

Pollution Credit Certificates Theory: An Analysis on the Quality of Solid Waste Management in Brazil

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ABSTRACT

Purpose: This paper aims to introduce an economic instrument called Theory of Pollution Credit Certificates in the management of municipal solid waste in Brazil, in order to create opportunities to achieve the goal established in the above mentioned policy at lowest possible social costs.

Methodology/Approach: The methodology adopted has as a starting point the “constructo” of a scenario in which a city comprised of five brazilian districts produces its urban solid waste made up of 50% organic material. In the proposed scenario, similar to what happens in practice, a fee for collection and treatment of organic material would be charged for two different situations.

Findings: The result showed that the use of Pollution Credit Certificates Theory has a better cost-effectiveness for solid waste management because it allows reaching the environmental goal at a lower cost to society.

Research Limitation/Implication: Subjectivity of the analysis, due to the “constructo” proposition in the studies.

Originality/Value of paper: From the results obtained, we inferred that the use of the Pollution Certificates Theory for the management of brazilian municipal solid waste benefits from economies of scale as it allows in the scenario determined, that districts sell their spaces at the landfill and parallel to this, to promote the practice of composting organic waste in the municipality.

Category: Research paper

Keywords: solid waste management; SWM; pollution credit; certificates theory

1 INTRODUCTION

Solid waste management is a challenge for present and future generations. The option of not generating waste will always be the ideal, but in the current consumerist model, the optimum becomes the attempt to mitigate environmental impacts by adding regulatory and economic instruments to maximize the welfare of society at lower environmental costs (Gupta, Yadav and Kumar, 2015; Johari et al., 2014; Allesch and Brunner, 2014; Barbosa, Oliveira and Santos, 2018; Santos, Rebelo and Santos, 2017; Bravi et al., 2020). The purpose of this study is to evaluate the environmental and economic efficiency of a urban solid waste management system in a municipality through a comparison of total costs to achieve an environmental goal, reducing the destination of organic waste to landfill where each district of the city should focus on fulfilling that goal and achieving the total costs obtained when additionally a system of pollution credits certificates is used whereby the reduction is not necessarily unitary (by district) allowing the exchange of organic waste. The relevance of the actual application of this technique is economically to stimulate social actors to manage their solid waste generated so that they could be also continually encouraged to a further reduction of organic waste for disposal in landfills causing the extension of their useful life. The elaboration of a strategy is fundamental for the organization of the plans (Miezah et al., 2015; Santos et al. 2019a; Barbosa et al., 2020; Santos et al., 2019). A strategy to develop the study in 5 district-city was organized and a representative resident's association was created.

In this study, two districts have a vocation to compost the waste generated in the city, and to improve the rates, only 30% of the organic waste from the municipality could be launched at the municipal landfill with the remainder being composted. Then two ways to accomplish this task were analysed: the first way with a system where each district would send 30% of their organic waste to the landfill; and the second way considering a system where the goal of sending 30% of organic waste would be extended to the whole town having the districts a mandate to negotiate pollution credits certificates in order to reach a pattern according to marginal costs, as determined by the condition of each district. From the calculations of total costs for these two above management strategies addressed, it was possible to conclude that for the same environmental target, the use of economic instruments like Credit Certificates as a management tool makes it possible to lower costs to society, having in mind a better cost-effectiveness.

2 THEORETICAL REFERENTIAL

World Bank statistics estimate that the volume of waste is expected to grow to 2.2 billion tons in 2025 (Word Bank Group, 2012; Espuny et al., 2021). The generation of waste in households, commercial and industrial sphere has been considered a major concern for political, socio-economic and environmental purposes. However, routinely can be seen that many initiatives have been taken as the improvement, expansion and innovation of services and techniques of

collection for the disposal of these wastes (IPT, 2016; Deus, Battistelle and Silva, 2017; Ribeiro et al., 2017; Reis et al., 2021).

Many of the major solid waste found in urban areas, are still discarded incorrectly, endangering the environment and the lives of those who are financially dependents of such waste, as garbage collectors. Brazil still had most of its waste being released into open-air dumps which expose soils, waters and the life of the population in economic (devaluation of homes and real states) and health terms (diseases related to environmental contamination) (see Figure 1) (CEMPRE, 2018).

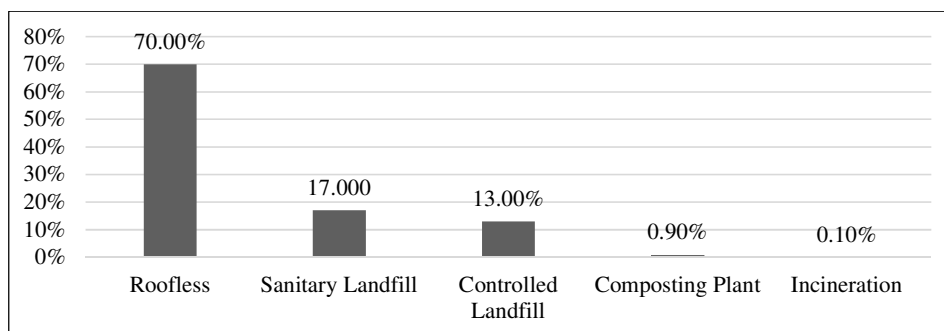


Figure 1 – Forms of Disposal of Solid Waste in Brazil in 2002 (CEMPRE, 2018)

As a solution to the problems of overconsumption and the disposal of materials that may still have some use, municipal administration in Brazil has been charging collection and domiciliary waste management fees making each citizen educated to consume less and reuse more (CEMPRE, 2018). The guidelines applicable to solid waste, establishing the protection of public health and environmental quality; the promotion of the 3R's (reduce, reuse, recycle); and on promoting the treatment and final disposal of the waste properly. This also aims to strengthen existing management systems; reverse logistics (Rathi, 2006; Arena and Di Gregorio, 2014; Gupta, Yadav and Kumar, 2015). The inadequate management and disposal of solid waste cause major environmental impacts, such as problems in urban drainage network (contribution to floods and landslides) soil, air and water contamination, being in addition a transmitter of diseases (Alwaeli, 2015; Bing et al., 2016; Yan et al., 2016).

The problem of solid waste management in today's societies has become complex due to the amount and diversity of waste, the explosion of urban areas, the limited public financial resources in many cities, the impact of technology and the limitations of both energy and natural resources (Zarea et al., 2019; Alwaeli, 2015; Bing et al., 2016; Gupta, Yadav and Kumar, 2015; Félix et al., 2018). In Brazil, the collection, management and disposal of these solid wastes is the responsibility of the municipal government. Often, the waste generated in industries, for example, depending on their classification, are processed and collected by the enterprise itself to a more correct destination and even to the reuse of such waste (SELURB, 2011, 2018, 2019).

The solid waste management generates as a consequence of its application in urban areas, an incentive for recycling of waste and also leads to environmental education to society that will consume thinking about how the product purchased can affect the environment, that is, how sustainable is it (Laurent et al., 2014; Ma, Ho and Fu, 2011; Espuny et al., 2021; Murmura, Bravi and Santos, 2021; Santos et al., 2020). The “Entrepreneurial Commitment to Recycling” is a non-profit association dedicated to the promotion of recycling within the integrated waste management concept. Founded in 1992 and headquartered in Sao Paulo, CEMPRE is maintained by private companies of various industrial sectors and works to educate the society about the importance of reducing, reusing and recycling through publications, technical surveys, seminars and databases. Awareness programs are directed mainly to opinion leaders, such as mayors, directors of companies, academics and non-governmental organizations (CEMPRE, 2018).

The Brazilian cities that deployed this system of garbage collection, as well as other ways of solid waste management have an expense to the collection and provision, charged as a fee for garbage collection, which is paid by all users of selective collection in the municipality in which they live. The orderly and efficient management of solid waste contributes to the understanding of the actions necessary for the proper functioning of public policies regarding the provision of municipal solid waste management services, urban health and quality of life (Dong et al., 2014; Nijkamp and Kourtit, 2017; Abd El-Salam and Abu-Zuid, 2015).

The expenditure on the selective collection is shown in Figure 2 in which it can be realized that the cost per ton in the selective collection is still high. Research by CEMPRE in 2012, concluded that the average cost of selective collection in the surveyed cities was US\$ 212 per ton.

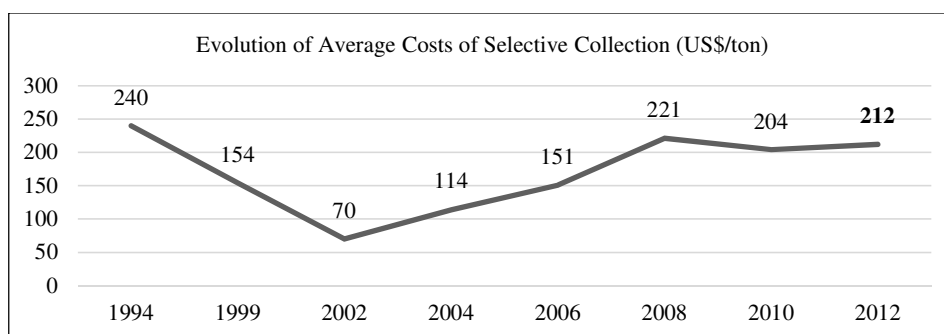


Figure 2 – Costs of separate waste collection from 1994 to 2012 (CEMPRE, 2018)

If the solid waste management is carried out in an orderly and efficient manner fundamental relations involved can be identified and adjusted to data standardization and a better understanding of the actions necessary for the smooth running of public policies concerning municipal services provision of solid waste management. Economic and innovative instruments are being used in

many countries to improve environmental quality and these approaches cover a wide range of possible mechanisms (Zgodavova et al., 2020). In an extreme situation, it can be included fines or penalties that are tied to traditional regulations of “command and control” type (Wang, Yin and Chen, 2019; Halkos and Paizanos, 2016; Leoni, Sampaio and Corrêa, 2017; Abd El-Salam and Abu-Zuid, 2015).

Already the economic instruments generate lower costs. The improvement of the quality management system (Sá et al., 2019; Araújo et al. 2019; Costa et al., 2019; Santos et al., 2021; Sá et al., 2020; Africano, Rodrigues and Santos, 2019) and also reach the environmental target (Teixeira et al., 2021; Silva et al., 2020), despite having a greater requirement for the real application because this requires a higher technical knowledge for surveillance, may increase the cost for the environmental agencies. The integration of management systems as well as the optimization of production helps to reduce waste (Santos et al., 2011; Wang, Yin and Chen, 2019; Santos et al., 2016; Talapatra et al., 2019; Santos et al., 2014; Rebelo, Santos and Silva, 2015).

3 METHODOLOGY

The methodology adopted has as a starting point the “constructo” of a scenario in which a city comprised of five districts produces its urban solid waste made up of 50% organic material. In the proposed scenario, similar to what happens in practice, a fee for collection and treatment of organic material would be charged for two different situations. In the first situation, only 30% of organic waste would be sent to a municipal landfill, due to the need to increase its useful life and 70% of the remaining organic waste would be composted. Every district, in this case should send 30% of their organic waste to a landfill.

In the second scenario, the same 30% of organic waste generated in the municipality would be sent to a municipal landfill, however, it would be awarded to each district the right to market certified organic waste credits. Not necessarily every district should send 30% of their organic waste to the landfill, this being a function of the marginal costs of collection and disposal of each district. For both, it was assumed that two of the districts of that municipality, due to a specific characteristic, would have composting systems capability to receive and treat 70% of the organic waste generated in that district. We considered that these two districts endowed with composting units, would be granted by the government the permission to provide services to other districts in the form of collection and treatment of organic waste generated and that they may charge for such service. Thus, districts, represented by their respective resident’s associations, in this situation would have a central to receiving organic waste generated by households in their districts by sending part of its waste to landfill and composting plants for part of the two existing districts in this county. For a better visualization of the proposed scenario, Figure 3 shows a fictitious political map of the town.

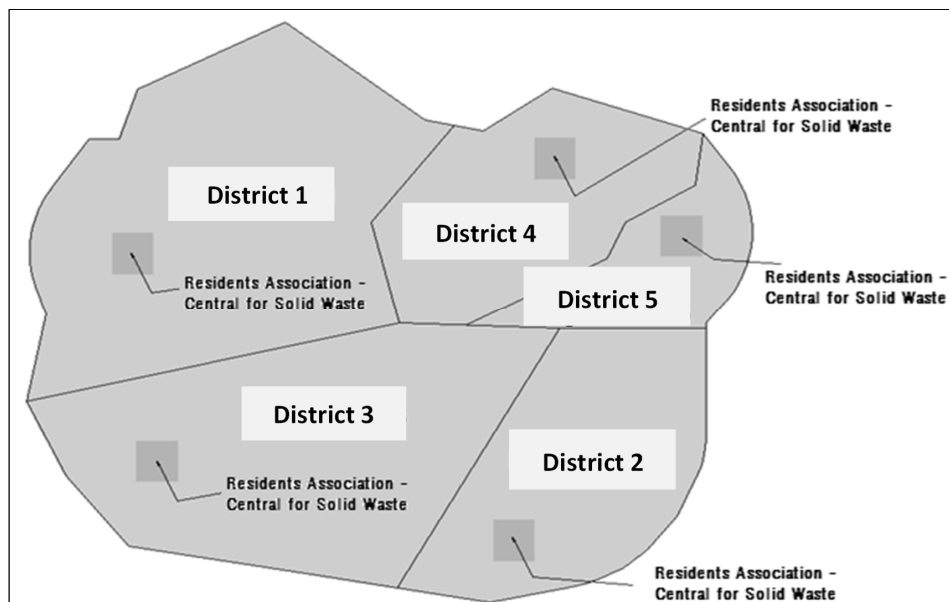


Figure 3 – Political Map of the Town Fictitious

According to this scenario, it would be possible to compare the collection and treatment costs of organic waste disposal in landfills and the application of the Theory of Pollution Certificates initially proposed by John Dales in 1968, the consortium composting units administered by independent and resident associations. Table 1 shows the production of organic waste established for each district in this scenario.

Table 1 – District Population and Production of Organic Waste [t/Day] in the Fictitious Town

| District | Population | Production of Organic Waste [t/day] |
|----------|------------|-------------------------------------|
| 1 | 10,000 | 4.0 |
| 2 | 20,000 | 8.0 |
| 3 | 15,000 | 6.0 |
| 4 | 30,000 | 12.0 |
| 5 | 5,000 | 2.0 |
| Total | 80,000 | 32.0 |

In the first scenario, we considered that the districts would have the collection and disposal of its organic waste regulated by the government so that only 30% of this waste could be destined for landfill with the remainder sent for composting in districts geared to both. Every district should necessarily send 30% of organic waste to landfill.

Table 2 – Waste Production and Marginal Costs of Collection and Disposal of Organic Waste

| District | 70% of Organic Waste Production [t/d] | 70% of Marginal Cost of Collection and disposal of Organic Waste [US\$/t] |
|----------|---------------------------------------|---|
| 1 | 2.80 | 42.00 |
| 2 | 5.60 | 52.50 |
| 3 | 4.20 | 35.00 |
| 4 | 8.40 | 56.00 |
| 5 | 1.40 | 63.00 |
| Total | 22.40 | 248.50 |

In the second scenario, we assumed that two of the districts of this city would have ability and permission granted by public authority to act as a collecting agent and handlers of 70% of organic waste of this market and that districts would be free to send to landfill quantities of organic waste that minimize the costs of collection and arrangement and thereof provide the maintenance of the goal (to send 30% of the total organic waste to landfill). In this situation, we considered that the districts with the largest area (districts 1 and 3) would be geared to achieving waste composting and therefore could provide service to other districts, including garbage collection. In parallel, in this configuration, the residents' associations in each district would be organized and representative enough to maintain in their respective districts an Organic Waste Central (OWC) for which residents would send their waste daily. The data for the assumptions that formed the basis for estimating the marginal costs of collection and disposal of organic waste presented in Table 2 were taken from the scenario in which a city composed of five Brazilian districts produces.

4 RESULTS

The calculation of the total costs of collection and disposal (composting) of organic waste, considering the government standard which requires each district to allocate 30% of their organic waste to landfill and the remaining waste for composting into the districts with the largest area (districts 1 and 3) is shown below. Total cost of the district (TCD) = 70% of organic residue production [t/d] x 70% of the marginal cost of collection and disposal of organic residue [US\$/t].

$$\text{TCD1} = 2.8 \text{ [t/d]} \times 42.00 \text{ [US\$/t]} = 117.60 \text{ [US\$/day]} \quad (1)$$

$$\text{TCD2} = 5.6 \text{ [t/d]} \times 52.50 \text{ [US\$/t]} = 294.00 \text{ [US\$/day]} \quad (2)$$

$$\text{TCD3} = 4.2 \text{ [t/d]} \times 35.00 \text{ [US\$/t]} = 147.00 \text{ [US\$/day]} \quad (3)$$

$$\text{TCD4} = 8.4 \text{ [t/d]} \times 56.00 \text{ [US\$/t]} = 470.40 \text{ [US\$/day]} \quad (4)$$

$$\text{TCD5} = 1.4 \text{ [t/d]} \times 63.00 \text{ [US\$/t]} = 88.20 \text{ [US\$/day]} \quad (5)$$

The distribution of total costs from the perspective of the first scenario, using the government standard can be depicted from Figure 4.

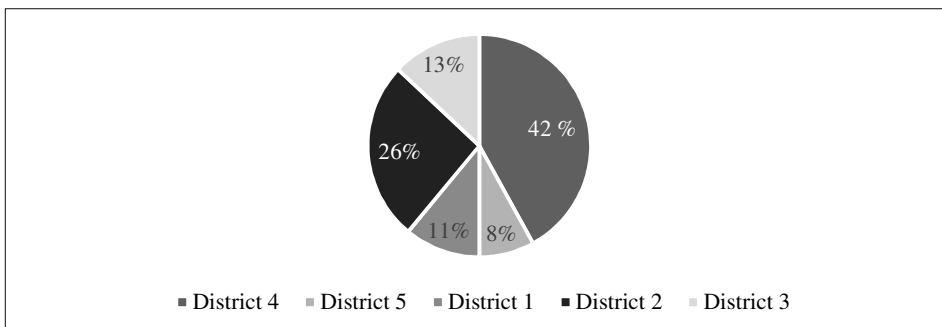


Figure 4 – Distribution of Collection and Disposal Cost of Organic Waste by Brazilian Districts Without a Trading Among Them

In the second scenario in which by a governmental decision only 30% of organic waste should be destined for landfill, but not necessarily by district, we chose to evaluate the applicability of the Pollution Certificates Theory in terms of costs and compliance to environmental goals. In this sense, it was established that the governmental authority would distribute credits of organic waste among districts, in proportion to their emissions, and still allow those credits to be traded. Despite the value of these credits vary according to the laws of supply and demand, for purposes of calculation we considered the amount of US\$ 45.00 per tonne of organic waste to be composted. In this sense, it was possible to construct Table 3 indicating the amount of Organic Waste Credit Certificates allocated by the government to the district evaluated.

Table 3 – Quantity Allocated of Organic Waste Collection and Disposal Credit Certificates

| District | Quantity of Credit Certificates of Collection and Disposal of Organic Waste |
|----------|---|
| 1 | 1,200 |
| 2 | 2,400 |
| 3 | 1,800 |
| 4 | 3,600 |
| 5 | 600 |
| Total | 9,600 |

From the data in Table 3 it was possible to calculate the total cost for each district with application of the Pollution Certificates Theory as follows: District 3 has to compost 70% of its generation of organic waste, spending for this 4.2 [t/day] x 35.00 [US\$/t] = -147.00 [US\$/day]. Now, as the district has

1,800 certificates and would have to send to landfill 1,800 kg of organic waste per day, it has to compost 30% of its further generation of organic waste spending for these $1.8 \text{ [t/day]} \times 35.00 \text{ [US\$/t]} = -63.00 \text{ [US\$/day]}$ for it to sell their certificates.

This district sells their 1,800 certificates for the value of $1.8 \text{ [t/day]} \times 45.00 \text{ [US\$/t]} = +\text{US\$ } 81.00$. The final balance of the district is: $-147.00 \text{ [US\$/day]} - 63.00 \text{ [US\$/day]} + 81.00 \text{ [US\$/day]} = -129 \text{ [US\$/day]}$. Therefore this district sends zero tonnes of organic waste to landfill and 6.0 tonnes of organic waste for composting. District 5 receives 600 certificates from the government and therefore has to compost 1.4 [t/day] of organic waste; instead of composting the waste itself, district 5 buys 1,400 Collection and Disposal Certificates from District 3 and spends therefore $1.4 \text{ [t/day]} \times 45.00 \text{ [US\$/t]} = -63.00 \text{ [US\$/day]}$. The balance of district 5 shall be $-63.00 \text{ [US\$/day]}$. So, this district will send zero tonnes of organic waste for composting and 2.0 tonnes of organic waste to the municipal landfill.

District 4 receives from government 3,600 certificates and, therefore has to compost 8.4 [t/day] of organic waste. Instead of composting the waste itself, district 4 will purchase 400 Collection and Disposal Certificates of the remaining sales as proposes district 3 and spends this way $0.4 \text{ [t/day]} \times 45.00 \text{ [US\$/t]} = -36.00 \text{ [US\$/day]}$. The balance of this district is not yet completed for District 4 still needs 8,000 certificates for not being obligated to compost. District 1 composts 70% of his generation of organic waste and spends $2.8 \text{ [t/day]} \times 42.00 \text{ [US\$/day]} = -117.6 \text{ [US\$/day]}$. Now the district has 1,200 certificates and would have to send to landfill 1,200 kg of organic waste daily. Then, the district composts additionally 30% of its generation of organic waste spending $1.2 \text{ [t/day]} \times 42.00 \text{ [US\$/t]} = -50.40 \text{ [US\$/day]}$, in order to sell its certificates; district 1 sells its 1,200 available certificates at a value of $1.2 \text{ [t/day]} \times 45.00 \text{ [US\$/t]} = +54.00 \text{ [US\$/day]}$.

The final balance of District 1 is equal to $-117.60 \text{ [US\$/day]} - 50.40 \text{ [US\$/day]} + 54.00 \text{ [US\$/day]} = -114.00 \text{ [US\$/day]}$. This district will send zero tonnes of organic waste to landfill and 4.0 tonnes of organic waste for composting. District 4 participates as a buyer of certificates, again, since district 1 is selling its credits. In this way, district 1 buys 1,200 certificates and spends with this purchase: $1.2 \text{ [t/day]} \times 45.00 \text{ [US\$/t]} = -54.00 \text{ [US\$/day]}$. Now, district 4 has $3,600 + 400 + 1,200 = 5,200$ certificates and, as there's no more sellers, it will have to compost 6.8 tons of his generation of organic waste per day, spending, thus: $6.8 \text{ [t/day]} \times 56.00 \text{ [US\$/t]} = -380.30 \text{ [US\$/day]}$. The final balance of district 4 is then $-36.00 \text{ [US\$/day]} - 380.30 \text{ [US\$/day]} - 54.00 \text{ [US\$/day]} = -470.3 \text{ [US\$/day]}$. This sends then, 5.2 tons of organic waste to the landfill and 6.8 tons of organic waste for composting. District 2 receives 2,400 from the government certificates and therefore has to compost 5.6 [t/day] of organic wastes. The district will have to compost 5.6 tonnes of organic waste per day, due to the absence of collection and disposal of organic waste certificates. With this action, the district has to spend $5.6 \text{ [t/day]} \times 52.50 \text{ [US\$/t]} = -295.00 \text{ [US\$/day]}$ and therefore, based on

that, the district balance shall equals -295.00 [US\$/day] and this district will send 2.4 tonnes of organic waste to landfill and 5.6 tonnes of organic waste for composting. Table 4 shows the total cost of each district after the application of the Pollution Credit Certificates Theory into organic solid waste considering that 30% of these residues are destined for the municipal landfill, although not necessarily each district must allocate 30% of their organic waste to this landfill.

Table 4 – Total Cost to Send Solid Waste to Landfill and Composting by Consideration of the Pollution Certificates Theory

| District | Final Quantity of Certificates | Waste sent to Landfill [t] | Waste sent to Composting [t] | Final Cost [US\$/day] |
|----------|--------------------------------|----------------------------|------------------------------|-----------------------|
| 1 | 0 | 0 | 4.0 | -114.00 |
| 2 | 2,400 | 2.4 | 5.6 | -294.00 |
| 3 | 0 | 0 | 6.0 | -129.00 |
| 4 | 5,200 | 5.2 | 6.8 | -452.80 |
| 5 | 2,000 | 2.0 | 0.0 | -63.00 |
| Total | 9,600 | 9.6 | 22.4 | -1052.80 |

From the data in Table 3 it was possible to calculate the total cost for each. According to the results obtained in terms of total cost of collection and disposal of organic waste in the fictional town, for the environmental established target of 30% of organic waste destined to landfill, we can realize that the management strategy based on the Theory of Certificates pollution achieved 5.8% savings as compared to the scenario without negotiation among the districts. Table 5 shows these results as well as the percentage of total costs reduction for the district with the trading of organic waste certificates of reductions between the districts involved.

Table 5 – Total Cost Comparison for the Two Scenarios Studied

| District | Total Cost without Negotiation [US\$] | Waste sent to Composting [t] | Cost Reduction [%] |
|----------|---------------------------------------|------------------------------|--------------------|
| 1 | 117.60 | 114.00 | 3.10 |
| 2 | 294.00 | 294.00 | 0 |
| 3 | 147.00 | 129.00 | 12.30 |
| 4 | 470.40 | 452.80 | 3.70 |
| 5 | 88.20 | 63.00 | 28.60 |
| Total | 1117.20 | 1052.80 | 5.80 |

5 CONCLUSION

From the results obtained, we inferred that the use of the Pollution Certificates Theory for the management of municipal solid waste benefits from economies of scale as it allows in the scenario determined, that districts sell their spaces at the landfill and parallel to this, to promote the practice of composting organic waste in the municipality. This benefit is expressed by means of obtaining lower overall costs of collection and disposal combined with the scope of environmental target of only 30% of organic waste produced in the municipality with the allocation thereof into a landfill.

Thus, in the formation of the organic waste market with technical Certificates of Pollution Credits, the districts will decide the amount of organic waste (through composting systems) they will recycle due to the variation of their costs. In short, each district can make based on their own costs, the decision to send the generated organic waste for composting or send it to the same organic waste deposit in the municipal landfill.

As possibilities for future studies further coverage of the values is suggested floating values of organic waste certificates, considering the shifts in supply and demand normal in any market, in addition to a greater coverage in terms of types of waste, not only applying to municipal solid waste, but also to industrial, commercial and construction site waste.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.



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