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Influence of the Covid-19 Crisis on Global $PM_{2.5}$ Concentration and Related Health Impacts

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Abstract: The decrease in human activities following the COVID-19 pandemic caused an important change in $PM_{2.5}$ concentration, especially in the most polluted areas in the world: China (44.28 and 18.88 μg/m^3 in the first quarters of 2019 and 2020, respectively), India (49.84 and 31.12, respectively), and Nigeria (75.30 and 34.31, respectively). In this study, satellite observations from all around the world of $PM_{2.5}$ concentration were collected on the grid scale with a high resolution of 0.125° (about 15km). Population data for 2020 were also collected on the same scale. Statistical data from the World Health Organization (WHO) concerning the diseases caused by air pollution (e.g., stroke) were obtained for each country to determine the change in mortality between the first quarter of 2019 and the first quarter of 2020. Expressed in disability-adjusted life years (DALY), it was found that the largest reductions were observed for China (−13.9 million DALY), India (−6.3 million DALY), and Nigeria (−2.3 million DALY).

Keywords: COVID-19; air pollution; DALY; human health

1. Introduction

The COVID-19 pandemic triggered an unprecedented change in people's daily lives all around the world, having an important impact on both the economy and human health [1–5]. The pandemic has officially caused more than 300,000 deaths (18 May, 2020 [6]), and the global economy is expected to shrink by 3.2% in 2020 [7]. This economic loss is partly due to the shortage of activity following the national lockdowns imposed by different governments.

Some studies attempted to confirm the link between air pollution and the COVID-19 pandemic [8,9]; others highlighted the change in pollutant concentration, especially in China [10]. However, no study has quantified the global damage reduction in the first quarter of the year.

Air pollution is one of the major causes of death every year in the world (about seven million, including more than 4.2 million due to ambient air pollution according to the World Health Organization (WHO) [11]); it is strongly linked to several diseases such as stroke and heart disease. It would be interesting to observe if the temporary reduction in activity in the first quarter of 2020 had an impact on $PM_{2.5}$ concentration, which is often used as one of the key indicators to estimate the burden from air pollution, such as in life-cycle assessment (LCA) [12,13].

Therefore, this research aimed at evaluating the global mortality reduction in the first quarter of 2020 due to the reduction in $PM_{2.5}$ concentration. Compared to recent studies on the topic [14–16], we highlighted the change in global $PM_{2.5}$ concentration but also tried to estimate the reduction in burden due to the change in concentration. Compared with the traditional approach (national or continental) used, for example, in LCA, this study was based on a grid-scale approach to improve the accuracy of the assessment.

This research did not aim to minimize the number of deaths from COVID-19 but rather to support the idea that the improvement in air quality has helped to indirectly save several lives during this period.

2. Methodology

2.1. $PM_{2.5}$ Concentration Data

$PM_{2.5}$ concentration (μg/m^3) was collected from the European Centre for Medium-Range Weather Forecasts (ECMWF) satellite [17] at grid scale (0.125°, which is about 15 km or 4,150,080 grids globally); data were collected for the periods from 1 January to 30 April, 2019, and from 1 January to 30 April, 2020. Data post-treatment was performed using MATLAB software [18]. For each month, the average concentration as a common indicator for air quality measurement was calculated for both 2019 and 2020. Several studies demonstrated the reliability of satellite data in comparison with ground measurements [19–21]. As ground measurement stations are still limited in Africa and Southern America [22], the satellite data helped to overcome this limitation.

2.2. Population Data

The gridded population data were collected for 2020 from the Center for International Earth Science Information Network (CIESIN) [23]; the data are represented in Figure 1. The different age groups for each grid were obtained from the same source for 2010, which was the year with the latest data available. We further confirmed from different sources [24,25] that the share in the age groups in the cities did not change significantly in the last 10 years. Finally, the data provided by the CIESIN at a resolution of 0.042° were converted to the same scale as the $PM_{2.5}$ concentration data (0.125°).

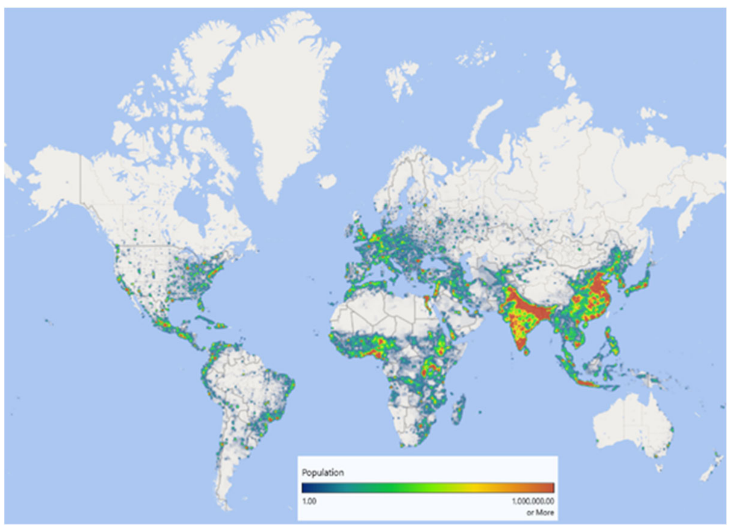
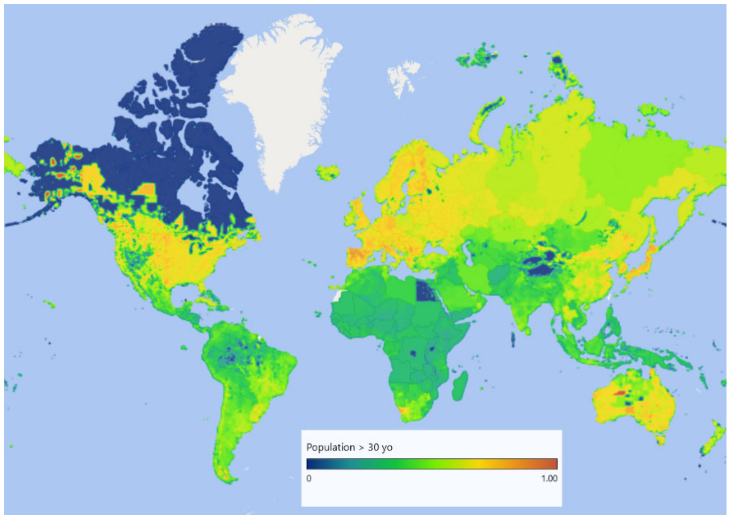


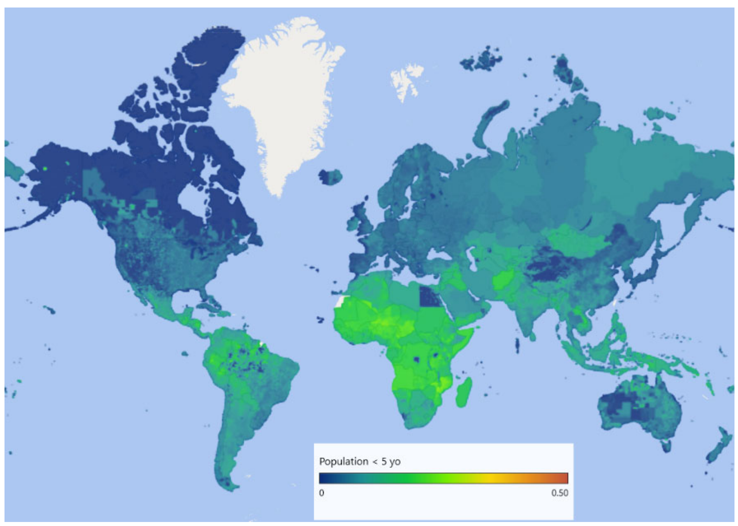
Figure 1. World population in 2020 [23].

2.3. WHO Data

Data from the WHO [26] were collected for each country (Table A1), representing the annual mortality rate per health effect (in 2016). In accordance with previous studies [13,27,28], the population under 5 years old and over 30 years were considered. The information collected corresponds to the mortality rate for health diseases related to air pollution: for people aged above 30 years old, ischemic heart disease (IHD), stroke, lung cancer (LC), and chronic obstructive pulmonary disease (COPD) and for people aged under five years old, acute lower respiratory infections (ALRI). The maps of the populations under 5 years old and over 30 years old are shown in Figure 2.



(a)



(b)

Figure 2. Ratio of population (a) > 30 years old and (b) < 5 years old.

2.4. Concentration Response Function (CRF)

Based on previous cohort studies [13,27,29], it was decided to pick a relative risk of 1.01 per μg/m^3 per health effect. The equation for the CRF applied in each grid is

$$\mathrm{CRF} = \mathrm{RR} * \mathrm{MR} * \Delta\mathrm{C} * \mathrm{Pop}$$

where:

- RR is the relative risk of a health effect due to exposure to $PM_{2.5}$ (μg/m^3 of air).
- MR (death/person/month) is the mortality rate specific to each country for the health effects related to air pollution.
- ΔC is the difference in $PM_{2.5}$ concentration (μg/m^3 of air) between each monthly average in the first quarter of years 2019 and 2020.
- Pop is the population under 5 years old and over 30 years old in the grid.

To express the overall burden, the number of deaths was converted to disability-adjusted life years (DALYs) using the WHO data (Table A1 [26]).

3. Results

3.1. Results Per Country

The highest reductions in burden occurred for China (−13.9 million DALY), India (−6.3 million), and Nigeria (−2.3 million). Italy (26,943 DALY), Germany (23,150), and Switzerland (4,744) showed increases in mortality compared to the same period last year. The results are shown in Table 1 and Figure 3. The results for each grid (including main parameters) are provided in the Supplementary Information.

The $PM_{2.5}$ concentration was generally low in Western Europe in the first quarter of the year; events related to lockdowns, such as the reduction in transportation or the temporary reduction in industrial activity, did not affect the level of pollution.

The total reduction in the burden globally was 34.4 million DALY (or 1.3 million deaths), confirming that the actions taken against the COVID-19 pandemic indirectly helped to improve air quality.

Table 1. Comparison of the burden of air pollution at the country level between Q1 2019 and Q1 2020.

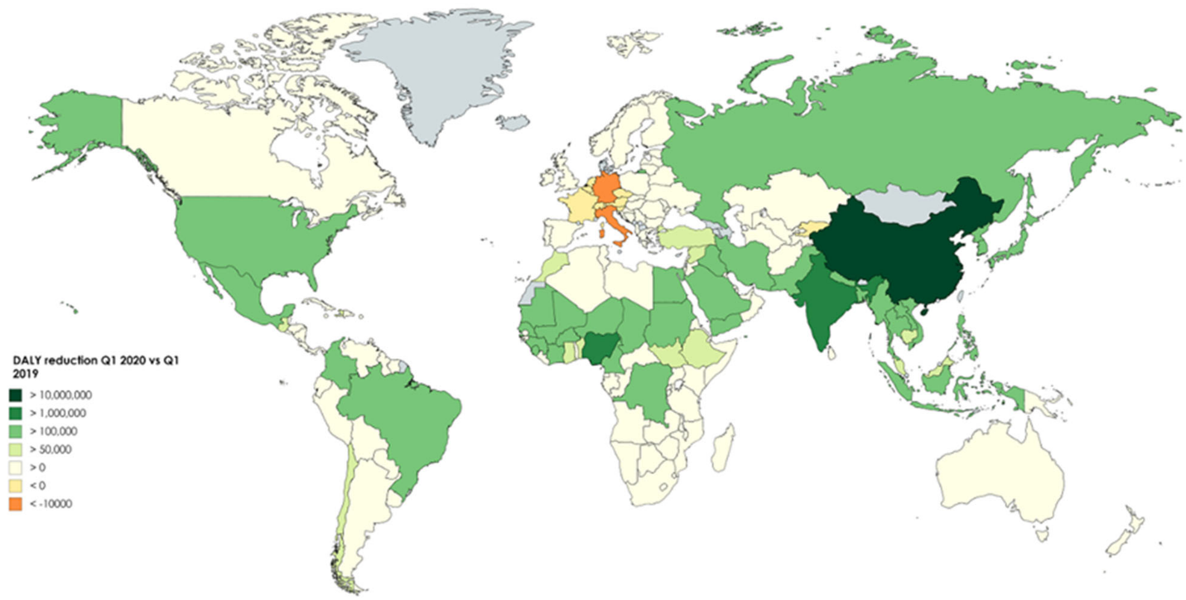
Rank (By DALY Reduction)	Country	Average Concentration Q1 2019 (μg/m³)	Average Concentration Q1 2020 (μg/m³) [difference in %]	ΔBurden (DALY) (Year)	ΔBurden (death) (person)
1	China	44.28	18.88 [−57%]	**−13,904,672**	**−646,164**
2	India	49.90	30.99 [−38%]	**−6,300,012**	**−206,727**
3	Nigeria	75.30	34.31 [−54%]	**−2,296,551**	**−40,790**
4	Indonesia	12.44	5.33 [−57%]	**−938,082**	**−32,650**
5	Pakistan	43.96	27.76 [−37%]	**−822,236**	**−24,560**
6	Bangladesh	70.44	45.26 [−36%]	**−728,264**	**−24,836**
7	Egypt	65.13	12.28 [−81%]	**−567,987**	**−21,409**
8	Niger	121.56	43.91[−64%]	**−531,374**	**−9,221**
9	Mexico	21.55	17.52 [−19%]	**−391,795**	**−18,050**
10	Mali	108.49	38.52 [−64%]	**−371,698**	**−7,666**
11	USA	6.24	4.56 [−27%]	**−345,296**	**−16,826**
12	Chad	108.44	44.61 [−59%]	**−335,997**	**−5,266**
13	Sudan	67.60	24.43 [−64%]	**−326,182**	**−8,689**
14	Philippines	16.97	5.99 [−65%]	**−286,481**	**−9,135**
15	Myanmar	51.17	24.21 [−−53%]	**−265,381**	**−8,674**
16	Korea	45.67	19.82[−57%]	**−248,186**	**−11,682**
17	Viet Nam	37.58	16.62[−56%]	**−231,642**	**−9,426**
18	Saudi Arabia	91.00	15.95 [−82%]	**−216,057**	**−8,157**
19	DR Korea	41.00	21.09[−49%]	**−209,621**	**−9.047**
20	Burkina Faso	79.81	34.64 [−57%]	**−206,691**	**−4,301**
21	Senegal	103.73	33.31 [−68%]	**−194,609**	**−5,111**
22	Iraq	65.42	27,33 [−58%]	**−194,020**	**−6,251**
23	Japan	12.53	7.05 [−44%]	**−190,996**	**−11,610**
24	Yemen	64.34	12.00 [−81%]	**−187,702**	**−5,047**
25	Guinea	78.47	29.07 [−63%]	**−176,165**	**−3,771**
26	Russia	3.29	2.09 [−37%]	**−175,918**	**−8,925**
27	Cameroon	49.28	26.35 [−47%]	**−174,854**	**−3,622**
28	Laos	134.95	34.20 [−75%]	**−154,851**	**−4,166**
29	Brazil	6.03	3.74 [−38%]	**−151,322**	**−6,336**
30	Thailand	34.40	16.89 [−51%]	**−141,147**	**−5,685**

31	Iran	33.12	14.26 [−57%]	**−138,746**	**−6,358**
32	Côte d'Ivoire	38.58	16.56 [−57%]	**−123,258**	**−2,752**
33	Nepal	37.21	28.85 [−22%]	**−119,319**	**−4,289**
34	Colombia	18.35	10.00 [−46%]	**−119,130**	**−5,243**
35	Congo DR	14.84	10.80 [−27%]	**−109,275**	**−2,054**
36	Mauritania	113.31	21.76 [−81%]	**−106,973**	**−2,303**
37	Sierra Leone	75.40	23.66 [−69%]	**−103,114**	**−2,266**
38	Ghana	49.27	22.89 [−54%]	**−94,944**	**−2,775**
39	Chile	8.60	3.33 [−61%]	**−91,702**	**−4,455**
40	Syrian Arab Republic	44.39	22.60 [−49%]	**−82,341**	**−3,311**
41	Turkey	13.48	7.81 [−42%]	**−79,542**	**−3,461**
42	Benin	61.28	27.52 [−55%]	**−69,186**	**−1,345**
43	Malaysia	13.59	5.90 [−57%]	**−68,465**	**−2,724**
44	Guatemala	40.11	11.38 [−72%]	**−63,437**	**−1,980**
45	Haiti	24.80	9.20 [−63%]	**−63,354**	**−1,766**
46	Morocco	27.56	5.90 [−50%]	**−57,008**	**−2,691**
47	Ethiopia	20.27	13.30 [−34%]	**−56,294**	**−1,280**
48	South Sudan	39.58	23.27 [−41%]	**−55,947**	**−998**
49	Cambodia	47.79	17.67 [−63%]	**−55,843**	**−1,724**
50	Venezuela	16.17	7.24 [−55%]	**−45,261**	**−1,907**
51	Uzbekistan	25.09	12.16 [−52%]	**−44,100**	**−1,805**
52	Peru	5.94	4.49 [−24%]	**−43,536**	**−1,794**
53	Libya	79.65	12.65 [−84%]	**−40,488**	**−1,586**
54	Somalia	15.74	6.12 [−61%]	**−40,184**	**−623**
55	Sri Lanka	21.55	13.49 [−37%]	**−40,079**	**−1,654**
56	Turkmenistan	28.43	15.06 [−47%]	**−36,702**	**−1,305**
57	Argentina	6.12	3.64 [−41%]	**−35,376**	**−1,779**
58	Dominican Republic	25.58	8.95 [−65%]	**−35,302**	**−1,380**
59	Togo	54.84	25.98 [−53%]	**−34,637**	**−805**
60	UAE	79.41	15.44 [−81%]	**−32,864**	**−869**
61	Uganda	16.39	10.79 [−34%]	**−32,578**	**−642**
62	CAF	49.91	29.97 [−40%]	**−32,128**	**−674**
63	El Salvador	48.74	10.57 [−78%]	**−31,487**	**−1,426**
64	Ukraine	6.94	5.70 [−18%]	**−30,239**	**−1,611**
65	Algeria	67.05	20.12 [−70%]	**−28,523**	**−1,098**
66	Gambia	96.73	36.07 [−63%]	**−28,479**	**−655**
67	Lebanon	36.85	20.14 [−45%]	**−28,453**	**−1,367**
68	Canada	1.00	0.77 [−23%]	**−28,230**	**−1,497**
69	Romania	8.42	6.36 [−24%]	**−26,036**	**−1,418**
70	Jordan	54.94	12.88 [−77%]	**−25,171**	**−937**
71	United Republic of Tanzania	5.67	2.83 [−50%]	**−25,075**	**−574**

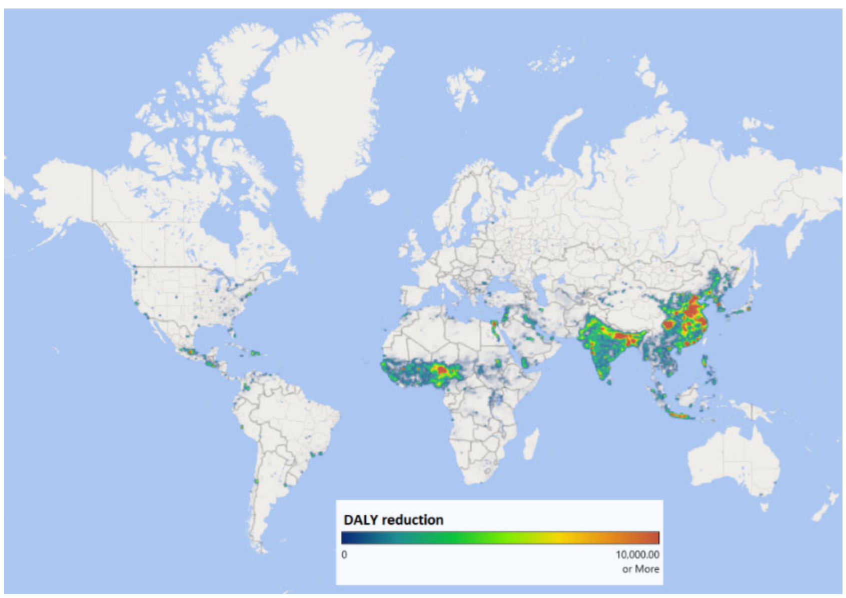
72	South Africa	11.24	4.61 [−59%]	**−23,956**	**−760**
73	Guinea−Bissau	88.07	32.12 [−64%]	**−23,582**	**−468**
74	Afghanistan	22.92	14.04 [−39%]	**−23,285**	**−540**
75	Israel	52.89	17.89 [−66%]	**−22,654**	**−1,227**
76	Angola	6.42	2.91 [−55%]	**−21,834**	**−382**
77	Kuwait	102.18	32.21 [−68%]	**−21,474**	**−664**
78	Qatar	84.64	20.91 [−75%]	**−21,457**	**−622**
79	Greece	12.79	4.85 [−62%]	**−19,301**	**−1,147**
80	Bulgaria	9.77	5.06 [−48%]	**−18,738**	**−1,015**
81	Australia	19.56	3.38 [−83%]	**−18,118**	**−1,057**
82	Honduras	26.58	13.70 [−48%]	**−18,097**	**−703**
83	Ecuador	13.35	7.80 [−42%]	**−17,392**	**−736**
84	Cuba	12.52	7.67 [−39%]	**−17,241**	**−877**
85	Tunisia	45.76	14.42 [−68%]	**−17,028**	**−788**
86	Liberia	30.90	8.96 [−71%]	**−16,825**	**−383**
87	Kazakhstan	10.05	6.48 [−36%]	**−15,329**	**−679**
88	Singapore	64.49	25.35 [−61%]	**−11,832**	**−537**
89	Oman	66.80	11.83 [−82%]	**−9,612**	**−324**
90	Spain	6.47	4.77 [−26%]	**−8,932**	**−543**
91	Kenya	9.20	5.59 [−39%]	**−8,222**	**−140**
92	Mozambique	3.80	2.25 [−41%]	**−8,209**	**−158**
93	UK	5.06	4.14 [−18%]	**−7,558**	**−416**
94	Azerbaijan	11.55	8.92 [−23%]	**−6,922**	**−298**
95	Mongolia	20.92	5.92 [−71%]	**−6,510**	**−231**
96	Poland	6.87	6.16 [−10%]	**−6,493**	**−345**
97	Tajikistan	7.09	7.62 [7%]	**−6,073**	**−217**
98	Portugal	7.28	4.09 [−44%]	**−5,830**	**−349**
99	Belarus	5.35	4.20 [−21%]	**−5,725**	**−296**
100	Georgia	7.82	5.14 [−34%]	**−5,573**	**−303**
101	Papua New Guinea	5.39	2.79 [−48%]	**−5,246**	**−142**
102	Bahrain	97.49	37.87 [−61%]	**−5,007**	**−172**
103	Panama	13.30	5.28 [−60%]	**−4,970**	**−228**
104	Serbia	8.62	6.44 [−25%]	**−4,859**	**−243**
105	Bhutan	25.49	18.93 [−26%]	**−4,708**	**−143**
106	Nicaragua	14.32	6.42 [−55%]	**−4,607**	**−162**
107	Costa Rica	14.69	4.73 [−68%]	**−4,600**	**−230**
108	Jamaica	25.67	10.54 [−59%]	**−4,592**	**−243**
109	Burundi	11.96	9.87 [−17%]	**−4,479**	**−88**
110	Zambia	4.16	2.21 [−47%]	**−4,445**	**−87**
111	Hungary	8.06	6.67 [−17%]	**−4,366**	**−229**
112	Albania	10.32	4.60 [−55%]	**−4,251**	**−226**
113	Paraguay	9.00	7.48 [−17%]	**−4,020**	**−161**

114	Eritrea	30.16	20.08 [−33%]	**−3,933**	**−94**
115	Malawi	4.63	2.91 [−37%]	**−3,544**	**−77**
116	Bosnia and Herzegovina	7.67	4.78 [−38%]	**−3,381**	**−176**
117	Rwanda	18.19	15.53 [−15%]	**−3,270**	**−81**
118	Namibia	14.40	2.32 [−84%]	**−3,232**	**−100**
119	Republic of Moldova	7.71	5.53 [−28%]	**−3,203**	**−164**
120	New Zealand	5.74	1.95	**−3,074**	**−172**
121	Sweden	2.87	1.56 [−45%]	**−3,013**	**−181**
122	Djibouti	25.86	11.00 [−57%]	**−2,926**	**−79**
123	Madagascar	2.60	2.01 [−23%]	**−2,644**	**−65**
124	Croatia	8.44	6.37 [−25%]	**−2,556**	**−145**
125	Armenia	10.59	7.68 [−27%]	**−2,307**	**−120**
126	Cyprus	21.41	7.83 [−63%]	**−2,225**	**−126**
127	Uruguay	6.09	3.64 [−40%]	**−2,020**	**−106**
128	Lesotho	9.57	4.30 [−55%]	**−1,933**	**−58**
129	Cape Verde	52.28	12.22 [−77%]	**−1,841**	**−97**
130	Denmark	5.69	3.96 [−30%]	**−1,747**	**−95**
131	Zimbabwe	3.96	2.75 [−30%]	**−1,743**	**−41**
132	Macedonia	8.76	5.52 [−37%]	**−1,729**	**−81**
133	Latvia	6.33	4.97 [−21%]	**−1,524**	**−87**
134	Finland	2.40	1.57 [−35%]	**−1,408**	**−81**
135	Trinidad and Tobago	12.04	6.71 [−44%]	**−1,231**	**−54**
136	Norway	2.21	1.55 [−30%]	**−1,201**	**−69**
137	Slovakia	7.57	6.62 [−13%]	**−1,198**	**−61**
138	Equatorial Guinea	10.64	6.95 [−35%]	**−1,120**	**−24**
139	Montenegro	8.65	3.99 [−54%]	**−1,080**	**−59**
140	Ireland	5.61	4.16 [−26%]	**−1,079**	**−59**
141	Botswana	7.99	2.51 [−69%]	**−1,017**	**−35**
142	Gabon	8.03	5.02 [−38%]	**−1,004**	**−30**
143	Lithuania	6.19	5.29 [−15%]	**−983**	**−59**
144	Suriname	10.67	3.65 [−66%]	**−968**	**−39**
145	Estonia	5.82	3.94 [−32%]	**−754**	**−44**
146	Congo	13.22	9.49 [−28%]	**−753**	**−18**
147	Swaziland	9.97	6.18 [−21%]	**−728**	**−19**
148	Guyana	9.94	4.52 [−55%]	**−709**	**−27**
149	Malta	20.97	6.87 [−67%]	**−709**	**−41**
150	Brunei Darussalam	25.30	10.55 [−58%]	**−707**	**−26**
151	Timor−Leste	4.47	2.18 [−51%]	**−575**	**−14**

152	Fiji	4.17	2.20 [−47%]	**−377**	**−13**
153	Bolivia	4.03	3.63 [−10%]	**−372**	**−14**
154	Belize	12.95	6.43 [−50%]	**−270**	**−11**
155	Solomon Islands	3.13	0.98 [−69%]	**−162**	**−5**
156	Barbados	11.53	7.41 [−36%]	**−115**	**−6**
157	Mauritius	7.09	6.05 [−15%]	**−99**	**−4**
158	Maldives	14.25	7.67 [−46%]	**−78**	**−3**
159	Vanuatu	4.55	2.54 [−44%]	**−71**	**−2**
160	Saint Vincent and the Grenadines	10.52	6.81 [−35%]	**−61**	**−3**
161	Saint Lucia	9.61	6.78 [−29%]	**−57**	**−3**
162	Grenada	11.32	7.20 [−36%]	**−47**	**−2**
163	Sao Tome and Principe	4.99	3.27 [−34%]	**−32**	**−1**
164	Iceland	1.40	1.31 [−6%]	**−23**	**−1**
165	Tonga	5.36	3.21 [−32%]	**−18**	**−1**
166	Micronesia (Federated States of)	7.39	4.28 [−42%]	**−17**	**−1**
167	Samoa	2.47	1.36 [−42%]	**−17**	**−1**
168	Antigua and Barbuda	6.84	5.32 [−22%]	**−10**	**0**
169	Seychelles	3.62	2.28 [−37%]	**−9**	**0**
170	Kiribati	4.22	3.50 [−17%]	**−4**	**0**
171	Comoros	5.63	5.30 [−6%]	**−2**	**0**
172	Bahamas	5.60	7.12 [+27%]	**83**	**3**
173	Luxembourg	5.20	6.62 [+27%]	**112**	**6**
174	Slovenia	7.13	7.44 [+4%]	**186**	**11**
175	Czechia	7.28	7.44 [+2%]	**357**	**20**
176	Netherlands	6.36	6.43 [+1%]	**811**	**44**
177	Kyrgyzstan	7.26	6.92 [−5%]	**845**	**37**
178	Austria	5.19	6.29 [+21%]	**1,148**	**70**
179	Belgium	6.43	7.18 [+12%]	**1,327**	**75**
180	France	6.48	6.19 [−4%]	**1,616**	**92**
181	Switzerland	2.92	6.32 [+117%]	**4,744**	**283**
182	Germany	5.25	6.12 [+17%]	**23,150**	**1,373**
183	Italy	7.52	8.19 [+9%]	**26,943**	**1,826**



(a)



(b)

Figure 3. DALY reduction Q1 2020 vs. Q1 2019: (a) by country; (b) by grid.

3.2. Results Per City

The results for each city were observed: the top 10 is occupied by Chinese cities (eight) and Indian cities (two). With these cities having a high population density and being among the most polluted cities in the world, these results were expected (Table 2).

Table 2. Comparison of the burden of air pollution at the city(area) level between Q1 2019 and Q2 2020 (top10 DALY reduction).

Rank	City/Area [country]	Average Concentration Q1 2019 (ug/m³)	Average Concentration Q1 2020 (ug/m³) [difference in %]	ΔBurden (DALY) (year)	ΔBurden (Death) (person)
1	Beijing [CHN]	85.03	51.24 [−40%]	**−405,447**	**−18,922**
2	Chongqing [CHN]	76.94	36.33 [−53%]	**−389,247**	**−18,110**
3	Shanghai [CHN]	61.07	26.28 [−57%]	**−323,425**	**−15,104**
4	Chengdu CHN]	94.51	48.61 [−49%]	**−297,614**	**−13,889**
5	Xian [CHN]	109.98	53.02 [−52%]	**−274,686**	**−12,788**
6	Tianjin [CHN]	92.09	48.76 [−47%]	**−236,113**	**−11,014**
7	Wuhan [CHN]	102.54	48.58 [−53%]	**−235,140**	**−10,691**
8	Hangzhou [CHN]	58.97	27.37 [−54%]	**−210,310**	**−9,808**
9	New Delhi [IND]	87.54	54.95 [−37%]	**−190,616**	**−6,325**
10	Kolkata [IND]	97.25	59.75 [−39%]	**−189,126**	**−6,502**

4. Discussion

4.1. Confirmation of the Results in Accordance with the National Lockdowns

To confirm the validity of the results, we compared the results obtained in this study with the level of confinement in the different countries. The duration of these confinements was considered, as shown in Table 3 and Figure 4.

Table 3. Definition of the confinement level [30].

Level	Description
0	No restrictions
1	Low restrictions (e.g., public gatherings >5000 people forbidden)
2	Medium restrictions (e.g., borders closed, public gatherings >100 people forbidden, schools and restaurants closed)
3	High restrictions (e.g., household confinement as much as possible, public gatherings banned)

From the previous information, it was confirmed that the countries with the highest burden reduction adopted strict measures to stop the progress of the COVID-19 pandemic. It can also be supposed that the reduction of pollutant emissions in each country probably improved the air quality in the surrounding countries (even though these surrounding countries adopted less strict measures). Several studies highlighted the importance of the air pollution transboundary effect [12,31,32].

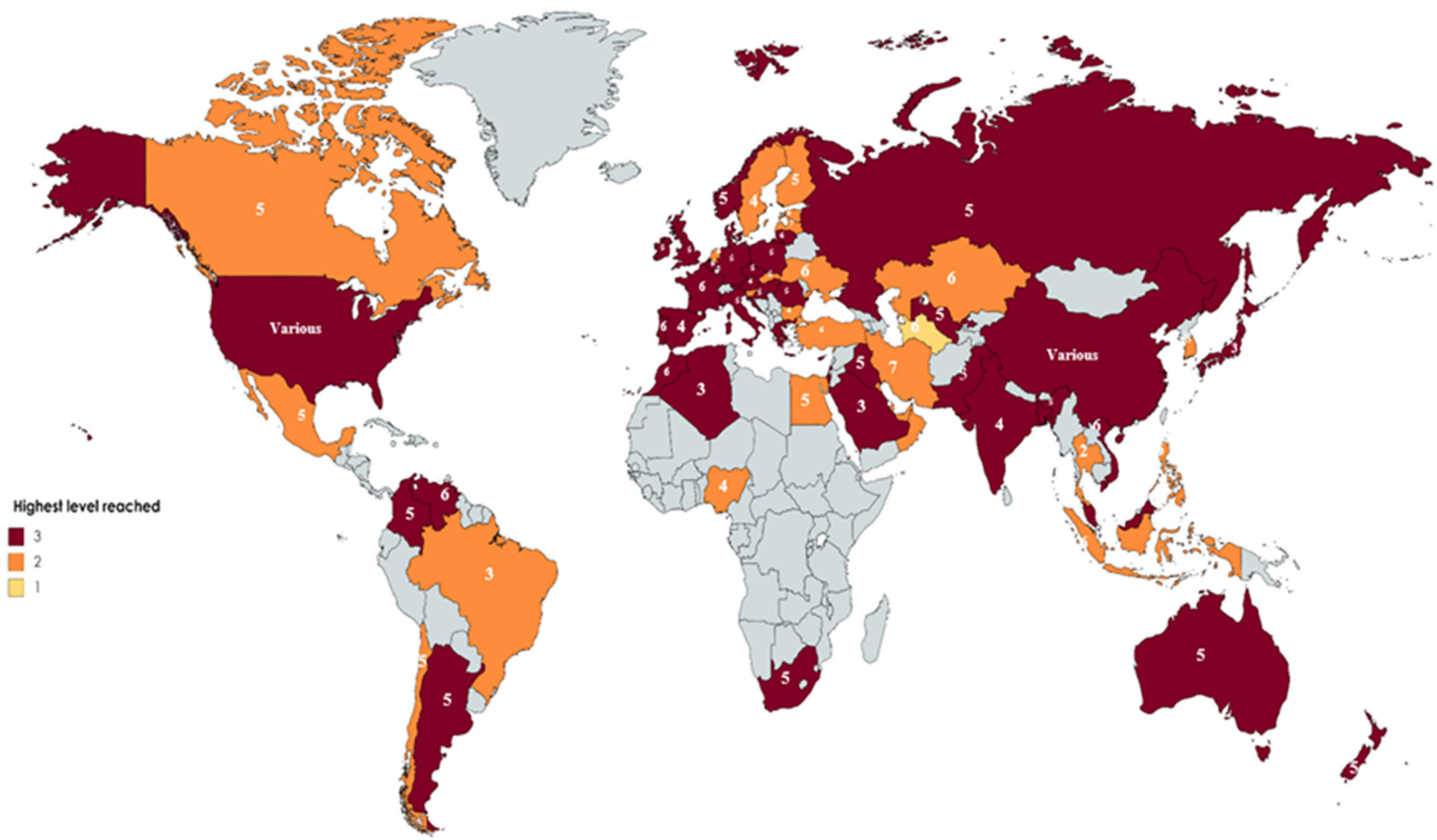


Figure 4. Highest confinement level by country between 1 January and 30 April 2020 (numbers represent the number of weeks under the highest level).

4.2. Comparison with the Annual WHO Estimation

The results were also compared with the annual estimation of the WHO [11]. A comparison for the countries experiencing a reduction in burden above 500,000 DALY according to our results is shown in Table 4.

Table 4. Comparison between this study and the annual burden of air pollution.

Rank (by reduction Q12020	Country	DALY reduction Q1 2020 vs. Q1 2019 (year)	Annual DALY Attributable to air pollution (WHO, 2016) (year)	Reduction Q1 vs. annual estimation WHO 2016
1	China	−13,904,672	25,824,548	−54%
2	India	−6,300,012	33,727,823	−19%
3	Nigeria	−2,296,551	7,523,259	−31%
4	Indonesia	−938,082	2,953,382	−32%
5	Pakistan	−822,236	4,705,933	−17%
6	Bangladesh	−728,264	2,580,528	−28%
7	Egypt	−567,987	2,068,658	−27%
8	Niger	−531,374	841,844	−63%

Except for China (54%) and Niger (63%), all of the results were below 50%. Even though direct comparison of the results is difficult (2020 vs. 2016), several studies, such as in China [33,34], showed that the monthly concentration at the end and the beginning of each year are much more important than during the rest of year. This would explain why the reduction in each country was within the range of 20–50%. To confirm this observation, the monthly average for 2019 of each country listed above was collected (Figure 5). In these countries, the level of air pollution in the first quarter of the year (as well as the last quarter of the year) was the highest.

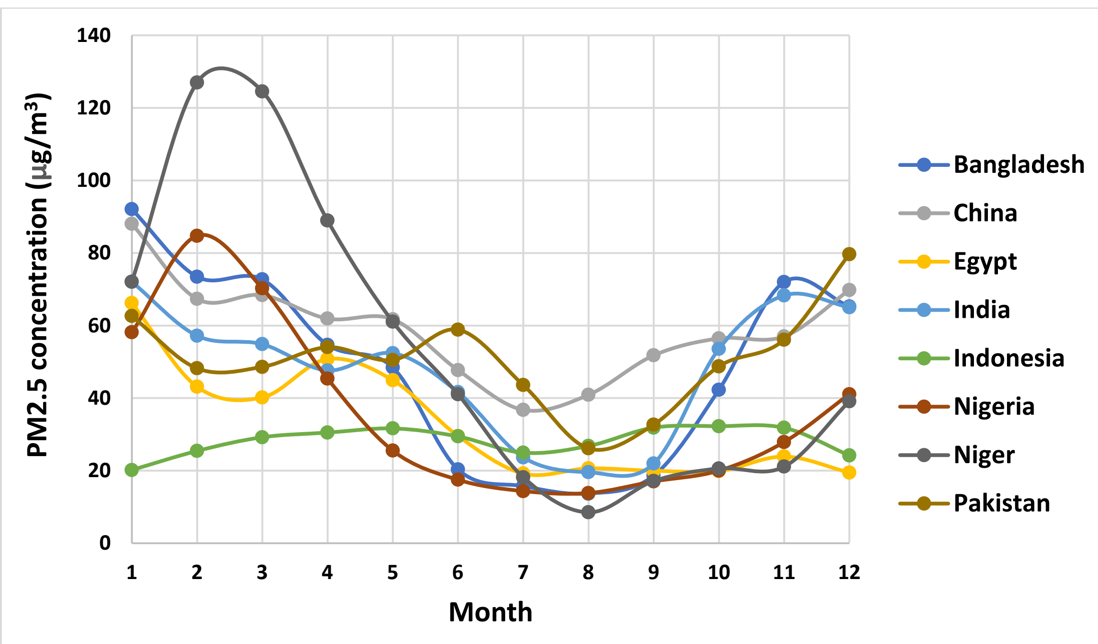


Figure 5. Monthly population-weighted $PM_{2.5}$ (µg/m³) concentration in 2019.

4.3. Sensitivity Analysis

To confirm the accuracy of our calculation, we considered different methodologies. First, using He et al. 2016 [29] and the conversion provided by the WHO (0.65 $PM_{10} = PM_{2.5}$ [35]) coupled with the United Nations (UN) population data [36], different relative risks for each age group were determined: 1.029 for the age group 0–5 years old, 1.006 for the 30–50-year-olds, 1.01 for the 50–60-

year-olds, and 1.014 for the population over 60 years old. Then, a different approach based on different relative risks (RRs) for each disease related to air pollution [27] was considered: 1.013 for cardiopulmonary diseases, 1.014 for lung cancer and 1.024 for ischemic heart disease, with ALRI not being considered in the study. The results obtained in this study for the 20 countries with the highest reductions in burden (representing 85% of the global reduction of burden) were compared using these two different approaches, as shown in Table 5.

Table 5. Comparison between different approaches based on different relative risks (RRs) in DALY (death).

Country (Ranked by the highest reduction in section 3.1)	This study (constant RR = 1.01)	He et al. 2016 [29] (RR based on age groups) [Comparison with the approach used in this study]	Krewski et al. 2009 [27] (RR based on diseases) [Comparison with the approach used in this study]
China	−13,904,672 (−646,164)	−16,403,411 (−779,350) [+18%]	−22,746,387 (−1,093,541) [+64%]
India	−6,300,012 (−206,727)	−9,203,451 (−283,933) [+46%]	−9,748,511 (−361,514) [+55%]
Nigeria	−2,296,551 (−40,790)	−5,754,759 (−86,523) [+151%]	−1,099,094 (−41,984) [−52%]
Indonesia	−938,082 (−32,650)	−1,214,983 (−41,680) [+30%]	−1,544,644 (−58,038) [+65%]
Pakistan	−822,236 (−24,560)	−1,510,268 (−37,912) [+84%]	−1,008,465 (−41,348) [+23%]
Bangladesh	−728,264 (−24,836)	−1,202,456 (−39,118) [+65%]	−1,004,931 (−39,889) [+38%]
Egypt	−567,987 (−21,409)	−708,513 (−25,717) [+25%]	−1,063,102 (−42,649) [+87%]
Niger	−531,374 (−9,221)	−1,342,248 (−19,729) [+153%]	−233,392 (−8,929) [−56%]
Mexico	−391,795 (−18,050)	−519590 (−23,163) [+33%]	−691,548 (−34,472) [+77%]
Mali	−371,698 (−7,666)	−902,714 (−16,700) [+143%]	−228,988 (−9,178) [−38%]
USA	−345,296 (−16,826]	−413,510 (−20,925) [+20%]	−624,464 (−31,412) [+81%]
Chad	−335,997 (−5,266]	−872,974 (−11,864) [+160%]	−115,100 (−4,200) [−66%]
Sudan	−326,182 (−8,689)	−574,027 (−12,892) [+76%]	−418,553 (−15,005) [+28%]
Philippines	−286,481 (−9,135)	−382,932 (−11,405) [+34%]	−445,912 (−16,059) [+56%]
Myanmar	−265,381 (−8,674)	−430,630 (−12,470) [+62%]	−322,872 (−12,892) [+22%]
Korea	−248,186 (−11,682)	−271,290 (−13,360) [+9%]	−402,701 (−19,459) [+62%]
Viet Nam	−231,642 (−9426)	−301,894 (−12,029) [+30%]	−343,165 (−15,579) [+48%]
Saudi Arabia	−216,057 (−8157)	−241,187 (−9,212) [+12%]	−423,174 (−16,461) [+96%]
DR Korea	−209,621 (−9047)	−287,163 (−12,925] [+37%]	−319,766 (−14,305) [+52%]
Burkina Faso	−206,691 (−4301)	−489,007 (−8,780) [+137%]	−143,608 (−5,541) [−31%]

The following observations were noted from the results. Based on the approach adapted from He et al. [29], for the most developed countries on the list (USA, China, and Korea), the results were estimated to be less than 20% higher; for the African countries, the results were estimated to be more than 100% higher. In these developed countries, the age groups are homogeneous, whereas, for African countries, the population under five years old is the highest in the world. Based on the approach by Krewski et al. 2009 [27], an opposite trend was observed: the results were higher for the most developed countries, but lower for the African countries. The two reasons for this are that ALRI is not considered in this method, and, more importantly according to the WHO statistics, that the sub−Saharan African population is young, so this population suffers less from heart diseases.

These results confirm the approach chosen in this study. To avoid any over- or underestimation due to the lack of detailed information concerning each country, we chose a constant relative risk of 1.01, which is midway between the relative risk of 1.006 adapted from He et al. [29] (age group 30–50) and the relative risk of 1.024 for IHD in Krewski et al. [27]. This constant relative risk is also in the same range as the value adapted from He et al. [29] for the age group 50–60 (RR = 1.01) and the RRs for lung cancer and cardiopulmonary disease in Krewski et al. [27] (1.013 and 1.014, respectively).

4.4. Why Did the $PM_{2.5}$ Concentration Not Fall to Zero?

One of the last questions that one may ask could be: "why have air pollution levels not dropped to zero and even increased in some areas where a lockdown was active?".

It should be clarified that $PM_{2.5}$ emissions as a primary source, followed by NO_x, SO_2 and, NH_3 as secondary sources, contribute to the $PM_{2.5}$ concentration.

There are several reasons that the $PM_{2.5}$ concentration did not fall to zero: electricity generation from industry decreased [37], but electricity generation in the residential sector did not stop during the lockdown period [38]. Many countries (e.g., in Asia) still rely considerably on coal-fired power plants, which emit a large amount of $PM_{2.5}$, NO_x and SO_2 (especially when technologies such as electrostatic precipitators (ESP), selective catalytic redactors (SCR) and flue-gas desulfurization (FGD) are not applied), thereby contributing to the $PM_{2.5}$ concentration. According to the user data provided by Apple [39], in different cities all around the world, key workers were still active during lockdowns. Shipments by heavy trucks, one of the major contributors of NO_x emissions, were popular during the different lockdowns. Finally, agriculture, a major source of NH_3 emissions, also contributed to keeping the $PM_{2.5}$ concentration at a certain level.

4.5. Limitations and Future Work

The results of this study were obtained from models but not clinical observations; therefore, caution is needed when interpreting the results. Heterogeneity also exists between the population of the same country following, for example, their economic situation or their access to medical structure. Cohort studies conducted in developing countries (e.g., those in South/Southeast Asia and Western Africa) are urgently required, as only models based on the situation in developed countries are available for predicting the damage caused by air pollution in developing countries.

As highlighted in Section 4.4, even during strict lockdowns, the levels of air pollution remained at a certain level. Some additional work is needed to isolate the sources of air pollution in each country; the lockdowns provide a good opportunity to isolate the different sources as reported by some recent studies [40,41]. Similar to water [42] or carbon dioxide [43,44], a detailed database for air pollution could be created. Once such a database is established, different scenarios could be considered to keep the $PM_{2.5}$ concentration under a certain level in daily life.

5. Conclusions

In this study, it was confirmed that national lockdowns helped to reduce the impact of air pollution in the first quarter of 2020, especially in Asia and Western Africa. The greatest reductions were observed in China (−13.9 million DALY), India (−6.3 million DALY), and Nigeria (−2.3 million DALY). In developed countries, such as those in Western Europe, no major difference was observed compared with 2019.

These observations provide some indications. In Western Europe, advanced technologies (e.g., electricity from renewable energies, vehicles with high fuel efficiency) already help to keep the air pollution level low in daily life. Conversely, with these technologies still being unavailable in several parts of the world, the suspension of activity directly reduced the impact of polluting technologies. Advanced technologies are usually expensive; using a cost−benefit approach, future works might focus on comparing the affordability of advanced technologies and opportunities for teleworking in developing countries.

Supplementary Materials: Supplementary Materials: The following are available online at www.mdpi.com/2071-1050/12/13/5297/s1,

Author Contributions: conceptualization, S.K. and N.I.; methodology, S.K. and N.I.; software, S.K.; formal analysis, S.K.; investigation, S.K.; resources, N.I.; writing—original draft preparation, S.K.; supervision, N.I. All authors have read and agreed to the published version of the manuscript.

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Appendix

Table A1. WHO data for each country concerning the diseases related to air pollution.

ISO Alpha–3 CODE [45]	Stroke (DALY/ person/ month)	IHD (DALY/ person/ month)	LC (DALY/ person/ month)	COPD (DALY/ person/ month)	ALRI (DALY/ person/ month)	Stroke (DALY/ Death)	IHD (DALY/ Death)	LC (DALY/ Death)	COPD (DALY/ Death)	ALRI (DALY/ Death)
AFG	1.2×10^{-4}	2.7×10^{-4}	8.9×10^{-6}	3.6×10^{-5}	2.0×10^{-4}	28	28	33	29	91
ALB	2.6×10^{-4}	3.6×10^{-4}	5.5×10^{-5}	3.0×10^{-5}	2.2×10^{-5}	17	18	24	19	93
DZA	7.1×10^{-5}	2.0×10^{-4}	1.2×10^{-5}	1.8×10^{-5}	5.5×10^{-5}	22	21	30	28	91
AGO	7.9×10^{-5}	9.9×10^{-5}	2.1×10^{-6}	2.4×10^{-5}	2.7×10^{-4}	25	24	30	30	91
ATG	8.5×10^{-5}	1.5×10^{-4}	6.7×10^{-6}	2.2×10^{-5}	3.2×10^{-6}	22	21	28	21	94
ARG	7.5×10^{-5}	1.8×10^{-4}	3.7×10^{-5}	7.6×10^{-5}	1.2×10^{-5}	22	18	25	18	92
ARM	1.1×10^{-4}	4.4×10^{-4}	6.6×10^{-5}	5.1×10^{-5}	2.2×10^{-5}	21	17	26	18	92
AUS	6.1×10^{-5}	1.3×10^{-4}	4.9×10^{-5}	5.0×10^{-5}	1.8×10^{-6}	16	15	21	18	95
AUT	6.7×10^{-5}	2.7×10^{-4}	5.8×10^{-5}	5.0×10^{-5}	2.7×10^{-7}	18	14	23	18	99
AZE	1.2×10^{-4}	3.9×10^{-4}	1.9×10^{-5}	2.6×10^{-5}	6.3×10^{-5}	23	21	31	24	92
BHS	6.8×10^{-5}	1.2×10^{-4}	1.6×10^{-5}	9.8×10^{-6}	2.6×10^{-5}	23	22	27	27	92
BHR	1.2×10^{-5}	6.0×10^{-5}	7.7×10^{-6}	6.8×10^{-6}	2.4×10^{-6}	33	27	25	40	95
BGD	1.4×10^{-4}	1.4×10^{-4}	1.6×10^{-5}	7.7×10^{-5}	9.3×10^{-5}	25	26	27	24	91
BRB	1.6×10^{-4}	1.7×10^{-4}	2.0×10^{-5}	2.7×10^{-5}	5.0×10^{-6}	18	18	24	18	95
BLR	1.9×10^{-4}	7.6×10^{-4}	4.3×10^{-5}	2.6×10^{-5}	3.8×10^{-6}	22	18	27	24	95
BEL	8.2×10^{-5}	1.7×10^{-4}	7.7×10^{-5}	7.7×10^{-5}	1.7×10^{-6}	17	15	23	18	93
BLZ	7.8×10^{-5}	1.5×10^{-4}	2.2×10^{-5}	2.6×10^{-5}	1.8×10^{-5}	23	22	28	23	92
BEN	1.2×10^{-4}	1.4×10^{-4}	1.3×10^{-6}	3.6×10^{-5}	2.7×10^{-4}	27	24	34	29	91
BTN	8.1×10^{-5}	1.9×10^{-4}	9.0×10^{-6}	7.6×10^{-5}	8.2×10^{-5}	29	30	33	30	92
BOL	8.3×10^{-5}	1.8×10^{-4}	7.4×10^{-6}	4.4×10^{-5}	9.0×10^{-5}	27	22	25	20	91
BIH	2.5×10^{-4}	3.9×10^{-4}	6.6×10^{-5}	4.7×10^{-5}	5.2×10^{-6}	20	18	25	21	95
BWA	8.6×10^{-5}	1.2×10^{-4}	4.5×10^{-6}	4.0×10^{-5}	6.8×10^{-5}	23	23	31	28	91
BRA	8.3×10^{-5}	1.3×10^{-4}	2.3×10^{-5}	4.7×10^{-5}	2.2×10^{-5}	23	24	25	21	92
BRN	5.0×10^{-5}	9.7×10^{-5}	2.5×10^{-5}	2.8×10^{-5}	4.4×10^{-6}	29	26	25	29	93

BGR	$3.6x10^{-4}$	$6.2x10^{-4}$	$6.3x10^{-5}$	$6.3x10^{-5}$	$1.8x10^{-5}$	18	18	27	21	92
BFA	$8.3x10^{-5}$	$1.5x10^{-4}$	$2.8x10^{-6}$	$2.2x10^{-5}$	$1.9x10^{-4}$	28	25	32	31	91
BDI	$1.0x10^{-4}$	$1.1x10^{-4}$	$2.3x10^{-6}$	$3.3x10^{-5}$	$2.2x10^{-4}$	27	26	34	29	91
KHM	$1.4x10^{-4}$	$1.1x10^{-4}$	$1.7x10^{-5}$	$2.8x10^{-5}$	$8.7x10^{-5}$	25	25	28	34	92
CMR	$1.2x10^{-4}$	$1.4x10^{-4}$	$2.3x10^{-6}$	$3.9x10^{-5}$	$2.3x10^{-4}$	26	24	39	28	91
CAN	$4.5x10^{-5}$	$1.4x10^{-4}$	$7.3x10^{-5}$	$5.0x10^{-5}$	$1.5x10^{-6}$	21	17	22	18	95
CPV	$1.1x10^{-4}$	$2.4x10^{-4}$	$3.3x10^{-6}$	$3.4x10^{-5}$	$4.7x10^{-5}$	21	18	32	22	91
CAF	$1.7x10^{-4}$	$1.6x10^{-4}$	$2.6x10^{-6}$	$4.3x10^{-5}$	$3.9x10^{-4}$	25	25	33	28	91
TCD	$1.3x10^{-4}$	$1.7x10^{-4}$	$1.6x10^{-6}$	$3.7x10^{-5}$	$5.8x10^{-4}$	29	26	35	30	91
CHL	$7.8x10^{-5}$	$1.0x10^{-4}$	$2.8x10^{-5}$	$3.8x10^{-5}$	$4.5x10^{-6}$	21	20	23	17	92
CHN	$2.0x10^{-4}$	$1.9x10^{-4}$	$6.2x10^{-5}$	$8.7x10^{-5}$	$2.0x10^{-5}$	23	19	23	20	92
COL	$6.3x10^{-5}$	$1.7x10^{-4}$	$2.2x10^{-5}$	$3.6x10^{-5}$	$2.5x10^{-5}$	23	21	25	18	92
COM	$9.0x10^{-5}$	$1.4x10^{-4}$	$2.8x10^{-6}$	$2.6x10^{-5}$	$2.4x10^{-4}$	27	26	31	29	91
COG	$8.9x10^{-5}$	$1.2x10^{-4}$	$1.9x10^{-6}$	$2.8x10^{-5}$	$1.4x10^{-4}$	25	23	29	29	91
CRI	$5.4x10^{-5}$	$1.3x10^{-4}$	$1.2x10^{-5}$	$4.0x10^{-5}$	$7.2x10^{-6}$	19	21	22	16	93
CIV	$1.6x10^{-4}$	$2.3x10^{-4}$	$2.4x10^{-6}$	$4.2x10^{-5}$	$2.9x10^{-4}$	31	28	31	31	91
HRV	$1.9x10^{-4}$	$3.8x10^{-4}$	$8.4x10^{-5}$	$5.5x10^{-5}$	$3.1x10^{-6}$	18	16	24	18	94
CUB	$1.0x10^{-4}$	$2.3x10^{-4}$	$6.3x10^{-5}$	$5.5x10^{-5}$	$1.1x10^{-5}$	19	19	23	19	92
CYP	$6.9x10^{-5}$	$1.9x10^{-4}$	$4.4x10^{-5}$	$5.2x10^{-5}$	$4.9x10^{-7}$	17	18	23	15	94
CZE	$1.0x10^{-4}$	$3.6x10^{-4}$	$6.2x10^{-5}$	$4.5x10^{-5}$	$3.4x10^{-6}$	19	16	23	22	93
PRK	$2.7x10^{-4}$	$1.8x10^{-4}$	$8.0x10^{-5}$	$1.8x10^{-4}$	$5.1x10^{-5}$	23	21	27	21	92
COD	$1.1x10^{-4}$	$1.1x10^{-4}$	$1.6x10^{-6}$	$3.2x10^{-5}$	$2.8x10^{-4}$	25	24	31	28	91
DNK	$7.8x10^{-5}$	$1.2x10^{-4}$	$9.0x10^{-5}$	$9.3x10^{-5}$	$1.2x10^{-6}$	18	17	21	18	93
DJI	$8.9x10^{-5}$	$1.4x10^{-4}$	$4.1x10^{-6}$	$2.3x10^{-5}$	$1.6x10^{-4}$	27	25	32	30	91
DOM	$1.1x10^{-4}$	$2.3x10^{-4}$	$2.1x10^{-5}$	$2.0x10^{-5}$	$5.8x10^{-5}$	24	23	25	22	91
ECU	$5.9x10^{-5}$	$1.0x10^{-4}$	$1.1x10^{-5}$	$3.5x10^{-5}$	$4.4x10^{-5}$	22	20	23	16	91
EGY	$1.2x10^{-4}$	$3.5x10^{-4}$	$1.0x10^{-5}$	$3.6x10^{-5}$	$3.9x10^{-5}$	24	25	30	28	92
SLV	$4.0x10^{-5}$	$2.0x10^{-4}$	$1.1x10^{-5}$	$2.8x10^{-5}$	$2.9x10^{-5}$	24	20	23	20	92
GNQ	$7.9x10^{-5}$	$1.2x10^{-4}$	$4.8x10^{-6}$	$2.7x10^{-5}$	$2.5x10^{-4}$	27	25	34	30	91
ERI	$1.3x10^{-4}$	$1.3x10^{-4}$	$3.5x10^{-6}$	$3.8x10^{-5}$	$1.6x10^{-4}$	25	24	34	27	91
EST	$9.4x10^{-5}$	$5.5x10^{-4}$	$6.7x10^{-5}$	$2.6x10^{-5}$	$2.2x10^{-6}$	23	15	22	21	98
ETH	$8.8x10^{-5}$	$1.3x10^{-4}$	$4.6x10^{-6}$	$2.8x10^{-5}$	$1.7x10^{-4}$	25	24	34	28	91

FJI	3.0×10^{-5}	2.8×10^{-4}	7.9×10^{-6}	2.8×10^{-5}	4.4×10^{-5}	33	27	28	31	92
FIN	9.9×10^{-5}	2.5×10^{-4}	5.2×10^{-5}	3.0×10^{-5}	8.5×10^{-7}	19	15	21	23	94
FRA	6.8×10^{-5}	1.2×10^{-4}	6.8×10^{-5}	4.1×10^{-5}	7.0×10^{-7}	17	15	24	14	98
GAB	8.6×10^{-5}	1.2×10^{-4}	7.4×10^{-6}	2.5×10^{-5}	1.1×10^{-4}	22	20	32	27	91
GMB	9.7×10^{-5}	1.8×10^{-4}	2.8×10^{-6}	3.1×10^{-5}	1.7×10^{-4}	27	24	31	28	91
GEO	3.8×10^{-4}	7.1×10^{-4}	3.3×10^{-5}	6.2×10^{-5}	1.2×10^{-5}	19	17	27	20	92
DEU	8.5×10^{-5}	2.8×10^{-4}	6.8×10^{-5}	7.0×10^{-5}	1.1×10^{-6}	18	15	23	19	94
GHA	1.5×10^{-4}	1.6×10^{-4}	3.0×10^{-6}	2.5×10^{-5}	1.2×10^{-4}	25	23	31	29	91
GRC	1.6×10^{-4}	2.4×10^{-4}	8.0×10^{-5}	7.0×10^{-5}	2.7×10^{-6}	15	16	22	18	92
GRD	1.2×10^{-4}	2.1×10^{-4}	2.3×10^{-5}	2.4×10^{-5}	3.0×10^{-5}	19	21	24	22	92
GTM	5.3×10^{-5}	1.1×10^{-4}	5.3×10^{-6}	2.6×10^{-5}	7.8×10^{-5}	21	20	25	20	91
GIN	1.4×10^{-4}	1.8×10^{-4}	2.1×10^{-6}	4.0×10^{-5}	2.8×10^{-4}	27	25	37	29	91
GNB	1.1×10^{-4}	1.5×10^{-4}	2.6×10^{-6}	3.1×10^{-5}	2.9×10^{-4}	27	24	32	30	91
GUY	1.7×10^{-4}	2.8×10^{-4}	6.3×10^{-6}	3.3×10^{-5}	4.6×10^{-5}	25	26	27	24	91
HTI	1.7×10^{-4}	2.5×10^{-4}	1.0×10^{-5}	3.5×10^{-5}	2.6×10^{-4}	26	25	27	25	91
HND	3.9×10^{-5}	1.6×10^{-4}	8.0×10^{-6}	3.2×10^{-5}	3.7×10^{-5}	25	22	26	21	92
HUN	1.3×10^{-4}	5.2×10^{-4}	1.1×10^{-4}	7.4×10^{-5}	4.2×10^{-6}	21	17	26	23	94
ISL	6.1×10^{-5}	1.9×10^{-4}	5.9×10^{-5}	5.4×10^{-5}	–	17	14	21	19	–
IND	9.8×10^{-5}	2.2×10^{-4}	1.2×10^{-5}	1.1×10^{-4}	1.1×10^{-4}	26	27	30	27	91
IDN	1.7×10^{-4}	2.1×10^{-4}	2.2×10^{-5}	4.1×10^{-5}	6.7×10^{-5}	26	26	28	32	92
IRN	6.4×10^{-5}	2.0×10^{-4}	1.0×10^{-5}	2.1×10^{-5}	3.1×10^{-5}	21	20	26	24	92
IRQ	7.6×10^{-5}	2.3×10^{-4}	1.7×10^{-5}	1.3×10^{-5}	8.3×10^{-5}	25	22	27	31	91
IRL	5.3×10^{-5}	1.5×10^{-4}	5.6×10^{-5}	5.9×10^{-5}	1.1×10^{-6}	19	17	22	18	93
ISR	5.1×10^{-5}	1.0×10^{-4}	4.3×10^{-5}	3.7×10^{-5}	9.2×10^{-7}	19	16	23	19	93
ITA	1.2×10^{-4}	2.2×10^{-4}	6.7×10^{-5}	6.1×10^{-5}	6.7×10^{-7}	14	14	20	14	94
JAM	1.4×10^{-4}	1.2×10^{-4}	2.9×10^{-5}	2.9×10^{-5}	1.1×10^{-5}	18	17	24	20	93
JPN	1.1×10^{-4}	1.4×10^{-4}	7.2×10^{-5}	5.8×10^{-5}	2.9×10^{-6}	17	15	17	17	93
JOR	7.5×10^{-5}	1.8×10^{-4}	1.4×10^{-5}	1.5×10^{-5}	2.5×10^{-5}	23	25	28	28	92
KAZ	1.8×10^{-4}	4.5×10^{-4}	3.9×10^{-5}	5.4×10^{-5}	2.4×10^{-5}	24	20	27	24	92
KEN	3.9×10^{-5}	4.1×10^{-5}	2.7×10^{-6}	1.3×10^{-5}	1.3×10^{-4}	25	24	28	31	91
KIR	1.3×10^{-4}	1.3×10^{-4}	2.1×10^{-5}	3.5×10^{-5}	1.7×10^{-4}	30	30	30	35	91
KWT	3.1×10^{-5}	1.1×10^{-4}	8.3×10^{-6}	7.8×10^{-6}	8.6×10^{-6}	29	32	26	37	92

KGZ	$1.7x10^{-4}$	$4.4x10^{-4}$	$1.7x10^{-5}$	$4.7x10^{-5}$	$7.1x10^{-5}$	24	19	29	21	92
LAO	$1.6x10^{-4}$	$2.0x10^{-4}$	$1.8x10^{-5}$	$4.3x10^{-5}$	$2.0x10^{-4}$	26	25	29	32	91
LVA	$3.1x10^{-4}$	$5.6x10^{-4}$	$5.9x10^{-5}$	$2.0x10^{-5}$	$4.8x10^{-6}$	18	16	24	24	95
LBN	$5.7x10^{-5}$	$4.0x10^{-4}$	$2.9x10^{-5}$	$3.1x10^{-5}$	$7.2x10^{-6}$	23	20	26	23	93
LSO	$1.8x10^{-4}$	$1.7x10^{-4}$	$4.1x10^{-6}$	$8.7x10^{-5}$	$2.5x10^{-4}$	22	22	31	24	91
LBR	$9.1x10^{-5}$	$1.4x10^{-4}$	$2.1x10^{-6}$	$1.9x10^{-5}$	$2.1x10^{-4}$	25	23	35	29	91
LBY	$6.5x10^{-5}$	$2.3x10^{-4}$	$2.1x10^{-5}$	$2.2x10^{-5}$	$1.9x10^{-5}$	25	24	28	28	92
LTU	$2.4x10^{-4}$	$6.7x10^{-4}$	$5.6x10^{-5}$	$2.5x10^{-5}$	$3.4x10^{-6}$	18	15	24	22	96
LUX	$5.6x10^{-5}$	$1.3x10^{-4}$	$5.6x10^{-5}$	$5.0x10^{-5}$	$2.8x10^{-7}$	19	17	23	18	96
MDG	$1.3x10^{-4}$	$9.8x10^{-5}$	$9.2x10^{-6}$	$3.8x10^{-5}$	$1.5x10^{-4}$	27	25	29	28	91
MWI	$6.1x10^{-5}$	$8.9x10^{-5}$	$1.4x10^{-6}$	$2.1x10^{-5}$	$1.3x10^{-4}$	23	22	31	27	91
MYS	$7.9x10^{-5}$	$2.0x10^{-4}$	$2.7x10^{-5}$	$2.8x10^{-5}$	$7.9x10^{-6}$	25	23	28	36	92
MDV	$3.6x10^{-5}$	$1.3x10^{-4}$	$9.2x10^{-6}$	$3.7x10^{-5}$	$9.9x10^{-6}$	24	20	29	26	92
MLI	$1.2x10^{-4}$	$1.7x10^{-4}$	$2.9x10^{-6}$	$5.3x10^{-5}$	$2.7x10^{-4}$	27	24	34	28	91
MLT	$8.4x10^{-5}$	$2.6x10^{-4}$	$5.4x10^{-5}$	$4.0x10^{-5}$	$3.1x10^{-6}$	17	16	22	18	91
MRT	$8.7x10^{-5}$	$1.7x10^{-4}$	$1.9x10^{-6}$	$2.4x10^{-5}$	$2.3x10^{-4}$	26	23	35	28	91
MUS	$1.1x10^{-4}$	$2.1x10^{-4}$	$1.8x10^{-5}$	$6.7x10^{-5}$	$1.6x10^{-5}$	24	23	26	26	92
MEX	$4.9x10^{-5}$	$1.4x10^{-4}$	$9.8x10^{-6}$	$3.9x10^{-5}$	$2.5x10^{-5}$	21	20	24	18	92
FSM	$1.5x10^{-4}$	$2.2x10^{-4}$	$2.8x10^{-5}$	$5.5x10^{-5}$	$8.5x10^{-5}$	25	24	28	30	91
MNG	$1.8x10^{-4}$	$2.4x10^{-4}$	$2.5x10^{-5}$	$1.2x10^{-5}$	$4.1x10^{-5}$	29	25	27	30	92
MNE	$3.5x10^{-4}$	$3.6x10^{-4}$	$7.3x10^{-5}$	$3.6x10^{-5}$	$2.4x10^{-6}$	17	18	30	19	102
MAR	$7.8x10^{-5}$	$2.3x10^{-4}$	$2.0x10^{-5}$	$2.3x10^{-5}$	$5.2x10^{-5}$	20	19	31	24	91
MOZ	$9.0x10^{-5}$	$8.0x10^{-5}$	$3.6x10^{-6}$	$1.8x10^{-5}$	$1.8x10^{-4}$	25	23	27	30	91
MMR	$1.7x10^{-4}$	$1.0x10^{-4}$	$2.9x10^{-5}$	$7.4x10^{-5}$	$1.6x10^{-4}$	25	24	28	28	91
NAM	$1.1x10^{-4}$	$1.4x10^{-4}$	$4.9x10^{-6}$	$4.8x10^{-5}$	$1.3x10^{-4}$	23	22	30	27	91
NPL	$1.2x10^{-4}$	$2.5x10^{-4}$	$2.0x10^{-5}$	$1.0x10^{-4}$	$9.1x10^{-5}$	24	24	30	26	91
NLD	$7.5x10^{-5}$	$1.4x10^{-4}$	$8.4x10^{-5}$	$6.9x10^{-5}$	$9.5x10^{-7}$	18	16	22	20	92
NZL	$7.1x10^{-5}$	$1.6x10^{-4}$	$5.1x10^{-5}$	$5.2x10^{-5}$	$5.9x10^{-6}$	17	16	22	19	92
NIC	$4.8x10^{-5}$	$1.4x10^{-4}$	$9.8x10^{-6}$	$2.7x10^{-5}$	$6.2x10^{-5}$	25	20	26	20	91
NER	$1.1x10^{-4}$	$1.6x10^{-4}$	$9.8x10^{-7}$	$3.2x10^{-5}$	$3.2x10^{-4}$	28	25	33	29	91
NGA	$9.9x10^{-5}$	$1.6x10^{-4}$	$1.4x10^{-6}$	$2.9x10^{-5}$	$3.7x10^{-4}$	28	25	34	30	91
NOR	$7.0x10^{-5}$	$1.5x10^{-4}$	$5.8x10^{-5}$	$6.7x10^{-5}$	$8.1x10^{-7}$	18	15	22	18	93

OMN	2.4×10^{-5}	1.1×10^{-4}	4.7×10^{-6}	4.6×10^{-6}	1.1×10^{-5}	31	27	29	48	92
PAK	1.4×10^{-4}	2.9×10^{-4}	8.0×10^{-6}	6.4×10^{-5}	2.1×10^{-4}	24	24	30	28	91
PAN	7.3×10^{-5}	1.2×10^{-4}	1.5×10^{-5}	3.8×10^{-5}	3.6×10^{-5}	19	20	23	18	92
PNG	1.2×10^{-4}	1.8×10^{-4}	8.2×10^{-6}	4.3×10^{-5}	1.5×10^{-4}	28	28	30	35	91
PRY	9.6×10^{-5}	1.7×10^{-4}	2.2×10^{-5}	2.9×10^{-5}	3.6×10^{-5}	24	22	25	21	92
PER	4.8×10^{-5}	1.2×10^{-4}	1.5×10^{-5}	2.7×10^{-5}	2.5×10^{-5}	26	21	23	21	92
PHL	1.7×10^{-4}	2.3×10^{-4}	2.1×10^{-5}	5.0×10^{-5}	8.7×10^{-5}	29	27	29	33	91
POL	1.1×10^{-4}	4.0×10^{-4}	8.3×10^{-5}	5.1×10^{-5}	3.8×10^{-6}	21	17	25	20	93
PRT	1.4×10^{-4}	1.4×10^{-4}	4.8×10^{-5}	5.4×10^{-5}	2.9×10^{-6}	16	16	24	15	92
QAT	7.8×10^{-6}	4.7×10^{-5}	5.0×10^{-6}	2.3×10^{-6}	6.4×10^{-6}	42	31	34	69	93
KOR	6.8×10^{-5}	6.4×10^{-5}	4.7×10^{-5}	2.5×10^{-5}	1.2×10^{-6}	22	19	21	26	97
MDA	2.4×10^{-4}	6.1×10^{-4}	3.9×10^{-5}	3.0×10^{-5}	4.5×10^{-5}	21	18	28	21	92
ROU	2.7×10^{-4}	5.1×10^{-4}	6.5×10^{-5}	4.6×10^{-5}	4.3×10^{-5}	18	17	27	22	92
RUS	2.8×10^{-4}	5.4×10^{-4}	5.6×10^{-5}	2.7×10^{-5}	8.3×10^{-6}	20	18	27	24	93
RWA	6.2×10^{-5}	6.6×10^{-5}	2.1×10^{-6}	2.5×10^{-5}	8.8×10^{-5}	25	23	33	28	91
LCA	1.3×10^{-4}	1.2×10^{-4}	1.5×10^{-5}	4.0×10^{-5}	1.6×10^{-5}	19	21	30	25	92
VCT	1.4×10^{-4}	2.4×10^{-4}	1.3×10^{-5}	2.5×10^{-5}	3.3×10^{-5}	21	18	29	23	92
WSM	1.1×10^{-4}	1.8×10^{-4}	1.2×10^{-5}	3.6×10^{-5}	2.7×10^{-5}	24	22	31	31	92
STP	1.2×10^{-4}	1.1×10^{-4}	2.0×10^{-5}	7.1×10^{-5}	7.9×10^{-5}	23	20	26	22	91
SAU	5.5×10^{-5}	1.4×10^{-4}	4.4×10^{-6}	8.9×10^{-6}	1.3×10^{-5}	25	26	30	33	91
SEN	9.1×10^{-5}	1.6×10^{-4}	2.4×10^{-6}	3.2×10^{-5}	1.3×10^{-4}	25	22	36	27	91
SRB	2.0×10^{-4}	3.1×10^{-4}	8.5×10^{-5}	5.8×10^{-5}	3.5×10^{-6}	20	18	27	21	94
SYC	8.1×10^{-5}	1.8×10^{-4}	2.1×10^{-5}	3.1×10^{-5}	1.4×10^{-5}	27	24	27	35	92
SLE	1.6×10^{-4}	2.2×10^{-4}	1.9×10^{-6}	4.0×10^{-5}	2.9×10^{-4}	31	28	36	31	91
SGP	5.0×10^{-5}	1.1×10^{-4}	4.3×10^{-5}	1.3×10^{-5}	4.5×10^{-6}	22	21	22	27	92
SVK	1.1×10^{-4}	3.1×10^{-4}	5.7×10^{-5}	2.6×10^{-5}	1.0×10^{-5}	22	17	25	24	92
SVN	1.2×10^{-4}	2.3×10^{-4}	6.9×10^{-5}	3.3×10^{-5}	5.2×10^{-7}	18	15	24	18	109
SLB	1.2×10^{-4}	1.5×10^{-4}	9.7×10^{-6}	4.5×10^{-5}	7.9×10^{-5}	26	25	31	31	92
SOM	1.1×10^{-4}	1.5×10^{-4}	3.0×10^{-6}	2.6×10^{-5}	5.7×10^{-4}	28	27	33	29	91
ZAF	1.0×10^{-4}	1.4×10^{-4}	2.5×10^{-5}	5.6×10^{-5}	1.2×10^{-4}	24	24	28	28	92
SSD	9.0×10^{-5}	1.1×10^{-4}	3.3×10^{-6}	2.4×10^{-5}	3.5×10^{-4}	26	25	31	30	91
ESP	7.3×10^{-5}	1.4×10^{-4}	5.6×10^{-5}	6.8×10^{-5}	1.2×10^{-6}	16	15	23	14	93

LKA	$9.3x10^{-5}$	$2.1x10^{-4}$	$9.9x10^{-6}$	$3.9x10^{-5}$	$9.0x10^{-6}$	23	23	27	32	93
SDN	$1.2x10^{-4}$	$3.3x10^{-4}$	$2.6x10^{-6}$	$3.5x10^{-5}$	$1.7x10^{-4}$	28	28	31	29	91
SUR	$1.5x10^{-4}$	$1.9x10^{-4}$	$2.2x10^{-5}$	$2.0x10^{-5}$	$2.3x10^{-5}$	24	24	26	25	92
SWZ	$1.1x10^{-4}$	$1.4x10^{-4}$	$4.5x10^{-6}$	$5.4x10^{-5}$	$1.9x10^{-4}$	24	23	31	27	91
SWE	$8.4x10^{-5}$	$2.2x10^{-4}$	$5.1x10^{-5}$	$5.6x10^{-5}$	$1.5x10^{-6}$	17	15	20	20	93
CHE	$5.5x10^{-5}$	$1.7x10^{-4}$	$5.1x10^{-5}$	$4.3x10^{-5}$	$9.3x10^{-7}$	18	14	22	20	93
SYR	$6.8x10^{-5}$	$3.7x10^{-4}$	$2.3x10^{-5}$	$1.8x10^{-5}$	$2.8x10^{-5}$	27	22	27	28	91
TJK	$1.5x10^{-4}$	$3.2x10^{-4}$	$8.5x10^{-6}$	$4.0x10^{-5}$	$1.3x10^{-4}$	22	20	32	22	92
THA	$8.9x10^{-5}$	$1.2x10^{-4}$	$3.9x10^{-5}$	$5.2x10^{-5}$	$1.6x10^{-5}$	25	22	26	28	92
MKD	$2.6x10^{-4}$	$2.4x10^{-4}$	$5.6x10^{-5}$	$4.4x10^{-5}$	$1.3x10^{-5}$	20	21	28	22	92
TLS	$1.0x10^{-4}$	$1.5x10^{-4}$	$3.4x10^{-5}$	$3.4x10^{-5}$	$1.9x10^{-4}$	26	25	30	36	91
TGO	$1.2x10^{-4}$	$1.8x10^{-4}$	$1.8x10^{-6}$	$3.6x10^{-5}$	$2.1x10^{-4}$	28	25	33	29	91
TON	$9.5x10^{-5}$	$1.8x10^{-4}$	$4.7x10^{-5}$	$5.4x10^{-5}$	$2.8x10^{-5}$	22	22	25	26	92
TTO	$1.1x10^{-4}$	$2.2x10^{-4}$	$1.7x10^{-5}$	$2.3x10^{-5}$	$2.3x10^{-5}$	21	23	26	22	92
TUN	$1.0x10^{-4}$	$2.9x10^{-4}$	$2.5x10^{-5}$	$3.1x10^{-5}$	$1.8x10^{-5}$	21	20	29	24	92
TUR	$6.7x10^{-5}$	$2.0x10^{-4}$	$4.9x10^{-5}$	$5.5x10^{-5}$	$7.7x10^{-6}$	23	21	30	22	92
TKM	$1.6x10^{-4}$	$4.3x10^{-4}$	$1.7x10^{-5}$	$1.3x10^{-5}$	$1.4x10^{-4}$	28	23	35	31	91
UGA	$7.7x10^{-5}$	$8.2x10^{-5}$	$3.4x10^{-6}$	$2.6x10^{-5}$	$1.6x10^{-4}$	27	25	34	29	91
UKR	$2.2x10^{-4}$	$8.5x10^{-4}$	$4.7x10^{-5}$	$3.2x10^{-5}$	$1.2x10^{-5}$	21	17	28	23	93
ARE	$2.2x10^{-5}$	$5.4x10^{-5}$	$3.0x10^{-6}$	$6.9x10^{-6}$	$5.7x10^{-6}$	38	34	33	58	94
GBR	$7.7x10^{-5}$	$1.5x10^{-4}$	$7.3x10^{-5}$	$7.4x10^{-5}$	$2.8x10^{-6}$	18	17	20	18	92
TZA	$6.7x10^{-5}$	$1.2x10^{-4}$	$1.1x10^{-6}$	$2.3x10^{-5}$	$1.5x10^{-4}$	26	23	30	29	91
USA	$6.3x10^{-5}$	$2.1x10^{-4}$	$6.7x10^{-5}$	$8.3x10^{-5}$	$3.0x10^{-6}$	22	18	22	23	93
URY	$1.2x10^{-4}$	$1.8x10^{-4}$	$6.1x10^{-5}$	$7.7x10^{-5}$	$6.1x10^{-6}$	19	17	25	18	92
UZB	$1.0x10^{-4}$	$4.0x10^{-4}$	$8.9x10^{-6}$	$1.1x10^{-5}$	$5.8x10^{-5}$	25	21	32	29	92
VUT	$1.1x10^{-4}$	$1.9x10^{-4}$	$1.3x10^{-5}$	$4.3x10^{-5}$	$6.6x10^{-5}$	26	24	30	31	92
VEN	$7.8x10^{-5}$	$1.9x10^{-4}$	$2.4x10^{-5}$	$3.2x10^{-5}$	$2.8x10^{-5}$	22	22	27	22	92
VNM	$1.4x10^{-4}$	$1.2x10^{-4}$	$3.7x10^{-5}$	$3.8x10^{-5}$	$4.5x10^{-5}$	23	19	27	29	92
YEM	$1.5x10^{-4}$	$3.6x10^{-4}$	$4.6x10^{-6}$	$4.1x10^{-5}$	$1.6x10^{-4}$	28	28	29	28	91
ZMB	$6.5x10^{-5}$	$9.5x10^{-5}$	$2.2x10^{-6}$	$2.2x10^{-5}$	$1.6x10^{-4}$	26	25	29	31	91
ZWE	$6.9x10^{-5}$	$1.0x10^{-4}$	$4.2x10^{-6}$	$3.1x10^{-5}$	$1.4x10^{-4}$	26	22	27	29	91

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