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Post-COVID-19: Time to Change Our Way of Life for a Better Future

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Post-COVID-19: Time to Change Our Way of Life for a Better Future

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Rationale: From the year 1 *anno Domini* until 1855 with the third Plague, major pandemics occurred on average every 348 years. Since then, they have occurred on average every 33 years, with Coronavirus disease 2019 (COVID-19) now underway. Even though current technologies have greatly improved the way of life of human beings, COVID-19, with more than 700 000 000 cases and 6 950 000 deaths worldwide by the end of 2023, reminds us that much remains to be done. **Objective:** Given the frequency and duration of recent pandemics, it might be wise to start thinking about preventative methods to minimize the impact of future pandemics. This report looks back at 18 months of COVID-19, from March 2020 to August 2021, with the aim of highlighting potential solutions that could prove practical, or even essential, for the future. **Material:**COVID-19 data, including case and death reports, were extracted daily from the *Worldometer* platform to build a database for macroscopic analysis of the spread of the virus around the world. Demographic data were integrated into the COVID-19 database for a better understanding of the spatial spread of the SARS-CoV-2 virus in cities/municipalities. **Method**: Without loss of generality, we only analyzed data from the top 30 (out of 200 and above) countries ranked by total number of COVID-19 cases. Statistics (regression, t-test ($p < 0.05$), correlation, mean ± std, etc.) were carried out with Excel software. Spectral analysis, using Matlab software, was also used to try to better understand the temporal spread of COVID-19. **Results:** A good linear correlation was observed between the number of cases and the respective number of deaths depending on the country, i.e. $y = 0.0121x + 19559$ with $R^2 = 0.8042$. The analysis then focused mainly on the number of cases.This study showed that COVID-19 mainly affects G20 countries. The most interesting result is that cities/municipalities with high population density are a powerful activator of the spread of the virus. The current demographic context seems to be becoming a societal problem that must be addressed adequately. Spectral analysis highlighted that the very first months of spread of COVID-19 were the most notable with a strong expansion of the SARS-CoV-2 virus. On the other hand, the following six months showed a certain stability due mainly to multiple preventive measures such as confinement, closure of non-essential services, wearing of masks, distancing of 2 meters, etc. **Discussion:** Analysis of case and death data showed that COVID-19 mainly affects G20 countries. Nevertheless, the most interesting result of this study is that cities and municipal areas with population densities of several thousand inhabitants per square kilometer largely favored the spread of the SARS-CoV-2 virus. It is believed that such a demographic context is becoming a societal problem that developed countries around the world will sooner or later face and therefore needs to be adequately addressed.**Conclusions :**COVID-19 has made us understand that it is time to act both preventatively and curatively. Phenomenological insights suggest that the next pandemic could occur in less than 50 years. It may be time to launch new societal projects aimed at relieving congestion in densely populated regions.

Keywords: COVID-19; pandemics; population density; prevention; public health

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1. Introduction

Since the first known cases identified in Wuhan, China, in December 2019, Coronavirus disease 2019 (COVID-19) has rapidly spread throughout the world [1]. Indeed, COVID-19 is a contagious disease caused by the virus SARS-CoV-2, which quickly led to a pandemic.

The symptoms of COVID-19 may include fever [2], cough, headache [3], fatigue, breathing difficulties, loss of smell [4], and loss of taste [5]. In 2020, the Centers for Disease Control and

Prevention (CDCP) noted that 14% of COVID-19 patients developed severe symptoms (dyspnea, hypoxia, or lung involvement) while 5 % developed critical symptoms (respiratory failure, shock or multiple organ dysfunction) [6].

Some people continue to experience a range of effects for months or years after infection with the virus, and damages to organs have been observed; this is now called "long COVID" [7]. It has also been observed that older people are at a higher risk of developing severe symptoms.

Transmission of SARS-CoV-2 through direct person-to-person contact has been recognized since the early stages of the COVID-19 pandemic [8]. Although the risk is highest when people are in close proximity, it appears that the virus can be transmitted on longer distances through the inhalation of virus-laden aerosols [9,10]. It should be noted that aerosols are small respiratory particles that can linger in the air and disperse or travel up to 2 meters in certain circumstances [11].

There is much more to say about the SARS-2 Coronavirus, including variants [12,13,14], virology [15,16], pathophysiology [17,18], diagnosis, prevention [19,25], treatment [26,29], mortality, etc. While those topics are well documented elsewhere, they are also well beyond the scope of the present investigation.

This study revisited and retrospectively analyzed 18 months of data on cases and deaths in the early stages of the COVID-19 pandemic. We believe that such a phenomenological knowledge will help minimize the impact of potential future pandemics.

2. Material and Method

From March 2020 to August 2021 inclusive, data related to COVID-19, i.e. the toll of cases and deaths, were extracted daily from the *Worldometer* platform [30] to constitute a database in Excel format. At the beginning of this study, the toll of cases and deaths was quite coherent with data from the *World Health Organization* [31]. *Worldometer* COVID-19 data have been used by many countries and official institutions, including the UK government, the Johns Hopkins CSSE and the New York Times [32].

Very briefly, *Worldometer* is a reference site that provides real-time counters and statistics on various topics. It is run by an international team of developers, researchers, and volunteers with the aim of making world statistics available in a thought-provoking and-time relevant format to a wide audience around the world. They claim to be completely independent and self-funded through automated programmatic advertising sold in real time across multiple ad exchanges [32].

While *Worldometer* data made it possible to carry out a macroscopic analysis of the spread of COVID-19 taking into account the majority of countries in the world, we also extracted some statistics from several government communication sites and from *Statista* [33] in order to perform a more specific analysis based on the spread of COVID-19 in cities and municipal areas. Furthermore, demographic data (population, area, population density) were extracted from numerous websites, including *Wikipedia* [34] and *La Banque Mondiale* [35].

Demographic data were integrated into the COVID-19 database. Without loss of generality, we only analyzed data from the top 30 (out of 200 and above) countries ranked by total number of COVID-19 cases. Statistics (regression, correlation, mean ± std, etc.) were carried out with Excel software. Spectral analysis, using Matlab software, was also used to study the temporal spread of COVID-19.

3. Results

Table 1. shows the top 30 countries ranked by total number of COVID-19 cases as of September 2021. It is observed that the first 11 are exclusively G20 members, while 80% of the first 20 and 73% of the first 30 are G20 members. At that time, those countries accounted for 81% (362 444 064 / 445 277 485) of the total COVID-19 cases, 83% (4 978 325 / 6 016 074) of the total number of deaths from COVID-19, as well as 47% (3 783 837 303 / 8 000 000 000) of the world's population. It should be noted that the G20 includes the European Union, which itself includes 27 countries [34].

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It should be noted that a good linear correlation was observed between the number of cases and the respective number of deaths depending on the country, i.e. y = 0.0121x + 19 559 with R^2 = 0.8042. From that, the following analysis then focused mainly on the number of cases.

(a) Impact of population density on the spread of COVID-19 in cities and municipal areas

Table 2. presents a summary view of the population density of the cities and municipal areas among the most affected in their respective countries by COVID-19. Although the average population density of a country is only about 61 inhabitants per km^2 [35], it has been observed that some cities and municipal areas have thousands of inhabitants per km^2. To be more precise, the countries in Table 2 represented a median value of 118 inhabitants per km2 with [min max] = [4 531] in year 2021 while cities and municipal areas showed a median value of 4 100 with [min max] = [1283 28154].

Apart from population density, the ranking of cities (or municipal areas) based on the total number of COVID-19 cases in their respective countries as of September 2021 is shown in Table 2. It has been observed that cities (or municipal areas) with high population densities constitute a powerful activator of the spread of COVID-19. This sample of cities and countries is not exclusive. This list is presented primarily for illustration purposes.

Table 2. Summary view of the population density of the cities and municipal areas among the most affected in their respective countries by COVID-19. The ranking of cities (or municipal areas) based on the total number of COVID-19 cases in their respective countries (or states) as of September 2021 is also presented.

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Population densities (PD : inhabitants per square kilometer) of cities and municipalities among the most affected by COVID-19

Cities or Municipalities			States		Countries	
Rank	**Name**	**PD**	**Name**	**PD**	**Name**	**PD**
1	Buenos Aires	15 372			Argentina	17
2	Cordoba	2 274				
1	Sao Paulo	8 149			Brazil	25
5	Rio de Janerio	4 836				
1	Montréal-Nord	7 623	Quebec	6	Canada	4
1	Peel	1 283	Ontario	14		
1	Bogota	4 100			Colombia	42
2	Prague	2737			Czechia	136
2	London	5 598			England	260
1	Cologne	2 649			Germany	235
2	Munich	4 988				
3	Hanover	2 600				
1	Tokyo	6 511			Japan	328
2	Osaka	5 740				
1	Putrajaya	1 387			Malaysia	99
1	Mexico City	6 163			Mexico	
1	Utrecht	3 705			Netherlands	461
2	Rotterdam	2 995				
1	Quezon City	17 666			Philippines	369
2	Cavite	2 835				
3	Laguna	1 725				
1	Moscow	10 900			Russia	8
2	Saint-Petersburg	3 850				
1	Gyeonggi	1 335			South Korea	531
2	Seoul	17 000				
3	Busan	4 791				
1	Kyiv city	3 531			Ukraine	71
1	Los Angeles	3 206	California	98	USA	36
2	San Diego	1 636				
1	Brooklyn	14 917	New York	166		
2	Queens	8 542				
3	Manhattan	28 154				
1	Hanoi	2 398			Vietnam	290
2	Ho Chi Minh City	4 481				
3	Hi Phong	1 358				

(a) Spectral analysis of the temporal evolution of COVID-19

Figure 1a shows the number of COVID-19 cases worldwide by week, from 2020-03-01 to 2021-08-31. For that period, a quadratic regression profile ($R^2 = 0.7592$) of the spread of the SARS-CoV-2 virus offered some hope since some *stability* in the trend could be observed towards fall 2020. Nevertheless, given the complex profile of the COVID-19 spread curve, it was deemed potentially more informative to analyze the data sampled over three consecutive 6-month periods, i.e. from 2020-03-02 to 2020-08-31, from 2020-09-01 to 2021-02-28 and from 2021-03-01 to 2021-08-31; this is shown in Figure 1a. The following sections present the results for each of these periods, separately.

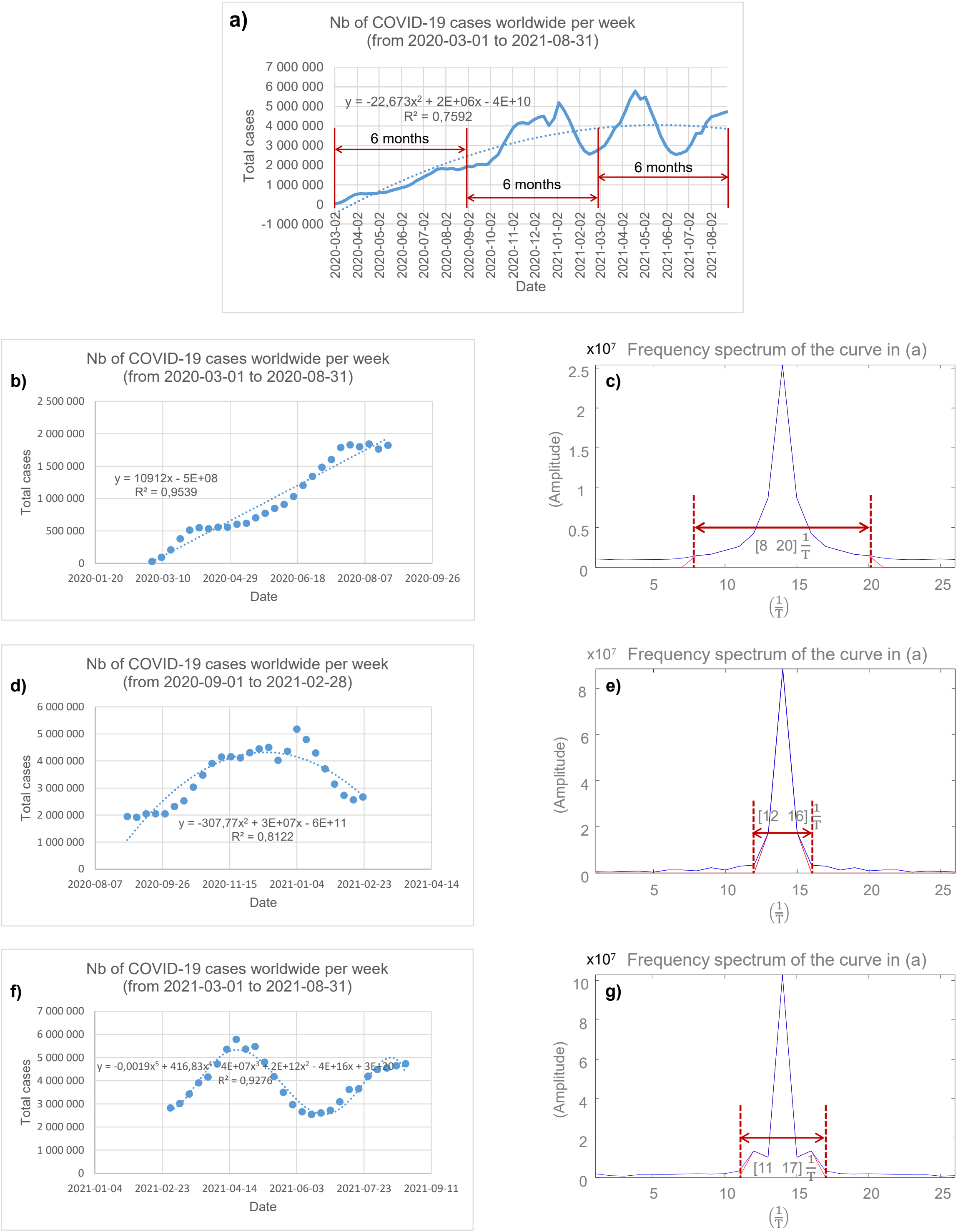

Figure 1. (a) Number of COVID-19 cases worldwide by week, from 2020-03-01 to 2021-08-31. The quadratic regression profile (R^2 = 0.7592) appears to indicate some stability in the spread trend of the SARS-CoV-2 virus towards fall 2020. The data were sampled over three consecutive 6-month periods, i.e. from 2020-03-02 to 2020-08-31, from 2020-09-01 to 2021-02-28 and from 2021-03-01 to 2021-08-31 for further investigations; b) Number of COVID-19 cases worldwide by week, from 2020-03-01 to 2020-08-31; c) COVID-19 spectrum showing width of $[8\ \ 20]_{\frac{1}{T}}$ at threshold 5% of maximum amplitude, T = 1 week period; d) Number of COVID-19 cases worldwide by week, from 2020-09-01 to 2021-02-28; e) Spectrum of COVID-19 spread profile showing wide bandwidth $[12\ \ 16]_{\frac{1}{T}}$, T = 1 week period; f) Number of COVID-19 cases worldwide by week, from 2021-03-01 to 2021-08-31; g) Spectrum of COVID-19 spread profile showing wide bandwidth $[11\ \ 17]_{\frac{1}{T}}$, T = 1 week period.

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(a) ***COVID-19 spread from 2020-03-02 to 2020-08-31***

Figure 1b shows the number of COVID-19 cases worldwide by week, from 2020-03-01 to 2020-08-31. For this 6-month observation period, the linear regression profile (R^2 = 0.9539) of the spread of COVID-19 appears to indicate that a large expansion of the SARS-CoV-2 virus was underway. Additionally, the COVID-19 spectrum, shown in Figure 1c, has a width of $[8 \;\; 20]\frac{1}{T}$ calculated with a threshold of 5% of the maximum amplitude; T being the period, i.e. T = 1 week.

(b) COVID-19 spread from 2020-09-01 to 2021-02-28

Figure 1d shows the number of COVID-19 cases worldwide by week, from 2020-09-01 to 2021-02-28. For this 6-month observation period, a quadratic regression profile (R^2 = 0.8122) of the spread of COVID-19 appears to indicate some stability in the expansion of the SARS-CoV-2 virus. The COVID-19 spectrum, shown in Figure 1e, has a width of $[12 \;\; 16]\frac{1}{T}$; i.e. a third of that in Figure 1c and is therefore in agreement with the hypothesis of stability of the spread of the SARS-CoV-2 virus during this period of time.

(c) ***COVID-19 spread from 2021-03-01 to 2021-08-31***

Figure 1f shows the number of COVID-19 cases worldwide by week, from 2021-03-01 to 2021-08-31. For this 6-month observation period, a polynomial regression profile of order 5 (R^2 = 0.9276) is observed. However, it is important to note that the COVID-19 spectrum, shown in Figure 1g, has a width of $[11 \; 17]\frac{1}{T}$ and represents a 50% increase over that in Figure 1e.

Discussion

(a) COVID-19 data reliability

The COVID-19 data reported in this study, i.e. the number of cases and deaths, were extracted daily from the *Worldometer* platform [30] and were fully consistent with those of the World Health Organization [31]. For obvious reasons, developing countries have not been able to provide their data with the same frequency as developed countries, but we believe that such a disadvantage does not skew the results of this investigation as much. In fact, COVID-19 appears to have affected much more developed countries.

Additionally, at the end of data compilation in August 2021, China was not officially among the top 50 countries (out of 200+) ranked in terms of total number of COVID-19 cases. Today, almost two and a half years later, in February 2024, China is ranked 92nd with 503 300 total cases. Given the etiology of COVID-19 [1] and the fact that China is one of the two most populous countries in the world, these statistics may be questioned.

The COVID-19 data reported in this study extend from March 2020 to August 2021 inclusive. Since then, the spread of SARS-CoV-2 has likely evolved, but the results and conclusions remain essentially the same in 2024.

(b) Spread of COVID-19 in G20 countries

As of September 2021, analysis of case and death data showed that COVID-19 mainly affects G20 countries. As shown in Table 1, the top 11 countries ranked in terms of total number of COVID-19 cases are exclusively G20 members, while 80% of the top 20 and 73% of the top 30 are G20 members; this outlook remains essentially the same today, almost two and a half years later, in February 2024.

Table 1. Ranking the top 30 countries by total COVID-19 cases as of September 2021. G20 countries, printed in blue, accounted for 81% of total COVID-19 cases and 83% of total COVID-19 deaths.

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List of top 30 countries ranked by total number of COVID-19 cases as of September 2021						
Rank	**Country**	**Total cases**	**Total deaths**	**Population**	**Superficy (km2)**	**Population density-1**
1	USA	80 912 619	983 837	334 252 383	9 834 000	34
2	India	42 962 953	515 063	1 425 775 850	3 287 263	434
3	Brazil	29 033 052	651 988	215 089 085	8 510 000	25
4	France	23 011 998	139 243	65 515 351	551 695	119
5	UK	19 119 181	162 008	68 483 074	243 610	281
6	Russia	16 861 793	355 537	146 039 239	17 100 000	9
7	Germany	15 723 907	124 670	84 232 506	357 592	236
8	Turkey	14 326 217	95 379	85 858 254	783 562	110
9	Italy	12 991 055	155 782	60 312 960	302 073	200
10	Spain	11 100 428	100 431	46 785 101	506 030	92
11	Argentina	8 934 328	126 708	45 890 064	2 780 000	17
12	Iran	7 084 306	137 747	85 792 424	1 648 000	52
13	Netherlands	6 640 403	21 608	18 001 900	41 850	430
14	Colombia	6 070 616	139 037	51 790 765	1 141 748	45
15	Poland	5 734 042	112 535	37 777 204	322 575	117
16	Indonesia	5 723 858	149 918	278 365 371	1 905 000	146
17	Mexico	5 554 392	319 604	131 200 388	1 973 000	66
18	Japan	5 274 596	24 604	125 828 159	377 973	333
19	Ukraine	4 862 459	106 485	43 293 825	603 628	72
20	Vietnam	4 292 564	40 726	98 804 778	331 690	298
21	S. Korea	4 212 652	8 796	51 343 064	100 210	512
22	South Africa	3 683 172	99 543	60 560 331	1 220 000	50
23	Israel	3 669 119	10 274	9 326 000	22 145	421
24	Philippines	3 666 672	56 879	112 022 278	300 439	373
25	Czechia	3 624 963	38 911	10 742 247	78 867	136
26	Malaysia	3 595 172	33 173	33 060 108	330 803	100
27	Belgium	3 586 292	30 259	11 674 074	30 688	380
28	Peru	3 524 504	210 995	33 740 598	1 285 215	26
29	Australia	3 344 617	5 403	25 995 140	7 688 000	3
30	Portugal	3 322 134	21 182	10 146 927	92 152	110
Total		**362 444 064**	**4 978 325**	**3 807 699 448**		

It seems relevant to note that 9 of the 10 countries (90%) with the most medals at the 2020 Summer Olympics [36] are in the list of top 30 countries ranked by total number of COVID-19 cases (Table 1); the only exception being China, discussed in the section above. Additionally, 28 of the top 30 countries (93%) in terms of total COVID-19 cases were medalists at the 2020 Summer Olympics. Since developed countries usually top the medal table at the Summer Olympics, this provides further argument that COVID-19 has primarily affected G20 countries.

(c) Impact of population density on the spread of COVID-19

Table-2 indicates that cities (or municipal areas) with high population density are a powerful activator of the spread of COVID-19. Indeed, the main cities (and municipalities) most affected by COVID-19 generally have a population density greater than several thousand inhabitants. This is probably the most important result of this investigation, as it highlights a potential solution to counter possible future pandemics to come.

Transmission of SARS-CoV-2 through direct person-to-person contact has been recognized since the early stages of the COVID-19 pandemic [8]. Additionally, it has also been observed that the virus can be transmitted through inhalation of virus-laden aerosols [9;10]. In both cases, because the risk

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of transmission is higher when people are in close proximity, it is clear that the virus is fully activated in densely populated cities.

Although it seems easier to say than to implement, it might be wise to start thinking about depopulating densely populated cities (and municipalities) in favor of less populated ones. This is becoming a societal problem that developed countries around the world will face sooner or later and therefore needs to be adequately addressed. In fact, densely populated cities may lack quality services, especially in the context of a pandemic. This was particularly true for health services at the start of the COVID-19 pandemic in many countries, leading to a heavy burden of deaths.

(d) What we learned from the spectral analysis of COVID-19

The observation of the first months of spread of COVID-19, from 03/01/2020 to 08/31/2020, seems to be the most striking with a strong expansion of the SARS-CoV-2 virus, as indicated by a broad spectrum width in Figure 1c.

The following six months, from 09/01/2020 to 02/28/2021, seem to indicate some stability in the expansion of the SARS-CoV-2 virus, as shown in Figure 1e with a reduction in the width of the spectrum by 67%. This is mainly *a posteriori* to the multiple measures that have been taken around the world to counter the spread of COVID-19, namely confinement, closure of non-essential services, wearing of masks, distancing of 2 meters, etc.

The last six months studied, from 03/01/2021 to 08/31/2021, show a locally periodic signal (Figure 1f) then inducing a 50% increase in the width of the spectrum (Figure 1g). This probably results from a mixture of opposing and alternating measures, notably confinement and deconfinement mainly. Variants of SARS-COV-2 could also potentially fit into this picture.

(e) The very next pandemic could be closer than expected

From the year 1 *anno Domini* until today (2024), our planet has survived close to twenty pandemics, starting with the Antonine Plague in 165 and ending with COVID-19 in 2019. For the purposes of this discussion, we only report pandemics that resulted in one million or more deaths per year, regardless of their duration, as Table 3 illustrates.

Table 3. Major pandemics of the Christian era that resulted in at least one million deaths per year. "Year diff" gives the difference in years between the respective beginnings of pandemic N+1 and pandemic N, N ≥ 1. The " * " in "End (yr)" column indicate that these pandemics, namely HIV/AIDS and COVID-19, are not quite over.

List of some major pandemics in the Christian era						
Pandemic name	**Begin (yr)**	**End (yr)**	**Duration**	**Death toll**	**Death toll/yr**	**Yr diff**
Plague of Justinian	541	542	1	40 000 000	40 000 000	---
Black death (Bubonic Plague)	1347	1351	4	200 000 000	50 000 000	806
Smallpox	1520	1520	1	56 000 000	56 000 000	173
The Third Plague	1855	1855	1	12 000 000	12 000 000	335
Russian Flu	1889	1890	1	1 000 000	1 000 000	34
Spanish Flu	1918	1919	1	45 000 000	45 000 000	29
Asian Flu	1957	1958	1	1 100 000	1 100 000	39
HIV/AIDS	1981	2022*	41	42 100 000	1 026 829	24
COVID-19	2019	2023*	4	6 961 398	1 740 350	38

In addition, from the year 1 *anno Domini* until 1855, the year of the third plague, major pandemics occurred on average every 348 years; since then, they have occurred on average every 33 years [37], as illustrated in Figure 2. In other words, the very next major pandemic could be closer than expected.

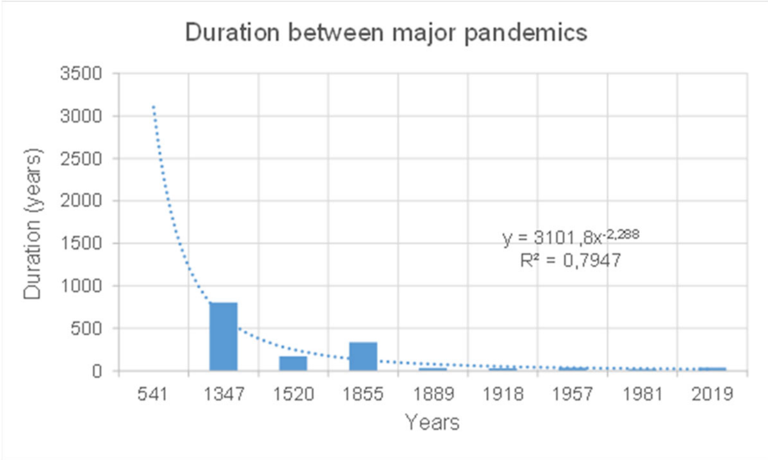

Figure 2. From the year 1 *anno Domini* until 1855 with the third Plague, major pandemics occurred on average every 348 years; since then, they have occurred on average every 33 years, with COVID-19 now underway.

5. Conclusions

Today, phenomenological knowledge, as reported in Table 3 and Figure 2, tends to indicate that the frequency of major pandemics has increased considerably and that the next one could occur in less than 50 years.

The COVID-19 pandemic has taught us that population densities in cities (and municipalities) have a significant impact on the burden of pandemics in terms of cases and then deaths.

Although new knowledge and emerging technologies can provide new vaccines in a relatively short period of time, vaccination remains primarily a curative solution in the context of a pandemic. Indeed, vaccines do not necessary prevent viral infection but mainly aim to minimize its impact on the physiological system.

It is perhaps time to launch new societal projects aimed at relieving congestion in densely populated regions. This seems an adequate solution to minimize the impact of future pandemics.

Even though new knowledge and emerging technologies have considerably improved the human way of life, new challenges arise to optimize and maintain these achievements but also to intelligently prepare for the future. COVID-19 has made us understand that it is time to act both preventatively and curatively.

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