Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454

Vol. 21 | No. 5 (Suppl) | pp. 2291-2297 | 2022

Original Research Paper

https://doi.org/10.46488/NEPT.2022.v21i05.024

Open Access Journal

Analysis and Characterization of Municipal Solid Wastes Generated in a Community in the Northern Philippines

J. M. Ngohayon†* and J. Tulagan*
*Ifugao State University, Potia Campus, Potia, Alfonso Lista, Ifugao, Philippines
†Corresponding author: J. M. Ngohayon; engrjoelngohayon@gmail.com

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 26-05-2022
Revised: 30-06-2022
Accepted: 01-07-2022

Key Words:
Municipal solid waste
Waste generation
Waste composition
Waste volume

ABSTRACT

The residential community of Potia in the Northern Philippines experiences various problems arising from mismanaged municipal solid waste. Hence, a waste analysis and characterization study on the generated municipal solid wastes was conducted to determine the municipal solid waste generation data which can be used for planning and formulation of potential solutions. For three consecutive days, the generated municipal solid wastes were gathered from the sample which included residential sources, commercial sources (food establishments, service centers, general stores, and markets), industrial sources, and institutional sources (institutions and health units). The total generated municipal solid waste in Potia is about 508.30 kg.day^{-1} of which most were contributed by the residential sources (70.59%), followed by commercial (25.09%), industrial (2.64%), and institutional (1.70%). The overall composition of the generated MSW is also dominated by biodegradable waste (76.90%), followed by residual waste (14.66%), recyclable waste (7.35%), and special waste (1.08%). The total volume of daily generated MSW is about 3.37 m^3.day^{-1}.

INTRODUCTION

The management of municipal solid waste (MSW) is one of the major problems in developing countries (Ferronato & Torretta 2019) including the Philippines. Even with the existence of the Republic Act 9003 (Ecological Solid Waste Management Act 2000) which enforces proper MSW management, it remains a relentless problem that, unfortunately, is widely ignored in the country. The study by Guisansana et al. (2020) has cited several reasons for the persistence of this problem: (1) Lack of willingness and/or very low priority of the local government unit in implementing the law. (2) Rising population growth. The increase in population will result in an increase in the rate of consumption and also the waste generation rate (Liu et al. 2019, Supangkat & Herdiansyah 2020). In relation to this is the increasing family size which also increases the rate of consumption and rate of waste generation (Suthar & Singh 2015, Xiao et al. 2015, Noufal et al. 2020). (3) Lack of initiatives and discipline of the Filipino people especially on waste generation and segregation. A lot of people are still throwing their waste anywhere. Even if there are trash bins available, only a few are following the waste segregation at source (Paz et al. 2020).

Mismanaged MSW can be a precursor to various community problems and ecological disturbances: (1) it can affect the overall aesthetics of the community (Abdel-Shafy & Mansour 2018), (2) it can clog the drainage and pipe systems (Daniels 2014), (3) it attracts and promotes proliferation of disease-causing vectors (Krystosik et al. 2020), (4) it can pollute the surface water and groundwater through the leachate it produces, and (5) it can pollute the air through the greenhouse gases and other toxic gases it emits upon burning (Ejaz et al. 2010, Liao & Chiu 2011, Alam & Ahmade 2016).

Potia is one of the developing communities in the Northern Philippines. It has a population of approximately 2,188 residents and has had a positive growth rate of 2.30% since 2015 (Philippine Statistics Authority 2021). Currently, the community experiences the following problems regarding MSW management: (1) The absence of an engineered and centralized MSW storage facility. The community has a designated Materials Recovery Facility (MRF), but it only functions as a temporary storage location as it doesn't contain any MRF elements such as weighing equipment, sorting equipment, and designated sorting area among others (Asian Development Bank 2013). The capacity of the designated temporary storage location is also not enough, hence trash containers are lying around the storage structure. (2) The absence of a proper disposal facility for biodegradable wastes. The waste collectors are only collecting nonbiodegradable wastes, thus the

responsibility for the disposal of the biodegradable wastes is tasked to the community and its constituents. While some have backyard compost pits and other ways to utilize the biodegradables (e.g. feeding vegetable and fruit peels to livestock), most are still thrown out and left to rot in nearby ravines. (3) Mixed wastes. Some of the wastes brought to the temporary storage facility contain biodegradables, hence these end up not being collected by the waste collectors. (4) The lack of recycling facilities. While there are efforts to recycle, generally there is no recycling facility to receive the recyclables. Thus, these recyclables are also sent to the storage facility for collection and disposal. Hence, there is a need for the community to plan an MSW management that can effectively minimize or eliminate these aforementioned problems. However, before planning the MSW management strategy, it is important to conduct an initial assessment to know the profile and location of the waste generators and the characteristics of the generated MSW such as the quantity, the composition, the bulk density, and the volume as this information can help in planning the appropriate handling, storage, collection, treatment, and disposal of the generated MSW.

Until now, there are no studies in the community of Potia regarding the characteristics of the generated MSW, hence the primary aim of this paper is to initially assess the baseline MSW generation data. This assessment study is limited to providing the MSW generation data such as waste generation rate, MSW generated daily, waste composition, bulk density, and volume of MSW generated daily. The results obtained from the study can be used by the community as a basis for future planning on MSW management including the formulation of strategies, programs, campaigns, projects, and activities that would address the issues and concerns aforementioned. Furthermore, the results can be used to design long-term waste processing and diversion facilities such as MRFs and composting facilities among others. Moreover, the results can be used by succeeding waste characterization studies to assess the changes and determine trends in the MSW generation data for the community.

MATERIALS AND METHODS

The waste analysis and characterization study (WACS) approach used in this study was adapted from the set of guidelines published in the "Waste Analysis and Characterization Study – A Manual" by the Philippine Environmental Governance Project (EcoGov Project 2011). The guidelines are in accordance with R.A. 9003 and were designed for use by the communities within the country.

The study was conducted at Potia, a residential community that is located in the Northern Philippines. The inventory of the waste generators (residential and non-residential including commercial, institutional, and industrial) was obtained from the office of the community. For a relatively small community like Potia, a sample size of at least 30 households for the residential waste generators was included in the sample size. The following considerations were taken into account in narrowing down the target households: (1) it must have 4 - 6 members to reduce the variability of waste generated, (2) it must not be operating a home-based business, (3) the residents must be willing to cooperate with the researcher, and (4) there are no celebrations during the data gathering. Random sampling was done to obtain a total of 33 households which consist of 153 people. For the non-residential waste generators, at least 10% of the inventory of the non-residential waste generators was included in the sample size. The summary of the inventory and the actual number of samples used for the data gathering is given in Table 1.

Table 1: The inventory of waste generators in the community and the actual sample size.

Waste Generator	Included	Unit	No. of Geneators	Sample Size
Residential	Households	capita	2,188	152
Commercial				
Food Establishments	restaurants, eateries, snack houses, bakeries, and food stalls	store	18	5
Service Centers	computer shops, tailor shops, transport terminals, barber shops, repair shops, and gasoline stations	shop	19	3
General Stores	small-scale groceries, neighborhood sundry stores (sari-sari stores), dry goods stores, and hardware shops	store	95	10
Markets	wet market	stall	9	4
Industrial	furniture-making and rice mills	industry	4	2
Institutional				
Institutions	offices, churches, and schools	capita	176	85
Health Units	health centers and pharmacies	capita	21	16

Before the conduct of the data gathering, permission was obtained from the head of the community and the heads and owners of the households and non-households included in the sample. They were briefly oriented about the study and its objectives, how they will store their generated waste in the provided containers, and how the collection will be done. They were also assured of their anonymity and the confidentiality of the obtained data.

The data gathering was done for three consecutive days from November 12 to 14, 2020. Two waste containers were provided to the identified sampling points: a container for biodegradables and nonbiodegradables (including recyclables, residuals, and special wastes). The collection for each sampling day was on the following day e.g. waste generated on Thursday starting from 8:00 AM will be collected on Friday at 8:00 AM. The collected MSW were then brought to the laboratory in Ifugao State University Potia Campus for analysis.

The total mass of the MSW from each waste generator was measured using a calibrated weighing scale. The generation rate for each type of waste generator was calculated using the formula (Kawai & Tasaki 2016):

$$Generation\ Rate = \frac{Total\ Mass\ of\ MSW}{Number\ of\ Units\ per\ Sample} \quad \ldots(1)$$

The total volume of the MSW from each type of waste generator was measured using a calibrated container. The bulk density was then calculated using the formula (Palanivel & Sulaiman 2014):

$$Bulk\ Density = \frac{Total\ Mass\ of\ MSW}{Bulk\ Volume\ of\ MSW} \quad \ldots(2)$$

The containers for biodegradable and nonbiodegradable were checked for any mixed waste contents. After that, the nonbiodegradables were segregated into residuals, recyclables, and special wastes. Furthermore, the recyclables were segregated into papers, tins, bottles, and textiles. The description of each waste category is presented in Table 2. After segregation, the masses of each type of waste per waste generator were measured using a weighing scale. The gravimetric composition of each type of waste was calculated using the formula (Miguel et al. 2016):

$$\%\ type\ of\ waste = \frac{Mass\ of\ Type\ of\ Waste}{Total\ Mass\ of\ MSW} \times 100 \quad \ldots(3)$$

After the analysis, the collected MSW were disposed of - the biodegradable wastes were buried in a compost pit, while the nonbiodegradable wastes were packaged and brought to the nearest waste collection point for pickup by the waste collectors of the community.

The average of the obtained MSW generation data from the three-day sampling was calculated and was used for the succeeding analysis and discussion.

RESULTS AND DISCUSSION

MSW Generation Rate and MSW Generated Daily

The summary of the calculated MSW generation rate and the daily generated MSW per type of waste generator in Table 3 shows that the largest portion of the generated MSW came from residential sources (70.59%). This is because the community is largely utilized as a residential area. In addition, because of the prevalence of the COVID-19 pandemic and the quarantine restrictions, most of the commercial establishments, industries, and institutions were either closed or not operating at full capacity, thus there were relatively fewer MSW generated in these sources as compared to the residential sources. Moreover, since most people were forced to stay and work within the confinements of their homes, waste production must have shifted from

Table 2: Description of the categories used in the gravimetric characterization of the generated MSW.

Category*	Description*	Sample Waste Recovered from the Study
Biodegradable	Waste can be easily decomposed and can be turned into compost once it is exposed to various agents of decomposition.	food wastes, fruit and vegetable peelings, meat and fish scraps, garden and yard wastes, wet/soiled paper wastes, used tissue paper, wood shavings, and rice husk
Recyclables	Wastes that are in relatively good condition enough to be recovered and converted into new products.	dry/unsoiled paper wastes, cartons, cardboard, metal scraps, glass bottles, plastic bottles, tin cans, textile trimmings, and rubber
Residual	Wastes cannot be recycled anymore due to several factors such as market demand, technological limitations, costs, and quality of recycled products, among others. These are immediately transported to sanitary landfills for disposal.	ashes, soot, dirt, tattered packaging materials, plastic straw, laminates, and composite materials, sando bags, food wrappers, and packaging, used napkins and diapers
Special	Household hazardous waste.	chemical containers, broken light bulbs, expired drugs, used dry cell batteries and used face masks

*Source: National Solid Waste Management Commission 2018

Table 3: The MSW generation rate and MSW generated daily in Potia.

Waste Generator	MSW Generation Rate	No. of Generator	MSW Generated Daily*	
			kg.day^{-1}	%
Residential	0.164 kg.day^{-1}.capita^{-1}	2,188 capita	358.83	70.59
Commercial			127.46	25.09
Food Establishments	1.425 kg.day^{-1}.store^{-1}	18 store	25.65	5.05
Service Centers	0.812 kg.day^{-1}.shop^{-1}	19 shop	15.43	3.04
General Stores	0.728 kg.day^{-1}.store^{-1}	95 store	69.16	13.61
Markets	1.913 kg.day^{-1}.stall^{-1}	9 stall	17.22	3.39
Industrial	3.350 kg.day^{-1}industry^{-1}	4 industry	13.40	2.64
Institutional			8.62	1.70
Institutions	0.040 kg.day^{-1}.capita^{-1}	176 capita	7.04	1.39
Health Units	0.075 kg.day^{-1}.capita^{-1}	21 capita	1.58	0.31
Total			508.30	100.00

*MSW Generated Daily = MSW Generation Rate × No. of Generators

institutional, industrial, and commercial to residential (Roy et al. 2021, Sinha et al. 2020).

While most commercial establishments in the community were not operating at full capacity, a considerable amount of MSW is still being generated in these sources (25.09%). In particular, the general stores, which include mostly small-scale groceries and neighborhood sundry stores, have the highest contribution (13.61%) to the generated MSW from commercial sources. Since the residents don't have the luxury anymore to travel to the nearby city to buy their household necessities, they are relegated to consuming the goods available within the community. Food is still a daily necessity for the population, pandemic or not, therefore food establishments and markets also contribute a sizable amount of MSW from commercial sources. Since people could not use shared services like transit terminals, computer stores, and barbershops among others due to quarantine laws at the time, the service centers make up the least of the MSW generated.

Daily, the total generated MSW from all the waste generators is approximately 508.30 kg.day^{-1}. On a yearly basis, this is about 185,529.50 kg.yr^{-1} or 185.52 MT.yr^{-1}

MSW Composition

The summary of the waste composition from the various waste generators is shown in Table 4. Most of the waste generators, except for the service centers, generated MSW that was dominated by biodegradable wastes, followed by residual waste, recyclable waste, and special wastes. The relatively high biodegradable fraction for the generated MSW in the community is similar to the results of several studies (Adeleke et al. 2021, Montero et al. 2019, Enteria & Orig 2019) which have also observed this trend among communities dominated by residential areas.

Table 4: The composition of the generated MSW in Potia.

Waste Generator	Bio [%]	Recyclable [%]				Residual [%]	Special [%]
		Paper	Tin	Bottle	Textile		
Residential	79.03	0.66	1.22	1.68	1.59	15.14	0.68
Commercial							
Food Establishments	72.71	0.00	0.53	1.48	0.00	25.23	0.04
Service Centers	0.36	27.81	0.00	1.62	65.18	4.53	0.50
General Stores	78.54	0.00	0.00	3.01	0.00	14.27	4.18
Markets	94.86	0.00	0.00	0.12	0.00	5.02	0.00
Industrial	100.00	0.00	0.00	0.00	0.00	0.00	0.00
Institutional							
Institutions	51.59	18.52	0.34	2.01	0.00	26.23	0.92
Health Units	59.26	9.24	1.16	1.16	0.00	26.99	2.20
Overall	76.90	1.59	0.90	1.76	3.10	14.66	1.08

The service centers are the only group of waste generators that generated MSW that was not dominated by biodegradable wastes. This is because the stores and shops belonging to this group don't primarily engage in activities that consume goods that produce biodegradable wastes such as food waste. The few biodegradable wastes recovered were mostly yard wastes from their cleaning activities. Instead, the generated MSW is dominated by recyclable wastes, such as paper waste and textile trimmings due to the nature of activities in the various service centers such as computer shops, tailor shops, and repair shops.

The industries produced the highest biodegradable fraction as the rice mills and the furniture shops in the community are only producing rice hull and wood shavings, respectively, from their activities.

The generated MSW from the institutional source also has a relatively high fraction of paper waste among the recyclable waste generated. This result is very similar to the observations from several studies (Goa & Sota 2017, Montero et al. 2019, Pathak et al. 2020) on the generated MSW from institutional sources. This is because the activities in the institutional sources heavily involve the usage of paper products for printing, note-taking, and crafting among others.

The overall composition shows that the bulk of the generated MSW is biodegradable (76.90%). Daily, this amounts to approximately 390.88 kg of biodegradable waste generated. With this many biodegradables, these must be properly handled and disposed of because mismanaged biodegradable wastes can easily attract disease-causing vectors and can be unsightly and smelly in just a few hours. As mentioned, this type of waste is not being collected for disposal in the sanitary landfill, and the responsibility for handling and disposal of the generated biodegradable wastes is left to the individual waste generators. Some residents are utilizing their food wastes as animal feed for their pets and livestock. However, not all biodegradable wastes, such as garden waste and soiled paper waste, can be used as animal feed. In addition, not all residents have pets or livestock. While there are some efforts to compost, these are only limited to those who are knowledgeable about composting and those who have spare backyard space. Hence, the community can develop a centralized facility that will receive the generated biodegradable wastes from residents who don't own pets or livestock and/or who don't have spare backyard space for backyard composting. The centralized facility can then employ various treatment methods for biodegradable wastes like composting and waste-to-energy processes among others.

Recyclable waste is just a small percentage (combined with 7.35%) of the overall generated MSW. Since the community has no dedicated treatment or recovery facilities, such as junk shops and recycling facilities, these potentially-recyclable materials end up as residuals and are sent to the sanitary landfill for disposal. Similarly, this is also the case for special waste (1.08%) which has no dedicated receiving and treatment facility within the community. Hence, this brings to a total of 23.1% residuals of the overall generated MSW daily.

Bulk Density and Volume of MSW Generated Daily

The summary of the calculated bulk densities and the volumes of generated MSW daily per type of waste generator is shown in Table 5. The generated MSW from the markets has the highest bulk density (245.58 $kg.m^{-3}$) among the waste generators. This can be attributed to

Table 5: The bulk density and the volume of MSW generated daily in Potia.

Waste Generator	Bulk Density [$kg.m^{-3}$]	MSW Generated Daily [$kg.day^{-1}$]	The volume of MSW Generated Daily* [$m^3.day^{-1}$]
Residential	162.00	358.83	2.21
Commercial			
Food Establishments	166.55	25.65	0.15
Service Centers	128.76	15.43	0.12
General Stores	117.01	69.16	0.59
Markets	245.58	17.22	0.07
Industrial	162.28	13.40	0.08
Institutional			
Institutions	62.88	7.04	0.11
Health Units	61.77	1.58	0.03
Total		508.30	3.37

* Volume of MSW Generated Daily = Bulk Density × MSW Generated Daily

the high biodegradable content (94.86%) of the generated MSW which is mostly food waste that has relatively high bulk densities (Foday et al. 2017). This is similar to the observation of Hailu et al. (2018) where the highest bulk density was recorded on the waste generator having the highest amounts of biodegradable in the generated waste. While the generated MSW from the industries is 100% biodegradable, the type of biodegradable wastes generated (rice hull and wood shavings) have relatively higher volume owing to their porous and loose nature as compared to the market's biodegradables (food waste) which are less porous and are more compact.

The generated MSW from the institutions and the health units have the lowest bulk densities because of the relatively high fraction of paper waste and residuals (mostly plastics). Since paper and plastics have low densities (Foday et al. 2017), then the overall generated MSW which is dominated by these components is also expected to have low bulk densities (Bowan & Tierobar 2014). The generated MSW in the service centers, despite having a higher fraction of paper waste than either of the former two, have a higher bulk density. This can be attributed to the following: (1) the generated MSW in the service centers has lower residual (plastics) content as compared to generated MSW in the institutions and the health units, and (2) the generated MSW in the service centers have a high fraction of textile trimmings (65.18%) which have high densities (United States Environmental Protection Agency 2016).

The residential and the food establishments have almost similar bulk densities because of the similarities in their waste composition - both are dominated by biodegradable wastes. While the general stores have close amounts of biodegradables with the residential and food establishments, it has a lower bulk density than the former two. This can be attributed to the higher fraction of recyclable bottles and chemical containers (special waste) which adds to the bulkiness and volume of the generated MSW.

Similarly, since the community is largely utilized as a residential area, the bulk of the volume of generated MSW daily came from residential sources. The total volume of the generated MSW is approximately 3.37 $m^3.day^{-1}$. If packed in a cube, the generated MSW daily will be approximately 1.5 m on each side. On a yearly basis, the volume of generated MSW is approximately 1,230.05 $m^3.yr^{-1}$.

CONCLUSIONS

The total generated MSW in Potia is about 508.30 $kg.day^{-1}$ of which most were contributed by the residential sources (70.59%), followed by commercial (25.09%), industrial (2.64%), and institutional (1.70%). The overall composition of the generated MSW is also dominated by biodegradable waste (76.90%), followed by residual waste (14.66%), recyclable waste (7.35%), and special waste (1.08%). Without a receiving treatment facility for recyclable waste and special waste, these types of waste can also end up in the sanitary landfill, hence bringing a total of 23.1% residual waste. The large amount of biodegradable waste generated and the lack of proper treatment and disposal for this type of waste can also be a good starting point for the community to explore potential treatment methods for this type of MSW. The highest bulk density was recorded on the generated MSW which is dominated by biodegradable wastes. The total volume of daily generated MSW is about 3.37 $m^3.day^{-1}$ of which most were also contributed by the residential sources. The MSW generation data obtained from Potia is similar to most communities which are also largely utilized as a residential areas.

ACKNOWLEDGEMENT

The authors would like to acknowledge the residents of Potia for their willingness to participate in the data gathering and for the manpower provided during the actual experiment. The authors would also like to acknowledge the assistance provided by the Ifugao State University, especially during the sample collection.

REFERENCES

Abdel-Shafy, H.I. and Mansour, M.S. 2018. Solid waste issue: Sources, composition, disposal, recycling, and valorization. Egypt. J. Petrol., 27(4): 1275-1290.

Adeleke, O.A., Akinlabi, S.A., Jen, T.C. and Dunmade, I. 2021. An overview of factors affecting the rate of generation and Physical Composition of Municipal Solid Waste. IOP Conf. Ser. Mater. Sci. Eng., 1107(1): 012096.

Alam, P. and Ahmade, K. 2016. Impact on health and the environment. Live Cell Assays, 13: 197-217.

Asian Development Bank. 2013. Materials Recovery Facility Tool Kit. Asian Development Bank, Tokyo.

Bowan, P.A. and Tierobaar, M.T. 2014. Characteristics and management of solid waste in Ghanaian markets: A study of WA municipality characteristics and management of solid waste in Ghanaian Markets. Civil Environ. Res., 6: 114-119.

Daniels, N.C. 2014. Drainage system cleaner is a solution to environmental hazards. Int. Ref. J. Eng. Sci., 3(3): 54-60.

EcoGov Project. 2011. Waste Analysis and Characterization Study: A Manual. Second Edition. Philippine Environmental Governance Project, Diliman, Quezon City, The Philippines.

Ecological Solid Waste Management Act. 2000. R.A. 9003, 2000. https://www.officialgazette.gov.ph/2001/01/26/republic-act-no-9003-s-2001/

Ejaz, N., Akhtar, N., Nisar, R. and Ali Naeem, U. 2010. Environmental impacts of improper solid waste management in developing countries: A case study of Rawalpindi City. WIT Trans. Ecol. Environ., 142: 379-387.

Enteria, O. and Orig, A. 2019. Comparative waste analysis and characterization study (WACS) among the selected rural areas in the northern part of Mindanao, Philippines. Int. J. Sci. Res., 8(2): 1549-1553.

Ferronato, N. and Torretta, V. 2019. Waste mismanagement in developing countries: A Review of Global issues. Int. J, Environ, Res. Pub. Health, 16(6): 1060.

Foday, E.H., Ramli, N.A., Nabilah Ismail, H., Malik, N.A., Basri, H.F., Aziz, F.S.A., Nor, N. S.M. and Jumhat, F. 2017. Municipal solid waste characteristics in Taman Universiti, Skudai, Johore, Malaysia. J. Adv. Res. Design, 38(1): 13-20.

Goa, E. and Sota, S.S. 2017. Generation rate and physical composition of solid waste in Wolaita Sodo Town, southern Ethiopia. Ethiop. J, Environ. Stud. Manag., 10(3): 415.

Guisansana, L.G.G., Mag, J.D.R.U., Nabing, C.B.P. and Festijo, F. 2020. Solid waste management: The enactment of the ecological solid waste management act of 2000 (R.A 9003) in addressing the waste crisis. Europ. J. Mol. Clinic. Med., 7(2): 4186-4196.

Hailu, H., Rao, R.S.V., Dawit, M. and Feyisa, A. 2018. Assessment of reuse, recycle, and recoverable potential of solid waste. MATEC Web oConf., 276: 06007.

Kawai, K. and Tasaki, T. 2016. Revisiting estimates of municipal solid waste generation per capita and their reliability. J. Mater. Cyc. Waste Manag., 18(1): 1-13.

Krystosik, A., Njoroge, G., Odhiambo, L., Forsyth, J.E., Mutuku, F. and LaBeaud, A.D. 2020. Solid wastes provide breeding sites, burrows, and food for biological disease vectors, and urban zoonotic reservoirs: A call to action for solutions-based research. Front. Pub. Health, 7: 56

Liao, C.H. and Chiu, A.S.F. 2011. Evaluate municipal solid waste management problems using a hierarchical framework. Proced. Social Behav. Sci., 25: 353-362.

Liu, J., Li, Q., Gu, W. and Wang, C. 2019. The impact of consumption patterns on the generation of municipal solid waste in China: Evidence from provincial data. Int. J< Environ. Res. Pub. Health, 16(10): 1-19.

Miguel, M.G., Paixao Filho, J.L.D., Benatti, J.C.B., Leme, M.A.D.G., Mortatti, B.C., Gabrielli, G., Elaiuy, M.L C., Pereira, S.Y. and Teixeira, E.N. 2016. Gravimetric composition of municipal solid waste disposed of in a large-scale experimental cell in Southeastern Brazil. Int. J. Environ. Waste Manag., 17(2): 128.

Montero, S., Hapinat, H. and Penaflorida, M. 2019. Waste Analysis and Characterization Study (WACS): Measures Towards Effective Municipal Waste Management in Batad, Iloilo, Philippines. Food and Fertilizer Technology Center for the Asian and Pacific e-Journal. Retrieved from https://ap.fftc.org.tw/article/1650

Noufal, M., Yuanyuan, L., Maalla, Z. and Adipah, S. 2020. Determinants of household solid waste generation and composition in Homs city, Syria. J. Environ. Pub. Health, 2: 20.

Palanivel, T.M. and Sulaiman, H. 2014. Generation and composition of municipal solid waste (MSW) in Muscat, Sultanate of Oman. APCBEE Proced., 10: 96-102.

Pathak, D.R., Mainali, B., Abuel-Naga, H., Angove, M. and Kong, I. 2020. Quantification and characterization of municipal solid waste for sustainable waste management in newly formed municipalities of Nepal. Waste Manag. Res. J. Sustain. Circular Econ., 38(9): 1007-1018.

Paz, V.D., Domingo, R. and Roxas, F.M. 2020. Strategy to improve the solid waste management of Barangay Matictic, Norzagaray, Bulacan. IOP Conf. Ser. Earth Environ. Sci., 511(1): 012004.

Philippine Statistics Authority 2021. 2020 Census of Population and Housing [Data Set]. Philippine Statistics Authority. Retrieved from https://psa.gov.ph/sites/default/files/attachments/ird/pressrelease/CAR.xlsx

Roy, P., Mohanty, A.K., Wagner, A., Sharif, S., Khalil, H. and Misra, M. 2021. Impacts of COVID-19 outbreak on the municipal solid waste management: Now and beyond the pandemic. ACS Environ., (1): 32-45.

Sinha, R., Michelsen, J.D., Akcura, E. and Njie, L. 2020. COVID-19's Impact on the Waste Sector. International Finance Corporation.

Supangkat, S. and Herdiansyah, H. 2020. Analysis correlation of municipal solid waste generation and population: Environmental perspective. IOP Conf. Ser. Earth Environ. Sci., 519(1): 012056.

Suthar, S. and Singh, P. 2015. Household solid waste generation and composition in different family size and socioeconomic groups: A case study. Sustain. Cities Soc., 14(1): 56-63.

United States Environmental Protection Agency 2016. Volume-to-Weight Conversion Factors for Solid Waste. US EPA. Retrieved from https://www.epa.gov/smm/volume-weight-conversion-factors-solid-waste

Xiao, L., Lin, T., Chen, S., Zhang, G., Ye, Z. and Yu, Z. 2015. Characterizing urban household waste generation and metabolism considering community stratification in a rapidly urbanizing area of China. PLoS ONE, 10(12): 1-16.