Air quality in Central Asian cities

Nassiba Baimatova,

Ph.D., Associate Professor

Head of the ”Ecology of Biosphere" laboratory
Faculty of Chemistry and Chemical Technology,
Al-Farabi Kazakh National University, Almaty, Kazakhstan

Cities of Central Asia: New hotspots of air pollution in the world

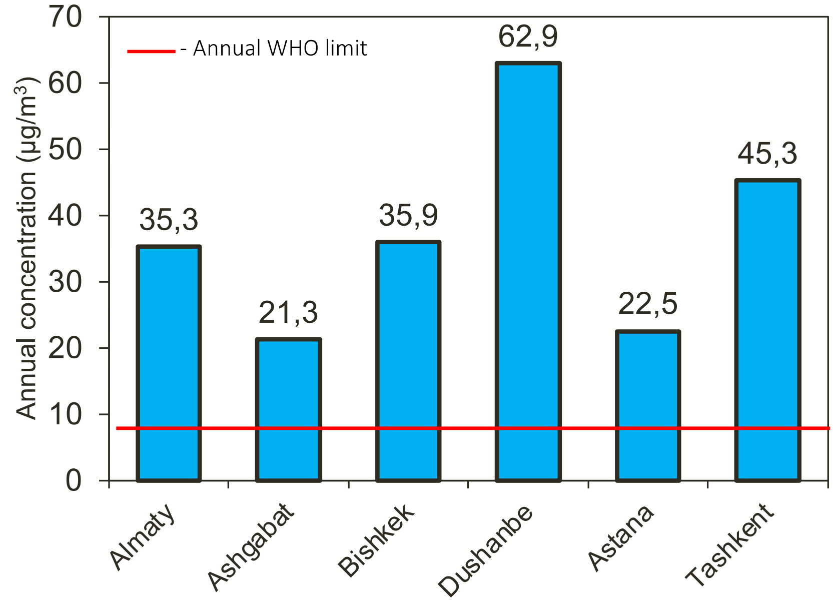
The most polluted countries in the world based on $PM_{2.5}$ exposure:

4th – Tajikistan
7th – Kyrgyzstan
12th – Uzbekistan
23rd – Kazakhstan
44th – Turkmenistan

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

Source: https://www.iqair.com/us/world-air-quality-report

$PM_{2.5}$ levels in Central Asia cities exceeded the WHO annual limit (5 µg/m³) by 4–13 times.



Annual $PM_{2.5}$ concentrations data from US Embassy (BAM – 1020) from 2018 to 2021

Source: Tursumbayeva et al., 2023.

What's wrong with monitoring?

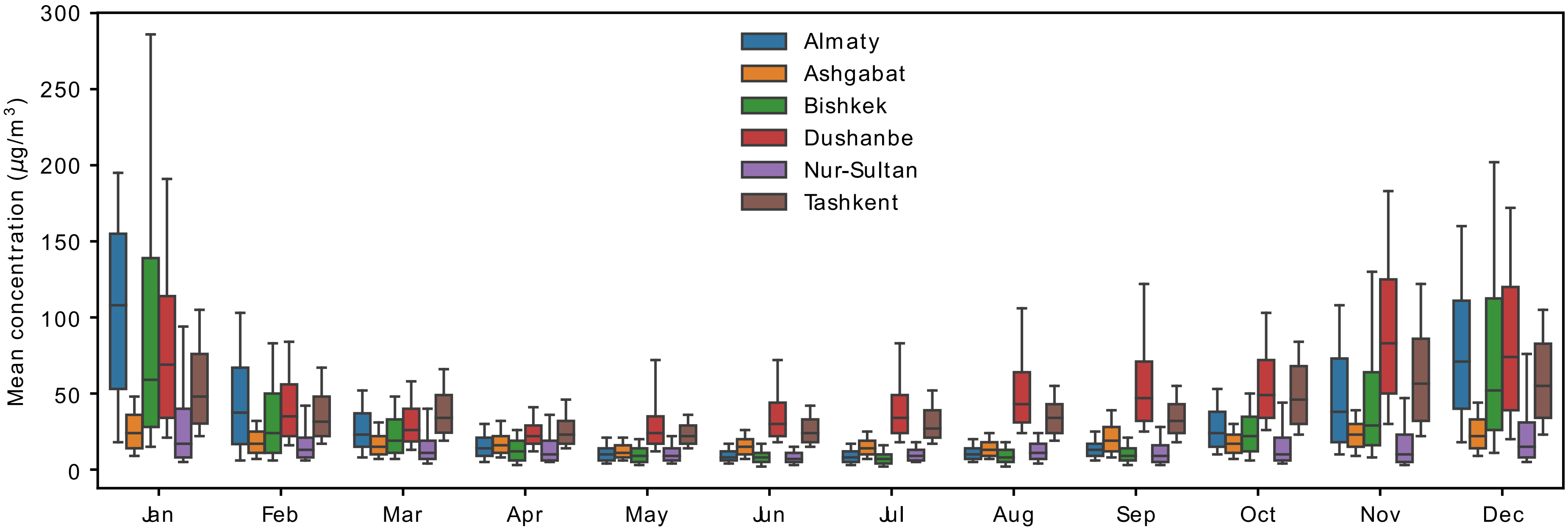
- Limited availability of reliable ground-based air quality measurements
- Outdated air pollutant limits
- $PM_{2.5}$ Source apportionment studies have not been conducted
- The lack of coal consumption data

WHO, EU, and Kazakhstan limit values for pollutants in the air

Air pollutant	EU limits*	Kazakhstan limit **
$PM_{2.5}$	5 µg/m^3 (annual) 15 µg/m^3 (24 h)	160 µg/m^3 (single measurement) 35 µg/m^3 (24 ч)
PM_{10}	15 µg/m^3 (annual) 45 µg/m^3 (24 h)	300 µg/m^3 (single measurement) 60 µg/m^3 (24 ч)
NO_2	10 µg/m^3 3 (annual) 25 µg/m^3 (24 h)	200 µg/m^3 (single measurement) 40 µg/m^3 (24 ч)
SO_2	40 µg/m^3 (24 h)	500 µg/m^3 (single measurement) 50 µg/m^3 (24 ч)
CO	10 mg/m^3 (8 h)	5 mg/m^3 (single measurement) 3 mg/m^3 (24 h)
O_3	100 µg/m^3 (8 h)	30 µg/m^3 (24 h) 160 µg/m^3 (single measurement)

* https://ec.europa.eu/environment/air/quality/standards.htm
** https://adilet.zan.kz/rus/docs/V1500011036

Higher $PM_{2.5}$ concentrations in winter in the cities of CA could be associated with the increase in energy demand for heating



Maximum

Bishkek - 112 µg/m³
Almaty - 110 µg/m³
Astana - 40 µg/m³
Ashgabat - 27 µg/m³

Dushanbe - 99 µg/m³
Tashkent 74 µg/m³

Minimum

Bishkek - 9 µg/m³
Almaty - 10 µg/m³
Astana - 9 µg/m³

Ashgabat - 13 µg/m³
Dushanbe - 28 µg/m³
Tashkent - 24 µg/m³

Source: Tursumbayeva et al., 2023.

Daily $PM_{2.5}$ concentrations

In 2021, the share of days $PM_{2.5}$ concentrations > WHO 24-hour limit (15 μg/m³) was

42% in Astana

61% in Almaty

Most "polluted" days (>15 μg/m³) were registered in winter:

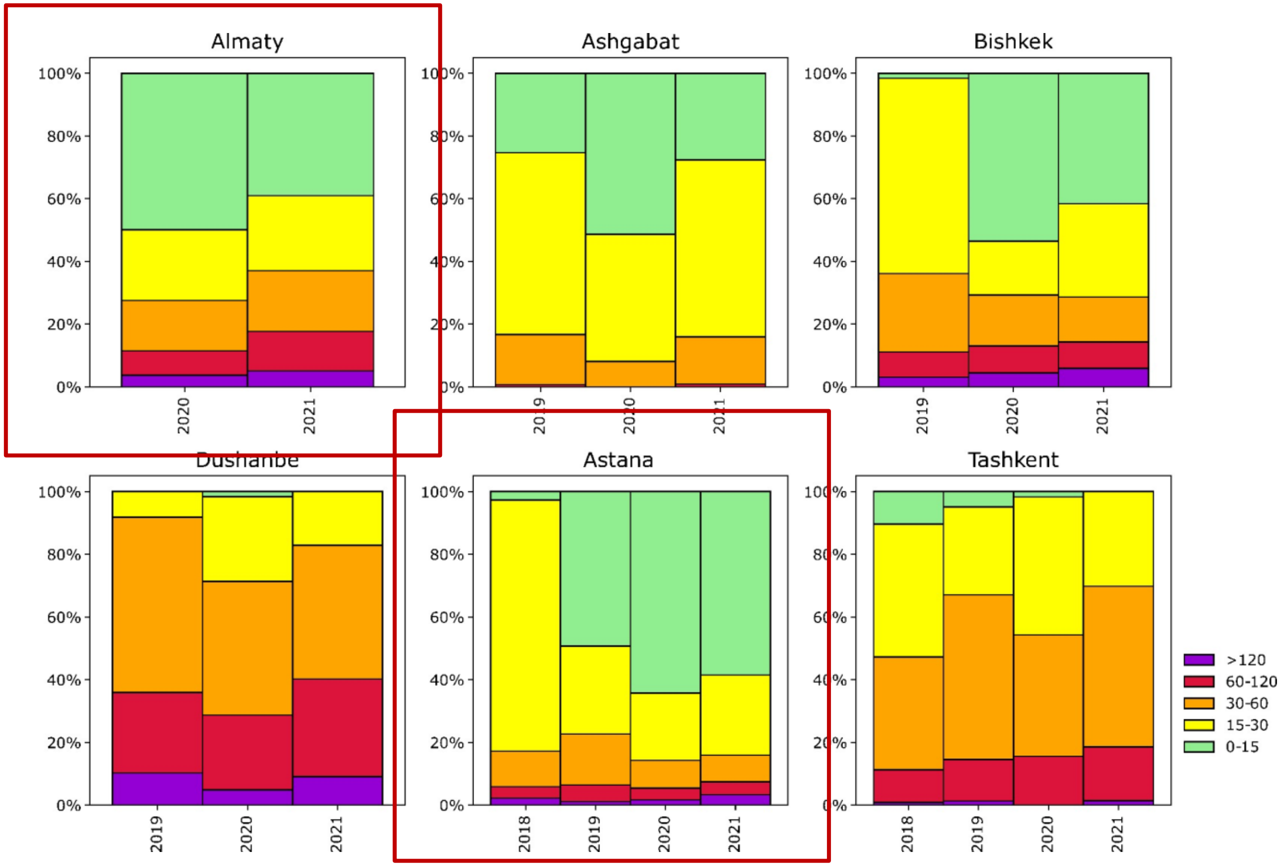
98% of days in Almaty

90% of days in Astana

Daily concentrations over **120 μg/m³** (8-fold exceeding the WHO limits)

5% in Almaty

3% in Astana of the days in a year



The frequency of days by the ranges of the average daily concentration of $PM_{2.5}$: 0-15 μg/m³; 15-30 μg/m³; 30-60 μg/m³; 60-120 μg/m³; >120 μg/m³.

Source: Tursumbayeva et al., 2023.

Premature mortality due to air pollution in Central Asian countries was 61 – 89 people per 100,000 of population in 2021

	Tajikistan	Kyrgyzstan	Kazakhstan	Uzbekistan	Turkmenistan
Number of premature deaths in 2021 due to exposure to ambient and indoor air pollution	**7,365**	**4,018**	**11,557**	**29,913**	**3,582**
Mortality rate due to exposure to ambient and indoor air pollution, per 100,000 in 2021	**78**	**61**	**63**	**89**	**70**

Total economic damage due to premature deaths from air pollution

Tajikistan	Kyrgyzstan	Kazakhstan	Uzbekistan	Turkmenistan
$480 mln **5.9% of GDP**	$432 mln **5.1% of GDP**	$12,022 mln **6.7% of GDP**	$ 4,241 mln **7.3% of GDP**	$2,412 mln **5.8% of GDP**

https://www.euro.who.int/__data/assets/pdf_file/0004/276772/Economic-cost-health-impact-air-pollution-en.pdf#:~:text=the overall annual economic cost,stood at US%24 1.575 trillion.

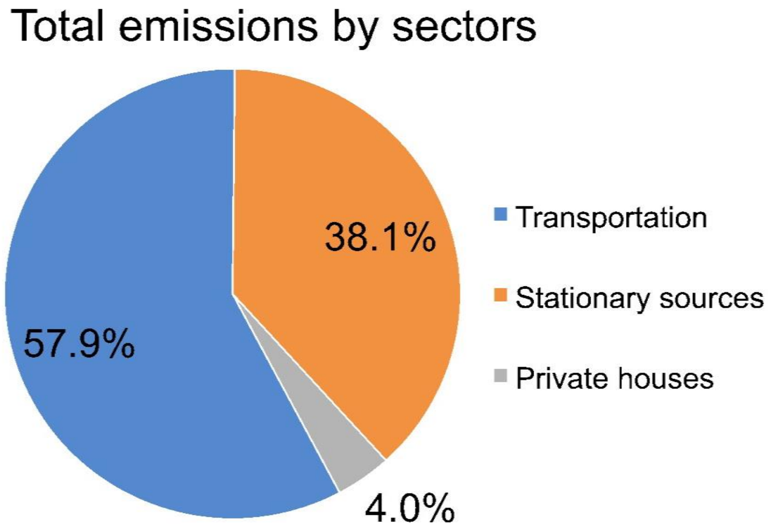
Official inventory estimations of pollutant emissions: Incorrect inventory methodology

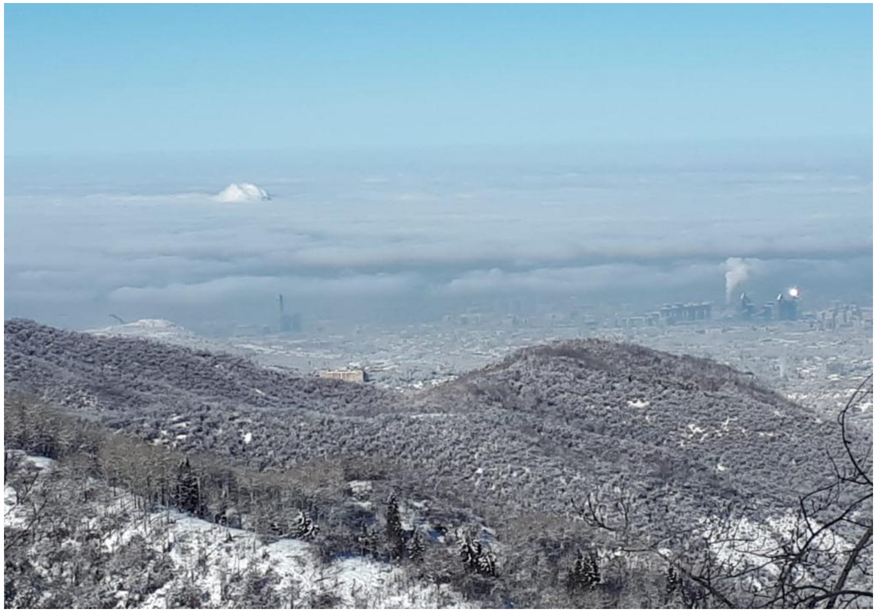
Based on Official inventory estimations, transportation is the main source of air pollution :

- Almaty - 52%
- Dushanbe - 60%
- Astana - 55%
- Tashkent - 90%

Air pollutant emissions (PM, SO_2, NO_2, CO, and others) are summed up without consideration of the toxicity of each pollutant.

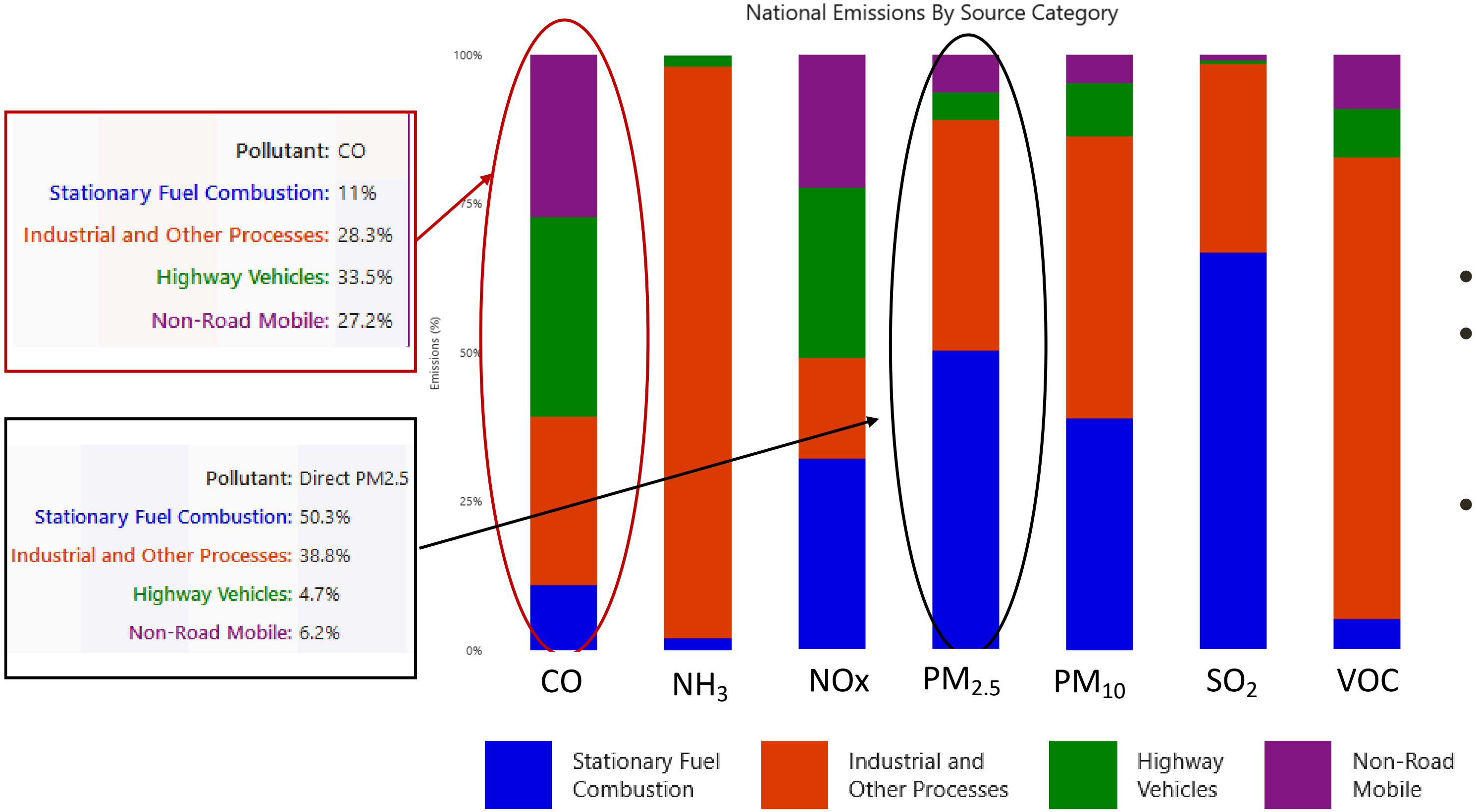
Emissions inventory study for Almaty, Kazakhstan





Source: EcoExpert, 2020.

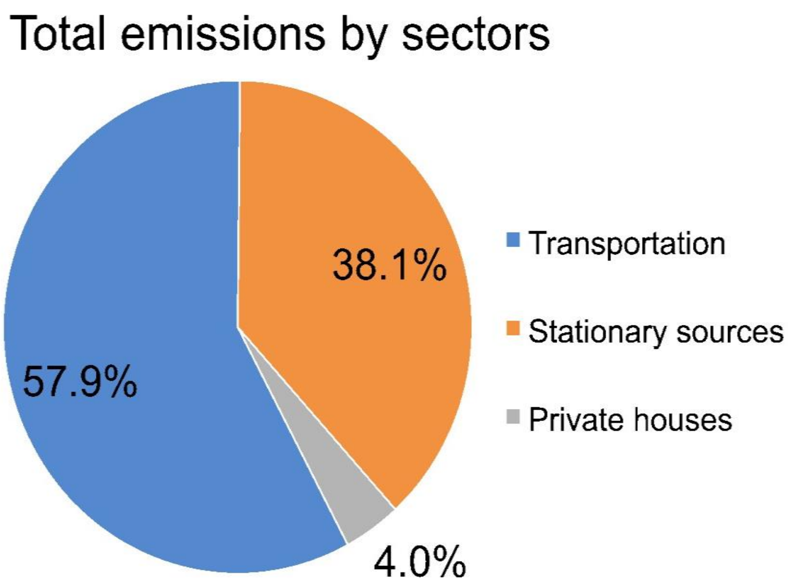
Inventory estimations in the US, Canada, China, and the EU share of air pollutant emissions by the source is presented separately for each pollutant

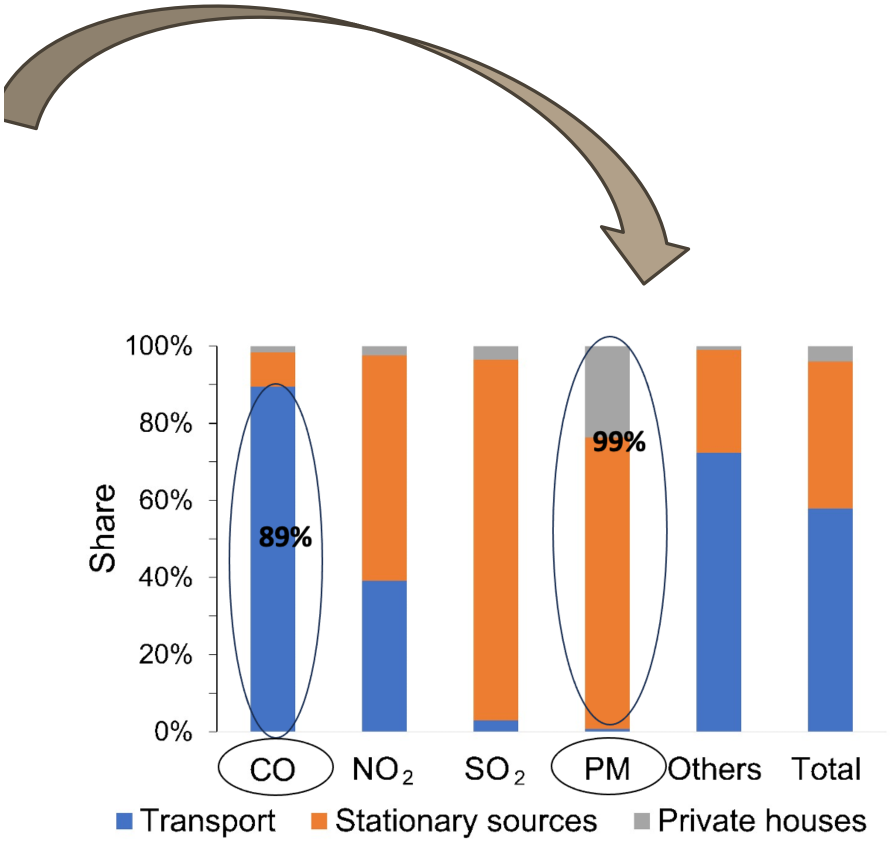


- EPA, 2022;
- European Environment Agency, 2022;
- Government of Canada, 2022.

Source: Our Nation's Air. Trends through 2022 by EPA. https://gispub.epa.gov/air/trendsreport/2023/#air_pollution.

Official inventory estimations of pollutant emissions in Almaty, Kazakhstan





Emissions by sources presented by each pollutant separately

$PM_{2.5}$ concentrations during the lockdown

City	Lockdown (Mar 19 - Apr 14)			Pre-lockdown (Feb 21 - Mar 18)			Seasonal Difference (%)	
	2019	2020	Difference (%)	2019	2020	Difference (%)	2019	2020
Bishkek	26.5	16.9	-36.4*	51.3	36.8	-28.2*	-48.3*	-54.2*
Astana	36.9	21.8	-40.9*	44.7	20.0	-55.2*	-17.6*	8.7*
Tashkent	23.4	31.1	32.9*	33.3	42.3	26.9*	-29.9*	-26.6*

Note: * indicate that the difference is statistically significant (two-tailed paired t-test, p<0.05)

Data source - US Embassy

Table 4 Average air quality parameters during the winter and the spring

Analyte	Period	Winter			Spring			Difference (%)	
	Year	2018–2019	2020	Difference (%)	2018–2019	2020	Difference (%)	2018–2019	2020
CO[a]	Almaty	1.6	1.6	2.7	1.3	1.1	**-13.3**	**-20.6**	**-33.0**
	Nur-Sultan	1.1	0.8	**-25.7**	0.9	0.6	**-29.6**	**-23.1**	**-27.1**
NO_2[b]	Almaty	147.6	132.7	-10.1	101.9	73.4	**-28.0**	**-30.9**	**-44.7**
	Nur-Sultan	96.0	106.2	10.7	94.6	57.4	-39.3	-1.5	-46.0
TSP[b]	Almaty	147.2	172.5	**17.2**	135.7	158.0	**16.5**	**-7.8**	**-8.4**
	Nur-Sultan	344.1	206.8	**-39.9**	688.9	194.7	**-71.7**	**100.2**	-5.8

*Highlighted in bold – statistically significant ($p \leq 0.05$);
Concentration units: a – mg/m^3, b – $\mu g/m^3$

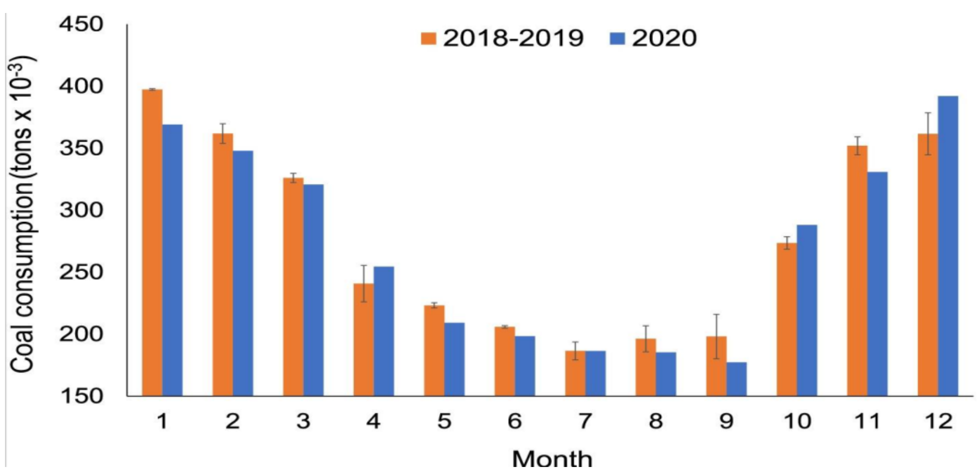
Data source - Kazhydromet

Source: Tursumbayeva et al., 2023, Baimatova et al., 2022.

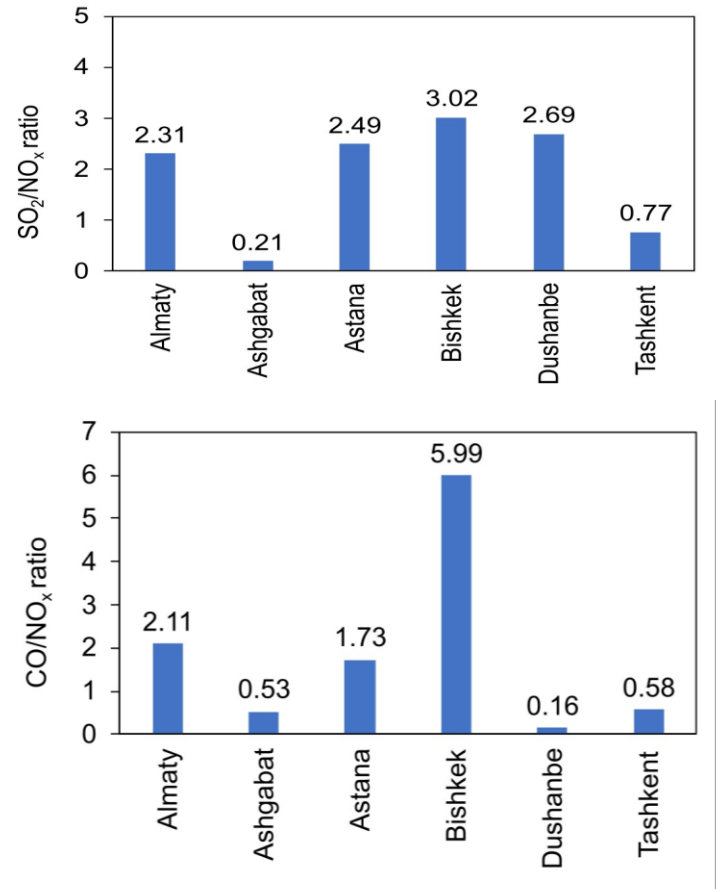
Main contributors of $PM_{2.5}$

Based on **the ratio analysis**:

- *mobile sources* are characterized by high CO/NOx (≥10) and SO_2/NO_x (≤0.6) ratios
- *stationary sources* have high SO_2/NO_x (≥0.6) and low CO/NO_x ratios (≤10) (Halim et al., 2018)



Daily coal consumption in tones at the CHP-2 and CHP-3 in Almaty in 2018–2019 and 2020 (Baimatova et al., 2022)



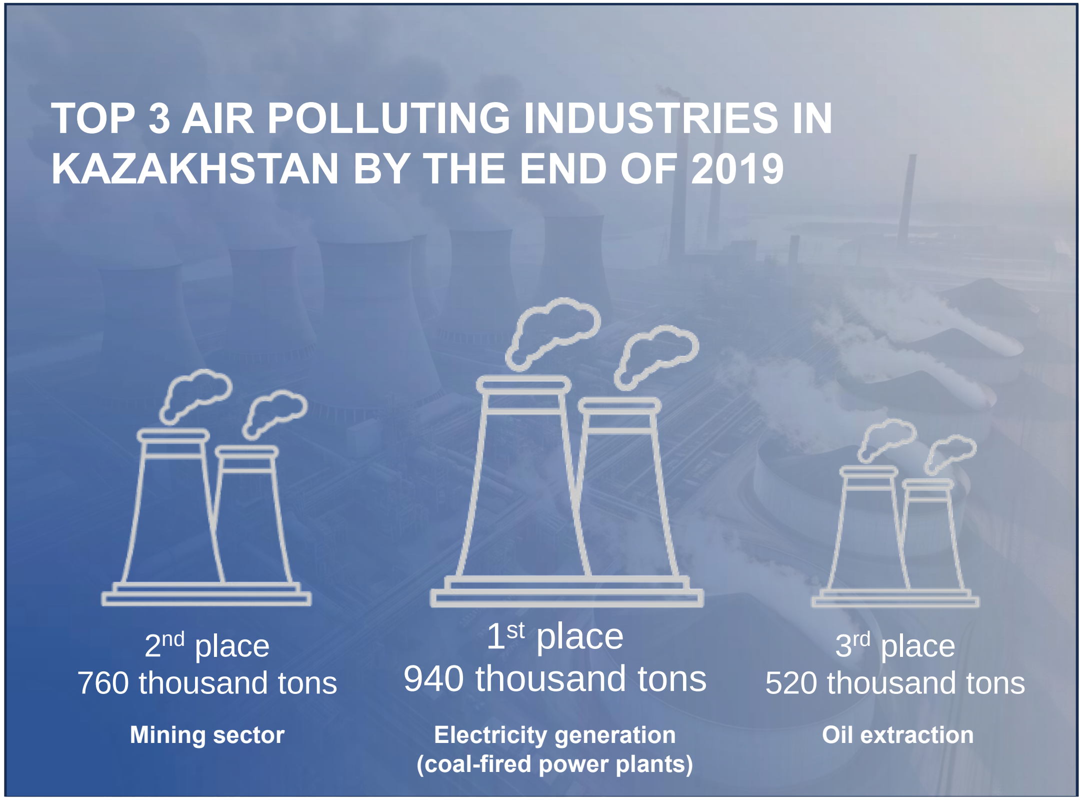
SO_2/NO_x and CO/NO_x ratios from EDGAR emission database

Air pollution in Kazakhstan

The view of Almaty from mountains, November 25, 2021

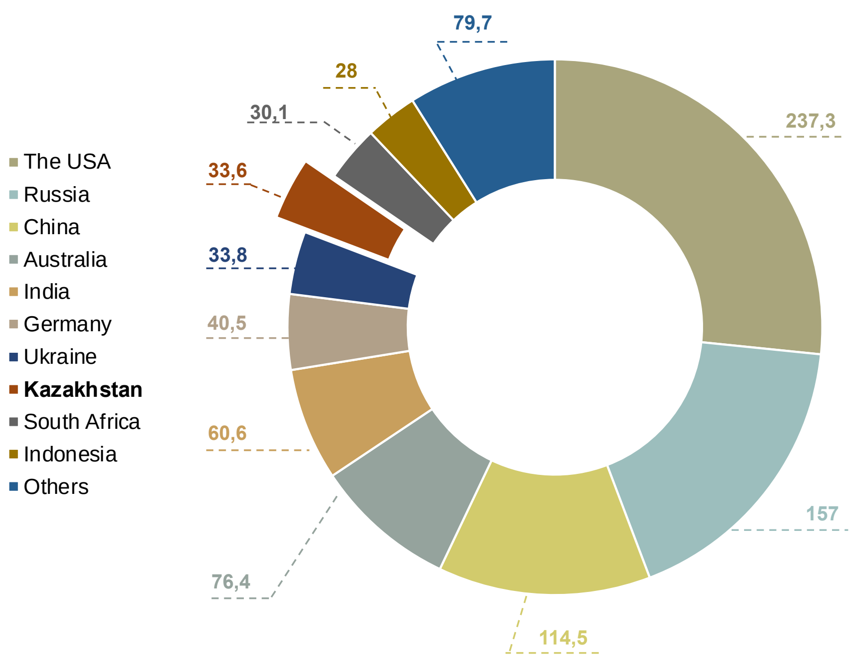
Potential sources of air pollution

- Coal-fired power plants, domestic heating stoves using coal, and vehicle exhaust (Kerimray et al., 2020).
- Desert dust and mineral dust (Abdullaev and Sokolik, 2020; Hofer et al., 2017).
- Vehicle exhaust, coal-fired power plants, and coal usage by private houses for heating (Isaev et al., 2022).
- Coal-fired stoves, power plants, and industries (Assanov et al., 2021).



https://ecomuseum.kz/activities/kachestvo-vozdukha/istochniki-zagryazneniya-vozdukha/index.php

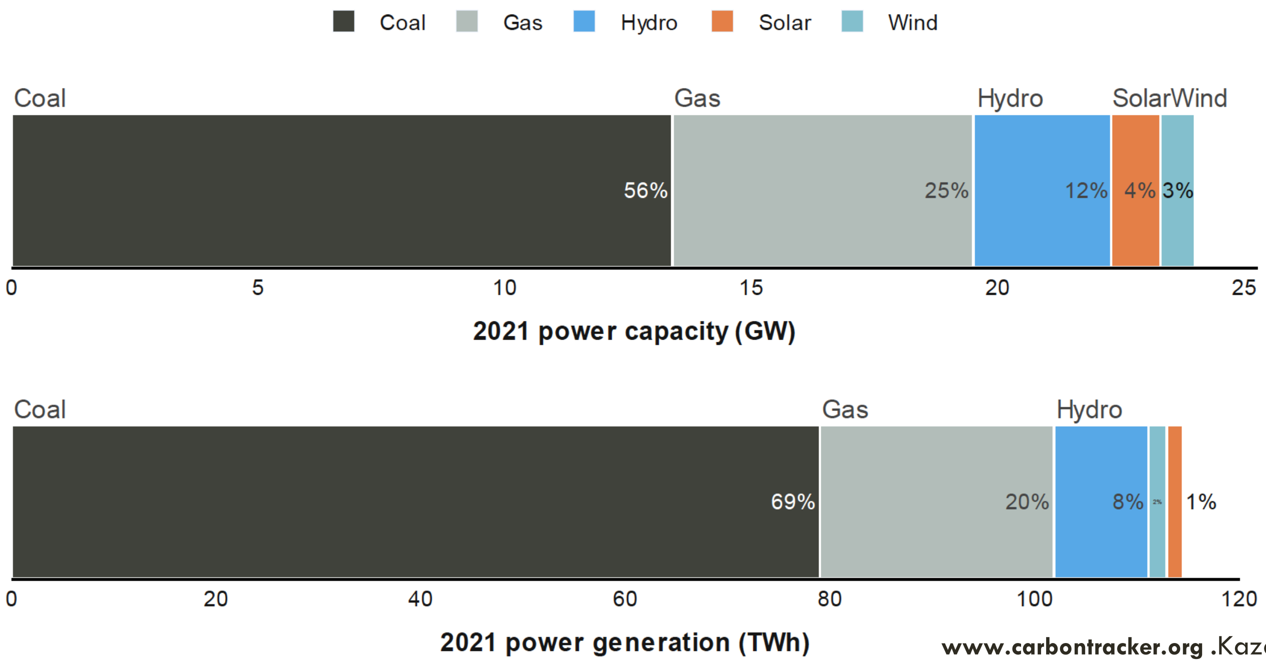
Kazakhstan is the largest and economically stable country with an above–average income in CA



Kazakhstan is in top 10 countries in terms of coal reserves, with 33.6 billion tons across 400 deposits, of which 29.4 billion tons are proven and probable (2.4% of the world's total).

Annual production was 109.2 million tones of coal and lignite from which 80% were consumed in domestic market and 20% was exported (Kazenergy, 2021)

Kazakhstan installed capacity and electricity production

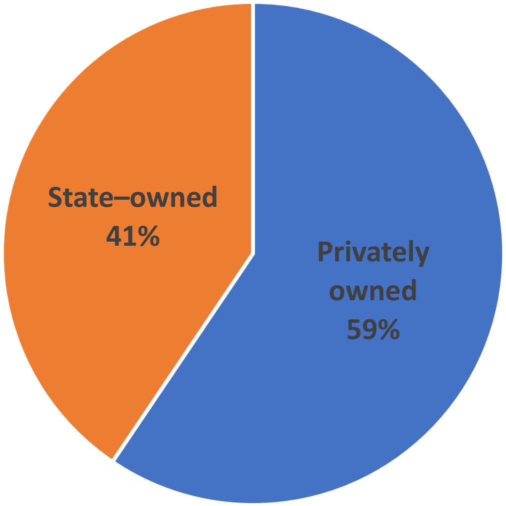


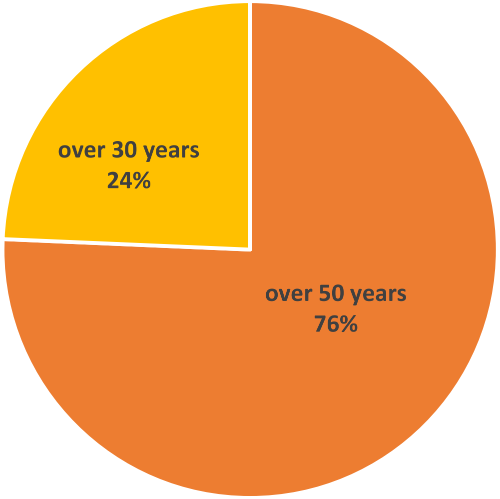
www.carbontracker.org .Kazakhstan Energy Transition

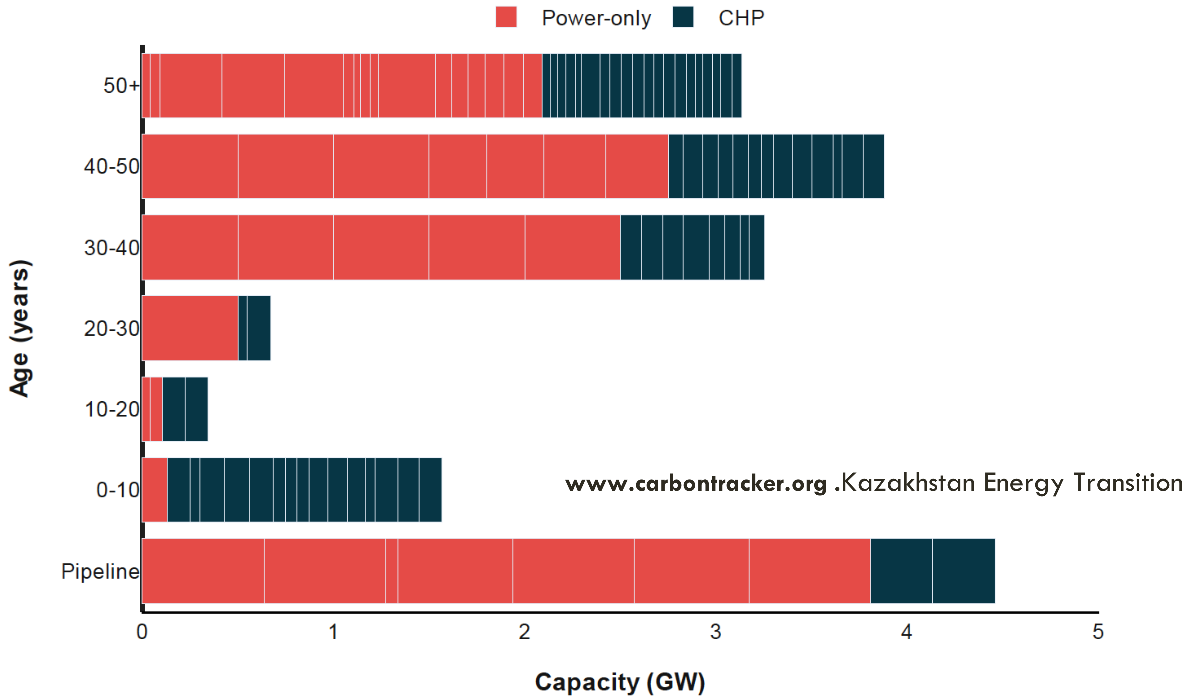
- The power system is dominated by coal-fired power plants, which accounted for 56% of installed capacity and 69% of generation in 2021.
- Gas power is the next dominant source accounting for 25% of capacity and 20% of generation in 20218.

Source: KEGOC Annual Report 2021, CTI

The average wear of 37 Coal-fired power plants operating in Kazakhstan is 66%







The emissions from Kazakhstan's CHPs exceeded the limits of European countries
by over 10 times for PM,
over 20% for NOx,
and up to 2.5-fold for SOx (Tursumbayeva et al., 2023)

The air quality in Almaty is one of the lowest in Kazakhstan

Electricity and heat in Almaty are provided by three Combined Heat and Power Plants. The **CHP-1** uses **natural gas** as a fuel, while **CHP-2 and CHP-3 – low-grade coal (42% ash content)**

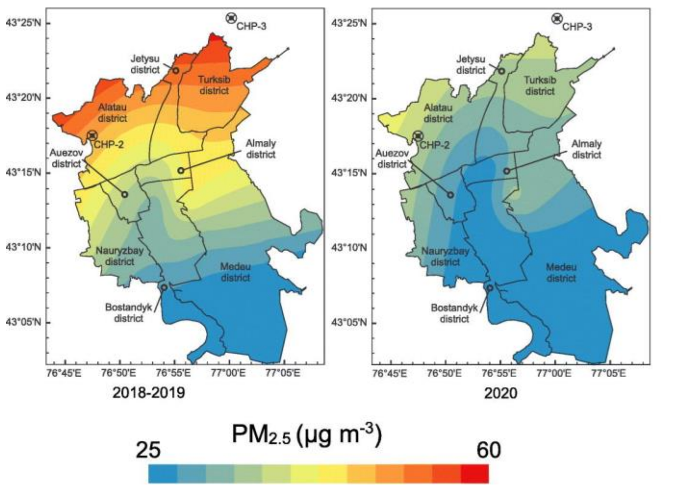
The health damage from air pollution in **Kazakhstan** amounts to **$12 billion or 6.7% of GDP**[1]

Almaty 8th most polluted city by BTEX in 20 major cities worldwide[2]

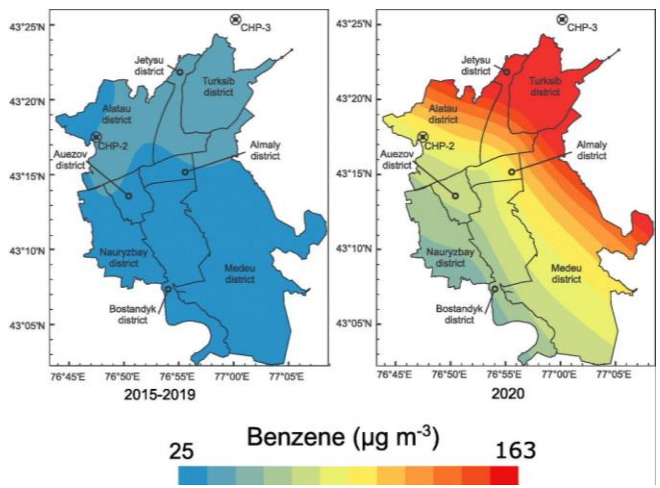
The number of studies based on the assessment of air quality in Almaty is **very limited** and monitoring program determines **only two VOCs (formaldehyde, phenol)**

1. World Bank. The Global Health Cost of PM2.5 Air Pollution: A Case for Action Beyond 2021. International Development in Focus. Washington, DC: World Bank.
2. Carlsen L., Kenessov B.N., Baimatova N.K., Kenessova O.A. Assessment of the Air Quality of Almaty . Focussing on the Traffic Component // International Journal of Biology and Chemistry. - 2013. - Vol. 1 (5). - P. 49–69.

Assessing air quality changes in Almaty during COVID-19 lockdowns



- $PM_{2.5}$ concentration reduced by 21% with spatial variations of 6–34% compared to the average of the same days in 2018–2019
- CO and NO_2 concentrations reduced by 49% and 35%, respectively.
- O_3 concentrations increased by 15% compared to the preceding 17 days before the lockdown.
- Concentrations of benzene (101 μg/m^3) and toluene (67 μg/m^3) were 3 and 2 times higher in 2020 than in the same seasons of 2015–2019
- Concentrations of ethylbenzene (1.0 μg/m^3) and *o*-xylene (1.6 μg/m^3) were 4 and 2.7 times lower in 2020



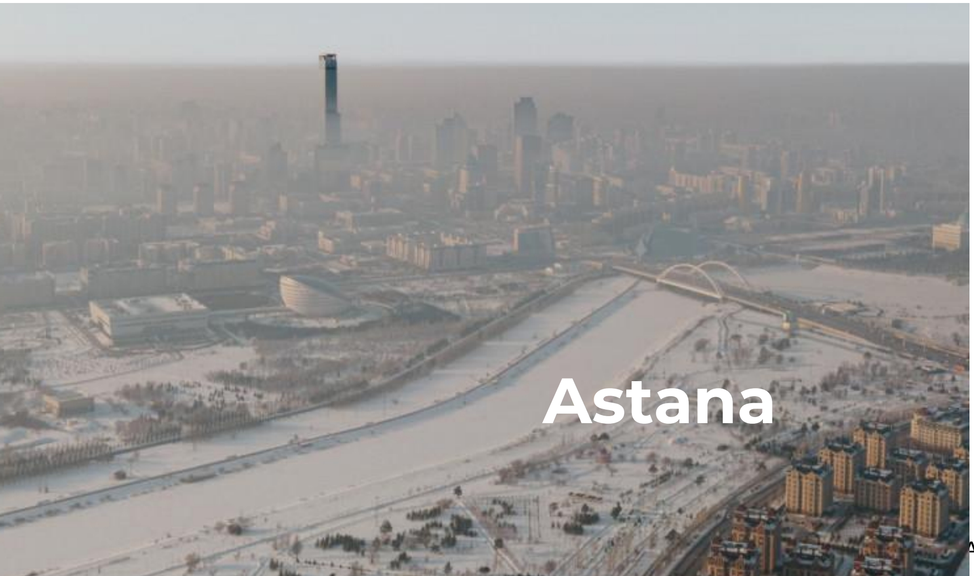
Traffic-free conditions could not cause substantial reductions in pollution levels since several primary emission sources dominate the pollution profile over the city.

Source: Kerimray et al, 2020.

Mortality and economic costs of air pollution in 2022 attributable to exposure to high concentrations of $PM_{2.5}$

- **1,786-2,342** deaths
- **84-111** deaths per 100,000 population

- **$970 – $5,877 million**
- **2.8%-16.8% of GRP**



- **557-750** deaths or
- 43-58 deaths per 100,000 population

- **$308 – $1,881 million**
- **1.6%-9.5% of GRP**

ADB with appropriate permission.

Data source: Baimatova et. al, BR10965258

Information on sources of air pollution is crucial

- Estimation of the effectiveness of emission reduction policies (before and after).
- Determinations of the contribution of natural sources and anthropogenic sources of emissions.
- Air quality improvement plans.
- Quantifying transboundary pollution.
- Public Awareness.

Thank you for your attention!

Photo credits: @Dots_foto

energy investment forum

ADB

CAREC ENERGY

BR10965258

AL-FARABI SMART UNIVERSITY

Ecology of Biosphere

La B