

Oyedotun, Temitope D. Timothy et al.

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Municipal waste management in the era of COVID-19: Perceptions, practices, and potentials for research in developing countries

Temitope D. Timothy Oyedotun^{a,*}, Oluwasinaayomi Faith Kasim^{a,b}, Ayomide Famewo^b,
Temitayo Deborah Oyedotun^c, Stephan Moonsammy^d, Nasrudeen Ally^a, Donna-Marie Renn-Moonsammy^e

^a Department of Geography, Faculty of Earth and Environmental Sciences, University of Guyana, P. O. Box 10 1110, Turkeyen Campus, Georgetown, Guyana

^b Department of Urban and Regional Planning, University of Ibadan, Nigeria

^c Faculty of Education and Humanities, University of Guyana, P. O. Box 10 1110, Turkeyen Campus, Georgetown, Guyana

^d Department of Environmental Studies, Faculty of Earth and Environmental Sciences, University of Guyana, P. O. Box 10 1110, Turkeyen Campus, Georgetown, Guyana

^e Pensa Fuori Concepts, #4 Parakeet Street, Trincity, West Indies, Trinidad and Tobago

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ABSTRACT

The novel COVID-19 pandemic has significantly impacted all facets of society globally. Often overlooked is the potential contamination of the waste disposed by individuals diagnosed with the virus. The proliferation of contaminated waste is expected to increase as cases increase. The pandemic has caused a surge in waste material stemming from the widespread use of disposable personal protective equipment at the household level. In the developing countries where waste management measures are relatively inadequate, the vulnerability of COVID-19 contraction from contaminated waste is high. This study intended to unravel the susceptibility of communities in the developing countries of Guyana and Nigeria to the potential spread of the virus through waste. The study explored the possibility of cross-contamination between residents and landfill scavengers, the community perception on the effectiveness of their solid waste practices, the notable changes in waste collection and waste disposal patterns, and also, the potential knowledge / policy gaps that exist. An online survey was administered within all the districts of the two countries and the qualitative assessment was conducted demonstrating the proportional trends in the responses of the participants. Findings showed that the communities were relatively perceptive about the issue of waste disposal and the potential contamination of COVID-19. The communities readily recognized the inefficiencies of the waste management systems and the need for policy intervention. Tackling the issue of COVID-19 and waste management in the developing countries of Guyana and Nigeria requires policies that are holistic and participatory involving stakeholder at all levels.

1. Introduction

Since the declaration of coronavirus infectious disease 19 (COVID-19) as a global pandemic (WHO, 2020a), its progression in countries around the world has been rapid and the daily reported statistics of the cases and casualties have been alarming (MacLean et al., 2020; Worldometers, 2020; WHO, 2020b). Notably, the effects of this pandemic have greatly impacted the social, economic, health, education, environmental and tourism sectors of society (AWWA, 2020; Fine, Reichle & Lord, 2020; CCSA, 2020; Wuyts et al., 2020). In the last few months, one of the areas where the environmental impacts of COVID-19 are most pronounced is in waste management (Klemeš et al., 2020; Nzediegwu & Chang, 2020). This is a major environmental concern because of the surge in the demand for and the use of plastic

products, protective gears, personal protective equipment (PPE), disposable life support equipment and general plastic supplies like syringes (Klemeš et al., 2020; Kampf et al., 2020; Nzediegwu & Chang, 2020), all used in the prevention and treatment of the virus. Before the COVID-19 pandemic, pollution of the terrestrial and marine environment as a result of increasing waste generation and poor waste management was already a growing issue globally (Yousif & Scott, 2007; Cecilia, 2012; Marshall & Farahbakhsh, 2013; Mukama et al., 2016; Boucher & Billard, 2019; Rajmohan et al., 2019). With the emergence of the pandemic, these concerns are now extended (Clark, 2020; Dente & Hashimoto, 2020; Nghiem et al., 2020; Ro, 2020).

To mitigate the spread of the COVID-19, countries around the world adopted and enforced many unprecedented measures (closure of schools, social and physical distancing, restrictions of a local and

* Corresponding author.

E-mail address: temitope.oyedotun@uog.edu.gy (Temitope D. Timothy Oyedotun).

international movement, workplace closures). Despite these adopted methods, the advanced countries had to maintain priority in delivering essential services which play a vital role in curbing the spread of COVID-19. Such indispensable essential services include waste collection and management (AWWA, 2020; Lodder, & de Roda Husman, 2020; Mallapaty, 2020; Nghiem et al., 2020; CDC, 2020; WHO, 2020c). Within developed countries, green, and sustainable waste management is a common practice (Nzediegwu & Chang, 2020), and as a result, the established management structure contributes to the capacity to reduce the threats of spreading of the virus through the increasing waste generated at the household level. However, the poor and inadequate waste management strategies within developing and least developed countries contribute to a higher threat of community spread of COVID-19 (Nzediegwu & Chang, 2020). Examples of such poor or inadequate waste management practices are: open and poorly managed landfills where both human and animal scavengers can roam freely and interact with possible contaminated waste, reuse of potentially contaminated bottles, packages, and materials (Butot et al., 2007; World Bank, 2019; Nzediegwu & Chang, 2020).

Given the morphology and structure of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2; the viral name for COVID-19), the virus has a three-hour lifespan in the air as part of aerosols, a four (4) hour lifespan on copper surfaces, a twenty-four (24) hour lifespan on cardboards, a two to three (2–3) day lifespan on stainless steel materials, three (3) day lifespan on plastics and sewage, and a three to four (3–4) day lifespan on solid faeces (van Doremalen et al., 2020; Ye et al., 2016; Chin et al., 2020; Nghiem et al., 2020). Hence, the structure and lifespan of SARS-CoV-2 on some mediums or surfaces that are found in waste are of tremendous concern in the increasing spread of COVID-19 (Qu et al., 2020). Proper waste collection from households, quarantine facilities, hospitals, and structural management is, therefore, critical in the efforts to curb the spread of the disease through environmental media.

There are currently a significant number of documented and published impacts of COVID-19 on Nigeria (Akintunde, Chen & Di., 2020; Edomah & Ndulue, 2020; Okuonghae & Omame, 2020; Ohia, Bakarey & Ahmad, 2020; Mogaji, 2020; MacLean et al., 2020), while there are only a few references for Guyana in some of the published research works of the Caribbean and South America regions (Oyedotun & Moonsammy, 2020; WHO, 2020b). However, in all the publications for the two countries researched and as at the time of the writing of this paper, there is neither a published work on the impacts of COVID-19 on waste management for the two countries nor a published work on the perception of residents in the two coun-

tries relating to waste management. Considering these observations and coupled with the impact of COVID-19, this paper fills the gap in documenting the understanding of how COVID-19 is impacting waste handling and management in the developing countries.

This paper aims to 1) investigate the perceptions of residents living in Guyana and Nigeria on waste management systems and practices in place amidst COVID-19; and 2) identify and contribute to potential research gaps that can help in the policies strategized at addressing or mitigating the challenges of the pandemic. In this study, we examined the potential of the existing waste management practices in spreading or encouraging the spread of the SARS-CoV-2. We recognise that developing countries, especially Nigeria and Guyana sampled for this survey, have socio-economic and environmental difficulties that precede the COVID-19 pandemic. It is, therefore, hoped that this paper presents the needed information that can guide the policymakers across the sampled and similar countries in the planning on how to address the challenges that preceded but which are now exacerbated by the pandemic and thereby, chart a new course of action for individual countries and environments.

2. Materials and methods

2.1. Survey methods and contents

The primary sources for the data used in this study were generated through random questions prepared and presented in Google Forms and administered through social media to households of Guyana in South America and Nigeria in Africa (Fig. 1). The questionnaires were completed by a total of 489 households between 29th May and 7th June 2020. A three (3) step approach was used in data collection:

1) The creation of data collection form using Google Form (Mansor, 2012; Wiemken et al., 2018). The form that contained the questions for the survey was created and linked to one of the authors' Google user's accounts. The data and information on the survey were not made public until co-authors reviewed, edited, and corrected the questions where necessary. The Google Form created had 25 fields including but not limited to date/time stamp, location of the respondents' households, socioeconomic characteristics of the respondents and their households including their age, gender, etc., current situation and observation regarding general waste generation in their area, and some specific questions that related to waste management practices at the time of the pandemic in the respondent's community. The structure of the form provided flexibility with both open-ended

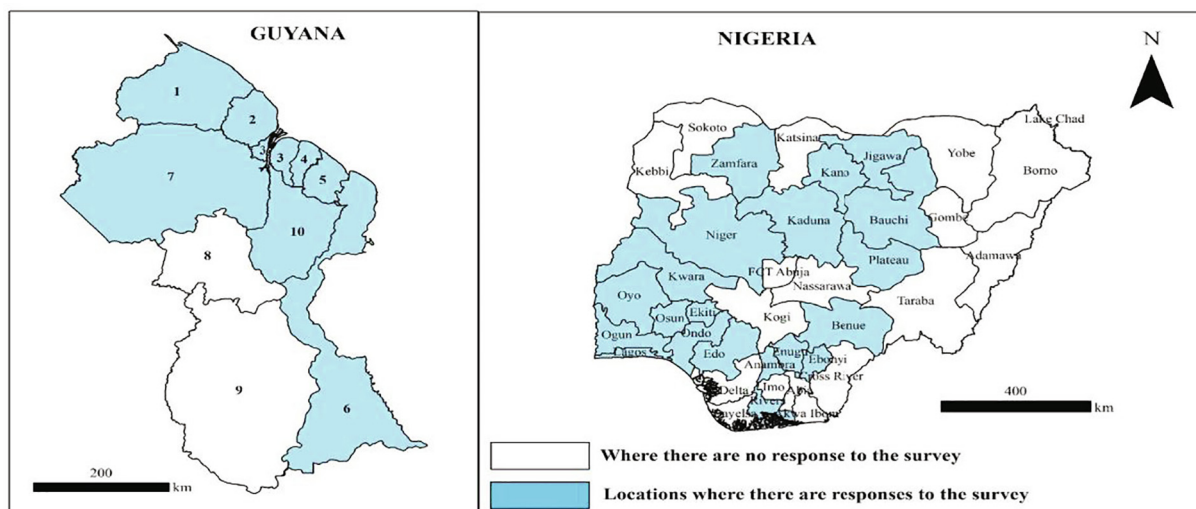


Fig. 1. Study areas indicating where there are household responses to the survey.

and closed-ended questions. The flexibility provided with the survey ensured that respondents could input text where necessary, while dropdown lists were also made available in addition to radio button provision for the selection of some variables and parameters.

2) The administration of the created form was published, and the links provided to individual households to help to respond the survey. We utilised several options for this task including sending the link through WhatsApp, Facebook, emails and professional networks. Due to the government-enforced lockdown restrictions and the social distancing regulations, a convenience sampling technique was used in this study. The campaign for this survey lasted for ten days.

3) The transfer of the collected data from Google Form to a spreadsheet for synthesis and qualitative analysis of the responses. Responses to the survey were automatically saved and stored in Google Forms. Google Forms allow direct linking of input with Google spreadsheets through the “responses” tab on the form (Mansor, 2012; Wiemken et al., 2018). The spreadsheets containing the data were downloaded and analysed using Microsoft Excel. For the findings presented in this paper, descriptive and exploratory analyses were performed.

2.2. Study area and survey overview: states and regions where the respondents' households are located and the overview of the survey

Out of the 489 households who responded to the survey, 273 households completed the questionnaires in Nigeria. The country has 36 states and questionnaires were gathered from respondents living in 21 states and the Federal Capital Territory, Abuja. Out of the ten (10) regions in Guyana, 216 households completed the survey and were principally from eight (08) out of the ten (10) regions (Fig. 1). From each household, one member was requested to respond to the survey. Household respondents to the survey conducted in Nigeria were based in states such as: Lagos, Oyo, Ondo, Osun, Ekiti, Ogun, Edo, Rivers, Anambra, Ebonyi, Enugu, Benue, Kwara, Kaduna, Niger, Jigawa, Plateau, Kano, Bauchi, Zamfara and Federal Capital. Similarly, respondents to the survey in Guyana are domiciled in all the regions apart from Regions 8 and 9 (Fig. 1). From the survey, Oyo State has the largest share of respondents both in the south-western part of Nigeria and in the survey generally, as it accounted for about two-fifths (39.7%) of the total respondents. This was followed by Lagos State which accounted for about one-fifth (21.7%) of the responses. In south-eastern Nigeria, Enugu had the largest share of respondents which accounted for about 3.3% of the total sampled respondent; while in mid-western Nigeria, the Federal Capital Territory, Abuja, had the highest number of households that responded to the survey, as this accounted for about 4.0% of the respondents sampled. From the responses to the survey (mapped and represented in Fig. 1), there are no responses from most of the states in the north west and north east of Nigeria. One of the reasons accounted for is that many households in these regions do not have access to online surveys like it was in the south.

In Guyana, Region 4 (Demerara-Mahaica) had more than half (51.4%), of the households that responded to the survey. This is followed by Region 10 (Upper Demerara-Upper Berbice) which accounted for about one third (26.9%), of the respondents, while Region 1 (Barima-Waini) has the least number of respondents at 0.9%. However, there were no respondents from Regions 8 (Potaro-Siparuni) and 9 (Upper Takutu – Upper Essequibo). Lack of internet access in these two regions might have accounted for the inability of households in providing their response to the survey.

2.3. COVID-19 situation and PPE in the study areas

The first COVID-19 confirmed case in Nigeria was reported on 27th February 2020 with the arrival of an Italian citizen to Lagos who tested positive for the virus (NCDC, 2020; MacLean et al., 2020; Ayinde et al., 2020). Whereas, the first confirmed case for Guyana was reported on

13th March 2020 (WHO, 2020a; Oyedotun & Moonsammy, 2020). From the dates of these confirmations to 7th August 2020, the number of confirmed cases and deaths that resulted from COVID-19 has increased significantly across the two countries. As of 7th August 2020, the total cumulative confirmed cases for Nigeria stood at 45,244 and the total number of mortalities from the virus was 930; while, confirmed positive cases for Guyana were 509 and cumulative deaths from the virus were 22, respectively. For these two developing countries sampled in South America/Caribbean (Guyana) and Africa (Nigeria), confirmed cases of COVID-19 continue to rise as its spread could be attributed to both symptomatic and asymptomatic cases (Rutayisire et al., 2020).

At the inception of this pandemic in developing countries, there was a paucity of data for its projection and impacts (Ayinde et al., 2020). However, over the months, many statistical models have been developed to project and confirm the active nature of COVID-19 in both developed and developing countries (Abdulmajeed, Adeleke & Popoola, 2020; Ademir, 2020; Ayinde et al., 2020; Giordano et al., 2020; Khan & Atangana, 2020; Yonar et al., 2020; Oyedotun & Moonsammy, 2020).

The primary waste management concerns are largely unexplored but pose the greatest challenge in spreading the virus with the proliferation of disposable PPE. The rampant increase in confirmed cases worldwide indicates a significant portion of the population undiagnosed using and disposing of PPE daily. The governments of many developing countries and their developed counterparts are taking measures to contain and reduce the spread of COVID-19. One of such measures adopted in Nigeria and Guyana is the use of face masks which is compulsory in public places with a fine charged on offenders (Rover, 2020; Africa Check, 2020). Because of this mandate and enforcement in these two countries, hundreds of thousands of PPE are manufactured and used daily (refer to Table 1 for the estimate). There is a possibility that the high volume of PPE disposed daily can be contaminated and a greater possibility of the contaminated PPE ending up as waste poses serious environmental and health risks (Kampf et al., 2020; Nzediegwu & Chang, 2020).

3. Results and discussion

3.1. Socio-demographic background and household perception

Table 2 presents the socio-demographic characteristics of the respondents. The study revealed that in Nigeria a majority of respondents (73.3%) were above 28 years while about 45.8% of the same age-bracket participated in the survey in Guyana. Thus, it can be implied that the majority of respondents in the two countries were above 28. Broadly, as revealed in Table 2, more than two thirds (63.7%) of respondents in Nigeria were male and about one-third (36.3%) were female; while in Guyana, about one-third (31.9%) were male and about two-thirds (68.1%) were female.

Presented in Table 3 is the summary of the household's perception of their waste generation when compared with the waste generated before and at this time of COVID-19 pandemic and the resultant lockdown that followed. In Nigeria, about two-thirds (60.8%) of households averred that there were increases in the quantity of their waste when the COVID-19 pandemic began, while over one-third (39.2%) believed that their waste did not increase as a result of COVID-19 pandemic. Similarly, in Guyana, two-thirds (63.4%) of respondents also affirmed that there was an increase in the waste generated as a result of the pandemic. However, about one-third (36.6%) did not observe any dramatic changes in the number of wastes generated during this period. The aforementioned attest that waste size was also impacted during COVID-19. This result further implies that through mobility restrictions and self-quarantine (Rover, 2020; Africa Check, 2020), more residents staying at home have caused an increase

Table 1
Estimated daily PPE use in Guyana and Nigeria.

Country	*Population	**COVID-19 cases as of 07 August 2020	*Urban Population (%)	***PPE Acceptance Rate (%)	***Average Daily PPE per capita	Total Daily PPE
Guyana	786,552	509	27	80	2	339,790
Nigeria	206,620,302	45,244	52	80	2	171,908,091
Total						172,247,881

Total Daily PPE = population × urban population (%) × PPE Acceptance Rate (%) × Average Daily PPE per capital / 10,000 (modified after [Nzediegwu & Chang, 2020](#))

*Data retrieved on 08 August 2020 from <http://www.worldometers.info>.

**Data retrieved on 08 August 2020 from <http://who.int>.

***Adopted data from [Nzediegwu and Chang \(2020\)](#).

Table 2
Socio-demographic characteristics of the respondents in Nigeria and Guyana.

Variable	Nigeria	Guyana
<i>Age</i>	Percentage (%)	Percentage (%)
Less than 18	0.4	8.3
19–23	5.1	24.5
24–28	21.2	21.3
Above 28	73.3	45.8
<i>Gender</i>		
Male	63.7	31.9
Female	36.3	68.1

Table 3
Changes in household-level solid waste during Covid-19 pandemic.

Variable	Nigeria	Guyana
<i>Waste Quantity</i>	Percentage (%)	Percentage (%)
Increase in waste	60.8	63.4
No increase in waste	39.2	36.6
<i>Level of increase</i>		
By less than a quarter	42.2	48.6
Two times increase	Nil	0.7
More than two times increase	57.8	50.7

in the quantity of solid waste generated at the household level. Although, the net change in solid waste might be accounted for by the expected fall in wastes at workplaces and/or as a result of the decrease in industrial activities. Thus, an increase in solid waste at household levels in these two countries might necessarily not imply an increase in solid waste at the municipal level or any regional or national scale.

Of those that indicated an increase in the household waste generation during this period, 57.8% of households in Nigeria averred that there was a double increase in the household waste quantity during the period, while 42.2% claimed that their waste increased by approximately a quarter. Similarly, in Guyana, about half, 50.7% of the households affirmed that their waste increased more than twice during the COVID-19 while more than two-fifths (48.6%) stated that their waste increased by less than a quarter of the usual amounts during the pandemic and at the time of the survey ([Table 3](#)). It thus, posits that there has been a significant increase in household solid waste generated as a result of the COVID-19 pandemic.

The summarised responses presented in [Table 4](#) show the presence/absence of PPE in household solid waste in the two countries sampled. In Nigeria, more than half (57.5%) of respondents affirmed the presence of PPE in solid wastes in recent times, while about two-fifths (42.5%) have not paid attention nor noticed the presence of PPE in household solid waste recently. Similarly, In Guyana, more than two-thirds (63.4%) respondents affirmed that PPE was present in their solid waste in recent times and about one-third (36.6%) claimed that PPE was not noticeable in their waste in recent times. The foregoing

Table 4
Presence of PPE of Household Solid Waste in Nigeria and Guyana.

Variable	Nigeria	Guyana
<i>Presence of PPE in Household Solid Waste</i>	Percentage (%)	Percentage (%)
Present	57.5	63.4
Absent	42.5	36.6
<i>Type of PPE present in the waste</i>		
Sanitizer's containers	2.6	0.9
Masks	11.0	12.0
Masks and sanitizers containers	6.6	6.5
Masks and gloves	8.8	2.8
Gloves	3.7	2.3
Gloves and sanitizer containers	0.7	0.5
All the above (Presence of all types of PPEs in household wastes)	27.5	38.4

observation therefore, suggests that there is a significant increase in PPE in recent times in the two countries as similar to other places in the world ([Kampf et al., 2020](#); [Nghiem et al., 2020](#); [Nzediegwu & Chang, 2020](#)). With the estimated daily use of 339,790 PPEs in Guyana, 171,908,091 in Nigeria and a combined total of 172,247,881 of PPE usages per day for the two countries ([Table 1](#)), noticeable presence of discarded PPE in solid wastes is a possibility in these countries.

With more countries around the globe recommending the use of PPE in addition to social distancing and frequent handwashing, many households are observing different types of PPE waste in their bins and surroundings. Of paramount notables observed are waste materials such as facemasks, medical gloves, and sanitiser containers ([Table 4](#)). For the 60.9% of households in Nigeria and 71.5% in Guyana, the presence of PPEs as observed in their waste ([Table 4](#)) shows that the materials that were previously being used by essential service providers/workers (e.g. caregivers, nurses, doctors, other people handling patients, etc.) are now being used by households. The high usage of these materials in the sampled countries are typical examples of household waste disposal circumstances and dynamics present around the world. The findings corroborate with the literature as voluntary and enforced recommendations of the use of PPE in countries ([Rover, 2020](#); [Africa Check, 2020](#)), is generating high volumes of PPE ([Nzediegwu & Chang, 2020](#)) thereby, presenting disposal and management challenges to the new forms of exponential waste type.

Prior to the COVID-19 pandemic, the municipal solid waste collection has been very critical, lacking public services in many cities especially in slum areas of many developing countries ([Mukama et al., 2016](#); WHO, 2020c). However, since the advent of COVID-19, there appears to have been a short-term impact on the treatment or attention given to municipal waste management in the developing countries ([Nzediegwu & Chang, 2020](#)). Based on the responses from the households sampled for this survey, 41.8% of the households in Nigeria where there was municipal waste collection arrangement previously, observed some short-term changes in the schedules of the waste collec-

tion (Table 5). However, in Guyana, the majority (75.9%) of households at the time of the survey affirmed the notable changes in their schedules of waste collection.

In area where there is no arranged municipal waste collection, different household waste disposal systems were adopted at the household level. In Nigeria, 65.9% considered taking their wastes to nearby dumpsites while about one-quarter (24.9%) adopted the burning or dumping in rivers, etc. (Fig. 2). Similarly, in Guyana, more than two-thirds (69.4%) prefer to dispose their waste at nearby dump sites despite the impacts of the pandemic on man and the environment. About one-fifth (20%) burn their waste, 3.7% adopt a long storage system by storing waste in the garbage until waste collectors come, and similarly, about 3.7% adopt other forms of unauthorized disposal methods. This observation implies that without an efficient centralized method, households are likely to be increasingly exposed to COVID-19 infection because of the methods of waste disposal and management practices. The surge in these types of household wastes from the COVID-19 pandemic is a threat indeed that could overwhelm the existing waste management systems in a similar note as the healthcare facilitators. (Klemeš et al., 2020).

3.2. Concerns for solid waste contamination and the spread of COVID-19

It was observed from Fig. 3 that more than one-third (35.5%) of respondents in Nigeria were extremely concerned about the contamination of solid waste during the pandemic, about one third (27.5%) were fairly concerned, about one-third (31.5%) were yet to give their thoughts on the issue and about 5.5% were unconcerned. In Guyana, about one-third (34.3%) respondents were extremely concerned with the contamination of solid waste, about one-third (31%) of respondents were fairly concerned, over one fifth (25.9%) of respondents were yet to give thoughts about the concern and about (8.8%) revealed that they were unconcerned. The foregoing analysis therefore, suggests that residents were fairly concerned with solid waste contamination of the virus during this pandemic. The results indicate a fair level of awareness regarding the waste management issue and COVID-19 spread amongst citizens of the two countries.

Presented in Table 6 is the level of agreement on the special waste collection strategy for PPE by respondents in the two countries. In Nigeria, more than nine-tenths (92.3%) of respondents agreed that there should be a special waste collection at the household level while about 7.7% disagreed. Similarly, in Guyana, more than nine-tenths (90.7%) of respondents agreed that a special waste strategy should be adopted at the household level, while about one-tenth (9.3%) disagreed on the special waste collection system. The conclusion that can be drawn from the foregoing analysis is that respondents in the two countries largely agree on a special waste collection strategy for PPE. The overwhelming consensus amongst the participants again demonstrates a public perception and the understanding of the dynamics of the waste management issue in curbing the virus. This bodes

Table 5
Municipal waste collection systems during the pandemic.

Variable	Nigeria	Guyana
<i>Change in schedule</i>	Percentage (%)	Percentage (%)
General observed changes	41.8	75.9
No observed changes	18.3	24.1
Undecided	39.9	-
<i>Specific routine changes</i>		
No routine	30.4	81.0
Daily	1.8	
Once per week	29.7	17.1
Twice weekly	1.1	0.5
Once per month	12.8	0.9
Twice per month	24.2	0.5

well for waste management policy strategies requiring public involvement.

The analysis in Table 6 shows that in Nigeria, a majority (88.3%) of respondents agreed on the separation of waste into different bags or bins, while about 11.7% of respondents disagreed on the separation strategy of sorting wastes into different bags/ bins. In Guyana, about nine-tenths (92.6%) agreed on the separation of waste into different kinds of bags/bins, while about 7.4% disagreed on sorting of waste into different bins. The public willingness to comply with potential waste management measures at the household level is noteworthy.

3.3. Potential contamination at landfills/dump and as source of the spread of COVID-19

The analysis in Table 7 reveals that in Nigeria, more than two-thirds (69.6%) respondents averred that there are no landfills/dumps within their neighbourhood while about one-third (30.4%) claimed that there is the presence of landfill/waste dump within their neighbourhood. Similarly, in Guyana, the majority (72.2%) of respondents averred that they do not have landfills/waste dump within their neighbourhood, while about one third (27.8%) of respondents in Guyana opined that there is the presence of waste dump in their neighbourhood. In Nigeria, the designation of landfill/ waste dumps is often addressed either by the federal and state government. However, the lack of regulated sanitary landfills at the local government levels might be a reason for the proliferation of dumps and unsanitary landfills in the neighbourhood.

As presented in Table 7, in Nigeria, a majority of (79.3%) respondents agreed that landfills can serve as food banks for livestock, while about one-fifth (20.7%) disagreed that landfills can serve as food banks for livestock. Similarly, in Guyana, a majority (76.2%) of respondents also agreed that landfills can serve as food banks for livestock, while slightly above one-fifth (23.8%) of respondents disagreed that landfills/dumps can serve as food banks for livestock. Due to the presence of many unsanitary landfills and dumps at the neighbourhood level, there is a high possibility that many of these unsanitary landfills are food banks for livestock. This view is also supported by the results obtained (refer to Table 7), hence, there is the need to control unsanitary landfills and dumps at the neighbourhood level. As the World Bank (2019) affirmed that in many developing countries, Nigerian and Guyana inclusive, solid wastes which are indiscriminately dumped at the open and often poorly managed landfills are locations of attraction for scavengers who often search for recyclable materials (often without any form of PPE) for their use or resale. Hence, such kinds of landfills could expose e scavengers (both human and livestock) to COVID-19, and thereby contribute to its spread (Nzediegwu & Chang, 2020).

To further ascertain if the existing landfills/waste dumps in these two countries serve as food banks for animals, the types of animals observed by the respondents were documented. The study revealed that in Nigeria, about two-thirds of animals noticed on landfills include a combination of dogs, goats, cows, pigs, and hens while dogs singlehandedly accounted for slightly one-tenth (13.9%), rodents accounted for 11.5%, and pigs accounted for 8.7%. However, in Guyana, more than nine-tenths (91.7%) of animals such as dogs, goats, cows, pigs, and hens were evident. As observed, the record for pigs is about 2.9% which is on the low end of the spectrum as with the other animals.

Furthermore, Table 8 shows the responses to the perception of households on the possibility of exposure of livestock to the COVID-19 and also the likely transmission of the virus from animals to humans at the neighbourhood level. In Nigeria, more than a half (56%) of the respondents averred that this is possible and slightly over two-fifth (44%) of respondents were on the contrary. However, in Guyana, about 45.8% of respondents affirmed the possibilities of exposure of livestock to the virus and subsequent animal to human trans-

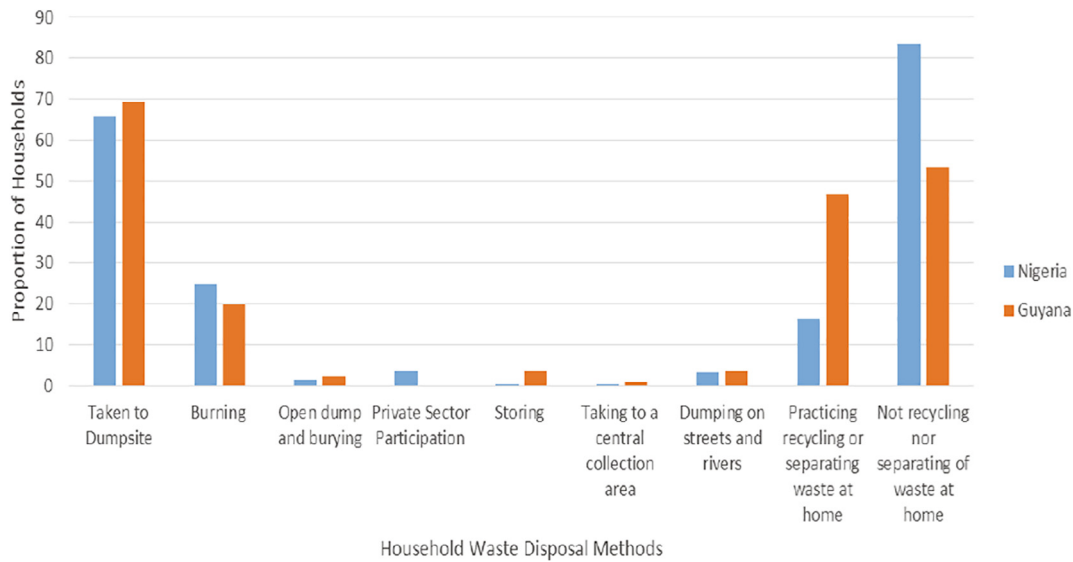


Fig. 2. Household Waste Disposal Approaches since COVID-19.

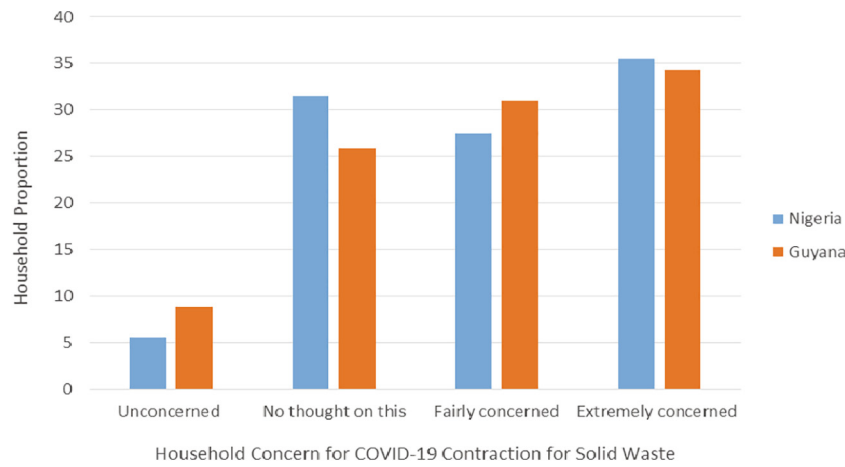


Fig. 3. Concern for Solid Waste contamination during this Pandemic.

Table 6
Special waste collection strategy for PPE at the household level.

Variables	Nigeria	Guyana
<i>Special waste collection for PPE at household</i>	Percentage (%)	Percentage (%)
Agree	92.3	90.7
Disagree	7.7	9.3
<i>Separation strategy with various bins/ bags use for various kinds of waste</i>		
Agree	88.3	92.6
Disagree	11.7	7.4
<i>The regularity of special waste collection</i>		
Daily	28.9	20.4
Twice per week	31.9	38.9
Once a week	37.7	37.5
Once a month	1.5	3.2

Table 7
Landfills/waste dump in the neighbourhood.

Variable	Nigeria	Guyana
<i>Presence of landfill/waste dump in the neighbourhood</i>	Percentage (%)	Percentage (%)
Present	30.4	27.8
Absent	69.6	72.2
<i>Landfills/dump serving as a food bank for livestock, animals/waste pickers</i>		
Yes	79.3	76.2
No	20.7	23.8
<i>Animals present at the site</i>		
Dogs	13.9	Nil
Dogs, goat, cow, pig, and hen	61.5	91.7
Pigs	8.7	2.9
Birds	1.0	0.9
Rodents	11.5	Nil
Reptiles	1.0	Nil
Horse	Nil	0.9
Scavengers	1.4	1.8
All the above	1.0	1.8
<i>Possibilities of the exposure of livestock to COVID-19 at landfills/dumps and the transmission to humans</i>		
Yes	56.0	45.4
No	44.0	54.6

mission, while more than half (54.6%) were on the contrary. The result reveals a contrasting opinion of residents in the two countries reviewed. However, it can be noted that the research about the novel coronavirus is still ongoing, hence residents might not be knowledgeable enough to ascertain the possibility of the virus as being transmis-

Table 8
Suggestions on how to tackle Livestock exposure to COVID 19 at landfills and subsequent transmission to man.

Variable	Nigeria	Guyana
	Percentage (%)	Percentage (%)
Use of special garbage systems for affected or suspected cases	2.1	2.0
Relocation of waste to minimize impacts	2.1	2.0
Animals should be kept away from landfills by owners	4.1	2.0
Perimeter fencing of dump	2.1	5.8
Regulations about waste disposal and Animal control	89.6	88.2
<i>Paying attention to livestock contamination and transmission of COVID-19</i>		
Yes	61.7	69.5
No	38.3	30.5
<i>Those to charge with the responsibility of securing landfills/dumpsites against roaming</i>		
Households	8.5	1.6
Community	15.5	3.1
Municipal authority	13.1	43.8
Public-private partnership	0.9	3.9
Government agencies	43.2	38.2
Collaborative efforts	18.8	9.4

sible from animals to humans, and this might account for their responses above. This matter on the possible transmission of COVID-19 by animals, however, are well discussed in the international media and this remains a matter of concerns globally (Dolan, 2020; Hollingsworth, 2020; Hong Kong Press Release, 2020; Krever & Picheta, 2020; Leroy, Grouilh, & Brugère-Picoux, 2020; Maestro & Spary, 2020)

The results of respondents' suggestions on management of livestock exposure to COVID-19 at landfills and transmission of the animal to man was presented in Table 8. In Nigeria, a majority (89.6%) of the surveyed respondents suggested legislation on waste disposal and animal control, about 4.1% opined that animals should be kept away from landfills by owners, about 2.1% respondents suggested the use of special garbage systems for affected cases or relocation of waste to minimize impacts, and perimeter fencing respectively. Also, in Guyana, the majority (88.2%) of respondents suggested regulations about waste disposal and animal control legislation. About 5.8% suggested perimeter fencing, 2% suggested the use of special garbage systems for suspected or affected cases, relocation of waste to minimize impacts, and keeping away of animals from landfills by owners respectively. This result implies that residents in the two countries largely suggest legislation on waste disposal and animal control.

In Table 8, respondents noted that there is the need to pay attention to the obvious possibility that COVID-19 can be transmitted from livestock exposure at landfills to man. In Nigeria, about two-thirds (61.7%) of surveyed respondents averred that there is a need to pay attention to the transmission of COVID-19 from animals to humans, while about one third (38.3%) do not agree with this. Likewise, in Guyana, more than two-thirds (69.5%) also see the need to pay attention to the transmission of COVID-19 from animals to man through livestock exposure at landfills, while about one-third (30.5%) do not agree to the need to focus attention on the transmission of the virus from animal exposure at landfills/dumps and subsequent transmission to man. Although this debate on the animals to human transmission is documented (Dolan, 2020; Hollingsworth, 2020; Hong Kong Press Release, 2020; Krever & Picheta, 2020; 2020; Leroy, Grouilh, & Brugère-Picoux, 2020; Maestro & Spary, 2020), the kind of relationship between human being and their pets should be of interest to how this matter should be considered, especially if the pets are allowed to roam in the communities unhindered. The wider publically that the possibility of animals being infected with COVID-19 may also provoke violent reactions to pets, especially cats and dogs (e.g., Leroy, Grouilh, & Brugère-Picoux, 2020), hence the need to pay attention to this issue.

Detailed in Table 8 are the results of respondents' opinions on who takes the responsibility for securing landfills/dumpsites from contamination with the pandemic. In Nigeria, about two-fifths (43.2%) of respondents opined that government agencies should take responsibility, about one-fifth (18.8%) suggested collaborative efforts, 15.5% of respondents suggested community, more than one-tenth (13.1%) opted for municipal authority, 8.5% suggested household and relatively few (0.9%) opted for public-private-partnership (PPP). In Guyana, more than two-fifths (43.8%) respondents suggested neighbourhood and local democratic council, about two-fifths (38.2%) suggested government at the national, regional and local levels, about one-tenth (9.4%) opined for collaborative efforts, and relatively insignificant responses for environmental agencies and public health ministries, community and household respectively. From the results obtained in Nigeria, residents largely suggested that government agencies (mainly at the state level) should take responsibility for securing landfills/dumps from contamination of COVID-19, while in Guyana, it is the neighbourhood/local democratic councils that were the main suggestion. These two contrasting opinions reveal the present realities on the management of municipal wastes in the two countries.

3.4. Solid waste management approaches during COVID-19 pandemic

The previous analysis considered the management of landfills/dumps and the transmission of the virus from infected livestock feeding at dumps. Residents opined that government agencies at the state (Nigeria) and local levels (Guyana) should be responsible for securing landfills from such contamination. In this section, a broader view of solid waste management during the pandemic was ascertained through opinions from sampled respondents.

Detailed in Table 9 are the summarized results of the type of waste easily contaminated with COVID-19. In Nigeria, more than nine-tenths (94.8%) of respondents listed cans, glass, bottles, plastics, fabrics, bags, and newspapers are easily contaminated materials, while relatively few (4.1%) emphasized all types of wastes and biodegradable material. Similarly, in Guyana, more than nine-tenths also affirmed that drink cans, glass bottles, plastics, fabrics, bags, and newspapers are some likely contaminants, and slightly about 2.4% mentioned all types of waste. This observation is not surprising as it is well known that coronavirus has active life spans varying between three hours to seven days on these types of materials (van Doremalen et al., 2020; Ye et al., 2016; Chin et al., 2020; Nghiem et al., 2020). The respondents' ability to identify the materials in Table 9 can be attributed to

Table 9
Waste materials contamination with COVID-19.

Variable	Nigeria	Guyana
	Percentage (%)	Percentage (%)
<i>Type of waste material easily contaminated</i>		
Drink cans, glass bottles, plastics, fabrics, bags, and newspaper	94.8	95.7
All and Biodegradable materials	4.1	2.4
None	1.1	1.9
<i>Awareness of waste collectors being trained to curtail the spread of COVID-19</i>		
Aware	12.5	12.5
Not aware	87.5	87.5
<i>Waste bucket being decontaminated</i>		
Agree	96.0	97.2
Disagree	4.0	2.8
<i>Who should drive the process</i>		
Government	14.0	11.9
Household	26.0	29.7
Local government / Neighbourhood democratic council [NDC]	18.4	23.4
Private companies	2.8	2.6
Collaborative efforts from all parties	38.8	32.3

the volumes of information on COVID-19 spread circulating through the media and public information services globally.

3.5. Awareness of household waste/quarantine facilities suspected with COVID-19

For countries significantly affected by COVID-19, home isolation and temporary quarantine facilities are the most adopted practices by countries to contain those infected and as such, allow hospital rooms /wards be prioritised to patients with severe cases. (Nghiem et al., 2020). Documented in Table 10 were respondents' level of awareness of household waste/quarantine facilities suspected with the virus. In Nigeria, only about 15% of respondents were aware of household waste/quarantine facilities for those suspected with the virus, while a majority (85%) were not aware of such. Likewise, in Guyana, only slightly above one-tenth (12.5%) of sampled respondents were aware of household waste/ quarantine facilities suspected with the virus, while a majority (87.5%) of respondents were not aware of household waste/quarantine facilities suspected with the virus. The understanding that can be drawn from the survey is that most residents were not aware of household waste/quarantine facilities of those infected with COVID-19. This lack of awareness may be as a result of guilt, shame or reproach almost associated with any contaminable diseases (Abraham et al., 2020; Ansari, Grier, & Byers, 2020; Manson, 2020; Conway III, Woodard, Zubrod, & Chan, 2020; Costello et al., 2020)

Table 10 also shows respondents' perception of the treatment of contaminated waste. In Nigeria, the majority of households do not have an idea of how contaminated waste can be treated, about 12.7% suggested burning, 8.1% opined for disinfection and fumigation and a relatively few other options were itemized. In Guyana, a majority (85%) of respondents do not have an idea and 2.7% of respondents opined for burning.

3.6. Nexus for potential research on waste management

A limitation of our study is that it relied on responses provided by household members and did not fully observe the waste management practices in the two countries. However, these responses have provided the perspectives and useful insights into solid waste management practices and concerns during the ongoing COVID-19 pandemic. This study from household respondents identified the different sections of waste management in the era COVID-19 that can be considered as areas of urgent research. Table 11 provides suggestions on areas of further research as conceived by residents in the

two countries studied. In Nigeria, about two-fifths (36.3%) of sampled respondents suggested waste recycling, about one-tenth (10.4%) respondents suggested community enlightenment, about 6.9% suggested air pollution and management of hazardous waste, and generally on the three R's (reduce, re-use and recycling) of waste management respectively. Similarly, in Guyana, about two-fifths (37%) of participants suggested waste recycling as an area of further research, about one-fifth (18.5% suggested waste segregation. Some other areas of research suggested for Guyana are the three "Rs", separation of medical waste from residential waste among many others. These suggestions are indications that the documented poor and improper waste management for the developing countries (World Bank, 2019) should be given proper consideration by the thinkers and policymakers. The responses from the households are, therefore, another reason why the waste management sector in the two sampled countries should be given the utmost attention if the curbing of COVID-19 or other contaminable diseases can be effectively addressed.

The analysis in Table 11 also shows respondents' opinions on the need to review waste management policies in the two countries. In Nigeria, more than nine-tenths (90.5%) of sampled respondents agreed on the need to review the country's waste management policies and plans, while about one-tenth (9.5%) of respondents did not agree to this. It is important to note that waste management policies in Nigeria are formulated at the federal and state levels, but implementation is done at the local levels. Most state governments in Nigeria create a state-wide agency in managing waste. However, due to the capital-intensive nature and technical requirement needed for effective waste management, most local government areas in Nigeria could not carry any implementation agenda and often depend on efforts initiated by their respective state government. In Guyana, more than nine-tenths (96.8%) respondents agreed that there is a need to review waste management policies in Guyana, while, relatively about 3.2% of respondents did not agree on the need to review waste management policies in the country. Waste management in Guyana is often coordinated at the neighbourhood/local levels. It can be averred that residents in the two countries would prefer a review of their waste management policies in the light of the present pandemic challenge. The inter-relations of the pandemic with waste management calls for a need to critically examine its nexus to waste management so as to curtail the spread of the virus through effective strategies when devised. Waste remains a serious environmental and human health problems in developing countries (Um et al., 2018; World Bank, 2019; Margallo et al., 2019). The COVID-19 pandemic has created the urgency for the needed attention that this sector deserves in the

Table 10
Awareness of household waste/quarantine facilities suspected or infected with COVID-19.

Variable	Nigeria	Guyana
<i>If residents were aware of household waste and quarantine facilities suspected with COVID-19 treated specially</i>	Percentage (%)	Percentage (%)
Aware	15.0	12.5
Not aware	85.0	87.5
<i>Treatment of suspected contaminated waste with COVID-19</i>		
Burning	12.7	2.7
Dumping	Nil	1.1
Don't know	74.6	85.0
Disposal at landfill	Nil	1.6
Incinerating	Nil	2.1
Disinfection and fumigation	8.1	Nil
Taking precautions with disposal or burning with chemicals	1.0	3.2
Similarly, like other uncontaminated waste	1.0	1.6
Separated, quarantine and treated differently	2.5	2.7

Table 11
Suggestions on areas of further research in Waste Management.

Variable	Nigeria	Guyana
<i>Respondents recommended of waste research</i>	Percentage (%)	Percentage (%)
Contamination of water supplies and patient mapping strategy	Nil	3.7
Plans for re-opening of business	Nil	3.7
Waste recycling	36.3	37.0
The three Rs	6.9	5.6
Waste segregation	6.0	18.5
Separating medical waste from residential waste	6.0	3.7
Effective waste management	3.4	1.9
Air pollution & management of hazardous waste	6.9	3.7
E-waste and COVID-19	2.6	3.7
Medical waste research	4.3	Nil
Community Enlightenment	10.4	Nil
Others	17.2	18.5
<i>Need to review the waste plan, policy, and practices in Nigeria</i>		
Agree	90.5	96.8
Disagree	9.5	3.2

developing countries. This sector (waste management sector) has evolved from being a careless disposition of litters to the more integrated, sophisticated, advanced and technologically imperative systems in human history (Margallo et al., 2019); Therefore, the developing countries of Nigeria and Guyana, should establish or revise their waste management policies/acts, strengthen the enforcement of the municipal waste ordinances and generally improve the sector to a proper 21st century sector that can withstand the environmental and health challenges posed by the continuous generation of wastes induced by the COVID-19 or other future pandemics.

4. Conclusion

The present realities of the novel COVID-19 pandemic have created an urgency to understand the inter-relations between municipal waste management and the pandemic. Waste managers and residents are thus faced with a greater responsibility of curtailing the spread of the virus and risks of exposure to the virus. The perceptions of residents in two developing countries, Nigeria and Guyana respectively, were sought to create an inclusive approach to policy formulation. The findings of this study demonstrate that the people of Nigeria and Guyana are perceptive about the waste management issues in spreading the virus. Most respondents outlined the need for intervention, their willingness to comply with the necessary policy measures, and the recognition of the need for an improved waste management system. Circumventing the waste management issue and COVID-19 spread requires a participatory effort between the communities, central government, municipalities, and private sector agencies (Kulkarni & Anantharama, 2020).

The waste management system in Nigeria and Guyana is plagued with questionable practices that are of concern to the communities and households. Unregulated dumping activities, unmonitored community landfills, and roaming livestock in dumps are all potential festering grounds for viral spread in these countries. Our modest study demonstrated the community's insight into some of these waste management challenges and strongly affirms the vulnerability of COVID-19 spreading through improper waste disposal and handling. Further exacerbating our affirmation, the households surveyed indicated an increase in their waste disposal. Thus, as cases increase, so will the contamination of wastes. Further work is needed to explore the environmental epidemiology behind the COVID-19 waste management issue. The insights provided by this paper into the community perception of waste management and COVID-19 from these two developing countries' perspectives can contribute to the development of a broader pandemic management plan by including the relatively overlooked issue of waste being a factor.

CRedit authorship contribution statement

Temitope D. Timothy Oyedotun: Conceptualization, Methodology, Formal analysis, Investigation, Writing - review & editing. **Oluwasinaayomi Faith Kasim:** Formal analysis, Writing, Reviewing. **Ayomide Famewo:** Formal analysis, Methodology. **Temitayo Deborah Oyedotun:** Writing - review & editing. **Stephan Moonsammy:** Writing - review & editing. **Nasrudeen Ally:** Methodology, Review and editing. **Donna-Marie Renn-Moonsammy:** 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.

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