Toward a Solid Waste Economy in Colombia: An Analysis with Respect to Other Leading Economies and Latin America

José J. Rúa-Restrepo, Gloria I. Echeverri and Henry A. Colorado

Abstract This investigation aims to analyze critically the historical situation, current, and potential trends of the main solid wastes in Colombia, not only from a detailed and internal point of view, but also in the Latin American countries. To give a better context and understanding of the issue, some data is also studied in comparison with some leading economies worldwide. Most countries worldwide including Latin America still work with the linear economy model, where the wastes are not intended to be minimized, re-used, or considered in the initial design as is in the circular economy. To implement the circular economy, one of the major challenges in many countries is the quantification and thus reliable and verifiable data for waste, therefore being one of the main goals of the current investigation in Colombia, particularly focused in the main solid wastes. In addition, important clues have been found in relation with the waste, economy, population, gross internal product, regulation, and society practices. Results from the current investigation can be used for similar economies and for countries with comparative waste numbers to Colombia.

Keywords Sustainable economy · Circular economy · Solid waste · Colombia · Latin America

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G. Gaustad et al. (eds.), *REWAS 2019*, The Minerals, Metals & Materials Series,
https://doi.org/10.1007/978-3-030-10386-6_41

Introduction

Today, the estimation is that the world generates about 1.3 billion tons yearly of solid wastes, and it is expected to double this number for 2025 with the population increase [1], which is considered now a worldwide problem [2]. In Europe, the uncontrolled growing of wastes derived from the world consuming its natural resources faster has forced that politics are all adapted to promote the use and exploitation of these wastes with the optimal strategy according to the socioeconomic projections [3]. It is known the relation among the solid waste generation, the population increase, and the industrial production [4] and Bruvoll and Ibenholt [5]: the increase in the population has generated an increase in the raw materials and correlation with the economic level, production, and generated wastes overall. This has been validated by Berglund and Söderholm [6], using econometrics for a flow analysis of the used raw materials in the paper industry, showing a relation among the generated waste, the management, and the economy, for industry and communities [7]. In order to minimize the waste, because targeting this one to zero is impossible itself by the thermodynamics laws, the strategy of minimizing the waste has been compared to recycling [8], finding the first as the more effective solution. The waste minimization concepts [9] have been collected by the circular economy (CE) model [10], as an alternative to the take-make-dispose alternative [11] and to take actions to preserve and make sustainable the available the planet Earth resources [10, 12–16].

Important research of the circular economy has been conducted in Asian nations, led by China [17–19], which shows a positive interest on the CE as their population and industrial production numbers have been increased significantly in the last few years, having a lot of public health issues [15]. Circular economy directly contributes to the sustainable development [20], but deserve a complete change not only in the procedures and technical aspects including the exploitation of natural resources, design, logistics, and manufacturing, but also in the politics and the economic model [21], and in the society role as well [22].

Organizations such as the Organization for Economic Co-operation and Development (OECD) [23] have been informing about the potential world-scale catastrophic scenario that can overcome a weak take in action and poor regulation in the correct implementation of the needed environmental and economical politics. The manufacturing sector plays a significant position in the accomplishing of these goals [24], with a main role of the plastic industry as a derived from a very contaminant oil industry [25], in the last years always being the focus of public attention, since the derived materials are typically not properly exploited or recycled [26], pero con alto potencial de aprovechamiento [27].

In particular in Colombia, and in other developing countries in Latin America and the Caribbean and also in Africa, the problems are even worst because the regulation is weak, the politicians are not really interested, and also because the waste statistics are not well-known. The numbers regarding the correct disposition and exploitation of waste with respect to the total amounts generated constitute the starting point for the circular economy of plastic materials [28–30].

In this paper, several data is presented and also other is generated mainly about the solid waste in Colombia and the main regulations. In addition, comparison with other nations are presented and most importantly presented in the Latin American context. Some details of the plastic waste generation and recycling are also discussed in relation with the Gross Domestic Product (GDP) and the population, all this conducted in order to set the bases for the calculation of a realistic and reliable circular economy model.

Materials and Methods

The materials analyzed in this investigation correspond mainly to plastic, organic, paper, and ordinary solid wastes. In order to establish feasible statistics about these wastes, not only local but also international databases have been studied, which include provided and official data. The main sources are detailed below.

American Society of Testing Materials—ASTM

The ASTM-D5231-92 [31] established a characterization methodology for the generated wastes from the residential and urban areas. Commercial and industrial wastes are also included. The mean composition determination for the municipal solid waste (MSW) starts with the collection and manual classification of wastes for a selected period of time of minimum a weak. Three main procedures are involved:

- Random sample collection in site.
- Collection time of data.
- Sectoral analysis for the characterization of different parts of the simple.

United Nations for Environmental Protection (UNEP)

UNEP has a detailed procedure for the solid waste management that includes its characterization and quantification [32]. Among other information, the solid wastes must be divided into the following types:

- Municipal solid wastes (residential and commercial)
- Construction and demolition wastes
- Industrial solid wastes (nonhazardous)
- Hazardous wastes (industrial, health, laboratory, and construction and demolition wastes).

The collection of information for the must follow the following steps:

- Step 1: Classification of the characteristics to measure
- Step 2: Procedure for sample collection
- Step 3: Waste quantification
- Step 4: Analysis methods.

World Bank (WB)

By the What a Waste [1] source, the World Bank (WB) studies the socioeconomic model, the demographic growing, the level of life, and the income level, all against the solid waste generation. The results are clear and reveal that more plastic waste is generated in the nations with a highest per capita income, where more materials are consumed and therefore more waste is expected, see Fig. 2. For Fig. 3, it can be seen how the waste is sectorized, it is also possible to observe the quantity of them and the classification of them in different types according to the countries analyzed, and it should be noted that this documentation is the result of the consolidation of data obtained during several years of research until 2012, including only member countries of the OECD. Analysis of the flow and econometrics using the Hodrick and Prescott (HP) can be used to determine the relationship between the flow and the reduction in the quantity of waste in a measure of time [33].

Hodrick and Prescott analysis use time series for analyze the data, using as a main parameter the period measured, such as year, each 3 months, and each 6 months, in order to give an approximation or an estimate of the behavior of the variables [34]. For the trend estimation, HP filter takes each point of data for every year, after it builds a trend according to the algorithm [35] and afterward describes the behavior of the variables and according to the inclination of the curve it is possible to predict data for ten years in the future. In the research, the data from different sources (see Fig. 5) is analyzed with HP filter, the variation of the algorithm uses an alpha of 100, since the data is given annually and the results can be detailed in Figs. 6 and 7, in which a cycle of behavior is presented, and the behavior of the softened curve explains the model that allows to describe the future data for the selected variable. Plastics are used as a variable of study.

Results and Analysis

Figure 1 shows a general overview of the OCDE countries for the solid waste data between 2010 and 2012 from D-Waste Atlas 2013 [36]. Figure 1a shows the solid waste per capita, which is very high in North America and Australia. Figure 1b shows the plastic waste generated relative to the total production, high in more distributed countries and also high in South America. Figure 1c shows the organic

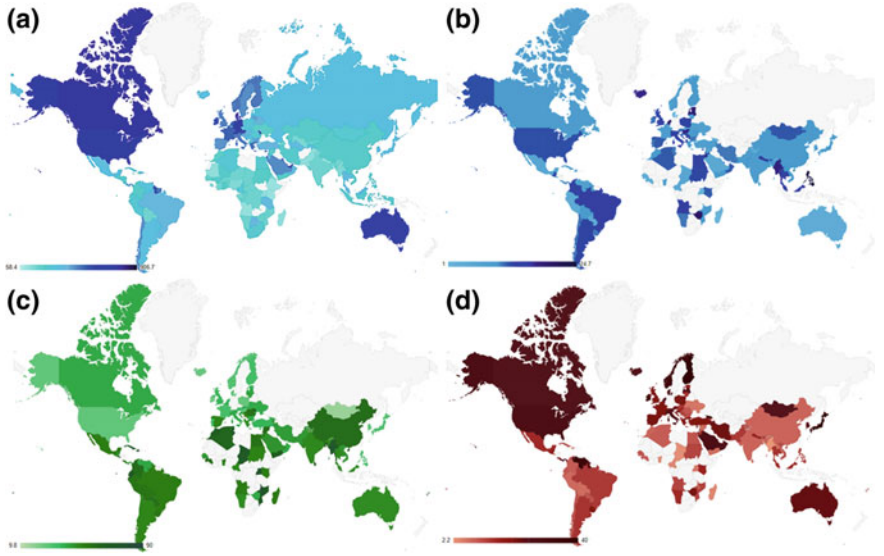


Fig. 1 Sectorized generation of Global Solid Waste (GSW): **a** Per capita solid waste generation (Kg/Año). **b** Plastic waste (%) regarding to total generation. **c** Organic waste (%) regarding to total generation. **d** Paper and cardboard (%) regarding to total generation. *Source* D-Waste Atlas (2013)

waste generated, also with a very important contribution from Latin and Central America. Finally, Fig. 1d shows the paper and cardboard waste generated, very high in the more developed countries, including USA, Canada, Australia, and Europe. These maps clearly show two faces: one is revealing an environmental problem, the other one is an opportunity for innovation and creative ways to use and recycle wastes. Particularly in Latin America and the Caribbean (LAC), an economics that includes solutions for the organic and plastic wastes can be a route toward the development.

The Situation with Respect the Leading Economies

The solid waste generation and the global income economy of the country have been summarized in Fig. 2 with data from World Bank. In this representation, solid waste was characterized by the type (organics, paper, plastic, glass, metals, and other solid wastes) and summarized by the type of economy of the country in general: high, medium-high, medium-low, and low-income country. In general, it is clear and accepted the inverse relation between the country income and the amount of waste generated. However, specifically low-income countries produce more organic waste than high-income countries; and high-income countries produce more plastic waste. In general, people with better economy have a higher product consumption of

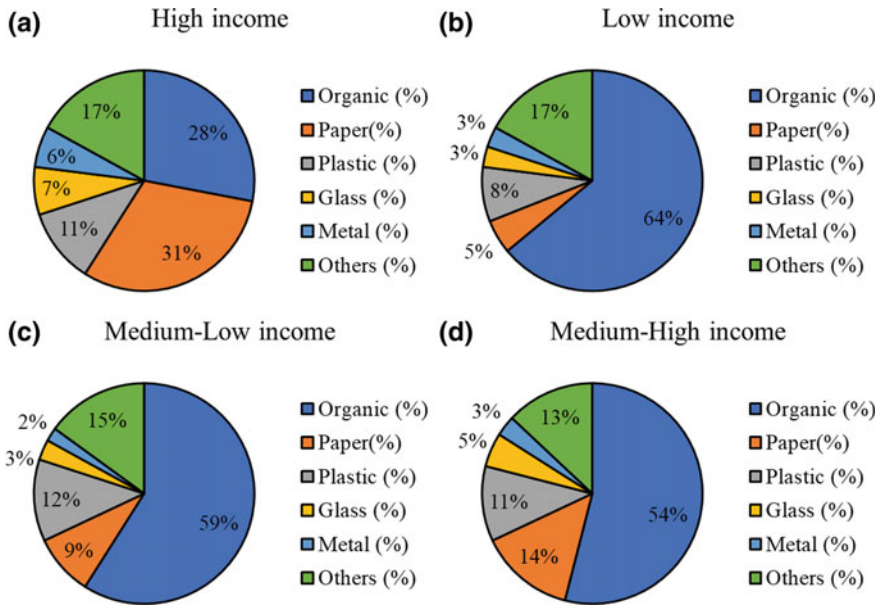


Fig. 2 Global waste generated by stream of waste and by economic income. **a** High income. **b** Medium-high income. **c** Medium-low income. **d** Low income. *Source* What a waste (2012)

materials and parts. These graphs also reveal that low-income countries need to work more in the use of organic wastes, which is better treated in the leading economies.

Figure 3a also supports Fig. 2, since countries as USA and Australia, show the lowest organic waste generated, but the highest numbers in terms of the plastic and paper wastes. On the other hand countries with weak economies show the organics as its main solid waste. Medium-high income countries show a high organic waste volume, and similar amount of plastic waste among them, with Denmark out of the trend with just 1 wt% of plastic waste, which is of course a consequence of good practices not only for recycling and utilization of the generated wastes but also a decrease in the solid waste generation.

Figure 3b suggests how each country manages its waste given by the numbers obtained directly from the landfills, with information including the classification and use of waste. Some countries such as Japan and Denmark have significant numbers of energy recovery in incineration plants of these wastes. The other part of the pie is revealed by countries with 100 wt% of wastes disposed of only in landfills, which suggests no programs and strategies for classification, recuperation and use of the solid wastes. Countries including Colombia, Costa Rica, and Uruguay, still have an important open to air landfills, which in most cases is the result of lack of interest of the government in a better solution. In Colombia, the regulation and politics for the solid waste management are proved to be not very efficient as there are several serious and active conflicts with the communities in the areas of interest. Moreover,

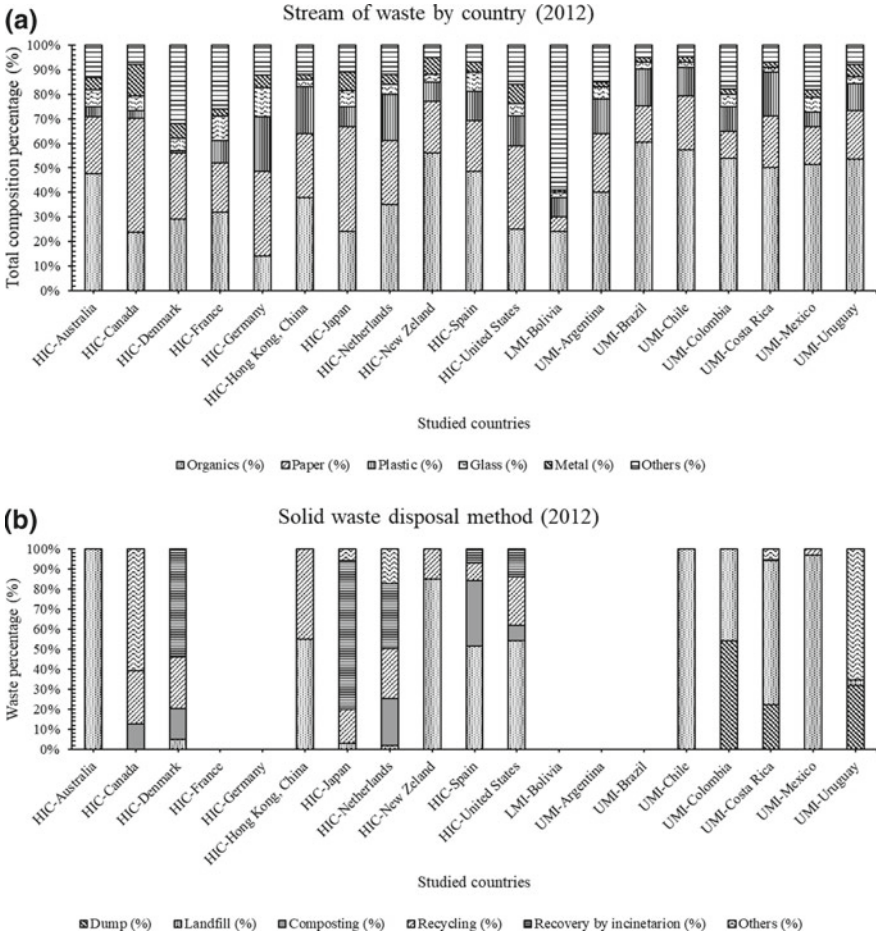


Fig. 3 Waste typology by country regard to income level: high income (HIC), low medium income (LMI) and upper medium income (UMI). **a** Stream of waste by country. **b** Solid waste disposal method. *Source* What a waste (2012)

the solid waste statistics and the official information provided the governing agencies is still in many cases in consolidation, as regulation just started to be applied and therefore in sectors like plastics, not much information is available, and the USA Environmental Protection Agency (APA) is being taken as a reference but still with a lot of limitations.

Figure 4 shows waste data for three different agencies in the same year: EPA, World Bank (WB), Statista. EPA and WB statistics show very close trends in the flow of waste materials, particularly in plastics and organics. STATISTA data present significant differences in the same waste types, which can be associated with differences in the information consolidation by each organization, with differences in the

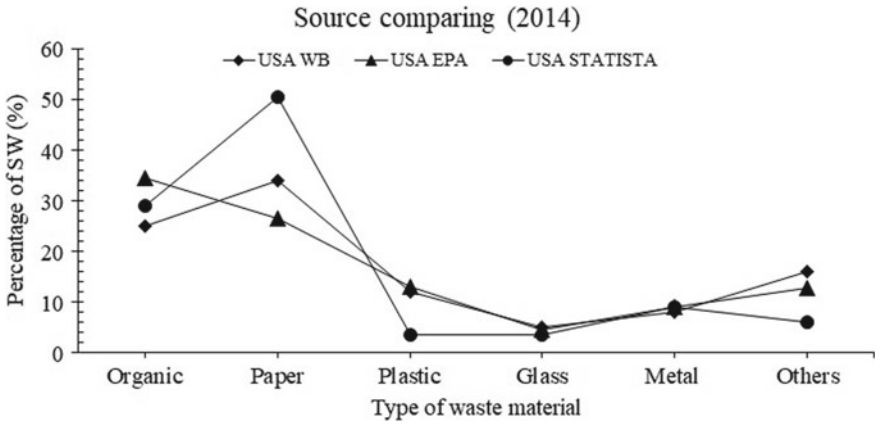


Fig. 4 Solid waste generation in United States according to different sources. *Sources* World Bank, EPA and Statista

classification, measurement, and management. From Waste 360, see Fig. 5a, USA has a particular waste flow with an increasing trend, particularly in plastics. In order to better understand and compare with Latin American and the Caribbean, the flow of paper cardboard and plastics were extracted and analyzed by the area under the curve [10, 37]), and results appear Fig. 5b. Paper and cardboard showed a peak in 2000, and after 2010, it shows a stabilization which is related to the economics of construction industry. Plastics had an important increase up to 2005, and then also show a plateau curve. Figure 5b is showing the positive effect of the environmental politics; as well as recycling, waste utilization, valorization and minimization for these wastes adopted after 2010 [29, 38, 39]. In addition, time series Hodrick and Prescott (HP) [40] were used to analyze the waste generation numbers, see Fig. 6. For paper, plastics, metals, and rubber, there is a trend to decrease the wastes after 2010, perhaps, as a result of improvement in waste management, and also due to a lack in the economy growth. The HP cycle also allows to predict future numbers, as a softened curve, see Fig. 7. This curve reveals a constant growing from 1960 with a slight decrease in the growth after 2010 (Table 1).

The Situation in Latin America

In South America, the data from the Inter-American Development Bank (IDB) for solid wastes was compared with the information from the Gross Domestic Product (GDP).

Figure 8a shows a strong relation between the GDP and the generated solid wastes for different countries in Latin America ordered by the amount of solid wastes. The two curves have the same trend. Figure 8b shows the wastes per capita generation,

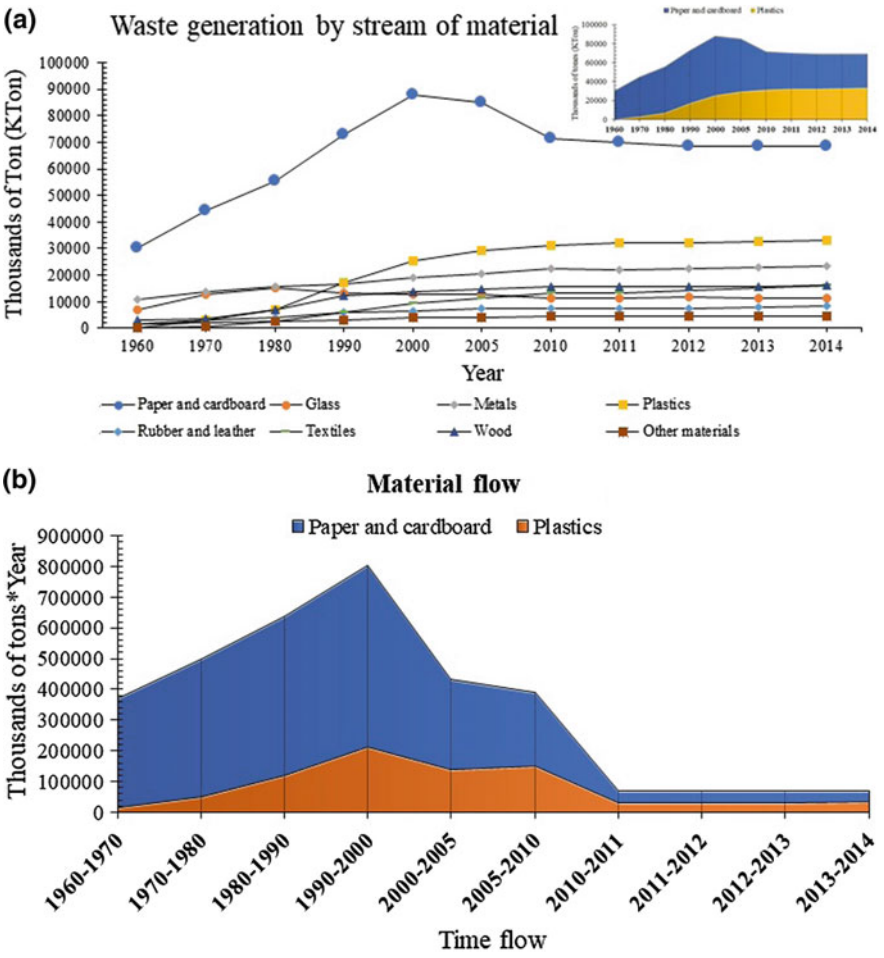


Fig. 5 Waste generation trend according to EPA and Waste 360.org análisis: **a** Historical generation by material flow. **b** Area under the curve

with also some relation with the GDP. Brazil is leading in the amount of wastes generated which is consistent with its largest population of the continent. However, when the waste amount is divided over the GDP, Bolivia pass to lead the statistics with 105 tons/year per million dollars, against lowest one, Venezuela, with 27 tons/year per million dollars. Figure 8c is a summary of the wastes by type, where organics, as shown before, are very significant in Latin America. The graph also reveals the progress in Brazil besides the large industry compared with other Latin American countries, have a better waste management plans.

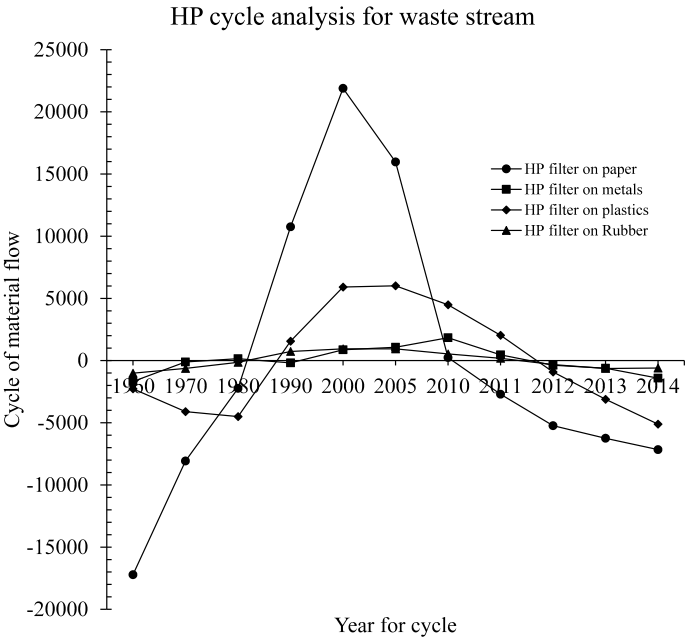


Fig. 6 Hodrick and Prescott analysis for time series of waste generation in Fig. 5. Presenting the most relevant stream of waste paper, plastics, metals, and rubber

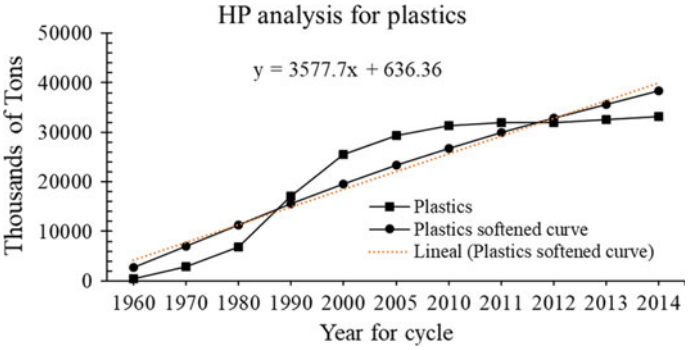


Fig. 7 Examples of softened curve for plastic waste stream

Figure 9 shows waste statistics for Colombia data from WB and BID, which is very consistent. Both sources share information from The Pan American Health Organization (PAHO) and the World Health Organization (WHO).

Figure 10 is a summary of the waste utilization rates in Colombia by the type of waste. A lot of work needs to be done for improving the use of organics, cement and concrete, and plastics.

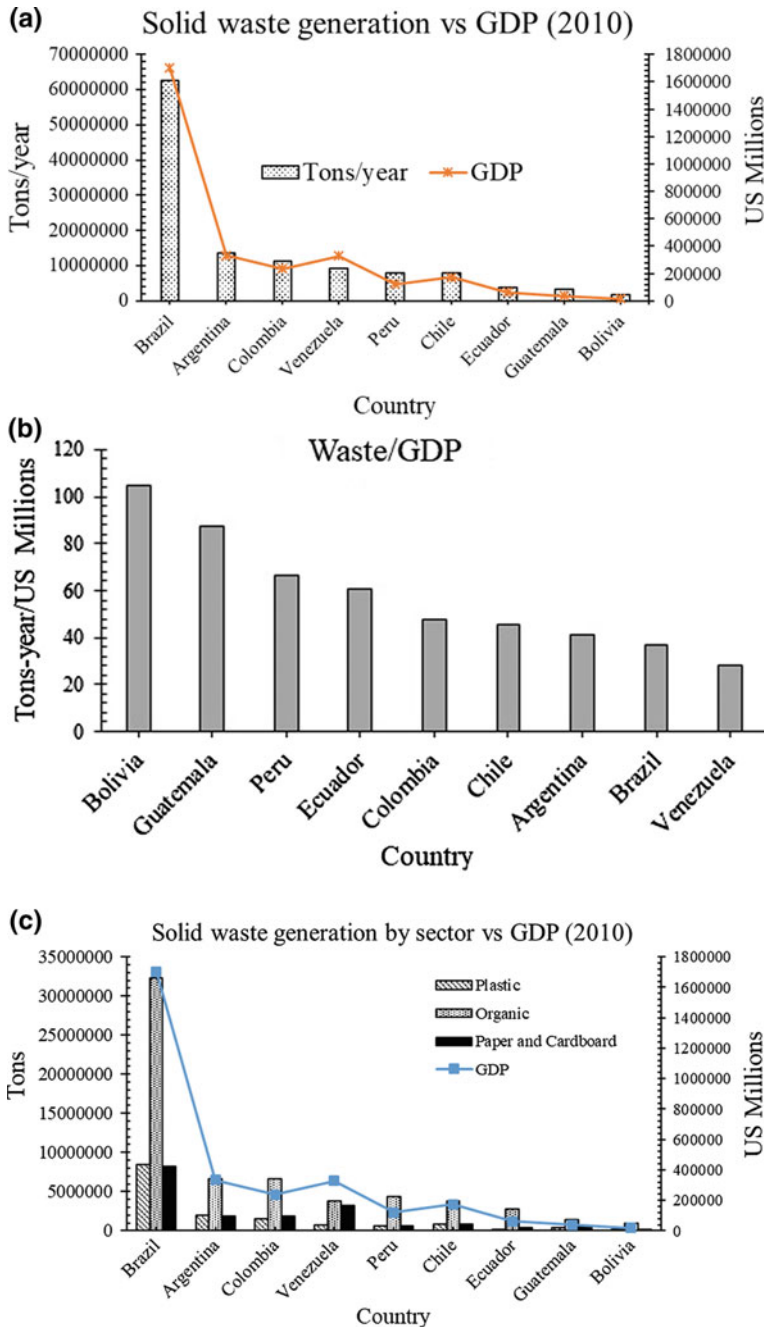


Fig. 8 Solid waste generation by country according to IDB and Waste Atlas: **a** solid waste versus GDP. **b** Solid waste versus per capita GDP. **c** Solid waste by stream of waste. **d** Generation radius versus GDP

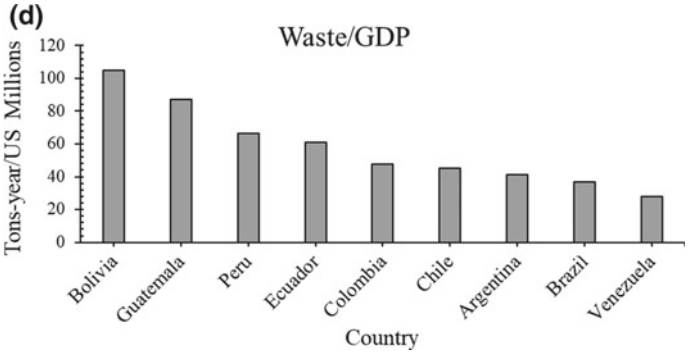


Fig. 8 (continued)

Table 1 Solid waste classification according to WB

Solid waste classification according to World Bank	
Organic	Food waste, yard (leaves, grass, foliage), trash, wood, process waste
Paper	Pieces of paper, cardboard, newspaper, magazines, bags, boxes, pone guides, paper cups for drinks. Strictly paper is organic, but at least that it is contaminated with food, it does not classify as organic
Plastic	Bottles, cups, bags, all plastic items
Glass	Bottles, broken glassware, light bulbs, colored glass
Metal	Cans, aluminum paper, pieces of electronics, and others
Others	Textiles, leather, rubber, multilayer materials, electronic waste, home appliances, ash and other inert materials

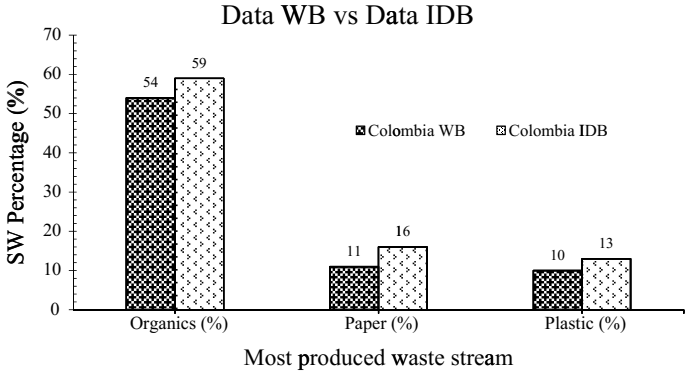


Fig. 9 Sources consulted and compared through the mayor waste stream

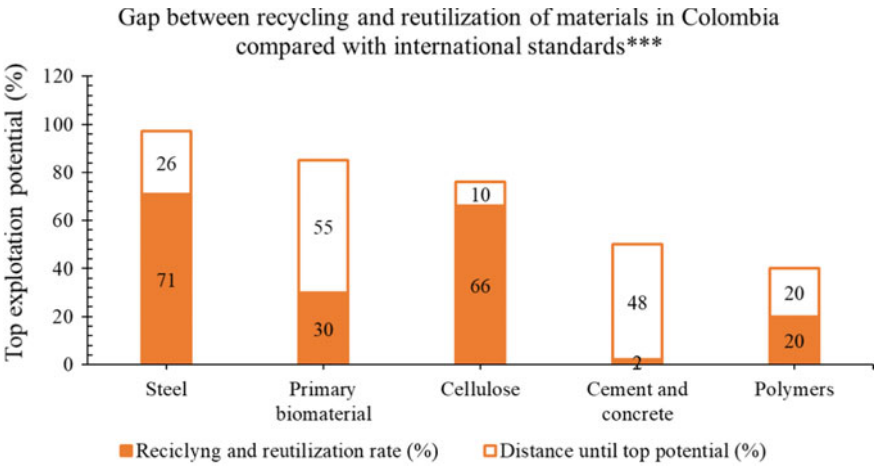


Fig. 10 Comparative exploitation rates of waste in Colombia with other countries. *Source* Tecnalia

The Situation Inside Colombia

In Colombia, there enough legislation and policies about the solid waste management and waste utilization, however, a poor law enforcement and real implementation mainly at the high-level government make this initiative obsolete. Some of the landmark laws and other regulations are listed below.

- Law 99 December 22 of 1993 (Ley 99 de diciembre 22 de 1993). For the creation of the Environmental Minister [41].
- Law 142 of 1994 (Ley 142 de 1994). For establishing the regimens for the home public services, which includes the public waste management service [42].
- Decree 605 of 1996 (Decreto 605 de 1996). For an adequate public service of the waste services [43].
- National policy for the integral waste management, 1997.
- Resolution 201 of 2001 (Resolución 201 de 2001). Establishes the conditions for the elaboration, update, and evaluation of environmental management's plans.
- Decree 1713 of 2002 (Decreto 1713 de 2002). Over the final disposition of solid wastes.
- Decree 005 January 7 of 2003 (Decreto 005 de enero 7 de 2003). To prevent the sanitary emergency in the city of Medellin.
- Resolution 1045 September 26 of 2003 (Resolución 1045 del 26 de septiembre de 2003). Method for the elaboration of Comprehensive Solid Waste Management Plans (PGIRS).
- Resolution 008 of 2004 (Resolución 008 de 2004). Master plan for the Metropolitan Area of Medellin for the Comprehensive Solid Waste Management.
- GTC 86: 2003-10-22. Guide for the implementation of Comprehensive Solid Waste Management GIR–[44].

- GTC 53-2: 2004-07-28. Guide for the use of plastic waste [44].

Among the main actors responsible for the national environmental policies and waste management plans elaboration and implementation, there are the Environmental Minister, the National Planning Department (DANE), the Superintendence of Public Services, the Single Information System (SUI), System of Environmental and Economic Accounts (SCAE), and the National Administrative Department of Statistics (DANE). Corantioquia is an important institution in the state level of Antioquia. Besides their efforts and the new appearance in high-level documents of the Circular Economy and other world-class initiatives (CONPES 3874), there is not an optimal implementation of the goals projected in the laws and the situation of wastes is still far away from a circular economy. Details of the solid wastes from Colombia are summarized in Fig. 11 [45], where waste materials in Colombia are classified as wastes and residual products. Waste is materials or parts that went, until the end of their useful life as a product. Residual products came from the production and immediately can be used in the same process, or even commercialized as raw semi-virgin materials for other products or processes. Figure 12a shows details about this flow, in which the residual products are produced in highest amount than wastes. The increase in the waste generated can be associated with an increase in the GDP for a larger industrial production and consumption, see Fig. 12b. Figure 12c shows the solid waste disposal growth rate in the main cities in Colombia from 2012, showing stability in the trend, associated with the beginning of the implementation of diverse national level strategies in the Compes developing plan (plan de desarrollo Compes).

Conclusion

The presented results showed some differences for the solid waste numbers not only for the case of Colombia but also for other nations from local and international databases. Particularly in the case of Colombia, the environmental topics was not even a topic of discussion in the government 10 years ago, however, even the lack of technology of the country, there is now an important social and international pressure for the improvement in the environmental regulations, policies and the main problem, their implementation. The main problem is that the case of Colombia is not a particularity, is the situation of if not half, more than half of the countries worldwide, and without a real interest of the government in investment in topics as the circular economy rather than just mentioning in campaigns, the situation will worsen with days and the population, pollution, and other derived environmental effects will increase. With the potential adhesion of Colombia to the OECD, an effort that the past and current government is pursuing, perhaps the country can progress in the current situation and give better number for 2020.

This work has provided and also summarizing some of the most representative data from Colombia in terms of solid wastes, but most importantly with respect to

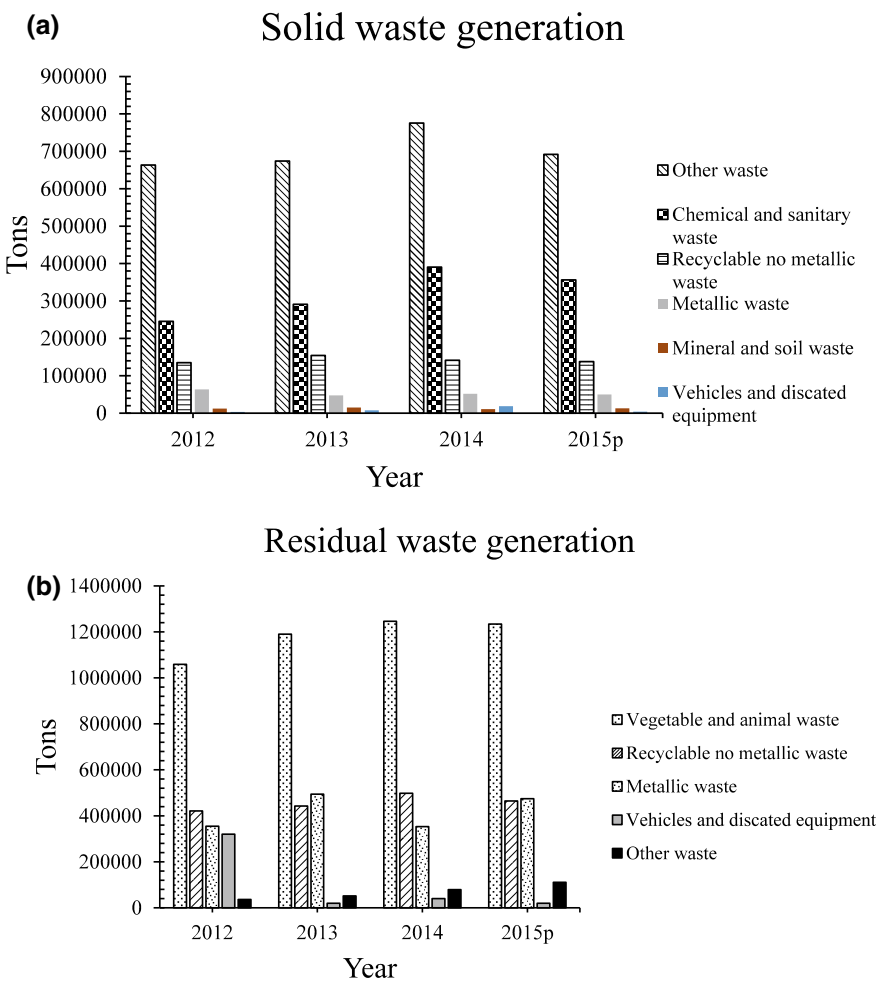
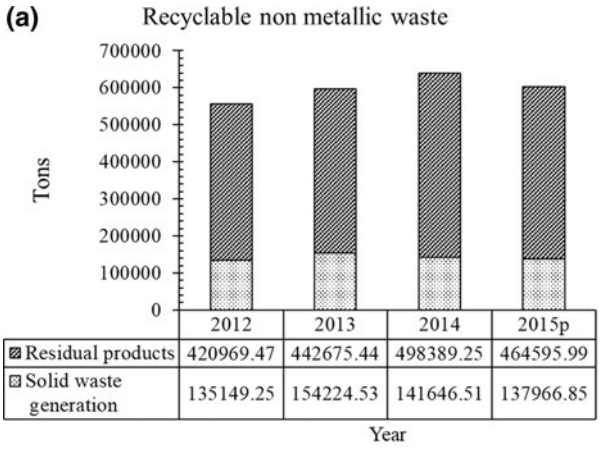
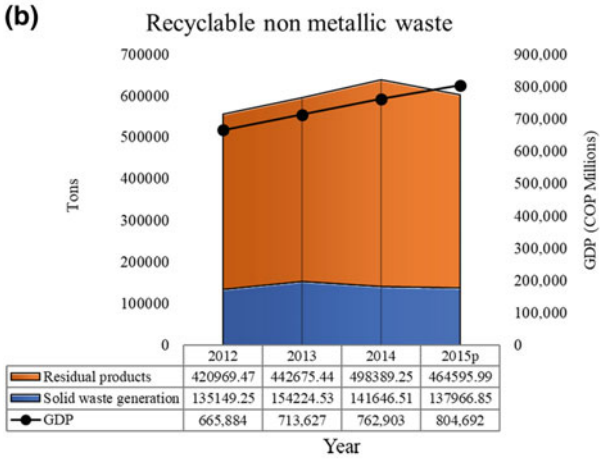


Fig. 11 Generation and classification of Waste in Colombia **a** solid waste generation. **b** Residual products generation. Environmental accounts (Environmental system of information-Colombia, 2017) [45]

leading economies and Latin America. It is clear than today more than before wastes had a profound impact in the economy of a country, and appropriate resources must be involved in order to adapt all the country statements and align the industrial and residential sectors in order to implement the circular economy model. In the case of Colombia, organic and plastic wastes represent an opportunity also generating new industries, which certainly is convenient for an economy mostly based in agriculture and raw materials sells. Finally, the study presented here has revealed a lack of communication in the data managed by the official agencies in Colombia, which certainly is affecting the implementation of correct strategies and plans to decrease





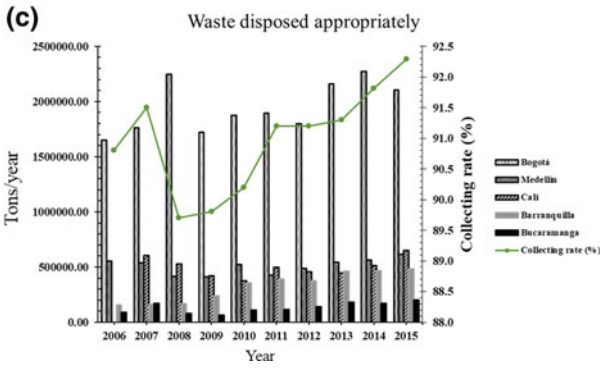


Fig. 12 Waste and collection rate. **a** Comparative between residual products and solid waste 2012–2015. **b** Flow rate residuals waste and GDP **c** waste disposed versus collection rate

the negative consequences of the non-properly managed wastes, and its adverse influence in the public health. This also diminishes the economic competitiveness of the country with respect to other economies and certainly bad preparation for environmental contingencies. A better plan is needed, and the circular economy is the way, with all society sectors working together.

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