

Article

Influence of Handling Practices on Material Recovery from Residential Solid Waste

Luis F. Marmolejo ^{1,*}, Luis F. Diaz ², Patricia Torres ¹, Mariela García ¹, Mary H. Burbano ³, Carolina Blanco ³, Katherine Erazo ¹ and Jairo F. Pereira ¹

¹ Facultad de Ingeniería, Universidad del Valle, Calle 13 No. 100-00, Cali, Colombia;

E-Mails: patoloz@univalle.edu.co (P.T.); magarcia@univalle.edu.co (M.G.);

katherineerazo777@hotmail.com (K.E.); jairop045@hotmail.com (J.F.P.)

² CalRecovery Inc., 2454 Stanwell Drive Concord, CA 94520-4811, USA;

E-Mail: Ludiaz@Calrecovery.com

³ Sede Zarzal Universidad del Valle/Calle 14 Carrera 8 Esquina. Zarzal, Valle del Cauca, Colombia;

E-Mails: mahebuca81@hotmail.com (M.H.B.); carolina.blancomoreno@hotmail.com (C.B.)

* Author to whom correspondence should be addressed;

E-Mail: luis.marmolejo@correounivalle.edu.co; Tel.: +57-2-3312175.

Received: 17 June 2010 / Accepted: 29 June 2010 / Published: 9 July 2010

Abstract: Material recovery from municipal solid waste (MSW) is becoming widely adopted in several developing countries. Residential solid waste is one of the most important components of MSW and the handling practices of the MSW by the generators have a major impact on the quality and quantity of the materials for recovery. This article analyzes the generation and composition of residential solid waste and the handling practices by users in three municipalities in Colombia that have a solid waste management plant (SWMP). The findings show that, although there are significant amounts of useful materials, their handling of the materials as “garbage”, the low recognition of recovery work, and the inadequate storage and source management practices, affect material recovery and the operation of SWMPs. These results may be taken as a reference for this type of municipality, because the solid waste management system and the type of operation of the SWMPs analyzed is similar to all of the SWMPs in the country as well as in other countries in the region.

Keywords: handling practices; material recovery; municipal solid waste; residential solid waste; developing countries

1. Introduction

The management of municipal solid waste (MSW) in Colombia is undergoing a substantial evolution, changing from a period in which priority was given to collection, transport and final disposal to a gradual inclusion of material recovery in the solid waste management system [1]. In this presentation, material recovery is used to mean the segregation and recovery of various types of materials discarded as wastes. The foregoing is demonstrated by the development and construction of Solid Waste Management Plants (SWMPs) in several locations in the country. The main objective of these facilities is the recovery of the largest quantity of materials from the MSW, and the final disposal of useless and unmarketable fractions. SWMPs have been mainly implemented in small municipalities [2]. Small municipalities happen to be those experiencing the most difficulties in the management of their solid waste [3], due to factors such as lack of trained personnel, application of inappropriate technologies, and the use of inadequate methods of finance. These actions demonstrate that the country is following the outcomes of world events, such as the Rio and Johannesburg Summits, during the last two decades.

For material recovery and for the proper operation of the SWMPs, handling practices in residential areas become fundamental due to the fact that residential solid wastes represent the largest portion of the raw materials (unprocessed garbage) arriving to those facilities. According to the Pan American Health Organization [4], in Colombia, the average per capita production (pcp) of MSW is 0.64 kg/person-day and it is equivalent to the residential solid wastes. While in Latin America and the Caribbean (LAC) municipalities, with populations lower than 50,000 inhabitants, the average pcp for MSW is 0.62 kg/person-day and the pcp for residential solid wastes is 0.54 kg/person-day.

The quantity and quality of the unprocessed garbage arriving to SWMPs mainly depends upon the resident or generator practices, who may consider the materials as “waste” (something that may be used by others) or as “garbage” (that which is thrown away because it is considered useless). Likewise, he or she decides how, when and where to deliver his or her wastes to the collection and transport services. At the same time, the knowledge by the users of the existence of the SWMP and the way the facility operates adequately, may contribute to change their waste management practices at household level.

This article analyzes the generation and composition of residential solid waste and handling practices by residential users of the urban area of three Colombian municipalities, located in the northern portion of the Department of Valle del Cauca: Bolívar, La Victoria and Versalles. These municipalities were the first to implement SWMPs in this Department. Table 1 shows general information about the three localities.

In the three cases, the public cleaning service includes the collection of all residential, commercial as well as non-hazardous institutional solid waste. Ninety percent or more of the users are residential; wastes are transported to SWMP, where materials are segregated manually.

Table 1. General information about the three Colombian municipality localities.

Information	Bol ívar	La Victoria	Versalles
Population (inhabitants)	3,632 ^[5] .	9,550 ^[6] .	3,831 ^[7] .
Annual population growth rate (%)	-1.5 ^[5] .	-1.4 ^[6] .	-1.4 ^[7] .
Masculinity index	1 ^[5] .	1 ^[6] .	1.1 ^[7] .
Average number of inhabitants per home ^[8] .	Less or equal to 3.5	Between 3.6 and 3.7	Less or equal to 3.5
Alphabetization rate (%)	76.3 ^[5] .	86.3 ^[6] .	82.8 ^[7] .
Inhabitants with Unsatisfied Basic Needs (%)	13.2 ^[5] .	14.6 ^[6] .	11.1 ^[7] .
Human Development Index	0.75 ^[5] .	0.78 ^[6] .	0.78 ^[7] .
per-capita GDP (Col \$ 2005)	7.126.579 ^[5] .	8.643.431 ^[6] .	9.232.364 ^[7] .
Altitude ^[9] .	976	915	1860
Local average temperature (°C) ^[9] .	23	26	18

The analysis shows the impact of variables such as: acknowledgement of the existence of the SWMP, the utilization and storage of the materials at home and the manner of putting out the wastes for the waste collector and the material recovery carried out at the SWMP. These results may be taken as reference for this type of municipalities, because the type of operation of the SWMPs analyzed is similar to all of the SWMPs in the country [2] as well as in other countries in the region.

2. Methodology

This investigation was developed during 2008 and 2009, and included direct contact with the citizens of all three municipalities, through visits to randomly selected homes, surveys, interviews and workshops.

Maps containing all of the homes in each locality were used as sampling frames. These maps were supplied by the Public Service Company of each municipality. Homes to be surveyed were selected by using a random sampling method with a systematic selection. This method aimed to achieve a representative sample of the population. The availability of a resident older than 15 years old was established as basic criterion to carry out the survey. Most of the survey participants were adult women, generally mothers and/or housekeepers.

Sample sizes were determined taking into account the availability of local logistic resources. Equation (1) was used to estimate each sample size:

$$n = \frac{[z^2 * p(1-p) + ME^2]}{ME^2 + [z^2 * p * (1-p) / N]} \quad (1)$$

Where:

n: sample size

z: *z* value of standard Normal Distribution (e.g., 1.96 for 95% confidence level)

p: proportion picking a choice, expressed as decimal

ME: margin of error

N: size of the population

Table 2 shows data on the number of homes surveyed in each locality.

Table 2. Surveyed homes.

Location	Total number of homes	Number of homes surveyed	Sampling error (%)	Confidence level (%)	Response rate (%)
Bol ívar	1,080	340	5	95	80
La Victoria	2,788	53	12	90	80
Versalles	1,045	108	10	95	80

Handling practices were evaluated in the framework of the research projects developed by the Universidad del Valle [10,11]. Similarly, the most recent residential solid waste characterization studies carried out in Bol ívar [12], and in La Victoria and Versalles were taken into consideration (generation and composition) [10].

For the cases of La Victoria and Versalles, each home was surveyed with a survey instrument consisting of four elements: 1) General information about the home, 2) Family group characterization, 3) Handling of solid waste at home and 4) The perception of both the waste collection system and the operation of the SWMP. The answers to the survey were complemented with *in situ* observations of the solid waste handling. In addition, in Bol ívar, the surveyors consulted the users about the meaning of the terms “solid waste” and “garbage”. The information collected was complemented with structured and semi structured interviews as well as with the observations of the service providers of collection and transport, and the operators of the SWMP.

3. Results and Discussion

3.1. Generation and Composition Analysis of Residential Solid Waste

The data in Table 3 present information pertinent to waste generation (pcp) and physical composition of solid waste generated at the three localities. As can be seen, the pcp is lower than the average indicated by [4] for LAC with populations having less than 15,000 inhabitants (0.59 kg/inhabitant-day). This situation may be associated with the practice of an old custom of waste recovery at home combined with the low purchasing power of those populations.

All cases show a relatively high concentration of bio-wastes (food and garden wastes), which is in agreement with the indicators given in several sources [4], for developing countries [13]. The agricultural and cattle raising activities of the northern portion of the Department del Valle del Cauca, offers a potential market for the compost that could be produced using those materials.

The generation of recyclable materials such as paper, cardboard, plastic, glass and metals, reaches approximately 11.7; 16.8 and 5.1 tons per month for Bol ívar, La Victoria and Versalles, respectively. These amounts, together with those generated by the commercial and institutional sectors, also have market possibilities in the region, as all three municipalities are located less than 30 km from at least one intermediate city where all of the recovered materials could be marketed. On the other hand, the operators of the municipal waste collection service have a high interest in improving the material recovery process, due to the reduction of the useful life span of the disposal sites and the difficulty of citing new landfills, as the population exhibits a strong resistance to the implementation of new disposal sites in their vicinity. This situation may lead to the use of existing regional sanitary landfills,

which would lead to significant increase in the tariffs for the service due to the increase in transport and waste disposal costs.

Table 3. Generation (pcp) and physical composition of residential solid waste in the locations under study. * Includes garden wastes **Included in others.

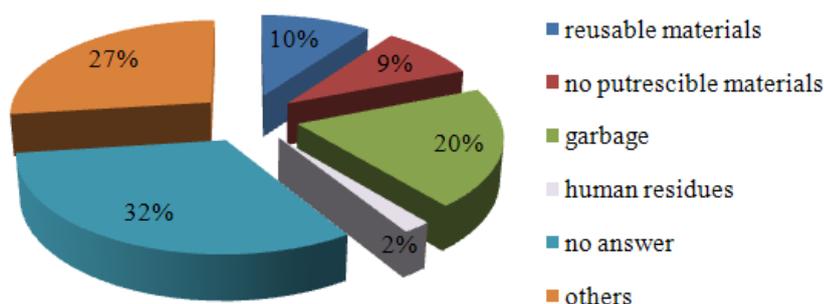
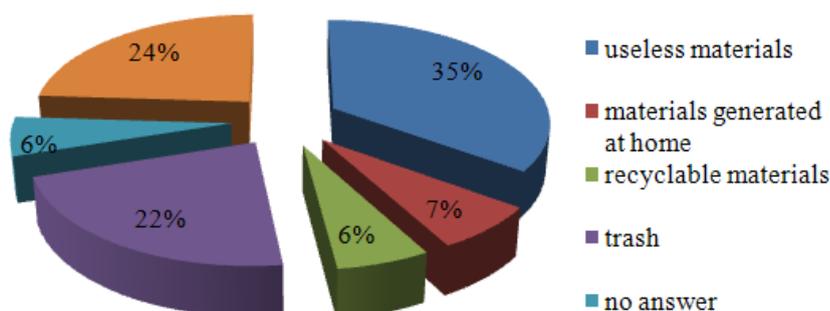
		Bol íar ¹	La Victoria ²	Versalles
pcp (kg/person-day)		0.31	0.43	0.27
Physical Composition (%)	Food	51.3*	64.48	64.5
	Garden		5.22	1.0
	Hygienic wastes	4.4	8.93	9.0
	Paper	9.7	3.08	3.2
	Carton	2.8	1.24	1.4
	Plastic	17.1	7.20	8.7
	Glass	3.9	1.15	2.0
	Metals	1.4	1.01	1.1
	Rubber and leather	0.2	0.72	**
	Textile	3.0	2.99	3.2
	Wood	**	0.45	**
	Ceramic	**	1.77	0.5
	Bones	0.1	0.38	0.8
Others	6.0	1.36	4.6	

Sources ¹ [12], ² [10]

3.2. Evaluation of Waste Handling Practices

3.2.1. Concept of solid waste and garbage

Terms like “take out” or “throw out the garbage”, “garbage collection truck”, “garbage collecting” referring to the method of storage, collection and transport of the wastes, are common in the localities. The survey at the municipality of Bol íar, allowed the identification of the concepts used by the users with respect to the terms “solid waste” and “garbage”. Regarding the term “solid waste” (Figure 2), most of the population (32%) ignored the meaning or did not answer the question, 20% thought it was “garbage” and only one-tenth of those surveyed associated it with “reusable”. In so far as the term “garbage” is concerned (Figure 3), 57% of those surveyed defined it as “useless materials” or as “trash”, with a closer definition to that established by the Colombian norm regulating solid waste management (Decree 1713, 2002 [14]). It should be kept in mind that the standardization of the terms “solid waste” and “garbage” may have an influence on handling practices, because to list materials as garbage, makes it unnecessary to store or deliver them separately, thus reducing the possibilities of recovery.

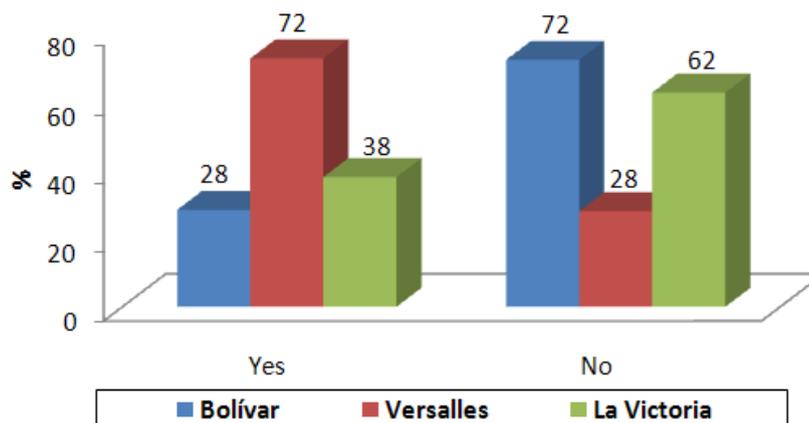
Figure 2. Definition of solid waste by users in Bolívar.**Figure 3.** Definition of garbage by users in Bolívar.

Another factor reinforcing the concept and material handling such as garbage is the collection service of mixed wastes in the different locations. Barr *et al.* [15] indicate that the largest influences in performance of recycling by the people are those factors such as norm acceptance, available logistics for recycling and the convenience and knowledge of recycling. Similarly, a study carried out by Brixworth [16] showed that positive attitudes of users with respect to recycling were associated with their knowledge of the issue and the availability of an adequate and well-publicized collection scheme.

Keeping in mind the reports from these authors, the concept of garbage may have been stimulated by the solid waste management tendencies established in the country before the nineties. According to [1], between the sixties and the nineties, most municipalities began the task of providing and improving their collection and transport systems and designing and operating final disposal systems (open dumping). This concept used the notion of “throwing out or rejecting”, associated to what needs to be done with “that which is useless”. Few cases contemplate actions like reduction, recovery or waste treatment.

3.2.2. Acknowledgment of the existence of a local SWMP

Although in all three locations the survey showed that more than 77% of users showed satisfaction with the municipal waste collection service, Versalles was the only locality where there was a high recognition of the existence of a SWMP, as seen in Figure 4. This is due to the active development of continuous awareness by the waste collection service company. In Bolívar and La Victoria, awareness activities were only carried out during start up of the systems.

Figure 4. Acknowledgment of the existence of SWMP in the localities.

Acknowledgement of the existence of a SWMP and its operating benefits could be an important factor to stimulate source separation and storage practices of the materials to be delivered to the municipal waste collection service. In addition to the sanitary and environmental benefits associated to material recovery, this can have a positive impact on service tariffs (paid by the users) due to the cost reduction in collection, transport and final disposal. A good understanding of these aspects may encourage the user to deliver the waste in such a way that it would facilitate its recovery.

3.2.3. Recovery by the residential sector

As shown in Figure 5, more than 30% of residential users keep waste fractions for recovery or final disposal, keeping at home items such as food waste, paper, cardboard, plastic, glass, metal and hygienic wastes. The first six are mainly used for internal recovery purposes or delivery to waste pickers and hygienic wastes normally are disposed internally.

Regarding the handling of food waste, as shown in Figure 6, whereas La Victoria and Versalles predominate in the delivery of material to the collection vehicle; in Bolívar it is common to use the material as animal food as well as the production of what people call “fertilizer”, reaching significant percentages when compared to other locations. The practice of recovering materials at the household level positively impacts the operation of the SWMP in Bolívar; as the recovery materials received at the SWMP show a lower degree of mixture and moisture, the facility is free of unpleasant odors or the presence of birds scavenging for food.

Paper, cardboard, plastic, glass and metals are recoverable materials that many users do not completely deliver to the municipal collection service. The data in Table 4 show the use given to the various components of the waste stream in each location. This practice is related to the marketing possibilities with local and external purchasers who, due to their geographical location, are higher in number in Bolívar and in La Victoria municipalities, or with the existence of local waste pickers, also found more frequently in those municipalities.

Figure 5. Percentage of homes that keep waste fractions for internal recovery or final disposition.

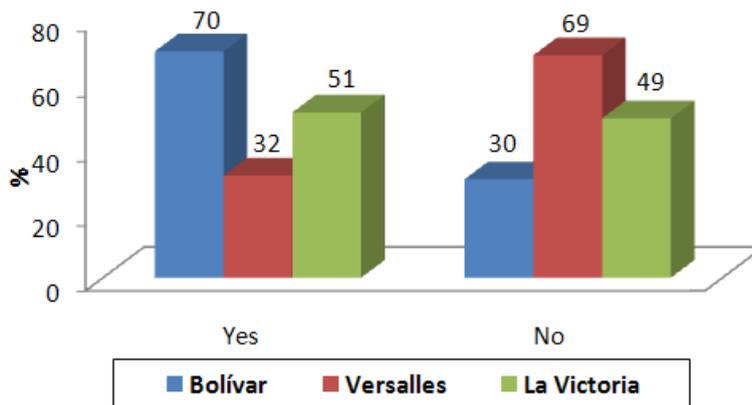
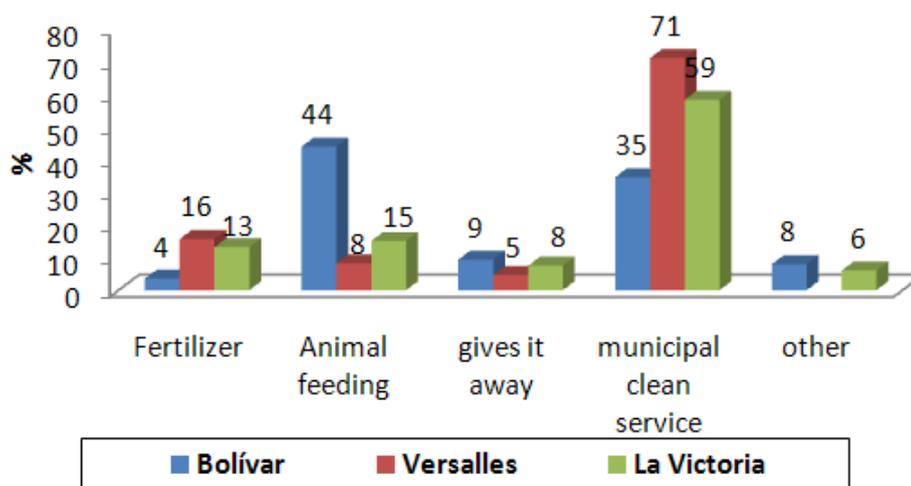


Figure 6. Uses given to bio-wastes by the householders.



Since marketing of these materials is one of the most significant sources of income for the SWMPs, in Versalles the collection company is implementing a strategy known as “the recycling store”, through which they purchase recovered materials from the users or waste pickers at competitive prices with those offered by external purchasers. The value of the waste is discounted from the payment of the tariff, stimulating the prompt payment for the service and higher volume marketing of the waste, at better selling prices. Table 4 also shows that reuse is not a popular practice and is only reported in Bolívar.

Table 4. Use given to recoverable materials in each of the municipalities under study.

Type of Waste	Municipality	Use given to recoverable waste (%)			Deliveries to the municipal collection service	Other
		Sells it	Gives it away	Reuses		
Paper	Bol íar	5.6	5.0	2.1	73.5	13.8
	Versalles	1.9	0.9	0.0	96.3	0.9
	La Victoria	1.9	11.3	0.0	81.1	5.7
Cardboard	Bol íar	6.2	9.4	1.5	70.0	13
	Versalles	4.6	1.9	0.0	92.6	0.9
	La Victoria	1.9	17.0	0.0	77.4	3.8
Glass	Bol íar	5.3	2.1	0.9	73.8	18
	Versalles	3.7	0.9	0.0	95.4	0.0
	La Victoria	0.0	3.8	0.0	96.2	0.0
Plastic	Bol íar	2.9	1.8	1.5	80.9	13
	Versalles	0.9	1.9	0.0	96.3	0.9
	La Victoria	1.9	11.3	0.0	81.1	5.7
Metal	Bol íar	13.8	3.5	1.8	61.8	19.2
	Versalles	3.7	0.9	0.0	95.4	0.0
	La Victoria	5.7	3.8	0.0	90.6	0.0

3.2.4. Storage and putting the waste out

The research in the field showed that these activities normally are the responsibility of adult women who determine the basic aspects such as location and cleanliness of the container. As shown in Figure 7, delivery to the collection vehicle in only one container is the predominant practice. Mixed collection results in mixing the materials and leading to a deterioration in their quality and decreased possibilities of recovery [17]. Waste mixing enhances cross contamination. In the case of Versalles, the significant proportion of users using three or more containers is attributed to factors such as the implementation of campaigns stimulating separation at the source, led by the Municipal Collection Company and by the educational sector, and also to the high level of acknowledgment of existence of the SWMP and positive evaluation by the users of the municipal collection service.

The effects of segregation practices are significant in recovery processes such as in compost products [18]. A pilot scale evaluation of composting bio-wastes was done. It used both materials separated at the source and mixed residential wastes of La Victoria. Waste separated at the source exhibited parameter values like Carbon/Nitrogen and ash content, offering better conditions for the process. This waste reflected a higher degree of degradation, lower stabilization times, and a higher microbiological quality of the product [10]. In the case of recyclable waste recovery such as paper, cardboard and plastic, recovered from mixed sources, the costs and requirements of resources such as water for the cleaning processes of the recovered materials are significant, and the recovered materials have significantly lower prices than those separated at the source.

Figure 7. Number of containers delivered to the municipal collection service.

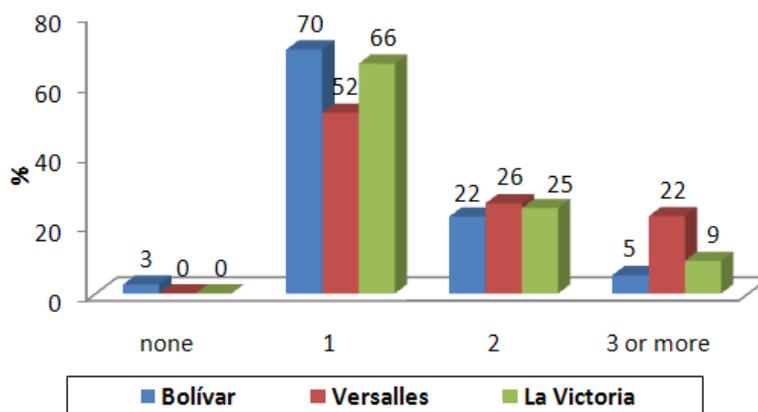
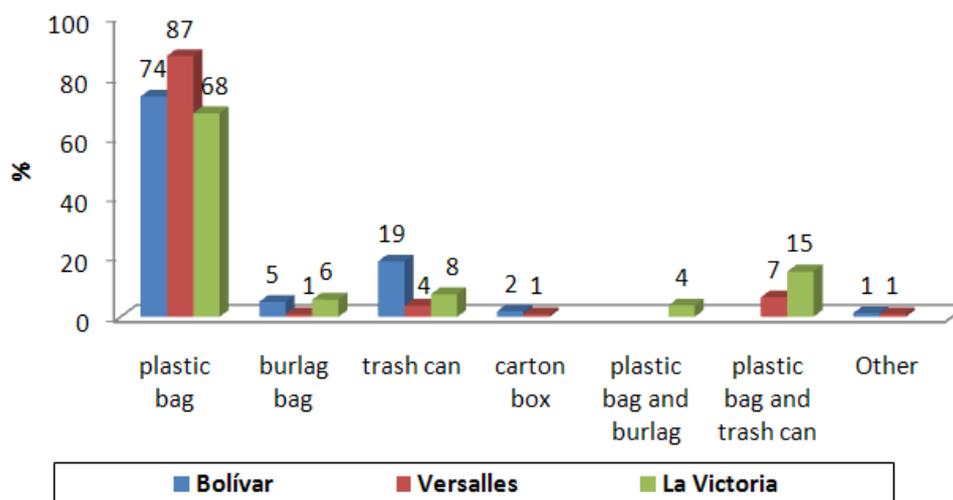


Figure 8 shows the type of containers used for delivery of the solid waste, indicating a higher use of plastic bags with sufficient capacity to store the amounts of waste generated and easily handled by the collectors. However, because plastic bags are normally manufactured using Low Density Polyethylene (LDP) and because the LDP is contaminated with waste, generally their recovery and commercialization at the SWMP is difficult, culminating in significant amounts at the final disposal sites. Due to the fact that wastes put out in trash cans and in burlap bags should be emptied directly into the collection vehicle (because the containers have to be returned), their use helps mixing of the materials in the vehicle and consequently affects the recovery of high quality materials.

Figure 8. Type of containers delivered to the municipal collection service.



Waste containers are normally set out in front of the residence (Figure 9) from where they are picked up by the operator of the municipal collection service; users and waste collector are satisfied with this situation, and in general, they establish good cooperation to facilitate the collection. With respect to the delivery of waste containers to the collection vehicle at la Victoria and Versalles (Figure 10), although there are significant percentages of users that do it at the moment the vehicle passes through, the proportion of users that do it one or more hours ahead of time is also high. At La Victoria, normally informal pickers are observed removing materials from the waste containers,

before or during the collection process. According to the operators of the SWMP, this situation is reflected in a significant reduction of materials received at the facility.

Figure 9. Place of delivery of solid waste to the municipal collection service.

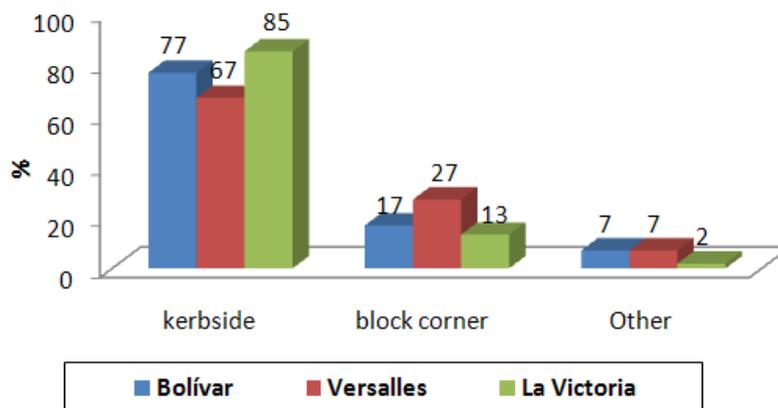
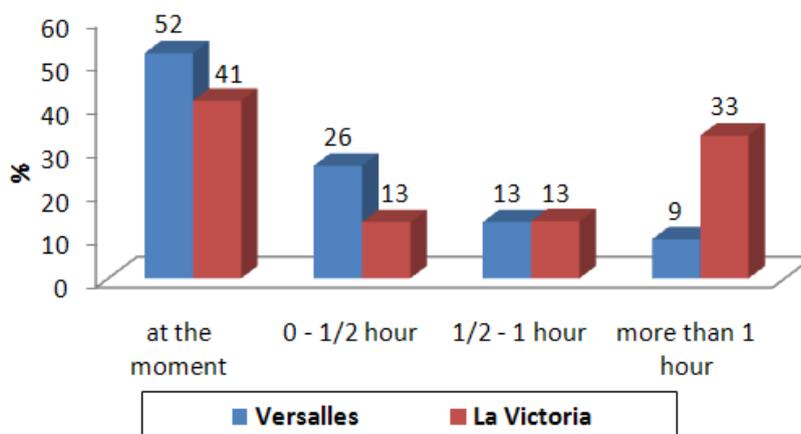


Figure 10. Time ahead of delivery of solid waste to the municipal collection service.



According to [19], a recovery system of recyclable waste acting to advance in the direction of social and environmental sustainability requires the combination of at least two factors: generator’s responsibility regarding production and the integration of waste pickers into the process. Given the existence of SWMPs in the cases under study, it becomes necessary to establish agreements between the operators of the public cleaning service, users and waste pickers to facilitate planning of the operation regarding quantity and quality of waste to be processed.

4. Conclusions

Recovery of waste at the household level considerably influences the waste production (pcp) at the locations studied. In all cases, the pcp is lower than 0.59 kg/person-day, the average value indicated in [4] for municipalities with a population of less than 15,000 inhabitants. The foregoing appears to be related to a tradition of recovery at home, as well as with the relatively low purchasing power of the population.

The physical composition of residential solid waste shows that in all cases proportions of bio-wastes and recyclable materials such as cardboard, paper, plastic and glass reach proportions, is higher

than 78.7%. These values, together with the existence of markets for the materials, show the importance of strengthening recovery of some components in the solid waste management in the localities. Therefore, these municipalities can get benefits from material recovery, especially because they show limitations for final disposal *in situ*.

A high proportion of residential users mix their waste in the storage containers. This situation affects not only the amount but the quality of materials and therefore, their recovery. For this reason, it is necessary that projects for the development of infrastructure for SWMPs be accompanied with awareness programs stimulating and committing the users to handling the materials under conditions favoring their recovery. The fundamental elements to structure awareness programs are the perceptions and practices of adult women who generally are responsible for the handling of the material at home.

Cultural practices such as the recovery of bio-wastes at home, favor the conservation of the quality of the recovered materials in non source separation recovery systems. Similarly, the resulting reduction in moisture content eases the operating conditions and maintenance at the SWMP.

The impact of practices such as: segregation of materials at the source, relatively quick delivery of the waste to the municipal collection service and the tariffs paid by the users may be very useful tools to stimulate their participation. These strategies form a good starting point to promote separation at the source. Additionally, users must be stimulated to be aware of the sanitary and environmental benefits of the material recovery, as well as of the development of jobs at local levels, instead of only indicating economic benefits. It is also necessary to promote a decrease in consumption patterns and reuse of materials.

Handling practices have a high influence on the quality and quantity of materials to be recovered in the studied localities. Such practices affect both the efficiency of public cleaning services as well as the operation and sustainability of the SWMP; for these reasons it is imperative to strengthen the relationship between the users, the local governments and the operators of the public cleaning service, recognizing the benefits of material recovery from municipal solid waste.

References and Notes

- 1 Ministerio del Medio Ambiente, República de Colombia. *Selección de Tecnologías de Manejo Integral de Residuos Sólidos*; Ministerio del Medio Ambiente: Bogotá DC, Colombia, 2002; p. 183.
- 2 República de Colombia. Superintendencia de Servicios Públicos Domiciliarios. Diagnóstico Sectorial Plantas de Aprovechamiento de Residuos Sólidos-Marzo de 2008.
- 3 UNICEF-Fondo de las Naciones Unidas para la Infancia—Colombia; Procuraduría General de la Nación. *La infancia, el agua y el saneamiento básico en los Planes de Desarrollo Departamentales y municipales*; UNICEF: Bogotá Colombia, 2006.
- 4 Organización Panamericana de la Salud. *Informe de la Evaluación Regional de los Servicios de Manejo de Residuos Sólidos en América Latina y el Caribe, 2005*; Organización Panamericana de la Salud: Washington, DC, USA, 2005.
- 5 PNUD—Programa de las Naciones Unidas para el Desarrollo. *Sugerencias y recomendaciones del informe de desarrollo humano para el Valle del Cauca para la formulación del plan de desarrollo*

- del municipio de Bolívar, 2008; PNUD: Cali, Colombia, 2008; Available online: <http://www.idhvalle-pnud.org/documentos/sugerencias/BOLIVAR.pdf> (accessed on 31 March 2010).
- 6 PNUD—Programa de las Naciones Unidas para el Desarrollo. Sugerencias y recomendaciones del informe de desarrollo humano para el Valle del Cauca para la formulación del plan de desarrollo del municipio de La Victoria, 2008; PNUD: Cali, Colombia, 2008; Available online: <http://www.idhvalle-pnud.org/documentos/sugerencias/LAVICTORIA.pdf> (accessed on 31 March 2010).
 - 7 PNUD—Programa de las Naciones Unidas para el Desarrollo. Sugerencias y recomendaciones del informe de desarrollo humano para el Valle del Cauca para la formulación del plan de desarrollo del municipio de Versalles, 2008; PNUD: Cali, Colombia, 2008; Available online: <http://www.idhvalle-pnud.org/documentos/sugerencias/VERSALLES.pdf> (accessed on 31 March 2010).
 - 8 DANE—Departamento Administrativo Nacional de Estadística. Censo 2005.
 - 9 Gobernación del Valle del Cauca. *El Valle del Cauca*; Available online: <http://www.valledelcauca.gov.co/publicaciones.php?id=270> (accessed on 31 March 2010).
 - 10 Universidad del Valle. Estrategias para el mejoramiento de opciones tecnológicas de aprovechamiento de residuos sólidos en cabeceras municipales del Valle del Cauca menores a 20,000 habitantes, con visión de sostenibilidad. Informe Final Proyecto de Investigación, 2010.
 - 11 Prácticas y representaciones sociales sobre el manejo de los residuos sólidos en el municipio de Bolívar Valle. Proyecto de Investigación; Universidad del Valle: Cali, Colombia, 2010.
 - 12 Corporación Autónoma Regional del Valle del Cauca; Pacífico Verde. Elaboración de la estructura tarifaria y del diseño de ampliación de la PMIRS del municipio de Bolívar y diseño para la construcción de la PMIRS del municipio de Roldanillo. Convenio 061 de 2008. Cali, Colombia, 2009.
 - 13 United Nations Environment Programme; CalRecovery Incorporated. *Solid Waste Management*; United Nations Environment Programme: Nairobi, Kenya, 2005; Volume 1.
 - 14 Ministerio de Desarrollo Económico, República de Colombia. Decreto 1713 de 2002 “Por el cual se reglamenta la ley 142 de 1997, la Ley 632 de 2000 y la Ley 689 de 2001 en relación con la prestación del servicio público de aseo, y el decreto 1974 y la Ley 99 de 1993 en relación con la Gestión Integral de Residuos sólidos, 2002.
 - 15 Barr, S.; Gilg, A.W. Conceptualising and analysing household attitudes and actions to a growing environmental problem: Development and application of a framework to guide local waste policy. *Appl. Geogr.* **2005**, *25*, 226–247.
 - 16 Tonglet, M.; Phillips, P.S.; Bates, M.P. Determining the drivers for householder pro-environmental behavior: Waste minimisation compared to recycling. *Resour. Conserv. Recycl.* **2004**, *42*, 27–48.
 - 17 Marmolejo, L.F.; Torres, P.; Oviedo, E.R.; Bedoya, D.F.; Amezcua, C.; Klinger, R.; Albán, F.; Diaz, L.F. Flujo de residuos. Elemento base para la sostenibilidad del aprovechamiento de residuos sólidos municipales. *Ingeniería y Competitividad* **2009**, *11*, 79–93.
 - 18 Zhang, H.; He, P.J.; Shao, L.M. Implication of heavy metals distribution for a municipal solid waste management system—A case study in Shanghai. *Sci. Total Environ.* **2008**, *402*, 257–267.

- 19 Marcolino Polaz, C.N.; do Nascimento Teixeira, B.A. Indicadores de sustentabilidade para a gestão municipal de resíduos sólidos urbanos: um estudo para São Carlos (SP). *Engenharia Sanitaria e Ambiental*. **2009**, *1*, 411–420.

© 2010 by the authors; licensee MDPI, Basel, Switzerland. This article is an Open Access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/3.0/>).