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Recycling and household waste insight: the impact after four successive waves of the COVID-19 pandemic. Study in Guelma city, North-East of Algeria

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Abstract: The coronavirus disease 2019 (COVID-19) pandemic has wreaked havoc especially in 2020 and the first half of 2021 and has left severe after-effects affecting not only the health sector but also all aspects of human life. The aim of this study is to inspect the current trends of the quantities of household waste produced during the first four waves of the pandemic. The study was carried out in Guelma city, northeastern of Algeria, where the first containment was registered on February 25, 2020, it concerns an Italian national (Mohamed et al. 2021). An increase in the production of household waste of approximately 14% during the first containment was recorded in the study area, with the interruption of recycling, which caused an enormous pressure on the technical landfill center of Guelma. The results showed that the trend of waste production decreased at the following averages: 205.80; 198.92; 196.69 and 192.43 tons, for the first four waves of COVID-19 respectively. Therefore, a return to the pre-pandemic state would be close, which dampens the impact and pressure on the landfill and the environment. This research allows for perceiving the waste management status in Algeria, between the pandemic and post--pandemic period.

Introduction

The WHO weekly epidemiological update on COVID-19 shows that the number of new weekly cases in the world decreased by 10% from the previous week from 3 to 9 October 2022. In the African region, the number of new deaths per week decreased by 41 per cent, and the number of new deaths per week decreased by 53 per cent, while in Algeria, there was more than one new death per 100,000 (WHO 2022). Coronavirus disease 2019; has caused havoc, especially in 2020 and the first half of 2021, and has had severe consequences not only in the health sector, but also in all aspects of human life (Contributors 2021). The virus first appeared on a small scale in November 2019 with the first large cluster appearing in Wuhan, China in December 2019 (WHO 2020). Since its outbreak, the COVID-19 pandemic has been declared a Public Health Emergency of International Concern (PHEIC), and caused closures in many countries (Kandel et al. 2020, Anderson et al. 2020). SARS-CoV-2 virus is quickly and easily transmitted by liquid droplets produced by infected people (Chen et al. 2020). The pandemic has posed many global challenges, mainly in the health sector. where the number of cases requiring hospitalization and staying in intensive care units (Remuzzi and Remuzzi 2020). This situation sent shock waves through the world economy and triggered the largest global economic crisis in more than a century and all countries were forced to intensify procuring procedures for further medical resources, PPE, hospital beds, hydro-alcohol gel, and additional equipment (Ranney et al. 2020). Since then, the economic impact of the epidemic has shaken the world not only with enormous health problems such as deaths and mental problems (Zandifar and Badrfam 2020), but also economic problems such as job losses among other socio-economic difficulties, but also, many countries recorded huge problems of waste management (Acter et al. 2020). The coronavirus disease 2019 (COVID-19) pandemic has changed the hazardousness of household waste, which may be contagious because some medical waste contains mask, gloves, discarded tissues, test kits, etc., also as reported many researches, the coronavirus can persist in plastic, metal and cardboard (component of the waste) for several hours or days (Kampf et al. 2020).

In consequence, worldwide production of plastic-based PPE (e.g. gloves, masks, face shields, protective clothing, bottles and hand sanitizing packaging made of polypropylene and polyethylene) became huge, and after consumption this PPE can lead to the contamination of these wastes, and thus

mishandling of these wastes by treatment staff can potentially increase the spread of viral disease (Mol and Caldas 2020). Therefore, to avoid the spread of the virus, it is crucial to consider the waste management issues of the plastic-based PPE generation caused by the COVID-19 pandemic (Klemeš et al. 2020). Investigations such as those conducted by Van Fan et al. (2021) on the quantity, composition, timing, distribution of household waste and the risk of infection in Singapore have shown that additional 1334 tons of plastic waste was produced in April 2020, which can be explained by changes in consumer behavior during the COVID-19 pandemic (Van Fan et al. 2021). In Northeastern Algeria, the increase of household waste produced during the first containment was reported as 14% compared to the same period in the previous two years (Mohamed et al. 2021). In the city of Melbourne, the amount of illegally dumped waste has increased by 70% in April 2020 compared with the same period in 2019, which could be related to the increase in home improvement and renovation work, packaging waste from online delivery, disposal of unwanted goods and used PPE such as gloves and masks (Boroujeni et al. 2021). During this pandemic, the existing waste collection and management system suffered enormous pressure and has led to an overall change in the nature and quantity of household flow also in inappropriate waste management strategies, such as direct dumping, local burning and mobile incineration (Adyel 2020, Leveau et al. 2022). Indeed, the waste management is influenced by several factors related to the size of the settlement, i.e., the area and population, and the characteristics of the waste management companies (the number of collection routes, and workers) (Kebaili et al. 2022). Nonetheless, it is also influenced by the Coronavirus pandemic; however, we demonstrated in a recent investigation, that there was an important increase in household waste flow in the northeast of Algeria, during the first containment caused by the outbreak of Coronavirus (Mohamed et al. 2021). The purpose of this investigation carried out in the city of Guelma (East of Algeria) is to explore current trends in waste production rates within two years of the outbreak, and to evaluate whether the production curve follows the same slope path or decreases.

Material and Methods

The containment was imposed in most countries at the outset of the Covid-19 pandemic among other restrictions e.g., establishments closing, social distancing, transportation stop; in consequence, the obtention of information needed in waste management became a challenge for researchers. Fortunately, with time, the restrictions were lifted and access to facilities became more convenient.

Epidemiological status and main measures in Algeria

In Algeria, the first COVID-19 case was registered on February 25, 2020 and concerns an Italian national (Mohamed et al. 2021). On October 23, 2022, the total number of infected persons reached 271,771 cases with 6881 deaths. Many factors significantly influence the development of the infection: health status, age and physical activity, non-compliance with the prevention measures promoted by the WHO, smoking, and vaccination (Aouissi et al. 2022).

Since the beginning of this pandemic, Algeria has implemented a national emergency plan to deal with this new threat. A crisis management plan has been put in place, which mainly imposes: limitation of public transport and traffic between affected-free areas, closure of educational, sports and religious institutions, home discontinuous quarantine, strengthening border control and establishing a surveillance system (crisis unit set up at the national and local level) (DGPPS 2020).

Algeria is among the pioneer countries that have adopted the hydroxychloroquine protocol (HQC). After benefited from the support of Chinese allies, medical care was administered free of charge, where all patients were treated equally, whatever their social class or age (Aouissi et al. 2021). On December 31, 2020, Algeria began a massive vaccination campaign, first with medical personnel and patients with comorbidities. On February 20, 2022, more than 7.46 million people have received at least one dose of COVID-19 vaccine, which represents about 16.7% of the total population (Lounis et al. 2022).

Study area

The study was carried out in the city of Guelma – Northeast of Algeria – that is one of the largest countries in Africa and the Arab world (Worldmeter 2015). Climate is highly variable throughout the country; the predominant type of climate is Mediterranean, with dry, hot summers and mild, wet winters. Concerning the temperature, there are two main periods: a cool period around 10.3°C (from November to April) and a dry one about 27.2°C (from May to October) while the average rainfall is around 800 mm. Noting that, these climatic factors have a crucial function in the process of waste biodegradation. The city of Guelma is located in the northeast of the country (Fig. 1) and geographically constitutes a meeting point between north and south, rural and industrial region. It covers a land area of 3686.84 km^2 with a population of 594,079 inhabitants (estimated at the end of 2009) distributed differently throughout 34 municipalities (Andi 2020).

The engineered landfill center (ELC) of Guelma is located in Bouguerguer (36°29'12.2"N 7°28'19.6"E), at 5 km of the chief town in the Northeast of the city. Since 2012, the center has been operating with two cells: one has already been filled and the second almost full (Mohamed et al. 2021).

Data collection

Detailed data have been directly collected from the center's technical services concerning the daily flow of household waste brought to the center of Guelma. In addition, the following parameters have been recorded: localization of the household waste origin received, types and timing of the household waste trucks, background and storage of the household waste treatment, quantitative data on the recoverable waste recycling and the main breakdowns noted. We also designed our project on the basis of recent research (MDPI, Science Direct, Springer and Scopus) and online collected information (reports, Google and websites) related to waste management in pre-pandemic and pandemic periods (national and international context), management of contaminated waste, and environmental and societal impacts caused by COVID-19.

Data covering time

Data obtained from the center's technical services mainly relate to household waste received between 01/01/2016 and 15/07/2022 with more details from February 2020 (outbreak period of the pandemic in Algeria).

Impact of the COVID-19 pandemic on HW management system in Guelma

The municipalities are responsible for organizing and transporting household waste while the inhabitants are responsible for pre-collection. The generated waste masses are daily collected in order to avoid their encumbrance as well as their decomposition on site. The collection is done in rotation: a waste collection trucks with a driver and two workers make their daily travel between district crossing specific collection points. It should also be noted that the selective sorting of waste according to its source does not take place in the residential or commercial areas of Guelma, which inhibits the waste treatment and affects the costs and the time. Historically, it is well-known how critical is the importance of the household waste management in preventing the spread of disease (Paleologos et al. 2018). This situation is even more worrying in the developing countries where the rational household waste management is limited to only 30–35% of the population, living mainly in urban areas (Vaverková et al. 2020). In Algeria, the coronavirus pandemic impacted the quantity, composition and timing of household's wastes in most regions of the country including the study area (Mohamed et al. 2021). However, COVID-19 spreading in this region effected heavily the waste management systems which had to be faced with a significant growth of household wastes and involved the municipalities to increase the rotation number in order to ensure an efficient collection. In consequence, this has constrained the human and logistical municipalities resources that are already suffering financially. xIn addition, waste recycling has been suspended as health measure but did not last very long and comeback after the alleviation of the sanitary situation, while the sorting and recycling in the informal sector did not mark a stop even if the prices of plastic soared during the critical period (Ebner and Iacovidou 2021).

Covid-19, household waste hazard

Several studies report the change in nature and safety of household waste composition during the pandemic of Coronavirus Disease 2019 (COVID-19) (Mohamed et al. 2021, Van Fan et al. 2021) and highlight the presence of PPE (facemasks, gloves,) in household waste. Most probably the high PPE quantity daily disposed during the pandemic is contaminated and getting into the household waste flow, engendering serious risks to public health (Kampf et al. 2020). Kampf reports that the virus could persist in different types of waste, e.g., 3 hours in paper, 2 days in cloth and he also added that the SARS-CoV-2 virus could easily contaminate all types of wastes and biodegradable materials. Hence, inappropriate disposal of used plastic bottles is a potential source of SARS-CoV-2 virus spreading, as these bottles may be infected. Therefore, any reuse increases the risk of viral transmission (Iyer et al. 2021, Nzediegwu AND Chang 2020). Within this context, taking necessary precautions to minimize the spread of SARS-CoV-2 virus that can get into the waste is almost essential, by ensuring safe and effective waste management system protocols (Klemeš et al. 2020).

Results and Discussion

Amount of household waste generated

In Algeria, household waste and assimilated are the flows coming from households, small businesses, markets, restaurants, administration, and industrial installations. The waste quantity produced can be expressed in mass or volume, however, only the mass is a reliable data that can be easily measured with weighbridge. Thus, Algeria produced 13.5 million tons of household waste in the year 2020, the amount can reach 23 MT on the horizon of 2035 according

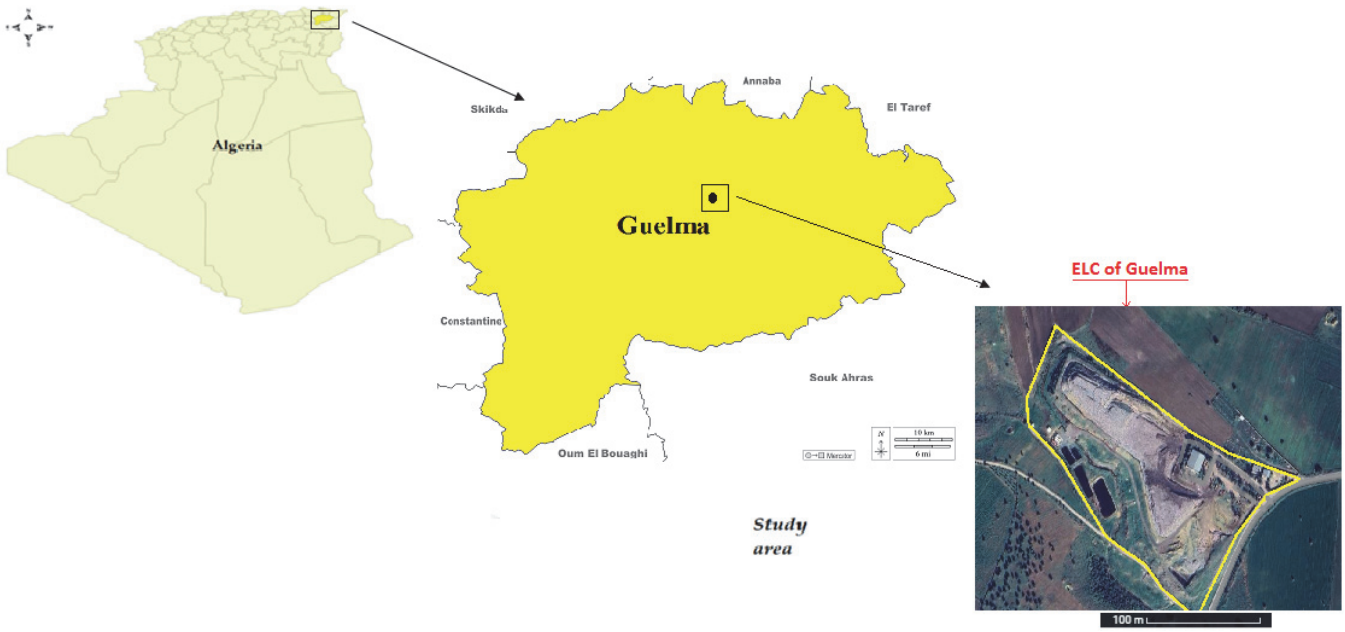

Fig. 1. Geographical location of the ELC of Guelma, Algeria

to the national waste management strategy (SNGID-2035) (SNGID 2019). This increase should be limited to less than that by implementing an effective strategy.

In the city of Guelma, the Engineering Landfill Center received in the last five years important quantities of household waste with an annual increase of approximately 2.94%, until the arrival of the coronavirus pandemic (February, 2020), where an increase of 5.29% was recorded; indeed, the annual quantity increased from 66,385.06 t to 69,895.38 t (Table 1). This observed change could be explained by the increase in the waste disposal rate in households. In fact, the COVID-19 pandemic has caused major difficulties in the management sector due to this unpredictable change (Van Fan et al. 2021). On average, the ratio of waste production per person was 0.72 kg/day for the whole of the previous four years and this for the pre-pandemic period in the Guelma area; while during the pandemic period (year 2020), the ratio increased to 0.76 kg/person/day (Table 1).

Household waste under four waves of the COVID-19 pandemic

The total amount of waste landfilled in the ELC of Guelma from the first wave until the end of the fourth wave with monthly and daily average is shown in (Table 2).

It is really difficult to find such a significant comparison with the same previous periods, since the waste is generated in unequal periods on the temporal axis and according to the duration consumed by each wave of coronavirus (even from 4 to 10 months). For this reason, we try to follow only the trend of the average daily waste production during each wave separately, and this for the four waves of the coronavirus pandemic, as a single means of monitoring the impact on the household waste management sector. This monitoring remains a very important planning and decision support tool.

During the first wave, which lasted for 316 days, we recorded the largest amount of waste produced with an average of 205.80 t/d, a quantity never received before. The second wave lasted for only 122 days, during which we registered 198.92 t/d, which means a slight decrease in the flow of household waste compared to the first wave. The third wave took more time – 212 days and produced less waste of 196.69 t/d; the trend continued to decrease compared to the two previous waves. The fourth wave lasted for 227 days, during which the amount of waste produced continued to decrease, where we recorded 192.43 t/d (Table 2).

One of the major repercussions of COVID-19 pandemic on SWM sector is undoubtedly the increase in the amounts of waste produced especially during the first wave. As reported in several regions of the world: In Tunisia, an increase in the production of household food waste during containment was observed, with an online survey conducted during the first 2 weeks of containment (Jribi et al. 2020). In Singapore, daily household waste collected increased by 3% in the containment period from April 7 to June 1, 2020, compared to March 2020 (Low and Koh 2020). Singapore produced an additional 1334 T of plastic waste (e.g. disposable forks, containers and spoons) in the quarantine period (Low and Koh 2020). Many studies explain that the closures and panic buying caused by the coronavirus pandemic led to irrational storage of food, due to fears of perishable food shortages without taking into account their shelf life, and consequently, this led to more waste being produced (Jribi et al. 2020, Hyun 2020). Jibri adds that the coronavirus crisis has motivated an amplification of the public's knowledge about food waste, due to the food supply shortages that are occurring (Jribi et al. 2020).

This can explain the decrease in the daily production of waste during the three waves that followed the first one in which it was recorded (W2: 198.92 t/d; W3: 196.69; W4: 192.43) as

Table 1. Amount of household waste generated last five years (expressed in Tons), in the city of Guelma

Year	Quantity		Daily average	Rate Kg/p/d
		% increase		
2016	60,825.16		166,64	0.69
2017	62,688.59	3.06%	171,75	0.72
2018	64,415.02	2.75%	176,48	0.72
2019	66,385.06	3.05%	181,88	0.72
2020	69,895.38	5.29%	191,50	0.76

Table 2. Amount of household waste generated during the four waves of coronavirus (in Tons), in the city of Guelma

	Amount	**Monthly average**	**Daily average**
First wave 20/02/2020 → 31/12/2020	65,814.84	6,174	205.80
Second wave 01/01/2021 → 02/05/2021	23,906.20	5,967.6	198.92
Third wave 03/05/2021 → 30/11/2021	41,304.9	5,900.7	196.69
Fourth wave 01/12/2021 → 15/07/2022	37,523.85	5,772.9	192.43

shown in (Fig. 2). Therefore, the trend of waste production decreases successively wave after wave, which is positive for the SWM sector, relieving the pressure on the engineered landfill center, which suffers largely from oversaturation. In general, the alleviation of the sanitary situation and the gradual return to normal life by removing the sanitary restriction measures (the closure, cessation of studies, and the use of masks and gloves) that have caused a psychological effect on the general public by generating anxiety, fear, public stress and overeating. (Q. Chen et al. 2020, Yang et al. 2020). Consequently, a return also to the initial situation, with a decrease in the daily production of waste was marked in Guelma.

Recovery of recyclable waste

One of the most important issues of the circular economy is recycling, one of the major solutions that aims to reduce the costs of the raw material and also reduce the environmental impacts caused by different materials contained in household waste (Plastic, Metals, etc). The COVID-19 pandemic has exposed the vulnerability of the recycling sector to macroeconomic shocks among other circumstances (Ebner and Iacovidou 2021). In general, the recovery of the valuable waste is done directly at the level of cell, or mechanically at the level of the sorting centers, which have chains of sorting and specialized equipment. In Algeria, the recovery rate of household waste is about 9.83%, all channels combined. This rate remains relatively low compared to the annual production of ~13.5 million tons (2020), which could exceed 20 million tons in 2035. In the city of Guelma, the recovery in 2021slightly exceeded 1% from formal sector, while in the informal sector it exceeded 4% (AND 2020). The quantities of recoverable waste in ELC Guelma in four previous years are summarized in (Fig. 3).

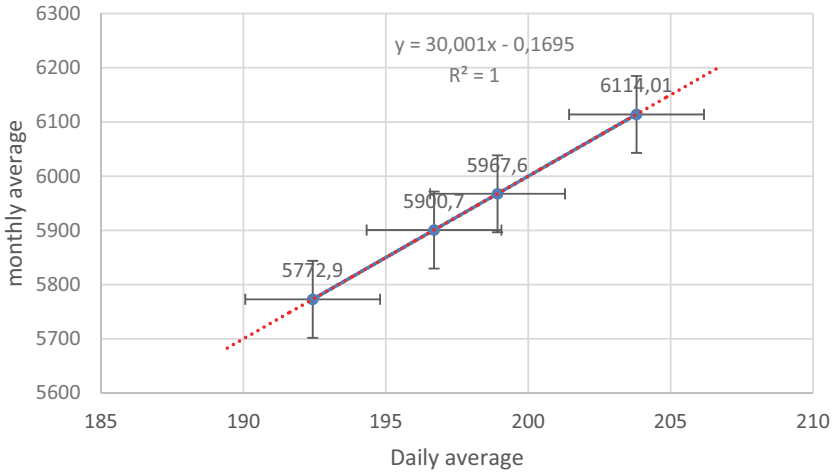

Fig. 2. Average of the amount of household waste under four waves of COVID-19, in the city of Guelma

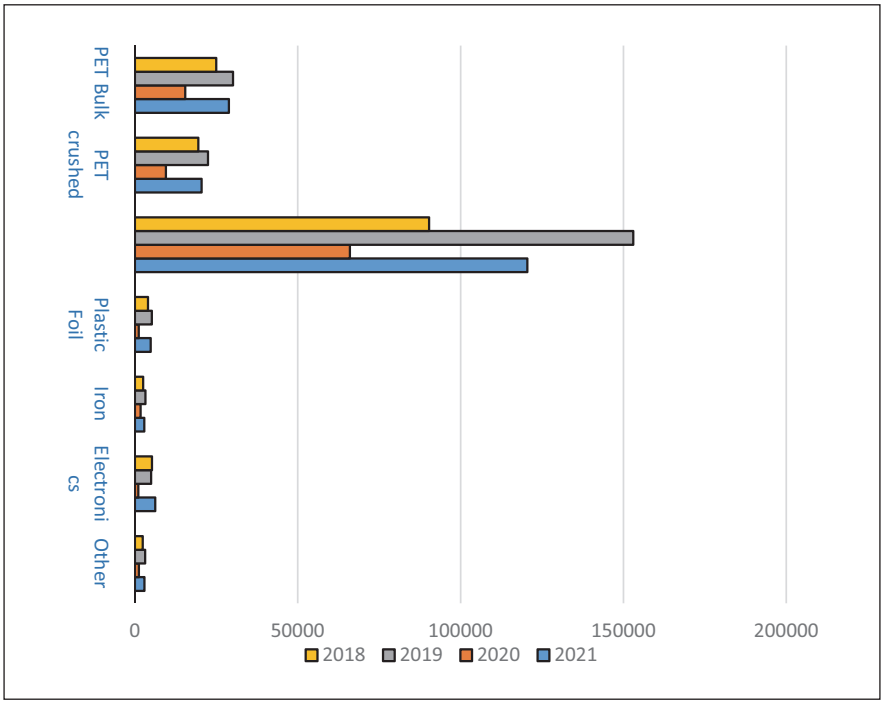

Fig. 3. The amount of recoverable waste last four years, in the ELC of Guelma

For bulk PET, which includes bottles, bags, etc., we can say that a decrease in the quantities recovered during the year 2020 is clearly remarkable, which corresponds to the critical period of COVID-19, as shown in (fig. 3). However, the pre-pandemic period represented by the years 2018 and 2019 recorded an important quantity of 24960 and 30126 kg respectively, where an increase of 21% was marked. During the pandemic period (2020), the amount recovered of bulk PET was 15456 kg, therefore we can estimate that a loss of 20996.46 kg was marked, that is to say, 58% of the estimated quantity (out of pandemic phase). A relief and a return of recycling, where the center recovered 28845 kg, marked the year 2021.

Cardboard and paper are the most important materials recovered at the center of Guelma. In addition, as shown in (fig. 3), the quantities recovered during the years 2018 and 2019, which correspond to the pre-pandemic period when 90,315 and 153,000 kg were recovered respectively, mark an increase of 69%. During the pandemic period (2020), only 66,000 kg are recorded, thus a decrease, comparing this amount with the previous rate, we can estimate a loss of 192570 kg, which is 75% of the estimated quantity (out of pandemic). The year 2021 has been marked by return of recycling when the center recovered 120500 kg. The same trend and remarks characterize the other products (plastic, PVC, iron, aluminum, HDPE and rubber), with significant fluctuation during the pre-pandemic period (2018–2019). During the pandemic period (2020), the amount recovered materials declines, before increasing again in the post-pandemic period.

In terms of environmental impact, recycling amortizes the impact and improves the sustainability of waste management systems (Amin et al. 2022, Chen et al. 2020) as it provides a gain of space and species. In our case, in terms of environmental impact or on the management system, the year 2020 (during the COVID-19 pandemic) was a critical time, when recycling was interrupted. Noting that, recycling is considered the best solution, while incineration is considered the second best technology (Roy et al. 2021). It should be noted that there is a lack of adequate waste management infrastructure specialized in recycling, especially for organic waste (composting) and all treatment is done by elimination in landfill cells. The strategy of waste management in Algeria, on the horizon of 2035, fixes as objective to reach a recycling rate of more than 50% of household and assimilated waste (separate the clean organic waste from the dry recyclable waste) (Ghennam 2020).

Conclusion

This study has raised important questions about the emerging challenges in household waste management due to the coronavirus pandemic, in the city of Guelma (Northeast of Algeria). The coronavirus pandemic has left a huge after--effect on the household waste management field around the world, accelerating the saturation of the cells among other technical, financial, logistical and environmental problems. Household waste management data play a key role in waste planning, decision making, especially during health crises such as the coronavirus pandemic. This investigation highlights quantitatively the recycling sector alteration of the studied center during 2020 when the coronavirus pandemic reached its peak. The recovery of recyclable materials shows a noticeable fall following an interruption imposed by the health measures to blow again during the year 2021.

In contrast to the literature on the COVID-19 and waste equation, which covers the pandemic in general, the findings from this study make several contributions to the current literature using a new detail that tracks the flow of waste quantities during each wave separately to determine the level and the trends of the household waste. This study showed that waste production was decreasing progressively wave after wave, and the return to the previous pre-pandemic state was notable. This compensates for the impacts on the waste management sector and the environment, and thus marks a significant return to sustainability. A complete assessment of waste production must be accomplished in other regions of Algeria for more conclusive understandings of better management of waste sector.

Limitations

The major limitation of this study was the small sample size that did not allow for building a statistical analysis; and with the naked eye, we can see the decrease in the quantities of waste produced (only four averages). An additional uncontrolled factor is the lack of spatial analysis as well as the small number of factors studied, which remain determinant in similar investigations. Besides, it should also be noted that the method of investigation is a direct analysis data recorded during a given period with no reference to a spatio-temporal framework analysis.

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