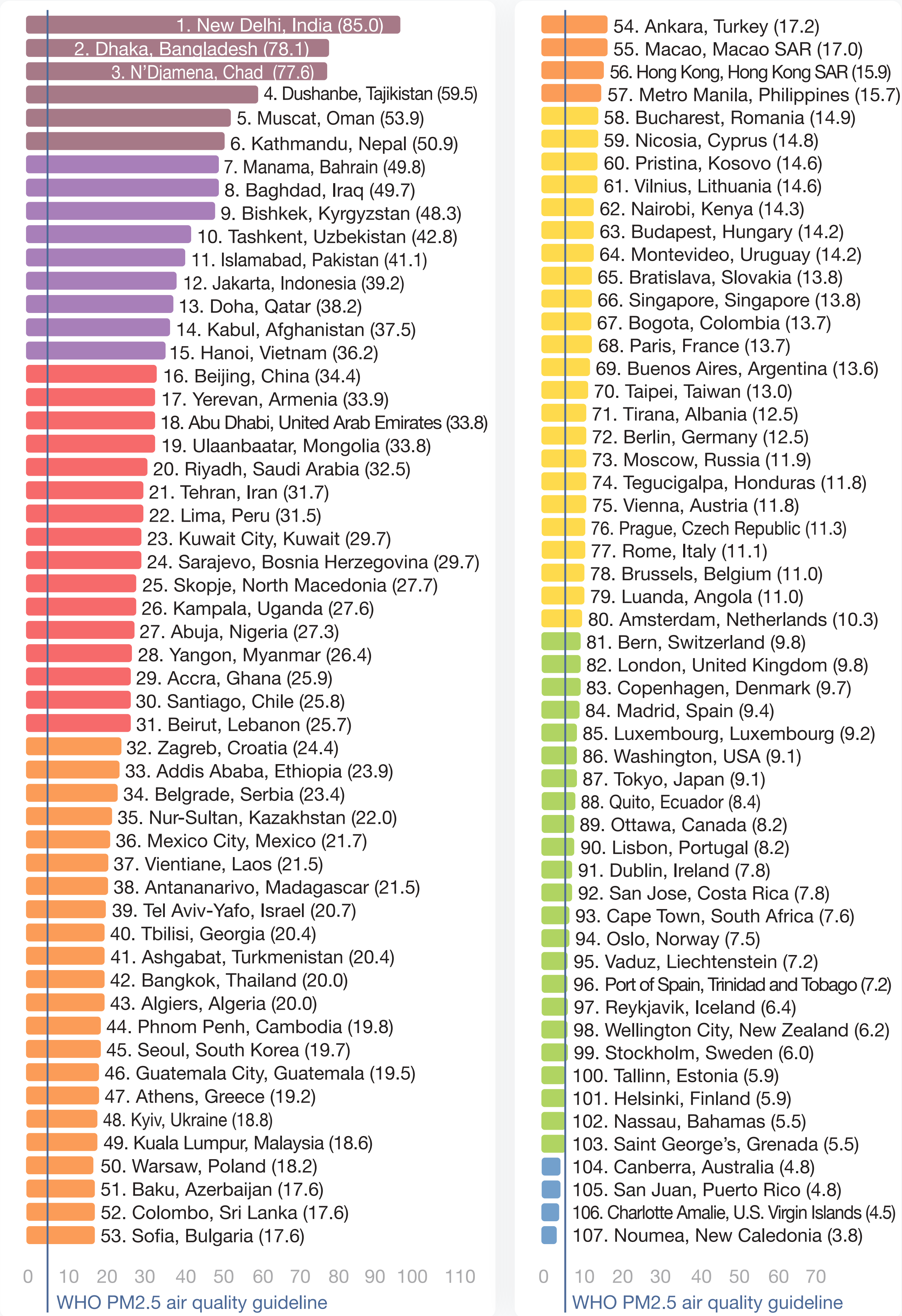
2021 Country/region ranking

Population weighted, 2021 average PM2.5 concentration (µg/m³) for countries, regions, and territories in descending order

Rank	Country/region	PM2.5
1	Bangladesh	76.9
2	Chad	75.9
3	Pakistan	66.8
4	Tajikistan	59.4
5	India	58.1
6	Oman	53.9
7	Kyrgyzstan	50.8
8	Bahrain	49.8
9	Iraq	49.7
10	Nepal	46.0
11	Sudan	44.1
12	Uzbekistan	42.8
13	Qatar	38.2
14	Afghanistan	37.5
15	United Arab Emirates	36.0
16	Montenegro	35.2
17	Indonesia	34.3
18	Nigeria	34.0
19	Armenia	33.9
20	Mongolia	33.1
21	Saudi Arabia	32.7
22	China	32.6
23	Kazakhstan	31.1
24	Iran	30.3
25	Kuwait	29.7
26	Peru	29.6
27	Egypt	29.1
28	Bosnia Herzegovina	27.8
29	Uganda	27.6
30	Ghana	25.9
31	Myanmar	25.9
32	Lebanon	25.7
33	Serbia	25.5
34	North Macedonia	25.4
35	Croatia	25.3
36	Vietnam	24.7
37	Ethiopia	23.9
38	Syria	23.0
39	South Africa	22.7
40	Chile	21.7
41	Laos	21.5
42	Georgia	21.0
43	Madagascar	21.0
44	Turkmenistan	20.4
45	Thailand	20.2
46	Turkey	20.0
47	Algeria	20.0
48	Cambodia	19.8
49	Guatemala	19.5
50	Malaysia	19.4
51	Mexico	19.3
52	Poland	19.1
53	Greece	19.0
54	South Korea	18.9
55	Israel	18.7
56	Ukraine	18.5
57	Azerbaijan	17.6
58	Sri Lanka	17.4
59	Macao SAR	17.0
60	Bulgaria	16.3
61	Taiwan	16.2
62	Slovakia	16.0
63	Hong Kong SAR	15.9
64	Philippines	15.6
65	Hungary	15.5
66	Romania	15.3
67	Italy	15.2
68	Cyprus	14.8
69	Kosovo	14.7
70	Kenya	14.3
71	Uruguay	14.2
72	Colombia	14.1
73	Czech Republic	13.9
74	Singapore	13.8
75	Brazil	13.6
76	Malta	13.5
77	Slovenia	13.3
78	Lithuania	13.2
79	Albania	12.5
80	Russia	12.3
81	Honduras	11.8
82	Belgium	11.5
83	Austria	11.4
84	France	11.4
85	Netherlands	11.3
86	Angola	11.0
87	Switzerland	10.8
88	Spain	10.7
89	Germany	10.6
90	USA	10.3
91	Denmark	9.6
92	Japan	9.1
93	Luxembourg	9.0
94	United Kingdom	8.8
95	Canada	8.5
96	Ecuador	8.4
97	Argentina	8.2
98	Ireland	8.0
99	Costa Rica	7.8
100	Norway	7.5
101	Andorra	7.3
102	Liechtenstein	7.2
103	Trinidad and Tobago	7.1
104	Portugal	7.1
105	New Zealand	6.8
106	Sweden	6.6
107	Iceland	6.1
108	Estonia	5.9
109	Australia	5.7
110	Bahamas	5.5
111	Grenada	5.5
112	Finland	5.5
113	Saba	5.1
114	Cape Verde	5.1
115	Puerto Rico	4.8
116	U.S. Virgin Islands	4.5
117	New Caledonia	3.8

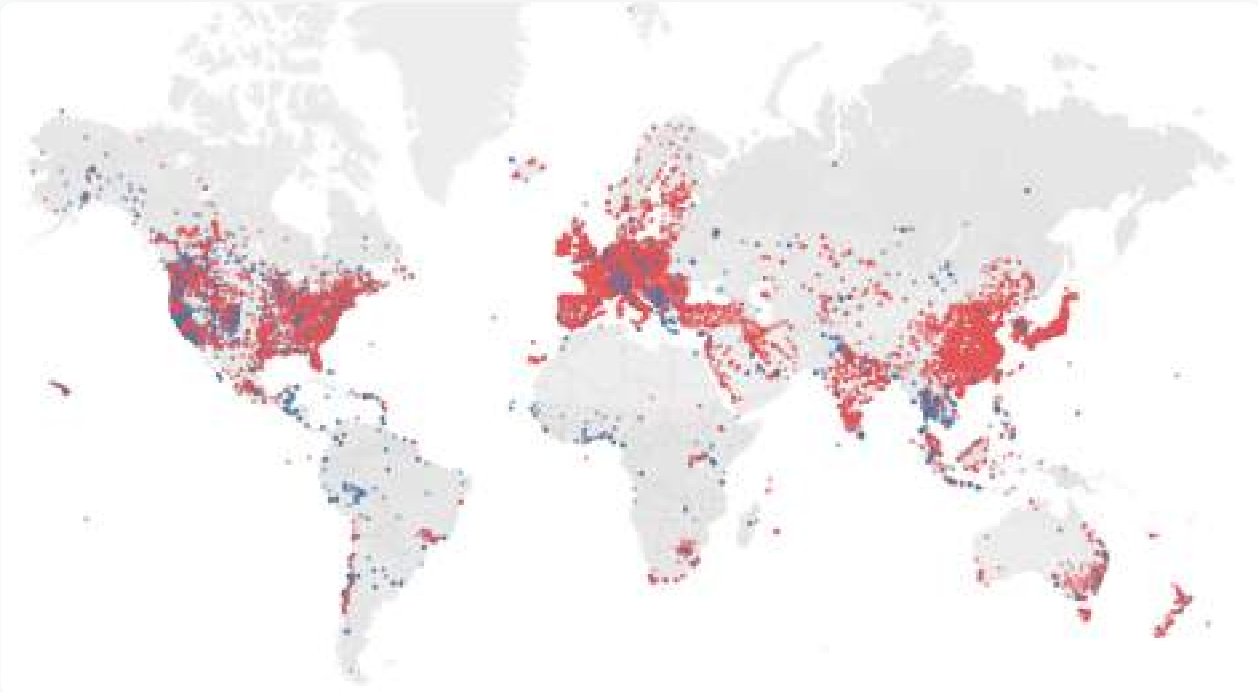
2021 Capital city ranking

Average annual PM2.5 concentration (µg/m³) for regional capital cities in descending order



Overview of public monitoring status

Global distribution of PM2.5 monitoring stations



Distribution of global PM2.5 air quality monitoring stations that contributed data to this report. Government stations are shown in red. Independently operated monitoring stations are shown in blue.

Publicly available air quality monitoring station data continued to increase in 2021. India, New Zealand, and Canada, in particular, saw significant increases.

Government air quality monitoring networks continue to be most commonly found in China, the United States, Japan, and in Europe.

It should be noted that developed countries have a higher density of air quality monitoring stations than developing countries and regions. Latin America, Africa, and Central Asia remain sparsely monitored, despite the high population density in many of these regional areas.

Given the low cost point, ease of deployment, and significant reduction in operational costs, low-cost air quality monitors are increasingly becoming a viable public alternative to those countries, regions, and territories that lack government-operated air quality monitoring stations. In 2021, non-governmental low-cost air quality monitoring provided the only real-time air quality data for Albania, Angola, Azerbaijan, the Bahamas, Belize*, Benin*, Bermuda*, Cambodia, Cameroon*, Cape Verde, Democratic Republic of the Congo*, Dominican Republic*, Egypt, Ethiopia, French Polynesia*, Gambia*, Grenada, Guam, Guyana*, Honduras, Jamaica*, Jersey*, Lebanon, the Maldives*, Moldova*, Morocco*, Nicaragua*, Niger*, Panama*, Qatar, the Republic of the Congo*, Rwanda*, Saba, Senegal*, Sierra Leone*, South Sudan*, Suriname*, Timor-Leste*, Togo*, Uruguay, U.S. Virgin Islands, Venezuela*, Zambia*, and Zimbabwe*.

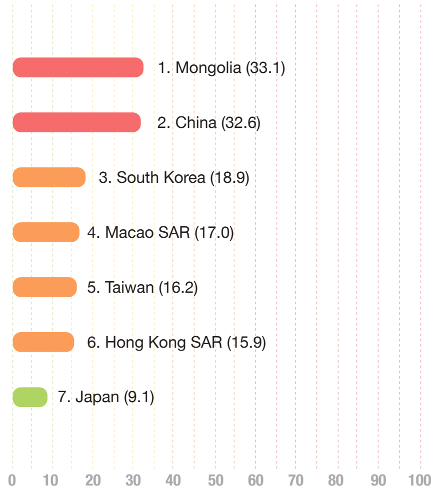
**Cities in these countries did not meet the required limit of 60% annual data availability and were therefore excluded from the report.*

EAST ASIA

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

City markers indicating 2021 PM2.5 levels, size adjusted for population

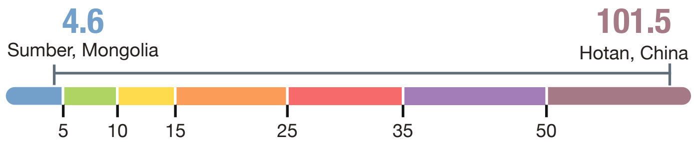
Country/Region Ranking



2021 PM2.5 average (µg/m³)

0.1%

Regional cities that met the WHO PM2.5 guideline in 2021



Range of 2021 average PM2.5 (µg/m³) across regional cities

Most Polluted Regional Cities

Rank	City	2021
1	Hotan, China	101.5
2	Kashgar, China	83.2
3	Shihezi, China	55.7
4	Linfen, China	55.5
5	Puyang, China	52.8
6	Hebi, China	51.4
7	Aksu, China	51.2
8	Anyang, China	50.8
9	Xiangyang, China	50.6
10	Changji, China	49.8
11	Luohe, China	49.7
12	Turpan, China	49.6
13	Zibo, China	49.2
14	Heze, China	48.5
15	Yuncheng, China	48.4

Least Polluted Regional Cities

Rank	City	2021
1	Sumber, Mongolia	4.6
2	Ogasawara, Japan	5.3
3	Minami Ward, Japan	5.3
4	Kushiro, Japan	5.5
5	Chonogol, Mongolia	5.6
6	Tsukisamuchūodori, Japan	5.7
7	Tanabe, Japan	5.8
8	Rishiri, Japan	5.9
9	Minamiaizu, Japan	5.9
10	Okinawa, Japan	6
11	Gero, Japan	6.3
12	Hitachi, Japan	6.3
13	Rikaze, China	6.3
14	Nasushiobara, Japan	6.3
15	Hirosemachi, Japan	6.4

SUMMARY

The region of East Asia included data from 1,347 cities. Of these cities, 143, or about 11%, had annual average PM2.5 concentrations greater than seven times WHO's PM2.5 guideline of 5 µg/m³. All 143 cities were located in China. The Chinese city of Hotan was the region's most polluted city, with an annual average PM2.5 concentration of 101.5 µg/m³, over 20 times the WHO guideline value. The city of Handan, China showed the region's greatest reduction in absolute PM2.5 concentration, dropping from a 2020 average of 58.9 to 45.6 µg/m³ in 2021. Japan continues to be the regional country with the best air quality in terms of PM2.5 concentrations, with a 7% reduction in 2021 compared to 2020. Of the 529 Japanese cities reporting data in both 2020 and 2021, 81% have seen air quality improvements. Ogasawara and Minami Ward had Japan's best air quality with an annual PM2.5 concentration of 5.3 µg/m³. Tanabe, Japan improved its last year average by over 35%, dropping from a 2020 concentration of 9.0 µg/m³ to a 2021 concentration of 5.8 µg/m³. Besides Japan, the Mongolian towns of Sumber and Chonogol were the least polluted in the region.

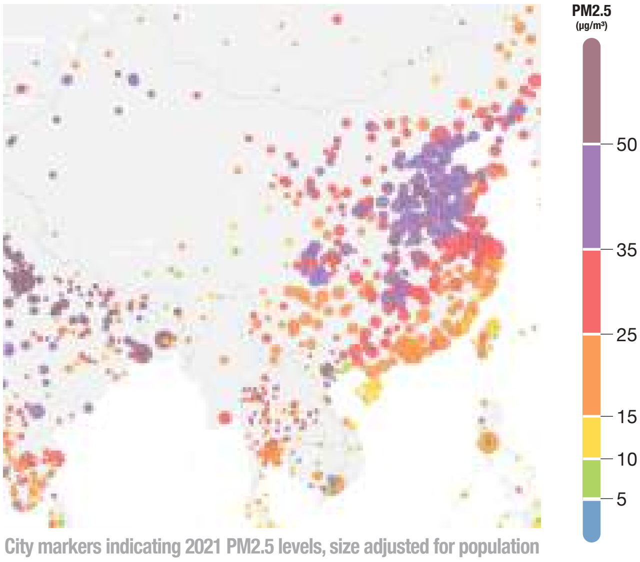
In South Korea, air quality improved in 60% of cities reporting data in both 2020 and 2021. Some of the primary contributors of PM2.5 in the region include coal-based energy production, industrial activity, gas and diesel-powered transportation, and household heating.

MONITORING STATUS

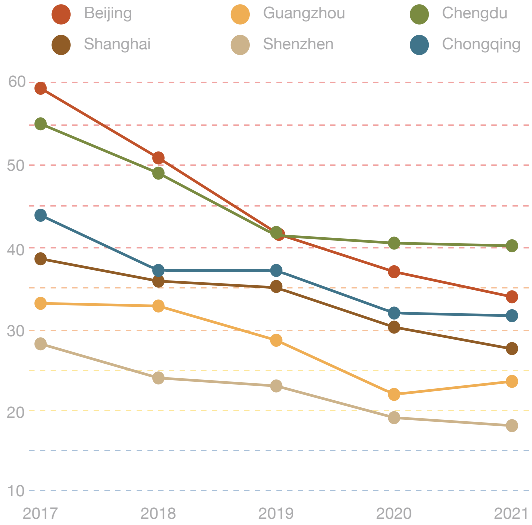
Government-operated air quality monitoring stations in China, Japan, and South Korea provide East Asia with an extensive network of air quality monitors, resulting in some of the most comprehensive air quality monitoring coverage in the world. Regionally, China has the largest air quality monitoring network in terms of land mass monitored. However, in terms of station density, Japan's network provides the highest monitoring resolution.

In 2021, regional air quality monitoring was expanded to include 114 new cities, primarily located in China (86) and Japan (24).

CHINA



City markers indicating 2021 PM2.5 levels, size adjusted for population



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

City	2021	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2020
Beijing	34.4	39.8	62.7	83.1	33.2	25.1	18.5	15.8	19	19.3	26.2	44.5	27.5	37.5
Chengdu	40.3	75.5	61	48.5	27.9	36.8	31.1	21.5	19.1	18.8	23.5	50	63.6	40.5
Chongqing	31	64.1	51.8	30.7	24.3	24	19.6	15	14.4	15.8	21.3	40.4	52.5	31.7
Guangzhou	24.4	47.3	28.4	30	26.1	16.3	15.2	15.8	15.7	21.8	20.1	25	31.4	22.6
Shanghai	27.7	39.1	29.3	36.5	31.1	30	22.6	17	17	18.5	16.4	30.8	43.1	31.5
Shenzhen	17.9	35.3	18.8	18.4	18.2	9.6	10	10.3	10.6	14.9	16.4	23.2	26.3	19

PROGRESS

Air quality in China continued to improve in 2021, with data from 66% of Chinese cities showing decreased PM2.5 concentrations compared to 2020. In 2021, air pollution in the capital city of Beijing continued a five-year trend in PM2.5 reductions and marked the first time the city achieved its own air pollution targets.[12] Since 2018, China overall has seen a 21% reduction in annual PM2.5 concentrations. However, no Chinese city included in this report met the revised WHO PM2.5 guidelines of 5 µg/m³. Hotan was the country's most polluted city for the second consecutive year and exceeded WHO guidelines by over 20 times.

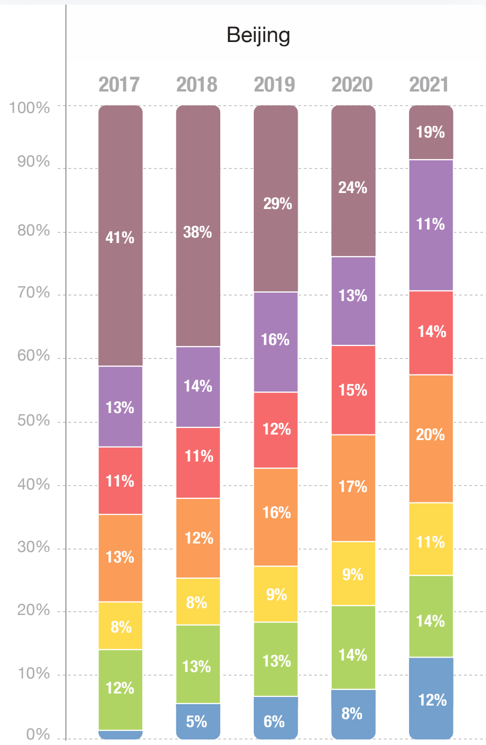
CHALLENGES

China is the world's largest producer and consumer of coal, and coal remains one of the most significant sources of PM2.5 pollution in China along with industrial sources and motor vehicle emission.[13] Coal is used to produce as much as 60% of the country's electricity. The government has pledged to reduce coal usage for electricity generation by 1.8% before the year 2025, but coal continues to be a significant environmental and health hazard in China.[14]

HIGHLIGHT: SANDSTORMS

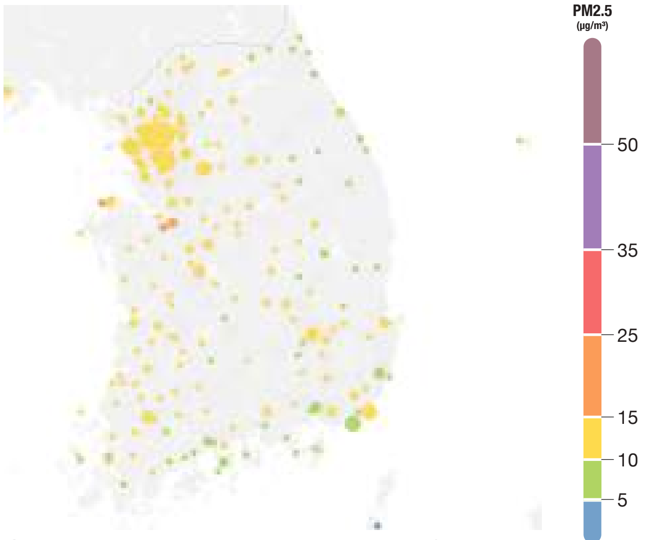
Seasonal sandstorms due in part to desertification fueled by climate change and other factors continue to raise PM2.5 levels in Northern China. In March of 2021, Northern China was hit with the strongest sandstorms in a decade, causing the city of Beijing's sky to turn yellow with dust. The sky discoloration was an indicator of PM2.5 concentrations at ten times the WHO's recommended daily limit.

Primarily affecting cities close to the Gobi Desert, sandstorms have raised PM2.5 pollution as high as 20 times the levels deemed to be healthy, causing significant loss of property and even the loss of life.[15] Every year, sandstorms aerosolize 800 million tons of sand in this region.

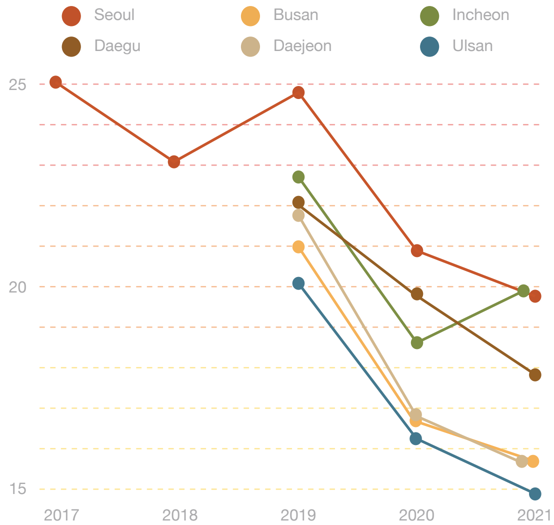


Annual hours spent at different AQI levels

SOUTH KOREA



City markers indicating 2021 PM2.5 levels, size adjusted for population



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

City	2021	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2020
Seoul	19.7	21.1	29.4	31.1	18.5	19.4	19.5	15.6	13.2	7.1	13.4	26.3	22.7	20.9
Busan	15.6	18.6	21	21.7	15.8	19.9	15.3	9.4	9.9	7.8	12.3	17.9	18.6	16.7
Daegu	17.8	21.2	23.5	22.4	16.5	17.5	20.1	10.5	11.6	9.8	15.2	22.4	22.7	17
Daejeon	15.6	17.4	21	21.1	14.2	16.7	17.3	9	9.5	7.7	14.3	19	20.5	16.9
Incheon	19.9	19.4	27	31.9	18.2	19.2	22	17.5	13.1	8.3	13.8	25.4	23.6	22.1
Ulsan	14.9	16.6	20.2	20.3	16	16.6	16.9	9.7	10.6	7.7	11.4	16.8	16.3	16.3

PROGRESS

South Korea continues the trend of reducing annual average PM2.5 concentrations, dropping from 19.5 μg/m³ in 2020 to 19.1 μg/m³ in 2021. None of the South Korean cities in the 2021 report met the WHO PM2.5 annual guideline. The city of Gangneung has shown significant improvement over the past 4 years, with over a 50% reduction in PM2.5 concentration between 2017 and 2021 from 24.6 to 11.0 μg/m³. Cheonan had the highest PM2.5 concentration at 28.1 μg/m³ and was one of the top 20 most populated cities in the country.

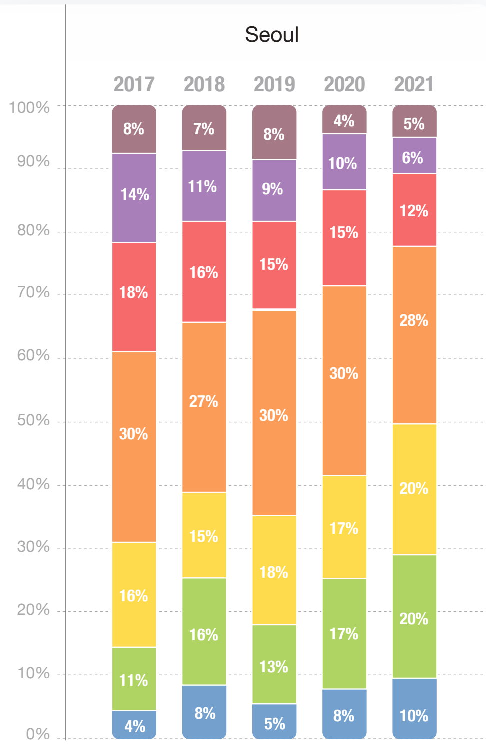
South Korea has many green incentives and helps finance sustainability research and development.[16] As of 2015, South Korea's energy supply was 65% coal and oil, 31% nuclear, and 2% hydro, but recent policies created the National Strategy for Green Growth, which incentivizes renewable energy. South Korea also imposed taxes to disincentivize nonrenewable energy use, such as a 25% coal import tax.

CHALLENGES

South Korea experiences increased air pollution around the capital city of Seoul and areas with high concentrations of manufacturing and industrial sites, as well as sand and dust storms from the Gobi Desert.[17] These dust storms have become more frequent and extreme, because of drought and increasing temperatures due to climate change.[17]

HIGHLIGHT: SEA FOG TEMPERATURE INVERSIONS

The Yellow Sea, plays a significant role in atmospheric and environmental conditions across the Korean Peninsula. Sea fog forms due to temperature inversions over the Yellow Sea. Studies have shown that sea fog facilitates the transport of air pollutants from East Asia to the Korean Peninsula, and that chemical reactions occurring in the sea fog create new aerosols. These factors have been shown to result in increased PM2.5 concentrations not only along South Korea's western coast, but even further inland in the Seoul Metropolitan Area.[18,19]

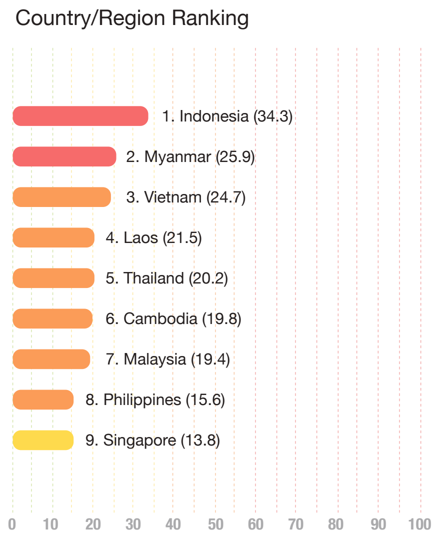


Annual hours spent at different PM2.5 pollution levels

SOUTHEAST ASIA

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

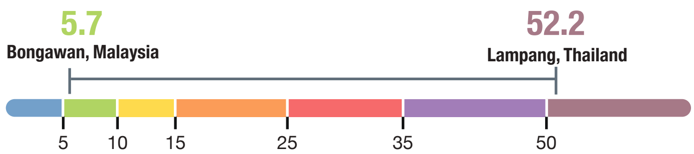
City markers indicating 2021 PM2.5 levels, size adjusted for population



2021 PM2.5 average (µg/m³)

0.4%

Regional cities that met the WHO PM2.5 guideline in 2021



Range of 2021 average PM2.5 (µg/m³) across regional cities

Most Polluted Regional Cities

Rank	City	2021
1	Lampang, Thailand	52.2
2	Pai,Thailand	47.1
3	Thanh Pho Thai Nguy-en, Vietnam	40.8
4	Nan, Thailand	39.5
5	Cho Lon, Vietnam	39.3
6	Jakarta, Indonesia	39.2
7	Klang, Malaysia	38.2
8	Pho Moi, Vietnam	36.9
9	Warin Chamrap, Thailand	36.2
10	Hanoi, Vietnam	36.2
11	Surabaya, Indonesia	34.8
12	Phra Samut Chedi, Thailand	33.7
13	Bandung, Indonesia	33.4
14	Petaling Jaya, Malaysia	32.5
15	Phrae, Thailand	31.7

Least Polluted Regional Cities

Rank	City	2021
1	Bongawan, Malaysia	5.7
2	Samarinda, Indonesia	6.2
3	Tawau, Malaysia	7.1
4	Kapit, Malaysia	7.1
5	Banda Aceh, Indonesia	7.3
6	Mukah, Malaysia	7.7
7	Limbang,Malaysia	7.8
8	Sandakan, Malaysia	7.9
9	Putatan, Malaysia	8.1
10	Sibu, Malaysia	8.4
11	Kota Samarahan, Malaysia	8.4
12	Sri Aman, Malaysia	8.5
13	Kuching, Malaysia	8.9
14	Sarikei, Malaysia	9.7
15	Kuah, Malaysia	9.9

SUMMARY

Rapid population growth and the accompanying economic development have been significant factors contributing to increased air pollution in Southeast Asia. Oil and coal are the biggest sources of fuel in the power sector, and with the demand for electricity expanding at a rate of approximately 6% per year, the combustion of fossil fuels is a primary contributor to PM2.5. Other PM2.5 sources in urban areas include construction, industrial emissions, and transportation. Rural PM2.5 emission sources include open burning practices used to manage farmland and clear forests.

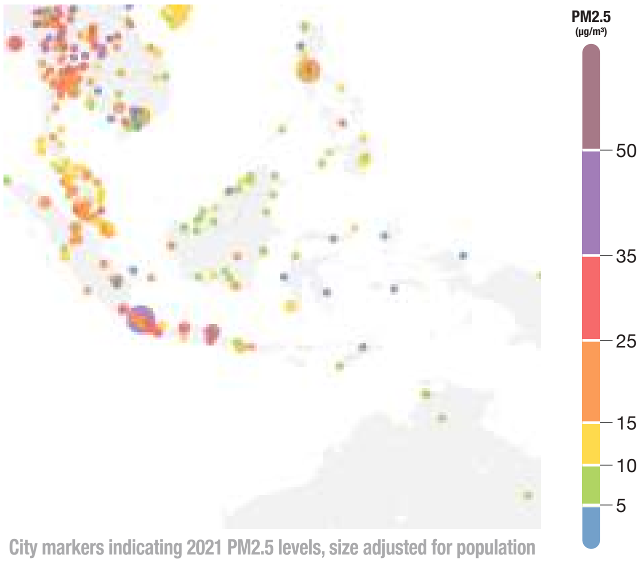
Most countries in the region have laws against open burning. However, due to a lack of enforcement, the practice continues to remain widespread. Open burning is estimated to contribute as much as 5 - 30% of the total human-made emission inventory in Southeast Asia.[20] The practice adds to the transboundary movement of air pollutants, creating seasonal air pollution cycles in the countries of Singapore and Malaysia. Human-made changes in land use through deforestation and agriculture have intensified wildfires, another key source of regional pollution.[21]

Regional PM2.5 levels dropped by about 5% from 2020 to 2021. This reduction was driven by six countries showing improved air quality in 2021 and led by Indonesia with a 16% reduction in annual PM2.5 concentrations. Despite the improvements, Indonesia continues to be the region's most polluted country (ranked 17th globally) with a 2021 PM2.5 annual concentration over 30% greater than the region's second ranked country of Myanmar (ranked 31st globally). Interestingly, the three least polluted regional countries, Malaysia, Philippines, and Singapore showed the most significant increases in PM2.5 concentrations in 2021, with relative increases of 24%, 22%, and 17% respectively compared to 2020.

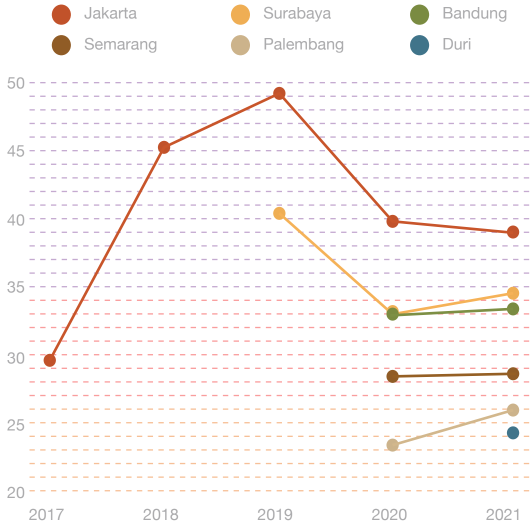
MONITORING STATUS

Non-governmental organizations and individuals operate about two-thirds of the region's air quality monitoring stations. Thailand's government operates the region's largest air quality monitoring network encompassing 113 cities, none of which were able to meet the WHO PM2.5 guideline in 2021. Two of the top 10 populated cities in the region, Jakarta and Hanoi, had annual average PM2.5 concentrations that exceed the PM2.5 WHO air quality guideline by more than seven times.

INDONESIA



City markers indicating 2021 PM2.5 levels, size adjusted for population



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

City	2021	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2020
Jakarta	39.2	27.9	24.3	36.2	41	45.3	54.5	57.2	46.4	39.8	43.5	23.8	29.7	39.6
Surabaya	34.8	24.5	25.2	41.9	38.9	32.4	37.2	38.6	32.9	27.7	42.9	41.6	24.1	33.4
Bandung	33.4	19.6	21.1	32.6	35	39.3	42	39	33.5	29.6	41.7	29.1	34.7	33.2
Semarang	28.6	23.2	16.2	31.7	26.5	25.9	22.3	39.3	27.7	26.2	35.6	31.8	32.8	28.5
Palembang	26	25.6	29.3	27.6	30.5	23.6	25.6	24.5	23.4	23.1	34.4	24.1	22	23.4
Makassar	13.5	6.8	6.4	No Data	16.8	14.3	14.2	17.8	16.1	16.1	16	9.2	8.6	14.6

PROGRESS

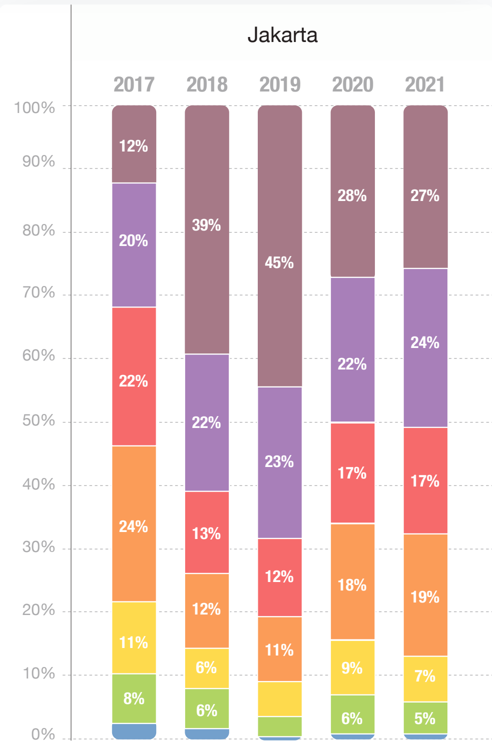
Overall air quality in Indonesia has improved from an average PM2.5 concentration of 40.7 µg/m³ in 2020 to 34.3 µg/m³ in 2021. However, persistently poor air quality in the country's most populous cities continues to endanger the health of residents. The worst air quality in 2021 was measured in the capital city of Jakarta. Jakarta's 2021 annual average PM2.5 concentration was 39.2 µg/m³, a level exceeding the WHO guideline by more than seven times, as well as exceeding all WHO interim targets. Makassar, Indonesia's fifth largest urban center, saw an 8% reduction in PM2.5 concentrations. Of the six most populated cities in Indonesia reported here, only Makassar recorded significant PM2.5 reductions in 2021. The countrywide PM2.5 concentration reductions resulted from significant reductions in the lesser populated cities of Bogor, Pekanbaru, and Denpasar. There was little to no improvement in air quality between 2020 and 2021 for Indonesia's most populated cities like Jakarta, Bandung, and Semarang.

CHALLENGES

Poor air quality in Indonesia is a relatively recent phenomenon. Prior to 2013, estimated PM2.5 annual average concentrations remained below 15 µg/m³.[22] Increases in PM2.5 concentrations accelerated dramatically in 2016, with levels peaking in 2019 at 51.7µg/m³. In 1999, the Indonesian government enacted air quality regulation policies establishing the initial air quality standards and emissions limits for motor vehicles and industrial sources.[23] However, existing regulatory policies are now both outdated and inadequate to protect the public health in Indonesia's key cities. Examples of ineffective policy include those around burning practices for waste management and forest clearing. Though open burning was prohibited by the 1999 Forestry Law, both practices remain commonplace. Activist lawsuits culminated in a September 2021 decision by the Central Jakarta District Court that President Joko Widodo, members of his cabinet, and three provincial governors were guilty of negligence by failing to combat Jakarta's air pollution.[24] In 2021, the Indonesian government revised the national air quality standards (Govt Reg No. 22/2021) lowering the annual PM2.5 concentration limit to 15µg/m³.[25]

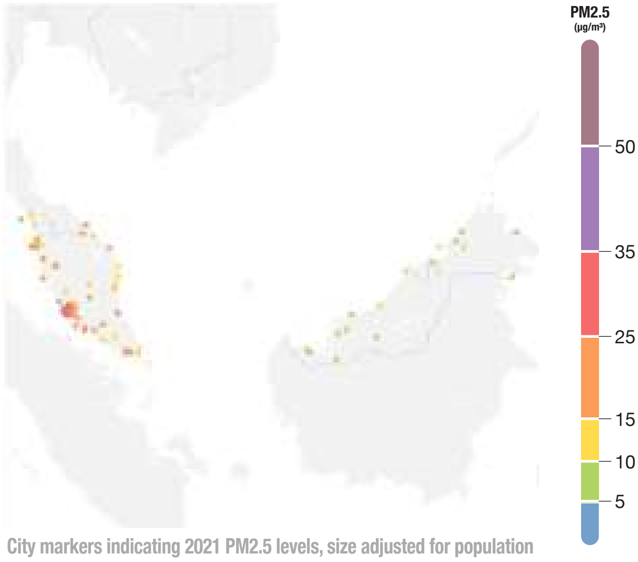
HIGHLIGHT: OPEN BURING PRACTICES

Open burning is still very common in Indonesia despite policies countering the practice. Much of the land in Indonesia has been cleared by open burning to replace forestland with cash crops.[26] Continued forest logging causing flammable dry land in the province of Riau has resulted in the region containing the most vegetation fires in the country, with 60% of the country's total.[27] Wildfires in the country are increasing in frequency and extremity, and these short-term exposures to extreme pollution levels are associated with both short- and long-term health problems.

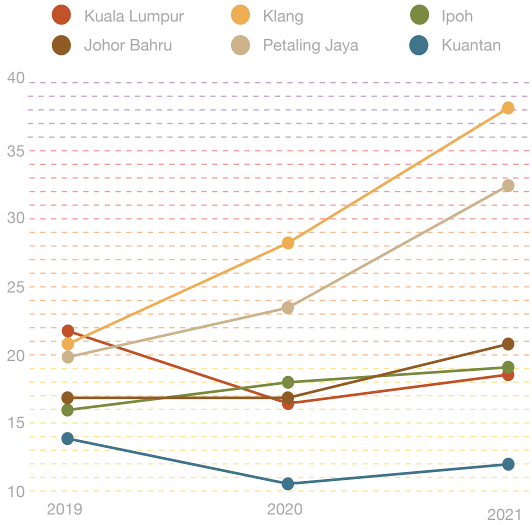


Annual hours spent at different PM2.5 pollution levels

MALAYSIA



City markers indicating 2021 PM2.5 levels, size adjusted for population



PM2.5 annual average (µg/m³) over 3 years

City	2021	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2020
Kuala Lumpur	18.6	14.6	20.8	22.8	21.4	22	18.8	20.5	15.9	17.4	16.9	14.6	17.2	16.5
Klang	38.2	31.2	40.6	37	33.7	42.4	31.8	38.5	33.5	34.1	43.9	39.1	52.1	28.4
Ipoh	19.3	20.1	28.2	27.2	19	19	16.9	24	16.9	18.7	16	11.9	13.9	16.9
Johor Bahru	20.7	12.8	19.7	19.6	27.9	23.8	26.1	23.8	16.5	17.9	26.2	18.7	15.5	16.7
Petaling Jaya	32.5	39.4	38.2	41.5	36.7	34.2	26.5	30.9	26.9	30.9	31.7	20.9	25.5	23.6
Kuantan	11.8	11.2	14.8	8.8	11.1	10.5	13.7	18.3	11.3	10.6	12.3	7.9	11.6	10.5

PROGRESS

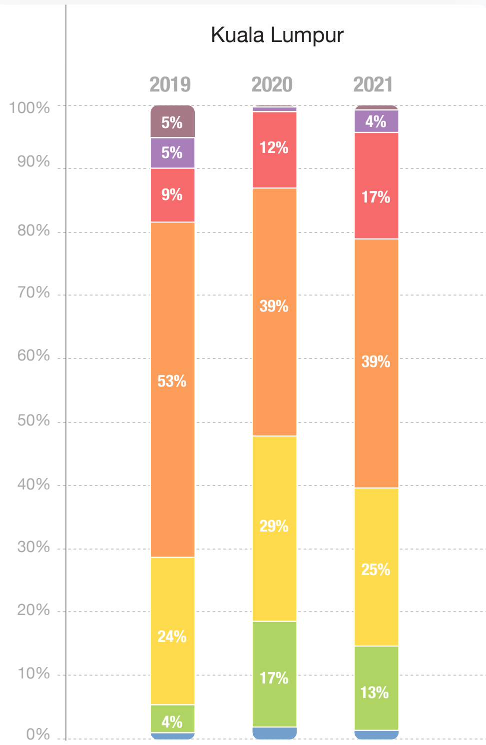
In 2021, the country of Malaysia saw a 25% increase in PM2.5 concentrations relative to 2020. Malaysia's 2021 annual average of 19.4 µg/m³ marked an absolute increase of 3.8 µg/m³ over 2020 levels and a return to 2019 levels, erasing the 19% improvement in PM2.5 concentrations recorded in 2020. This change was largely driven by the increased PM2.5 concentrations in all of the country's ten most populous cities reporting data in 2021, with an average increase of 4.5 µg/m³. Nationwide, a total of 49 cities reported escalating PM2.5 concentrations, with average increases of 2.7 µg/m³ in 2021 compared to 2020. Malaysia's annual PM2.5 average was tempered by the 11 Malaysian cities that reported reductions in 2021 compared to 2020.

CHALLENGES

Major sources of air pollution in Malaysia are combustion of fossil fuels by vehicles, industry and households, as well as forest fires and dust.[28] According to the WHO, air pollution is responsible for one out of every nine deaths in Malaysia, making it one of the top causes of death.

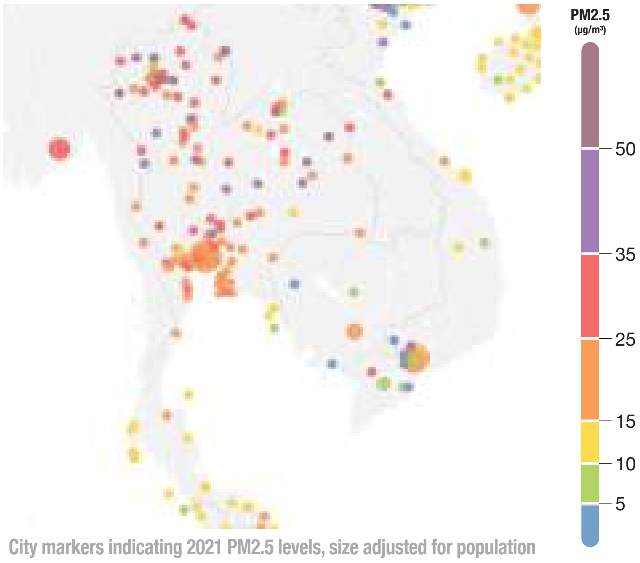
HIGHLIGHT: TRANSBOUNDARY HAZE

Agricultural burning to clear fields for new crops in Indonesia has led to ongoing transboundary haze issues in Malaysia.[20] The most notable and consequential incident of transboundary haze in Malaysia occurred in 2015. Agricultural burning haze drifted to Malaysia and other countries in the region from late June until October. Researchers from Harvard and Columbia have since concluded that 6,500 Malaysians died from the 2015 haze incident alone, and as many as 100,000 people died in the region.[29] The ASEAN Agreement on Transboundary Haze was established in 2003 by the nations of Malaysia, Indonesia, Thailand, Singapore, Brunei, Myanmar, Vietnam, Laos, Cambodia and the Philippines.[30] However there are concerns about Indonesia's enforcement of deforestation laws.

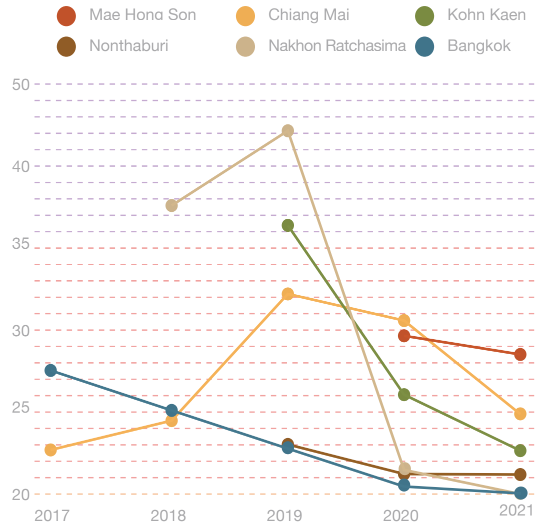


Annual hours spent at different PM2.5 pollution levels

THAILAND



City markers indicating 2021 PM2.5 levels, size adjusted for population



City	2021	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2020
Bangkok	20	42.3	45.2	27	19.7	11.5	8.4	6.9	7.3	10	14.5	18.7	30.6	20.6
Chiang Mai	24.9	43.2	46.9	83.2	34.4	13.5	7.9	5.5	7.3	6.6	9.4	15.8	25.7	30.5
Khon Kaen	22.6	40.4	39.1	51	26.1	18.1	9.8	7.1	9.8	6	12.9	18.9	31.5	26.1
Mae Hong Son	28.5	34	43.5	145.4	48.7	12.4	6.6	4.5	5	5	9.2	12.6	20	29.7
Nakhon Ratchasima	20.3	37.7	38.7	44.2	20.4	13.7	11.5	8.1	10.2	9	12.8	13.9	24.3	21.6
Nonthaburi	20.8	45.2	49.9	28.5	21.5	10.8	7.4	6.2	6.8	9.1	14.6	18.9	33.1	21.1

PROGRESS

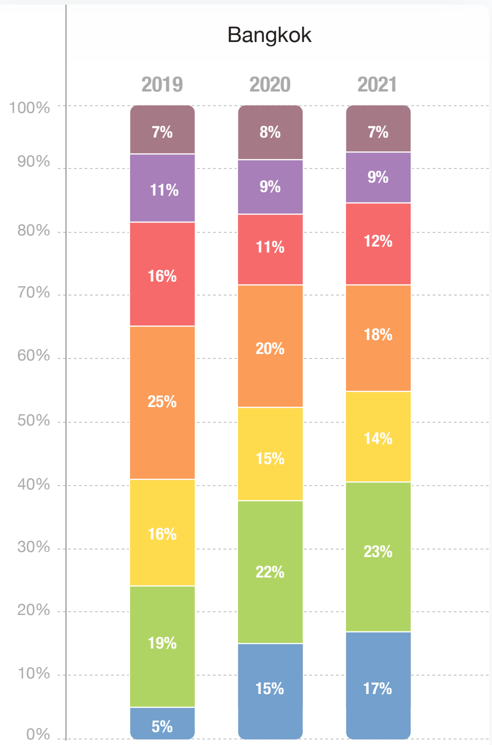
Thailand continued the trend of gradual reductions in country-level PM2.5 concentrations dating back to 2018, marking a 5% overall reduction in 2021. Only one city of the top 10 most populous cities, Surat Thani, recorded an increase in PM2.5 concentrations in 2021, measuring a 30% increase compared to 2020. Significant improvements in air quality occurred in the cities of Chiang Mai and Khon Kaen in 2021, with both cities dropping from WHO Interim Target-1 to Target-2 levels following 18% and 13% PM2.5 concentration reductions. However, not one Thai city met the WHO annual average PM2.5 concentration guideline of 5 μg/m³ in 2021, and only two cities, Ko Kut and Nong Khai, achieved the WHO Interim Target-4 with annual averages of 7.1 and 7.8 μg/m³. Air pollution was highest in the city of Chiang Rai with a PM2.5 concentration of 27.1 μg/m³ in 2021, which is more than five times the WHO air quality guideline of 5 μg/m³. In 2021, Bangkok, the nation's capital and most populous city, continued the trend of incremental PM2.5 improvements with an annual average concentration of 20.0 μg/m³, down from 20.6 μg/m³ in 2020.

CHALLENGES

Thailand's major sources of air pollution include vehicle exhaust, industrial emissions, crop burning, transboundary haze, and electricity generation.[31] Hindrances to combating air pollution include a lack of air quality monitoring, a lack of public awareness about the health impacts of crop burning, and a lack of enforcement of anti-crop burning laws.[32]

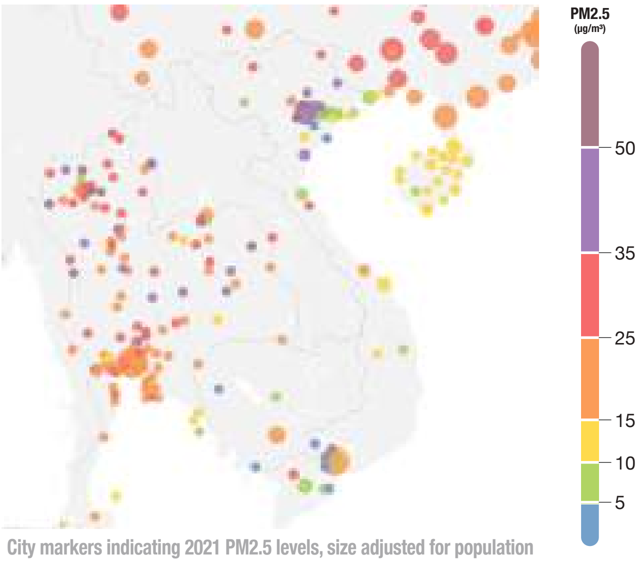
HIGHLIGHT: AGRICULTURAL BURNING

Farming and agricultural burning to prepare land for the next crop is common in Thailand.[31] Agriculture burning can raise PM2.5 concentrations to two to three times the WHO Air Quality Guidelines. Crop burning is an issue in Chiang Mai in the north of Thailand. In addition to the air pollution from crop burning, poor air quality can be exacerbated by geographical features and weather anomalies, causing pollutants to linger in the region during the winter months.[33]

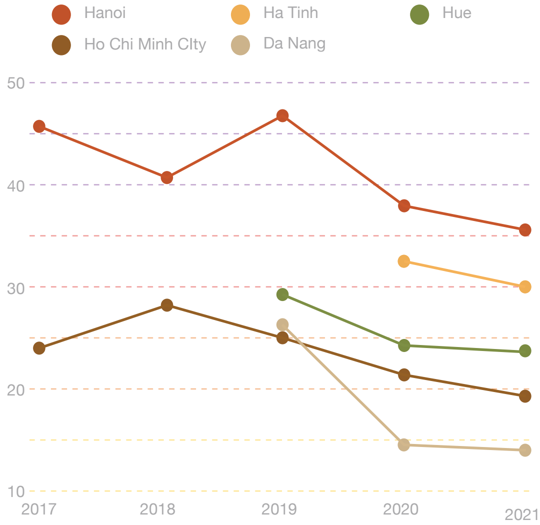


Annual hours spent at different PM2.5 pollution levels

VIETNAM



City markers indicating 2021 PM2.5 levels, size adjusted for population



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

City	2021	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2020
Hanoi	36.2	67.1	41.7	36.8	29.7	22	19.9	18.9	21.8	25.1	31.5	45.2	74.7	37.9
Da Nang	14.1	24.8	14.6	15.7	14.6	10.9	9.4	7.8	6.9	7.1	13.1	18.3	26.2	14.8
Ha Tinh	30	74.2	35.8	42.8	30.2	23.2	11.5	9.4	12.9	15.5	No Data			33.4
Ho Chi Minh City	19.4	33.3	27.6	19.2	20.2	13.8	15.7	10.9	12.2	10	17.9	24.3	28.5	22
Hue	23.8	42.1	25.2	35.9	28.1	26.6	10.8	9.6	10	10.6	20.1	28.7	37.9	24.2

PROGRESS

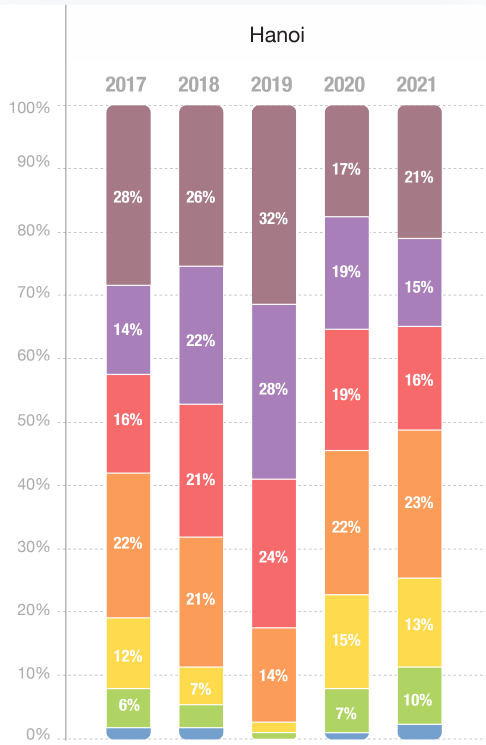
In 2021, Vietnam continued to exhibit a declining trend in annual average PM2.5 concentrations. Peaking in 2019 at a concentration of 34.1 µg/m³, annual PM2.5 concentrations fell in 2021 to 24.7 µg/m³. Despite declining concentrations, none of the 15 Vietnamese cities included in this report met the annual average WHO PM2.5 air quality guideline concentration of 5 µg/m³. Annual average PM2.5 concentrations for the capital city of Hanoi decreased by 4.5% in 2021 compared to 2020, dropping from 37.9 to 36.2 µg/m³ and achieving the WHO's annual PM2.5 Interim Target-3. Air quality in Ho Chi Minh City, Vietnam's most populous city, also improved in 2021 with a decrease in PM2.5 concentration from 22 µg/m³ in 2020 to 19.4 µg/m³ in 2021.

CHALLENGES

As manufacturing activity increased in Vietnam, the country's economy has grown over the past decade, increasing the demand for electricity. In 2020, half of the electricity generated in Vietnam came from coal-fired power plants.[34] Vietnam's usage of fossil fuels for power generation is a primary cause of air pollution, along with exhaust from cars and motorbikes, and factory emissions.[34]

HIGHLIGHT: RENEWABLE ENERGY

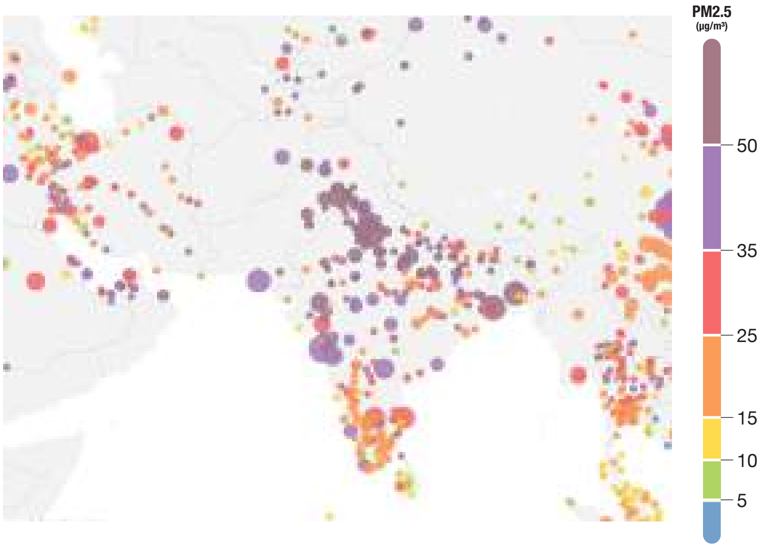
At the UN COP26 conference in 2021, Vietnam vowed to reach carbon neutrality by 2050. With the largest solar power infrastructure in Southeast Asia and the addition of offshore and onshore wind farms, Vietnam is poised for a transition away from the use of fossil fuels to power its growing economy.[35] Actions to achieve carbon neutrality will also have the co-benefit of improving air quality by reducing the use of fossil fuels, the country's major source of air pollution.[34]



Annual hours spent at different PM2.5 pollution levels

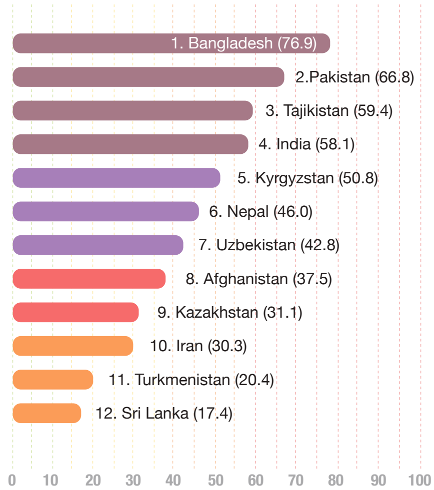
CENTRAL & SOUTH ASIA

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



City markers indicating 2021 PM2.5 levels, size adjusted for population

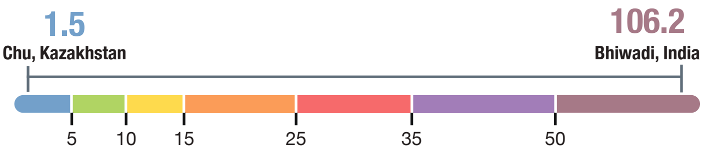
Country/Region Ranking



2021 PM2.5 average (µg/m³)

0.8%

Regional cities that met the WHO PM2.5 guideline in 2021



Range of 2021 average PM2.5 (µg/m³) across regional cities

Most Polluted Regional Cities

Rank	City	2021
1	Bhiwadi, India	106.2
2	Ghaziabad, India	102
3	Delhi, India	96.4
4	Jaunpur, India	95.3
5	Faisalabad, Pakistan	94.2
6	Noida, India	91.4
7	Bahawalpur, India	91
8	Peshawar,Pakistan	89.6
9	Bagpat,India	89.1
10	Hisar, India	89
11	Faridabad, India	88.9
12	Greater Noida, India	87.5
13	Rohtak, India	86.9
14	Lahore, Pakistan	86.5
15	Lucknow, India	86

Least Polluted Regional Cities

Rank	City	2021
1	Chu, Kazakhstan	1.5
2	Zhezqazghan, Kazakhstan	3.5
3	Digana, Sri Lanka	7.3
4	Sanandaj, Iran	8
5	Stepnogorsk, Kazakhstan	8.8
6	Borazjan, Iran	9.9
7	Aqtobe, Kazakhstan	10.6
8	Beyneu, Kazakhstan	11.1
9	Aktau, Kazakhstan	11.4
10	Comilla, Bangladesh	12.1
11	Dambulla, Sri Lanka	12.1
12	Paveh, Iran	13.1
13	Kokshetau, Kazakhstan	13.1
14	Pavlodar, Kazakhstan	13.6
15	Semnan, Iran	14.1

SUMMARY

In 2021, Central and South Asia had some of the world's worst air quality and was home to 46 of the world's 50 most polluted cities. According to the United Nations Environment Programme, 70% of global air quality related deaths occur in this region.[36] Only two cities in this region met the WHO air quality guideline for annual average concentration of 5 µg/m³, Chu and Zhezqazghan, both in Kazakhstan.

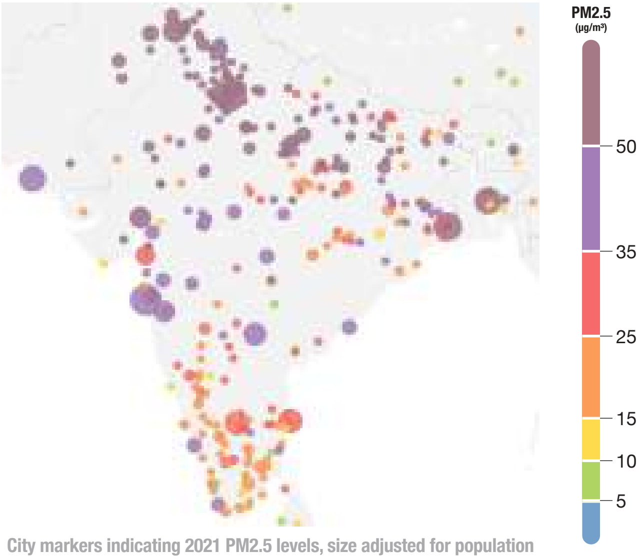
Industrialization and urbanization brings added pressure to air pollution burdens in South Asia. Burning biomass, a popular fuel for cooking in the rural areas, is a frequent source of pollutants in the air. Other sources include dust from construction and vehicles, fossil fuel combustion, and agricultural burning.[37]

India and Pakistan generally experience the worst air quality in this region, with 48% and 67% respectively of cities with PM2.5 concentrations greater than ten times the 2021 WHO air quality guideline level. With the exception of Afghanistan, Bangladesh, and Sri Lanka, PM2.5 concentrations increased in Central and South Asian countries in 2021, wiping out nearly all quarantine-correlated air quality improvements.

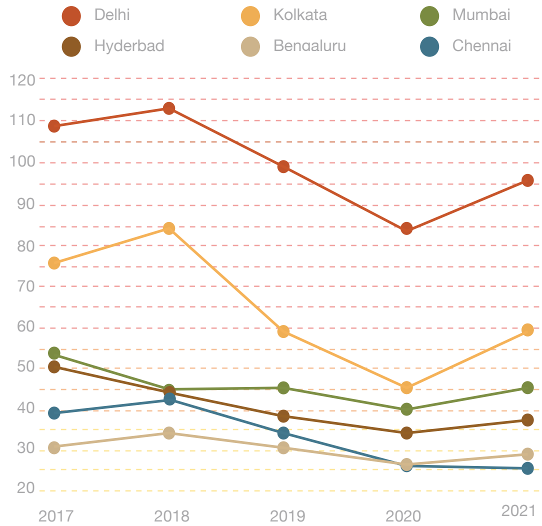
MONITORING STATUS

In 2021, nearly all Central and South Asia countries have expanded their air quality network by increasing the number of monitors publicly reporting PM2.5 concentration data. Region-wide, the number of air quality monitoring stations increased by 50% during the course of 2021. Government-operated monitoring stations continue to provide most of the public air quality data in the region, with nearly three times as many government-operated stations than independently-operated ones.

INDIA



City markers indicating 2021 PM2.5 levels, size adjusted for population



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

City	2021	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2020
Delhi	96.4	183.7	142.2	80.5	72.9	47.4	47.1	35.6	36.9	30.2	73.7	224.1	186.4	84.1
Kolkata	59	124.3	103.6	72.8	44.2	28.4	29.7	24	27.6	19.6	49.8	81.6	104.7	46.6
Mumbai	46.4	98.5	70.7	66	39.5	27.9	22.5	19.6	19.4	15.3	39.9	63.3	74.6	41.3
Hyderabad	39.4	64.6	63	56.4	46.9	23.6	16.9	12	16.7	13.6	46.7	45.5	68.4	34.7
Bengaluru	29	37.1	43.1	42.6	43.7	21.5	14.7	13.9	16.8	17.1	29.4	27.8	40.8	27.5
Chennai	25.2	37.9	37.2	30.9	22.5	13.1	22.7	19.2	20.4	21.1	23.9	20.7	33.5	26.5

PROGRESS

India's annual average PM2.5 levels reached 58.1 µg/m³ in 2021, ending a three-year trend of improving air quality. India's annual PM2.5 averages have now returned to pre-quarantine concentrations measured in 2019.

India was home to 11 of the 15 most polluted cities in Central and South Asia in 2021. Delhi saw a 14.6% increase in PM2.5 concentrations in 2021 with levels rising to 96.4 µg/m³ from 84 µg/m³ in 2020. No cities in India met the WHO air quality guideline of 5 µg/m³. In 2021, 48% of India's cities exceeded 50 µg/m³, or more than 10 times the WHO guideline.

CHALLENGES

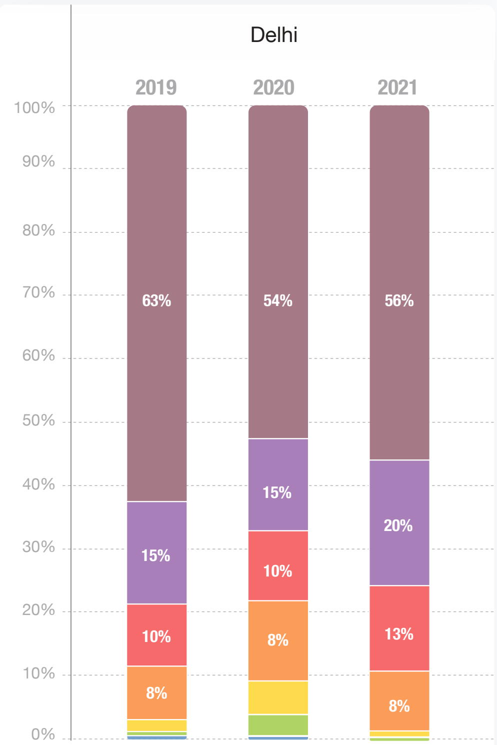
Air pollution has a massive impact on human health in India. It is the second biggest risk factor for disease, and the economic cost of air pollution is estimated to exceed $150 billion dollars annually.[38] Major sources of air pollution in India include vehicular emissions, power generation, industrial waste, biomass combustion for cooking, the construction sector, and episodic events like crop burning.[39]

In 2019, India's Ministry of Environment, Forest and Climate Change (MoEF&CC) enacted the National Clean Air Program (NCAP). The plan seeks to reduce PM concentrations by 20% to 30% by 2024 in all identified non-attainment cities, increase air quality monitoring, and implement a city, regional, and state-specific clean air action plan as well as conduct source apportionment studies.

However, the lockdowns, restrictions, and resulting economic downturn due to the COVID-19 pandemic have made it difficult to determine the plan's impact based on air pollution levels alone. A recent report found that apart from city-specific action plans, no other plans have been formulated under NCAP prescribed timelines.[40] Additionally, there is little information about the activities related to the NCAP, making it difficult to dispel the public's dissatisfaction with the slow progress under the program.

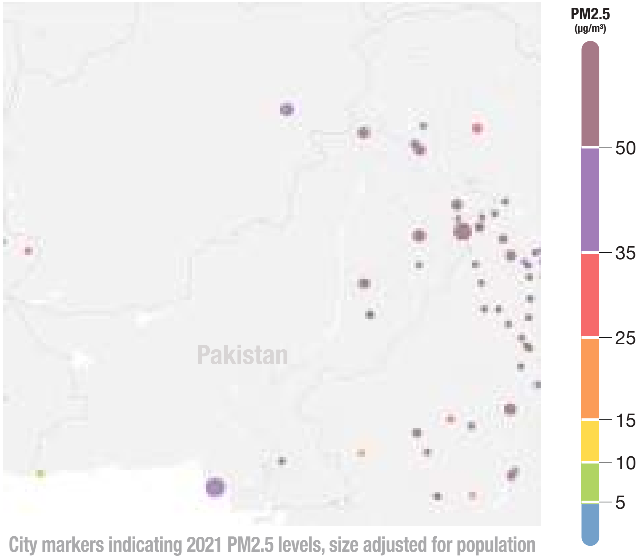
HIGHLIGHT: VEHICULAR EMISSIONS

It is estimated that 20% to 35% of total urban PM2.5 concentrations is directly or indirectly due to internal combustion engines in motor vehicles.[41] Annual vehicle sales in India are expected to increase, with an estimated fleet number reaching 10.5 million in 2030.[42] In an effort to curtail the contribution to air pollution from motor vehicles, India has adopted rigorous vehicle emission standards for new vehicles. The BS-VI standard is currently equivalent to the Euro 6-1 standard and will be equivalent to the Euro 6-2 standard beginning in April 2023.[43] Emissions testing methodologies capable of measuring emissions under real-world driving conditions, rather than more simple laboratory drive cycles, are in development at the International Centre for Automotive Technology in India with an anticipated release of 2023.[44]

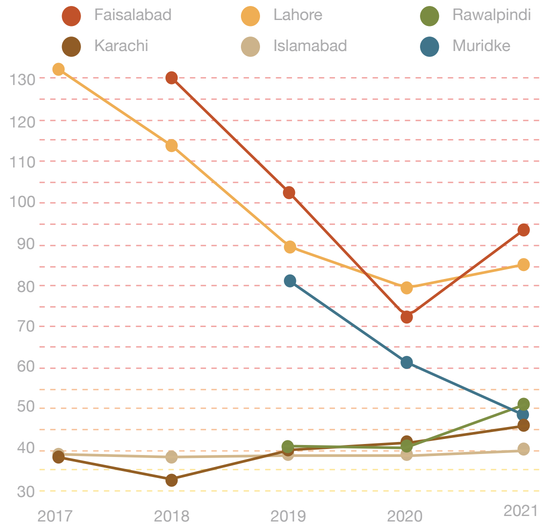


Annual hours spent at different PM2.5 pollution levels

PAKISTAN



City markers indicating 2021 PM2.5 levels, size adjusted for population



PM2.5 annual average ($\mu g/m^3$) over 5 years

City	2021	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2020
Islamabad	41.1	68.8	71	28.1	17.4	18.7	25.1	26.2	36.6	36.2	30.7	59.8	75.6	39
Faisalabad	94.2	207.1	118	71.2	44.6	51.2	44.7	50.4	50	51.9	No Data	234.5	241.7	73.2
Karachi	45.9	97.9	70	42.2	32.8	24.1	25.9	24.1	18.8	28.1	52.3	79.2	68.1	43.8
Lahore	86.5	140.6	135.1	55.8	38.7	33.8	27.9	25	36.5	45.6	85.1	205.4	212.1	79.2
Muridke	47.6	92.9	86.3	35.7	26.1	26.3	22.3	21.9	25.8	30.3	46.1	68.7	82.2	61.6
Rawalpindi	51.4	104.6	91.4	37.7	20.9	22.5	26.1	31.1	37.7	37.4	33.1	73.3	91.7	42.4

PROGRESS

In 2021, Pakistan ranked as the third most polluted global country. Every Pakistani city included in this report reported annual average PM2.5 concentrations at least eight times higher than the recommended WHO guideline. The city of Murikle was the only Pakistani city in which there was a decrease in annual PM2.5 concentrations to 47.6 $\mu g/m^3$ in 2021 from 61.6 $\mu g/m^3$ in 2020. The national average PM2.5 concentration increased in 2021 by 8%.

The average life expectancy in Pakistan would increase by 3.87 years if the country reached the WHO Interim Target-4 value of 10 $\mu g/m^3$.[45]

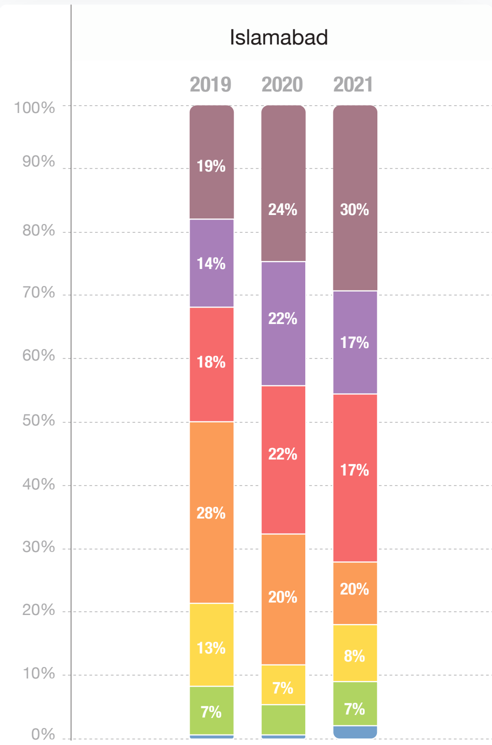
CHALLENGES

Pakistan continues to see poor air quality resulting from transportation, its biggest source of air pollution. In Punjab, the second largest province of Pakistan, 43% of air pollution emissions are from transportation, 25% from industrial sites, and 20% from agriculture.[46] Seasonal air quality issues also affect Pakistan. Crop burning and winter weather patterns result in temperature inversions that promote air stagnation and help to keep air pollution trapped close to the ground.

Environmental health researchers at the University of Punjab have found a 40% decrease in lung capacity during Pakistan's smog events, primarily affecting individuals with tuberculosis, asthma, and cardiovascular disease.[47] In addition, lower literacy study participants were almost 80% more likely to experience multiple symptoms of adverse health effects resulting in wage loss and diminished quality of life compared to those with higher literacy levels.

HIGHLIGHT: AIR QUALITY IMPROVEMENT EFFORTS

Pakistan announced a revised Pakistan Clean Air Plan (PCAP) in June of 2021, which assesses air pollution reduction at the national and local level. The PCAP was created to monitor air quality and implement policies and technologies based on measurements in different provinces.[48] Pakistan's Environmental Protection Agency has already implemented federal policy to limit annual average PM2.5 concentrations in ambient air with the current National Environmental Quality Standard at 15 $\mu g/m^3$. Despite the federal limit in place, annual average PM2.5 concentrations in Pakistan remain some of the highest in the world. Without enacting source-specific PM2.5 emission standards and emission load reduction targets, it remains unclear how effective additional policy changes will be.[49]



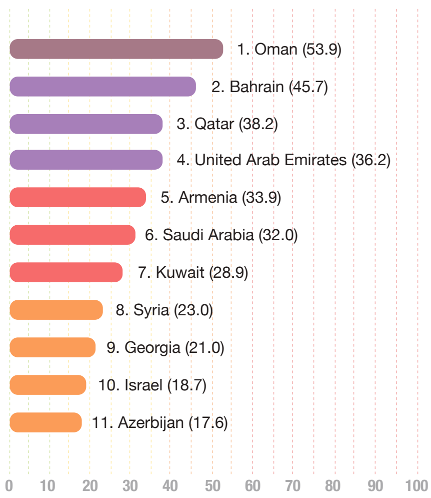
Annual hours spent at different PM2.5 pollution levels

WEST ASIA

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

City markers indicating 2021 PM2.5 levels, size adjusted for population

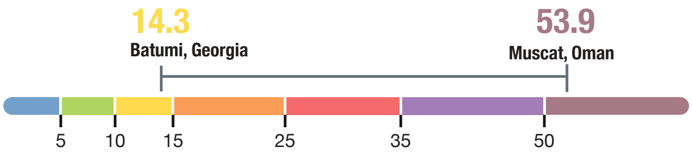
Country/Region Ranking



2021 PM2.5 average (μg/m³)

0%

Regional cities that met the WHO PM2.5 guideline in 2021



Range of 2021 average PM2.5 (μg/m³) across regional cities

Most Polluted Regional Cities

Rank	City	2021
1	Muscat, Oman	53.9
2	Manama, Bahrain	45.7
3	Doha, Qatar	38.2
4	Dubai, United Arab Emirates	36.9
5	Yeghegnavan, Armenia	36.7
6	Rust'avi, Georgia	34.8
7	Abu Dhabi, United Arab Emirates	34.3
8	Yerevan, Armenia	33.9
9	Riyadh, Saudi Arabia	32.1
10	Jeddah, Saudi Arabia	32
11	Dhahran, Saudi Arabia	29.9
12	Quneitra, Syria	29.4
13	As Salimiyah, Kuwait	29.4
14	Kuwait City, Kuwait	28.9
15	Jaffa, Israel	26.9

Least Polluted Regional Cities

Rank	City	2021
1	Batumi, Georgia	14.3
2	Nesher, Israel	14.4
3	Kiryat Tiv'on, Israel	16
4	Kiryat Malakhi, Israel	16
5	Arwad, Syria	16.1
6	Gan Yavne, Israel	16.1
7	Haifa, Israel	16.3
8	Bu`eina, Israel	16.4
9	Yad Binyamin, Israel	16.4
10	Afula, Israel	16.5
11	Ketura, Israel	16.5
12	Ashdod, Israel	16.5
13	Erez, Israel	17.1
14	Kiryat Ata, Israel	17.2
15	Qiryat Shemona, Israel	17.3

SUMMARY

The capital cities of Muscat (Oman), Manama (Bahrain), Baghdad (Iraq), and Doha (Qatar) experienced the region's highest PM2.5 concentrations in 2021. The region's most polluted city, Muscat, ranks as the fifth most polluted capital city, with an annual average PM2.5 concentration of 53.9 μg/m³, a level exceeding the WHO guideline by more than ten times. While all other regional countries have seen PM2.5 concentrations increase by a median rate of 23%, Qatar and Kuwait achieved a nearly 15% reduction in PM2.5 emissions during 2021.

Major anthropogenic sources of air pollution in the West Asia region include fossil fuel-based energy production, emissions from industrial processes, waste burning, construction, and motor vehicles.[50]

Dust storms are also a common source of natural air pollution in this region, especially from May to August as the temperatures rise and lead to large amounts of airborne dust. In early June 2021, strong winds carried dust from the Tigris-Euphrates River Valley to the western coast of the Persian Gulf and created a dust plume spanning over 500 kilometers or 310 miles.[51]

MONITORING STATUS

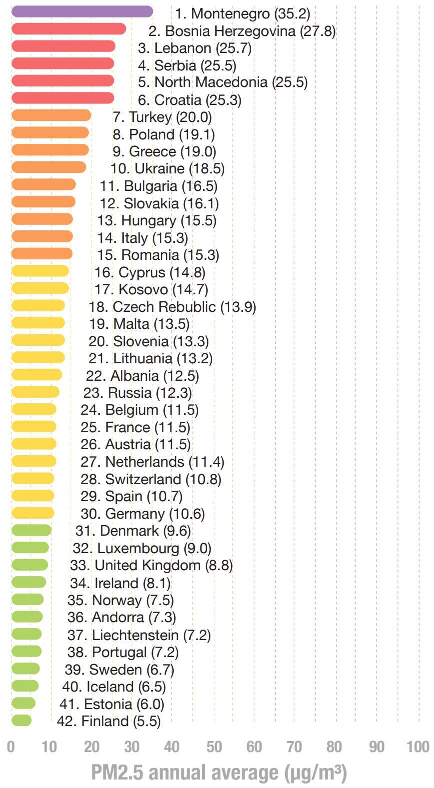
West Asia is a region with generally scarce air quality monitoring. However, the number of monitors in this region increased by 86% in 2021, primarily due to the large increase in the number of monitors both in Israel and Saudi Arabia whose monitors accounted for 73% of the total number of regional monitors. Government-monitored air quality data was not available for Qatar and Azerbaijan. Both countries are represented here by U.S. State Department monitors or low-cost sensors from organizations or private individuals. Bahrain and Kuwait each have a single regulatory-grade monitor managed by the U.S. State Department.

EUROPE

Albania | Andorra | Austria | Belgium | 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

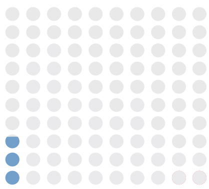
City markers indicating 2021 PM2.5 levels, size adjusted for population

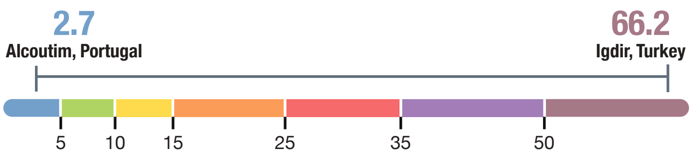
Country/Region Ranking



2.7%

Regional cities which met the WHO PM2.5 guideline in 2021





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

Most Polluted Regional Cities

Rank	City	2021
1	Igdir, Turkey	66.2
2	Krasnoyarsk, Russia	49.8
3	Novi Pazar, Serbia	47.2
4	Foca, Bosnia Herzegovina	46
5	Duzce, Turkey	44.4
6	Laktasi, Bosnia Herzegovina	42.8
7	Polistena, Italy	42.6
8	Prijedor, Bosnia Herzegovina	42.2
9	Cacak, Serbia	41.5
10	Mala Kladusa, Bosnia Herzegovina	38.7
11	Orzesze, Poland	38.2
12	Trn, Bosnia Herzegovina	37.2
13	Lukavac, Bosnia Herzegovina	37
14	Doboj, Bosnia Herzegovina	37
15	Ceglie Messapica, Italy	36.6

Least Polluted Regional Cities

Rank	City	2021
1	Alcoutim, Portugal	2.7
2	Salao, Portugal	2.8
3	Muonio, Finland	2.9
4	Corfu, Greece	3.1
5	Saransk, Russia	3.1
6	Albalat dels Tarongers, Spain	3.2
7	Alta, Norway	3.3
8	Bredkalen, Sweden	3.4
9	Vladivostok, Russia	3.4
10	Bodo, Norway	3.7
11	Faro, Portugal	3.7
12	Vaasa, Finland	3.8
13	Saint-Joseph, France	3.8
14	Korsholm, Finland	3.9
15	Midlothian, United Kingdom	4

SUMMARY

The region of Europe is represented by 42 countries in 2021 and a total of 1,588 cities. Average PM2.5 concentrations in this region span from 5.5 μg/m³ in Finland (ranked globally at 113) to 35.2 μg/m³ in Montenegro (ranked globally at 16). PM2.5 concentration data for both 2020 and 2021 was available for 39 European countries. In 2021, air quality improved in 14 countries and declined in 25 countries compared to 2020. Region-wide, only 55 cities were able to meet the recommended 5 μg/m³ WHO PM2.5 annual air quality guideline. The United Kingdom was home to ten cities achieving the guideline, more than any other country in the region, followed by Finland which had eight cities achieve the guideline.

Increased levels of PM2.5 have been reported to be the most serious environmental health risk in Europe, even though emissions have greatly decreased this century.[52] The northern and western parts of Europe have higher PM2.5 levels than southern and eastern Europe due to the burning of coal and biomass for heating in countries that experience long, cold winter months.

A summer of record-breaking heat in southern Europe and central Russia generated immense wildfires in 2021. European countries affected spanned from Spain to Turkey. At one point, the citizens of Athens, Greece, were told to remain indoors due to high levels of air pollutants.[53] Russia suffered through its biggest wildfire season ever recorded, contributing greatly to the unparalleled global levels of fire-produced CO2 emissions.[53,54]

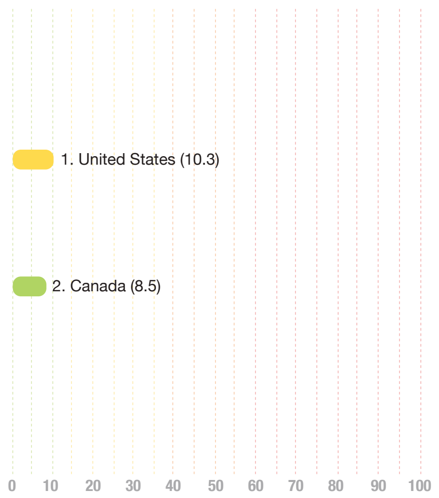
MONITORING STATUS

Most European countries have robust governmental air quality monitoring networks. Complementing government monitoring are a large number of low-cost sensors operated by numerous individuals and organizations, especially in Bosnia Herzegovina, Greece, Kosovo and Russia.

NORTHERN AMERICA

United States | Canada

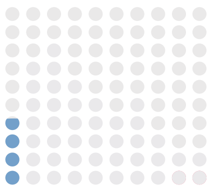
City markers indicating 2021 PM2.5 levels, size adjusted for population

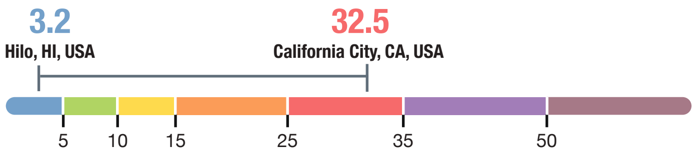


2021 PM2.5 average (μg/m³)

3.9%

Regional cities that met the WHO PM2.5 guideline in 2021





Range of 2021 average PM2.5 (μg/m³) across regional cities

Most Polluted Regional Cities

Rank	City	2021
1	California City, CA, USA	32.5
2	Three Rivers, CA, USA	27.4
3	Pollock Pines, CA, USA	26
4	Indian Hills, NV, USA	25.1
5	Terrell, TX, USA	24.7
6	Altamont, OR, USA	24.4
7	South Lake Tahoe, CA, USA	23.5
8	Susanville, CA, USA	22.6
9	Johnson Lane, NV, USA	22.3
10	Exeter, CA, USA	22.1
11	Klamath Falls, OR, USA	21.6
12	Trail, BC, Canada	21.3
13	Castlegar, BC, Canada	21.1
14	Quincy, CA, USA	21.1
15	Eagle Point, OR, USA	21.1

Least Polluted Regional Cities

Rank	City	2021
1	Hilo, HI, USA	3.2
2	Labrador City, NL, Canada	3.3
3	Kapolei, HI, USA	3.4
4	Waimea HI, USA	3.5
5	Sahuarita, AZ, USA	3.6
6	Fortuna Foothills, AZ, USA	3.8
7	Florence, OR, USA	3.8
8	Kitimat, BC, Canada	3.9
9	Honolulu, HI, USA	3.9
10	Kihei, HI, USA	3.9
11	Delta, BC, Canada	4.1
12	Terrace, BC, Canada	4.1
13	New River, AR, USA	4.1
14	Longview, WA, USA	4.1
15	Oak Harbor, WA, USA	4.1

SUMMARY

Air quality monitoring networks in both the United States and Canada grew in 2021, as did emissions in the two nations. In 2021, 96% of U.S. and Canadian cities were not able to get below the WHO annual 5 μg/m³ guideline for PM2.5 levels, with those cities accounting for more than 98% of the region's population. The main sources of pollution were gas and diesel-powered transportation, coal-based energy production, industrial emissions, and wildfires.[55]

Annual premature deaths blamed on human-made PM2.5 particulates are estimated at 200,000 in the United States and approximately 15,000 in Canada.[56,57] The 2021 wildfire season in North America was a large factor in the record-setting levels of wildfire-produced CO2 levels in earth's atmosphere.[58] Wildfires were estimated to have generated as much as 70% of ambient PM2.5 on the days that national PM2.5 standards were surpassed.

Last year, the Canadian national heat record was broken, topped the next day, and then topped once more the following day. These unprecedented temperatures greatly contributed to a severe wildfire season. By September 2021, 6,317 outbreaks had scorched 10.34 million acres of land.[59]

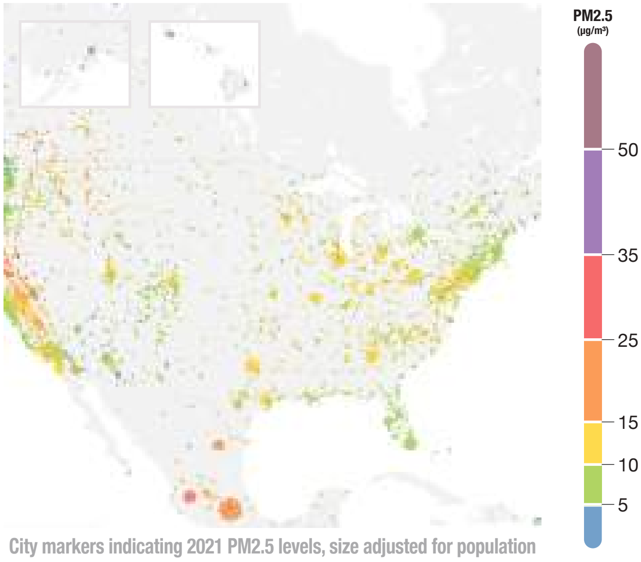
MONITORING STATUS

Northern America has the largest number of air quality monitors of all regions, covering 2,632 cities.

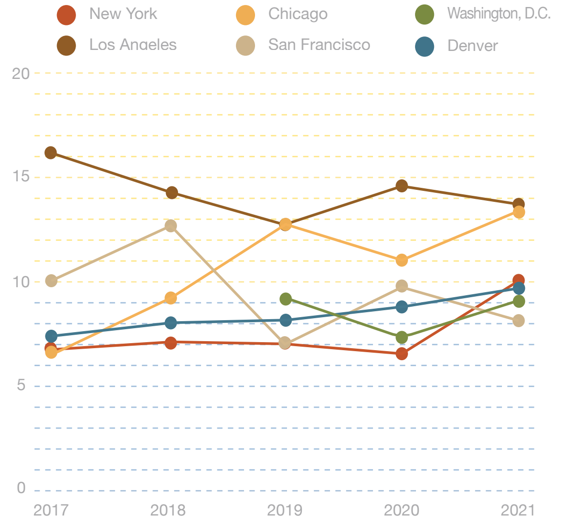
The vast majority of air quality monitoring stations in this region are in the United States with an approximate monitoring station to population ratio of 1 to 23,000, compared to Canada's 1 to 51,000. This high monitoring ratio is largely due to the increased number of low-cost sensors operated by local organizations and individuals in the U.S., now comprising 87% of the station total.

Air quality monitoring stations are present in 2,406 cities. Canada has a monitoring in 226 cities.

UNITED STATES



City markers indicating 2021 PM2.5 levels, size adjusted for population



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

City	2021	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2020
Washington, D.C.	9.1	8.5	11	7.5	7.3	7.3	8.6	15.6	11.2	8.1	6.9	8.8	8.9	7.4
New York	10	8.7	7.4	6	5.4	4.7	6.3	12.2	8.7	7.3	6.7	7.3	9.1	6.5
Los Angeles	13.7	11.9	12.4	7.2	10.7	12.1	12.1	14.3	16.6	18.2	10.5	21.8	16.5	14.6
Chicago	13.4	17.4	16.2	12.1	12.4	9	10.3	19.4	16.6	9.3	12.1	12.2	13.6	11.1
San Francisco	8.2	11.3	4.7	4.2	7.6	6.5	4.4	6.1	11.2	11.8	4.9	13.8	11.4	9.6
Denver	24.4	9.5	10.9	9.2	6.4	6.5	8	14.3	24.8	13.2	4.8	5.9	4.6	8.7

PROGRESS

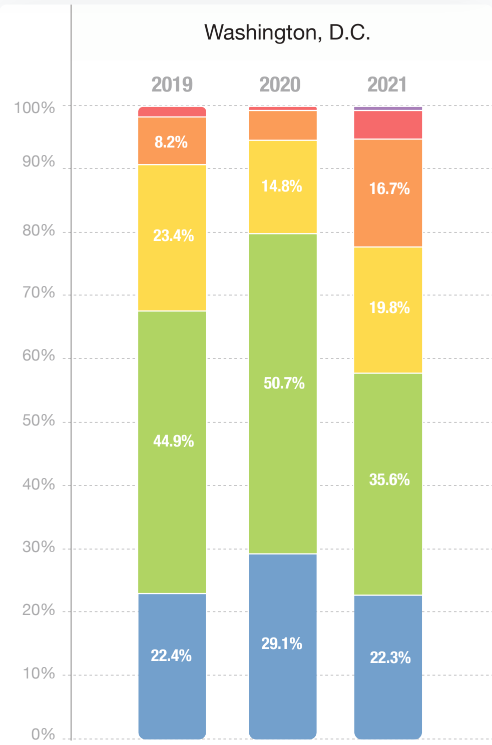
The Clean Air Act has helped reduce PM2.5 air pollution levels while the U.S. economy, population, and energy demands have grown in the last 50 years. While policies continue to reduce air pollution and greenhouse gas (GHG) emissions, in 2021 PM2.5 concentrations increased by 7% compared to 2020. The country's reliance on fossil fuels, increasing severity of wildfires as well as varying enforcement of the Clean Air Act from administration to administration have all added to U.S. air pollution.[60,61] Nationwide, 264 million people lived in areas where pollution levels were above the WHO annual guideline for PM2.5 concentrations in 2021. The U.S. contains the largest number of air quality monitors in the world. In 2021, approximately 87% of data came from low-cost sensors and 13% from regulatory monitoring stations operated by different levels of government.

CHALLENGES

While improvements in air quality have saved lives, air pollution from fossil fuel combustion and vehicular emissions are estimated to have been responsible for 230,000 premature U.S. deaths in 2020.[62] In 2021, 97% of U.S. cities reporting data did not meet the WHO target of 5 μg/m³. The West Coast of the United States along with the nation's urban centers report the country's highest PM2.5 concentrations. A 2020 study investigating historic PM2.5 concentrations found that disadvantaged communities disproportionately bear the burden of air pollution for the past 40 years.[63, 64]

HIGHLIGHT: WILDFIRES

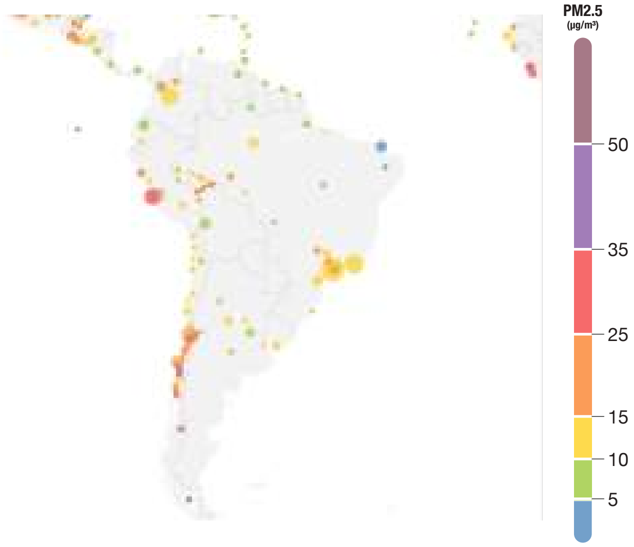
California continues to experience extreme pollution events during an increasingly long and extreme fire season. In 2021, the Dixie fire became the second largest fire in acres burned in California history. The Dixie fire burned across multiple counties, totaling 963,309 acres, and resulted in peak hourly PM2.5 concentrations of 212 μg/m³. The Caldor fire also burned at the same time, just south of the Dixie fire, and reached concentrations of 587 μg/m³. Smoke from the Bootleg fire in Oregon spread across the U.S. and north to Canada.[65] During this time, elevated levels of PM2.5 were found across the United States and reaching into Canada.[66]



Annual hours spent at different PM2.5 pollution levels

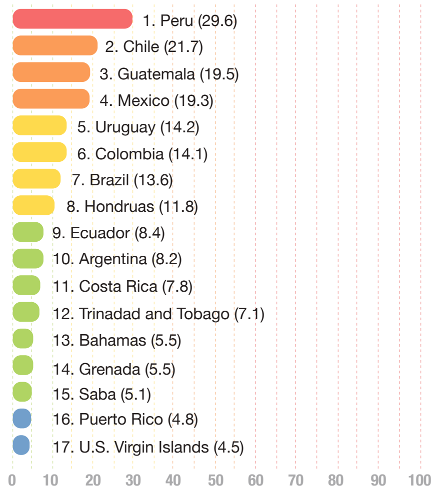
LATIN AMERICA & CARIBBEAN

Argentina | Bahamas | Brazil | Chile | Colombia | Costa Rica | Ecuador | Grenada | Guatemala | Honduras | México | Perú | Puerto Rico | Saba | Trinidad and Tobago | U.S. Virgin Islands | Uruguay



City markers indicating 2021 PM2.5 levels, size adjusted for population

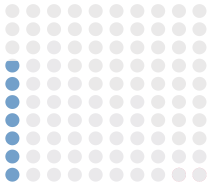
Country/Region Ranking

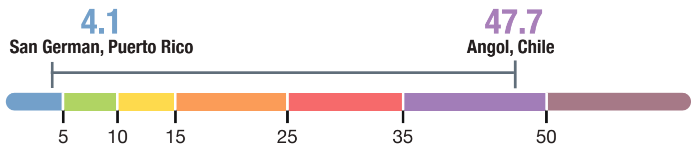


2021 PM2.5 average (µg/m³)

6.9%

Regional cities that met the WHO PM2.5 guideline in 2021





Range of 2021 average PM2.5 (µg/m³) across regional cities

Most Polluted Regional Cities

Rank	City	2021
1	Angol, Chile	47.7
2	Padre las Casas, Chile	37.2
3	Coyhaique, Chile	36.1
4	San Juan de Lurigancho, Peru	34
5	Coronel, Chile	33.3
6	Temuco, Chile	32.7
7	Lima, Peru	32
8	Traiguen, Chile	30.1
9	Metepec, Mexico	28.4
10	Nacimiento, Chile	26.2
11	Santiago, Chile	25.8
12	Quilicura, Chile	25.5
13	La Pintana, Chile	25.4
14	Guadalajara, Mexico	25.4
15	Rancagua, Chile	25.4

Least Polluted Regional Cities

Rank	City	2021
1	San German, Puerto Rico	4.1
2	Governor's Harbour, Bahamas	4.1
3	Puerto Baquerizo, Ecuador Moreno	4.2
4	Camuy, Puerto Rico	4.3
5	Fortaleza, Brazil	4.3
6	Punta Arenas, Chile	4.3
7	Manati, Puerto Rico	4.4
8	Charlotte Amalie, U.S. Virgin Islands	4.5
9	Cruz Bay, U.S. Virgin Islands	4.6
10	Pianco, Brazil	4.6
11	Caguas, Puerto Rico	4.6
12	San Juan, Puerto Rico	4.8
13	Arecibo, Puerto Rico	5.1
14	Saba	5.1
15	Rosario, Argentina	5.3

SUMMARY

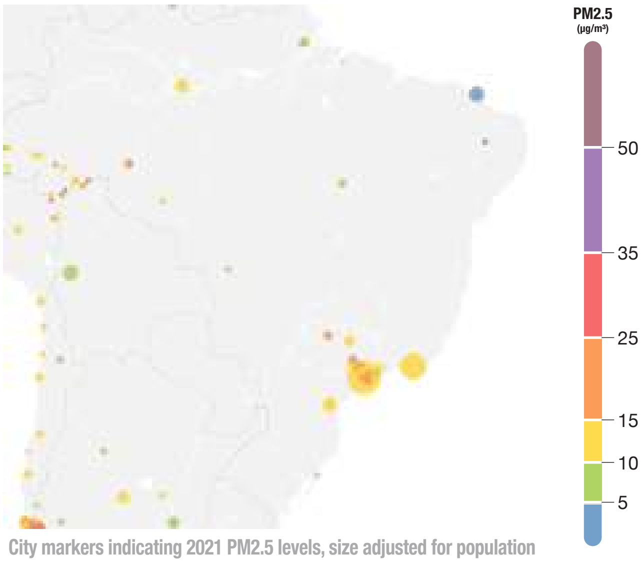
Latin America and the Caribbean have faced several air quality challenges as regional cities grow and urban populations expand. Urban population growth is a multifaceted air quality issue; as demand for energy and transportation increases, so do PM2.5 emissions. Increases in fossil fuel-generated energy production, vehicle exhaust from outdated vehicle fleets, the rising use of solid-state fuels as a heat source in lower income cities, and the absence of governmental air quality regulation all contribute to poor air quality. Despite all this, the region of Latin America and the Caribbean has made some progress in 2021. Country level PM2.5 concentrations fell in four regional countries; Argentina, Brazil, Colombia, and Costa Rica.

While some progress has been made, the air quality improvements correlating with pandemic mandatory quarantines have shown signs of erosion in 2021 with Peru, Chile, and Ecuador now close to reaching or even exceeding 2019 PM2.5 levels. Steady increases in wood burning use for heating and cooking in lower income regional cities, combined with lower precipitation rates in addition to the post-quarantine economic mobilization are factors that have contributed to this year's increase. Out of the regional 174 cities contributing data to this report, only 12 cities, accounting for only 2% of the regional population, met the 2021 WHO air quality guidelines for PM2.5.

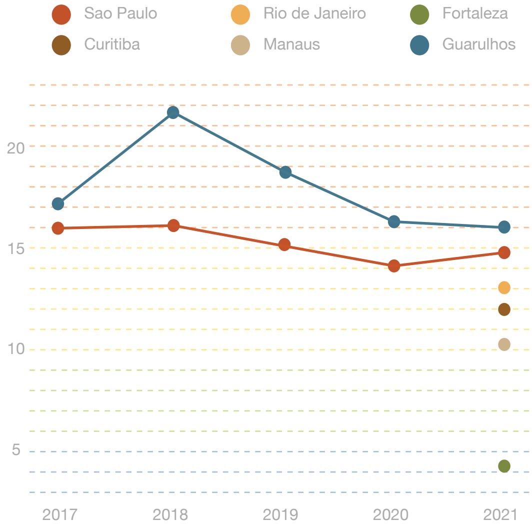
MONITORING STATUS

In 2021, the number of air quality monitoring stations in this region increased by over 50% compared to 2020, with real-time air quality data now available for an additional 24 cities. The countries of Chile, Colombia, and Mexico had the greatest gains in air quality monitoring with the number of monitoring stations increasing by 51%, 38%, and 28% respectively. Citizens in this region play an active role in air quality monitoring. Local organizations and individuals now operate 55% of the region's monitoring stations, highlighting the effectiveness of grassroots efforts by citizen scientists in taking the lead to expand air quality networks. One such group is the Aires Nuevos Citizen Air Quality Network for Early Childhood in Latin America which operates numerous air quality monitoring stations in eight Latin American countries; Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, and Uruguay.[67] Despite these gains, much work remains to be done before ambient air quality monitoring in this region catches up to other regions in the world.

BRAZIL



City markers indicating 2021 PM2.5 levels, size adjusted for population



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

City	2021	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2020
Sao Paulo du Campo	15.2	13.7	15.3	15.4	9.7	18.3	15.1	18.8	19.5	20.2	11.3	12.4	12	15.9
Rio de Janeiro	13	No Data	12.4	13.8	8.8	16.6	14.6	21.6	15.3	17.4	8.4	7	6.4	No Data
Fortaleza	4.3	5.2	6.9	5.3	3.7	2.5	2.3	2.5	3.2	6	4.9	3.1	5	No Data
Curitiba	12	No Data	6.9	10.4	5.3	17.1	17.4	No Data	16.8	18.1	7.7	7.6	6.7	No Data
Manaus	10.3	5.9	5.9	4.8	4.8	7.1	9.6	13	20.4	18	18.5	10	7.2	No Data
Guarulhos	16.1	11.9	11.4	13.8	11.7	20.4	16.7	25.5	24	22.8	10.2	11.9	11.4	16.4

PROGRESS

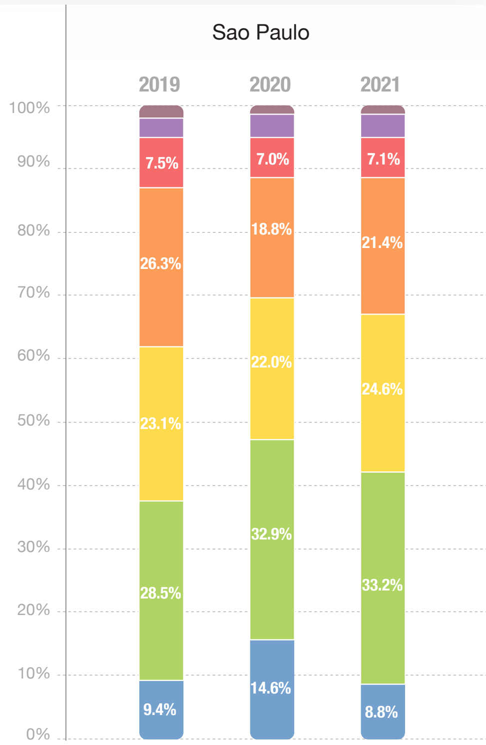
Brazil continues to make incremental progress in lowering rates of air pollution. Overall, PM2.5 concentrations dropped from 14.2 µg/m³ in 2020 to 13.6 µg/m³ in 2021. Of the 33 Brazilian cities included in this report, only Fortaleza and Pianco met the revised WHO air quality guidelines for PM2.5. Contributing sources to air pollution in Brazil include the cement industry, petrochemical production, steel production, mining, forest and agricultural burning, and vehicle production.[68]

CHALLENGES

Recent economic challenges in Brazil have led to an increased number of households using firewood as the energy source for cooking. Unemployment, rising prices, and inflation are some of the reasons that wood is now the second most used energy source in the nation, preceded by electricity.[69] Wood burning contributes to PM2.5 pollution, resulting in asthma attacks, heart attacks, and heart failure amongst other health effects.[70]

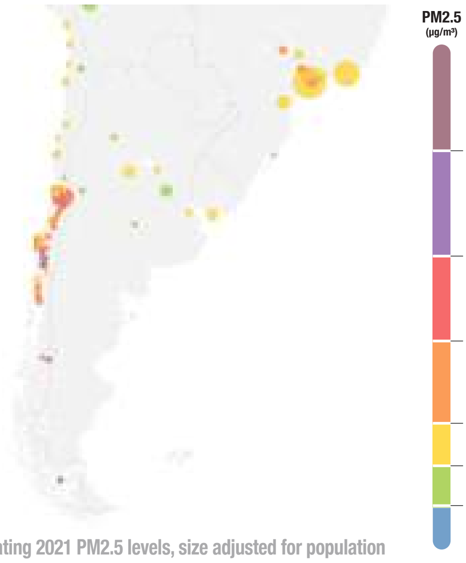
HIGHLIGHT: DEFORESTATION

Deforestation and wildfires are a continuing threat to the health and welfare of Brazilian citizens. Despite a decrease in the overall number of fires and total area burned in 2021 compared to 2019 and 2020, over 1.4 million square kilometers burned in Brazil during the period of January 1 through September 5, 2021.[71] A report released in August 2021 from Brazil's National Institute for Space Research (INPE) showed that deforestation in Brazil's Amazon rainforest was at a 15-year high.[72] Due to deforestation for agricultural and industrial purposes, wildfires in the Amazon have resulted in the world's largest rainforest now emitting more CO2 than it absorbs.[72]

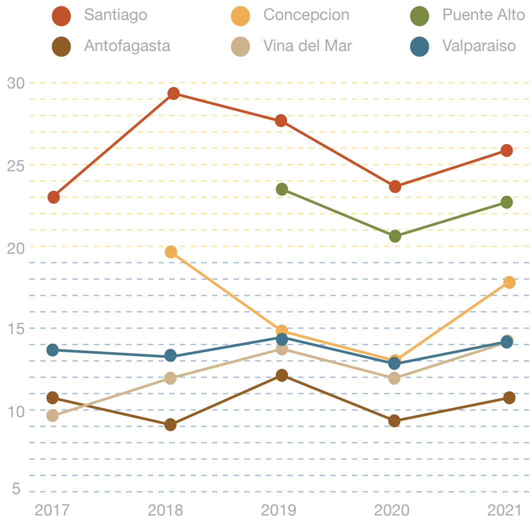


Annual hours spent in different PM2.5 pollution levels

CHILE



City markers indicating 2021 PM2.5 levels, size adjusted for population



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

City	2021	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2020
Santiago	25.8	12.3	16.1	15	28	43.8	41	51.1	41.9	21.8	13.9	11	13.3	23.6
Concepcion	17.7	8.8	10	10.5	11.3	22	28	40.9	30.6	18.8	11.7	7.9	11.5	13
Puente Alto	22.7	13.1	13	14	20.7	35	35.5	46.4	35.4	17.7	13.6	11.5	13.6	20.6
Antofagasta	10.7	5.9	7.1	6.7	9.7	14.5	13.7	17.1	13.6	10.4	11.7	9.5	7	9.4
Vina del Mar	14.3	15.4	12.2	12.3	14.3	17.5	16.1	22.2	17.9	10.6	10.4	9.8	11	12.1
Valparaiso	14.2	12.6	10.8	12.5	17.7	18.1	14.4	21	19.1	11.7	11.4	10.2	12.2	12.9

PROGRESS

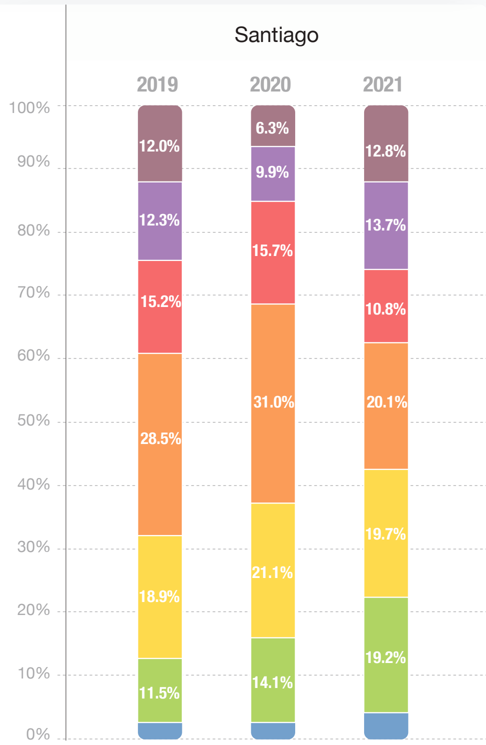
Significant efforts continue in Chile to expand air quality monitoring networks. In 2021, the number of air quality monitoring stations increased by nearly 50%. Most air quality stations, about 60%, are operated by a government entity in Chile. The expansion of air quality monitoring, however, continues to highlight the urgent need for action, as the air quality in Chile is the worst in the region. Chile hosts 11 of the top 15 most polluted cities in Latin America and the Caribbean, where nine out of 10 people live in cities. In 2021, only one Chilean city met the 2021 WHO air quality guideline leaving 99% of the regional population in areas that exceed the guideline by a factor of five. Efforts are being made to reduce emissions in the region, but more than 90 million people still rely on polluting fuels for cooking and heating. Each year, air pollution costs the Chilean health sector approximately $670 million and leads to 4,000 premature deaths.

CHALLENGES

Chile's geographical and topographical features are significant contributing factors to the country's poor air quality. Many Chilean cities sit in valleys that can trap air pollution, particularly during winter months. This problem is compounded by the common practice of using wood burning stoves. The combustion of firewood is a very significant contributor to PM2.5 concentrations. This trend is quite apparent in the cold weather months in Chile (June to August), when PM2.5 levels rise sharply. The region's top three most polluted cities are in Chile, with a peak PM2.5 concentration in June 2021 of 125 µg/m³ in the city of Angol, 25 times the WHO annual air quality guideline level of 5 µg/m³.

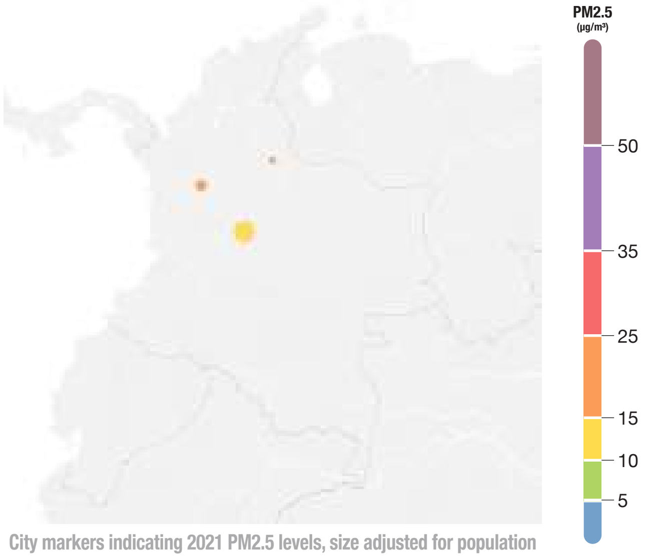
HIGHLIGHT: FIREWOOD HEATERS

Chile is working on taking action to tackle the problem of air pollution. Firewood makes up 94% of fine particulate matter (PM2.5) emissions in some Chilean cities. However, replacing firewood with alternative, clean energy sources has been challenging. Chile remains committed to the task of improving air quality and in 2014 initiated a program to replace 200,000 firewood heaters with more energy-efficient heating devices such as new gas, paraffin, or wood-pellet based heaters.

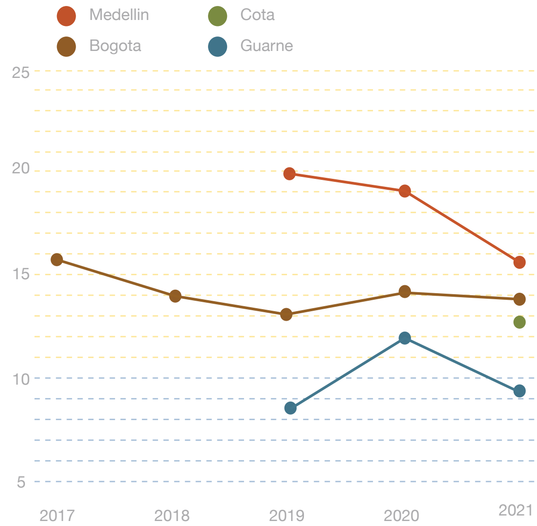


Annual hours spent at different PM2.5 pollution levels

COLOMBIA



City markers indicating 2021 PM2.5 levels, size adjusted for population



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

City	2021	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2020
Bogota	13.7	15.2	16.9	19.2	11.6	10.4	11.1	7.6	11	10.6	15	18.7	17.6	14.3
Cota	12.8	13.6	16	17.6	10.9	9	10.2	7	9.5	11	14.4	16.9	18.1	No Data
Guarne	9.4	9.8	12.1	13.2	8.7	7.3	7.7	7.8	9.3	8.2	8.6	9.8	9.9	12
Medellin	15.6	16.8	18.5	19.8	14.8	12.5	12.8	12.2	14.6	15	15.3	17.1	17.5	19.1

PROGRESS

As a country, Colombia has seen a 10% reduction in PM2.5 concentrations from 2020 to 2021. This reduction is primarily due to quarantine-related mobility restrictions along with public transportation fleet upgrades to low-carbon, hybrid, and electric buses. This reduction marked the first decrease in annual PM2.5 concentrations in the past three years. The municipality of Guarne saw the greatest concentration reduction year-over-year with a 22% drop in PM2.5 and an annual average of 9.4 µg/m³. This resulted in the city achieving the 2021 WHO Interim Target-4 goal of 10 µg/m³.

The number of Colombian air quality monitoring stations more than doubled in 2021 in comparison to 2020. This expansion is largely due to the public's growing awareness and interest in knowing the quality of the air they are breathing in their cities. In 2017, Colombia created a $2.5 million "Biodivercities" project that funds low-cost measurement of air quality in the country's capital city.[73]

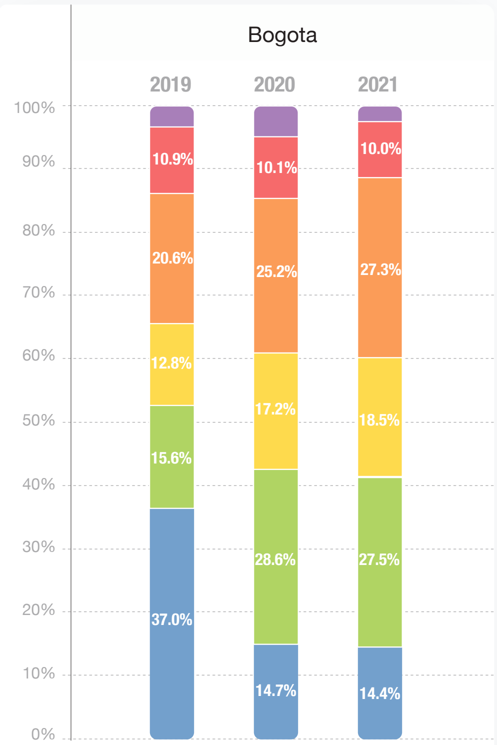
CHALLENGES

Mobile sources of air pollution, principally road transportation and private vehicles, make a disproportionately large contribution to air pollution in Colombia. In addition to common sources of air pollution, Colombia is also challenged by most of its population living in the Andes Mountains, which are subject to temperature inversions, heavy congestions, enclosed streets, and hilly roads that can affect air quality and contribute to some of the highest air pollution levels in Latin America.[73]

HIGHLIGHT: PRODUCTIVE AIR QUALITY POLICIES

In 2020, Bogotá became the first Latin American city to declare a climate emergency, pioneering real climate action strategies. The strategies are binding and have the necessary budget to promote citizen health and environmental protection.

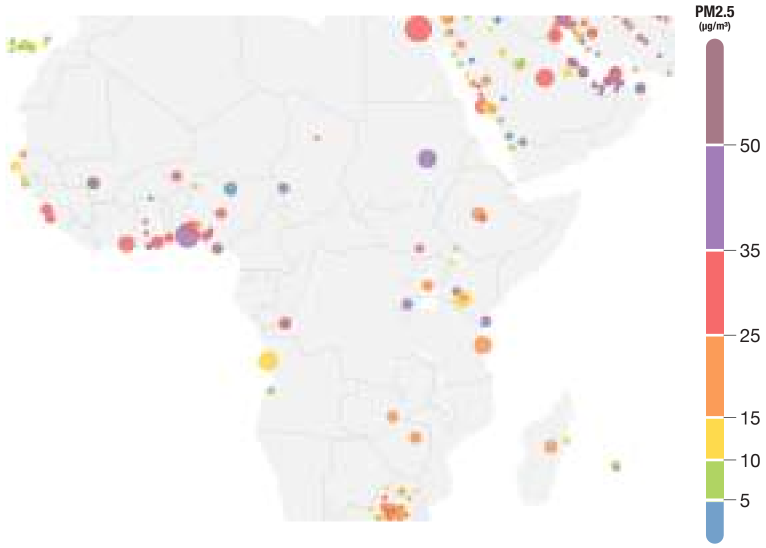
In 2021, Bogota ordered 1,485 electric buses to replace diesel buses being used, a significant change as 28% of emissions for the country come from transportation.[73,74] The country has also pledged to lower black carbon emissions by 40% from 2014 levels by no later than 2030 according to the country's Nationally Determined Contribution, a non-binding plan to address climate change.[73]



Annual hours spent at different PM2.5 pollution levels

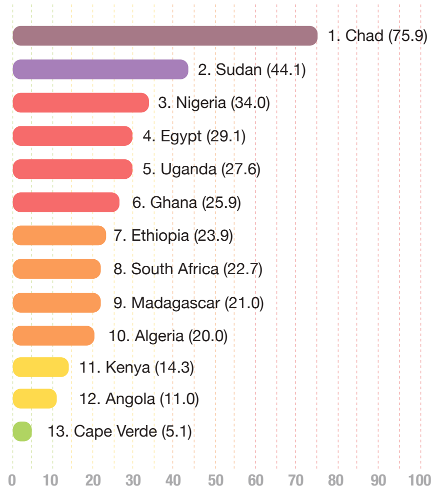
AFRICA

Algeria | Angola | Cape Verde | Chad | Egypt | Ethiopia | Ghana | Kenya | Madagascar | Nigeria | South Africa | Sudan | Uganda



City markers indicating 2021 PM2.5 levels, size adjusted for population

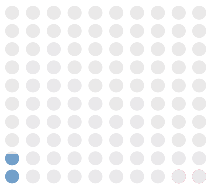
Country/Region Ranking



2021 PM2.5 average (µg/m³)

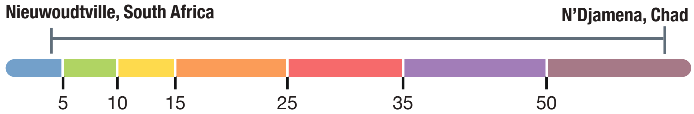
1.6%

Regional cities that met the WHO PM2.5 guideline in 2021



3.9 Nieuwoudtville, South Africa

77.6 N'Djamena, Chad



Range of 2021 average PM2.5 (µg/m³) across regional cities

Most Polluted Regional Cities

Rank	City	2021
1	N'Djamena, Chad	77.6
2	Port Harcourt, Nigeria	51.6
3	Khartoum, Sudan	44.1
4	Bloemfontein, South Africa	42.2
5	Tshwane, South Africa	38.5
6	Ekurhuleni, South Africa	33.8
7	Vanderbijlpark, South Africa	32.9
8	Edenvale, South Africa	30.7
9	Benin City, Nigeria	29.7
10	Sebokeng, South Africa	29.7
11	New Cairo, Egypt	29.1
12	Kintampo, Ghana	28.9
13	Ermelo, South Africa	27.8
14	Kampala, Uganda	27.6
15	Johannesburg, South Africa	27.3

Least Polluted Regional Cities

Rank	City	2021
1	Nieuwoudtville, South Africa	3.9
2	Espargos, Cape Verde	5.1
3	Knysna, South Africa	6.1
4	Lobuni, Ethiopia	7.3
5	Sunset Beach, South Africa	7.5
6	Cape Town, South Africa	7.6
7	Worcester, South Africa	8.3
8	Burgersfort, South Africa	8.9
9	George, South Africa	10.2
10	Port Elizabeth, South Africa	10.5
11	Phalaborwa, South Africa	11
12	Luanda, Angola	11
13	Pietermaritzburg, South Africa	11.9
14	Potchefstroom, South Africa	11.9
15	Hendrina, South Africa	12.7

SUMMARY

Sparse air quality data makes gauging the exact extent of Africa's air pollution problem difficult. Additionally, the task of measuring the health impacts from dirty air also remains difficult. It is calculated that air pollution is the cause of an estimated 780,000 African deaths a year.[75]

Windblown dust from deserts is a common source of PM2.5 pollution in Africa. So too are fossil fuel combustion, waste, and agricultural burning. With the African population predicted to double in the next 30 years, rapid transportation growth, industrialization, and urbanization is likely to negatively impact regional air quality.[76]

Based on NASA satellite data, 70% of the world's wildfires take place in Africa. Most of these fires burn through grasslands and generate a large amount of ambient PM2.5. To make matters worse, the fires can occur year after year because the frequently burned savanna can regrow burnt grass within a year's time.

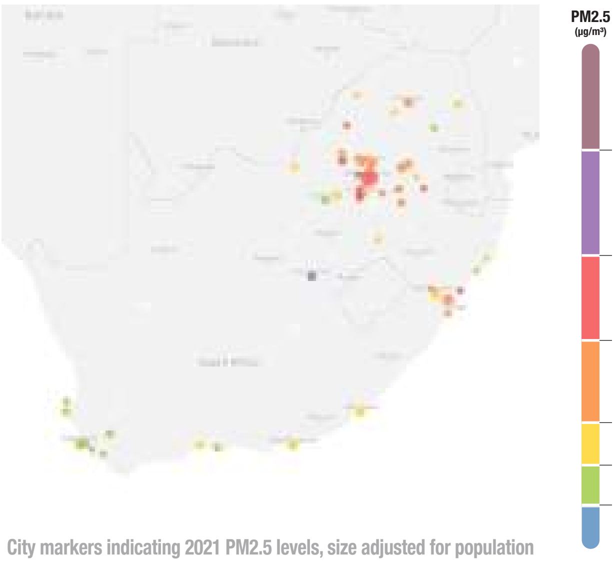
Of the cities reporting air quality data in Africa, N'Djamena, Chad ranked number one as the most polluted regional city with an annual average PM2.5 concentration of 77.6 µg/m³ - a value greater than 10 times the WHO air quality guideline.

MONITORING STATUS

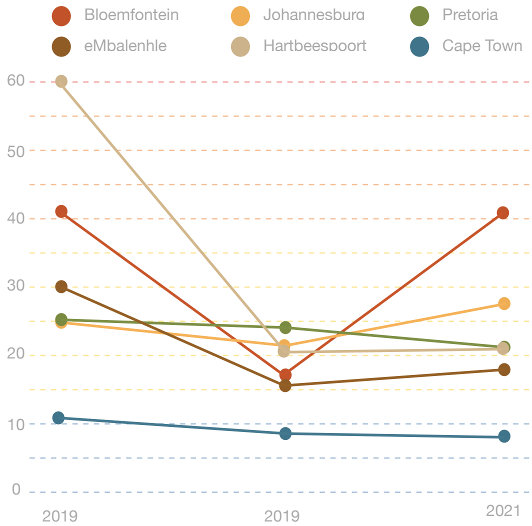
Air quality monitoring in Africa remains sparse. Most African countries lack air quality monitoring data, leaving most people on the continent without the information necessary to make important health decisions.

Limited air quality data in Africa contributes to low public air pollution awareness. South Africa has the largest public, real-time governmental air quality monitoring network on the continent. Most African countries in this report relied on monitoring stations operated by the U.S. State Department, individuals and non-governmental organizations.

SOUTH AFRICA



City markers indicating 2021 PM2.5 levels, size adjusted for population



PM2.5 annual average (µg/m³) over 3 years

City	2021	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2020
Cape Town	7.6	6.1	5.9	6.2	8.6	7.9	12.2	8.7	10	8.5	7.5	4.2	5.6	8
Bloemfontein	42.2	20.9	30.9	26.5	43.5	81.5	71.4	84.8	39.8	33.5	27.1	23.6	22	17.2
eMbalenhle	17.1	10.8	10.7	13.4	18.1	26.4	24.1	23.4	19.5	17.7	14.6	13.2	12.5	15.6
Hartbeespoort	17	16.5	16.5	16	23.8	20.6	21.8	21.3	17.9	18.1	12.8	10.2	8.9	20.8
Johannesburg	27.3	16.6	20.2	24.4	36.1	41	41.1	35.9	29.4	27.4	22	17.3	15.9	22.3
Pretoria	21.6	12.3	11.8	19.4	26.4	29.1	31	31.5	29.5	24.5	16.9	13.4	11.7	24.4

PROGRESS

South Africa's constitution guarantees a clean environment free of pollution: a right enshrined within the country's Bill of Rights.[77] However, poor air quality in many cities means that right remains unrealized for far too many South Africans.

Air quality in a few South African cities did show slight, continued improvement in 2021, building on previous improvements in air quality measured in 2020. However, the country's overall PM2.5 concentrations increased from 18 µg/m³ in 2020 to 22 µg/m³ in 2021.

In 2021, Nieuwoudtville in the Northern Cape province recorded an average PM2.5 concentration of 3.9 µg/m³. It was the only city in South Africa – and in Africa – that met the WHO recommended air quality guidelines that year. Air quality continued to improve in Pretoria over a three-year period, from an annual average PM2.5 concentration of 25.5 µg/m³ in 2019 to 24.4 µg/m³ in 2020 and finally 21.6 µg/m³ in 2021.

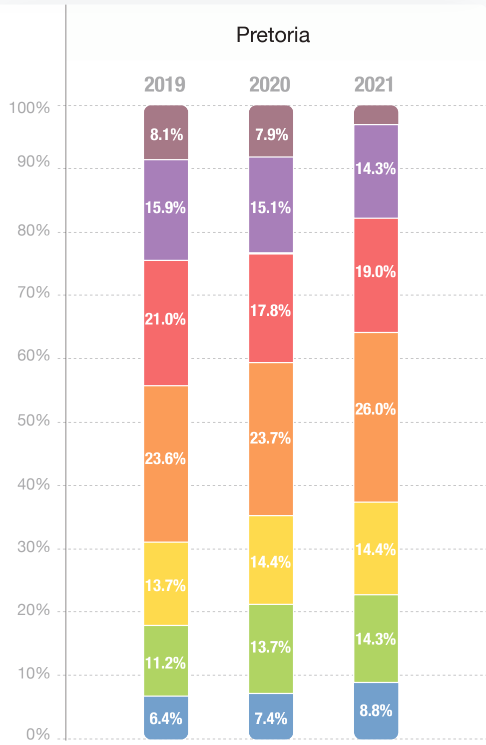
CHALLENGES

Residents along South Africa's western and southern coastal regions generally experience better air quality than other parts of the country. The western coastal cities of Cape Town and Worcester recorded a relatively low PM2.5 concentration of 7.6 µg/m³ and 8.3 µg/m³ respectively for 2021. But inland regions, particularly in the eastern coal belt region of the Highveld, home to 12 coal-fired power stations, struggle with poor air quality.[78]

Major cities in the Highveld measured some of the highest average concentrations of PM2.5 in 2021. Bloemfontein had the highest annual average at 42.2 µg/m³, more than eight times the WHO recommended guideline. Vereeniging's average annual PM2.5 was 26.6 µg/m³ – roughly as poor as the year prior – while Johannesburg's annual average measurement of 27.3 µg/m³ represented an increase of 22% over 2020.

HIGHLIGHT: COAL DEPENDENCE AND COAL-TO-LIQUID FUEL

Coal is a major industry in South Africa, and the country's biggest energy provider for electricity, fulfilling over 80% of the country's energy needs. Coal is also a feedstock for vehicle liquid fuel. Government subsidies play a key role in the coal-to-liquid (CTL) fuel sector, with as much as 5% of a South African driver's fuel bill going to a single South African firm.[79] The company owns a CTL plant in Secunda that has been identified as the world's largest single site source of greenhouse gas emissions.[80]

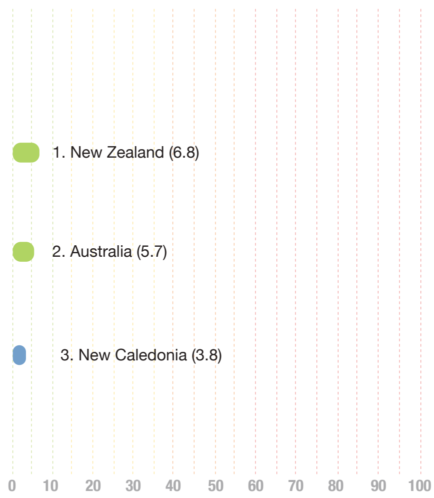


Annual hours spent at different PM2.5 pollution levels

OCEANIA

Australia | New Caledonia | New Zealand

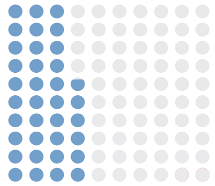
City markers indicating 2021 PM2.5 levels, size adjusted for population

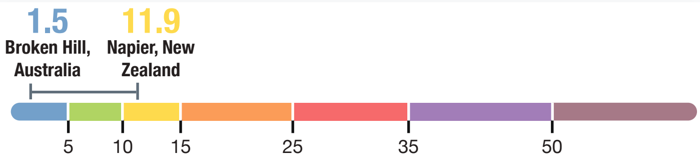


2021 PM2.5 average (μg/m³)

35.7%

Regional cities that met the WHO PM2.5 guideline in 2021





Range of 2021 average PM2.5 (μg/m³) across regional cities

Most Polluted Regional Cities

Rank	City	2021
1	Napier, New Zealand	11.9
2	Blenheim, New Zealand	11.5
3	Armidale, Australia	11.4
4	Richmond, New Zealand	11.1
5	Masterton, New Zealand	11
6	Tokoroa, New Zealand	10.8
7	Otorohanga, New Zealand	10.4
8	Bathurst, Australia	10.3
9	Kaiapoi, New Zealand	10.2
10	Ludmilla, Australia	9.6
11	Timaru, New Zealand	9.2
12	Geraldine, New Zealand	9.1
13	Cockburn, Australia	8.9
14	Bungendore, Australia	8.7
15	Waimate, New Zealand	8.6

Least Polluted Regional Cities

Rank	City	2021
1	St Helens, Australia	1.9
2	Judbury, Australia	2
3	Emu River, Australia	2.1
4	Mornington, Australia	2.4
5	Gretna, Australia	2.6
6	Derby, Australia	2.6
7	Exeter, Australia	2.7
8	West Ulverstone, Australia	2.9
9	Cygnet, Australia	3
10	Hobart, Australia	3
11	Bream Creak, Australia	3
12	Smithton, Australia	3
13	George Town, Australia	3.3
14	Glenorchy, Australia	3.6
15	Fingal, Australia	3.6

SUMMARY

Oceania has the cleanest overall air quality in the world. Yet, typical challenges to air quality in the region can include brushfires and dust storms originating from Australia's desert interior. The 2020/2021 Australian bushfire season was less intense than in previous years, in part due to a cool, wet summer.[81] However, the 2019/2020 fire season was one of the most destructive fire seasons in the country's history. PM2.5 emissions impacted the region as smoke drifted as far away as South America.[81]

Consistent with the previous year, there were higher concentrations of recorded PM2.5 in some cities in Australia and in New Zealand's Canterbury region between May and August. This may be because of increased wood burning in winter. Heaters cause about 40% of winter air pollution in Australia's capital and the region's largest city, Sydney.[82]

Forty-six cities in Australia, one in New Zealand, and one in New Caledonia all met the WHO PM2.5 air quality guideline of 5 μg/m³. However, a further 63 cities in Australia and 20 in New Zealand failed to meet this standard, impacting the health of over 21 million people.

As the population in the region grows, there will be increasing pressure for potentially fossil-burning transportation and energy consumption. Coupled with climate change, the region will become hotter and more arid, creating more intense dust storms and brushfires.

MONITORING STATUS

Generally, higher-income countries tend to have more air quality monitoring sensors within their networks. However, Oceania doesn't follow that trend. This is probably due to the fact that Australia and New Zealand have less dense populations than most wealthier nations and lower air pollution levels. In 2021, the number of regional air quality monitoring stations grew by 40%, largely driven by gains in Australia and New Zealand, home to 99% of the monitoring stations in the region.

Next Steps

What can governments do?

Decrease air pollution emissions

- Pass legislation to incentivize the use of clean air vehicles for personal and industrial use.
- Invest in renewable energy sources.
- Provide financial incentives, such as trade-in programs, to limit the use of internal combustion engines.
- Provide subsidies to encourage the use of battery and human-powered transportation methods.
- Expand public transportation and power with clean and renewable energy sources.
- Build additional infrastructure to encourage pedestrian and bicycle traffic.
- Strengthen and enforce emission limits for vehicles and industry.
- Adopt new air quality standards based on the 2021 World Health Organization Air Quality Guidelines.
- Implement forest management strategies to limit wildfires.
- Ban agricultural and biomass burning.
- Develop innovative civic strategies for improving air quality.

Expand the air quality monitoring framework

- Increase the number of public air quality monitoring stations.
- Provide incentives to non-governmental organizations and individuals who set up their own air quality monitoring stations.

What can I do?

- Support local and national initiatives, propositions, measures, organizations and politicians who advocate for better air quality.
- Contact elected representatives to voice support for and/or encourage air quality issue advocacy.

Limit your exposure to air pollution

- Reduce activities outdoors when air quality is unhealthy.
- Wear a KN95, N95, or FFP2 respirator mask when air quality is unhealthy.
- Prevent polluted outdoor air from entering homes and workspaces by closing doors and windows and setting A/C systems to recirculation mode.
- Use air filters and air purification systems where possible.
- Follow real-time and forecasted air quality reports to stay informed and safe.
- When possible, heat homes and cook with gas or electric rather than wood burning stoves.
- When outdoor air quality improves, even briefly, ventilate indoor spaces by opening windows and setting A/C systems back to fresh air intake.

Lower your personal air pollution footprint

- Choose cleaner, greener modes of transport such as walking, biking, and riding public transportation.
- Lower personal energy consumption.
- Reduce waste by recycling, upcycling, and purchasing less.
- Help to raise air pollution awareness in your community.

Become an air quality data contributor

Expanding awareness of, and access to, air quality information is an important action in the fight against air pollution and its harmful health consequences. Once people know where to find timely local air quality information, there is a much better chance they will become clean air advocates.

Even though the number of air quality monitoring stations, and their global distribution, continues to grow, there are still many areas around the world that do not have access to local air quality information.

Local air quality monitoring by governmental agencies and non-governmental entities is essential to overcome the lack of air quality information and awareness.

Technological advancements over the last few years have allowed the easy deployment of low-cost air quality monitors that can be turned into publicly reporting stations. The more stations that come online, the more air quality data is available for researchers, policymakers, and communities to help create knowledge, awareness, and action for cleaner air and healthier communities.

Methodology

Data sources

The PM2.5 air quality data used to create this report was generated exclusively by ground-level monitoring stations. Of those stations, 44% were operated by governmental agencies. The remaining 56% were privately-owned stations operated mainly by individuals, educational institutions, and non-profit organizations.

Most data employed in the report was collected in real time, aggregated on an hourly basis as the measurements were made publicly available. However, there are instances where data collected from ground-based monitors was not published in real time but rather published as year-end historical data sets. These cases primarily occurred for data from European cities. Historical data was obtained from the European Environment Agency (EEA) and integrated with the data collected in real time to provide the most comprehensive global data analysis possible.

Data validation

Both regulatory-grade air quality monitors and low-cost monitors are subject to data anomalies and inaccuracies because of sensor defects or temporary hyperlocal emissions near the sensor. Post-data acquisition quality control measures are implemented in IQAir's cloud-based data platform to mitigate potential bias introduced by such events. Data points from individual sensors deemed to be outliers are flagged and quarantined prior to additional data processing and integration into the platform. Flagged data points are checked against subsequent data points collected from the same sensor, as well as cross-referenced to nearby sensors. Data points that do not meet the quality control criteria for these two standard reference checks are discarded.

Data calibration

Low-cost PM2.5 sensors included in this report quantify PM2.5 concentrations using laser scattering technology. 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.

Data calculation

The data presented in this report, PM2.5 annual average concentrations for cities, countries, regions, and territories, is a function of data collected from the individual stations located within the geographical borders of the given location. Each individual sensor periodically samples the ambient air to measure the real-time PM2.5 concentration, recording the data point and the time it was measured. Every hour the data is aggregated by averaging all data points collected during the prior 60 minutes, creating a calculated value defined as the hourly average PM2.5 concentration. Throughout the course of the year, this procedure creates a series of hourly average PM2.5 concentrations for each individual sensor. These values are then used to calculate the annual average PM2.5 concentration values for cities, countries, regions, and territories.

City level data

City level data included here are reported as both annual and monthly average PM2.5 concentration values. Monthly average PM2.5 concentration values are determined by averaging together all hourly average PM2.5 concentration values for all stations within that city for that month. This ensures the data for each hour of the day and each individual station is weighted the same in the city-level average calculation. City level annual average PM2.5 concentration values are calculated in the same manner, with the averaging period extended to include all data points collected within the year.

Country/region data

Country, region, and territory annual average PM2.5 concentrations are calculated as a function of the city-level annual average PM2.5 concentration and the population for all cities within the geographical boundaries of the country, region, or territory being calculated. In this section, for the sake of clarity and brevity, the term "area" will be used in place of "country, region, and territory".

A primary purpose of this report is to provide an overview of the state of air quality around the world and to report the data in such a way that allows for meaningful comparisons of the ambient air quality experienced by individuals in different areas. A simple metric for comparing air quality would be to average all individual city-level PM2.5 concentrations to obtain a composite PM2.5 average concentration for an area. However, this simple composite calculation could very easily fail to convey any meaningful information about relative air quality experienced if the population density varied among cities.

In order to reflect a more accurate representation of the average air quality experienced in an area, city population data must also be considered. Using population weighting as a normalization factor allows for the air quality conditions experienced in more densely populated urban environments to be proportionately reflected in annual area-level averages. In this way, cities that have larger populations influence the overall area-level average concentration more heavily than those cities with smaller populations. This ensures the composite area concentration is more reflective of the average air quality experienced within that area, providing additional context necessary to directly compare data across global areas.

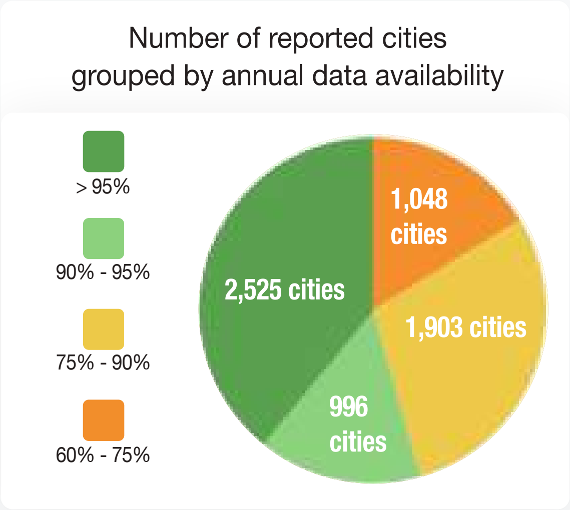
The following calculation is used to determine area-level, annual average PM2.5 concentration based on the city-level data contained in this report, population weighted to provide global context.

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

Data availability

Annual availability was the primary metric used to determine if the average annual PM2.5 concentration value calculated for a particular city was sufficiently representative of that city's actual air quality. This value is defined as the fraction of total hours in a year (8,760 total) for which there is hourly average PM2.5 data available. In order to meet the threshold for report inclusion, a city was required to have an annual data availability of at least 60%, or at least 5,256 recorded values for hourly average PM2.5 concentrations.

A summary of the 2021 data availability is provided below.



The pie chart shows the distribution of the total number of reported cities (6,475) by annual data availability.

Disclaimer

This report is limited to PM2.5 data collected in 2021 from ground-level air quality monitoring stations comprised of regulatory-grade monitors and low-cost sensors.

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 a data visualization tool.

FAQ

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

- Some locations don't have sufficient public data for PM2.5. This report only includes cities for which validated PM2.5 measurements from ground based PM2.5 monitoring stations are available. No satellite data or satellite derived data are included in the World Air Quality Report.
- The area lacks adequate data availability in 2021 to be representative of the air quality for the year.

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

- There are different ways to calculate city averages including hourly, daily, monthly, and yearly. This report uses an hourly average value across all stations in a city. This hourly average helps to eliminate any outliers in the data that can influence averages calculated in different ways.
- Data in this report is aggregated from both private and government operated air quality monitors. Low-cost monitor data from independent contributors is often not included in a government data set, although they can provide a more comprehensive and representative picture of local air quality. Some governments also have monitoring stations for which they did not provide timely public air quality data to be included in this report.

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

- This report only includes data for cities that have an annual data availability of at least 60%. This means that to be included in this report, a city must have hourly PM2.5 data available for 60% of the total number of hours in a year.
- For some global locations that lack ground-level PM2.5 data, the IQAir AirVisual platform includes satellite data with PM2.5 values marked with an asterisk (*). While some modeled and satellite data is available on the IQAir AirVisual Platform, that data is not included in this report.

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

- The data set of the world's most polluted cities is provided in an interactive format on the IQAir website here. This ranking also includes monthly average values and historical annual average values.

What is adequate data availability?

- In order to be as inclusive as possible in the number of locations contributing air quality data to this report, a data availability threshold has been established requiring 60% annual data availability. This threshold allows the inclusion of many locations in historically underrepresented, developing countries or regions. In many of these places around the world, air quality monitoring is in its early stages. The 60% threshold criteria allows for an adequate level of rigor with regards to the quality of the data included in the report, while also allowing for the inclusion of emerging air quality networks.

References

1. World Health Organization. (2014). Burden of disease from the joint effects of household and ambient air pollution for 2012. https://www.who.int/airpollution/data/AP_joint_effect_BoD_results_May2018.pdf
2. Greenpeace. (2020). Toxic air: The price of fossil fuels. https://www.greenpeace.org/southeastasia/press/3594/toxic-air-the-price-of-fossil-fuels/
3. Harvard T.H. Chan School of Public Health. (n.d.). Coronavirus and air pollution. https://www.hsph.harvard.edu/c-change/subtopics/coronavirus-and-pollution/
4. World Health Organization. (2021). WHO global air quality guidelines: Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. https://apps.who.int/iris/handle/10665/345329
5. World Health Organization - Regional Office for Europe. (2017). Evolution of WHO air quality guidelines: past, present and future. WHO Regional Office for Europe. https://apps.who.int/iris/handle/10665/341912
6. Murray C, et al. (2020). Global burden of 87 risk factors in 204 countries and territories, 1990-2019: A systematic analysis for the global burden of disease study 2019. Lancet. DOI: 10.1016/S0140-6736(20)30752-2 https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)30752-2/fulltext
7. Brauer M, et al. (2019). Mortality–Air pollution associations in low-exposure environments (MAPLE): Phase 1. Health Effects Institute. https://www.healtheffects.org/publication/mortality%E2%80%93air-pollution-associations-low-exposure-environments-maple-phase-1
8. Brunekreef B, et al. (2021). Mortality and morbidity effects of long-term exposure to low-level PM2.5, black carbon, NO2 and O3: An analysis of European cohorts in the ELAPSE project. Health Effects Institute. https://www.healtheffects.org/publication/mortality-and-morbidity-effects-long-term-exposure-low-level-pm25-bc-no2-and-o3-analysis
9. Dominici F, et al. (2019). Assessing adverse health effects of long-term exposure to low levels of ambient air pollution: Phase 1. Health Effects Institute. https://www.healtheffects.org/publication/assessing-adverse-health-effects-long-term-exposure-low-levels-ambient-air-pollution
10. AirNow.gov. (n.d.). Air Quality Index (AQI) basics. https://www.airnow.gov/aqi/aqi-basics/#:~:text=The%20U.S.%20AQI%20is%20EPA%E2%80%99s%20index%20for%20reporting,air%20pollution%20and%20the%20greater%20the%20health%20concern.
11. AirNow.gov. (2018). Technical assistance document for the reporting of daily air quality – the Air Quality Index (AQI). https://www.airnow.gov/sites/default/files/2020-05/aqi-technical-assistance-document-sept2018.pdf
12. Lo J. (2022). 'Extraordinary progress' – Beijing meets air pollution goals after coal crackdown. Climate Home News. https://www.climatechangenews.com/2022/01/04/extraordinary-progress-beijing-meets-air-pollution-goals-coal-crackdown/
13. Pui D, et al. (2014). PM2.5 in China: Measurements, sources, visibility and health effects, and mitigation. ScienceDirect. DOI: 10.1016/j.partic.2013.11.001. https://www.sciencedirect.com/science/article/abs/pii/S1674200113002228
14. Schonhardt S. (2021). Energy crunch raises questions about China's devotion to coal. E&E News. https://www.eenews.net/articles/energy-crunch-raises-questions-about-chinas-devotion-to-coal/
15. Gang L, et al. (2021). Resurgence of sandstorms complicates China's air pollution situation. American Chemical Society. DOI: 10.1021/acs.est.1c03724 https://pubs.acs.org/doi/10.1021/acs.est.1c03724
16. UN Environment Programme. (2015). Air quality policies: South Korea. https://wedocs.unep.org/bitstream/handle/20.500.11822/17110/SouthKorea.pdf?sequence=1&amp%3BisAllowed
17. Shepherd G, et al. (2016). Global assessment of sand and dust storms. UNEP.org. https://wesr.unep.org/redesign/media/docs/assessments/global_assessment_of_sand_and_dust_storms.pdf
18. Choi JJ, et al. (2021). Role of sea fog over the Yellow Sea on air quality with the direct effect of aerosols. JGR Atmospheres. DOI: 10.1029/2020JD033498 https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020JD033498
19. Eck T. (2020). Influence of cloud, fog, and high relative humidity during pollution transport events in South Korea: Aerosol properties and pm2.5 variability. ResearchGate. DOI: 10.1016/j.atmosenv.2020.117530 https://www.researchgate.net/publication/340960424_Influence_of_cloud_fog_and_high_relative_humidity_during_pollution_transport_events_in_South_Korea_Aerosol_properties_and_PM25_variability

20. Climate & Clean Air Coalition (CCAC). (2019). Air pollution in Asia and the Pacific: Science based solutions. https://www.ccacoalition.org/en/resources/air-pollution-asia-and-pacific-science-based-solutions-summary-full-report
21. Greenpeace. (2020). Burning up: Health impact of Indonesia's forest fires and implications for the COVID-19 pandemic. https://www.greenpeace.org/static/planet4-southeastasia-stateless/2020/09/9295d7dd-burning-up-2020-health-impact-of-indonesia%E2%80%99s-forest-fires.pdf
22. van Donkelaar A, et al. (2016). Global estimates of fine particulate matter using a combined geophysical-statistical method with information from satellites, models, and monitors. Environmental Science and Technology. DOI:10.1021/acs.est.5b05833 https://pubs.acs.org/doi/abs/10.1021/acs.est.5b05833
23. UN Environment Programme. (2015). Air quality policies: Indonesia. https://wedocs.unep.org/bitstream/handle/20.500.11822/17217/Indonesia.pdf?sequence=1&isAllowed=
24. Karmini N. (2021). Indonesian court rules president negligent over pollution. AP News. https://apnews.com/article/environment-and-nature-lawsuits-indonesia-environment-business-b368916626b56e6f6c761c51ad637539
25. Greenpeace Indonesia. (2021). Factsheet: The Indonesia and the World Health Organization's Air Quality Guidelines. Greenpeace.org. https://www.greenpeace.org/static/planet4-indonesia-stateless/2021/09/03adc854-indonesia-and-the-world-health-organization-air-quality-guidelines.pdf
26. Organisation for Economic Co-operation and Development. (2016). Indonesia policy brief. https://www.oecd.org/environment/indonesia-promoting-green-growth-for-sustainable-resource-use.pdf
27. Purnomo E, et al. (2021). Observed data of forest fire hotspots effects on Respiratory Disorder by ARC-GIS in Riau Province Indonesia. IOP Science. https://iopscience.iop.org/article/10.1088/1755-1315/717/1/012036/meta
28. International Association for Medical Assistance Travelers. (2020). Malaysia. https://www.iamat.org/country/malaysia/risk/air-pollution
29. Mongabay.com. (2016). SE Asian governments dismiss finding that 2015 haze killed 100,300. https://news.mongabay.com/2016/09/se-asian-governments-dismiss-finding-that-2015-haze-killed-100300/
30. Association of Southeast Asian Nations. (2003). ASEAN haze agreement to enter into force. https://asean.org/asean-haze-agreement-to-enter-into-force/
31. Thaiger. (2021). Thailand on fire – NASA satellite website tracks the country's farm fires. https://thethaiger.com/hot-news/environment/thailand-on-fire-nasa-satellite-website-tracks-the-countrys-farm-fires
32. Nidam J, et al. (2021). Air quality in Thailand: Understanding the regulatory context. Stockholm environment Institute. https://cdn.sei.org/wp-content/uploads/2021/02/210212c-killeen-archer-air-quality-in-thailand-wp-2101e-final.pdf#:~:text=Poor%20air%20quality%20is%20a%20pressing%20concern%20in,time%2C%20industrial%20and%20vehicular%20pollution%20are%20year-round%20problems.
33. IQAir.com. (2021). New data exposes Thailand's 2021 "burning season." https://www.iqair.com/blog/air-quality/thailand-2021-burning-season
34. Reardon R. (2022). The reality of elderly poverty in Vietnam. The Borgen Project. https://borgenproject.org/category/vietnam/
35. International Finance Corporation. (2022). Wind power fuels green growth in Vietnam. https://www.ifc.org/wps/wcm/connect/news_ext_content/ifc_external_corporate_site/news+and+events/news/wind-power-fuels-green-growth
36. UN Environment Programme. (n.d.). Restoring clean air. https://www.unep.org/regions/asia-and-pacific/regional-initiatives/restoring-clean-air
37. The Energy and Resources Institute. (2019). Scoping study for South Asia air pollution. https://assets.publishing.service.gov.uk/media/5cf0f3b0e5274a5eb03386da/TERI_Scoping_Study_final_report_May27_2019.pdf
38. Roy A. (2020). Finding solutions to air pollution in India: The role of policy, finance, and communities. Observer Research Foundation. https://www.orfonline.org/research/finding-solutions-to-air-pollution-in-india-the-role-of-policy-finance-and-communities-74311/
39. Entertainment Times. (2017). Top 8 main causes for air pollution in Delhi. https://timesofindia.indiatimes.com/life-style/health-fitness/health-news/top-8-main-causes-for-air-pollution-in-delhi/articleshow/61626744.cms
40. International Organization of Motor Vehicle Manufacturers. (2020). 2020 production statistics. https://www.oica.net/category/production-statis-

tics/2020-statistics/

41. Brook JR et al. (2007). Assessing sources of PM2.5 in cities influenced by regional transport. Journal of Toxicology and Environmental Health. DOI:10.1080/15287390600883000 https://www.tandfonline.com/doi/abs/10.1080/15287390600883000

42. Singh R, et al. (2022). Measuring emissions from vehicles in the real world: Policy steps in India. DownToEarth. https://www.downtoearth.org.in/blog/pollution/measuring-emissions-from-vehicles-in-the-real-world-policy-steps-in-india-81046

43. The International Council on Clean Transportation. (2016). India Bharat Stage VI emission standards. https://theicct.org/sites/default/files/publications/India%20BS%20VI%20Policy%20Update%20vF.pdf

44. Tikku P. (2019). Indian real driving emissions (IRDE). International Centre for Automotive Technology. http://www.ecmaindia.in/uploads/files/Ms.%20Pamela%20Tikku%20(ICAT).pdf

45. Air Quality Life Index. (2022). Country spotlight: Pakistan. University of Chicago. https://aqli.epic.uchicago.edu/country-spotlight/pakistan/

46. Food and Agriculture Organization of the United Nations. (2019). FAO report analyzes the causes of smog in Punjab focusing on agriculture. https://www.fao.org/pakistan/news/detail-events/en/c/1179183/

47. Malik S. (2021). Air Quality Index in Pakistan worsens, coughs, allergies reported. https://www.samaaenglish.tv/living/health/2021/11/air-quality-index-in-pakistan-worsens-coughs-allergies-reported/

48. Asian Development Bank. (2021). New Pakistan Clean Air Plan (PCAP) announcement. https://www.adb.org/news/events/new-pakistan-clean-air-plan-pcap-announcement

49. International Grown Centre. (2021). Charting Pakistan's air quality policy landscape. https://www.theigc.org/wp-content/uploads/2021/06/Habib-March-2021-Final-report.pdf

50. United Nations Environment Programme. (2016). Global environment outlook GEO-6: Regional assessment for West Asia. http://wedocs.unep.org/bitstream/han-dle/20.500.11822/7668/GEO_West_Asia_201611.pdf

51. NASA MODIS. (2021). June 14, 2021: Dust over the Persian Gulf. https://modis.gsfc.nasa.gov/gallery/individual.php?db_date=2021-06-14

52. European Environmental Agency. (2020). Air pollution: How it affects our health. https://www.eea.europa.eu/themes/air/health-impacts-of-air-pollution

53. Roth, A. (2021). Russian forest fire damage worst since records began, says Greenpeace. The Guardian. https://www.theguardian.com/world/2021/sep/22/russia-forest-fire-damage-worst-since-records-began-says-greenpeace

54. Oshchepkov M. (2021). Siberia's 2021 fires were stronger than the fires in Greece, Turkey, Italy, the United States, and Canada combined. Climate Scorecard. https://www.climatescorecard.org/2021/10/siberias-2021-fires-were-stronger-than-the-fires-in-greece-turkey-italy-the-united-states-and-canada-combined/

55. Government of Canada. (2021). Air Pollutant Emissions.Canada.ca. https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/air-pollutant-emissions.html

56. Caiazzo F. (2013). Air pollution and early deaths in the United States. Part I: Quantifying the impact of major sectors in 2005. Atmospheric Environment. DOI: 10.1016/j.atmosenv.2013.05.081. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.700.6901&rep=rep1&type=pdf

57. Government of Canada. (2020). Health impacts from air pollution. https://www.canada.ca/en/environment-climate-change/campaigns/canadian-environment-week/ clean-air-day/health-impacts-air-pollution.html

58. Watts, J. (2021). Global wildfire carbon dioxide emissions at record high, data shows. The Guardian. https://www.theguardian.com/world/2021/sep/21/global-wildfire-carbon-dioxide-emissions-at-record-high-data-shows

59. The Canadian Interagency Forest Fire Centre. (2021). National fire situation report. https://ciffc.net/en/ciffc/ext/public/sitrep/

60. Harvard T.H. Chan School of Public Health. (2021). Decreased vehicle emissions linked with significant drop in deaths attributable to air pollution. Science News. https://www.sciencedaily.com/releases/2021/12/211213160134.htm

61. Clay K, et al. (n.d.). Recent increases in air pollution: Evidence and implications for mortality. University of Chicago. DOI: 10.1086/712983 https://www.journals.uchicago.edu/doi/pdf/10.1086/712983

62. EPA.gov. (n.d.). Benefits and costs of the Clean Air Act 1990-2020, the second prospective study. https://www.epa.gov/clean-air-act-overview/benefits-and-costs-clean-air-act-1990-2020-second-prospective-study

63. EPA.gov. (2021). Study finds exposure to air pollution higher for people of color regardless of region or income. https://www.epa.gov/clean-air-act-overview/benefits-and-costs-clean-air-act-1990-2020-second-prospective-study
64. Colmer J et al. (2020). Disparities in PM2.5 air pollution in the United States. Science. DOI: 10.1126/science.aaz9353 https://www.science.org/doi/10.1126/science.aaz9353
65. Popovich N et al. (2021). See how wildfire smoke spread across America. The New York Times. https://www.nytimes.com/interactive/2021/07/21/climate/wildfire-smoke-map.html#:~:text=In%20southern%20Oregon%2C%20the%20Bootleg%20Fire%20grew%20so,being%20felt%20thousands%20of%20miles%20from%20the%20flames.
66. McLaughlin K. (2021). Smoke from the Western wildfires has reached the East Coast, and it's causing air-quality issues and hazy skies. Insider. https://www.insider.com/western-us-wildfires-smoke-reached-east-coast-air-quality-2021-7
67. Aires Nuevos Citizen Air Quality Network for Early Childhood in Latin America. (n.d.). Where we are: The Aires Nuevos network has established strong partnerships in Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, and Uruguay. https://airesnuevos.org/con-que-y-que-medimos/
68. International Association for Medical Assistance to Travelers. (2020). Brazil general health risks: Air pollution. https://www.iamat.org/country/brazil/risk/air-pollution
69. Lima E. (2021). Amid economic crisis, Brazilians switch from gas to wood for cooking fuel. EarthBeat. https://www.ncronline.org/news/earthbeat/amid-economic-crisis-brazilians-switch-gas-wood-cooking-fuel
70. EPA.gov. (n.d.). Wood smoke and your health. https://www.epa.gov/burnwise/wood-smoke-and-your-health
71. San-Miguel-Ayanz J, et al. (2021). Weekly & monthly analysis of wildfires in the Amazon region and South America. Publications Office of the European Union. https://effis-gwis-cms.s3-eu-west-1.amazonaws.com/gwis/reports-and-publications/2020-amazon-weekly-reports/Wildfires_in_the_Amazon_November_30_-_December_6,_2020,_JRC_Technical_Report_vfinal.pdf
72. Taylor C. (2021). The Amazon rainforest is now releasing more carbon than it can absorb, study finds. CNBC. https://www.cnbc.com/2021/07/15/amazon-rainforest-now-releasing-more-carbon-than-it-absorbs-study.html
73. United Nations Environment Programme. (2021). Working with nature, Colombia fights air pollution. https://www.unep.org/news-and-stories/story/working-nature-colombia-fights-air-pollution
74. Climate & Clean Air Coalition. (n.d.). Colombia: CCAC partner since 2012. https://www.ccacoalition.org/en/partners/colombia
75. Bourzac K. (2019). Air pollution kills 780,000 people in Africa each year. Chemical and Engineering News. https://cen.acs.org/environment/pollution/Air-pollution-kills-780000-people/97/i17
76. The Economist. (2020). Africa's population will double by 2050. https://www.economist.com/special-report/2020/03/26/africas-population-will-double-by-2050
77. South African Government. (1996). Constitution of the Republic of South Africa, 1996 - Chapter 2: Bill of Rights. https://www.gov.za/documents/constitution/chapter-2-bill-rights#24
78. AFP. (2019). Pollution and smog plague lives on South Africa's Highveld. https://www.thesouthafrican.com/news/pollution-and-smog-plague-lives-on-south-africas-highveld/
79. Pant A, et al. (2020). Understanding the role of subsidies in South Africa's coal-based liquid fuel sector. International Institute for Sustainable Development. https://www.iisd.org/publications/subsidies-south-africa-coal-based-liquid-fuel-sector
80. Sguazzin A. (2020). The world's biggest emitter of greenhouse gases. Bloomberg. https://www.bloomberg.com/news/features/2020-03-17/south-africa-living-near-the-world-s-biggest-emitting-plant
81. Reuters. (2020). Australian bushfire smoke drifts to South America – WMO. https://www.reuters.com/article/us-australia-bushfires-wmo-idUSKBN1Z6271
82. Keywood MD, et al. (2017). Australia State of the Environment 2016: Atmosphere. Australia State of the Environment. https://soe.environment.gov.au/sites/default/files/soe2016-atmosphere-final-web-v3.pdf?v=1499655757

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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 AirVisual platform supports the free integration of air quality data from a wide variety of data sources and monitoring devices.