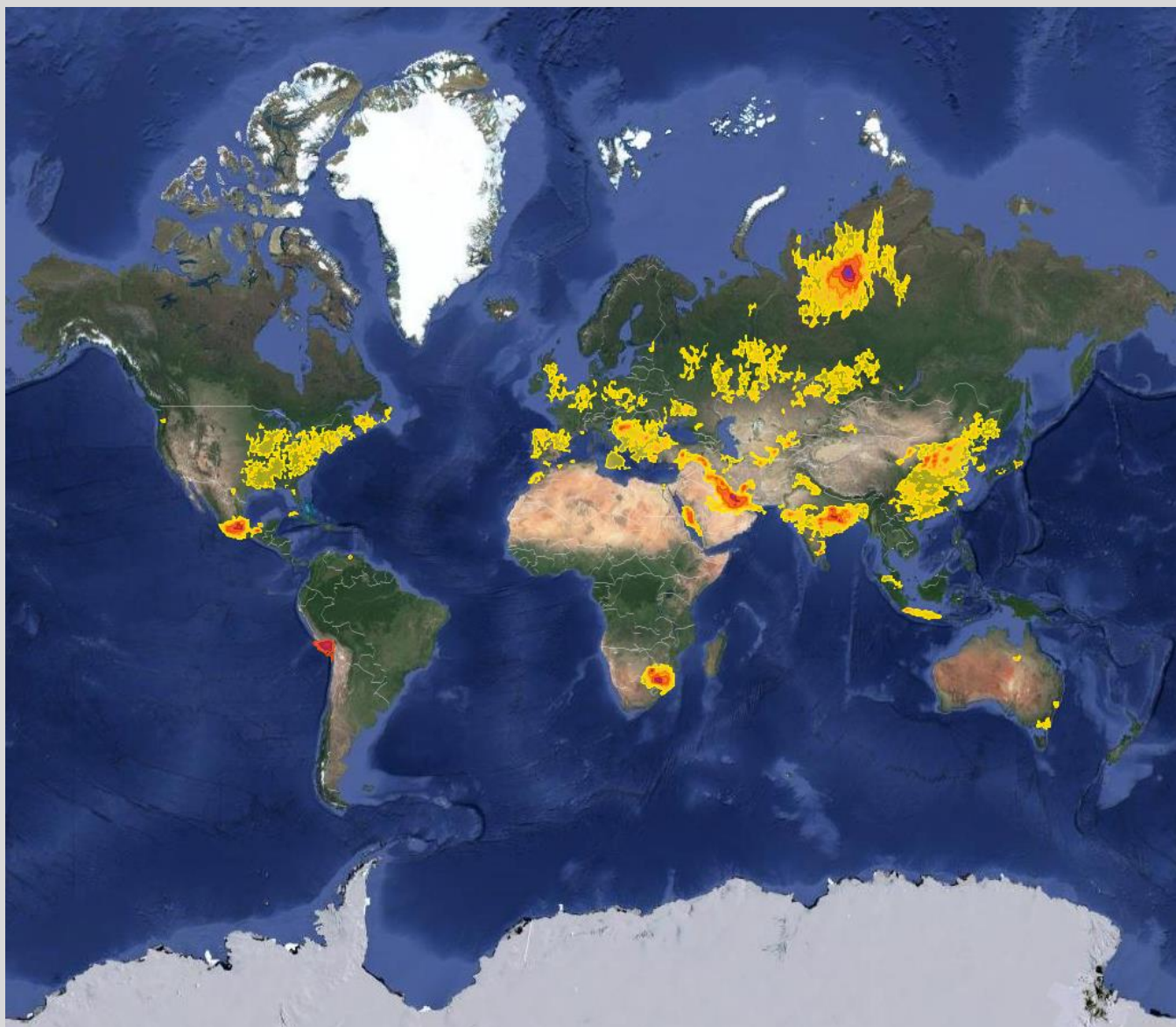


# Global SO<sub>2</sub> emission hotspot database

RANKING THE WORLD'S WORST SOURCES OF SO<sub>2</sub> POLLUTION



**GREENPEACE**  
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## Content

<b>Executive Summary</b>	<b>4</b>
<b>Introduction</b>	<b>6</b>
<b>Methodology</b>	<b>7</b>
<b>Data and Analysis</b>	<b>8</b>
<b>Way Forward</b>	<b>18</b>
<b>Power plant emission standards for SO<sub>2</sub> emissions for large coal based power plants (mg/Nm<sup>3</sup>)</b>	<b>19</b>
<b>Endnotes</b>	<b>xx</b>

Global SO<sub>2</sub> emission hotspot database

Ranking the world's worst sources of SO<sub>2</sub> pollution



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**Cover page image:**

Screenshot of SO<sub>2</sub> emission hotspot intensity  
map plotted on Google Maps based on NASA  
OMI database



**Power plants burning coal and oil are responsible for two-thirds of the anthropogenic SO<sub>2</sub> emissions tracked by NASA. Oil refineries and metals smelters are the other major sources worldwide.**

## Executive Summary

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Air pollution is a public health emergency, with more than 90% of the world's population living in areas where the air is unsafe.

Yet few of the countries and regions with the worst air quality have comprehensive inventories of the sources of the pollution. Satellite data enables us to reveal the worst emitters of pollution regardless of their location.

This briefing analyses NASA data on the largest point sources of SO<sub>2</sub>, one of the key pollutants contributing to deaths from air pollution worldwide. To accompany the briefing there is an online [interactive map](#)<sup>i</sup> of the world's worst sources of SO<sub>2</sub> pollution, which allows further exploration of emission hotspots across different regions.

Power plants burning oil and coal are responsible for two-thirds of the anthropogenic SO<sub>2</sub> emissions tracked by NASA. Oil refineries and metals smelters are the other major sources worldwide.

The largest SO<sub>2</sub> emission hotspots are found in Russia, South Africa, Iran, Saudi Arabia, India,

Mexico, United Arab Emirates, Turkey and Serbia.

At the states/provinces level, Krasnoyarsk in Russia has the highest anthropogenic SO<sub>2</sub> emissions levels globally followed by the Makkah province in the Kingdom of Saudi Arabia and Mpumalanga province in South Africa.

The country ranking shows India as the top emitter of SO<sub>2</sub> in the world, contributing more than 15% of the global anthropogenic SO<sub>2</sub> emissions from the point sources tracked by NASA. Saudi Arabia ranks as the first Arab country in SO<sub>2</sub> emissions, and ranks 6<sup>th</sup> globally, followed by the United Arab Emirates (14<sup>th</sup>), Qatar (15<sup>th</sup>), Kuwait (17<sup>th</sup>), Iraq (23<sup>rd</sup>) and Morocco (25<sup>th</sup>).

Air pollutant emissions from power plants and other industries continue to increase in India, Saudi Arabia and Iran. In Russia, South Africa, Mexico and Turkey, emissions are currently not increasing but there is not a lot of progress in tackling them either. Transitioning towards cleaner air in these countries is stunted by a high reliance



on coal and oil, weak emission standards and a lack of enforcement.

Out of the major emitters of  $\text{SO}_2$ , China and the United States of America have been able to reduce emissions rapidly. They have achieved this by

switching to clean energy sources and particularly China achieved it through dramatically improving the emission standards and enforcement for  $\text{SO}_2$  control.



## Introduction

Annually, 4.2 million people die prematurely from ambient, outdoor air pollution alongside another 3.2 million due to indoor and household air pollution (2016) according to the World Health Organization (WHO).<sup>2</sup> The same WHO report states that 91% of the world's population lives in areas exceeding the WHO air quality guidelines. In contrast to improvements of household air quality since the 1990s<sup>3</sup>, ambient air pollution stemming from increasing fossil fuel combustion remains a big problem throughout the world.

The World Bank recently estimated that "In 2013 exposure to ambient and household air pollution cost the world's economy some \$5.11 trillion in welfare losses. In terms of magnitude, welfare losses in South Asia and East Asia and the Pacific were the equivalent of 7.4 percent and 7.5 percent of the regional gross domestic product (GDP), respectively"<sup>4</sup>. Welfare losses due to air pollution continue to increase, mounting concern for countries across the world.

Emissions of sulfur dioxide (SO<sub>2</sub>) are a significant contributor to air pollution. SO<sub>2</sub> is released while burning materials that contain sulfur, which is found in all types of coal and oil across the world in varying proportions. The health impact of SO<sub>2</sub> derives both from direct exposure to SO<sub>2</sub> and exposure to fine particulate matter<sup>5</sup> (PM<sub>2.5</sub>)

produced when SO<sub>2</sub> reacts with other air pollutants to form sulfate particles. PM<sub>2.5</sub> is the air pollutant with the largest public health impact because it is a cocktail of all different kinds of pollution ranging from heavy metals to secondary gaseous pollutants such as sulphates and nitrates. These pollutants are so small that they can penetrate deeper into our organs and cells harming every organ in our body, causing everything from dementia and fertility problems to reduced intelligence as well as heart and lung disease<sup>6</sup>.

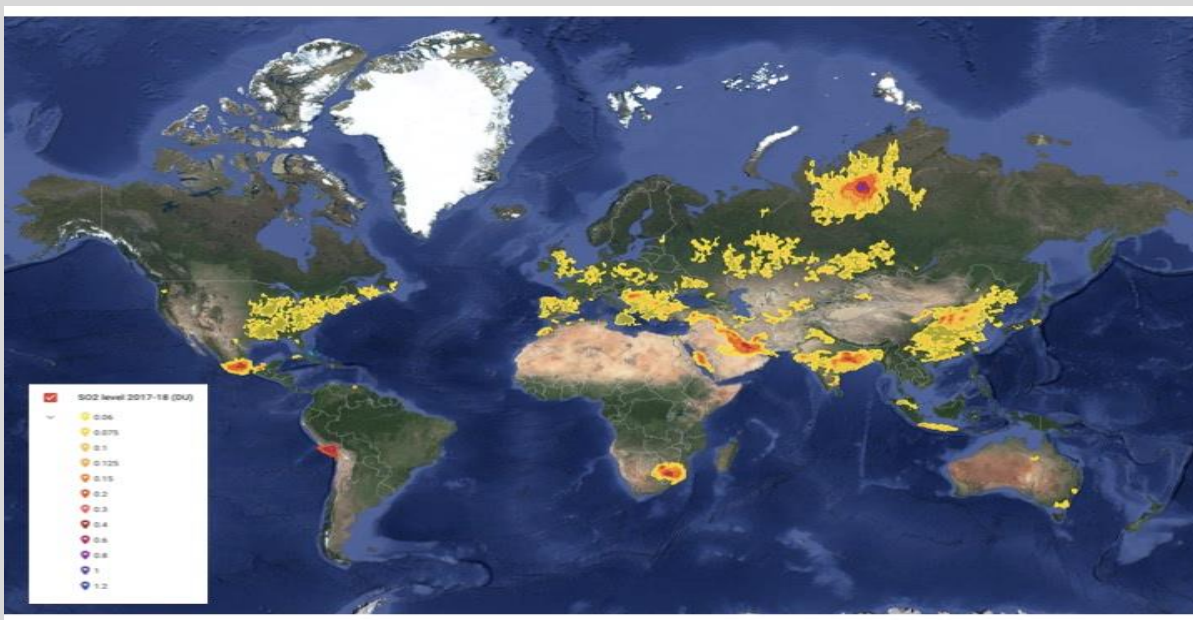
The greatest source of SO<sub>2</sub> in the atmosphere is the burning of fossil fuels in power plants and other industrial facilities. Smaller sources of SO<sub>2</sub> emissions include industrial processes such as extracting metal from ore; natural sources such as volcanoes; and locomotives, ships and other vehicles and heavy equipment that burn fuel with a high sulfur content. It is estimated that SO<sub>2</sub> commonly makes up >10% of the fine particles in China<sup>7</sup> and India<sup>8</sup>, often much more during heavy pollution episodes.<sup>9</sup> To tackle this problem adequately, it is important to understand both its extent and its causes. Where are pollution hotspots, what are their contributing sources, the history of their buildup and how do their emissions disperse over regions across the globe

## Methodology

The NASA OMI satellite has been monitoring air quality from space since 2004 with high consistency. Its worldwide observation coverage enables us to identify pollution hotspots which are not listed in emission inventories. Furthermore, by comparing upwind and downwind SO<sub>2</sub> levels, NASA has quantified emissions of large point sources and validated their results against in situ measurements in the U.S. and the European Union (EU).<sup>10,11</sup>

We use their MEaSUREs SO<sub>2</sub> source emission catalogue<sup>12</sup> to identify countries, administrative domains and the point sources with the largest anthropogenic SO<sub>2</sub> emissions. We refined this data

set, by breaking down the sources of a hotspot's emissions into several categories ie., coal, oil & gas and smelters (modified from NASA original classification). We also added details of smaller industries as well as the largest emission source in the region. This way, we better represent the contributions of individual emitters within a cluster, rather than just that of the biggest. The names for hotspots were adapted from NASA database by us to represent the region as hotspots instead of just the biggest polluter in the region. An [interactive map](#) showing the raw OMI SO<sub>2</sub> column amounts together with the locations of the retrieved emission sources is available (Fig. 1 depicts a screenshot of that map).



**Figure 1:** Presence of SO<sub>2</sub> emission hotspots detected by NASA OMI. Please refer to the interactive map at <https://bit.ly/30inNie>



## Data and Analysis

NASA OMI satellite data captured more than 500 major point sources of SO<sub>2</sub> emissions across the globe including natural sources such as volcanoes. Excluding all natural sources from our analysis and only investigating anthropogenic sources of SO<sub>2</sub>, we found a close correlation of high SO<sub>2</sub> emission levels within regions that have high fossil fuel consumption i.e., geographies with high coal

In many cases, the total emissions for a region cannot be attributed to an exact source because emissions from large sources may obscure those

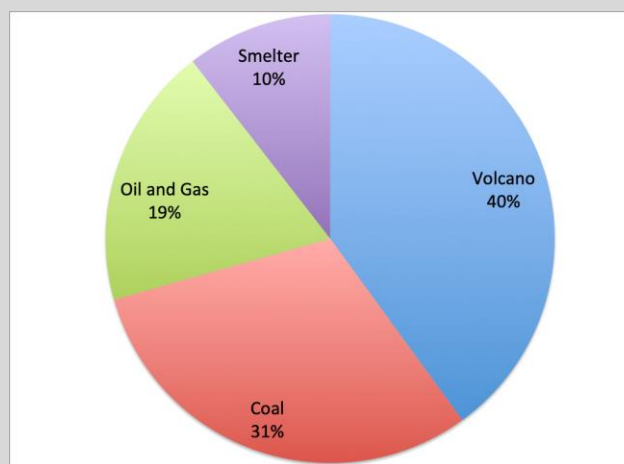
burning, oil combustion and refining as well as smelters.

Sixty percent of the total emissions detected by the satellite are anthropogenic. Regions with high capacity of coal combustion for power generation and industries, oil and gas refining/combustion and smelters, contributed 31%, 19% and 10% respectively (Figure 2, Table 1).

of other smaller nearby contributors. Therefore, in cases where multiple industries are present in the cluster, we take the largest sources as representing all other sources.

Source	SO2 emission 2018 (kt/yr)
Volcano	19868
Coal	15217
Oil and Gas	9385
Smelter	5216

**Table 1:** Major sectors contributing to anthropogenic SO<sub>2</sub> emission in 2018



**Figure 2:** Sources identified by NASA OMI for SO<sub>2</sub> emissions (kt/yr) across the world in 2018



The Norilsk (Норильск) smelter site in Russia continues to be the largest anthropogenic SO<sub>2</sub> emission hotspot in the world, followed by the Kriel area in Mpumalanga province of South Africa and Zagroz in Iran (Table 3). The Rabigh oil and gas power plant and industrial cluster in the Makkah province of Saudi Arabia is the largest anthropogenic SO<sub>2</sub> emission hotspot in the Arab World and the 4th globally. This hotspot has been catching up with the top three hotspots in the last

decade and have increased its pollution dramatically.

This is mainly caused by expanding oil refining/consumption and in part due to slow implementation and uptake of stringent emission standards. Some countries, such as China, have enforced more stringent emission regulation for fossil fuel combustion and other industrial processes, leading to a decrease of SO<sub>2</sub> emissions (Figure 3).

**Table 2: Country wise anthropogenic SO<sub>2</sub> emissions in 2018 estimated by NASA from identified point sources - Top 25 emitter countries**

Country	SO <sub>2</sub> emission from hotspots in 2018 (kt/yr)
1. India	4,586
2. Russia	3,683
3. China	2,578
4. Mexico	1,897
5. Iran	1,820
6. Saudi Arabia	1,783
7. South Africa	1,648
8. Ukraine	979
9. U.S.	967
10. Turkey	919
11. Kazakhstan	832
12. Australia	696
13. Cuba	637

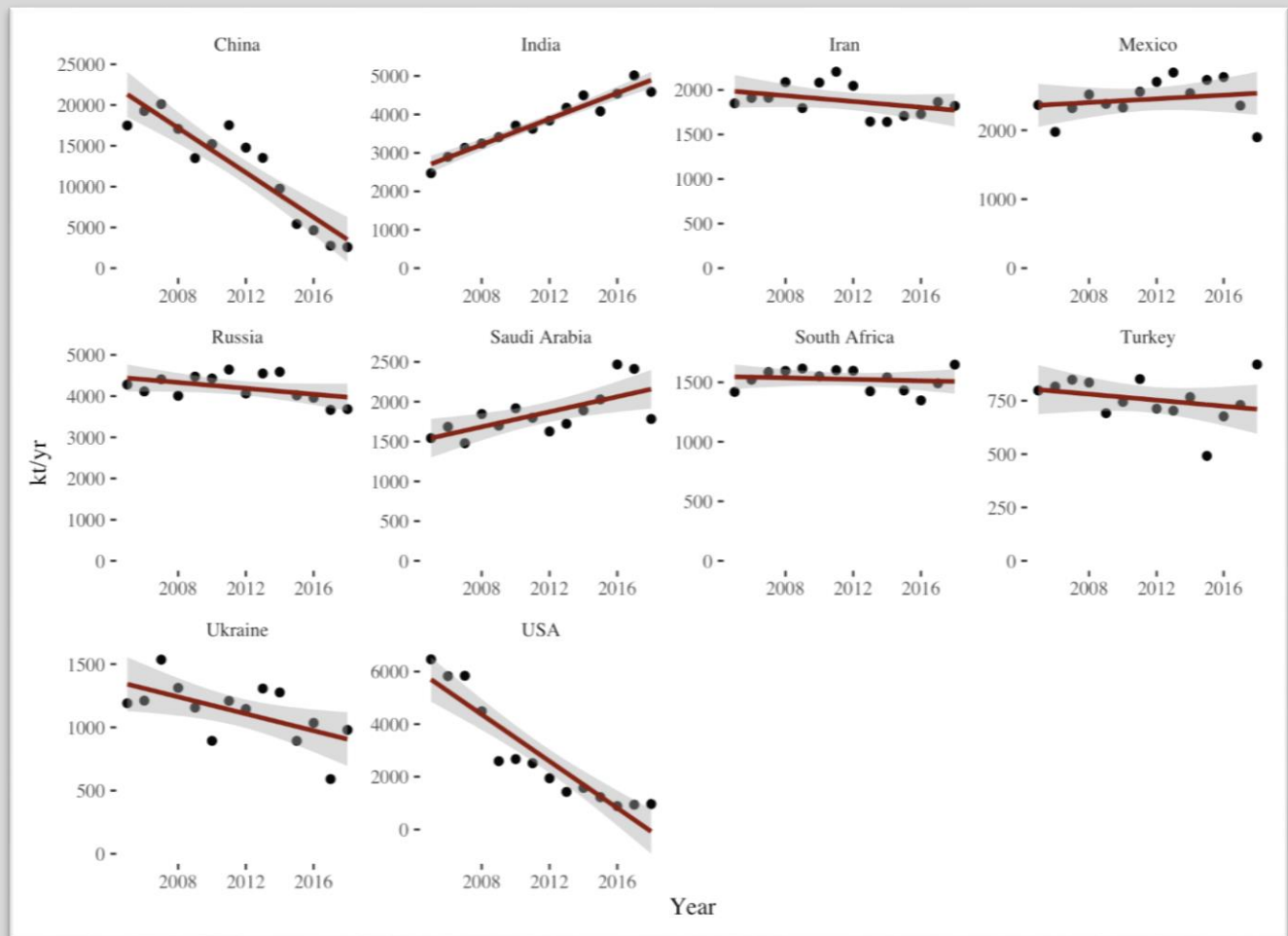
Country	SO <sub>2</sub> emission from hotspots in 2018 (kt/yr)
14. United Arab Emirates	406
15. Qatar	398
16. Serbia	394
17. Kuwait	394
18. Uzbekistan	381
19. Bulgaria	350
20. Venezuela	340
21. Peru	305
22. Indonesia	298
23. Iraq	258
24. Bosnia and Herzegovina	242
25. Morocco	216



**Table 3: Top 50 SO<sub>2</sub> emission hotspots (kt/yr) across the world in 2018**

Hotspot Name	SO <sub>2</sub> emissions (kt/yr)
1. Norilsk	1898
2. Kriel	714
3. Zagroz	614
4. Rabigh	515
5. Singrauli	507
6. Cantarell	461
7. Matimba	412
8. Reforma	407
9. Shaiba	398
10. Das Island	397
11. Neyveli	393
12. Sarcheshmeh	384
13. Talcher	347
14. Kemerkey	340
15. Ilo	305
16. Jharsuguda	301
17. Korba	280
18. Nikola Tesla	272
19. Afsin Elbistan	271
20. Al Doha	269
21. Fereidoon	267
22. Vuglegirska	265
23. Mubarek	243
24. Lethabo	243
25. Tuzla	242
26. Majuba	238
Hotspot Name	SO <sub>2</sub> emissions (kt/yr)
27. Jose	229

28. Kutch	228
29. Chennai	215
30. Kurakhovskaya	214
31. Suralaya	213
32. Mt Isa Copper, Lead, Zinc and Silver Mining Cluster	207
33. Maritsa East industrial complex	205
34. Petacalco	204
35. Laffan	200
36. Mesaieed	198
37. Khangiran	197
38. Khark Island	187
39. Nicaro	184
40. Guiteras	177
41. Singapore	175
42. Visakhapatnam	171
43. Tangshan	169
44. Jubail	163
45. Pavlodar	162
46. Bagdad	158
47. Ramagundam	157
48. Raigarh	154
49. La Trobe Valley	151
50. Yanbu	150



**Figure 3: Trends in anthropogenic SO<sub>2</sub> emissions by country since 2005**

Countries have different levels of SO<sub>2</sub> emissions depending on the presence of emitting industries and the stringency and enforcement of emission regulations.

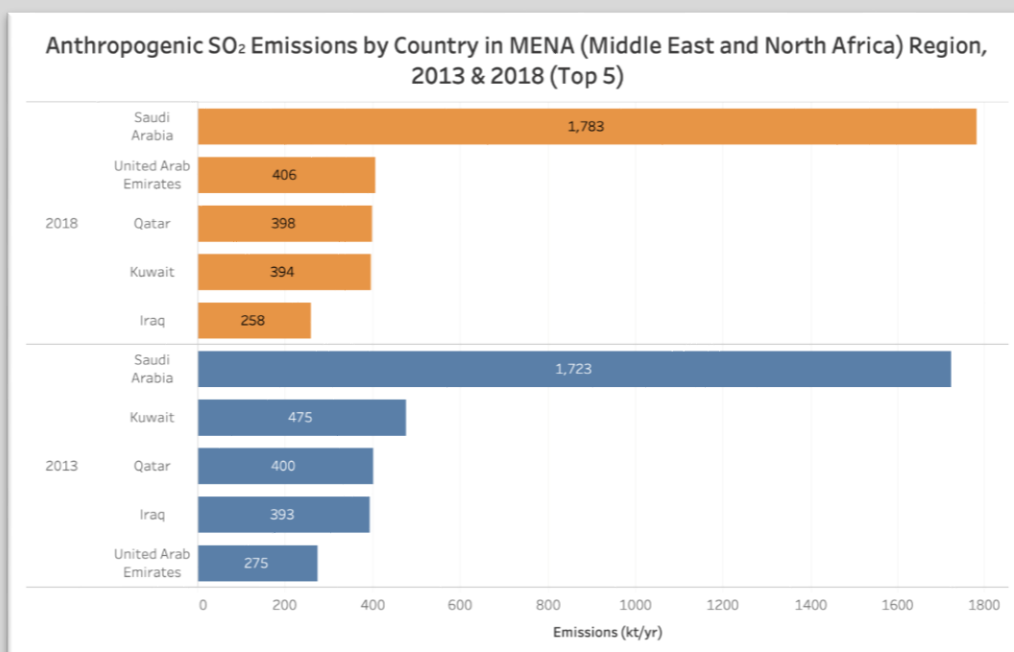
The worst sources of SO<sub>2</sub> pollution are discussed below; the full data set can be explored using the [interactive map](#)<sup>13</sup>.



## Geographical Regions

**India:** India is the largest emitter of SO<sub>2</sub> in the world, contributing more than 15% of global anthropogenic SO<sub>2</sub> emissions from NASA detected hotspots. The primary reason for India's high emission output is the expansion of coal-based electricity generation over the past decade. The vast majority of plants in India lack flue-gas desulfurization technology to reduce their air pollution. Singrauli, Neyveli, Talcher, Jharsuguda, Korba, Kutch, Chennai, Ramagundam, Chandrapur and Koradi thermal power plants or clusters are the major emission hotspots in the country.

**Saudi Arabia:** Saudi Arabia is the largest emitter of SO<sub>2</sub> in the Middle East and North Africa (MENA) region (Figure 4). Within 120 km of the Makkah province, one of the most populated provinces in the country, there are large clusters of SO<sub>2</sub> emission sources including Rabigh, Shaiba and Jeddah. Oil power plants and oil refineries in these locations emitted 59% of SO<sub>2</sub> among Saudi Arabia's total emissions in 2018. This high density of power plants is the reason why Makkah province has the 2<sup>nd</sup> highest anthropogenic SO<sub>2</sub> emissions levels among states/provinces globally (Table 4 & Figure 5). Other major sources of SO<sub>2</sub> in the kingdom are the power plants and refineries in Jubail, Yanbu, Al Hofuf, Riyadh, Uthmaniyah, Buraydah.



**Figure 4: Country ranking of anthropogenic SO<sub>2</sub> emissions in MENA 2013 & 2018**



**Russia:** The Norilsk smelters in Russia are responsible for more than 50% of the total emissions tracked by NASA in the whole of Russia. At most other locations, there has been a small decrease of emissions over the past 15 years. Karabash (Карабаш), Orenburg (Оренбург), Kirovgrad (Кировград), Ufa (Уфа) and Krasnouralsk (Красноуральск) are the other major SO<sub>2</sub> hotspots in Russia, hosting smelters, gas refinery and coal combustion facilities for power and industries.

**China:** Having the largest coal-fired power generation capacity in the world, China was the biggest emitter for SO<sub>2</sub> until about a decade ago. Since it started installing FGD systems across the electricity generation sector, air quality has substantially improved, while China still remains the third largest emitter in the world.

**Mexico:** Oil fields in the Gulf of Mexico are among the biggest hotspots in the world. Their emissions increased until 2016 before dropping for two consecutive years in 2017 and 2018. The other major SO<sub>2</sub> emission hotspots in the country are at the Reforma refinery region, the Petacalco power plants region, and the refinery and power plant region around Tula, contributing to air pollution in nearby areas including in Mexico City.

**Australia:** The largest SO<sub>2</sub> pollution hotspots in Australia are in Mount Isa, Queensland, a complex of mining operations with lead & copper smelters and in the La Trobe Valley,

**South Africa:** The Mpumalanga province in South Africa is not only the largest SO<sub>2</sub> pollution hotspot in Africa but in 2017 and 2018, the cluster of mega power plants in Nkangala, including Duvha (3600 MW), Kendal (4000 MW) and Kriel (3000MW) coal power stations in Mpumalanga region ranked second in the world for anthropogenic SO<sub>2</sub> emissions. There are 12 coal-fired power stations in the province, located just 100-200 km from South Africa's largest populated area, the Gauteng City region, posing a massive health concern. Power generation from these plants makes the Mpumalanga region the largest hotspot of SO<sub>2</sub> emissions from power generation in the world.

**Europe:** In Europe, three countries stand out for their SO<sub>2</sub> emissions - Ukraine, Serbia and Bulgaria. All three are in the list of largest 20 SO<sub>2</sub> emitters in the world. Without exception coal based power plants are the main source of high SO<sub>2</sub> emissions in all three countries. Bulgaria is the only EU country on the list. In 2017 the EU adopted stricter SO<sub>2</sub> emission limits for coal-fired power plants but Bulgaria is opposing these new rules and continues to permit operational power plants to emit more than the law allows and is also seeking exemptions from the rules, instead of taking steps to phase out coal.

Victoria, a group of coal-fired power plants located 100-150 kilometres away from Australia's second-largest metropolitan centre, Melbourne. Despite globally significant emissions of SO<sub>2</sub>,

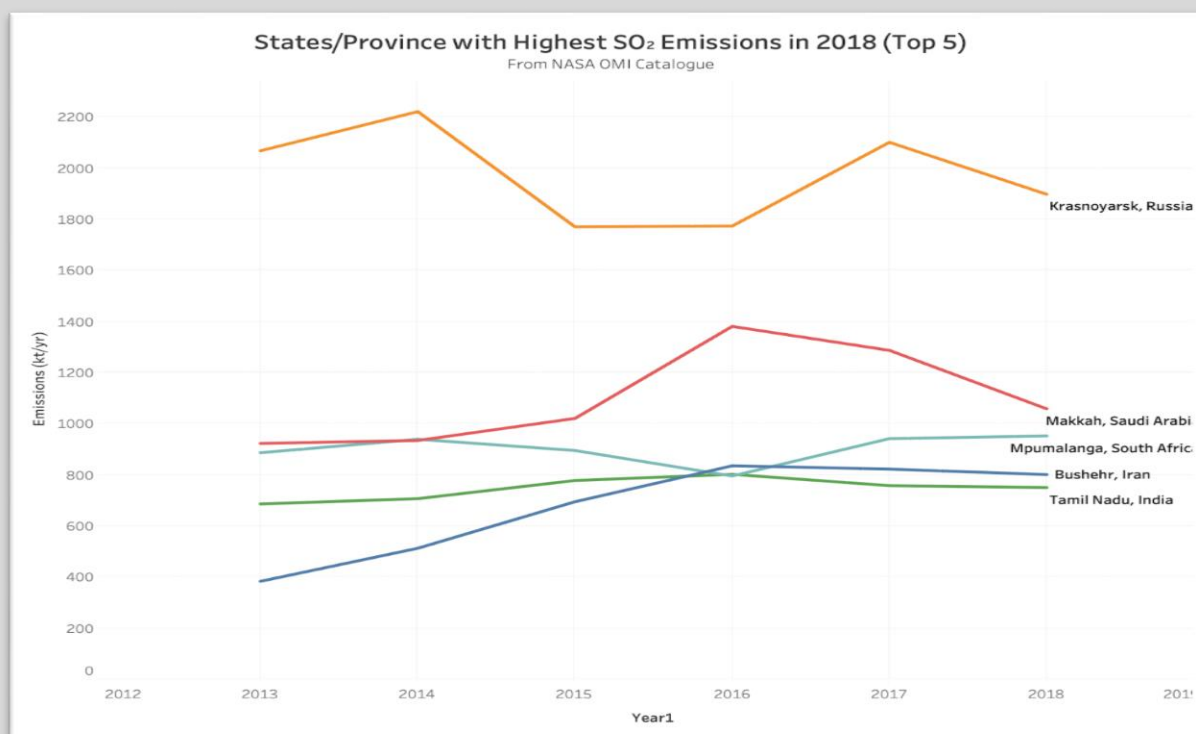


there are currently no national or statewide limits  
on power station emissions of SO<sub>2</sub> in any  
Australian jurisdiction, placing Australia's system

of pollution regulation behind countries  
including China, U.S. and the EU.

**Table 4: Global ranking of States/Provinces anthropogenic SO<sub>2</sub> emissions levels from 2005 to 2018**

Province	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1. <b>Krasnoyarsk, Russia</b>	1928	1764	2044	1816	2302	2158	2354	1806	2069	2222	1771	1774	2102	1898
2. <b>Makkah, Saudi Arabia</b>	719	799	693	936	829	701	768	668	923	935	1021	1381	1287	1059
3. <b>Mpumalanga, South Africa</b>	970	1031	1029	1057	1109	1048	1090	1126	887	939	896	796	942	952
4. <b>Bushehr, Iran</b>	868	804	758	902	771	861	950	557	384	513	695	836	823	801
5. <b>Tamil Nadu, India</b>	563	502	538	561	567	576	646	651	686	707	778	802	758	750



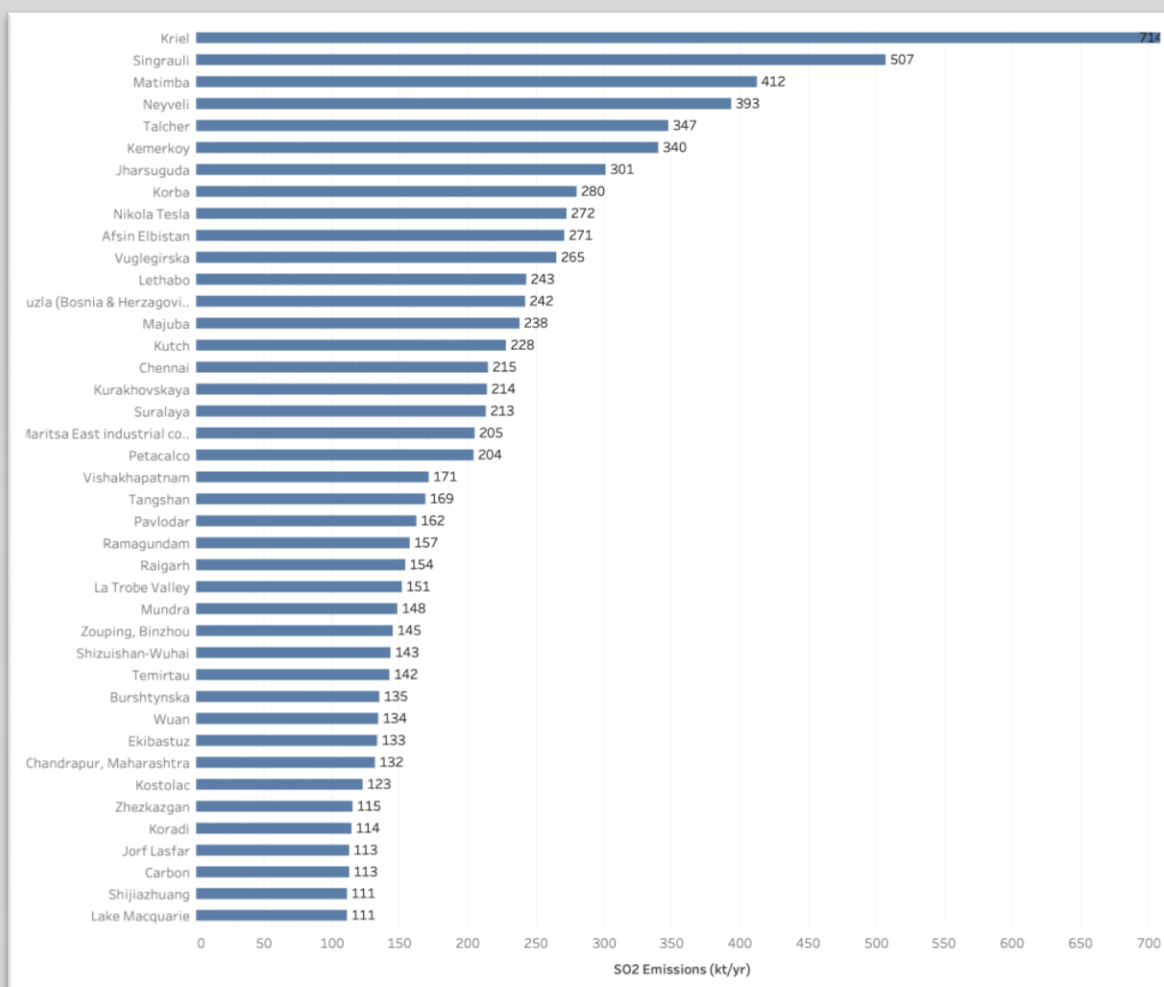
**Figure 5: Top 5 States/Provinces with highest SO<sub>2</sub> emissions in 2018**



## Major Polluting Sector

**Coal Combustion:** More than 51% of total anthropogenic SO<sub>2</sub> emissions are emitted in regions of high coal consumption for power generation and industries. Coal combustion for power generation is the major emission source in these regions, with smaller contributions from oil

refineries/consumption, smelters and others. The NASA MEaSUREs data, highlights that coal-based power plants are the major emission sector in India, China, Indonesia, Thailand, Mexico, South Africa, Bulgaria and Australia.

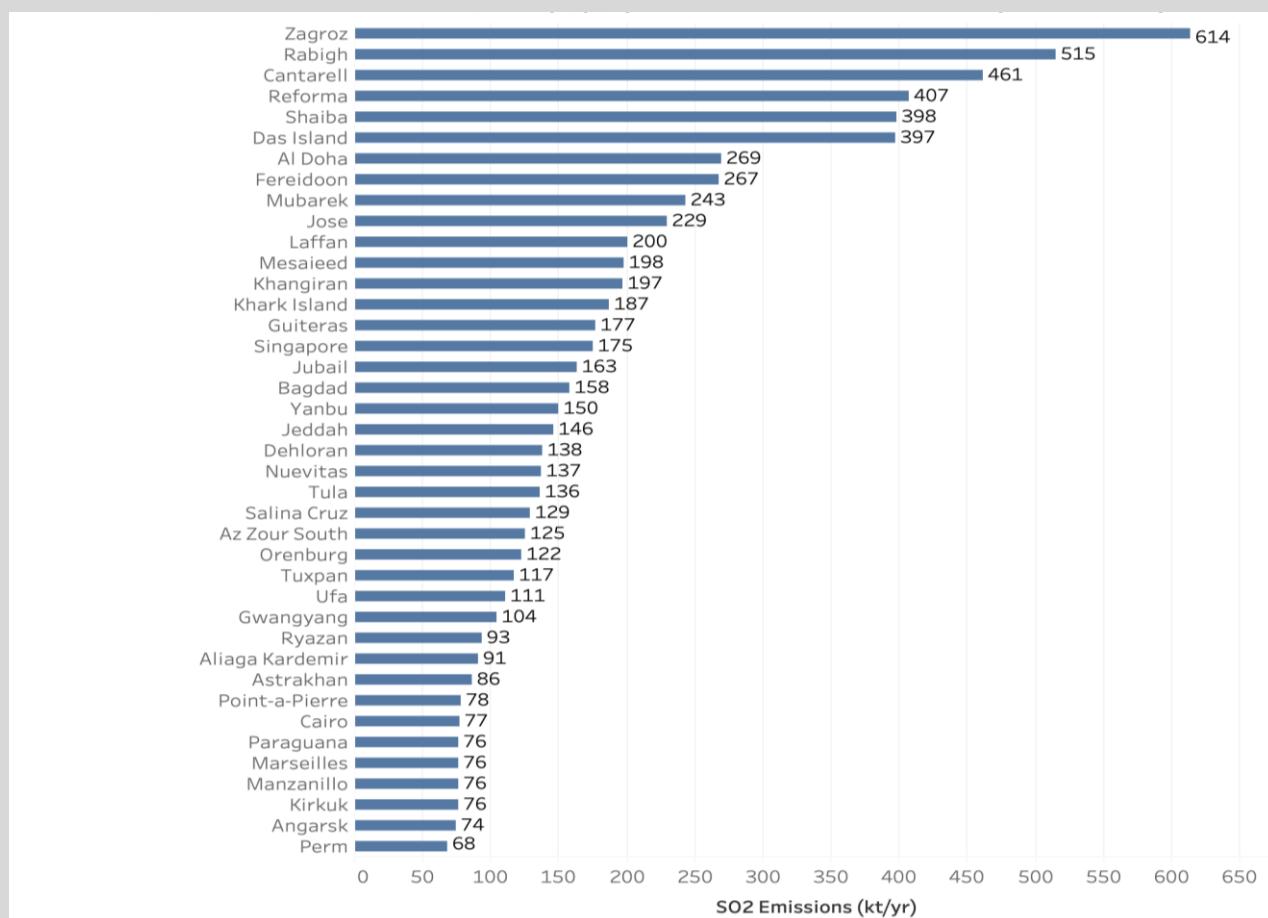


**Figure 6: Top 40 SO<sub>2</sub> emission hotspots (kt/yr) across the world in 2018 (Coal: Power generation/Industr**



In recent years many states and regions including China, India, South Africa and Indonesia have imposed or enhanced their emission standards for SO<sub>2</sub> and started deploying desulfurization technology. However, regulations and their enforcement differ between countries and in most places the emission standards are still far too weak to improve air quality effectively. This difference in emission regulation and varying efficiencies of SO<sub>2</sub> pollution control results in varying emissions from the same capacity of power plants across different regions.

**Oil and Gas Refining/Power Generation:** Oil refining and gas industries/power generation in Mexico, Saudi Arabia, Iran, United Arab Emirates (UAE), Russia, Uzbekistan and Venezuela pump large quantities of SO<sub>2</sub> emissions into the atmosphere. Hotspots detected by the NASA OMI instrument show the regions where oil refining and gas facilities are present. The OMI instrument captured more than 40 regions with oil and gas refining clusters. Saudi Arabia hosts some of the highest SO<sub>2</sub> hotspots resulting from oil refining and gas processing clusters, including, Rabigh, Shaiba, Jubail, Yanbu and Jeddah

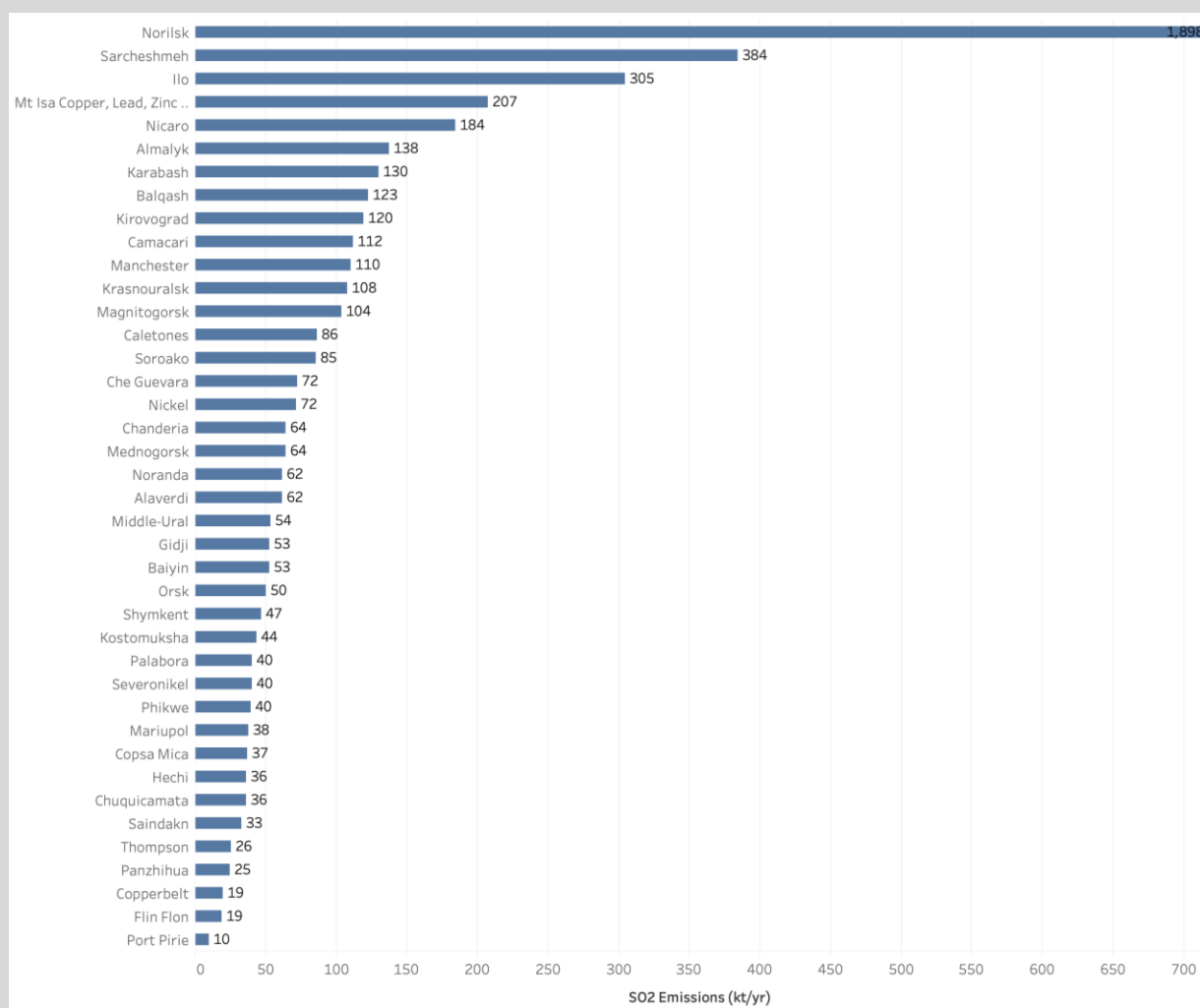


**Figure 7: Top 40 SO<sub>2</sub> emission hotspots (kt/yr) across the world in 2018 (Oil and Gas)**



**Smelters:** Metal smelters across the world are usually located in clusters around metal mines where raw metal ore can be extracted. The operation of these smelters, especially those without proper pollution control devices emits SO<sub>2</sub> into the atmosphere and can be detected by the NASA OMI instrument. Smelters are the principal

contributor to SO<sub>2</sub> in many of the biggest detected hotspots. Emission levels for these hotspots are shown in Figure 8. Norilsk in Russia remains the biggest emitting region worldwide, followed by Sarcheshmeh in Iran, Ilo in Peru, Nicaro in Cuba, Almalyk in Uzbekistan and Karabash in Russia.



**Figure 8: Top 40 SO<sub>2</sub> emission hotspots (kt/yr) across the world in 2018 (Smelters)**



## Way Forward

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The burning of fossil fuels such as coal, oil and gas is the largest source of anthropogenic emissions of SO<sub>2</sub> resulting in poor air quality and premature deaths across the world.

By identifying SO<sub>2</sub> emission hotspots in this briefing, we show the scale of air pollution across regions and where dramatic change needs to be implemented for human wellbeing.

Air pollution and the climate emergency share the same solutions. Emission hotspot regions across the world owe it to citizens to stop investing in fossil fuels and shift to safer, more sustainable sources of energy such as solar and wind energy, while reducing the impact of existing polluting facilities by adopting stricter emission standards.

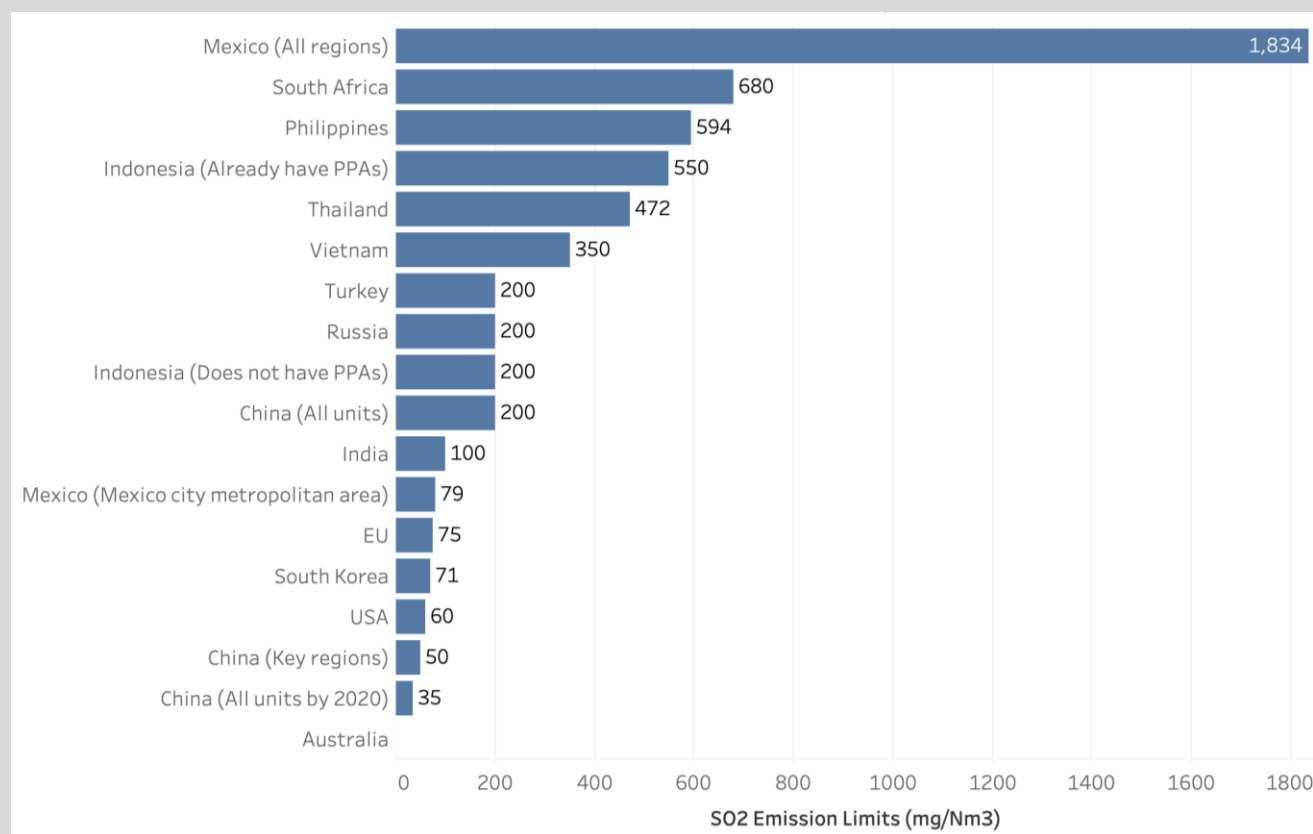


## Power plant emission standards for SO<sub>2</sub> emissions for large coal based power plants (mg/Nm<sup>3</sup>)

Country	Old Plants/Units		New Plants/Units	
<a href="#">China</a>	Rest of the country	200	Ultra Low Emission Standards to be adopted by 2020 across China (already applies to new units)	<a href="#">35</a>
	Key regions	50		
<a href="#">India</a>	Units commissioned before 31.12.2003	600	Units after 1.1.2017	100
	commissioned after 1.1.2004 till 31.12.2016	200		
<a href="#">U.S.</a>	Plants commissioned after 2005	160	New Power Plants	60
	Plants commissioned between 1997-2005	160		
	Plants commissioned between 1978-1996	640		
<a href="#">EU</a>	Existing Plants/Units commissioned before 31st July 2017 ≥ 300 MW	130	New Plants/Units after 31st July 2017 (applicable from 2021) ≥ 300 MW	75
	Fluidised bed boiler, ≥ 300 MW	180	Fluidised bed boiler, ≥ 300 MW	75
<a href="#">Mexico</a>	Mexico city metropolitan area, old Units	1441	Mexico city metropolitan area, new Units	79
	Critical zones, old Units	2882	Critic zones, new Units	183-262
	Rest of the country, old Units	5765	Rest of the country, new Units	576-1834
<a href="#">South Korea</a>	Plants commissioned before 31.12.14	142	Plants commissioned after 01.01.15	71
<a href="#">South Africa</a>	Old Power Plants	4760	All Power Plants from 2025	680
<a href="#">Thailand</a>	Old Power Plant Size > 500 MW commissioned Before 1996-2010	838		
	Old Power Plant Size 300- 500 MW Before 1996-2010	1179	New Power Plant Size > 50 MW 2010-Now	472
<a href="#">Indonesia</a>	Already in operation or having permits or PPAs before 23rd April 2019	550	New Power Plants (which does not have PPAs till 23rd April 2019)	200
<a href="#">Philippines</a>	Existing Power Plants	849	New Power Plants	594
<a href="#">Vietnam</a>	Existing Power Plants	500	New Power Plants	350
<a href="#">Russia</a>	Existing Power Plants/Units installed before 2001 with capacity 300 GW and more (Binding)	2000-3000	For Power Plants/Units installed after 2001 with a capacity of 250 MW or more (Bounding)	700
			Facilities licensed before 2013 and launched before 2014 for Capacity greater than 300 MW (Recommended)	200



	Facilities licensed before 2002 and launched before 2003 for Capacity greater than 300 MW (Recommended)	400		
<b>Australia</b>		N/A		N/A
<b><u>Turkey</u></b>			New Power Plants to come into operation in 2019, For Units $\geq$ 300 MW	200
	Power Plants in Operation before 2019, 100 MW $\leq$ Fuel Calorific Power $\leq$ 500 MW	2000 in 2004 400 in 2019		
	Power Plants in Operation before 2019, Fuel Calorific Power $\geq$ 500	1000 in 2004 400 in 2019		



**Figure 8: Power plant emission standards for SO<sub>2</sub> emissions for large coal based power plants (mg/Nm<sup>3</sup>)**



## Annexure: Emission hotspots & sources (2018) for SO<sub>2</sub> identified by OMI (NASA\_Aura Satellite)

S.No	Name	Country	SO <sub>2</sub> Emissions (kt/yr)_2018	Major Source	Remark
1	Norilsk	Russia	1898	Smelter	Norilsk smelters
2	Kriel	South Africa	714	Coal	Multiple sources including Duvha Power Station (3600 MW), Kendal Power Station (4000 MW), Kriel Power Station (3000MW), etc. Total 10 power plants with production >1000 MW each
3	Zagroz	Iran	614	Oil & Gas	Petrochemical complex
4	Rabigh	Saudi Arabia	515	Oil & Gas	Power Plant and Industrial Cluster
5	Singrauli	India	507	Coal	Power Generation and Coal Mining Cluster (Vindhyachal Super Thermal Power Station, Singrauli Super Thermal Power Station, and Rihand Thermal Power Station)
6	Cantarell	Mexico	461	Oil & Gas	Oil fields in the Gulf of Mexico
7	Matimba	South Africa	412	Coal	Coal power plant, ~4000 MW
8	Reforma	Mexico	407	Oil & Gas	Oil and gas factories near Reforma
9	Shaiba	Saudi Arabia	398	Oil & Gas	Shaiba Desalination and Power Plant, Oil refinery
10	Das Island	United Arab Emirates	397	Oil & Gas	
11	Neyveli	India	393	Coal	Neyveli Lignite Thermal power plants, 2740 MW (sum of three)
12	Sarcheshmeh	Iran	384	Smelter	Copper complex
13	Talcher	India	347	Coal	Power plant cluster, 3000 MW
14	Kemer koy	Turkey	340	Coal	Kemer koy, Yenikoy, and Yatagan coal power plant within 40 km
15	Ilo	Peru	305	Smelter	Ilo smelter
16	Jharsuguda	India	301	Coal	Power Plant and other factories in area



17	Korba	India	280	Coal	Power Plant Cluster (Korba Super Thermal power plant, other sources)
18	Nikola Tesla	Serbia	272	Coal	Coal power plant.
19	Afsin Elbistan	Turkey	271	Coal	Two Afsin Elbistan coal power plants 4 km apart. Kangal coal power plant located 80 km north.
20	Al Doha	Kuwait	269	Oil & Gas	Doha East and West power plants. Also Sabya power plant 40 km East
21	Fereidoon	Saudi Arabia	267	Oil & Gas	Oil Fields in Persian Gulf. A strong SO <sub>2</sub> signal.
22	Vuglegirska	Ukraine	265	Coal	Vuglegirska coal power plant. Combined with Zuevskaya power plant 50 km south and Slavyanskay power plant 50 km north
23	Mubarek	Uzbekistan	243	Oil & Gas	Mubarec gap processing plant, other oil and gas industrial sources
24	Lethabo	South Africa	243	Coal	The total capacity of 3,708MW. Construction of Lethabo started in 1980 and by December 1990, the station was fully operational.
25	Tuzla (Bosnia & Herzegovina)	Bosnia and Herzegovina	242	Coal	Tuzla, Ugljevik, and other coal power plants
26	Majuba	South Africa	238	Coal	Majuba coal power plant. The estimates may be affected by Kriel site.
27	Jose	Venezuela	229	Oil & Gas	Heavy oil refineries at Jose and Punta Araya
28	Kutch	India	228	Coal	Kutch Lignite Thermal Power Station
29	Chennai	India	215	Coal	North Chennai Thermal Power Station
30	Kurakhovskaya	Ukraine	214	Coal	Kurakhovskaya power plant
31	Suralaya	Indonesia	213	Coal	Suralaya Coal power plant, 3400 MW, other power plant and petrochemical factories in the area
32	Mt Isa Copper, Lead, Zinc and Silver Mining Cluster	Australia	207	Smelter	Industrial mining complex extracting copper, lead, gold and zinc
33	Maritsa East industrial complex	Bulgaria	205	Coal	There are several plants in the area: Maritsa East 1, Maritsa East 2, Maritsa East 3, Brikel



34	Petacalco	Mexico	204	Coal	Coal Power Plant
35	Laffan	Qatar	200	Oil & Gas	Laffan gas refinery, other sources
36	Mesaieed	Qatar	198	Oil & Gas	Oil refinery, other sources near Mesaieed
37	Khangiran	Iran	197	Oil & Gas	Shahid Hashemimjad (Khangiran) Gas refinery
38	Kharg Island	Iran	187	Oil & Gas	Oil rigs. Kharg Island is Iran's primary oil export terminal in the Persian Gulf.
39	Nicaró	Cuba	184	Smelter	Nicaró Cuba nickel smelter. The secondary source is from Punta Gorda / Moa Bay smelter
40	Guiteras	Cuba	177	Oil & Gas	Guiteras and Esta de la Habana power plants (Oil)
41	Singapore	Singapore	175	Oil & Gas	Singapore Refining Corporation Refinery, 285000 bbl/day; other sources?
42	Visakhapatnam	India	171	Coal	Power Plant
43	Tangshan	China	169	Coal	Douhe Power Plant and the Steel clusters nearby
44	Jubail	Saudi Arabia	163	Oil & Gas	Wasit Gas Plant & Jubail Water and Power Company
45	Pavlodar	Kazakhstan	162	Coal	Three power plants within 20 km
46	Bagdad	Iraq	158	Oil & Gas	Multiple power plants and oil fields in the area
47	Ramagundam	India	157	Coal	Power Plant
48	Raigarh	India	154	Coal	Power Plant and Stell Plant
49	La Trobe Valley	Australia	151	Coal	Yallourn, Loy Yang A and Loy Yang B power station
50	Yanbu	Saudi Arabia	150	Oil & Gas	Saline Water Conversion Corporation & Power and Water Utility Company for Jubail and Yanbu (MARAFIQ)
51	Mundra	India	148	Coal	Essar and Adani UMPP along with Oil refinery
52	Jeddah	Saudi Arabia	146	Oil & Gas	Saline Water Conversion Corporation, Saudi Electricity Company power plant
53	Zouping, Binzhou	China	145	Coal	Multiple aluminium and power plants in Zouping
54	Shizuishan-Wuhai	China	143	Coal	Coking/coal chemical/power plants



55	Temirtau	Kazakhstan	142	Coal	Coal power plant and steel mill. The signal is stronger in winter.
56	Dehloran	Iran	138	Oil & Gas	Oil fields. Another source in the area is Khuzestan, Iran; other sources
57	Almalyk	Uzbekistan	138	Smelter	Almalyk Copper smelter
58	Nuevitas	Cuba	137	Oil & Gas	
59	Tula	Mexico	136	Oil & Gas	Refinery, other sources
60	Burshtynska	Ukraine	135	Coal	Coal power plant
61	Wuan	China	134	Coal	Industry - coking, coal chemical, steel, power plants
62	Ekibastuz	Kazakhstan	133	Coal	Coal power plants. The signal is stronger in winter
63	Chandrapur, Maharashtra	India	132	Coal	Power Plants
64	Karabash	Russia	130	Smelter	Karabash copper smelter
65	Salina Cruz	Mexico	129	Oil & Gas	Salina Cruz Oil refinery
66	Az Zour South	Kuwait	125	Oil & Gas	Az Zour South (ZSPS) Thermal oil power plant
67	Balqash	Kazakhstan	123	Smelter	A large copper smelter
68	Kostolac	Serbia	123	Coal	Coal power plant.
69	Orenburg	Russia	122	Oil & Gas	Gas refinery, power plant within 20 km
70	Kirovograd	Russia	120	Smelter	Kirovograd smelter
71	Tuxpan	Mexico	117	Oil & Gas	Power plant and oil refinery near Tuxpan
72	Zhezkazgan	Kazakhstan	115	Coal	Copper smelter. Also power plants in the area
73	Koradi	India	114	Coal	Koradi thermal power station, 1080 MW
74	Jorf Lasfar	Morocco	113	Coal	Jorf Lasfar (JLEC) Thermal power plant
75	Carbon	Mexico	113	Coal	Carbon I and II Coal power plants
76	Camacari	Brazil	112	Smelter	Camacari copper smelter
77	Shijiazhuang	China	111	Coal	Industry - coking, coal chemical/cement/steel/power plants
78	Ufa	Russia	111	Oil & Gas	Oil refinery. Other oil power plants in the area.
79	Lake Macquarie	Australia	111	Coal	Vales Point and Eraring power stations



80	Manchester	Jamaica	110	Smelter	Bauxite plants. May not be correct position of the source.
81	Krasnouralsk	Russia	108	Smelter	Copper smelter. Other sources within 50 km
82	Seyitomer	Turkey	107	Coal	Seyitomer and Tuncbilek coal power plant located 36 km apart
83	Hejin-Hancheng	China	105	Coal	Industry - coking/steel/power plants
84	Gwangyang	South Korea	104	Oil & Gas	Steel Plant and Sub-Gas Plant
85	Liaoyang-Anshan	China	104	Coal	Industry - steel, oil, chemical and smelter
86	Magnitogorsk	Russia	104	Smelter	Magnitogorsk
87	Kothagudem	India	95	Coal	
88	Zaporizhya	Ukraine	95	Coal	Power plant and steel plant
89	Ryazan	Russia	93	Oil & Gas	Ryazan oil refinery. Other sources in the area.
90	Aliaga Kardemir	Turkey	91	Oil & Gas	Aliaga Kardemir refinery and power plant
91	Hunter Valley	Australia	91	Coal	Liddell and Bayswater Power Stations near Muswellbrook
92	Taiyuan	China	91	Coal	Industry - coal, chemical and smelter
93	Chandrapura, Jharkhand	India	89	Coal	Chandrapura coal power plant, Bokaro coal power plant 25 km West, other power plant in the area
94	Caletones	Chile	86	Smelter	Copper smelter
95	Astrakhan	Russia	86	Oil & Gas	Gas refinery, power plant within 20 km
96	Wuhan	China	85	Coal	Industry - steel, oil, chemical
97	Soroako	Indonesia	85	Smelter	Soroako nickel Smelter
98	Bobov Dol	Bulgaria	85	Coal	Bobov Dol power station
99	Homer City	U.S.	83	Coal	Keystone and Homer City coal power plant.
100	Kangal	Turkey	81	Coal	Kangal coal power plant
101	Tuticorin	India	81	Coal	Tuticorin power plant
102	Durgapur	India	80	Coal	Power Plant and Steel Plant
103	Martin Lake	U.S.	79	Coal	US Source #33, 77 kT in 2005.
104	Novocherkassk	Russia	79	Coal	



105	Reftinskaya	Russia	78	Coal	Reftinskaya power plant
106	Point-a-Pierre	Trinidad	78	Oil & Gas	Oil Refinery
107	Cairo	Egypt	77	Oil & Gas	Shoubrah El-kheima power plant, Cairo West power plant 7 km North-West
108	Laiwu	China	77	Coal	Industry - steel and power plants
109	Marseilles	France	76	Oil & Gas	Four oil refineries within 20 km. Also a large port.
110	Kirkuk	Iraq	76	Oil & Gas	Kirkuk oil wells
111	Paraguana	Venezuela	76	Oil & Gas	Paraguana Refinery Complex, Venezuela, one of the world's largest refinery complexes (940,000 bpd)
112	Manzanillo	Mexico	76	Oil & Gas	Manzanillo power plant and oil refinery
113	Xisaishang	China	75	Coal	Industry - steel, cement and power plants
114	Kryvorizka	Ukraine	75	Coal	
115	Angarsk	Russia	74	Oil & Gas	Multiple coal power plants. The signal is much stronger in winter
116	Mohammedia	Morocco	73	Coal	Mohammedia coal power plant Morocco
117	Che Guevara	Cuba	72	Smelter	Che Guevara nickel factory. Possible influence from Nicaro.
118	Wagner	U.S.	72	Coal	
119	Nickel	Russia	72	Smelter	Nickel town and smelter
120	Bellari	India	70	Coal	Coal Power Station, Steel Plant and other industries
121	Belchatow	Poland	70	Coal	Coal power plant
122	Perm	Russia	68	Oil & Gas	Perm Oil refinery. Very weak signal, just above the sensitivity level.
123	Abadan	Iran	68	Oil & Gas	Abadan oil refinery, other sources 40 km north
124	Dengfeng	China	68	Coal	Industry - cement and power plant
125	Hazira	India	68	Coal	Hazira Gseg Powerplant, other sources
126	Kota	India	67	Coal	Kota Coal Thermal power plant, 1241 MW
127	Chandaria	India	64	Smelter	Chandaria zinc and lead smelter, other sources in the area



128	Mednogorsk	Russia	64	Smelter	Mednogorsk copper smelter
129	Zmiivska	Ukraine	63	Coal	Zmiivska power plant
130	Topolobampo	Mexico	63	Oil & Gas	
131	Vijayawada	India	63	Coal	Vijayawada power plant
132	Surat	India	62	Coal	Surat lignite power station
133	Mettur	India	62	Coal	Mettur Thermal Power Station, 840 MW
134	Noranda	Chile	62	Smelter	
135	Alaverdi	Armenia	62	Smelter	Alaverdi Copper smelter
136	Bin Qasim	Pakistan	62	Coal	KESC Bin Qasim Thermal Power Station
137	Fengcheng	China	62	Coal	Industry - steel, building materials, power plant
138	Mariel	Cuba	61	Oil & Gas	Maximo Gomez oil-burning electrical power plant
139	Lambton	Canada	60	Coal	Multiple coal power plants near Sarnia
140	Varna	Bulgaria	60	Coal	Coal Power Plant and Chemical Complex
141	Arak	Iran	59	Oil & Gas	Arak refinery and power plant
142	Swedieh	Syria	59	Oil & Gas	Swedieh power plant, other sources
143	Jinzhou	China	57	Coal	Industry - oil, smelter, cement, power plant
144	Barrancabermeja	Colombia	56	Oil & Gas	
145	Pingdingshan	China	56	Coal	Industry - steel, coking, cement, power plant, chemical
146	Muskingum River	U.S.	56	Coal	Coal power plant, other coal power plants in the area
147	Udupi	India	54	Coal	Lanco Udupi Coal Mega power plant
148	Mildred Lake	Canada	54	Oil & Gas	Oil Sands mines with upgraders
149	Megalopolis	Greece	54	Coal	Coal power plant near Megalopolis.
150	Middle-Ural	Russia	54	Smelter	Middle-Ural Copper-Smelting Plant, other factories within 10 km
151	Soto de Ribera	Spain	53	Coal	Soto de Ribera Coal power plant Spain and 4 other coal power plant within 60 km radius
152	Gidji	Australia	53	Smelter	Gidji Gold Roaster and West Kalgoorlie Nickel Smelter



153	Ahvaz	Iran	53	Oil & Gas	Oil wells in Khuzistan; Marun. Fit includes other sources. Ahvaz power plant 30 km north-west
154	Linfen	China	53	Coal	Coking and power plants
155	Baiyin	China	53	Smelter	Baiyin copper smelter, other sources in the area
156	Novokuznetsk	Russia	52	Coal	Multiple coal power plants, other factories
157	Luhansk	Ukraine	51	Coal	Luhansk coal power plant
158	Shawnee	U.S.	51	Coal	US Source #82, 38 kT in 2005, another power plant (about 25 kT) 10 km west
159	Gandhi Nagar	India	51	Coal	Gandhi Nagar coal power plant
160	Yaroslavl	Russia	51	Coal	Very weak signal, just above the sensitivity level
161	Al Hofuf	Saudi Arabia	51	Oil & Gas	Uthmaniah Gas oil separation plant(GOSP) 6 Oil field, SHEDGUM gas plant / Saudi Electricity Company
162	Gallagher	U.S.	50	Coal	Gallagher power plant
163	Serov	Russia	50	Coal	Serov power plant. Also the town is the center of a mining area, with lignite, iron, bauxite, and gold mines
164	Orsk	Russia	50	Smelter	Nickel smelter in Orsk
165	Farakka	India	50	Coal	Farakka Coal power plant
166	Tianjin	China	50	Coal	Industry - power plant, cement, steel smelter
167	Kaiyuan, Honghe	China	50	Coal	Industry - power plant, cement, steel smelter
168	Zhanazhol	Kazakhstan	49	Oil & Gas	Zhanazhol crude oil has a high mercaptan and hydrogen sulfide content
169	Rockport	U.S.	49	Coal	Rockport coal power plant. Other coal power plant in the area.
170	Leland Olds	U.S.	49	Coal	Leland Olds power plant, 4 Other power plant within 35 km
171	Moscow	Russia	48	Coal	Moscow TEP-22 coal power plant, other sources
172	Riyad	Saudi Arabia	48	Oil & Gas	Power Plant, Industry and Refinery Complex
173	Brunner Island	U.S.	48	Coal	US Source #15, 105 kT in 2005



174	Choloma	Honduras	47	Oil & Gas	
175	Shymkent	Kazakhstan	47	Smelter	A large lead smelter was operational until 2008. One of the largest oil refineries in Kazakhstan is also located there.
176	Changzhou-Wuxi	China	47	Coal	Industry - power plant, manufacturing
177	Panipat	India	46	Coal	Panipat coal thermal power station, 1369 MW.
178	Shenyang	China	45	Coal	Industry - coking, smelter, power plant
179	Kostomuksha	Russia	44	Smelter	Kostomuksha ore-dressing mill
180	Novatsi	Macedonia (FYROM)	43	Coal	Power plant near Novatsi
181	Nanticoke	Canada	43	Coal	
182	Zouk	Lebanon	43	Oil & Gas	Zouk Thermal power plant Lebanon
183	Liaocheng	China	43	Coal	Industry - smelter, power plant
184	Raichur	India	42	Coal	
185	Bhilai	India	42	Coal	Bhilai Expansion power plant
186	Labadie	U.S.	42	Coal	US Source #48, 56 kT in 2005
187	Mumbai	India	42	Oil & Gas	Trombay Power Plant and Oil Refineries
188	Cadereyta	Mexico	41	Oil & Gas	Refineria Pemex Cadereyta
189	Novopolotsk	Belarus	41	Oil & Gas	Novopolotsk oil power plant
190	Anshun	China	40	Coal	cement, smelter, chemical, power plant
191	Palabora	South Africa	40	Smelter	Palabora, a large copper mine, smelter and refinery complex managed by Palabora Mining Company in the Limpopo Province of South Africa
192	Počerady and others	Czech Republic	40	Coal	Power plants near Most, Tusimice power plant 22 km South-West
193	Severonikel	Russia	40	Smelter	Smelters near Monchegorsk. Very weak signal, just above the sensitivity level.
194	Xan	Guatamala	40	Oil & Gas	
195	Dongguan	China	40	Coal	Industry - power plant, manufacturing
196	Sarni	India	40	Coal	Satpura thermal power station, 1143 MW



197	Linhai	Taiwan	40	Oil & Gas	Linhai Industrial Park
198	Phikwe	Botswana	40	Smelter	Nickel and copper mine and smelter
199	Frimmersdorf	Germany	39	Coal	Frimmersdorf power plant, other sources?
200	Kheda	India	39	Coal	Power Plant and Cement Plant
201	Parish	U.S.	38	Coal	US Source #49, 55 kT in 2005.
202	Suez	Egypt	38	Oil & Gas	
203	Mariupol	Ukraine	38	Smelter	Mariupol iron/steel factories
204	Copsa Mica	Romania	37	Smelter	Copsa Mica zinc Smelter
205	Ulsan	South Korea	37	Oil & Gas	Oil refinery & Chemical Factory
206	Lower Silesia	Poland	37	Coal	PGE Elektrownia Turow
207	Kyger Creek	U.S.	37	Coal	Kyger Creek and Gavin coal power plant located 2 km apart. Other coal power plant in the area.
208	Map Ta Phut	Thailand	37	Coal	Map Ta Phut Coal power plant, other power plant within 5 km
209	Monroe	U.S.	37	Coal	Coal power plant near Detroit
210	Isfahan	Iran	37	Oil & Gas	Isfahan oil refinery; Power plant 20 km south.
211	Hechi	China	36	Smelter	Strong signal in 2005-2007. Hechi smelters are the likely source.
212	Kolaghat	India	36	Coal	Kolaghat Thermal Coal power plant, other sources in the area
213	Ladyzhinska	Ukraine	36	Coal	Ladyzhinska thermal power plant
214	Chuquicamata	Chile	36	Smelter	Chuquicamata Copper smelter
215	Tarong	Australia	36	Coal	Tarong coal power plant
216	Silesia	Poland	35	Coal	Multiple coal power plant near Katowice. The signal is stronger in winter.
217	Uthmaniya	Saudi Arabia	35	Oil & Gas	Uthmaniyah Gas Processing Plant, and Gas oil separation plants
218	Hwange	Zimbabwe	35	Coal	Hwange power plant
219	Salamanca	Mexico	35	Oil & Gas	Oil refinery and power plant near Salamanca



220	Kot Addu	Pakistan	35	Oil & Gas	Oil power plant. Oil refinery 3 km East and power plant 30 km North
221	Aqaba	Jordan	35	Oil & Gas	
222	Lahore	Pakistan	34	Oil & Gas	Five oil power plant near Lahore
223	Keratsini	Greece	34	Oil & Gas	Other sources such as oil refineries are in the area
224	Manasi	China	34	Coal	Manasi coal power plant, other power plants in the area
225	Karachi	Pakistan	33	Oil & Gas	Oil power plant and refinery near Karachi
226	Saindakn	Pakistan	33	Smelter	Saindak Smelter, Pakistan
227	Shuozhou	China	32	Coal	Power plant near Shuozhou
228	Chengcheng	China	31	Coal	Power plant near Chengcheng
229	Yiliang, Kunming	China	31	Coal	Yangzonghai coal power plant. Could be influenced by Kunming power plants.
230	Sannis	U.S.	31	Coal	US Source #12, 107 kT in 2005
231	Xigu, Langzhou	China	31	Coal	Industry - oil, chemical, power plant
232	Lacq	France	31	Oil & Gas	Lacq gas field and sulfur factory
233	Tongshan, Xuzhou	China	31	Coal	Industry - steel, power plant
234	Rayalaseema	India	31	Coal	Rayala Seema (RTpower plant) Coal Power Station
235	Herne	Germany	30	Coal	Herne Powerplant. Multiple sources in the area.
236	Safi	Morocco	30	Oil & Gas	Sidi Ghouza Industrial
237	Shanghai	China	30	Coal	Multiple power plants near Shanghai
238	Lipetsk	Russia	30	Coal	Lipetsk, multiple sources related to iron production
239	Moron	Venezuela	30	Oil & Gas	Planta Centro Thermal power plant Venezuela, oil refineries in the area
240	Tehran	Iran	30	Oil & Gas	Besat Thermal power plant Iran (oil). Oil refinery 14 km south. Other sources are possible.
241	Al-Zara	Syria	30	Oil & Gas	Al-Zara Thermal power plant. Meharedh power plant in 35 km north.
242	Cayirhan	Turkey	29	Coal	
243	Jingxi, Baise	China	29	Coal	Guangxi Xinfu Aluminum & power plant



244	Kingston	U.S.	29	Coal	US Source #47, 56 kT in 2005
245	Villa De Reyes	Mexico	29	Oil & Gas	
246	Tampico	Mexico	28	Oil & Gas	Pemex Ciudad Madero Refinery, Altamira Oil power plant 25 km north-west
247	Baotou	China	28	Coal	Industry - steel, aluminium, smelter, power plant
248	Big Brown	U.S.	27	Coal	US Source #21, 91 kT in 2005
249	Sines	Portugal	27	Coal	Central Termoelectrica de Sines power plant
250	Troitsk	Russia	27	Coal	
251	Moni	Cyprus	27	Oil & Gas	Strong signal, but not sure about the exact source location. Copper smelters near Troodos could be additional sources.
252	Nashik	India	26	Coal	Nasik Coal Power Station India
253	Narva	Estonia	26	Oil & Gas	Narva: Balti and Esti oil power plants
254	Gorgas	U.S.	26	Coal	US SO <sub>2</sub> source #24, 84 kT. Alabama Power Company. Fit is with US source #54
255	Thompson	Canada	26	Smelter	Thompson nickel smelter
256	Panzhihua	China	25	Smelter	Power plants, smelters. The largest iron ore mine in China.
257	Miami Fort	U.S.	25	Coal	Miami Fort and Tanners Creek coal power plant located 6 km apart. Other coal power plant in the area.
258	Turceni	Romania	24	Coal	Rovinari, Turceni, Isalnita and other coal power plant. A very large source that can be analyzed as a single source.
259	Neka	Iran	24	Oil & Gas	Neka power plant
260	Nanjing	China	24	Coal	Power plant near Nanjing
261	Mae Moh	Thailand	24	Coal	Mae Moh power plant
262	Maoming	China	24	Coal	
263	Bayji	Iraq	24	Oil & Gas	Bayji power plant Iraq
264	John Sevier	U.S.	24	Coal	
265	Yueyang	China	23	Coal	Huaneng Yueyang power plant



266	Anning, Kunming	China	23	Coal	Huadian Kunming-II coal power plant or a different source nearby
267	Zhenhai	China	23	Oil & Gas	Zhenhai Refining & Chemical
268	Dadri	India	22	Coal	NTPC-Dadri coal power plant
269	Chagan Hada	China	21	Coal	Urals Plant
270	Bandar Abbas	Iran	21	Oil & Gas	Bandar Abbas Thermal Oil power plant. zinc smelter in 3 km North-West
271	Ust-Kamenogors	Kazakhstan	21	Coal	Coal power plant
272	Almaty	Kazakhstan	21	Coal	Almaty coal power plant
273	Jamshedpur.	India	20	Coal	Power Plant and Stell Plants
274	Ilva	Italy	20	Oil & Gas	Steel plant and oil refinery
275	Xining	China	20	Coal	Coal power plant, other sources near Xining
276	Akola	India	20	Coal	Paras Coal Power Station
277	Novokuybshevsk	Russia	20	Oil & Gas	Novokuybshevsk refinery and other sources
278	Majan	Oman	20	Oil & Gas	Copper Smelter. Other sources (oil power plant, refineries) within 30 km.
279	Copperbelt	Zambia	19	Smelter	Smelters in the Copperbelt region
280	Flin Flon	Canada	19	Smelter	Copper and zinc smelter
281	Hadera	Israel	19	Coal	Hadera power station, other sources
282	Zhuzhou	China	18	Coal	Zhuzhou power plant, Xiangtan power plant 12 km north-west
283	Drax	UK	18	Coal	Drax coal power plant. Other coal power plant and oil refineries within 50 km
284	Central Costa Sur	Puerto Rico	18	Oil & Gas	Central South Coast oil power plant
285	Rupnagar	India	18	Coal	Guru Gobind Singh Super thermal power plant
286	Xiashan	China	18	Oil & Gas	
287	Harrington	U.S.	18	Coal	Harrington Power Plant
288	Montour	U.S.	18	Coal	Coal power plant
289	Mitchell	U.S.	17	Coal	Power plant, other power plants in the area
290	Puerto Libertad	Mexico	17	Oil & Gas	



291	Muja	Australia	17	Coal	
292	Bhusawal	India	17	Coal	Bhusawal coal power station
293	Guaymas	Mexico	17	Oil & Gas	Carlos Rodriguez Rivero (Guaymas II) Thermal power plant
294	Kahalgaon	India	16	Coal	Coal Power Plant
295	Neijiang	China	16	Coal	
296	Zhangze	China	15	Coal	Zhangze power plant, also Changzhi steel plant
297	Will County	U.S.	15	Coal	Will County power plant and other sources
298	Jiaxing	China	14	Coal	Zhejiang Jiaxing coal power plant, other sources
299	Parli	India	14	Coal	Parli power plant
300	Jeffrey	U.S.	14	Coal	Jeffrey Energy Center
301	Aghios Dimitrios	Greece	14	Coal	Aghios Dimitrios Coal power plant Greece, 4 other power plants in the area
302	Ashkelon	Israel	14	Coal	
303	Fushina	Italy	14	Coal	Fushina power plant
304	Jiayuguan	China	13	Coal	Power plant, other sources near Jiayuguan
305	Mazatlan	Mexico	13	Oil & Gas	Jose Aceves Pozos (Mazatlan II) Thermal power plant
306	Wallerawing	Australia	13	Coal	Walleraving and Mt. Piper coal power plants 7 km apart
307	Karachaganak	Kazakhstan	13	Oil & Gas	Karachaganak gas and oil field
308	Guayama	Puerto Rico	12	Coal	Guayama - Alstom power station. Significant signal, but may be from a slightly different location.
309	Jinchang	China	12	Coal	Jinchang coal power plant and Jinchang (Tongling II), Copower planter Smelter. Yongchang coal power plant located in 20 km south.
310	Guangan	China	12	Coal	Guangan coal power plant
311	Ciudad Juarez	Mexico	12	Oil & Gas	Power plant near Ciudad Juarez
312	Teruel-Andorra	Spain	11	Coal	Coal power plant



313	Jinzhushan	China	11	Coal	Jinzhushan coal power plant
314	Buraydah	Saudi Arabia	11	Oil & Gas	Qassim Central power plant / Saudi Electricity Company
315	Ryazanskaja	Russia	11	Coal	Ryazanskaja power plant
316	Compostilla	Spain	10	Coal	Coal power plant. Other power plants within 70 km
317	Valero	Aruba	10	Oil & Gas	Valero Aruba Refinery (275000 bbl/day)
318	Tianshan, Wulumuqi	China	10	Coal	Hongyanchi and other coal power plant
319	Port Pirie	Australia	10	Smelter	Port Pirie Smelter
320	Tsumeb	Namibia	9	Smelter	Tsumeb Copper Smelter
321	Habshan	United Arab Emirates	9	Oil & Gas	Habshan oil field
322	Dalian	China	8	Coal	Huaneng Dalian coal power plant
323	Monticello	U.S.	8	Coal	US Source #28, 80 kT in 2005
324	Khetri	India	8	Smelter	Khetri Copper Complex (KCC)
325	Fushuizhen	China	8	Coal	Power plant near Fushuizhen
326	Puertollano	Spain	7	Coal	Puertollano coal power plant Spain, other sources
327	Gibson	U.S.	7	Coal	Gibson coal power plant.
328	Luohuang	China	7	Coal	Huaneng Luohuang coal power plant
329	Stanwell	Australia	7	Coal	
330	Rudny	Kazakhstan	6	Smelter	Rudny Smelter (Iron), Kazakhstan
331	Iranshar	Iran	6	Oil & Gas	Iranshar Power Plant
332	Chesterfield	U.S.	6	Coal	US Source #30 Dominion-Chesterfield Power Station, 78 kT in 2005
333	Datong	China	6	Coal	Multiple coal power plants in the area
334	Qianbei	China	6	Coal	
335	Cienfuegos	Cuba	5	Oil & Gas	Cienfuegos power plant
336	Tablazo	Venezuela	5	Oil & Gas	Tablazo Oil refinery
337	As Pontes	Spain	5	Coal	Coal power plant. A smaller Meirama power plant is 50 km away
338	Kiev	Ukraine	5	Oil & Gas	Kyiv-5 oil power plant, other sources



339	Bowen	U.S.	5	Coal	US SO <sub>2</sub> source #1, 186 kT Georgia Power Company Bowen Steam-Elect.
340	Cayuga	U.S.	4	Coal	US Source #31, 78 kT in 2005
341	Suratgarh	India	3	Coal	Suratgarh Super Thermal Power Station
342	Qingzhen	China	3	Smelter	Multiple sources near Qingzhen. Strong and significant signal, but not sure about the exact source type and location.
343	Conesville	U.S.	3	Coal	US Source #13, 107 kT in 2005
344	Ufaleynikel	Russia	2	Smelter	Ufaleynikel nickel smelter
345	Sundance	Canada	2	Coal	Sundance coal power plant, Other coal power plants near Edmonton
346	Yuanbaoshan	China	2	Coal	
347	Isla	Curacao	2	Oil & Gas	Isla oil refinery
348	Dushanzi	China	1	Coal	Dushanzi coal power plant
349	Ballsh	Albania	1	Oil & Gas	
350	Toos	Iran	1	Oil & Gas	
351	Dalong	China	0	Coal	Guizhou Dalong power plant
352	Severodvinsk	Russia	0	Oil & Gas	Severodvinsk oil power plant
353	Patnow	Poland	0	Coal	Patnow and Konin coal power plants
354	Mazovia	Poland	0	Coal	Kozienice coal power plant
355	Le Havre	France	0	Coal	Le Havre coal power plant?
356	Novaky	Slovakia	0	Coal	Novaky coal power plant
357	Kalatongke	China	0	Smelter	Kalatongke copper-nickel smelter
358	Sudbury	Canada	0	Smelter	A large nickel smelter
359	Plomin	Croatia	0	Coal	Plomin coal power plant
360	Kakanj	Bosnia and Herzegovina	0	Coal	
361	Bor	Serbia	0	Smelter	Bor copper smelter
362	Jilin	China	0	Oil & Gas	CNCP (PetroChina) Jilin Chemical Refinery
363	Toksun Mahatma	China	0	Coal	Toksun Mahatma coal power plant
364	Eastlake	U.S.	0	Coal	



365	Ed Edwards	U.S.	0	Coal	Ed Edwards Coal power plant
366	Tuocketuo	China	0	Coal	Ed Edwards Coal power plant
367	Beijing	China	0	Coal	Beijing power plant. May be a different source in the area
368	Hatfields Ferry	U.S.	0	Coal	Coal power plant
369	Kirikkale	Turkey	0	Oil & Gas	TuriKirikkale refinery
370	Harding Street	U.S.	0	Coal	US Source #57, 49 kT in 2005
371	Suancigou	China	0	Coal	Chimney Suancigou gangue power plant, multiple power plants
372	Pego	Portugal	0	Coal	Pego power plant
373	Sioux	U.S.	0	Coal	US Source #52, 51 kT in 2005
374	Clifty Creek	U.S.	0	Coal	
375	Stuart	U.S.	0	Coal	US Source #14, 106 kT in 2005
376	John Atmos	U.S.	0	Coal	John Atmos coal power plant
377	Morgantown	U.S.	0	Coal	Morgantown coal power plant.
378	Tabriz	Iran	0	Oil & Gas	
379	Dezhou	China	0	Coal	Huaneng Dezhou coal power plant
380	Paradise	U.S.	0	Coal	US Source #23 TVA, 84 kT in 2005
381	Clinch River	U.S.	0	Coal	Very small source - just above the noise level
382	San Juan	U.S.	0	Coal	
383	Roxboro	U.S.	0	Coal	Roxboro coal power plant
384	Belews Creek	U.S.	0	Coal	Belews Creek coal power plant
385	Aleppo	Syria	0	Oil & Gas	Aleppo power plant
386	Johnsonville	U.S.	0	Coal	US Source #36 , 75 kT in 2005
387	Marshall	U.S.	0	Coal	US SO <sub>2</sub> source#19, 101 kT in 2005. Duke Energy Corporation-Marshall Steam.
388	Zouxian	China	0	Coal	Zouxian Coal power plant
389	Qinbei	China	0	Coal	
390	Colbert	U.S.	0	Coal	US Source #79, 38 kT in 2005.
391	Xinan	China	0	Coal	



392	Huxian	China	0	Coal	Power plant near Huxian
393	Chovar	Iran	0	Oil & Gas	
394	Wansley	U.S.	0	Coal	US Source #18 Georgia Power Company Wansley Steam-Ele, 102 kT in 2005. Yates power plant (67 kt) 20 km east
395	Georgetown	U.S.	0	Coal	
396	Ernest Gaston	U.S.	0	Coal	US SO <sub>2</sub> source #7, 128 kT in 2005, Alabama Power Company. Ernest C. Gaston Electric Generating Plant
397	Harllee Branch	U.S.	0	Coal	US SO <sub>2</sub> source #22, 91 kT in 2005. Georgia Power Company Branch Steam-Elec. Fit is with US source #26.
398	Scherer	U.S.	0	Coal	US Source #26 Georgia Power Company Scherer Steam-Ele, 83 kT in 2005
399	Pingwei	China	0	Coal	
400	Yangzhou	China	0	Coal	
401	Barry	U.S.	0	Coal	US Source #51 Alabama Power Company, 54 kT in 2005
402	Big Cajun	U.S.	0	Coal	US source #70, 42 kT in 2005. Big Cajun 2 power plant
403	Sadow	U.S.	0	Coal	US Source #53, 51 kT in 2005
404	Sonora	Mexico	0	Smelter	Nacozari de Garcia, Sonora (La Caridad) Copper smelter
405	Bandar Imam	Iran	0	Coal	Bandar Imam Petrochemical complexes and power plant? Other sources.
406	Bidoo	Iran	0	Oil & Gas	Oil/gas flares near Bidoo
407	Qianqingzhen	China	0	Coal	Power plant in Qianqingzhen
408	Crystal River	U.S.	0	Coal	US source #17, 103 kT in 2005
409	Guixi, Yingtan	China	0	Smelter	Jiangxi Copper Smelter
410	Nayong	China	0	Coal	Nayong power plant
411	Al Shaheen	Qatar	0	Oil & Gas	Al Shaheen Oil Field. Small but detectable source surrounded by other sources.
412	Kaili, Qiandongnan	China	0	Coal	Qiandongnan?
413	Unchahar	India	0	Coal	



414	Qijing	China	0	Coal	Qijing Coal power plant China
415	Diandong	China	0	Coal	Hueneng Diandong coal power plant, other sources.
416	Shaogua	China	0	Coal	Shaoguan power plant
417	Heshan	China	0	Coal	Heshan and Laibin coal power plants
418	Barrackpore	India	0	Coal	
419	Minatitlan	Mexico	0	Oil & Gas	Refinería General Lázaro Cárdenas del Río, other oil refineries in the area
420	Tacoa	Venezuela	0	Coal	Tacoa
421	Sergipe	Brazil	0	Oil & Gas	Sergipe Oil Field. Very weak signal, just above the sensitivity level.
422	La Oroya	Peru	0	Smelter	Doe Run metals smelter in La Oroya, Peru. Operation temporarily stopped in August 2009. <a href="http://archive.livinginperu.com/news/12256">http://archive.livinginperu.com/news/12256</a>
423	Potrерillos	Chile	0	Smelter	Potrерillos Copper smelter



## Endnotes

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<sup>i</sup> <https://bit.ly/30inNie>

<sup>2</sup> Schraufnagel et al., [Air Pollution and Noncommunicable Diseases: A Review by the Forum of International Respiratory Societies' Environmental Committee, Part 1: The Damaging Effects of Air Pollution](#). Chest, 155 (2) (2019), pp. 409-416

<sup>3</sup> Dandona et al., [Nations within a nation: variations in epidemiological transition across the states of India, 1990–2016 in the global burden of disease study](#). Lancet. 390(10111) (2017), pp 2437–60

<sup>4</sup> World Bank and Institute for Health Metrics and Evaluation. 2016. [The Cost of Air Pollution: Strengthening the Economic Case for Action](#). Washington, DC: World Bank. License: Creative Commons Attribution CC BY 3.0 IGO, Accessed [10, June, 2019]

<sup>5</sup> Particles with aerodynamic diameter of around 2.5  $\mu\text{m}$  (roughly speaking)

<sup>6</sup> <http://www.rapidshift.net/air-pollution-is-slowly-killing-us-all-new-global-study-claims/>

<sup>7</sup> Huang, R.-J. et al. High secondary aerosol contribution to particulate pollution during haze events in China. Nature 514, (2014), 218–222

<sup>8</sup> Chakraborty, A., Gupta, T. & Tripathi, S. N. Chemical composition and characteristics of ambient aerosols and rainwater residues during Indian summer monsoon: Insight from aerosol mass spectrometry. Atmos. Environ. 136, (2016), 144–155

<sup>9</sup> Wang, G. et al. Persistent sulfate formation from London Fog to Chinese haze. Proc. Natl. Acad. Sci. 113, (2016), 13630–13635

<sup>10</sup> Fioletov, et al., Multi-source SO<sub>2</sub> emissions retrievals and consistency of satellite and surface measurements with reported emissions, Atmos. Chem. Phys., 17, (2017), 12597–12616, DOI: 10.5194/acp-17-12597-2017

<sup>11</sup>A global catalogue of large SO<sub>2</sub> sources and emissions derived from the Ozone Monitoring Instrument, <https://docserver.gesdisc.eosdis.nasa.gov/public/project/MEaSUREs/Krotkov/README.MSAQSO2L4.pdf>

<sup>12</sup> Excluding volcanic sources, NASA original database

[https://so2.gsfc.nasa.gov/kml/OMI\\_Catalogue\\_Emissions\\_AMF\\_S20km\\_2005-2018\\_T1.xlsx](https://so2.gsfc.nasa.gov/kml/OMI_Catalogue_Emissions_AMF_S20km_2005-2018_T1.xlsx) (10 May 2019)

Fioletov et al., Multi-Satellite Air Quality Sulfur Dioxide (SO<sub>2</sub>) Database Long-Term L4 Global V1, Greenbelt, MD, USA, Goddard Earth Science Data and Information Services Center (GES DISC), (2019) <https://doi.org/10.5067/MEASURES/SO2/DATA403>

<sup>13</sup> <https://bit.ly/30inNie>

<sup>14</sup> Converted from other units as required. Most countries normalize flue gas oxygen content to 6% or 7%, and temperature to 0°C or 25°C; this makes a difference of less than 10% and has not been harmonized. South Africa uses reference oxygen content of 10% which has been converted to 6%