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Research Paper

The first months of COVID-19 in Madagascar

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\textbf{A R T I C L E   I N F O}

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- Pandemic
- Covid-19
- Infectious disease
- Virus spread
- Confinement

\textbf{A B S T R A C T}

Using the officially published data and aware of the uncertain source and insufficient number of samples, we present a first and (for the moment) unique attempt to study the first two months spread of the pandemic COVID-19 in Madagascar. The approach has been tested by predicting the number of contaminated persons for the next week after fitting the inputs data collected within 7 or 15 days using standard least $\chi^2$-fit method. Encouraged by this first test, we study systematically during 67 days, 1–2 weeks new data and predict the contaminated persons for the coming week. We find that the first month data are well described by a linear or quadratic polynomial with an increase of about (4–5) infected persons per day. Pursuing the analysis, one note that data until 46 days favours a cubic polynomial behaviour which signals an eventual near future stronger growth as confirmed by the new data on the 48th day. We complete the analysis until 67 days and find that the data until 77 days confirm the cubic polynomial behaviour which is a remarkable feature of the pandemic spread in Madagascar. We expect that these results will be useful for some new model buildings. A comparison with some other SI-like models predictions is done. These results for infected persons may also be interpreted as the lowest values of the real cases due to the insufficient number of samples (about 12,907 for 27 million habitants on 05/06/20). The data analysis of the absolute number of cured persons until 67 days shows an approximate linear behaviour with about 3 cured persons per day. However, the number of percentage number of cured persons decreases above 42–46 days indicating the limits of the hospital equipment and care to face the 2nd phase of the pandemic for the 67th first days. Some comments on the social, economical and political impacts of COVID-19 and confinement for Madagascar and, in general, for Worldwide are shortly discussed.

1. Introduction

COVID-19 is scientifically named SARS (Syndrome Respiratoire Aigu Severe) or SARS (Severe Acute Respiratory Syndrome)-CoV-2 or COVID-2-19 or COVID-19 in reference to the SARS-CoV or Coronavirus pandemic (2002 – 2003) starting in China and propagated in 30 countries which has affected 8000 persons and caused 774 deceased (Van Werf et al., 2006). There is a slight difference between the two COVID in the genome structure of the virus thus the symbol 2.

Another pandemic named MERS-CoV (2012 – 2013) or SRAS of the MIDDLE EAST has been found for the first time in Saudi Arabia and has affected 1589 persons and caused 567 deceased in 26 countries.

The CORONAVIRUS are of animal origins. An asymptomatic animal transmits to another ones and then to human. It was bats for SARS-CoV and MERS-CoV which transmit the virus to masked palm civets for China and to camels for Saudi Arabia as intermediates and then to humans.

COVID-19 has been supposed to start from the Wuhan local market (Hubei province - China) in December 2019. It may also come from bats which have transmitted the virus to the pangolin sold in the Wuhan market and then the pangolin has transmitted to human. However, the origin of the transmission is not quite clear and there are some hypotheses that the virus may have been invented inside the Wuhan research laboratory and has been propagated inadvertently. The transmission mode from humans to humans is through saliva droplets, sneezes, coughing and contacts.

The virus has subsequently propagated to the rest of China and contaminated up to now (15/04/2020) 82295 persons. Today, almost all countries of the world are now affected leading to 1,997,321 infected persons with 500,819 cured and 127,601 deceased. The 5 countries with most affected persons relative to the total number of cases and to the population density are shown in Tables 1 and 2, where one can notice that the relative number per million of infected persons is very high in small area countries.

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COVID-19 then appears as the most devastating pandemic of the 21st century.¹ To face this unexpected drama where there is no known medicine² and vaccine³ to fight the virus, only urgent preventive measures have been taken by different countries.

As the virus is quite heavy, it cannot travel more than 1 m.¹ Its lifetime is relatively short on skin (few minutes) but long in air and copper (3–4 hours), clothes (12h), cartons (24 h), woods, plastics and metals (3–9 days).⁴ Different preventive barriers have to be used (masks, soaps, hydroalcoholic gels,..) to stop the virus.

However, in addition to these barrier precautions, drastic measures such as confinement have been taken by governments of different countries which ineluctably affect the social organizations and economic situations. Confinement may lead to a new form of society and economy, to a new way of leaving in the near future.

Different analysis of the propagation of COVID-19 appearing in China, Europe, UK, USA and Russia have been done in different works (see e.g. various new articles in arXiv (https://arxiv.org/search/?query=COVID-19, n.d.)) where most of them are based on Susceptible-Infected (SI) or Susceptible-Infected-Recovered (SIR) (Kermack and McKendrick, 1927) models (see e.g. various new articles in arXiv (https://arxiv.org/search/?query=COVID-19, n.d.)) while adding the data until 30 days (blue rectangles in Fig. 2), we obtained:

\[ \dot{x} = \frac{-\beta x y}{N} \]

\[ \dot{y} = \beta x y - \gamma y \]

\[ \dot{z} = \gamma y - \delta z \]

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Table 1
The top ten countries having the highest numbers of contaminated persons and above 100,000 persons on 08/05/2020. The data come from (Google, n.d.).

| Rank | Country   | Absolute # | # per million |
|------|-----------|------------|---------------|
| 1    | USA       | 1,289,235  | 3912          |
| 2    | Spain     | 221,447    | 4702          |
| 3    | Italy     | 215,858    | 3583          |
| 4    | United Kingdom | 206,715  | 3112          |
| 5    | Russia    | 177,160    | 1207          |
| 6    | Germany   | 169,430    | 2038          |
| 7    | France    | 137,779    | 2054          |
| 8    | Brazil    | 135,773    | 642           |
| 9    | Turkish   | 133,721    | 1608          |
| 10   | Iran      | 103,135    | 1298          |

Table 2
The top ten countries having the relative highest numbers of contaminated persons per million of population on 08/05/2020. The data come from (Google, n.d.).

| Rank | Country   | # per million | Absolute # |
|------|-----------|---------------|------------|
| 1    | USA       | 1,289,235     | 3912       |
| 2    | Spain     | 221,447       | 4702       |
| 3    | Italy     | 215,858       | 3583       |
| 4    | United Kingdom | 206,715  | 3112       |
| 5    | Russia    | 177,160       | 1207       |
| 6    | Germany   | 169,430       | 2038       |
| 7    | France    | 137,779       | 2054       |
| 8    | Brazil    | 135,773       | 642        |
| 9    | Turkish   | 133,721       | 1608       |
| 10   | Iran      | 103,135       | 1298       |

¹ For a more complete but simple review on the coronavirus, see e.g. (Santé Magazine, n.d.).
² Drugs based on chloroquine proposed by Pr. Didier Raoult - Marseille (ex-pert in tropical diseases), which were successful against paludism are promising though under debates. Some other pists are the uses of some endemic medicinal plants such as in Madagascar where some of them contains natural chloroquine.
³ There is some proposal from the Bill Gates foundation but doing the first tests in Africa are criticized.
⁴ However, new study (French TV source) recommends a distance above 2 m.
⁵ The true lifetime of the virus on inert objects is still under study and needs to be confirmed.

2. The spread of infected persons

2.1. First analysis: data up to 15 days

COVID-19 enters in Madagascar on 21th March through the Antananarivo-Ivato airport via passengers from Europe and from China. The official measure for closing the airport was too late despite the requests of many individuals or through the social networks.

We collect, in Table 3, data from different national newspapers (Midi-Madagasikara Newspaper Daily Press, n.d.) and TV (Television Malagasy (TVM) Daily News, n.d.) issued from the national representative (Centre de Commandement Operationnel (CCO) Ivato-Antananarivo, n.d.) of the World Health Organization (WHO/Organization Mondiale de la Santé (OMS)).

We use the data of the first 15 days to predict the ones from 15 to 20 days. Noting that some data do not agree each others and that the detection tests are only done for few samples of the population, we have introduced some estimated errors in order to quantify this deficit.

The analysis is shown in Fig. 1 where the input data are the green circles. Our prediction (filled region) comes from a standard least-χ² fit of the data using a Mathematica Program elaborated by (Wolfram Research Foundation, n.d.). The central value of the data is fitted by the lowest curve while the central value @ the estimated errors by the upper curve. The fit is extrapolated until 20 days.

The new data points in red are inside our prediction region which we consider as an encouraging positive test of the approach based on a standard least-χ² fit of the data.

We also show (dotted curve) the expectation from a simple linear parametrization of the data as given by:

\[ n(x) = -3.67 + 5.03x \]

where \( n(x) \) is the number of daily new infected persons as a function of the number \( x \) of days. The data show a linear increase for about 5 persons per day.

2.2. Second analysis: data up to 30 days

Encouraged by this positive test, we improve the analysis by adding the new data (see Fig. 2) collected from the 16th to 30th days.

The χ²-fit is shown by the continuous green line (green circle data from (Midi-Madagasikara Newspaper Daily Press, n.d.; Google, n.d.) and dot-dashed red curve (red triangle data from (WHO/OMS Compilation, n.d.).

Doing a linear fit of the data collected during 24 days, we obtain:

\[ n(x) = -1.42 + 4.73x \]

while adding the data until 30 days (blue rectangles in Fig. 2), we obtain:

\[ n(x) = 3.5 + 4.22x \]

The slopes of the linear curves obtained in Eqs. (2) and (3) ((blue dotted line) are consistent with the one in Eq. (1) shown in Fig. 2. This linear fit can be improved by using a quadratic fit of the data. In this way, one obtains:

\[ n(x) = -8.14 + 6.45x - 0.07x^2 \]
Table 3
Numbers of Contaminated Persons in Madagascar at different dates. The data from 21/03/ to 15/04/ have been communicated by the national press (Midi-Madagasikara Newspaper Daily Press, n.d.) and TV (Television Malagasy (TVM) Daily News, n.d.) issued from the WHO / OMS agency in Madagascar (Centre de Commandement Operationnel (CCO) Ivato-Antananarivo, n.d.) and from Google (Google, n.d.). Data compiled by WHO / OMS are from (WHO/OMS Compilation, n.d.). The added quoted errors are an estimate of about (10 – 20)% systematics which can be an underestimate. The 2 last columns are the number and percent of cured persons.

| Date   | # of Days | # of Infected | # of Cured | % of Cured |
|--------|-----------|---------------|------------|------------|
| 21/03  | 1         | 3(1)          | 0          | 0          |
| 22/03  | 3         | 12(3)         | 0          | 0          |
| 24/03  | 4         | 17(4)         | 0          | 0          |
| 25/03  | 5         | 19(5)         | 0          | 0          |
| 27/03  | 7         | 24(5)         | 0          | 0          |
| 29/03  | 9         | 49(5)         | 0          | 0          |
| 01/04  | 12        | 58(6)         | 0          | 0          |
| 02/04  | 13        | 62(6)         | 0          | 0          |
| 04/04  | 15        | 70(7)         | 0          | 0          |
| 05/04  | 16        | 72            | 2          | 2.8        |
| 06/04  | 17        | 80            | 77         | 2.6        |
| 07/04  | 18        | 88            | 77         | 9.0        |
| 08/04  | 19        | 93            | 92         | 11.8       |
| 09/04  | 20        | 93            | 93         | 11.8       |
| 11/04  | 22        | 102           | 95         | 12.1       |
| 12/04  | 23        | 104           | 104        | 19.2       |
| 13/04  | 24        | 106           | 106        | 19.8       |
| 14/04  | 25        | 108           | –          | 23.1       |
| 15/04  | 26        | 110           | –          | 29.4       |
| 16/04  | 27        | 111           | 110        | 30.0       |
| 17/04  | 28        | –             | 117        | 28.2       |
| 18/04  | 29        | –             | 117        | 30.0       |
| 19/04  | 30        | –             | 117        | 30.0       |
| 20/04  | 31        | 121           | 121        | 33.9       |
| 21/04  | 32        | 121           | 121        | 36.4       |
| 22/04  | 33        | 121           | 121        | 43.0       |
| 23/04  | 34        | 121           | 121        | 47.9       |
| 24/04  | 35        | 122           | 122        | 50.0       |
| 25/04  | 36        | 123           | 123        | 50.4       |
| 26/04  | 37        | 124           | 124        | 57.3       |
| 27/04  | 38        | 128           | –          | 58.6       |
| 28/04  | 39        | 128           | –          | 64.0       |
| 29/04  | 40        | 128           | –          | 70.0       |
| 30/04  | 41        | 128           | –          | 71.9       |
| 01/05  | 42        | 132           | 94         | 71.2       |
| 02/05  | 43        | 135           | –          | 71.9       |
| 03/05  | 44        | 149           | –          | 65.8       |
| 04/05  | 45        | 149           | –          | 66.4       |
| 05/05  | 46        | 151           | –          | 66.9       |
| 07/05  | 48        | 169           | –          | 59.8       |
| 09/05  | 50        | 169           | –          | 60.0       |
| 10/05  | 51        | 171           | –          | 61.0       |
| 11/05  | 52        | 186           | –          | 57.0       |
| 12/05  | 53        | 192           | –          | 56.0       |
| 13/05  | 54        | 212           | –          | 51.0       |
| 14/05  | 55        | 230           | –          | 47.0       |
| 15/05  | 56        | 238           | –          | 47.0       |
| 16/05  | 57        | 283           | –          | 40.0       |
| 17/05  | 58        | 304           | –          | 38.0       |
| 18/05  | 59        | 322           | –          | 37.0       |
| 19/05  | 60        | 326           | –          | 37.0       |
| 20/05  | 61        | 371           | –          | 35.0       |
| 21/05  | 62        | 405           | –          | 32.0       |
| 22/05  | 63        | 448           | –          | 30.0       |
| 23/05  | 64        | 488           | –          | 25.0       |
| 24/05  | 65        | 527           | –          | 27.0       |
| 25/05  | 66        | 542           | –          | 27.0       |
| 26/05  | 67        | 586           | –          | 25.0       |
| 27/05  | 68        | 612           | –          | 24.7       |
| 28/05  | 69        | 656           | –          | 23.4       |

(continued on next page)
Table 3 (continued)

| Date   | # of Days | # of Infected | # of Cured | % of Cured |
|--------|-----------|---------------|------------|------------|
| 29/05  | 70        | 698           | –          | 164        | 23.5       |
| 30/05  | 71        | 758           | –          | 165        | 21.8       |
| 31/05  | 72        | 790           | –          | 168        | 21.3       |
| 01/06  | 73        | 826           | –          | 174        | 21.07      |
| 02/06  | 74        | 845           | –          | 185        | 21.89      |
| 03/06  | 75        | 908           | –          | 195        | 21.47      |
| 04/06  | 76        | 957           | –          | 200        | 20.89      |
| 05/06  | 77        | 975           | –          | 201        | 20.62      |

Fig. 1. Number of new contaminated persons per day versus the number of days: green circles are the input data, filled region are the predictions limited by the lower curve (central value of the data) and by the upper curve (data with added positive estimated errors). Dashed red line is the linear fit. Triangles are data received after the fitting procedure. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 2. Number of new daily infected persons versus the number of days: green circles are the input data from (Midi-Madagasikara Newspaper Daily Press, n.d.; Google, n.d.). The red triangles are data from (WHO/OMS Compilation, n.d.) from the 17th day. Blue rectangles are new data (Midi-Madagasikara Newspaper Daily Press, n.d.; Google, n.d.; WHO/OMS Compilation, n.d.) from 25th to 30th days. The continuous olive curve is the fit from 1 to 25th days of (Midi-Madagasikara Newspaper Daily Press, n.d.; Google, n.d.) data while the red dot-dashed one is the fit of (WHO/OMS Compilation, n.d.) data which follows the red triangles data points. The dashed blue line is the linear fit given in Eq. (2). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 3. Data are the same as in Fig. 2. New data (red triangle) is not included in the fit. The continuous olive curve is the fit from 1 to 25th days of (Midi-Madagasikara Newspaper Daily Press, n.d.; Google, n.d.) data and 25th to 30th days of data from (Midi-Madagasikara Newspaper Daily Press, n.d.; Google, n.d.; WHO/OMS Compilation, n.d.). The dashed blue line is the linear fit in Eq. (3) while the dot-dashed green curve is the quadratic fit given in Eq. (4). The dot-dashed red curve is the fit from the SIR-like model used in (Zi and Zi, n.d.; Maltezos, n.d.) while the large dashed green curve is the one from a gaussian-like fit used in (Barmparis and Tsironis, 2020). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The fits indicate an average of about (4–5) persons infected per day.

2.3. Comments on these results

The previous analyses have been done using data from (Midi-Madagasikara Newspaper Daily Press, n.d.; Google, n.d.; WHO/OMS Compilation, n.d.). We are aware that these data may be inaccurate as there are some periods (week-end) where the data remain stable which may due to the break of the infection tests service. These data may also underestimate the real number of new daily infected persons due to the insufficient number of detection tests for the whole country which contains about 90% of rural population (see e.g. (Narison, 2018)). The recent news (Midi-Madagasikara Newspaper Daily Press, n.d.) indicates that about 2200 tests have been performed. The detection tests should be extended for improving the quality and reability of the analysis.

However, despite these warnings, the reported data can be considered as lower bounds of the real case and the results from the previous study may already be useful. The results of the analysis can be an important guide to the government for taking the right decision at the right time in order to control this tremendous pandemic.

Our analysis concerns only the officially declared contaminated cases and does not subtract the numbers of cured and deceased persons.

However with the last collected number (19/04/2020) for about 2200 tested persons (Midi-Madagasikara Newspaper Daily Press, n.d.) which are relatively small compared to the 27 million of population, one has (Google, n.d.; WHO/OMS Compilation, n.d.) 120 declared cases, 35 cured persons and 0 deceased. One can also notice that the number of cured persons increases linearly for about 2 persons per day.

2.4. Comparison with some other approaches

Our results from the $\chi^2$-fit (continuous olive line), from a linear (dashed blue line) and a quadratic (dotdashed green curve) parametrization of the data are shown in Fig. 3.

We shall compare our previous results with some from different approaches in Refs. (Zi, n.d.; Maltezos, n.d.; Mo et al., n.d.; Sardar et al., n.d.; Carcione et al., n.d.; Dehning et al., n.d.; Anastassopoulou et al., n.d.; Siettos and Russo, n.d.; Barmparis and Maltezos, n.d.) while the large dashed green curve is the one from a gaussian-like fit used in (Barmparis and Tsironis, 2020). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
Tsironis, 2020), though we are aware that these models are more accurate for a large number of events.

Among these different models and for an illustration, we choose the one in (Ziff and Ziff, n.d.; Maltezos, n.d.) using a variant of the (SIR) model (Kermack and McKendrick, 1927) with mixed power and exponential behaviours (Vasquez, 2006):

\[ n_i(x) = ax^b e^{-c x} \]  

(5)

The data are fitted by the parameters: \(a = 2.2, b = 1.5\) and \(x_0 \approx 28\) days which we show in Fig. 3 (small dashed red curve). One can notice a good agreement between the quadratic polynomial and the one from the SIR-like model of (Ziff and Ziff, n.d.; Maltezos, n.d.).

We also fit the data using a Gaussian-like function as in (Barmparis and Tsironis, 2020):

\[ n_i(x) = ax - \frac{b(x-x_0)^2}{2\sigma^2} \]  

(6)

The result is shown in Fig. 2 (large dashed green curve) for a gaussian centered at \(x_0 \approx 28\) days and \(a = 115.9, \sigma = 12.8\).

One can notice that all different models indicate a slow increase of the number of new daily infected persons which can be checked by more forthcoming data. Our Model with polynomial behaviour leads to a good fit of the data. However, the decrease shown by the Gaussian model may be unrealistic.

2.5. Extension of the analysis until 46 days

After the first version of the paper, new data based on 3700 detection tests appear (see Table 3), where one can observe an almost stable number of new daily infected persons from 30 to 42 days which requires a reparametrization of the different models. Therefore, we extend the analysis until 46 days. The results of the analysis are summarized in Fig. 4.

One can see from there that the mixed power- exponential model used in (Ziff and Ziff, n.d.; Maltezos, n.d.) (dot red curve with \(a = 3.74, b = 1.22, x_0 = 44.08\)) and the quadratic polynomial fit (dashed blue curve with \(n_i(x) = -4.81 + 6.00x - 0.06x^2\)) give almost the same predictions, while the gaussian-like model used in (Barmparis and Tsironis, 2020) (large dashed purple curve with \(a = 136.58, x_0 = 40.73, \sigma = 21.19\)) fails to describe the most recent three data. The linear fit provides a good smearing of the evolution number:

\[ n_i(x) \approx 20.82 + 2.98x \]  

(7)

indicating an average of about 3 infected persons per day. The best fit is obtained from the cubic polynomial:

\[ n_i(x) \approx -13.7 + 8.2x - 2x^2 + 1.6 \times 10^{-3}x^3 \]  

(8)

This cubic polynomial model signals a future sharper growth while the other models predict some future stabilities or even a decrease of the number. However, the features from these other models look unrealistic as the virus incubation period of about one month is just finished while the winter season is approaching which could be a favoured period for the virus.

2.6. Data of the 48th day as a signal of a new phase

We show in Fig. 4 the new data of the 48th day (red full circle) based on 3968 detection tests. It indicates a sudden jump compared to the previous data such that the different models successful to describe the data for the first 46 days fail here.

However, the new data agree with the least \(\chi^2\)-fit method used to fit the former data. This feature may signal a new phase for the spread of the infection. It coincides with the early partial deconfinement, the end of incubation period from contacts and the beginning of the winter time where the UV destruction on the virus may be less efficient.

2.7. Prediction from 48th to 58 days

Including the new data of the 48th day, we give a prediction for the next 10 days in Fig. 5. From this analysis, we expect that the most conservative predictions for the next 10 days are inside the region (purple colour) limited by the cubic polynomial (red) and least-\(\chi^2\)-fit (oliva) continuous curves.

We show the collected new data for the next ten days in Fig. 6 (green full circle) which are inside the predicted region.

2.8. Fit of the 58 days data and predictions until the 67th day

We show in Fig. 6 the analysis of the data until 58 days and the prediction until the 67th day. Again, the region delimited by the cubic polynomial and the least-\(\chi^2\)-fits gives a nice prediction of the next 10 days data.

One can notice the jump of the number of contaminated persons which indicates the 2nd phase of the pandemic from the 48th day.

2.9. Predictions beyond the 67th day

We show in Fig. 7 the new fit of the data before 67 days and the prediction (purple region) for the next 10 days where the cubic polynomial is parametrized as:

\[ n_i(x) \approx -13.7 + 8.2x - 2x^2 + 1.6 \times 10^{-3}x^3 \]  

(8)

This cubic polynomial model signals a future sharper growth while the other models predict some future stabilities or even a decrease of the number. However, the features from these other models look unrealistic as the virus incubation period of about one month is just finished while the winter season is approaching which could be a favoured period for the virus.
The new data (open green circles) favour the cubic polynomial behaviour. The analysis of these new data and those collected after the completion of this work is under consideration.

3. Evolution number of cured persons

3.1. Analysis until 46 days

We complete the paper by analyzing the evolution of the cured persons until 46 days. Fig. 8 shows the total number of cured persons per number of days. One can notice that the three parametrizations (linear and quadratic polynomials and the SIR-like mixed power-exponential model) provide a good description of the data with the forms:

\[ n_i(x) \approx -55.27 + 18.25x - 0.67x^2 + 0.008x^3 \]  \[ (9) \]

The new data (open green circles) favour the cubic polynomial behaviour. The analysis of these new data and those collected after the completion of this work is under consideration.

3.2. Analysis of the 48th day

The 48th day corresponds to a jump for the number of new daily infected persons which we consider as the beginning of the new phase of the infected persons.

One can see from Fig. 8 that the new data on the 48th day on the total number of cured persons can be better predicted within the error by the different models used to analyze the data below 46 days except the quadratic polynomial. However, for the percentage number of cured persons, only the least \( \chi^2 \)-fit can give a good prediction of the 48th day data as can be seen in Fig. 9.

These features indicate that with the new phase, the
The majority of the population tries is far to be achieved due to poverty and to the lack of education of the society. However, the implementation of confinement in developing countries is far to be achieved due to poverty and to the lack of education of the majority of the population. Due to poverty and to the bad organization of the society, most of the people have to work for finding what to eat day by day due to the informal forms of the trade, business and economy.

In addition, the accompanying help measures taken by the government are insufficient while the managements of some international funds and donations are not transparent. Middle class persons also suffer as they are not rich enough to be autonomous and not too poor to receive any help from the state. Due to the lack of education, most of the people are irresponsible and are not aware about the dangerous effect of the virus. Then, they do not see the importance of confinement and do not feel obliged to respect the barriers measures and the confinement.

5. Worldwide impacts of COVID-19 and confinement

More generally and as a consequence, these unprecedented pandemic and confinement security measures have large impacts for human beings:

5.1. Social organization

- Most of us learn about teleworks, indoor at outdoor houseworks.
- We re-discover the importance of a family and of the tradition
- We re-discover ourselves from our concentration and meditation.
- We see the usefulness of solidarity.
- We see the values of health personals, researchers, teachers, educators, firefighters, ...and in general the human values.
- Urban exodus in developing countries such as Madagascar are observed.
- However, the pandemic might enhance the social class inequalities like the increase of the difference between poor and rich peoples, the re-disappearance of middle class, mentioned earlier for Madagascar, which is the lungs of developments.

5.2. Environments

- Nature takes back its rights: returns of animals near cities and cetaceans near the coasts, returns of insects, birds, ...).
- Air pollution is decreasing due to a minimal road traffic. Megacities (Beijing, New-Delhi, New-York, Parish, ...) recover an improved atmospheric air.
- Cities become less noisy.
- ... 

5.3. Economy

- Globalization is suffering.
- Reduced size and local markets are developing.
- Small producers are reorganizing.
- On-line sales and drive markets are developing.
- Delocalisations of manufacturers and factories are questioned.
- Each country is looking for an independent and self-sufficient economy which may lead to a protectionism.

5.4. Politics

- COVID-19 has pressed the leaders of each country to revisit the orientation of their politics to the most useful ones for the population namely:
  - Health,
  - Research and Education,
  - Foods and different ways of Consuming,
  - Protections of the Environments.
- COVID-19 has stimulated the search of an autonomous country which, if not done carefully, may lead to an ultra-nationalism and to a withdrawal into oneself (closing of boarders, ...)

parametrization of the models should be updated. The sudden growth of the number of new daily infected persons also indicates the relative decrease of the care performance.

3.3. Analysis until the 67th day

We show in Fig. 10 the evolution of the absolute number of cured persons which is approximately linear with a slope of about 3 persons cured per day. The percentage of the cured over the contaminated numbers is shown in Fig. 11 which is approximately quadratic and has a peak around 42–46 days. The decrease of the curve above 46 days indicates the inability of the hospital equipment and drugs to face the second phase of the pandemic. It also indicates that the new CVO artemisia based tisane publicly announced by the Madagascar President on 29th april is not at all efficient until the 67th day of pandemic.

4. COVID-19 and confinement for Madagascar

4.1. Political decisions

As already mentioned in the introduction, in order to limit the spread of this dangerous virus which propagates via social contacts (coughing, saliva droplets,..) and waiting for a new efficient medical drugs, different countries have decided to confine the population and have asked the persons to strictly respect some barriers rules. About 3 billions of persons i.e. half of the humanity are now / have been confined.

4.2. Implementation

However, the implementation of confinement in developing countries is far to be achieved due to poverty and to the lack of education of the majority of the population.

Due to poverty and to the bad organization of the society, most of the people

![Graph of absolute number of cured persons for 67 days. The dashed curve is a quadratic fit.](Image 49x610 to 277x737)

Fig. 10. Absolute number of cured persons for 67 days. The dashed curve is a linear fit.

![Graph of cured percentage over days.](Image 49x75 to 277x198)

Fig. 11. The same as in Fig. 10 but for the per cent number of cured persons. The dashed curve is a quadratic fit.
6. Summary and conclusions

We have studied the first month spread of COVID-19 in Madagascar using standard least $\chi^2$ fit approach. We found that, for this first month, the spread of the virus per day increases almost linearly/quadratically for about (4–5) persons per day. A comparison of our results with the ones from some other SIR-like models is shown in Fig. 3.

The inclusion of the recent data from 28 to 46 days indicates new features which are essentially due to the plateau from 30 to 40 days (see Fig. 4) and requires a new parametrization of the data. Indeed, these additional data favour a cubic polynomial fit instead of the quadratic one and of the models used in (Ziff and Ziff, n.d.; Maltezos, n.d.; Barmparis and Tsironis, 2020).

These early data do not indicate any sign of an exponential growth of the number of new daily infected persons though the cubic polynomial signals a stronger increase in the near future.

Indeed, more recent data collected on the 48th days show a sudden jump which are not explained by the previous models except the least $\chi^2$ fit as shown in Fig. 4. This sudden jump signals a new phase on the spread of the virus which may coincide with the end of the incubation period (contact case), the arrival of the winter period which the virus may like and with the beginning of the partial deconfinement.

We show in Fig. 5 the new fit including this new data on the 48th day. The prediction for the next days are given by the purple region limited by the $\chi^2$-fit (oliva curve) and the cubic polynomial (red curve). Forthcoming new data from the 48th to the 58th days are shown inside this region.

A similar analysis is done in Fig. 6 using the data until the 58th day and the predicted purple region where the new data from the 59th to the 67th days are shown (full red circle).

We note that, for the first month, the number of new daily infected persons are relatively low, which can be due to the reduced number of detection tests. Another factor could be that the intense UV in the country (autumn season) during this first month may have partially neutralized the virus effects.

One should note that we have done a simple least square fit and polynomial parametrization to understand the spread of the pandemic during these first months which we have compared with two SIR-models used in (Ziff and Ziff, n.d.; Maltezos, n.d.). We expect that our results will be useful for new model buildings.

We have not discussed the basic reproductive number $R_0$-coefficient due to the insufficient pandemic tests in Madagascar for controlling more accurately this effect. An attempt to estimate $R_0$ for the week of 26 June to 2 July indicates that $R_0$ ranges from 1.2 to 1.7 in Antananarivo (Ratsimbarison, 2020) but the result can vary strongly from one region to another.

We have also analyzed the number of cured persons where we note that its behaviour is almost linear with a slope of about 3 persons per day. The linear/quadratic polynomial fit and the SIR-like model with mixed power-exponential behaviours fit quite well the data before the 40th days but, with the inclusion of the new data from 38 to 46 days, the whole data are better fitted by a cubic polynomial like in the case of infected persons.

One has also found that the percentage number of cured persons corresponding to the new data beyond 48 days are not reproduced by the different models discussed above but only by the least $\chi^2$-approach which signals a relative decrease of the percentage care as a consequence of the sudden increase number of new daily infected persons.

It is remarkable to note that the total number of about (2.9–3.5) officially cured persons per day relative to the number (4–5) of infected persons for the first month is a good performance despite the poor equipment of the hospitals. Then, one wonders if these care techniques are based on modern chemical drugs or complemented by some endemic medicinal plants? More explanation, on the technical cares used to get these successful results, is greatly appreciated.

However, the duration of the previous success is short as the percentage of cured relative to the contaminated persons has decreased drastically after the 42–46 days signaling the inefficiency of/and the limit of the hospital care after the 48th day jump of the number of contaminated persons.

During the period of our study until the 67th day of pandemic, there is also no indication of the efficiency of the new artemisia CVO based tisane mixed with some endemic plants (ravintsara, …) distributed from 29th April which is claimed by the President of Madagascar to prevent and cure the COVID-19 pandemic.

We have also noticed the relatively low number of tested persons which is around 9681 persons on 27th May 2020 compared to the total number 27 millions of population where 1.6 millions live in the capital Antananarivo. A large effort for increasing this number of detection tests, its origin and the kind of samples is required to have a more realistic basis for a more robust scientific analysis.

More transparency on the uses of the international donations for the hospital equipments, materials for detection tests, barrier material (masks, hydroalcoholic gel, …), the help to the poor peoples is continuously requested.

We have shortly reviewed the general Worldwide impacts of COVID-19 which has demonstrated the weakness of the current global system. This feature might announce a change towards a new model of society and economy and for a new form of political decisions in the near future.

Note added

During the submission of the paper, the spread of the pandemic in Madagascar has drastically changed. At present, the number of daily contaminated persons is about 100 times the one studied in this paper and it seems to behave exponentially where a peak has been eventually reached. We plan to study more carefully this new feature in a future work.

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