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Evaluation of Municipal Solid Waste Management in Brazilian Cities According to the Updated Waste Management Condition Index –ICGRA

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Abstract

The present study evaluates municipal solid waste management through environmental indicators. To this end, the updated Waste Management Condition Index (ICGRA), formulated through changes to the ICGR, a proposed index validated by Dantas KMC, et al. was designed and used as a tool. To create the ICGRA, 22 environmental performance indicators were inserted with the purpose of adjusting the index to the requirements of Brazil's National Solid Waste Policy (PNRS) and to the current conditions of the solid waste treatment. The scores were obtained by assigning weights to the indicators and with the value found for each municipality, the waste management was classified as adequate or inadequate, in a range between zero and ten points. The ICGRA method was applied in ten municipalities of small and medium size in the state of Rio de Janeiro. None of them reached the level of management considered adequate by the method. In addition to the 22 indicators inserted, the ICGRA worksheet contains the 40 original ICGR indicators used in the evaluation carried out in 2008. Thus, it was possible to evaluate the results in a comparative way, showing that only four of the ten municipalities studied improved. The improvement seen in the 4 municipalities is in relation to the index used in the evaluation, the ICGR, same index used in 2008. It does not mean that all aspects of solid waste management have evolved, but that the index composed of waste management evaluation indicators improved in relation to 2008. The results also reveal that the PNRS was not effective in its first seven years. The proposed method proved to be practical and easy to apply, helping to improve the evaluation methods in the area of waste management already developed in Brazil.

Keywords: Waste Management; ICGRA; Waste; Misconceptions

Abbreviations: CCW: Civil Construction Waste; SNIS: Solid Waste Information System; LR: Reverse Logistics; GT: Gigatons.

Introduction

Problems related to the inadequate management of solid waste have always been present in human societis and have become more complex with the evolution of social organizations and modes of production. According to Worrell W, et al. [1], until the Industrial Revolution little importance was given to the sanitary conditions of cities as far as solid waste is concerned. But with the intense growth of cities during the Industrial Revolution, waste began to gain importance, mainly due to public health issues.

Deficiencies in waste management systems generate damage to the environment and public health, which is particularly evident in developing and underdeveloped countries. From 1900 to 2015, humanity extracted from the planet a total of 3400 Gigatons (Gt) of Biomass, fossil fuels, ores, and minerals. From this number of natural resources, 73% were returned to the environment in the form of waste (solid, liquid, or gaseous) [2].

According to Marshall RE, et al. [3], developing countries such as Brazil need to invest in scientific, theoretical and practical improvements in solid waste management, allowing the creation of participatory, contextual and adaptive strategies that allow real progress towards strengthening the country's infrastructure.

A large part of the waste generated in the world has the potential for reuse or recycling. In 2016, more than 0.45 Gigatons (Gt) of Electronic Waste were produced worldwide, with less than 20% being reused through efficient and environmentally safe methods [4,5]. Municipal waste in low- and middle- income countries is predominantly food waste, while in high-income countries, waste is predominantly dry, such as plastics, paper, metal, and glasses [6]. Both organic matter and dry residues have high recycling potential.

The problems of waste management in developing countries include small coverage area, deficiencies in the collection, open dumps - and informal management, among others [7].

While in developed countries there is an increasing trend to reduce the amount of waste destined for landfills, increasing the rate of percentage of treatment such as recycling, composting, anaerobic digestion and incineration with energy use, Brazil has been unsuccessful in eradicating landfills and open dumps.

Federal Law 12.305 of 2010 established the National Solid Waste Policy (PNRS), aftrer nearly 20 years of debate in Congress, reflecting great difficulties and bureaucratic barriers that had to be overcome. Unfortunately, the effectiveness of this law is largely unknown [8]. According to Fernandes V, et al. [9], in a survey carried out in 2014 among 5.570 Brazilian municipalities, only 844 sent waste to sanitary landfills, 1.775 admitted that waste was disposed of incorrectly and 2.951 did not even respond to the survey.

Fernandes V, et al. [9] also pointed out that only 36.3% of the municipalities surveyed in 2014 had established the Basic Municipal Sanitation Plan required by the law and only about 37% performed some type of selective collection. Godoy MRB, et al. [10] pointed out that at the end of August 2012, only 10% of municipalities had developed solid waste plans. A bill approved by the Senate (PLS 425/2014) would extend the deadline for municipalities to eradicate dumps, but the bill has not yet been approved by the Chamber of Deputies (the lower house of Brazil's Congress). The real problem is twofold: the shortage of revenue to put the PNRS into action and the lack of follow-on regulations establishing penalties for failure of municipal governments and officials to comply.

In general, the effectiveness of MSW management has been assessed by the amount sent for final disposal in landfills. One of the main methods for evaluation of MSW landfills is the Landfill Quality Index (IQR), developed in a pioneering way by CETESB, the São Paulo state environmental agency, in 1997 [11]. This index ony requires evaluating the conditions of the disposal of MSW in landfills. It does not demonstrate the overall conditions of environmental management of MSW. Based on this premise, Dantas KMC, et al. [12] proposed a new evaluation methodo for urban solid waste management, through an index composed of indicators to evaluate the management as a whole, called the Waste Management Condition Index (ICGR in the Portuguese initials).

Although the ICGR is in line with the current situation, the requirements brought about by the National Solid Waste Policy in Brazil, as well as the evolution of treatment of residues through energy recovery technologies and other modern techniques, require the adaptation of the index through insertion of some new indicators, to update the method to evaluat the environmental performance of municipal solid waste management.

The ICGRA, was thought and developed as an evolution of the ICGR proposed by Dantas KMC, et al. [12]. Both indices are valid and can be applied separately or together. The ICGRA was developed in 2016 and applied in ten municipalities in the State of Rio de Janeiro.

The difference between the indexes is that the ICGRA has twenty-two indicators, in addition to those already used in the ICGR and the indicators of the ICGRA aims to evaluate modern aspects of solid waste management, not evaluated by the ICGR.

Through a critical analysis of the National Waste Policy we can raise some misconceptions. Second Ribeiro SG, et al. [13], the PNRS for some was the salvation of the country, but, in fact, does not want to change anything except, perhaps, the construction of some sanitary landfills rather than dumps, which is very little. A of the PNRS misconceptions presented by Ribeiro SG, et al. [13] was not to include the energy use of the residues in the hierarchy of management actions. Other misconceptions of the PNRS that we can cite are the following:

- The lack of encouragement for solutions other than the landfill, the definition of landfill as well as not attacking the bio-waste problem.
- Does not establish that the energy recovery of waste is higher than landfill in the hierarchy of actions, by the high percentage of non-recyclable plastics.
- Does not establish incentives for the sale of energy from waste heat treatment plants, which could make them viable.
- Does not cite the separation at source as the basis for recycling and composting.
- Through the PNRS, recycling in Brazil is incipient and stimulated by poverty.
- The recycling chain may have the participation of scavengers, but it has to be managed in a professional way, by the difficulty of organization of the collectors who in general, are of very low educational level.

According to Tchobanoglous G, et al. [14], integrated solid waste management is the selection and appropriate application of techniques, technologies and management programs to achieve the specific goals and objectives of a waste management plan. The authors mentioned also point out that the integrated management is adopted to apply the different federal and state legislations that were created on the subject, however, the strategies may be different in each region.

Tchobanoglous G, et al. [14] cited the case of the State of California in the USA as an example. The Environmental Protection Agency has defined the hierarchy of actions in waste management as follows: (1) reduction at source (2) recycling and composting (3) energy recovery / heat treatment (4) disposal in landfills. However, the State of California has replaced energy recovery from waste processing and, according to the authors cited, the differentiated interpretation of the hierarchy of actions for integrated waste management should remain variable in other American States.

Materials and Methods

Formulation of the Updated Waste Management Condition Index (ICGRA)

The design of the updated Waste Management Condition Index (ICGRA) assumed that the performance of a final solid waste disposal site does not represent the condition of municipal waste management as a whole. The PNRS and new technologies related to waste management and management have brought demands not covered by the indexes previously used in the evaluations.

In addition to the inclusion of 22 environmental indicators to update the ICGR, the proposal also entails changing the final framework of municipal performance into only two intervals: ICGRA from 0 to 7.9 → inadequate management; ICGRA from 8.0 to 10.0 → adequate management.

Based on the guidelines, instruments and tools proposed by the PNRS, in addition to the various techniques and recent studies on waste management, 22 environmental indicators were selected for inclusion in the original ICGR.

In order to assess the level of each indicator, as was done in the creation of the ICGR, a questionnaire was prepared and sent to professionals, technicians and researchers in the area of environment and solid waste. Each one assessed from 0 to 5 the importance of each indicator (weight) in the final index.

The 22 proposed indicators included in the updated ICGR are described in Table 1 below.

Indicator
1- Existence of standardized system of reverse logistics (LR) of the products listed in Article 33 of the PNRS (batteries, tires, lubricating oil, household appliances and fluorescent lamps).
2- Professionals involved in waste management have suitable technical training.
3- A contingency plan exists in case of strikes by sanitation workers.
4- Allocation of employees directly involved in public sanitation activity according to age and physical condition.
5- Existence of an information system on the management of waste and characteristics of various wastes, available online at a specific site or page.
6- GPS and/or GIS fleet control system
7- Performance of geotechnical and environmental monitoring of areas of irregular disposal or deactivated waste sites (landfills or controlled landfills).
8- Existence of specific public collectors for segregation, through PEV or public collectors and landfills differentiated for different types of MSW (organic / inorganic or glass / paper / plastic ...)

9- Existence of a waste sorting operation
10- Alternative collection schedules for impact reduction in urban traffic (outside business hours)
11- Collection and / or use of biogas in the final waste disposal areas.
12- Use of special vehicles for hard to reach areas (motorcycles, tricycles, etc.)
13- Waste barrier systems to protect and maintain watercourses
14- Provision of adequate collectors for pre-collection storage
15- Removal of large waste materials such as furniture, bicycles and others
16- Economic or tax incentives for non-generation, reduction, reuse and recycling actions
17- Existence of operations of sorting and reutilization of civil construction waste (CCW)
18- Provides data to the National Sanitation/Solid Waste Information System (SNIS)
19- There is contract for geotechnical and environmental monitoring of landfill(s) by an independent team from the landfill operator
20- Availability and transparency of data on the costs of waste disposal (on official websites, transparency portals etc.)
21- Requirement for contracting liability insurance by generators of hazardous waste in the event of an environmental accident or any damage
22- Implementation of ISO 9000 or 14,001 management system by waste management bodies (municipal government, public company or concessionaire)

Source: The authors.

Table 1: Twenty-two additional indicators composing the updated Waste Management Condition Index (ICGRA).

Figure 1 shows the evaluation worksheet proposed by the method, with the weight of each indicator in the ICGRA.

Indicator	Sub-item	Rating	Weight	Score	Indicator	Sub-item	Rating	Weight	Score
	System of standardization for reverse logistics of the products of article 33 of the NPSW	yes, for all	4			Use of specific vehicles for hard to reach areas such as tricycles, motobikes and etc	yes/not required	3	
		some products	2				no	0	
		no, no one	0						
	Professionals involved in management effective post of waste and with training in the area	yes, for all	3			Systems of barriers to protection of watercourses and maintenance of the same	yes, in all	4	
		some products	1				some points	2	
		no, no one	0				¢	0	
	Contingency plan for workers' strike of cleaning service	yes	3			Adequate collector available for pre-collecting storage	yes	3	
		no	0				no	0	
	Employ allocation according to age and cond. Physical	yes	2			Removal of waste materials such as furniture and other	yes	2	
		no	0				no	0	
	Information system on waste management in specific website or specific page	yes, implanted	4			economic incentives and / or tax credits for non-taxable generation, reduction, reuse and recycling	yes	4	
		some informations	2				incipientes	2	
		no information	0				no	0	
	Fleet control system for GPS and/ or GIS	yes	3			Sorting and repair operation of construction waste	yes	3	
		no	0				no	0	
	geotechnical monitoring and environ mental of waste disposal irre gular area disabled	yes or do not have	4			filling in the information of Of the National Waste Information System (SNIR)	yes, all	4	
		has some type	2				some	2	
		does not monitor	0				no, no one	0	
	specific public colectors for some type of segregation in generation	yes	4			Geotechnical monitoring contract and environmental of landfills	yes, including post- closing	5	
		In part of the municipality	2				yes, in the operation phase	3	
		no	0				No or no landfil	0	
	waste sorting operation licensed and functioning properly	yes	3			Data on the costs of the landfill destination	yes	2	
		no	0				no	0	
	Alternative collection times for reducing the impact in urban traffic	yes/not required	3			Hiring of responsible insurance forhazardous waste generators (Art. 40. NPSW)	yes	3	
		In few neighborhoods	1				no	0	
		no	0						
	Collection and / or use of biogas generated in the final disposal of waste	collection+ power gener	5			**sub-total 4**	**maximum**	**73**	
		collection and burn	3						
		without collection	0			**Sum of points (Sub-total 1+2+3+4)**		**#REF!**	
	It has some sort of management system implemented (ISO 9.000 ou 14.0001)	Yes	2			**ICGRA = Sum of points / 20,3**		**ICGRA**	**#REF!**
		No	0						
		Sub total maximum	40			**ICGRA**	**Rating**		
						0 A 7.9	Inadequate management		
						8.0 A 10.0	Proper management		
						Rating			

Source: The authors.

Figure 1: ICGRA Evaluation Worksheet.

After formulating and proposing the ICGRA as an assessment tool for municipal management, it was necessary to apply the method to validate it. For this purpose, a field survey was carried out in ten municipalities in the state of Rio de Janeiro.

Ten municipalities were selected for survey among the 20 already evaluated in 2007 and 2008, when the ICGR was proposed and validated.

The criteria for choosing the municipalities evaluated are described below in order of priority:

- Municipalities evaluated in 2007-2008 when designing and validating the ICGR.
- Municipalities up to 200 km from the state capital (to reduce costs)
- Municipalities that in the 2007-2008 evaluation presented some positive differential aspect in relation to the others regarding solid waste management, such as recycling and composting plants, selective waste collection and others.
- Municipalities whose officials demonstrated in previous studies good willingness to contribute to academic research.

Based on these selection criteria, 10 municipalities were selected for field research: Cachoeiras de Macacu, Bom Jardim, Silva Jardim, Cantagalo, Petrópolis, Teresópolis, São José do Vale do Rio Preto, Nova Friburgo, Sumidouro and Casimiro de Abreu [15].

Results and Discussion

The way in which the ICGRA evaluation worksheet is set up allows the generation of two evaluation indexes. The ICGR - Waste Management Condition index used in the evaluation performed by Dantas KMC, et al. [11] and the ICGRA - updated Waste Management Condition index, generated after insertion of the 22 indicators presented in Table 1. This method allowed evaluating, by the differences between the two indexes, the quantitative effect on the final score of including the new indicators.

Comparing the two indexes reached by each municipality evaluated, it can be seen that all had an updated index value (ICGRA) below the ICGR value. This shows that when assessing the aspects of the PNRS and new techniques, all the municipalities leave much to be desired, as shown in Table 2.

Cities	ICGR (2016)	ICGRA (2016)	ICGR-ICGRA Difference (%)
Nova Friburgo	7.08	6.16	13
Petrópolis	6.31	5.42	14
Cantagalo	7.08	5.32	25
Cachoeiras de Macacu	5.85	4.73	19
Sumidouro	4.38	3.99	9
Bom Jardim	4.62	3.79	18
Silva Jardim	3.62	3.1	14
São José V. do Rio Preto	3.23	3.05	6
Teresópolis	3.62	2.66	27
Casimiro de Abreu	2.92	2.61	11

Source: author.

Table 2: Results of the evaluation of waste management in the municipalities of the state of Rio de Janeiro in 2016 comparing ICGR with ICGRA. Source: The authors.

By comparing the 10 municipalities studied, considering that they were evaluated in 2008. It was possible to analyze the positive or negative evolution in the solid waste management systems, as shown in Table 3.

The indicators in Figure 1 were evaluated according to the level of service of each of them, reaching the final value, calculated through the weighted average of the indicators with their respective weights.

The differentiation of worse or better. Refers to the indices served in 2008 compared to the indices served in 2016. The same municipalities were evaluated in 2 different periods (2008 and 2016)

Cities	ICGR (Dantas, 2008)	ICGR (2016)	Comparison (2008-2016)	Percentage of improvement ICGR (%)
Nova Friburgo	7.69	7.08	Worse	-8
Petrópolis	7.54	6.31	Worse	-16
Cantagalo	6.54	7.08	Better	8
Cachoeiras de Macacu	3.62	5.85	Better	62
Sumidouro	6.15	4.38	Worse	-29
Bom Jardim	4.46	4.62	Better	4
Silva Jardim	3	3.62	Better	21
São José V. do Rio Preto	6.08	3.23	Worse	-47
Teresópolis	5.23	3.62	Worse	-31
Casimiro de Abreu	5.54	2.92	Worse	-47

Source: author

Table 3: Comparison of the ICGR in 2008 and 2016 of the 10 municipalities evaluated. Source: The authors.

According to the data presented in Table 3, between 2008 and 2016, the waste management of six municipalities deteriorated according to the ICGR while four improved, but in all cases this evolution was modest. With the exception of Cachoeiras de Macacu, which improved by 62% in the ICGR, the other three municipalities that presented improvement evolved by an average of 11% in the ICGR.

The mean ICGR deteriorartion of the six was almost 30%. Therefore, in addition to the larger number of municipalities obtaining worse scores (6 out of 10), the average percentage of deterioration was higher than the improvement percentage of the other four municipalities.

The differentiation of worse or better. Refers to the indices served in 2008 compared to the indices served in 2016. The same municipalities were evaluated in 2 different periods (2008 and 2016). Those that obtained the ICGR better in 2016 when compared to 2008 have improved.

According to the results, we can conclude that the PNRS has not been effective for the following reason: the indicators used in the ICGR assessment index contain elements predicted in the PNRS, such as reverse logistics, waste disposal, selective collection and others. In 6 of the 10 municipalities evaluated, the indices surveyed in 2016 were worse than those presented in 2008. Even in the municipalities that improved the indices, there were several problems in the field management in the waste management.

Conclusions

The ICGRA (Updated Waste Management Condition Index) is an evaluation metric that is practical, inexpensive and easy to apply. The scores showed that very few municipalities have evolved positively in relation to solid waste management.

Even after the first six years of the National Solid Waste Policy in Brazil (PNRS), there was little improvement and in the majority (60%) of the municipalities there was deterioration. The only effect of this policy, verified at the time of the research, was the relative reduction of waste disposal in leaks and dumps, at least in an indiscriminate manner, yet the enclosed leaks were neither remedied nor recovered. The research proved that the PNRS did not present effective results until the present.

Municipal governments do not give proper priority to solid waste management and are unable to effectively carry out waste management activities.

There is still a great difficulty in obtaining data on waste management in cities, which proves that transparency and access to information are not yet present in municipal public administrations, at least as they should be.

Another finding was the great difficulty of all the municipal governments surveyed to improve the forms of collection. Some do not charge garbage collection fees and none of systems are financially self-sufficient.

The government officals claim that one of the obstacles to good service delivery is the cost issue, but they do not carry out financial control of the system, they do not perform cost-benefit or opportunity cost analyses of investing in other sectors.

In the municipalities studied, waste management is still not seen as requiring an integrated system, there is no

integration of policies, projects or actions. In addition, the correct regulation and inspection of the services performed, either by the city governments themselves or by outsourced companies, was not verified.

It was verified from the verified results that the cities evaluated in 2008 and 2016 did not evolve satisfactorily in solid waste management.

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