Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 105 (2022) 86–91

www.elsevier.com/locate/procedia

29th CIRP Life Cycle Engineering Conference

Quantification and mapping of domestic plastic waste using GIS/GPS approach at the city of Guayaquil

J. Hidalgo-Crespo[a,b], César I. Álvarez-Mendoza[c], M. Soto[b], J. L. Amaya-Rivas[d] *

[a]*Universidad de Guayaquil, Facultad de Ingeniería Industrial, Av. Dr. Jiménez Lince y Av. Juan Tanca Marengo, 090501 Guayaquil, Ecuador*
[b]*Universidade da Coruña, Facultade de Ciencias, Rúa da Fraga 10, 15008 A Coruña, Galiza, España*
[c]*Universidad Politécncia Salesiana,Grupo de Investigación Ambiental en el Desarrollo Sustentable GIADES, Carrera de Ingeniería Ambiental, Quito, Ecuador*
[d]*Escuela Superior Politécnica del Litoral, ESPOL, Facultad de Ingeniería Mecánica y Ciencias de la Producción, FIMCP, Campus Gustavo Galindo Km. 30.5 Vía Perimetral, P.O. Box 09-01-5863, Guayaquil, Ecuador*

* Corresponding author. Tel.: +593-4-2269-295; fax: +0-000-000-0000. *E-mail address:* jorge-luis.amaya@espol.edu.ec

Abstract

A significant contributor to the waste stream is the domestic single-use plastic used in households, being the final disposal in most cases the local landfill. There is a significant opportunity to promote resource recovery and efficiency through the introduction of circular economy strategies. However, the knowledge and management of post-consumer plastic waste in the country is poor, and there is a lack of an efficient collection and sorting system. In this context, spatial information on domestic plastic waste generation (DPWG) is essential for recycling decision-making. The integration of Geographic Information Systems (GIS) and the Global Positioning System (GPS) shows an opportunity to collect, mapping, and analyse spatial DPWG issues. Thus, this paper had a double objective. The first was to assess the evolution of eight different types of plastic waste in the city's households and their daily per capita generation between 2019 and 2021. The second objective was to provide a complete geo-referenced information on the quantities and typologies of domestic plastic waste (DPW) produced in Guayaquil and analyse how the flows have shifted throughout the years. The results showed that PET is the most generated, recording 97.76% and 100.00 % of the households who generate this type of plastic for 2019 and 2021, respectively, with an average of 13.08 and 15.13 g/day/c. Following, we had HDPE, PP and PVC occupying the second, third and fourth place for 2019 with 5.86, 3.05, 2.54 g/day/c, respectively. On the other hand, for 2021, PP (7.43 g/day/c), HDPE (5.92 g/day/c), and LDPE (3.99 g/day/c) occupied the second, third and fourth, respectively. According to the spatial maps, the DPW increment is in most of the popular zones. These popular zones are neighborhoods with a considerable quantity of population and limited basic services. Most of these people live in extreme poverty, being a possible relation between the COVID-19 lockdown and the increasement of DPW.

© 2022 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the 29th CIRP Life Cycle Engineering Conference.

Keywords: Domestic Plastic Waste Management, Geographical Information Systems, GIS/GPS

1. Introduction

The most common type of plastic are thermoplastics [1], which can be softened and formed using heat. Thermoplastics advantages reside in their lightweight, inexpensive costs, durability, and taking the shape that they are formed into when cooled, but when reheated, they soften again. Thermoplastics include Polyethylene Terephthalate (PET), High-Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Low-Density Polyethylene (LDP), Polypropylene (PP), Polystyrene (PS), and other materials which are layered or mixed with plastics such as tetra-packs (TP). These remarkable attributes, have increased the production of plastics and their usage, introducing a great threat to the environment due to their persistence in terrestrial, aquatic, and marine environments [2].

The COVID-19 pandemic has reemphasised the indispensable role of plastics, specifically for packaging foods and beverages. The imposition of nationwide lockdown, social distancing, restriction on displacement and public gathering has emerged the inherent properties of plastics. They have become a life-saviour for protecting the health and safety of the

2212-8271 © 2022 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the 29th CIRP Life Cycle Engineering Conference.
10.1016/j.procir.2022.02.015

population looking to avoid conglomerations and serving themselves with online shopping and takeaway services for procuring essentials, including food items and groceries [3].

Lockdown actions and some policy measures have led to a massive surge of single-use plastic items, generating an enormous amount of plastic waste from household units, and with a non-stop growing tendency in the foreseeable future [4]. The estimated growth of plastic packaging is projected to surge from USD 909.2 billion as of 2019 to 1012.6 billion by 2021with an annual growth rate of 5.5% corresponding to the impact of the COVID-19 pandemic on plastic products consumption [5].

The composition of plastics usually discarded as waste by households in order of dominance are low density polyethylene, polyethylene terephthalate, high density polyethylene and polypropylene [6]. According to the Environmental Protection Agency (EPA), while plastics are found in all major municipal solid was (MSW) categories, the containers and packaging category have the most plastic tonnage including bags, sacks, and wraps; other packaging; polyethylene terephthalate (PET) bottles and jars; high-density polyethylene (HDPE) natural bottles; and other containers. Plastics are also found in nondurable products, such as disposable diapers, trash bags, cups, utensils, medical devices, and household items such as shower curtains [7].

Governors should seek a more efficient plastic waste recovery system, accompanied by restriction laws and regulations (including incentives and penalisations) for producing, using, and consuming plastic products [8]. In this context, Ecuador's Government released the Organic Law for the Rationalisation, Reuse and Reduction of Single-use Plastics on December 21st, 2020. The approved law seeks to regulate the generation of plastic waste the progressive reduction of single-use plastics through responsible use and consumption, the reuse and recycling of waste and, when possible, its replacement by packaging and products made with recycled material or biodegradable with a lower carbon footprint than the everyday used product, to contribute to health care and the environment [9].

To our knowledge, there has been only one attempt to quantify and classify domestic plastic waste in 2019. The study found the average plastic waste generation of 406 households from the city of Guayaquil, finding that the amount of domestic plastic waste generated per household weekly is 1.64 kg, being PET the most disposed of waste, followed by HDPE, PP, and LDPE [10]. Waste management functions as an exclusive competence of the city's municipality through a private company known as Consorcio Urvaseo. The collected material goes to Las Iguanas landfill without any previous sorting.

Geographical Information Systems (GIS) can localise previously GPS identified households and allocate them waste weight data. A significant amount of data can be efficiently stored, geo-referenced, retrieved, analysed, and displayed through GIS concerning user-defined specifications [11].

Identification, quantification, and geographical distribution of plastic waste is a necessary initial step for designing any recycling scheme inside a waste management system. It is indispensable for the collection and sorting process design, including the sizing and location of recycling bins in the city and evaluating its environmental and economic impacts.

This paper has a double objective. The first is to assess the evolution of the eight types of plastic waste in the city's households and their daily per capita generation between 2019 and 2021. The second objective is to provide complete geo-referenced information on the quantities and typologies of domestic plastic waste (DPW) produced in Guayaquil and analyse how the flows have shifted throughout the years.

The rest of this paper presents as follows; Section 2 shows the methodology undertaken to quantify and classify the eight different types of plastic waste, and how GIS software was used to locate this information with the GPS locations of each participating household for the years 2019 and 2021; section 3 presents the results with the quantities of plastic waste and their geospatial presence in the city. Finally, section 4 concludes and discusses the subject to offer alternatives and future perspectives.

2. Methods and materials

The authors divided the methods and materials into two sections.

2.1. The study area

Guayaquil is the capital of the province of Guayas. The city is located on the west bank of the Guayas River, Figure 1, which flows into the Pacific Ocean at the Gulf of Guayaquil. The total quantity of households for the city in 2010 was 412,876. Guayaquil is divided in districts, having a total of 16: Ayacucho, Bolívar, Carbo, Chongón, Febres Cordero, García Moreno, Letamendi, Nueve de Octubre, Olmedo, Pascuales, Roca, Rocafuerte, Sucre, Tarqui, Urdaneta, Ximena. The composition of urban waste for the city of Guayaquil was previously studied in 2018, however the composition and types of plastic were not measured. The waste consisted mainly of five types of waste: organic residues (69.73%), plastics (9.48%), paper and cardboard (6.96%), dust and ashes (3.72%), and glass (3.72%) [13].

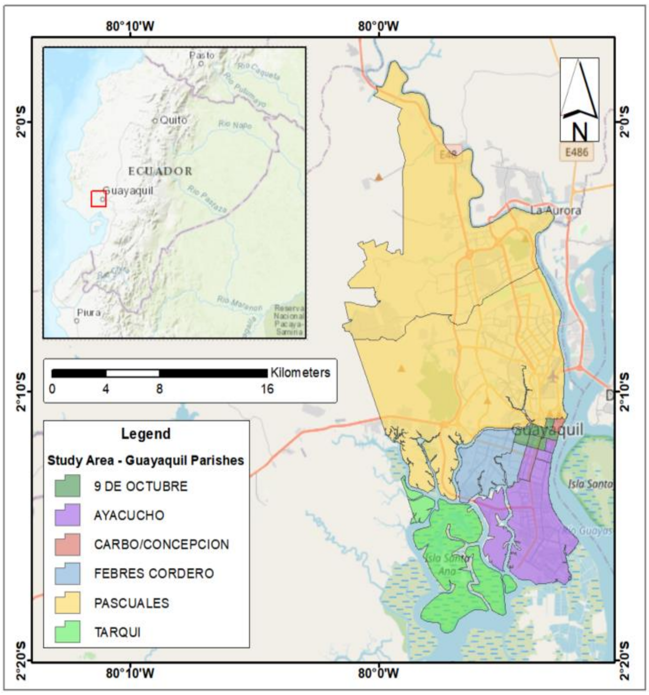


Figure 1. The study area focused on some Guayaquil urban parishes

2.2. Sampling

The procedure used to determine the minimum number of samples needed to gather reasonably accurate data was based on the central limit theorem, also applied by [14]. The central limit theorem is established with the condition that the sample size is sufficiently large [15,16]. The following equation was used for the calculations:

$$n = \frac{k^2 * p * q * N}{e^2 * (N-1) + k^2 * p * q} \qquad (1)$$

where n is the minimum number of samples, k is a constant that depends on the level of confidence (for 95% confidence k is 1.96), e is the sampling error, p is the proportion of inhabitants that possess the characteristic we seek, and q is the number of inhabitants that don`t possess it (Normally, 0.5 for each one).

2.3. Data gathering and GIS spatial interpolation

The study employed a case study research approach, as shown in Figure 2. The process to quantify and classify the different types of domestic plastic waste for both 2019 and 2021 were as follows:

- **Data Definition:** The project first was introduced to different university students and the objectives were presented to them. They were told that to participate they needed a total of 5 families from the city, including their own households if they were in fact located in the city, neighbours or other family members from the city which didn't inhabit with them.
- **Collection Data Planning:** Students, after needed to register in the project through an online form giving data, such as: families last names, GPS coordinates, household size, garbage truck collection frequency. They were trained with the help of a plastic data sheet to identify the 8 different types of plastic wastes and were asked to pass the information to every participating family. Each family were told to recover their plastic wastes and poured them into a plastic bag, which was before tagged by the students with a set codification to identify the household to the produced waste.
- **Plastic Waste Collection:** Each student recovered every plastic bag by the end of every week of the project. For 2019, project duration lasted 2 weeks and for 2021, 4 weeks. Every Sunday the filled plastic bags were recuperated from the families and a new plastic bag was given to continue the following week. The following Monday, each student had to transport each bag to the plastic waste storage, located in the university.
- **Plastic Waste Classification:** A different group of students from the university were trained into plastic waste recognition and a worktable was established. Each plastic bag was first weighted, and after with the help of 8 plastic bins, the different types of plastic were classified. One researcher was always close to supervise and answer any question on any type of not identified plastic. The students firstly tried to identify if the plastic waste contained the resin code, and if not, they would separate them according to their properties previously explained by the researchers.
- **Plastic Waste Quantification:** The project counted with two high precision of 0.1 grams scales to weight each type of plastic waste for each household. Using the code form the bag, the values of every type were connected to the previously online form information, giving us the mass per household per week of every GPS location.
- **Spatial Interpolation with GIS:** First the georeferenced coordinates were imported to a Microsoft Excel spreadsheet to generate a map of quantitative waste generation for each type of plastic. Thus, we map the field registers as a distribution point map around the Guayaquil urban parishes. The main objective was to develop spatial modelling using a geographic information system (GIS) for each kind of waste by year. The GIS software was ArcGIS 10.8. Consequently, the waste input dataset includes a simple statistical analyst to avoid null and extreme values. Converting the clean input dataset to a point shapefile, the inverse distance weighting (IDW) interpolation allows making spatial models as raster structures. The IDW is a deterministic method to assign values to unknown points in a location influenced by nearby known points (geo-referenced field samples). It is used to map some environmental pollution problems [17]. The equation 2 shows the IDW method, where x_u is the unknown value, w is the weight determined by the inverse distance and x is the know point value.

$$x_u = \frac{w_1 x_1 + w_2 x_2 + w_3 x_3 + \cdots + w_n x_n}{w_1 + w_2 + w_3 + \cdots + w_n} \qquad (2)$$

Moreover, the equation 3 shows the way to compute the weights (w), where d is the distance between the unknown value point to the known point.

$$w_1 = \frac{1}{d_1} \qquad (3)$$

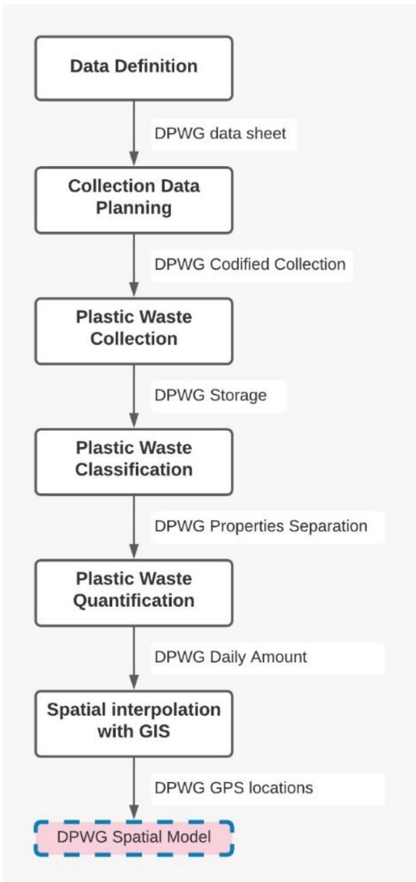


Figure 2. Study methodology undertaken.

3. Results

3.1. Estimated daily amount of plastic waste generated by a household in Guayaquil

Considering the total population of 413 thousand households for the city of Guayaquil, a sample of 401 households were involved in 2019, with 95% of confidence and 4.89% of sampling error, and finally a sample of 237 households for 2021 with also 95% confidence and 6.39% of sampling error. Table 1 shows the frequency to which we can find each type of plastic waste per household and the daily average per capita waste generation in grams, both for 2019 and 2021. In general terms, we can observe that the presence of each type of plastic waste has increased in households in the city from 2.24% for PET to 23.44% for TP. The study shows that among all the eight generated plastic waste types in the city, PET is the most generated, recording 97.76% and 100.00 % of the households who generate this type of plastic for 2019 and 2021, respectively.

Table 1. Types of plastic waste generated in 2019 and 2021

Plastic Type	2019		2021	
	Frequency	g/day/c	Frequenc y	g/day/c
PET	392 (97.76%)	13.08	237 (100.00%)	15.13
HDPE	266 (66.33%)	5.86	200 (84.39%)	5.92
PVC	55 (13.72%)	2.54	70 (29.54%)	2.51
LDPE	168 (41.90%)	2.33	152 (64.14%)	3.99
PP	284 (70.82%)	3.05	206 (86.92%)	7.43
PS	149 (37.11%)	1.55	139 (58.65%)	2.31
OP	49 (12.22%)	0.41	79 (33.33%)	1.85
TP	60 (14.96%)	0.44	91 (38.40%)	1.26

For 2019, PET was the most generated plastic waste (an average of 13.08 g), with HDPE, PP and PVC in second, third and fourth place (5.86g., 3.05g., and 2.54 g, respectively). On the other side, for 2021, PET also occupied first place with an average of 15.13 g.; however, the second, third and fourth places were occupied by PP (7.43 g), HDPE (5.92 g), and LDPE (3.99 g) respectively. OP and TP were the least generated plastics for both years, with an average of 0.44 g for TP in 2019 to 1.26 g in 2021 and 0.41 g for OP in 2019 to 1.85 g in 2021.

The evolution of plastic waste is such that OP, TP, PP, and LDPE have approximated increasing percentages of 351%, 186%, 144%, and 71%, respectively. This can be explained as a side-effect of pandemic times. New research indicates that Covid-19 will reverse the momentum of the years-long global battle to reduce plastic waste pollution [18].

Many sectors of the economy, especially small businesses owners, have entered online shopping not to shut down their operations. Almost everything can be acquired; however, all items need to be packed to facilitate transportations and maintain product quality and secure hygiene, causing a significant increase in packaging production, both in the productive sector and as residues [19].

One of the reasons behind the generation of PET by most households may be that it is affordable (cheap) and lightweight and that most beverage manufacturers use it for their businesses. The Regional Initiative for Inclusive Recycling and Recyclers (IRR) estimates that the annual demand for raw PET materials is 49,200 tons per year, to which recycling contributes 31% [20].

3.2. Results of spatial distribution of domestic plastic waste in Guayaquil

GIS software allows to locate and combine most of the geo-referenced data obtained by the research. Figure 3 shows the spatial distribution of relative DPW changes between 2019 and 2021. Colors from green to red were given to different ranges of DPW, as shown in the legends, being the green the lowest and the red the highest quantity. Considering the mapping, the northern area of the city increases DPW generation from 2 to 100 g/day/c in PET, HDEP, LDPE, PP, PS and PVC, between both years. It is in fact, interesting that some of the most popular sectors, such as "Bastion Popular, or "Pascuales", are in the north region. Another focal increase is in "Guasmo", a south neighborhood of the city. The focal increase is in the use of PET. Important to mention, that the three neighborhoods are considered urban-marginal for the city of Guayaquil, having a possible relationship between the COVID-19 lockdown and DPW increment, but additional is required to relate them [21].

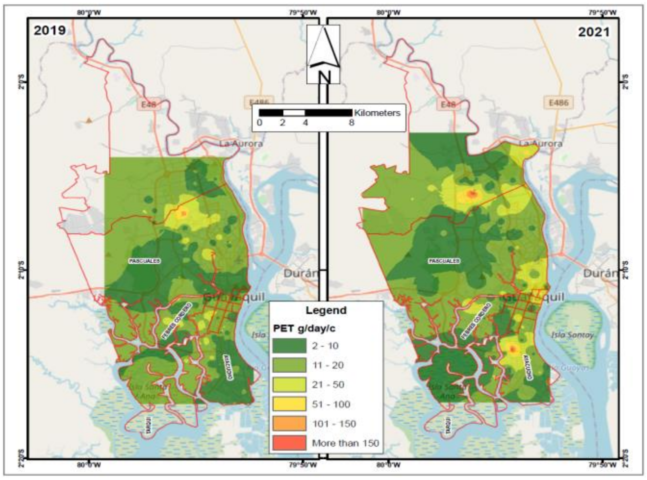
4. Conclusions and Discussion

The dependency on e-commerce shopping and takeaway services for home delivery of essential items during the COVID-19 pandemic has increased demand for HDPE carry bags and other types of plastic for packaging purposes, such as PS or PP. The rationale behind the study is to enable comparison on the plastic waste generated between years 2019 and 2021, and how the generation has shifted for the different types of plastics over the years.

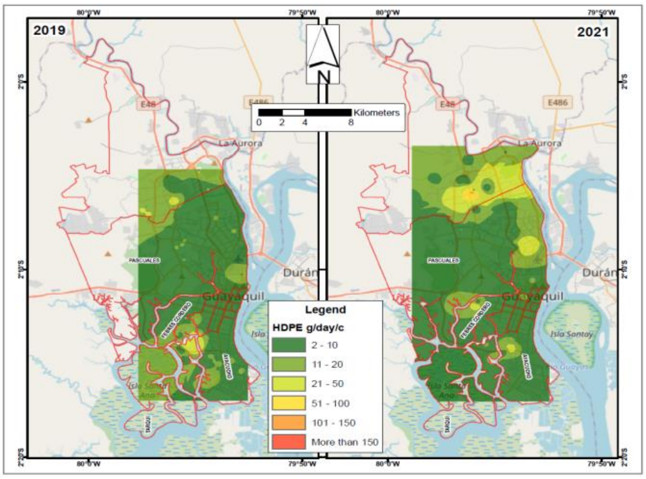
PET is the most generated, recording 97.76% and 100.00 % of the households who generate this type of plastic for 2019 and 2021, respectively. For 2019 and 2021, PET was the most generated plastic waste with an average of 13.08 and 15.13 g/day/c. HDPE, PP and PVC occupied the second, third and fourth place for 2019 with 5.86, 3.05, 2.54 g/day/c, respectively. On the other side, for 2021, PP (7.43 g/day/c), HDPE (5.92 g/day/c), and LDPE (3.99 g/day/c) occupied the second, third and fourth, respectively.

According to the spatial maps, the DPW increment is in most of the popular zones. These popular zones are neighborhoods with a considerable quantity of population and limited basic services. They all have started as illegal establishments and were after legalized by the local government. There could be a relation between the COVID-19 lockdown and the increasement of DPW in these popular areas, however, deeper analysis should be made to validate this assumption. The GIS database created allowed the generation of thematic maps on the spatial distribution of DPW in the city of Guayaquil. The results are easily manageable and will constitute a helpful tool for the local authorities to monitor the DPW production and adequately manage the DPW flow evolution throughout the years.

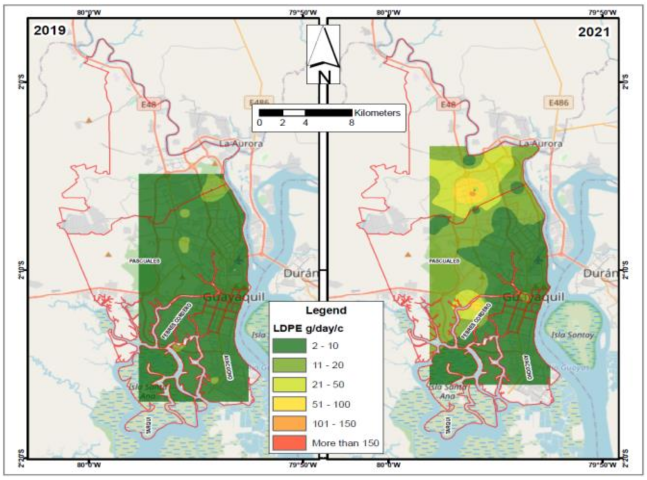
The effective management of plastic waste is a significant challenge, especially for a developing country, such as Ecuador. Improperly discarded plastic wastes can float around in the environment, accumulating various toxic pollutants and pathogens on their surfaces, especially in pandemic times, which could pose harmful environmental and health risks to humans and marine ecosystems.



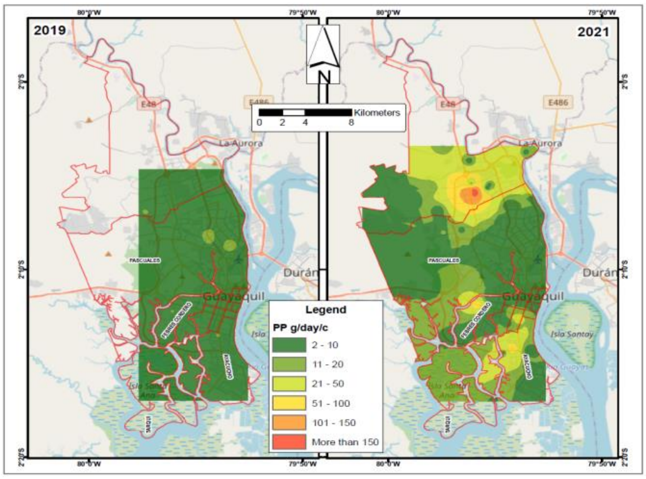
(a)



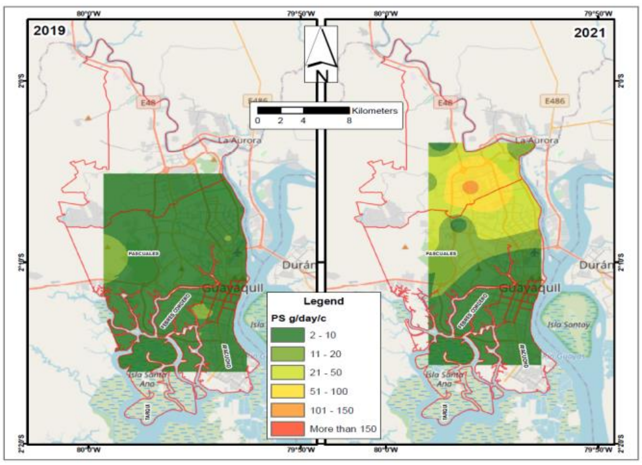
(b)



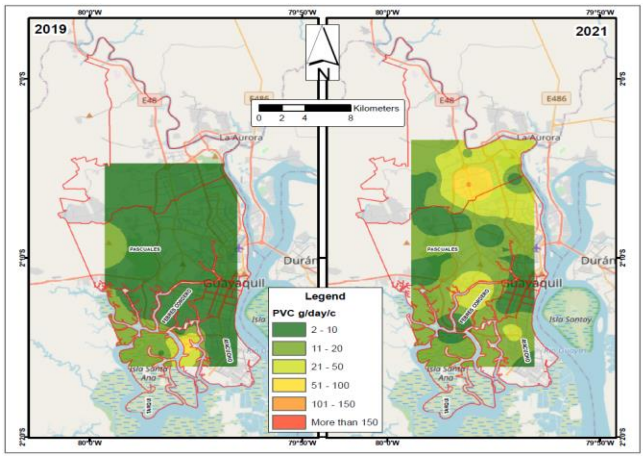
(c)



(d)



(e)



(f)

Figure 3. Spatial distribution and evolution of DPW: (a) PET, (b) HDPE, (c) LDPE, (d) PP, (e) PS and (f) PVC.

Although the use and consumption of plastics significantly improve our quality of life, it is essential to shift towards sustainable alternatives, such as recycling. Plastics should occupy the top of the country's political agenda to minimise single-use plastics leakage and pollution and promote sustainable growth and stimulate a more circular economy.

Consumers' irresponsible behaviours and attitudes, adding poor awareness and the stress on the waste management infrastructure for the city of Guayaquil, in terms of collection, operation, and financial constraints, are the major drivers to turn plastic into a pollutant.

This paper can promote sustainable solutions in urban waste management planning within the wider issue of minimising the amount of resin imported and waste rejected in the landfills. One example of this, is the improvement of kerbside recycling by urban mining. With this information, the possibility of a reuniting them to form a cooperative knowing the total amounts and the most pollutant districts, can represent a positive environmental impact and should be considered in the waste management chain [22]. On average, a recycler contributes to preventing 0.48 tCO2-eq per ton of recycled material [23].

Plastic can be a protector if appropriately managed and complemented by the circular economy strategies in terms of reduction, recycling, and recovery, thereby preventing leakage into the environment [24].

References

[1] Pitchel J. Waste management practices: Municipal, hazardous and industrial. New York, USA: Taylor and Francis Group, 2005.

[2] United Nations Development Program (UNDP). Informal Solid Waste Management. Nairobi, Kenya, 2018.

[3] Neha Parashar, Subrata Hait. Plastics in the time of COVID-19 pandemic: Protector or polluter? Science of The Total Environment, Volume 759, 2021, 144274, ISSN 0048-9697, DOI: 10.1016/j.scitotenv.2020.144274.

[4] Haque MS, Sharif S, Masnoon A, Rashid E. SARS-CoV-2 pandemic-induced PPE and single-use plastic waste generation scenario. Waste Manag Res. 2021 Jun; 39(1_suppl):3-17. doi: 10.1177/0734242X20980828.

[5] Business Insider, 2020. COVID-19 impact on packaging market by material type, application, and region-global forecast to 2021. https://markets.businessinsider.com/news/stocks/covid-19-impact-on-packaging-market-by-material-type-application-and-region-global-forecast- to-2021-1029187123. (Accessed August 26th, 2021).

[6] Gwada, B., Ogendi, G., Makindi, S. M., & Trott, S. (2019). Composition of plastic waste discarded by households and its management approaches. Global Journal of Environmental Science and Management, 5(1), 83–94.

[7] Plastics: Material-Specific Data. Available Online: https://www.epa.gov /facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data (Accessed November 26th, 2021).

[8] Haque MS, Sharif S, Masnoon A, Rashid E. SARS-CoV-2 pandemic-induced PPE and single-use plastic waste generation scenario. Waste Manag Res. 2021 Jun; 39(1_suppl):3-17. doi: 10.1177/0734242X20980828.

[9] Third Supplement of Official Gazette No. 354 of December 21, 2020. Available online: https://www.registroficial.gob.ec/index.php/registro-oficial-web/publicacones/suplementos/item/download/13312_750567ee67 423eb354dc562bf5f97b66 (accessed on 29 August 2021).

[10] J. Hidalgo-Crespo, J. L. Amaya, M. Soto, and L. Caamaño-Gordillo (2020). Domestic Plastic Waste in the city of Guayaquil: Generation Rate and Classification. Paper presented at the Proceedings of the 19th LACCEI International Multi-Conference for Engineering, Education, and Technology: "Prospective and trends in technology and skills for sustainable social development" "Leveraging emerging technologies to construct the future", Buenos Aires -Argentina, July 21-23, 2021, doi: 10.18687/LACCEI2021.1.1.168

[11] Ileana Blanco, Rosa Viviana Loisi, Carmela Sica, Evelia Schettini, Giuliano Vox, Agricultural plastic waste mapping using GIS. A case study in Italy. Resources, Conservation and Recycling, Volume 137, 2018, 229 - 242, doi: 10.1016/j.resconrec.2018.06.008.

[12] Instituto Nacional de Estadísticas y Censos: Guayaquil en cifra. Available online:https://www.ecuadorencifras.gob.ec/guayaquil-en-cifras/ (accessed on 29 August 2021).

[13] Hidalgo-Crespo, J., Moreira, C. M., Jervis, F. X., Soto, M., & Amaya, J. L. (2021). Development of sociodemographic indicators for modeling the household solid waste generation in Guayaquil (Ecuador): Quantification, characterisation, and energy valorisation. Paper presented at the European Biomass Conference and Exhibition Proceedings, 252-259.

[14] Gomez, G., Meneses, M., Ballinas, L., & Castells, F. Characterization of urban solid waste in Chihuahua, Mexico. Waste Management, 2008, 28(12), 2465–2471. doi:10.1016/j.wasman.2007.10.023

[15] Zhang, X.-F., Yang, F.-B. & Wang, X.-Z. A theorem for calculation of the appropriate sample size in an estimation. Chaos, Solitons and Fractals, 2017, 104, 291–297. doi:10.1016/j.chaos.2017.08.015.

[16] Hidalgo-Crespo, J., Amaya, J., Jervis, F., Moreira, C., Crespo-Vaca, T., Zabala-Ortiz, G., & Coello-Pisco, S. (2019). Waste-to-energy incineration: Evaluation of energy potential for urban domestic waste in guayaquil. RISTI - Revista Iberica De Sistemas e Tecnologias De Informacao, 2019(E23), 392-403

[17] C. I. Alvarez-Mendoza, A. Teodoro, A. Freitas, and J. Fonseca, "Spatial estimation of chronic respiratory diseases based on machine learning procedures—an approach using remote sensing data and environmental variables in quito, Ecuador," Appl. Geogr., 123, p. 102273, 2020, doi: 10.1016/j.apgeog.2020.102273.

[18] Nsikak U. Benson, David E. Bassey, Thavamani Palanisami. COVID pollution: impact of COVID-19 pandemic on global plastic waste footprint. Heliyon, Volume 7, Issue 2, 2021, e06343, ISSN 2405-8440, doi: 10.1016/j.heliyon.2021.e06343.

[19] de Sousa, F.D.B. Plastic and its consequences during the COVID-19 pandemic. *Environ Sci Pollut Res* **28,** 46067–46078 (2021). doi: 10.1007/s11356-021-15425-w

[20] Iniciativa Regional del Reciclaje Reciclaje inclusivo y recicladores de base en Ecuador. Available online: https://www.yumpu.com /en /document/read/54482978/libro-reciclaje-inclusivo-y-recicladores-debase-en-ecuador (accessed on 29 August 2021).

[21] Hidalgo-Crespo, J., Cañizalez, Y. G., Pisco, S. C., Monteses, J. B., Alonso Aguila, L. M., & Crespo-Vaca, T. (2019). Household electricity demand in marginal ecuador: Estimation and impact of explanatory variables. RISTI - Revista Iberica De Sistemas e Tecnologias De Informacao, 2019(E23), 378-391

[22] J. Hidalgo-Crespo, F.X. Jervis, C.M. Moreira, M. Soto, J.L. Amaya, Introduction of the circular economy to expanded polystyrene household waste: A case study from an Ecuadorian plastic manufacturer, Procedia CIRP, Volume 9, 2020, Pages 49-54, doi: 10.1016/j.procir.2020.01.089.

[23] Burneo, D.; Cansino, JM; Yñiguez, R. Environmental and Socioeconomic Impacts of Urban Waste Recycling as Part of Circular Economy. The Case of Cuenca (Ecuador). Sustainability 2020, 12, 3406. doi: 10.3390/su12083406

[24] Neha Parashar, Subrata Hait. Plastics in the time of COVID-19 pandemic: Protector or polluter?. Science of The Total Environment, Volume 759, 2021, 144274, ISSN 0048-9697, DOI: 10.1016/j.scitotenv.2020.144274.