Environ Monit Assess (2023) 195:155
https://doi.org/10.1007/s10661-022-10771-9

COVID-19 impacts on household solid waste generation in six Latin American countries: a participatory approach

Norvin Requena-Sanchez · Dalia Carbonel · Stephan Moonsammy · Larissa Demel · Erick Vallester · Diana Velásquez · Jessica Alejandra Toledo Cervantes · Verónica Livier Díaz Núñez · Rosario Vásquez García · Melissa Santa Cruz · Elsy Visbal · Kelvin Tsun Wai Ng

Received: 4 August 2022 / Accepted: 16 November 2022 / Published online: 28 November 2022

Abstract The COVID-19 pandemic has greatly impacted the Americas, the continent with the highest number of COVID-related deaths according to WHO statistics. In Latin America, strict confinement conditions at the beginning of the pandemic put recycling activity to a halt and augmented the consumption of plastic as a barrier to stop the spread of the virus. The lack of data to understand waste management dynamics complicates waste management strategy adjustments aimed at coping with COVID-19. As a novel contribution to the waste management data gap for Latin America, this study uses a virtual and participatory methodology that collects and generates information on household solid waste generation and composition. Data was collected between June and November 2021 in six countries in Latin America, with a total of 503 participants. Participants indicated that the pandemic motivated them to initiate or increase waste reduction (41%), waste separation (40%), and waste recovery (33%) activities. Forty-three percent of participants perceived an increase in total volume of their waste; however, the quantitative data showed a decrease in household waste generation in Peru (−31%), Honduras (−25%), and Venezuela (−82%). No changes in waste composition were observed. Despite the limited sample size, this data provides a much-needed approximation of household waste generation and composition in the pandemic situation during 2021.

Keywords Household Solid Waste · Waste Composition · COVID-19 · Latin America

Introduction

In March 2020, the arrival of COVID-19 in Latin America triggered declarations of health emergencies and confinement in most countries of the region. Between March and September 2020, most of Latin American countries imposed strict confinement measures and put most economic activities to a halt. Along with that, mask mandates were placed between April and July 2020 (France24, 2020). According to WHO data (WHO, 2022), the Americas is the region which the highest number of COVID-19 related deaths. Within Latin America, Brazil, Mexico, and Peru led the ranking of total number of deaths (Fig. 1).

This unprecedented situation worldwide has caused a series of positive and negative environmental impacts

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10661-022-10771-9.

N. Requena-Sanchez · D. Carbonel (✉)
Integrated Waste Management for Sustainable Development Group, Faculty of Environmental Engineering, National University of Engineering, 210 Túpac Amaru Ave, Rímac, Lima, Peru
e-mail: dcarbonelr@uni.pe

N. Requena-Sanchez
e-mail: nrequenas@uni.edu.pe

Extended author information available on the last page of this article.

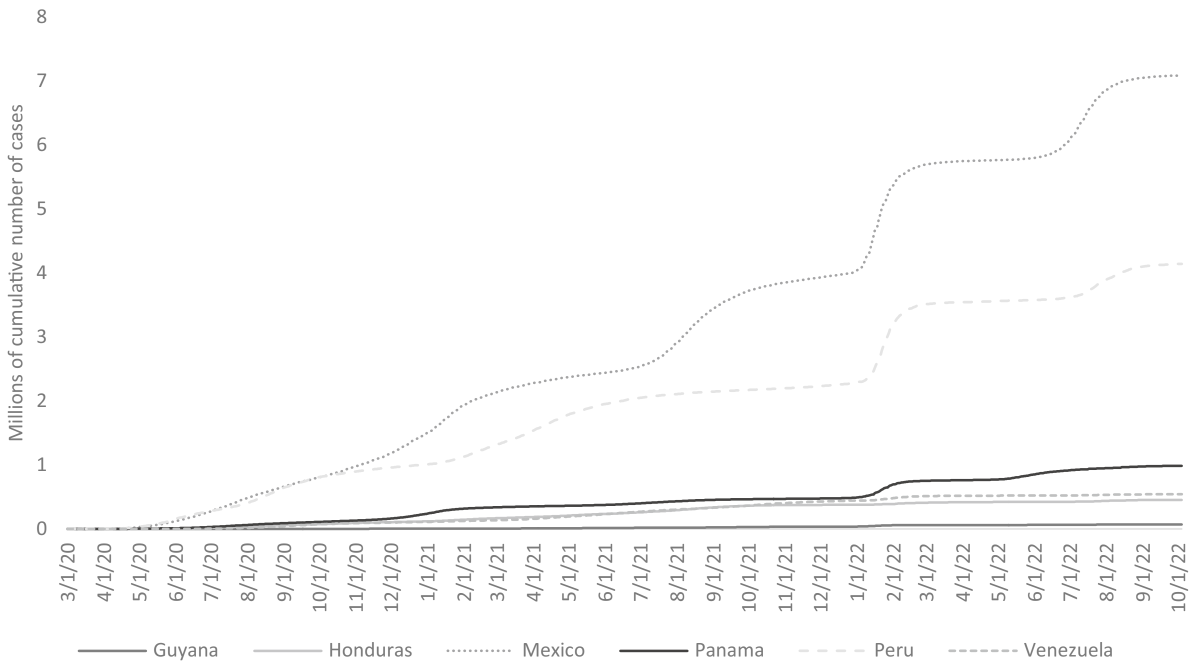


Fig. 1 Cumulative number of cases in the six countries of study from March 1st 2020 to October 1st 2022. Note. Data taken from WHO (2022)

(Zambrano-Monserrate et al., 2020). The positive environmental impacts are related to the short-term effects of confinements, such as the reduction of greenhouse gas emissions, the lessening of noise pollution, the improvement of environmental cleanliness and recovery of spaces by wildlife, among others. Negative impacts are associated with waste generation as a result of increased consumption of plastic products to protect against the spread of the virus (Wang et al., 2021), increased organic and inorganic contaminants due to an increased use of soaps and antibacterial products, increased water consumption and wastewater generation, among others (Ankit et al., 2021).

At the onset of the pandemic, people were required to stay at home for longer-than-conventional periods of time, which affected waste generation and composition (Vu et al., 2021a, b; Yousefi et al., 2021). In many cities there was an increase in municipal waste generation, but also an increased awareness of food waste generation (Vidal-Mones et al., 2021).

Just as the impact on waste generation and composition has varied globally, so have the strategies implemented by governments to deal with COVID-19 (Mahmud et al., 2022). At the beginning of the pandemic, fear of the spread of the virus led to a halt in recycling activities in many Latin American cities (Comunicarse, 2020; Urban & Nakada, 2021). Then, as day-to-day activities in the cities were resumed and health institutions recommended biosecurity measures against the spread of the virus, the consumption of plastics began to increase (Jiménez Gómez Tagle & Cilia-López, 2021; Singh et al., 2022b). In developed countries with more established recycling systems, intermediate storage, incineration or disposal was prioritized over recycling. During the first year of the pandemic, the UK Environment Agency allowed temporary storage of waste and incineration ashes at sites that did not have a permit to do so (You et al., 2020). In Norway, the government prioritized the expansion of interim waste storage site capacity and, in Austria's capital Vienna, no waste was taken directly to its final disposal site; rather, all waste treatment plants worked at maximum capacity, with the residual waste being taken to waste-to-energy plants (Tripathi et al., 2020).

This increase in the use of plastics was caused by two changes: the greater permanence of household members at home, which increased the frequency of online shopping, delivery and meal take-out behaviors (Richter et al., 2021), and by the resumption of activities outside the home, which increased the use of protective barriers against the virus, such as masks, gloves, face masks, and plastics in general (Almulhim et al., 2021).

This change in the generation and composition of municipal waste has increased the pressure on waste management systems. In developing countries, this has been particularly severe given that these systems were already not meeting waste management needs before the pandemic. In the pandemic context, waste management systems have collapsed, and local governments have not been able to adequately manage the excess waste (represented mainly in the form of plastics and facemasks) (Mahyari et al., 2022).

To address this situation, it is important to have real and updated information on the composition and generation of municipal solid waste. This type of information is essential for planning adequate storage, collection, treatment, recycling and final disposal of waste. However, in Latin America, there is a lack of information on this subject; indicators of waste generation and composition are often outdated, dispersed and so variable that it is difficult to compare them (Kaza et al., 2018; Savino et al., 2018).

To the authors' knowledge, there is no quantitative data for Latin America that accounts for the generation and composition of household solid waste (HSW) during the COVID-19 pandemic. It is precisely this information gap that the results and methodology applied in this study seek to fill. Based on the hypothesis that the COVID-19 pandemic has changed household solid waste generation and composition; the aim of the study was to gather quantitative and qualitative data on changes on household waste generation and composition. This study presents qualitative data on the perception of the impact of the pandemic on HSW and quantitative data on the generation and composition of HSW during the pandemic. It furthermore presents comparative trends on generation and composition during and prior to the pandemic in select countries. The results presented here are a first approximation of HSW generation utilizing source weighting data. The methodology proposed in this study can be useful to collect quantitative information and monitor changes in HSW generation to adapt local waste management strategies accordingly.

Material and methods

The study was conducted between June and November 2021. By the time of study, there were not any regulations in force in any of the study areas related to quarantine or stay at home mandates. Masks were still mandatory in public and enclosed spaces in five of the countries of study: Guyana, Honduras, Panama, Peru and Venezuela. Face shields were mandatory in public transportation in Panama and Peru.

Study participants

Students and volunteers from Panama, Honduras, Guyana, Venezuela, Mexico and Peru participated in the study (Table 1). Two groups of participants can be distinguished: university students participating as part of a class and adult volunteers. In both cases, the study sample was selected based on the willingness of university professors and researchers to collaborate in the study. The lead researchers of the study initially approached professors and researchers to explain the methodology and research objectives.

Both groups of participants invested the same amount of time and were delivered the same information. The students participated in the study as part of a class taught by their professors, who had been approached by the lead researchers of this study. The lead researchers would use two of the professors' classes as training sessions to expound the basic concepts of waste management and a detailed explanation of the study methodology. Students would have to complete all the required Google Forms and submit the data of the 7-day study conducted in their homes in order to pass the course. Through this incentive, continuous data delivery by study participants and a minimal dropout rate could be ensured. For the group of volunteers, a higher desertion rate was observed, since volunteer participants attended training sessions, applied the methodology and collected the data in their spare time.

Study sequence

The quantitative characterization of HSW was carried out by applying the methodology described in Requena-Sanchez et al. (2022). The study consisted of four stages:

Table 1 Number and prevenance of study participants in 2021

Country	City	Location	Month	Sample size
Peru	Lima	UNI	June	71
	Bagua	UNIFSLB	June	44
	Cerro de Pasco	UNDAC	June	32
	Lima	UNI	November	35
Honduras	Tegucigalpa	UNAH	June	25
Panama	Panama	UTC	June	40
	Panama	Volunteers convened by UNDP Accelerator Labs	October	136
Mexico	Gudalajara	UdeG	October	47
Venezuela	Caracas	USB, Caracas	October	25
Guyana	Georgetown	University of Guyana	November	24
			Total	503

UNI National University of Engineering, *UNIFSLB* Intercultural National University Fabiola Salazar Leguía from Bagua, *UNDAC* Daniel Alcides Carrión National University, *UNAH* National Autonomous University of Honduras, *UTC* Technological University of Panama, *UNDP* United Nations Development Program, *UdeG* University of Guadalajara, *USB* Simón Bolívar University

(i) participant registration, (ii) training sessions, (iii) 7-day waste characterization and (iv) data submission.

In the first stage, participants were provided with a Google Form into which they provided basic information such as name and location as well as six questions aimed at assessing participants' perception of changes in HSW at home caused by the pandemic. The first three questions were aimed at understanding to which degree participants felt that there had been changes regarding the amount of waste generated at their houses during the pandemic. Specifically, participants were asked whether they perceived any variations on the total, inorganic and organic waste generated at home. The latter three questions assessed whether confinement conditions had led to changes in their domestic waste generation habits, whether they had begun to separate their waste as a result of the pandemic, to recycle their organic waste or intended to reduce the amount of waste generated, respectively.

In the second stage, participants received two training sessions. The first one, usually given by the respective professors, on the solid waste management context in the study location. The second session was held by the lead researchers to reinforce some basic waste management concepts, sensitize the participants on the importance to segregate their waste, and give a detailed explanation on how to conduct the waste characterization study at home.

In the third stage, during the 7-day waste characterization study, participants installed segregation bins in their homes and provided household members with waste segregation instructions for the week of the study. Every day, participants weighted each waste fraction and recorded the fraction weights in a Word template provided by the research team. Participants classified their waste in ten categories (Online Resource 1): organics (pruning and garden waste, fruit and vegetable residues generated during food preparation and similar), plastics, recyclables (paper, carboard, glass, cans, and similar), sanitary (papers, pads and similar), food waste, non-recyclable plastics such as plastic wraps or single-use plastic bags (that participants would stuff in a plastic bottle to compact and thus form an "Ecobrick"), hazardous waste, used cooking oil, electronic waste, and others (fabrics, leather, and any other waste not considered in the any of the categories). In addition to that, a WhatsApp group was created so participants could have a space to share their progress during the week and ask any questions they had on specific types of waste and into which category to sort if.

In the fourth stage, after the completion of the study week, participants submitted all data via a Google Form. They input the total weight of each waste fraction generated during the entire week. In order to verify the data submitted by the participants, they were asked to attach the filled-in World template to the Google Form.

Data processing and analysis

Descriptive statistics were used to analyze qualitative survey data. Sample size was dependent on the number of participants willing to complete the study. After processing all submitted data, the sample size was calculated using the validated data. Only after having established the sample size, the margin of error of the waste per capita (WPC) value was estimated using Eq. (1) (Cantanhede et al., 2005).

$$n = \frac{Z^2_{1-\alpha/2}\, N\sigma^2}{(N-1)E^2 + Z^2_{1-\alpha/2}\sigma^2} \quad (1)$$

where $Z^2_{1-\alpha/2}$ is the confidence coefficient (1.96), (1-α) is the confidence level (95%), N the population size, n the sample size and E the margin of error.

The results of the WPC were compared with the 2020 results obtained with the same methodology and with unpublished results. Comparisons were made against 2020 data for the city of Lima and at the national level for Peru, Panama, and Honduras. The city of Lima is the biggest city of Peru and holds one third of the country population (Inei, 2018); therefore, it was relevant to depict the changes registered in the WPC for this particular city. The data at the national level for Peru comprises mainly the cities of Lima, Arequipa and Huancayo.

Official WPC data for Peru and Lima were obtained from the Ministry of Environment (Sigersol, 2021), the Urban and Household Sanitation Authority for Panama (INECO, 2017), and the Ministry of Environment (Mi Ambiente, 2017) for Honduras. The error of the official WPF data for Panama and Honduras was assumed to be 10%; this data point did not appear in the information sources, however, the 10% error is usually the basis on which the sample number is calculated in conventional waste characterization studies (Dangi et al., 2008; Gomez et al., 2008).

Results and discussion

Changes in waste segregation, recovery, and reduction habits at home

Participants answered three questions about the effect of the pandemic on their HSW generation practices (Fig. 2). Waste reduction activities were performed by more participants (42%) than segregation (24%) and recovery activities (18%). In line with those results, almost half of the participants reported not to have performed any waste recovery activities (49%) and more than a third (36%) reported they did not segregate their waste. Forty percent and 41% of participants responded that they started or increased the frequency of waste segregation and waste reduction activities during the pandemic. A third of the participants said they started or increased the frequency of waste recovery activities like composting.

At the onset of the pandemic, household waste management practices changed. For example, in Canada, Ikiz et al. (2021) studied the changes on recycling habits in multi-residential buildings in Toronto and found out that, during the early stages of the confinement, due to the halt of recycling activities, waste separation practices decreased to a large extent. At the same time, the pandemic conditions motivated greater environmental

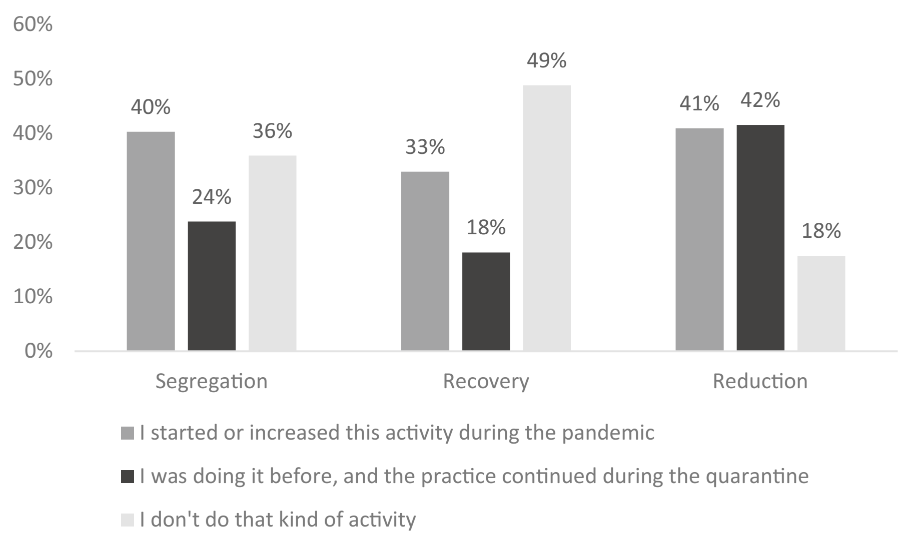


Fig. 2 Perceived changes in waste segregation, recovery, and reduction

awareness (Ali et al., 2021). Other authors have found positive changes in waste management practices and environmental awareness during the pandemic. After conducting a survey with 314 Chinese adults, Daryanto et al. (2022) concluded that the belief that the pandemic was caused by an excessive intervention of mankind into nature had a positive impact on environmental awareness. In line with those findings, Severo et al. (2021) found out that the pandemic influenced sustainable consumption and environmental awareness among the surveyed participants from Brazil and Portugal.

Even though there have been some positive changes in waste generation habits during the pandemic; now, in 2022, with the resumption of economic activities in Latin America almost back to normal, it will be important to evaluate the sustainability of those practices that were initiated or increased during confinement.

Waste generation

Overall, the majority participants do not perceive a decrease on HSW generation (Fig. 3). Almost half of the participants believe there has been some increase on their waste generation; 54% has felt an increase in their organic waste, 41% in their inorganic waste and 43% in their total volume of HSW. A little more than a third of the participants perceived that there are no changes in their waste generation for household (38%), inorganic (37%), and organic (36%) waste. The minority of participants has noticed a decrease in waste generation; 10% in their organic waste, 22% in the inorganic, and 19% in the total volume of waste.

Several survey-based studies have also consistently reported population perceived that the pandemic caused an increase in HSW generation. In a survey conducted in Nepal in August 2020 (Acharya et al., 2021), 34.8% of respondents thought that household waste generation increased during the confinement and curfew, 57.8% thought that there was no change and only 7.4% of participants perceived a decrease in waste volume. In another survey, conducted in Nigeria and Guyana between August and November 2020 (Filho et al., 2021), 45% and 55% of respondents, respectively, indicated an increase in the consumption of packaged food, fresh food, food delivery and waste generation.

The results of the household WPC values obtained in this study in 2021 (Table 2) are lower than the values of pre pandemic studies in Peru, Honduras, and Venezuela. In the case of Guyana, it is difficult to establish a comparison because the most recent value is from 2010 and corresponds to municipal waste. In the case of Panama and Mexico values are very similar, considering the upper limit of the margin error. However, it is important to note that the data cited is over 5 years old for both countries. Taking this into account, the household WPC of 2019 (the baseline before the pandemic) could be even higher than the one cited; and therefore, the household WPC of this study could be lower than the household WPC before the pandemic.

With more household members staying at home and the increase of plastic use, HSW generation is expected to rise (Mahyari et al., 2022). The results of this study demonstrate the opposite to what has been found by

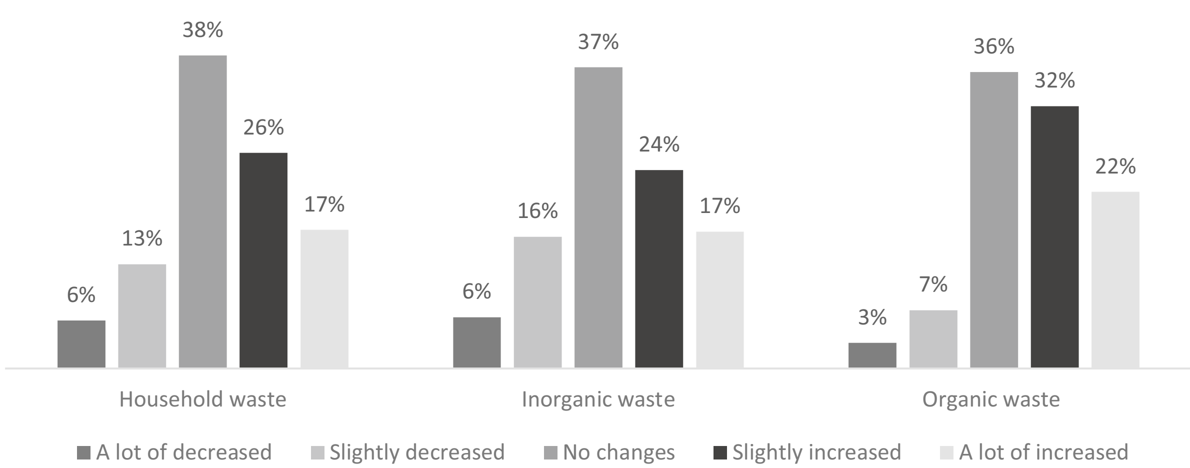


Fig. 3 Perceived changes in waste generation during the pandemic

Table 2 Household WPC (kg/capita/day) in the 6 study areas before and during the pandemic

	Peru	Honduras	Panama	Guyana	Mexico	Venezuela
This study (2021, during the pandemic)						
WPC	0.391	0.490	0.541	0.589	0.392	0.199
Error	8.39%	24.24%	20.55%	23.44%	24.61%	33.13%
N	166	27	50	22	31	9
Other studies (before the pandemic)						
WPC	0.46–0.57	0.50–0.61	0.55–0.660	1.35[a]	0.437–0.456[a]	0.11–0.63
Year	2018–2020	2003–2010	2010–2017	2010	2009–2017	2013–2018
Reference	(Minam, 2019, 2020, 2021)	(OPS, 2003; Tello Espinoza et al., 2011)	(Ineco, 2017; Tello Espinoza et al., 2011)	Ministry of Communities, 2017	(Alvarado Centeno et al., 2009; Araiza Aguilar et al., 2017)	(Sánchez et al., 2014; Villalba et al., 2019)

[a]Corresponds to data from Berriozábal (in Chiapas province). The municipal WPC calculated in this case study (0.619 kg/cap/day) is very similar to the municipal WPC reported for the country in 2020 (0.622 kg/cap/day). As no official national data were found for household WPC, these data were used

many researchers reporting an increase in HSW generation (Filho et al., 2021; Qian et al., 2020; Sarkodie & Owusu, 2020); although it is important to notice that these researchers report the results of survey-based studies which were implemented during 2020. Therefore, it is likely that the perception of the population regarding waste generation could have varied between 2020 and 2021. Also, this contradiction could be related to the different nature of the methodologies applied. To this date, there is no internationally agreed-upon standard method to conduct HSW characterization studies (Dahlén & Lagerkvist, 2008). The cited studies rely on surveys and the participants' observations and perceptions, whereas our results rely on quantitative data generated by the participants. Data obtained with the methodology proposed in this study relies on quantitative information collected in the form of daily weight values. Waste studies based on quantitative analysis are more objective and accurate (Langley et al., 2010). The reliability of the information on survey-based waste composition studies lies in the participant-recorded and recalled data. They require close cooperation by respondents and careful supervision by the interviewer (Pekcan et al., 2006). Furthermore, it is not uncommon that descriptions of methodology, especially in national official reports, lack significant information so that results can be reproducible and comparable. To obtain reliable data to plan and evaluate waste management strategies, authoritative data are required (Lebersorger & Schneider, 2011). Among the six countries evaluated, only the Ministry of Environment in Peru has published national guidelines to conduct waste characterization studies (Minam, 2018) which are based on the recommendations made by the Pan American Center, a specialized Sanitary Engineering and Environmental Science (CEPIS) center.

Figure 4a, b shows a comparison of data obtained with the same methodology in 2020 and 2021 for the city of Lima and at the national level for Peru. A progressive decrease in household WPC is observed between 2020 and 2021, −22% for Lima and −9% for Peru. This decrease could be related to the return and reactivation of economic activities; many household members could have resumed their work activities and spend less time at home compared to the previous year. It has been observed, for example, that eating alone causes less food waste (Qian et al., 2021). By spending less time at home, therefore, less waste is generated in the household. Furthermore, it has been observed that higher levels of education are correlated to reduced food waste volumes (Qian et al., 2021) and that students tend to generate less waste than other groups of people (Li et al., 2011).The decrease in WPC could thus be related to the characteristics of this particular sub-sample's participants, primarily students in environmental careers who might have above-average levels of awareness on their household volume of waste generated.

In the case of Panama, the household WPC of 2020 and June 2021 showed similar values; however, the value obtained in October 2021 was higher than the two previous ones (Fig. 4c). This result is possibly related to the October 2021 sub-sample that consisted

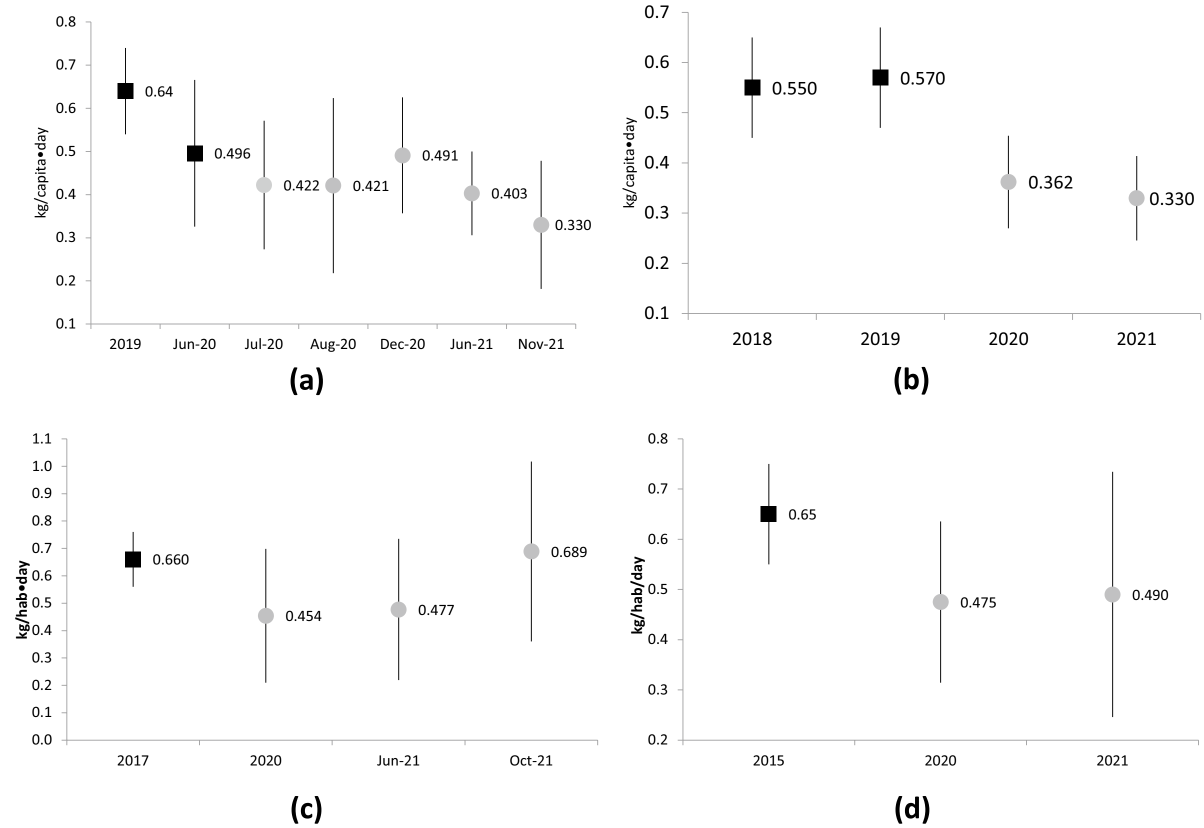


Fig. 4 Variation in household WPC (kg/capita/day) in Metropolitan Lima (**a**), Peru (**b**), Panama (**c**), and Honduras (**d**). Note: The bars represent the WPC margin error, the black square represents official data from the Ministry of Environment (**a**, **b**), the Urban and Household Cleaning Sanitation Authority for Panama (INECO, 2017) (**c**) and MiAmbiente data. The gray circles the data collected by the researchers of the study

of volunteers from different parts of the country convened by UNDP Panama, whereas the two previous sub-samples were undergraduate university students in Panama City. It is accepted that many factors such as economic, physical, sociocultural, geographical, and political ones can influence urban waste composition and generation (Gallardo et al., 2014). Some of these factors could account for the difference of the data for October 2021. The results of the 2020 and 2021 Honduras WPC are similar (Fig. 4d). Again, this may be related to the sample, which in both years consisted of university students.

The perceived increase in waste generation is contradicted by the quantitative results for 2020 and 2021. Many studies have reported an increase in municipal waste generation (Hantoko et al., 2021; Sharma et al., 2020; Tripathi et al., 2020). However, these values include municipal solid waste, commercial waste and, at least during the first half of 2020, recyclable waste (which was affected by the halt of recycling activities). The authors have not located another study that has performed a quantification of HSW generation during the pandemic and obtained a household WPC value between 2020 and 2021; therefore, in the absence of other data and the sample size limitations in the present study, it becomes difficult to ascertain whether a quantitative decrease in HSW generation actually occurred as indicated by the 2020 and 2021 results.

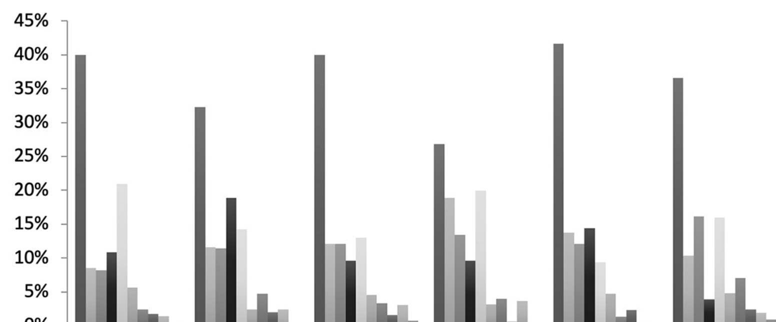
Responses indicating a perceived increase in HSW could be influenced by what respondents observe in the news, the participation in a waste-related survey, and even by the way the question is phrased. These factors could contribute to biasing participants' responses.

Similarly, a clear decrease in household WPC is observed when contrasted with official data from previous years. This could be due to the methodology used, the sub-samples selected in the study and to biases in the perception of the respondents. To verify this, a solid waste characterization study with field work would have to be carried out to compare the results. Another factor could be the currency, validity and quality of the official data as these data sets are not continuously updated and, in many of the countries studied, only the value of the WPC is reported but not the error, sample size or details of the methodology used. This is also the case for data sets on food waste quantity and composition for example, in which available data is fragmentary (Langley et al., 2010; Parfitt et al., 2010) and comparable systematic data is missing (Lebersorger & Schneider, 2011).

Waste composition

Figure 5 shows the waste composition according to the 10 categories of the methodology used (see Online Resource 1 for a detailed description of types of waste considered in each category). The composition of organic waste (organic plus food waste) varied between 48 and 62%; the plastic composition between 8.5 and 18.9%; that of recyclables (glass, metals, paper, and cardboard) between 8.2 and 16.1% and that of non-usable waste (sanitary, hazardous, others) between 18 and 29%. These percentages are similar to those reported by the World Bank for Latin America and the Caribbean (Kaza et al., 2018). In that report, the composition was 52% organic waste, 12% plastics, 21% recyclable waste (glass, metals, paper and cardboard) and 16% for non-usable waste (rubber, latex and others). The lack of detailed, current and reliable data makes it difficult to identify any changes on waste composition before and during the pandemic. In any case, there are no noticeable changes in waste composition in comparison to the World Bank pre-pandemic data for Latin America.

In general, data from scientific articles, publications and governments indicate an increase in food and plastic waste generation (Hantoko et al., 2021), packaged food and take-out food waste (Filho et al., 2021); and HSW in general (Oyedotun et al., 2020). However, more specific studies conducted at the beginning of the pandemic showed that staying at home and having to shop for several days has positively influenced the reduction of food waste (Ikiz et al., 2021; Jribi et al., 2020). A study done in Italy, between March and May 2020 on household food waste, found that during confinement the population generated a lower amount of waste per day. The authors explain that this is because households have had more time for meal planning and optimization of ingredients and leftovers, among others (Amicarelli & Bux, 2021). Taking into account that approximately 50% of waste is organic (Online



	Peru	Honduras	Panama	Guyana	Mexico	Venezuela
Organics	40%	32%	40%	27%	42%	37%
Plastics	8%	12%	12%	19%	14%	10%
Recyclable	8%	11%	12%	13%	12%	16%
Sanitary	11%	19%	10%	10%	14%	4%
Food waste	21%	14%	13%	20%	9%	16%
Others	6%	2%	5%	3%	5%	5%
Hazardous	2%	5%	3%	4%	1%	7%
Ecobrick	2%	2%	2%	1%	2%	2%
Used oil	1%	2%	3%	4%	0%	2%
Electronic waste	0%	0%	1%	0%	0%	1%

Fig. 5 Waste composition in the six study areas

Resource 1) and that the pandemic has motivated a greater awareness in food preparation and a reduction of this type of waste, this could be one of the reasons for the decrease in WPC. Another reason may be the low proportion of plastic waste. The increase in household waste generation has been explained by many authors by an increased consumption of plastics (Klemeš et al., 2020; Shekhar et al., 2022; Singh et al., 2022a). However, the waste composition results (Online Resource 1) show that the percentage of plastic waste varied between 8.5 and 13.7% (excluding Guyana). Coincidentally, in Guyana, the study area with the highest household WPC value (0.595 kg/inhab/day), the proportion of organic waste was the lowest and the proportion of plastics the highest. The low proportion of organic waste is not expected in Guyana as the management of organic waste has been recognized as one of the challenges faced by the waste management authorities in the country (Ansari, 2010). Furthermore, a household waste composition study found out that the vegetable fraction of waste accounted for 50.1% and the plastics fraction for 14.2% (Hydea, 2013). Therefore, these results could be influenced by the specific lifestyle choices from the participants of the study.

COVID-19 transmission can occur through contact with objects, the maximum survival time for the virus on plastics surfaces being up to 9 days (Kampf et al., 2020). As masks, gloves, and face shields could possibly be infectious, this is the main reason why they are considered hazardous waste (Kalantary et al., 2021). The pandemic has led to an increase in mask and glove littering and, along with it, an increase in the risk for potential infection via these items (Torkashvand et al., 2021). Furthermore, sick household members have augmented the volume of infectious waste generated (Kalantary et al., 2021).

It is no news that improper waste management can lead to health problems. As of 2000, the WHO reported that poor practices for medical waste management caused 21 million people infected with Hepatitis B (Selvan Christyraj et al., 2021). The proper management of hazardous waste will be extremely important in the future, as there are concerns that the virus can be transmitted from the waste to the community and waste management personnel (Nzediegwu & Chang, 2020) as well as waste pickers during transportation to final disposal facilities (Das et al., 2021).

Conclusions

This article presents a participatory virtual methodology to collect data on HSW generation and composition. The results gathered with this methodology provide an initial and first estimate of the waste generation and composition for a specific study area. To date, the authors are not aware of a similar study in which HSW generation is quantitatively estimated, nor of official data in the study areas of HSW generation during 2020 and 2021. Participants indicated that they initiated or increased waste reduction (41%), segregation (40%) and recovery (33%) activities as a result of the pandemic. Participants perceived an increase in waste generation; however, quantitative data showed a reduction on HSW generation during the pandemic in Peru (−31%), Honduras (−25%), and Venezuela (−82%). This could be related to the resumption of economic activities, which has reduced the time people spend in their homes and, therefore, the amount of HSW generated. However, in Panama, results showed an increase in HSW generation from 2020 to 2021 and, in Honduras, there were no major changes observed for the same period. Waste composition figures show no changes before and during the pandemic; however, the data available for comparison is limited.

These results provide a first-time quantitative approximation of HSW generation and composition during the pandemic in Latin America. Notwithstanding, it is important to mention the biases and limitations of the study. "Most participants (27%) are college and university students from environment-related courses between the age of 20 and 35 and the findings may not be representative for the whole country. Country selection depended on previous contacts from the lead researchers and the willingness of professors to participate in the study. Furthermore, the small and limited sample size prevents the extrapolation of results to a wider population. The latter and the absence of quantitative data collected through fieldwork restrict the comparison of the results. In this context, it is relevant to conduct further studies to compare the data gathered with this methodology and with a conventional field methodology to assess the difference among the collected data and make the necessary adjustments in the propose methodology.

Authors' contributions Norvin Requena-Sanchez: conceptualization, methodology, investigation, supervision. Dalia Carbonel:

formal analysis, investigation, writing—original draft, visualization. Stephan Moonsammy: investigation, writing—review and editing. Larissa Demel: validation, investigation, writing—review and editing. Erick Vallester, Diana Velásquez, Jessica Alejandra Toledo Cervantes, Verónica Livier Díaz Núñez, Rosario Vásquez García, Melissa Santa Cruz, and Elsy Visbal: investigation. Kelvin Tsun Wai Ng: writing—review and editing.

Funding This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the National Council of Science, Technology and Technological Innovation and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Consent to participate Informed consent was obtained from all individual participants included in the study.

Competing interests The authors declare that they have no competing interests.

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Authors and Affiliations

Norvin Requena-Sanchez · Dalia Carbonel · Stephan Moonsammy · Larissa Demel · Erick Vallester · Diana Velásquez · Jessica Alejandra Toledo Cervantes · Verónica Livier Díaz Núñez · Rosario Vásquez García · Melissa Santa Cruz · Elsy Visbal · Kelvin Tsun Wai Ng

S. Moonsammy
Department of Environmental Studies, Faculty of Earth and Environmental Sciences, University of Guyana, Turkeyen Campus, P. O. Box 10 1110, Georgetown, Guyana
e-mail: stephan.moonsammy@uog.edu.gy

L. Demel
United Nations Development Program, Casa de las Naciones Unidas, Edificio # 129, Ciudad del Saber, Panama City, Panama
e-mail: larissa.demel@undp.org

E. Vallester
Technological University of Panama, Avenida Universidad Tecnológica de Panamá, Vía Puente Centenario, Campus Metropolitano Víctor Levi Sasso, Panama City, Panama
e-mail: erick.vallester@utp.ac.pa

D. Velásquez
National Autonomous University of Honduras, Bulevar Suyapa, Tegucigalpa, Honduras
e-mail: diana.velasquez@unah.edu.hn

J. A. Toledo Cervantes · V. L. Díaz Núñez
University of Guadalajara, Av. Juárez No. 976, Colonia Centro, C.P. 44100 Guadalajara, Jalisco, Mexico
e-mail: toledojessica015@gmail.com

V. L. Díaz Núñez
e-mail: veronica.diaz01@academicos.udg.mx

R. Vásquez García
Daniel Alcides Carrion National University, Av. Los Próceres 703, Yanacancha, Cerro de Pasco, Peru
e-mail: rvasquezg@undac.edu.pe

M. Santa Cruz
Intercultural National University Fabiola Salazar Leguia From Bagua, Jirón Ancash N° 520 Bagua, Amazonas, Peru
e-mail: melly89sc@gmail.com

E. Visbal
Litoral Headquarters, Simón Bolívar University, Camurí Grande, Edo. Vargas Parroquia Naiguatá, La Guaira, Venezuela
e-mail: evisbal@usb.ve

K. T. W. Ng
Environmental Systems Engineering, Faculty of Engineering and Applied Science, University of Regina, 3737 Wascana Parkway, Regina, SK, Canada
e-mail: kelvin.ng@uregina.ca