

Impact of Waste Recovery on the COVID-19 Propagation

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Abstract: There are several techniques proposed to fight against the COVID-19 pandemic, such as contact limitation, hygiene, high-frequency tests, use of mask, home delivery, and quarantine.

Morocco is one of the rare countries which decided an early lockdown against the new Coronavirus. During this period, we offer techniques that allow efficient processing of household waste to avoid or minimize to take out the trash.

We are presenting different techniques that make it possible to treat waste. Then, we have modeled the spread of this pandemic in Morocco using the SIR model. Finally, we have shown the effects of waste management on the proliferation of Coronavirus.

The results show that it is better to sort the waste, install a composter or a domestic digester in buildings and hospitals (more precisely in the room of the contaminated person) to produce the compost or methane (renewable energy), which may finally contribute in limiting the spread of the COVID-19 pandemic.

Keywords: Covid-19; Containment; SIR model; Number of contacts; Recovery of household waste.

1. Introduction

In late December 2019, an outbreak of an emerging disease (COVID-19) due to a new coronavirus named SARS-CoV-2 started in Wuhan, China, and quickly spread to a significant number of

countries ^{1,2}. The epidemic was declared a pandemic by the WHO on March 11, 2020 ³.

In Morocco, the first case, reported on March 2, 2020, was a 39-year-old individual who had just arrived from the Italian city of Bergamo ⁴.

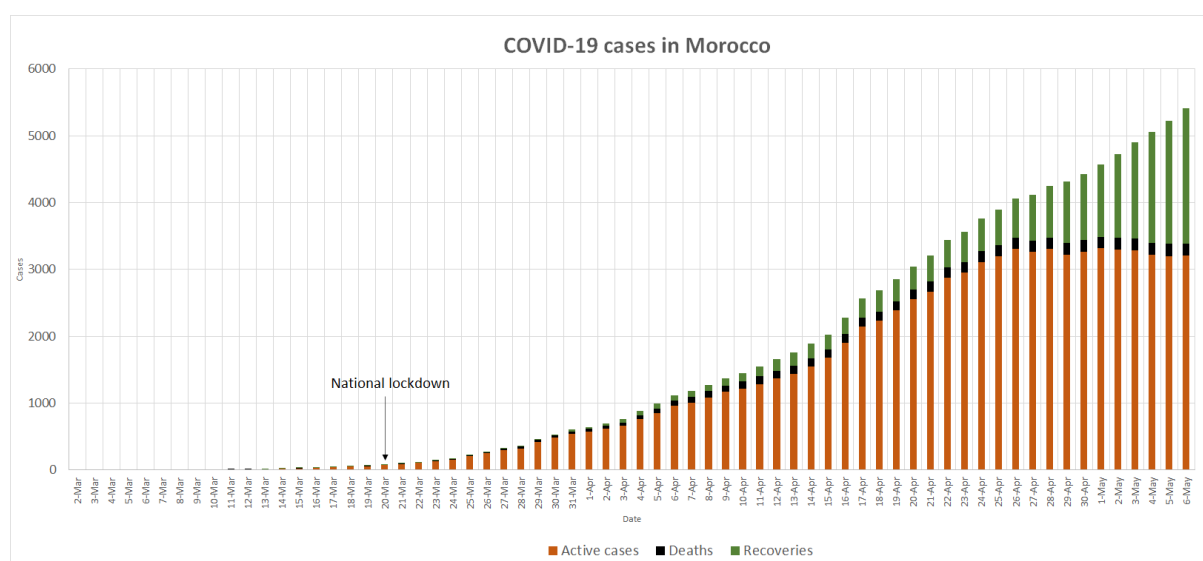


Figure 1. Evolution of Covid-19 contaminations in Morocco ⁴

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To keep the pandemic under control, the kingdom declared a state of health emergency and containment on March 20, 2020, when only 74 confirmed cases were detected ⁵.

The decision of containment was courageous and significant to avoid the scenarios of other countries like Italy, Spain, and the United States.

During quarantine, the question about managing and treating waste of different types (medical, household, and wastewater) was raised. Indeed, a lot of recent studies tackled this issue in the time of COVID-19.

According to J.J. Klemeš (2020), COVID-19 is leading to the mismanagement of plastic waste around the world, which affects the life cycles of various plastic products, especially those needed for personal protection and health care ⁶.

To manage medical waste during quarantine, H. Yu (2020) proposed a new multi-period and multi-target program to develop reverse logistics networks. The program aims to determine the best logistics strategy for efficient medical waste management in a limited time ⁷.

The study of J.Wang (2020) provided technologies of different types of hospital waste and wastewater disinfection in China, which is relevant for the development of national disinfection strategy for hospital waste and wastewater during the COVID-19 pandemic ⁸.

Recent studies have focused on medical waste management and wastewater disinfection, where the presence of the virus is confirmed, and precautions should be taken. Our research considers household waste management, where the presence of the virus is unpredictable. Therefore, it raises the risk of contamination, not only to neighbors but also to waste pickers and landfill workers.

To reduce contact between individuals, we offer several techniques to avoid or minimize to take out the trash: sorting and recycling waste within each home, producing compost, and recovering energy from waste.

Firstly, by sorting at source, organic matter is separated from non-organic matter. Among the advantages of sorting at source, we have the easy recovery of recyclable materials, in particular paper ⁹.

Secondly, the organic matter can be transformed into compost (natural fertilizer) ¹⁰.

Thirdly, organic matter such as fruit and vegetable waste and other food scraps can be recovered using the anaerobic digestion technique ¹¹.

This work is divided into two parts:

- In the first part, we present the different techniques to recover household waste for a 4-member family (Kenitra, Morocco).
- In the second part, we highlight the effect of waste recovery on the contact rate β , which appears in the SIR model ¹², as well as on the number of active cases. Then, we give a direct and simple mathematical description of the spread of COVID-19 to illustrate its speed, considering that no specific treatment or vaccine exists for the time being ¹³.

2. Waste management techniques to limit the spread of COVID-19

2.1. Household waste sorting

The sorting carried out in this study enables us to recover two kinds of materials:

- Organic matter, i.e., fruit and vegetable waste and other food leftovers
- Non-organic material: glass, plastic, paper...



Figure 2. Waste sorting

This work begins with the determination of the organic fraction of household waste obtained after

sorting in the case of a family home for one month.

The results are presented in [Figure 3](#).

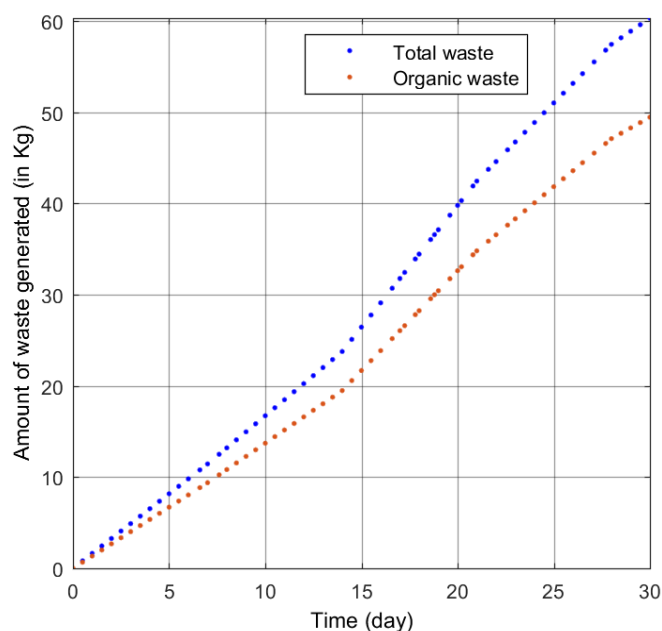


Figure 3. Evolution of the quantity (in kg) of waste generated by a 4-member family from Kenitra, Morocco

2.2. Anaerobic Digestion

Among the technological solutions allowing an efficient and less expensive treatment of the organic fraction of household waste, we have the anaerobic digestion (or methanization) which consists of the biological degradation, in the absence of oxygen, of

organic matter into a mixture of methane (CH_4) and carbon dioxide (CO_2) called 'biogas' ¹¹.

The use of a domestic digester allows citizens to recover energy from the organic part of their household waste.

- (1) Large-diameter pipe for substrate inlet
- (2) Hose for the outlet of the digestate
- (3) Biogas outlet pipe
- (4) System for the removal of CO_2 from biogas (purification)
- (5) Gas cooker
- (6) Insulator
- (7) Arduino board
- (8) P.C.
- (9) pH sensor linked to the Arduino card
- (10) Temperature sensor connected to the Arduino board

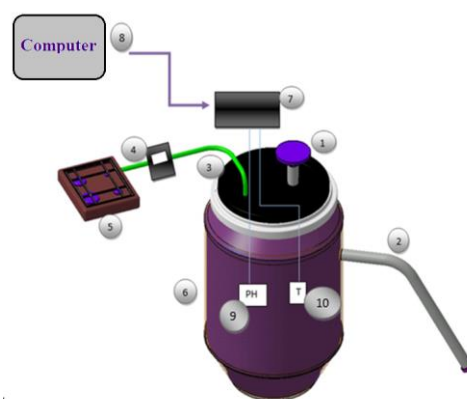


Figure 4. Concept of a domestic digester

The methane volume is estimated using Matteson and Jenkins' relation ¹⁴:

$$V_{CH_4} = q \cdot f_{vs} \cdot P_{CH_4} \cdot b \quad (1)$$

V_{CH_4} : Produced methane volume in dm^3

q : Available quantity of the organic fraction of household waste

f_{vs} : Ratio of volatile solids to total solids (without units)

P_{CH_4} : Methane potential in dm^3/T

b : Biodegradability

The possibility of thermal energy obtained from the biogas combustion produced by the anaerobic digestion of the household waste organic fraction is estimated by deriving the following equation ¹⁴:

$$H_{AD} = \frac{1}{1000} \cdot q \cdot f_{vs} \cdot P_{CH_4} \cdot b \cdot Q_{CH_4} \quad (2)$$

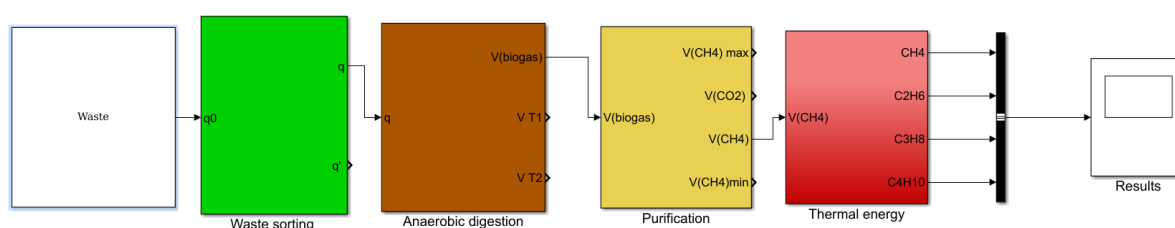
H_{AD} : Potential of thermal energy T.J./year

Table 1. Used parameters.

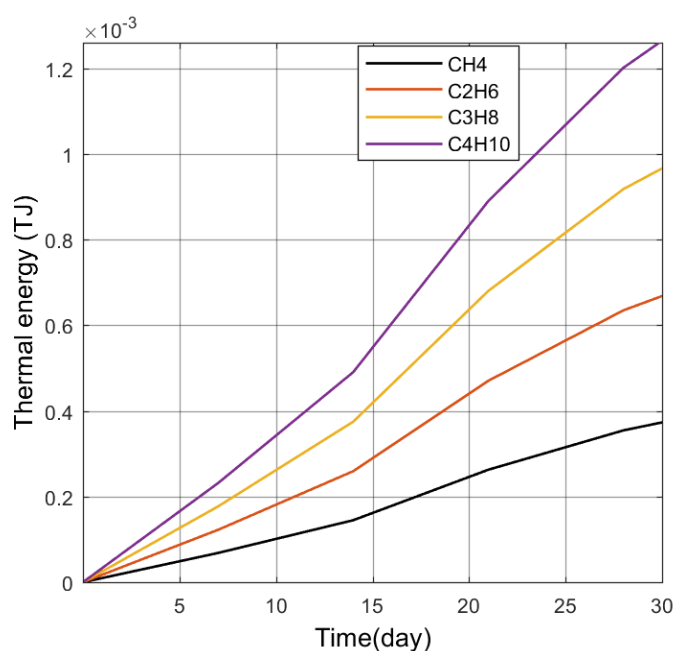
Symbols	Values	References
b	0,72	Karouach Fadoua (2014) ¹¹
f_{vs}	0,92	Karouach et al. (2013) ¹¹
Q_{CH_4}	36,3 MJ m ⁻³	Xian Fang Lou et al. (2013) ¹⁴
$Q_{C_2H_6}$	65 M.J. m ⁻³	Gross and Net Heating Values for some common Gases ¹⁵
$Q_{C_3H_8}$	94 M.J. m ⁻³	Gross and Net Heating Values for some common Gases ¹⁵
$Q_{C_4H_{10}}$	124,5 MJ m ⁻³	Xian Fang Lou et al. (2013) ¹⁴
P_{CH_4}	0,382 dam ³ /T	Xian Fang Lou et al. (2013) ¹⁴

By combining the equations (1) and (2), the results of Figure 3 and the parameters in Table 1 under the

Matlab/Simulink environment, we obtain the following scheme:

**Figure 5.** Simulation of household waste management under the Matlab/Simulink environment

We find the following results:

**Figure 6.** Evolution of thermal energy obtained by hydrocarbons combustion

3.2. Discussion and conclusion

Waste sorting has a remarkable effect on the frequency with which the trash has to be taken out. Indeed, non-organic waste can stay longer at home without any impact on health or the environment. Furthermore, waste sorting reduces the contact factor.

In the studied case, a potential of approximately 723 kg/year of household waste could be diverted to domestic digesters, offering the possibility of recovering energy in the form of heat.

Anaerobic digestion of the household waste generated in this home could produce approximately 5.44 GJ/year of heat potential.

The obtained results are very encouraging to adopt the sorting technique and the compost or the anaerobic digestion, in the medium or long term, or at least, during the containment period.

3. Optimization of contact between individuals

3.1. Modeling

The SIR model describes, with good approximation, the spread of pandemics. We consider three types of population S, I and R:

S : Number of susceptible people on day t

I : Number of infected people on day t

R : Number of removed people (recoveries and deaths) on day t

N : Total population number

With S_0 , I_0 and R_0 , the initial states of compartments S, I, and R, respectively.

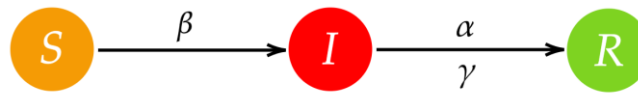


Figure.7 Types of population and possible SIR model migrations

According to the SIR model, the following system of differential equation is obtained ¹²:

$$\frac{dS}{dt} = \frac{-\beta}{N} \cdot S \cdot I \tag{3}$$

$$\frac{dI}{dt} = \frac{\beta}{N} \cdot S \cdot I - (\alpha + \gamma) \cdot I \tag{4}$$

$$\frac{dR}{dt} = (\alpha + \gamma) \cdot I \tag{5}$$

Where,

$$N = S + I + R = S_0 + I_0 + R_0 \tag{6}$$

- β : the contact rate that shows migration between susceptible and infected individuals
- γ : the recovery rate which governs the number of infected individuals who recover and then become immunized
- α : the death rate which controls the number of infected individuals who died from the disease

3.1 Parameters estimation

To estimate $\beta(t)$, $\alpha(t)$ and $\gamma(t)$, we refer on actual data from the Moroccan Health Ministry. We use a discretization of the differential equations (4) and (5) with a step of one day because the data are daily updated.

Then we have,

$$\forall k \in N$$

$$I(k+1) - I(k) = \frac{\beta(k)}{N} \cdot [N - I(k) - R(k)] \cdot I(k) - [\alpha(k) + \gamma(k)] \cdot I(k) \tag{7}$$

$$R(k+1) - R(k) = [\alpha(k) + \gamma(k)] \cdot I(k) \tag{8}$$

Using equation (8), $(\alpha + \gamma)$ is calculated every day k using the number of infected $I(t)$ and removed $R(t)$ people announced by the Moroccan government.

On the peak (day 60), there were about 30000 tested people. An estimate put the total population N at the double of this number ($2 \cdot 30000$) since the Moroccan data shows that we have reached the peak of active cases, and we suppose the same curve is symmetric (Figure 1).

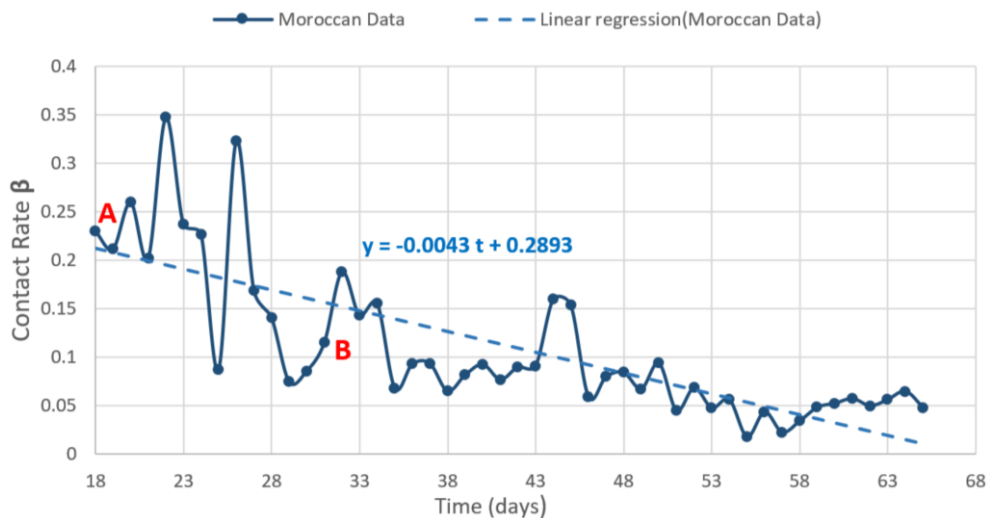


Figure 8. Variation of the contact rate as a function of time in Morocco

The $\beta(t)$ curve is plotted using equation (7) and Excel (Figure 8).

The day $t=0$ corresponds to the first recorded case in Morocco, i.e., March 2, 2020.

Note that point A, in Figure 8, represents the beginning of the national lockdown, which corresponds to March 20, 2020. And, point B represents the start of the lockdown effectiveness. A satisfying result is that 14 days after the official lockdown in Morocco, the variation amplitude of $\beta(t)$ around the linear regression line has considerably decreased. We consider the linear regression line as an estimate of the contact coefficient $\beta(t)$:

$$\beta(t) = -0.0043t + 0.2893 \quad (9)$$

To estimate the recovery and death rates $(\alpha + \gamma)$, we take the mean value:

$$(\alpha + \gamma)(t) = 0.0237 \quad (10)$$

Waste recovery reduces the contact rate $\beta(t)$ by decreasing the frequency with which the garbage has to be taken out. It could go from k times to $k-1$ times or $k-2$ times a week. Consequently, waste management shrinks the contact rate between infected and susceptible people. A linear regression line represents the new optimized contact coefficient:

$$\beta_{op}(t) = at + b \quad (11)$$

Therefore, we need to determine a and b . The effect of this waste recovery system on the contact coefficient could be seen as a decrease in the slope of the linear regression line. This slope has a dimension of (s^{-1}) and thus β_{op} will decrease more rapidly than β . To estimate a and b , we pose:

$$\beta = np \quad (12)$$

Where n is the number of contacts of a contaminated individual at time t and p is the contamination probability.

Then, we take a population of N_0 families (with N the total population). They take out the trash k times a week. The duration of the waste disposal is τ , in addition to their activities outside the home, which are estimated in T .

We will have a daily contact rate of:

$$\beta(t) = \frac{1}{7}(n_0 + n_1)p = \frac{1}{7}(n_0 + \frac{k\tau}{T}n_0)p = \frac{1}{7}(1 + \frac{k\tau}{T})n_0p \quad (13)$$

Where n_0 is the contact number of an individual per week, without considering the contact when they get the garbage out. n_1 is the number of connections that occur to take the trash out.

We estimate that, in reality, the population takes out the trash with a frequency of k_0 times a week. Hence, $\beta(t)$ observed in the real data has $k = k_0$ and β_{op} has a frequency of $k = k_1$ where $k_0 > k_1$.

$$\frac{\Delta\beta}{\beta} = \frac{\beta - \beta_{op}}{\beta} = \frac{(k_0 - k_1)\tau}{T + k_0\tau} \quad (14)$$

Finally,

$$\beta_{op} = \frac{T + k_1\tau}{T + k_0\tau} \beta \quad (15)$$

Then, we plot the new distribution of β_{op} by reducing the actual data by $\frac{T + k_1\tau}{T + k_0\tau} \%$, and we determine the

linear regression line.

For example, if T is maintained in 4 hours, τ in 2 min, k_0 in 3 and k_1 in 1, the value of β_{op} is $\beta_{op} = 0.984\beta$. Hence, the equation of the linear regression line is:

$$\beta_{op}(t) = 0.984\beta(t) = -0.0042t + 0.2847 \quad (16)$$

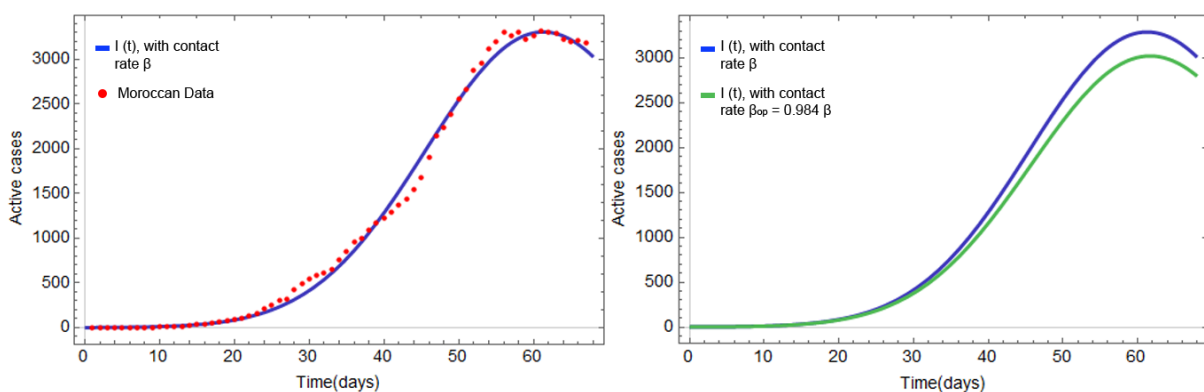


Figure 9. On the left, we have the fitting of the Moroccan pandemic curve using the SIR model with the contact rate $\beta(t)$. And, on the right, we have the estimated pandemic curve after the implementation of the waste recovery system. The total population is $N=60000$, the number of susceptible individuals, and the number of infected individuals at $t=0$ are respectively $S_0=59999$ and $I_0=1$

3.2. Results

We inject the estimated parameters in the differential equation (4) to obtain the total active cases (Figure 9). The effect of waste recovery is seen as a decrease in the peak number of actively infected people. In other words, we have been able to reduce the peak of active contaminated cases by 8.7% (291 cases).

3.3. Discussion

First, it was considered only the data reported after the official announcement of the containment (Figure 8), i.e., March 20, 2020, because the waste recovery system is supposed to be installed during this period.

Figure 8 showed us the evolution of the contact rate as a function of time. It allows us to predict $\beta(t)$. The same for $(\alpha+\gamma)(t)$, except that α and γ did not express any particular trend, so we took the average value, which gave a perfect fit. Afterward, we estimated the effect of the waste recovery system by reducing the actual contact rate.

The waste recovery system encourages citizens to stay at home by reducing the frequency of taking out the trash. Consequently, the number of contacts between susceptible and contaminated individuals will be reduced, which will slightly decrease the contact rate in the SIR model. Thus, the peak of active contaminated cases will be lower and, therefore, more controllable by the Moroccan health system.

Moreover, installing this system in hospitals will significantly reduce the contact rate between actively infected people and hospital cleaners who are in direct contact with the patients. This will limit the spread of the pandemic from the hospital to the outside.

Furthermore, Figure 9 shows an impressive result: the peak value of $I(t)$ in case of $\beta_{op} = 0.984\beta$ is 3024 infected individuals. Till May 14, 2020, the Moroccan government has announced the peak of active cases as 3315 infected individuals. Hence, if each home reduces the frequency of taking out the garbage from three times to once a week, this will shrink the peak of active contaminated cases by 8.7% (291 cases).

4. Conclusion

The main objective of this study was to restrict the propagation of the COVID-19 pandemic through an effective household waste treatment. It was finally proposed to optimize the contact rate β_{op} in the SIR model. This optimization allows us to decrease the peak by 291 cases.

Therefore, the results show that it is preferable to sort the waste and install a composter or a domestic digester in our houses, hospitals (more precisely in the contaminated person's room) to produce compost

or methane, and to limit the spread of the COVID-19 pandemic.

At all levels, the fight against COVID-19 is ongoing. It will also pass through our trash bins.

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