Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
COVID-19 and waste production in households: A trend analysis

Walter Leal Filho a,⁎, Viktoria Voronova b, Marija Kloga, Arminda Paço c, Aprajita Minhas a,⁎, Amanda Lange Salvia d, Celia Dias Ferreira e, Subarna Sivapalan f

a European School of Sustainability Science and Research, Hamburg University of Applied Sciences, Germany
b Tallinn University of Technology, Department of Civil Engineering and Architecture, Ehitajate tee 5, 19086, Tallinn, Estonia
c Universidade da Beira Interior, Núcleo de Estudos em Ciências Empresariais (NECEUBI), Rua Marquês d’Ávila e Bolama, 6201-001 Covilhã, Portugal
d Graduate Program in Civil and Environmental Engineering, University of Passo Fundo, Campus I-BR 285, São José, Passo Fundo, RS 99052-900, Brazil
e Universidade Aberta, Department of Sciences and Technology, Lisbon, Portugal
f Centre for Social Innovation, Institute for Self-Sustainable Building, Universiti Teknologi PETRONAS, 32610 Bandar Seri Iskandar, Perak Darul Ridzuan, Malaysia

⁎ Corresponding author.
E-mail addresses: walter.leal2@haw-hamburg.de (W.L. Filho), viktoria.voronova@taltech.ee (V. Voronova), apaco@ubi.pt (A. Paço), Aprajita.minhas@haw-hamburg.de (A. Minhas), celia.ferreira@uab.pt (C.D. Ferreira), subarna_s@utp.edu.my (S. Sivapalan).

HIGHLIGHTS
• The consumption of packed food, fresh food, and food delivery increased during lockdown.
• The highest generation of waste was observed for plastic packaging and food waste.
• The main challenges observed were increased packaging waste and health waste.

ABSTRACT
Apart from the health aspects and the high death toll, the COVID-19 pandemic has, since its official recognition in March 2020 caused many social and economic problems. It has also led to many environmental ones. For instance, the lockdowns have led to higher levels of consumption of packaged products, and of take-away food. This paper reports on an international study on the increased consumption and subsequent changes in the amounts of waste produced since the COVID-19 pandemic. The results show that 45–48% of the respondents observed an increased consumption of packed food, fresh food, and food delivery. One of the main reasons for the increased waste generation during the lockdown was the fact that people have spent more time at home. In addition, increases of 43% and 53% in food waste and plastic packaging. Drawing from comparisons on the amount of domestic waste produced before and during the pandemic, the findings suggest that some specific types of municipal waste have visibly increased, putting additional pressure on waste management systems. This characterises one of non-intended effects of the COVID-19 pandemic. The results from this study provide useful insights to city administrations and municipal utilities on consumption patterns during emergency situations. This, in turn, may support more systemic and strategic measures to be taken, so as to curtail the increase of household waste during pandemic situations.

© 2021 Elsevier B.V. All rights reserved.
1. Introduction

The novel 2019 coronavirus first emerged in December 2019 in Wuhan, China. It was not until January 2020 that researchers distinguished and classified the virus from ordinary pneumonia (Chen et al., 2020). The virus is easily transmitted through droplets released from an infected individual’s mouth or nose (Chen et al., 2020). Due to the easy transmission of COVID-19, the virus soon spread to other parts of the world, with international travel accounting for the largest percentage of the spread (Gössling et al., 2021). In March 2020, the World Health Organisation classified COVID-19 as a pandemic (WHO, 2020a). The virus’s epicentre shifted quickly from China to Europe and, after that, to the United States of America (WHO, 2020b). The highest number of confirmed cases was recorded in South Africa within the African continent, and this number rose rapidly as winter arrived (WHO, 2020c). The increase in cases in the southern hemisphere and the drop in increases in some countries in the northern hemisphere are attributed to seasonal patterns. COVID-19 has been shown to spread more quickly in colder temperatures than warmer temperatures (Poole, 2020). Since the outbreak of the pandemic in early 2020, the world has experienced a so-called “second wave” in early 2021, whereby the virus—and the mutant variations—have widely spread across the world.

The onset of the pandemic posed many global challenges, especially in the health sector. The influx of patients requiring hospital facilities and ICU spaces placed a significant burden on healthcare systems (Remuzzi and Remuzzi, 2020). Many countries were forced to intensifyprocuring procedures for additional medical resources, PPE, equipment, and hospital beds (Ranney et al., 2020), whereas other countries that had treaty agreements in place were forced to break such agreements and rationalise their medical resources for themselves (Anderson et al., 2020).

Apart from this, most countries put in place several lockdown regulations, causing many businesses to reduce the scope of their activities, or to simply close. In many instances, companies have had to retrench workers or place staff on short work hours (Parolin and Wimer, 2020). This has caused an increase in the unemployment rate in many countries (Bonaccorsi et al., 2020). In other cases, lockdown regulations have included international travel bans, which have caused substantial losses to the tourism industry and—since it contributes significantly to the economy of many countries—to a GDP decrease in countries around the world (African-Union, 2020; Ozili, 2020).

Apart from the health sector, the most severe effects of the pandemic were felt in households and day-to-day life. The lockdowns and the socio-distancing associated with them, have resulted in widespread job losses (Kawohl and Nordt, 2020). Aside from this trend, many breadwinners in the families have been infected or have lost their lives due to the virus, further diminishing income. The mental health of individuals who anticipated—or faced—financial constraints during the pandemic has also deteriorated, causing an increase in suicide rates (Bhuiyan et al., 2020). In all, the pandemic has caused numerous people and households to be plunged into poverty, thus increasing the poverty rate in many countries, especially in developing nations (Singh, 2020).

More specifically, the lack of—or substantially reduced—income has threatened the food security of millions of households. The lack of food compromises human health and makes people more susceptible to contracting the virus (Devereux et al., 2020). Studies have shown that household spending has increased by at least 50% despite the dwindling income. This has been attributed to people attempting to stockpile food at home. In contrast, a sharp decline in spending related to luxuries and travel (including public transportation) was also observed (Baker et al., 2020).

Aside from this, many schools have shut down due to lockdowns. Wealthier families have had the privilege of home-schooling their kids or using online learning tools. In other cases, more impoverished families are unable to provide the same benefit to their children, leading to inequalities in education systems as a result of lack of infrastructure and connectivity (Owusu-Fordjour et al., 2020; Sahu, 2020). A recent study has shown that the closure of schools and day-care facilities as a result of the pandemic has severely affected working mothers and has contributed to gender inequalities (Alon et al., 2020). Most working mothers form part of the workforce, and have had their work impaired by the pandemic. In some cases, unemployed fathers are now taking responsibility for children’s primary care, which is defying social norms in certain countries. This is not always possible, as some fathers do not have flexible work arrangements (Alon et al., 2020). Apart from the health aspects and the high death toll, the COVID-19 pandemic has caused many social and economic problems since it was officially classified as a world issue in March 2020. It has also led to some environmental ones. For instance, the lockdowns have led to higher consumption levels of packaged products and containers from take away food. In this context, the objective of this paper is to report on the increased consumption and subsequent changes in the amount of several types of household waste produced in an adverse context— the COVID-19 pandemic. Its novelty lies on the fact that this is an international study which investigated several types of household waste production across a number of different countries.

2. COVID-19 and consumption

According to World Health Organisation (WHO), the Americas, Europe, and South-East Asia have been reported as the most affected regions in absolute numbers of confirmed cases of COVID-19 (WHO, 2020d), as of November 24, 2020. France, Russia, Spain, United Kingdom, Italy, and Germany have been confirmed to be the most impacted countries by COVID-19 in Europe. The measures are taken to prevent and control the spread of COVID-19 have numerous effects on the food supply, eating behaviour, and dietary practices of millions of people worldwide.

According to the European Field Marketing Partners report (EFMP, 2020), some key stages in consumer behaviour linked to COVID-19 can be identified, as people moved from awareness about COVID-19 to physical restrictions and final lockdown in March 2020. Regarding food purchase and consumption, two main stages can be highlighted. The first stage is buying food in bulk or panic buying. At the beginning of the pandemic, the understanding of the virus and its consequences was limited, and people started to make provision of food, sometimes in inadequate large amounts, to mitigate future risks of food shortage. Such a situation was observed throughout different countries in the world. For example, 84% of respondents in Norway reported that they purchased extra dry goods, 38% reported buying additional canned goods, and 37%—extra frozen food due to the COVID-19 outbreak (Statista, 2020).

Similarly, in other countries in Europe and the USA, frozen and packaged food purchases have increased since March 2020, as people preferred to buy long lasting food products. According to market research data (Morrison, 2020), customer behaviour has rapidly changed during the first wave of COVID-19. Packed food sales in Italy have peaked by March 15, making 33.8% in comparison with a year ago. In France and the UK, the packed food demand continued to grow and reached the highest values by March 22, 49.8% and 69.6%. In the USA, the rapid increase of packed food sales from 10% to 76–77% was observed within the first two weeks in March 2020 (Morrison, 2020).

A similar tendency with growing customer demand was seen in the frozen food sector. The highest demand was observed in the USA and the UK with 92.7% and 84.4% respectively versus a year ago. In Italy, frozen food demand started to stabilize after March 15 and reached 36.7% by March 22. In France, the steady growth of customer demand for frozen food was observed from 8 to March 22 (Morrison, 2020). Buying food in bulk was observed in many other countries. Thus, in Vietnam, 38% of respondents reported that they had been engaged in panic buying, purchasing mainly dry food such as rice, noodles, pasta, and flour (Statista, 2020).

During the second wave of COVID-19 pandemic in autumn and winter 2020, panic buying was not an issue for most people since the fear of
merely running out of food has receded. The second stage, when analyzing consumer behaviour linked to COVID-19, is living in quarantine. During this period, people were getting used to living in their new reality and making less impulsive and irrational purchases. Going to restaurants or quick-service restaurants was restricted, and people started to cook more meals at home. Thus, according to Bracale and Vaccaro (2020), people began to buy more pasta, flour, eggs, long-life milk, frozen foods, and less fresh food during Italy's quarantine. The sales of snacks have dropped in relation to homemade bread, pizza, and cakes.

During the quarantine period, online grocery shopping and food delivery increases while the store visits decrease. According to market research by McKinsey and Company (2020) in October 2020, customers purchasing online in the “Food takeout and delivery” category has grown by 15–29% in the USA, Italy, and Japan. As of May 31, 16% of respondents in Germany and 19% in the UK stated that they had preferred restaurant delivery/takeaway online instead of offline shopping. Besides, 10% of respondents in Germany and 30% in the UK reported that they had chosen food and drink delivery (e.g., from the supermarket) instead of going to the stores (Statista, 2020). In Vietnam, more than 58% of respondents reported that they purchased more online during the COVID-19 outbreak (Statista, 2020).

The increase of online food purchase and restaurant delivery means the growth of packaging since it has been hailed as a key to ensure health and safety for the customers during the pandemic. According to some estimations, e-commerce and takeaway service are expected to continue growing alongside packaging materials (Felton, 2020). In addition to physical changes in lifestyle, many people have experienced negative emotions like depression, stress, and fear about COVID-19. These negative emotions could lead to overeating, the so-called “emotional eating,” particularly junk food. Thus, more than a third of consumers reported that they purchased more of alcohol and snack because they required it more during social distancing measures in the United States in 2020 (Statista, 2020). In Italy, more than 34% of respondents have reported that they had increased appetite, and more than 48% of the population had the perception of weight gain (Di Renzo et al., 2020).

It can be concluded that COVID-19 has a significant impact on people’s consumption behaviour around the world. Consumption patterns of the people changed to more practical during lockdown; however, it could sometimes lead to overeating. People preferred to buy products with long shelf life, such as packed or frozen food. Home delivery and takeaway sales have also increased since the COVID-19 outbreak.

3. Methodology

The study employed a quantitative research methodology. The data collection was carried out with the help of a survey, which was developed by the research team. The survey items were developed based on an extensive review of the international literature, including reports and public documents, around the subject matter of the production of waste within households (e.g. Devereux et al., 2020; Ikiz et al., 2021; Jribei et al., 2020) during the onset of the COVID-19 pandemic. The final version of the survey contained three sections, namely Section 1: Demographic Information, Section 2: Level of Consumption, and Section 3: Waste Generation and Management. Section 1 contained 11 items, while Sections 2 and 3 had 7 items and 11 items.

Before finalizing the survey for data collection, an expert validation exercise was conducted to determine the suitability of the items developed. A total of five international experts in the area of sustainable consumption and production, waste management and recycling, environment and sustainability, and public health provided feedback to the items in the survey. Some of the highlights from the expert validation exercise are as listed below:

1. Adjustments in the number of sections and items within each section
2. Fine-tune of the suitability of some of items related to the research aims. The survey was designed to identify the increases in consumption and changes in waste production since the pandemic. A few questions were modified in section 2, so as to cater for a better understanding of the extent of waste products such as packed food, fresh food (e.g. fruits and vegetables), online or takeaway food others. The goal was to identify whether they increased, decreased, or if no changes were observed. Following a recommendation by the panel of experts, more options were added in the questions related to increased waste production, and about waste segregation.

Upon addressing the feedback from the expert validation process, and in order to ensure the validity of the data, a pilot study (i.e. a pre-test) was conducted with six respondents. The pilot study’s findings revealed that the survey instrument was adequate, with minor changes. Both steps (i.e. the validation with experts in the area and pilot application with additional respondents) ensured the validity and reliability of the data collection instrument. The finalized survey items were then transferred into a Google Form. Using a purposive sampling approach, combined with techniques such as snowballing and chain referrals, the link to the on-line survey instrument was then shared with a global audience via the research team, the networks of the European School of Sustainability Science and Research, and via, the Inter-University Sustainable Development Research Programme (IUSDRP). Data collection was carried out from August 2020 to November 2020. In accordance with research ethics protocols, respondents were informed that their participation in the study was voluntary. Participants were informed that the answers they provided would be treated with the strictest confidence, and the protection of their personal data will be upheld at all times.

4. Results and discussion

4.1. Demographics

The survey resulted in a total of 204 responses. Participants of the study originated from 23 countries, namely Portugal, Italy, Germany, Brazil, Estonia, United States, Australia, Canada, Singapore, United Kingdom, Denmark, Spain, Poland, Finland, Bangladesh, Argentina, Chile, Ireland, New Zealand, Japan, Malaysia, Indonesia, and Vietnam. 61.6% of the respondents were male, while 37.4% were female. The balance 1% of respondents preferred not to disclose their gender.

In terms of the respondents’ age distribution, those between the ages of 31 and 40 made up the largest pool of respondents, with 36% of the total. This was followed by respondents between the ages of 21–30 years of age at 30%. Respondents between the ages of 41 to 50 were the third largest group of respondents totalling 15.3%, followed by those within the 15–20 age group, with 8.9%. 7.4% of the respondents were from the ages of 51–60, while those from the age group of 61 and over were the least represented in the survey, accounting for 2.5% of the total number of respondents. In terms of the level of education, the majority of the respondents have postgraduate qualifications. This group makes up 61.4% of the total number of respondents. This is followed by graduates at 33.2%. The remaining respondents were made up of those with qualification at high school or under.

Respondents of the survey are made up of many occupation levels, including upper management, middle management, junior management, administrative staff, trained professionals, skilled laborers, consultants, temporary employees, and the self-employed partners in a business, students, retirees, and the unemployed. They thus represent a variety of social sectors and income levels. Trained professionals and students made up two of the largest respondent groups at 24.3% each, while the unemployed made up the least, with a total respondent rate at 2.5%. The majority of respondents’ net monthly household income was €500–€1000 at 20.9%, while the 19.5% of respondents who preferred not to disclose their monthly household income made up the second-largest respondent group. Interestingly, 19.9% of respondents had also chosen not to reveal their monthly household income.

The majority of respondents, namely 81.5%, live in urban areas, with 40.8% of them living in flats and 32.8% and 17.4% of them living in...
detached houses and semi-detached houses. Most households have two adults and children less than 18 years of age. At the height of the COVID-19 pandemic, 55.7% of respondents were in partial lockdown, 37.4% in full lockdown, and 6.9% not in lockdown. When responding to the survey, 71% of the respondents were not experiencing lockdown, 25.3% were in partial lockdown, while the remaining respondents were in full lockdown.

### 4.2. Level of consumption and waste generation

The respondents were then asked about their consumption of packed food, fresh food such as fruits and vegetables, online or take-away food during the lockdown between March and June 2020, and any changes in the amount of waste generated. Table 1 shows the summary and extent of consumption and waste generation for the sample.

Table 1 shows that 45%–48% of the respondents observed increased consumption of packed food, fresh food, and food delivery during the pandemic. About 36–40% of respondents experienced no change, and 12–18% experienced decreased consumption. In terms of waste production, more than half of the sample (55%) indicated an increase in waste generation during the lockdown period. Most of the increase or decrease in consumption or waste generation is between 10% and 20%, as shown in Table 1. As stated by Morrison (2020), according to market researchers, frozen and packed food purchases increased due to panic buying, as consumers stocked their home with long-lasting food. Sharma et al. (2020) have also reported an increased demand for food delivery options and a consequent increase in waste generation, especially of plastic products.

Respondents were also asked about the reasons for the potential change in a waste generation. Fig. 1 summarises the results, pointing out a balanced distribution of responses across the provided options. Other responses include less socialization, eating at home instead of going out, using masks, and having children at home instead of nurseries, for example, which leads to an increase in cooking activities and therefore in waste generation. All these reasons relate to common causes explored by other authors: the stay-at-home policies and preventive measures against COVID-19 (e.g., increased consumption of masks, gloves, toilet papers, food delivery) (Ikiz et al., 2021; Sarkodie and Owusu, 2020).

Fig. 2 summarises the results of the change in types of waste generated during the lockdown. The highest increase was observed for plastic packaging and food waste (53% and 45%, respectively). Other types of packaging (e.g., metal, paper) and glass bottles, and gardening waste, are also among the items with a higher percentage of increased generation. Most respondents also reported no change in waste generation, with higher medical and electronic waste rates, for example.

Explicitly focusing on food waste, the respondents were asked to rank the necessary household items discarded during the lockdown (from 1 the least to 5 the most discarded). Table 2 presents the average per item, with the most discarded items, including fruits and vegetables (2.63) and the least discarded potatoes (1.08). In March 2020, more consumption and purchase were reported in Italy for bread (180.7%), yeast (189.6%), and cereals/grains (131.4%). Moreover, the UK reported an increased consumption of canned meat (143%). Similarly, the purchase of dried potato products increased in Germany by 202% (Morrison, 2020), Ikiz et al. (2021) and Jribi et al. (2020) reflect that although the lockdown led to an overall increase in food waste, in some contexts decreases may be possible, in respect of eating less food or increasing the re-use of leftovers.

Table 3 presents the responses to a set of questions related to regulations for waste separation by the local city council, existence of different litter bins to separate waste at home, and efforts to segregate waste. In case more changes in waste regulations have been applied, the sample might not have been aware or noticed any difference (49%), whereas 57% of the sample indicated changes in this aspect. Regarding household efforts, it was possible to observe that the separation of waste is still a topic that deserves further measures, as almost half the sample indicated a negative response. Just a third of the sample (32%) indicated they have increased their efforts to segregate waste properly during the lockdown.

The respondents were also asked about sustainable packaging purchases (e.g., reusable packaging, biodegradable packaging), where 30.9% agreed that they always look for sustainable packaging options.

---

**Table 1**

Summary of consumption and waste generation.

| Consumption and waste generation | Responses (%) | Distribution of responses (%) |
|----------------------------------|--------------|-----------------------------|
|                                  |              | Blanks | Up to 10% | Between 10% and 20% | Between 20% and 30% | Over 30% |
| Packed food (N = 204)            | No change    | 40%    | 100%      | 0%                   | 0%                   | 0%       |
|                                  | Yes, it has increased | 48%    | 0%         | 0%                   | 0%                   | 0%       |
|                                  | Yes, it has decreased | 12%    | 12%        | 36%                  | 32%                  | 12%      |
| Fresh food (N = 203)             | No change    | 36%    | 100%      | 0%                   | 0%                   | 0%       |
|                                  | Yes, it has increased | 45%    | 1%         | 22%                  | 37%                  | 23%      |
|                                  | Yes, it has decreased | 18%    | 0%         | 46%                  | 41%                  | 11%      |
| Food delivery (N = 204)          | No change    | 39%    | 100%      | 0%                   | 0%                   | 0%       |
|                                  | Yes, it has increased | 46%    | 0%         | 33%                  | 32%                  | 16%      |
|                                  | Yes, it has decreased | 16%    | 0%         | 22%                  | 19%                  | 19%      |
| Waste generation (N = 204)       | No change    | 21%    | 100%      | 0%                   | 0%                   | 0%       |
|                                  | Yes, it has increased | 55%    | 3%         | 36%                  | 35%                  | 16%      |
|                                  | Yes, it has decreased | 11%    | 5%         | 27%                  | 50%                  | 14%      |
|                                  | Don’t know    | 13%    | 100%      | 0%                   | 0%                   | 0%       |
4.3. Challenges, outcomes, and measures for waste management

The COVID-19 pandemic resulted in challenges and impacted waste management in various ways. For instance, in connection with changes in the amount of waste produced, changes were seen in connection with disposal rates in households, changes in waste composition, and shifts in waste distribution (Fan et al., 2021). Fig. 3 presents the main challenges regarding waste management at households during the lockdown. The highest percentages (45% of the respondents) were associated with an increased amount of health and packaging waste. A study by Fan et al. (2021) also reported increased plastic waste production, and that online meal delivery increased by 73% during the pandemic in Singapore.

Respondents were also argued about possible positive implications of the lockdown to their households (Fig. 4). 55% of the respondents indicated increased efforts to eat healthier, followed by efforts related to implement waste separation and prevent food wastage (36% and 33%, respectively).

The lockdown experience seemed to have made some people reflect about measures that could be intensified for better waste management during disaster situations. Most responses (Fig. 5) indicated the need for improving product design to use less packaging (66%) or to increase recyclability (61%). Moreover, about 51–52% of respondents indicated to extend the lifetime of product design and better communication between the local council and the community. According to the United Nations Environment Programme, in order to better raise awareness and extend the lifetime of product design and better communication between healthcare staff and the public, guidelines should be developed for the handling, treatment and disposal of waste generated during pandemic conditions. There should be clear responsibilities and roles assigned to collecting waste under such exceptional conditions (UNEP, 2020).

Implementing an appropriate waste management system assures the continuity and functionality of workers and waste services during the COVID-19 pandemic. It is also important to put measures in place to protect the safety of workers at waste collection and disposal facilities, and to foster the improvement in recycling services (Sarkodie and Owusu, 2020).

5. Conclusions

This study has presented evidences which show that the lockdowns triggered by the pandemic led to an increase in levels of consumption in households, and to changes in the amounts of waste and recycling. These items have, in turn, put an additional pressure on the waste management systems of many cities around the world. The increases in consumption were initially due to purchasing food in bulk or panic buying. It could then be explained by the fact that many citizens were forced to stay home. As a result, the purchase of frozen and packaged food increased significantly since March 2020. Many consumers preferred to buy long-lasting food products and changed their habits by shopping more online or taking away food.

The study presented here involved 204 consumers from several countries. About half of the respondents noticed an increase in packed food, fresh food, and food delivery. Consequently, more waste generation was reported, especially in respect of plastic packaging and food waste. But not all trends were negative, since a significant number of individuals mentioned their efforts to eat healthier food, and to separate the waste produced at home.

This situation also led to consumers being more critical with food producing companies, pointing out that they should implement measures such as improve product design to use less packaging, or increase the recyclability of the packaging they use. Nevertheless, this responsibility

### Table 2

Ranking of items most discarded during the lockdown (1 - the least; 5 - the most).

| Item                  | Average | Standard deviation |
|----------------------|---------|--------------------|
| Fruits/vegetables    | 2.63    | 1.42               |
| Meat                 | 2.25    | 1.35               |
| Dairy products       | 2.18    | 1.29               |
| Bread                | 2.16    | 1.24               |
| Fish/seafood         | 2.14    | 1.26               |
| Ready-made meals     | 2.05    | 1.26               |
| Canned food          | 1.99    | 1.20               |
| Milk                 | 1.97    | 1.29               |
| Cereal/grain products| 1.96    | 1.19               |
| Potatoes             | 1.8     | 1.08               |

### Table 3

Questions and responses related to waste management.

| Question                                                                 | Response options (%) |
|------------------------------------------------------------------------|----------------------|
| Have local council regulations been changed in your city/district/area in terms of household waste separation during the lockdown? (N = 204) | Yes 19 | No 57 | Don't know 49 |
| Do you use different bins for the separation of household waste (e.g. black waste for general waste, green bin for fruits/vegetables, etc.)? (N = 202) | Yes 55 | No 45 | – |
| Have your efforts to segregate waste (organic and recyclables) changed in your household during the lockdowns? (N = 204) | Yes, they decreased 4 | No change 64 | Yes, they increased 32 |
should be also shared with public entities. These may, for instance provide better infrastructure for selective waste collection, or for recycling. Complementarily, it could also be useful to identify effective ways to reward citizens who actively participate in waste prevention efforts. Although many people think it is challenging to reduce waste, small actions can be taken (e.g., composting, replacing disposable products with durable ones, avoiding over packaging, etc.).

Another issue is how the municipalities efficiently manage household waste during the pandemic. In our study, if some changes in waste regulations have been applied, it was observed that about half of the sample might not have been aware of these new regulations, or noticed any change. Thus, it is important to identify best practices and analyze the key success factors, so as to increase the capacity of waste management systems to respond to pandemic crises, while keeping waste prevention and recycling high on the agenda. In many places, the interruptions in some commercial activities, and diminishing tourist flows have also influenced waste generation, which may free capacity to focus on household waste management. Another matter of relevance is the communication with residents: changes to collection services should be better communicated, preferably well in advance. The population should also be “educated” to better collaborate with local management waste authorities, by engaging on reductions on the amount of waste generated in households.

Regarding the limitations of our study, we recognize that using a convenience sample that is country diversified reduces the possibility of picking specific local trends. On the other hand, it caters for a greater degree of generalization. The limited number of responses can be also considered a limitation of the study. Nonetheless, the study provides a welcome contribution to the literature since it has enabled an overview of trends in 23 countries spread across the various geographical regions. This serves the purpose of illustrating the wide-ranging impacts of the COVID-19 pandemic on households’ consumption habits, in face of the lockdowns it triggered.

In respect of future research, and since the world is still facing a second wave, it could be useful to analyze other stakeholders’ perspectives regarding household waste (e.g., municipalities, producers, supermarkets) since these sectors have also been experiencing changes due to the lockdowns. The search for other explanations about individuals’ behaviour could also be studied using other research perspectives such as green buying behaviour, green consumption, lifestyle changes, or economic incentives to consumers, among others.

**Funding**

This research was performed by the European School of Sustainability Science and Research (ESSSR), and the Inter-University Sustainable
Development Research Programme (IUSDPR). It did not receive any specific grant from funding agencies from the public, commercial, or not-for-profit sectors.

**CRediT authorship contribution statement**

Walter Leal Filho: Conceptualization, Supervision, Validation, Writing –original draft, Writing – review & editing. Viktoria Voronova: Writing –original draft, Writing – review & editing. Marija Kloga: Writing –original draft, Writing – review & editing. Arminda Paço: Writing –original draft, Writing – review & editing. Aparajita Minhas: Investigation, Project administration, Visualization, Writing – original draft, Writing – review & editing. Amanda Lange Salvá: Formal analysis, Investigation, Validation, Visualization, Writing – original draft, Writing – review & editing. Celia Dias Ferreira: Writing – original draft, Writing – review & editing. Subarna Sivapanal: Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing.

**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**References**

African-Union, 2020. Impact of the coronavirus (COVID-19) on the African economy. Available at: https://www.tralac.org/documents/resources/covid-19/2318-impact-of-the-coronavirus-covid-19-on-the-african-economy-african-union-report-april-2020/file. (Accessed 26 July 2020).

Alon, T.M., Doepeke, M., Olmstead-Rumsey, J., Tertilt, M., 2020. In: N. B. o. E. Research (Ed.). The importance of the coronavirus on gender equality. NBER Working Paper Series Vol. 26947.

Anderson, M., Mcke, M., Mossialos, E., 2020. Covid-19 exposes weaknesses in European response to outbreaks. Br. Med. J. 368, m1075. https://doi.org/10.1136/bmj.m1075.

Baker, S.R., Farrokhnia, R.A., Meyer, S., Pagel, M., Yannelis, C., 2020. In: N. B. o. E. Research (Ed.), How does household spending respond to an epidemic? Consumption during the 2020 COVID-19 pandemic. NBER Working Paper Series Vol. 26949.

Bhuiyan, Al, Sakib, N., Pakpour, A.H., Griffiths, M.D., Mamun, M.A., 2020. COVID-19-related suicides in Bangladesh due to lockdown and economic factors: case study evidence from media reports. Int. J. Ment. Heal. Addict. https://doi.org/10.11699/020-00307-9.

Bonacci, G., Pierri, F., Cinelli, M., Flori, A., Galeazzi, A., Porcelli, F., Quattrociocchi, W., 2020. Economic and social consequences of human mobility restrictions under COVID-19. Proc. Natl. Acad. Sci. 117 (27), 15330–15335. https://doi.org/10.1073/pnas.2007658117.

Bracale, R., Vaccaro, C.M., 2020. Changes in food choice following restrictive measures due to COVID-19 lockdown: an Italian survey. Journal of Transnational Medicine 18, 229. https://doi.org/10.1186/s12967-020-02399-5.

EFMP, 2020. European field marketing partners. The impact of COVID-19 on consumers purchasing in Europe. Available at: https://efmp.com/article.aspx?id=20. (Accessed 30 June 2020).

Fan, Y.V., Jiang, P., Hemzal, M., Klemeš, J.J., 2021. An update of COVID-19 influence on waste management. Sci. Total Environ. 754, 142014. https://doi.org/10.1016/j.scitotenv.2021.142014.

Felton, D., 2020. 4 inevitable packaging changes after COVID-19. Packag. Dig. Available at: https://www.packagingdigest.com/covid-19/4-inevitable-packaging-changes-after-covid-19. (Accessed 30 June 2020).

Gösling, S., Scott, D., Hall, G., 2021. Pandemics, tourism and global change: a rapid assessment of COVID-19. J. Sustain. Tour. 29 (1), 1–20. https://doi.org/10.1080/09665958.2020.1758708.

Ikiz, E., Maclaren, V.W., Alfred, E., Sivanesan, S., 2020. Impact of COVID-19 on household waste flows, diversion and reuse: the case of multi-residential buildings in Toronto, Canada. Resour. Conserv. Recycl. 164, 105111. https://doi.org/10.1016/j.resconrec.2020.105111.

Jribi, S., Ben Ismail, H., Doggi, D., Debbahi, H., 2020. COVID-19 virus outbreak lockdown: what impact on household food security? Environ. Dev. Sustain. 22, 3939–3955. https://doi.org/10.1007/s10668-020-00740-y.

Kawohl, W., Nordt, C., 2020. COVID-19, unemployment, and suicide. Lancet Psychiatry 7 (5), 389–390. https://doi.org/10.1016/S2215-0066(20)30141-3.

McKinsey & Company, 2020. Consumer sentiment and behaviour continue to reflect the uncertainty of the COVID-19 crisis. Available at: https://www.mckinsey.com/business-functions/marketing-and-sales/our-insights/a-global-view-of-how-consumer-behaviour-is-changing-amid-covid-19 (Accessed 24 Nov 2020).

Morrison, O., 2020. Coronavirus: consumer demand for staple foods “high but stabilizing”. William Reed Informing Business Growth. Available at: https://www.foodnavigator.com/Article/2020/04/08/Coronavirus-Consumer-demand-for-staple-foods-high-but-stabilising. (Accessed 29 June 2020).

Owusu-Fordjour, C., Koonmon, C., Hanson, D., 2020. The impact of Covid-19 on learning: the perspective of the Chalana student. European Journal of Education Studies 7 (3). https://doi.org/10.5281/zenodo.3753586.

Ozili, P.K., 2020. COVID-19 in Africa: socioeconomic impact, policy response and opportunities. Int. J. Sociol. Soc. Policy https://doi.org/10.2139/ssrn.3574767.

Parolin, Z., Wimer, C., 2020. Forecasting estimates of poverty during the COVID-19 crisis. Poverty and Social Policy Brief 2046. Center on Poverty and Social Policy, Columbia University https://ideas.repec.org/p/pov/povjri/2046.html. (Accessed 26 November 2020).

Poole, L., 2020. Seasonal Influences on the Spread of SARS-CoV-2 (COVID-19), Causality, and Forecastability (3-15-2020). https://doi.org/10.2139/ssrn.3554746.

Ranney, M.L., Griffith, V., Jha, A.K., 2020. Critical supply shortages—the need for ventilators and personal protective equipment during the Covid-19 pandemic. New England Journal of Medicine 382 (18), e41. https://doi.org/10.1056/NEJMep2006141.

Remuzzi, A., Remuzzi, G., 2020. COVID-19 and Italy: what next? The Lancet 395 (10221), 1225–1228. https://doi.org/10.1016/S0140-6736(20)30627-9.

Sahu, P., 2020. Closure of universities due to Coronavirus Disease 2019 (COVID-19): impact on education and mental health of students and academic staff. Cereus 12 (4), e7541. https://doi.org/10.7759/cereus.7541.

Sarkodie, S.A., Owusu, P.A., 2020. Impact of COVID-19 pandemic on waste management. Environ. Dev. Sustain. https://doi.org/10.1007/s10668-020-00956-y.

Sharma, H.R., Vanapalli, K.R., Cheela, V.K.S., Ranjan, V.P., Jaglan, A.K., Dubey, B., Coel, S., Bhattacharya, J., 2020. Challenges, opportunities, and innovations for effective solid waste management during and post COVID-19 pandemic. Resour. Conserv. Recycl. 162, 105052. https://doi.org/10.1016/j.resconrec.2020.105052.

Singh, D., 2020. Mental health of migrant laborers in COVID-19 pandemic and lockdown: challenges ahead. Indian J. Psychiatry 62 (3), 233. http://www.indianjpsychiatry.org/text.asp?2020/62/3/233/284460.

Stata, 2020. The statistics portal for market data. Available at: https://www.stata.com/. (Accessed 26 November 2020).

UNEP, 2020. United Nations Environmental Programme. Waste Management During the COVID-19 Pandemic. Responses to Recovery, From Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/WMC-19.pdf. (Accessed 11 December 2020).

WHO, 2020a. Coronavirus disease 2019 (COVID-19) situation report – 51. Available at: https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200311-sitrep-51-covid-19.pdf?sfvrsn=1ba62e57_10. (Accessed 20 March 2020).

WHO, 2020b. Coronavirus disease 2019 (COVID-19) situation report – 54. Available at: https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200314-sitrep-54-covid-19.pdf?sfvrsn=dd6751_8. (Accessed 20 March 2020).

WHO, 2020c. Coronavirus Disease (COVID-19) situation report – 193. Available at: https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200731-covid-19-sitrep-193.pdf?sfvrsn=42a0221d_2. (Accessed 1 August 2020).

WHO, 2020d. World Health Organisation. Available at: https://www.who.int/. (Accessed 24 November 2020).