



# ANALYSIS OF THE PRODUCTION OF SOLID WASTE AND DETERMINATION OF PRODUCTION FACTORS IN THREE COLOMBIAN CITIES A Proposal for a New Measurement Methodology<sup>1</sup>

## ANÁLISIS DE LA PRODUCCIÓN DE RESIDUOS SÓLIDOS Y DETERMINACIÓN DE FACTORES DE PRODUCCIÓN EN TRES CIUDADES COLOMBIANAS. Propuesta para una nueva metodología de medición

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### ABSTRACT

Colombian Law 142 issued in 1944 establishes how to measure waste consumptions of residential and non-residential producers in order to collect payments for the service of waste recollection. Therefore the Colombian's governmental agency which attends water and solid waste's affairs (Comisión Reguladora de Agua y Residuos Sólidos, CRA) determined by Resolution 15 of 1997 some production factors in order to establish this consumption's level, applying 0.12 tons or 120 kilos monthly for solid wastes, with a factor of 1 for users of socio-economics' layers 1, 2, 3, and 4 and for users of layers 5 and 6, these factors correspond respectively to 1.48 and 1.66. The Colombian government identified the social necessity to change these production factors because of outdated figures managed by Resolution 15 and also for user's heterogeneity: residential and non-residential, also inside each one of them, different socioeconomics layers and different industrial sectors. This paper presents

### RESUMEN

La Ley 142 expedida en 1944, establece la forma de medir los consumos de los productores de los residuos residenciales y no residenciales con el fin de cobrar los pagos por el servicio de recolección de residuos. Por lo tanto, la agencia gubernamental colombiana que atiende los asuntos relacionados con el agua y el manejo de los residuos sólidos (Comisión Reguladora de Agua y Residuos Sólidos, CRA) determinó por la Resolución 15 de 1997, unos factores de producción con el fin de establecer el nivel de este consumo, aplicando 0,12 toneladas o 120 kilos mensuales de residuos sólidos, con un factor de 1 para los usuarios de los estratos socioeconómicos 1, 2, 3 y 4 y para los usuarios de estratos 5 y 6, estos factores corresponden, respectivamente, a 1,48 y 1,66. El gobierno colombiano indicó la necesidad social de cambiar estos factores de producción debido a las cifras anticuadas utilizadas por la Resolución 15 y también por la heterogeneidad del usuario: residencial y no residencial, y dentro de cada uno

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the main outcomes of a consultancy contracted by CRA so as to propose a new classification and new production factors based in a research carried out into a set of users in three Colombian cities. Also at the beginning presents an introduction to solid waste issue presenting some performance in different countries of different development levels.

**Key words:** Solid Waste, Production Factors, Categorization, Seating Capacity of Waste Production, Residential Users, Non-residential Users, ISIC Classification.

de ellos, los diferentes estratos socioeconómicos y los diferentes sectores industriales. Este trabajo presenta los principales resultados de una consultoría contratada por la CRA con el fin de proponer una nueva clasificación y nuevos factores de producción basados en una investigación llevada a cabo en un conjunto de usuarios en tres ciudades colombianas. Al comienzo, se presenta una introducción a la cuestión de los residuos sólidos y se presentan algunos resultados en diferentes países con diferentes niveles de desarrollo.

**Palabras clave:** Residuos sólidos, factores de producción, categorización, capacidad de producción de residuos, los usuarios residenciales, usuarios no residenciales, la Clasificación ISIC.

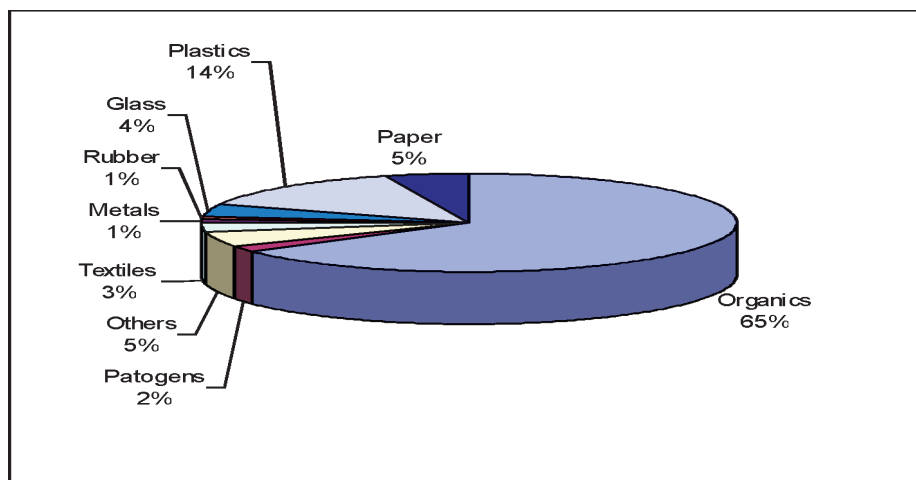
## Introduction

Nowadays both in developed and developing countries environmental topics are currently considered as a 'number one' interest affair. In Colombia, for example, the national policy for the management of the solid waste is based mainly on the Political Constitution. The Colombian Policy for management of wastes is based on two axes: First, obligation of the State to orient and to establish actions for governmental agencies with responsibilities of management solid wastes. Second, to demand private sector so as to the generation of solid waste to take into account cleanest production processes with

three specific goals: Minimization of the amount of solid waste generation, increasing of rational strategies to manage solid waste and improving novelty and high tech systems of elimination, treatment and disposition of solid wastes.

The Colombian production of solid waste is equivalent to a daily production average by inhabitant of 0.6 Kilograms. The solid wastes in Colombia are mainly compound of organics, plastics, glass, paper and cardboard, as it is showing in Graph 1. Nevertheless, these characteristics change according with geographic and economic conditions of the population.

Graph 1. Average composition of solid waste



Source: CRA, Information System of Solid Waste in [www.sui.gov.co](http://www.sui.gov.co)



Countries generation of solid waste, taking into account its economic development level, let us conclude that countries with smaller

income generate fewer residues and their components are less recyclable.

Table 1. Solid waste composition in developing countries

| Product         | %          |
|-----------------|------------|
| Organics        | 58 - 80,20 |
| Paper           | 2,6 - 5,0  |
| Plastics        | 3,8 - 7,4  |
| Cans and metals | 0,7 - 1,6  |
| Glass           | 1 - 3,8    |
| Others          | 2 - 4,1    |

Source: Acurio, G. et. al. 1997.

Table 2 has information about solid waste generation in a sample of four countries with different development levels. The generation of solid waste is different but basically

organics' share is lower in developed countries. For example, United States and France has 18% and 21% respectively and Colombia and México 56% and 32%.

Table 2. Solid waste composition in four different countries

|                     | USA | FRANCE | MEXICO | COLOMBIA |
|---------------------|-----|--------|--------|----------|
| Paper and cardboard | 40% | 35%    | 14%    | 22%      |
| Plastics            | 8%  | 7%     | 6%     | 5%       |
| Metals              | 9%  | 5%     | 3%     | 1%       |
| Textiles            | -   | 5%     | 1%     | 4%       |
| Glass               | 7%  | 12%    | 7%     | 2%       |
| Organics            | 18% | 21%    | 32%    | 56%      |
| Others              | 18% | 15%    | 37%    | 10%      |

Source: Uribe, S. 2006.

The amount of solid waste produced by a collectivity varies based on a great number of parameters but mainly because:

- Of the standard of life of the population: The higher the quality of life, the higher is the generation of solid waste.
- Of the year's season. The solid waste production usually has a maximum level in winter and a minimum in summer.
- Of the mobility of the population. During week ends and holidays diminish the production of residues in the origin places and increase in the destiny places.

- Of the weather. For example, an increase of ashes in winter coming from domestic cooks that use coal and wood. Also in places with little extreme climates an increase in the amounts of garden residues exists.
- Of the new tendencies of commercialization of merchandise. The commercialization of merchandise with non turn around packing and packages would generate an important volume of solid waste. Table 1 presents a briefly comparison of solid waste generation in different countries and cities.



Table 3. Solid waste generation (daily kilograms per citizen) a comparison

| City              | Population | Consumption<br>daily kilograms<br>per citizen |
|-------------------|------------|-----------------------------------------------|
| Santiago de Chile | 5,300,000  | 0,87                                          |
| La Habana         | 2,000,000  | 0,70                                          |
| Lima              | 7,500,000  | 0,56                                          |
| Buenos Aires      | 12,000,000 | 0,95                                          |
| México D.F.       | 15,600,000 | 1,20                                          |
| Guayaquil         | 2,300,000  | 0,70                                          |
| Caracas           | 3,000,000  | 1,18                                          |
| Sao Paulo         | 16,400,000 | 1,35                                          |
| Rio de Janeiro    | 9,900,000  | 1,00                                          |
| Bogotá            | 6,800,000  | 0,75                                          |
| Madrid            | 5,030,958  | 1,10                                          |
| Cataluña          | 6,115,579  | 1,10                                          |
| País Vasco        | 2,109,009  | 0,9                                           |

Source: Alonso, C. 2003.

At present the Colombian regulation's laws grant the gauging of waste solid produced by different kind of users: great producers -which always are industrial and services corporations- and, residential producers in order to establish the tariffs of domiciliary public service of cleanliness. This gauge is carries out using random sampling techniques into the population of waste's users. Also it is important to point out that users have the legal guarantee to ask the government for permanent evaluation of seating capacity of their waste production. The process derived to improve the seating capacity have high cost's amount of money especially for great producers.

The current procedure to establish the tariffs of payments for the service waste recollection is to assume average consumption levels to each one of subsets of the population. For example, for small non-residential users this estimation is one cubic meter monthly. For the unpredicted and permanent change for non-residential big producers the legislator has established an ordinary measurement of seat capacity doing by a random process that selects some firms. Nevertheless these firms have the duty to require different seat capacity measurements whenever they want.

The seat capacity measurement is always running by the same service firm which recollects the solid waste. The law establishes that this seat capacity measurement is valid for a period of one year. At the end of this year the tariff is renewed in the same conditions unless the big user demands a new measurement. After this seat capacity measurement is finished the tariff established into the bill that one user has to pay is readjusted at once. In order to do seat capacity measures is important to point out that what is measured are two variables Average Density(a) of solid waste (tons/cubic meter) and Volume (V) expressed in cubic meters (m<sup>3</sup>).

In 2005 CRA<sup>4</sup> decided to change the current methodology to fix tariffs for cleanliness services because new commandments received from central Colombian government forced it to do it. This change implies that CRA began to measure new variables so as to establish costs for different steps like sweep, recollection, transport and final waste's treatments. The new measurement grants an accurate estimation of each one of these steps for any user but also it has higher measurement costs. This is the main reason that leads CRA to contract a consultancy with a well-

4 Comisión de Regulación de Agua Potable y Saneamiento Básico (CRA) which is the national Colombian agency that measures the levels of waste production and also establishes the recollection tariffs for these services.



recognized engineering firm, Geovanis Arrieta Bernate, GAB. Such firm carried out the study such main outcomes are presenting here in this document.

### Estimation of production factors for residential users<sup>5</sup>

This specialized consultancy determined the estimation of the production factors<sup>6</sup> in residential users into three Colombian cities, Bogotá, Medellín and Barranquilla. For this purpose GAB worked a sample in each city, the amount of users utilized for each one of

them was 1,609,389 users in Bogotá, 642,043 in Medellín and 4,842 in Barranquilla. The figures were obtained from Data Bases (DB) gave by CRA. The methodology in this part of the work consequently was a statistical manages of these DB.

GAB analyzed the composition of users and the generation of residues obtaining data of volume and density of residues generated of each layer and type of user, validating finally the factors determined by the CRA. Table 4 presents the main outcomes getting in this exercise.

Table 4. Solid waste (tons) in three Colombian cities

|         | Bogotá | Medellín | Barranquilla |
|---------|--------|----------|--------------|
| Layer 1 | 0.0259 | n.a.     | n.a.         |
| Layer 2 | 0.0307 | n.a.     | n.a.         |
| Layer 3 | 0.0311 | 0.0427   | 0.0130       |
| Layer 4 | 0.0393 | 0.0517   | 0.0143       |
| Layer 5 | 0.0445 | 0.0568   | 0.0161       |
| Layer 6 | 0.0518 | 0.0831   | 0.0180       |

Source: GAB consultancy (2008).

n.a: Non available information in DB consulted for these cities.

In summary it is possible to make one conclusion: the lower the layer the lower of solid waste consumptions. Having finish the calculations for these three Colombian cities, GAB consultancy come to fit an average from

this three cities and then compare this with PGIR figures . This national average is compared with GAB's consultancy in Table 5 that shows this comparison.

Table 5. Averages solid waste consumptions (tons) in three Colombian cities

|         | PGIR   | GAB consultancy |
|---------|--------|-----------------|
| Layer 1 | 0,0405 | 0,0332          |
| Layer 2 | 0,0446 | 0,0376          |
| Layer 3 | 0,0540 | 0,0426          |
| Layer 4 | 0,0484 | 0,0484          |
| Layer 5 | 0,0702 | 0,0572          |
| Layer 6 | 0,0986 | 0,0778          |

Source: GAB consultancy (2008).

<sup>5</sup> It is very important to clear that residential users suffer a taxonomy which taking into account socioeconomics variables divided this set of users in six layers. Layer number 1 is the lowest with lesser income and lower standards of life. On the other hand layer 6 has both the higher income level and the better standards of life.

<sup>6</sup> A production factor is an index number that grants CRA could cover the correct tariff for recollection of waste consumption. Its estimation is doing dividing the average consumption of each layer over the average consumption of layer 4. The former but outdated production factors have its origins in Resolution 15 of 1997.

<sup>7</sup> This average is technically called as PGIR acronym which signifies in Spanish: "Planes de gestión integral de residuos sólidos". These averages are collected in each municipality's 'Urbanization and Development Plans' that every Colombian municipality should have.



As it is possible to comment that such GAB's averages are always lower than national averages previously estimated. Finally, Table 6

allows a comparison between current production factors and the figures that GAB's consultancy reaches.

Table 6. Comparison of Production Factors

|         | CRA  | GAB consultancy |
|---------|------|-----------------|
| Layer 1 | 0,95 | 0,69            |
| Layer 2 | 0,95 | 0,78            |
| Layer 3 | 0,95 | 0,88            |
| Layer 4 | 1,00 | 1,00            |
| Layer 5 | 1,09 | 1,18            |
| Layer 6 | 1,54 | 1,61            |

Source: GAB consultancy (2008).

#### Estimation of production factors for non-residential users

Non-residential users are divided in two sets, the first one are small producers and the second one is big producers. The methodology applied in this part of the consultancy was a revision of DB, estimating the averages for each one of these producers according with information contained in DB. The second step was to classify the producers according to the industrial sector to which

they belong following the International Standard Industrial Classification of All Economic Activities (ISIC) made by United Nations Organization (UNO) adapted to Colombia at three levels.

Table 7 shows the main figures got for GAB's consultancy, the results have consistency, the bigger the producer the higher the solid waste production is.

Table 7. Volume, density and waste solid generation in small and big producers

|                                | Small producers | Big producers |
|--------------------------------|-----------------|---------------|
| Volume (m <sup>3</sup> )       | 0,27            | 7,6           |
| Density (Tons/m <sup>3</sup> ) | 0,16            | 0,15          |
| Tons                           | 0,045           | 1,1           |

Source: GAB consultancy (2008).

The taxonomy for small producers is presented at Table 8. In this table is possible to point out that there are five different subsets of producer of solid waste, the average cover from a lower limit of 0.21 m<sup>3</sup> to an upper limit of 0.56 m<sup>3</sup>. It is not possible to infer some relationship between the ISIC belonging of the producers and the amount of solid waste production. The minimum pro-

duction ISIC 912 corresponds to 'Recreational, cultural and sporting activities' but in the same subset 1 we found the service ISIC 552 'Hotels and restaurants'. Similarly among subset 5 we found ISIC 527 'Retail trade, except of motor vehicles and motorcycles'; 801 'Education' and 155 which refers to 'Manufacture of food products and beverages' all of them with different production processes and different final production.



Table 8. Taxonomy for small producers by ISIC classification and volume levels (m<sup>3</sup>)

| Subset | ISIC | Volume (m <sup>3</sup> ) | Average (m <sup>3</sup> ) |
|--------|------|--------------------------|---------------------------|
| 1      | 921  | 0.13                     | 0.21                      |
|        | 525  | 0.18                     |                           |
|        | 452  | 0.19                     |                           |
|        | 659  | 0.22                     |                           |
|        | 701  | 0.22                     |                           |
|        | 516  | 0.23                     |                           |
|        | 742  | 0.24                     |                           |
|        | 702  | 0.24                     |                           |
|        | 553  | 0.25                     |                           |
| 2      | 524  | 0.26                     | 0.28                      |
|        | 369  | 0.26                     |                           |
|        | 930  | 0.27                     |                           |
|        | 453  | 0.27                     |                           |
|        | 741  | 0.27                     |                           |
|        | 851  | 0.28                     |                           |
|        | 271  | 0.28                     |                           |
|        | 523  | 0.29                     |                           |
|        | 924  | 0.29                     |                           |
| 3      | 281  | 0.30                     | 0.33                      |
|        | 642  | 0.31                     |                           |
|        | 514  | 0.31                     |                           |
|        | 521  | 0.31                     |                           |
|        | 749  | 0.32                     |                           |
|        | 289  | 0.32                     |                           |
|        | 517  | 0.33                     |                           |
|        | 242  | 0.33                     |                           |
|        | 503  | 0.34                     |                           |
|        | 502  | 0.34                     |                           |
|        | 513  | 0.34                     |                           |
| 4      | 455  | 0.35                     | 0.41                      |
|        | 712  | 0.36                     |                           |
|        | 252  | 0.38                     |                           |
|        | 223  | 0.38                     |                           |
|        | 372  | 0.40                     |                           |
|        | 361  | 0.41                     |                           |
|        | 181  | 0.41                     |                           |
|        | 343  | 0.41                     |                           |
|        | 222  | 0.41                     |                           |
|        | 633  | 0.42                     |                           |
|        | 519  | 0.42                     |                           |
|        | 515  | 0.43                     |                           |
| 5      | 512  | 0.44                     | 0.56                      |
|        | 522  | 0.45                     |                           |
|        | 527  | 0.48                     |                           |
|        | 158  | 0.51                     |                           |
|        | 155  | 0.59                     |                           |
|        | 801  | 0.65                     |                           |

Source: GAB consultancy (2008).



The taxonomy for big producers is presented at Table 9. In this table is possible to point out that there are five different subsets of producer of solid waste, the average cover from a lower limit of 4.76 m<sup>3</sup> to an upper limit of 91.31 m<sup>3</sup> a wide range that allows making the five different subsets. Clearly in all cases the averages producers' consumptions are higher than small producers' consumptions. It is nor possible to infer

some relationship between the ISIC belonging of the producers and the amount of solid waste production. The minimum production ISIC 292 corresponds to 'Manufacture of machinery and equipment' but in the same subset 1 we found the service sector ISIC 552 'Hotels and restaurants'. Similarly among subset 5 we found ISIC 152 which refers to 'Manufacture of food products and beverages' with a production of 91.31 m<sup>3</sup>.

Table 9. Taxonomy of big producers by ISIC classification and volume levels (m<sup>3</sup>)

| Subset | ISIC | Volume (m <sup>3</sup> ) | Average (m <sup>3</sup> ) |
|--------|------|--------------------------|---------------------------|
| 1      | 292  | 1.79                     | 4.76                      |
|        | 742  | 2.58                     |                           |
|        | 503  | 3.03                     |                           |
|        | 743  | 3.67                     |                           |
|        | 505  | 3.79                     |                           |
|        | 453  | 4.03                     |                           |
|        | 514  | 4.59                     |                           |
|        | 515  | 4.69                     |                           |
|        | 801  | 4.83                     |                           |
|        | 512  | 4.85                     |                           |
|        | 804  | 5.08                     |                           |
|        | 749  | 5.16                     |                           |
|        | 702  | 5.26                     |                           |
|        | 651  | 5.52                     |                           |
|        | 174  | 5.73                     |                           |
|        | 502  | 5.95                     |                           |
|        | 181  | 5.99                     |                           |
|        | 524  | 6.04                     |                           |
|        | 155  | 6.32                     |                           |
|        | 552  | 6.39                     |                           |
| 2      | 930  | 6.88                     | 7.23                      |
|        | 361  | 6.91                     |                           |
|        | 701  | 7.45                     |                           |
|        | 452  | 7.68                     |                           |
| 3      | 291  | 7.72                     | 10.57                     |
|        | 522  | 8.04                     |                           |
|        | 523  | 8.06                     |                           |
|        | 602  | 8.3                      |                           |
|        | 604  | 9.18                     |                           |
|        | 516  | 10.25                    |                           |
|        | 158  | 1.59                     |                           |
|        | 112  | 11.32                    |                           |
|        | 289  | 12.10                    |                           |





| Subset | ISIC | Volume            | Average<br>(m <sup>3</sup> ) |
|--------|------|-------------------|------------------------------|
|        |      | (m <sup>3</sup> ) |                              |
|        | 802  | 12.59             |                              |
|        | 659  | 12.75             |                              |
|        | 271  | 12.88             |                              |
|        | 851  | 13.59             |                              |
| 4      | 501  | 14.51             | 23.72                        |
|        | 642  | 15.38             |                              |
|        | 252  | 16.20             |                              |
|        | 154  | 19.10             |                              |
|        | 222  | 19.22             |                              |
|        | 171  | 19.32             |                              |
|        | 242  | 21.01             |                              |
|        | 521  | 23.68             |                              |
|        | 151  | 24.98             |                              |
|        | 551  | 26.40             |                              |
|        | 513  | 37.04             |                              |
|        | 921  | 47.80             |                              |
| 5      | 152  | 91.31             | 91.31                        |

Source: GAB consultancy (2008).

## Conclusions

The topics linked with environmental affairs have been getting outstanding importance into national policies for both developed and developing countries. Colombia has been supporting its own policy considering worldwide higher standards in order to improve Colombian's quality of life.

Different approaches to measure solid waste generation grant accurately identification of factors like sweep, recollection, transport and final waste's treatments.

The approaches presented here help to measure waste generation for residential and non-residential producers. Table 6 of this article suggests the estimation of production factors for six socioeconomic layers of residential producers. The outcomes obtained are lesser, in all cases, than the outdated former production factors.

For non-residential producers -divided in small and big producers- tables 8 and 9 suggest the possibility to consider the industrial sector belonging of the producer.

Both cases were presented to CRA as a new accurate way to make the bill that cover for cleanliness services. Former figures had not had nor complete treatment for each lay-

er neither for each ISIC belonging of any producer consider.

This paper is a turning-point methodology to measure solid waste generation both for residential and non-residential users.

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