

Case Report

Effect of Improving Environmental Sustainability in Developing Countries by Upgrading Solid Waste Management Techniques: A Case Study

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Abstract: The present research has focused on a contribution to the improvement of solid waste management in a waste collectors' cooperative located in Brazil (Marcos Moura district, Santa Rita, Paraiba State) through a technical and organizational up-grading. Collection, processing and final disposal of wastes still represent a problem in some regions of Brazil. The proposed strategy foresaw the analysis of the local situation, the evaluation of the cooperative efficiency rate and then the introduction of technical and operational improvements to the service. Besides the technical activity, a social inclusion program was developed in order to include local scavengers (called Catadores) and to improve the social and economic conditions of populations involved in the process. The project also increased their environmental awareness. The workgroup is still monitoring the obtained results in order to check for the achievement of foreseen targets, to plan further improvements and to replicate this experience in other Brazilian areas.

Keywords: waste management; sustainability; collection; scavengers; social aspects

1. Introduction

One of the most debated problems of the international scientific community that works on waste management is the possibility for offering suitable technical solutions to developing and emerging countries [1,2].

The rapid economic development is not always followed by a quick social growth. One of the problems that may arise from this imbalance is that, because of a growing quantity of waste to be properly disposed, there is a lack of feasible technical solutions really suitable at local levels [3]. A diffused activity in developing countries witnessing the strong social imbalance is the presence of scavengers that collect, among the waste, the most valuable fractions in order to re-sell them and gain a little income [4–6].

In Brazil, this phenomenon is particularly diffused since the strong growth of the last years left behind wide sacks of poverty. Groups of scavengers, the so called *Catadores* (lit.: “pickers”: workers who collect, sort and sell recyclable materials such as paper, cardboard, plastic, glass and ferrous or non-ferrous metals and other reclaimed materials—Brazilian Classification of occupations) [7], search in the waste dumps (controlled or not) settled around the cities and towns to recover valuable waste. The most sought fractions are: metal, paper and cardboard, plastic, wood and glass.

Recovery of recyclable materials from waste continues to remain a common income-generating activity for unemployed Brazilians. It has been estimated that around as 500,000 individuals recover materials from waste to sell them to industry for recycling [8].

The introduction of modern solutions for waste management may collide with both technical and social problems. If under a certain point of view, it is often difficult to propose solutions technically and economically sustainable, on the other hand, it is reasonable to include the poorest communities in a project of participation, social recovery and inclusion, through their direct participation in the waste collection, recovery and exploitation. In fact, active participation is crucial, therefore, to achieve good governance and to ensure that there is accountability in the delivery of public services. Helping individuals gain access to information and develop an increased understanding of the societal issues that impact their lives are fundamental tools for community change [9–11].

Several initiatives, in this direction, have been developed in the last years by entities active in the development and cooperation sector, often with the support of universities and research centers.

The present research settles itself inside this framework of international cooperation, aiming at guaranteeing the environmental sustainability of a Brazilian community. It was developed in the context of the “Social Inclusion and Environmental Sustainability” (SIES) program, financed by Regione Lombardia and coordinated by Brescia SIPEC foundation. Many partners collaborated on this project: Centro Dom Oscar Romero (local partner), Brescia Onlus Cauto social cooperative, CeTamb (Research centre on appropriate technologies for environmental management in developing countries) of Brescia University, Universidade Federal da Paraíba, Instituto Arcor, Iveco, Associação Mulher Centro da Vida, Grupo Flor Mulher and Insubria University. The research was developed at Santa Rita, a town of the Brazilian North-eastern State of Paraíba, which contains about 100,000 inhabitants, an illiteracy rate close to 30% and about the 65% of the overall population lives in conditions of poverty.

2. Materials and Methods

2.1. Methodology

In order to propose catadores organization, analysis and description of post-consumption reverse production chain in Grande João Pessoa Region has been carried out. The research method adopted has been based on in-field survey [12]. Characterization of the study area consisted in the collection of data regarding land area, geography, local economy and population.

Data for the characterization and management of solid wastes were obtained from production and management data of municipal solid waste (MSW) in the reference area at the base of post-consumption chain. Data collection took place through literature search and questionnaires filled by the officials of garbage enterprises.

Using qualitative methodology and the individual interview technique, this work presents the results of ongoing research that has been conducted together with the employees involved in the collection of household garbage in all the area of study, and those working in a plant for separating recyclable materials [13].

2.2. Current Situation

It is necessary to introduce the local situation, considering that it is so far from many other areas in Brazil. Santa Rita is located just next westward of State Capital and, with other towns, forms the immediate surroundings of the so called Grande João Pessoa Region. As other Brazilian municipalities, territory is quite wide, especially if compared to European standards, being about 700 square kilometres, the population counts about 126,000 inhabitants [14] and is mainly urban, being concentrated in the different town districts (Várzea Nova, Centro, Tibiri, Marcos Moura ed Heitel Santiago). IBGE [14] data show how the lowest land values are concentrated in the Marcos Moura district. This confirms the population trend to move toward other town districts.

The Grande João Pessoa area is partially served by a waste collection and disposal service. In the state capital there is, in fact, a controlled landfill, recently built and compliant with Brazilian laws.

Waste collection, in the served area, is performed three times a week; the inhabitants leave waste bags just outside their homes or at collection centers, diffused in the municipality.

The collection in the Santa Rita area is guaranteed by a local company that provides waste gathering and final disposal at the local landfill. The amount of waste produced in the area, as declared by this company, amounts to 77 tons per day (equal to about $0.77 \text{ kg inhab}^{-1} \text{ d}^{-1}$). This value is a little smaller than the mean federal value calculated by the IBGE, that is over $1 \text{ kg inhab}^{-1} \text{ day}^{-1}$ [14]. Moreover, 23 tons per day of wastes are collected from the cleaning of public roads and market areas.

Even industrial activities of the area concur with waste production. The majority of local industries, according to on site data [15], provides a primary separation of produced waste. The fraction deriving from production is recycled on site directly in the production process or is sold to other companies for reuse or recycling. The other fraction (for example, food waste from mess, papers and other office waste) is disposed at João Pessoa landfill.

The following Table 1 reports the mean composition of MSW disposed at João Pessoa landfill [16] and the mean composition of the ones of Marcos Moura District [17].

Table 1. Mean composition of MSW disposed at João Pessoa and mean weekly composition of MSW of Marcos Moura District (calculated mean amount: 0.41 kg/inhabitant/day).

Fraction	Mean composition of MSW disposed at João Pessoa	Mean weekly composition of MSW of Marcos Moura District
	(%)	(%)
Organic	58.30	81
Plastic	13.70	12
Paper-paperboard	6.80	3
Metals	3.70	1
Inert residue	3.60	-
Glass	2.40	2
Others	11.50	1

The differences among the two mean compositions are due to the fact that in the first case (Table 1, first column) the composition is registered after the Catadores action and reports just the waste disposed at the landfill. In the second column is reported a mean composition of the waste as produced. In both cases the high quantity of organic fraction is remarkable as it cannot be exploited because of the lack of composting plants.

As in other Brazilian regions, in Santa Rita, area many scavengers are active in the collection and exploitation of specific fractions of MSW. Scavengers or Catadores generally belong to the poorest sectors of the population. Even in this case study they are concentrated in the poorest and most peripheral areas of the town.

They work collecting the most exploitable fractions directly from the families or from sacks left on the curb, before the “official” waste collection. The collected material is sorted and sold to local intermediaries who take care of the final sale to recycling firms.

In Marcos Moura district there are just few centers for the storage of collected waste; some scavengers are able to store the waste directly at home. This allows the scavengers to sell bigger quantities of recovered waste.

Most interesting kinds of waste locally collected are: coconut shells (reused by local craftsmen), plastic and glass bottles reused as containers. Other fractions are beer cans (collected and pressed), specific plastic parts of shoes, plastic bottles not suitable for direct reuse, rigid plastic, paperboard and other metals.

Collected waste is sent to recycling or reuse on the base of their status. After being sent to the intermediary, a more accurate selection is done and they are divided by category: plastic, glass, *etc.*

The collection and resell of exploitable waste may lead to an income of about 170 R\$ per month, that is about 70 Euros [18]; the direct resell, without the intermediary, may increase this gain.

At both João Pessoa and Campina Grande there are some active cooperatives that gather local scavengers, providing collection and recycling of paper, glass, metals, *etc.* The activity of these cooperatives, often supported by local authorities, is helped by the presence of machineries like screw or hydraulic presses to produce plastic, aluminum and paperboard bales, and vans or camions to transport the recovered materials.

3. Results and Discussion

This study tried to solve Marcos Moura waste problems through the upgrading of a cooperative for recovery and exploitation of local resources, able to boost the participation and social inclusion of local scavengers. This cooperative is the COREMM—Cooperativa de Reciclagem de Marcos Moura [19].

The cooperative, created as part of the project “Social Inclusion and Environmental Sustainability” (SIES), was officially constituted in 2010. Nowadays it involves seventeen scavengers, three other employees working at the site for materials handling and one accountant. The three employees working at the site work five days per week, eight hours per day; the accountant works three day per week, four hours per day.

The cooperative COREMM occupies an area of 1200 square meters, including a warehouse (the covered area is 370 m²) and all the other areas needed for waste handling, separation and processing, plus service rooms (locker room, mess hall, meeting hall). The plant is provided with a mechanical balance, an electric balance and a press for paper and plastic.

The COREMM owns a closed van and distributes to each catadore one handcart to transport the collected materials. Operators are fully equipped with protective equipment and devices. The realization of the whole complex required, till now, about 40,000 Euros.

Waste is collected by the scavengers three times a week. Catadores collect separated materials from households through blue plastic bags distributed free of charge to the families by the catadores themselves; the materials abandoned along the streets and collected by catadores are little. The composition of the materials collected by the catadores is similar to the MSW composition at Marcos Moura except the organic fraction. Near the cooperative there are a few companies giving some refuse materials to the catadores: An industry producing mineral water gives refuse plastic (mainly HDPE), an industry producing alcohol gives paper and cardboard, an company producing lounges gives cardboard and polyethylene, a mechanical shop gives iron shavings. Contrarily to what happens in other developing countries, materials cannot be separated and taken away from the landfill because catadores are not admitted in.

The waste collection lasts about five hours and at the end of each collection every scavenger carries the waste to the cooperative and sorts the waste (this last activity takes about one hour, depending on the quantity and the quality of the materials); each fraction is then weighed. Both numbers are registered on a spreadsheet. About 10% of the materials brought to the cooperative by the catadores cannot be recovered (they are mainly very dirty or joint and inseparable materials) and represents the rejected part being disposed of.

Each scavenger is paid weekly or monthly according to his preferences, on the amount of collected materials. Each scavenger recovers on average about 200 kg of materials per week; the monthly income could reach a level of 200 R\$, a higher wage than the starting one (about 170 R\$, as mentioned), but still far from the minimal salary of 600 R\$ as settled at federal level.

Collected materials, as soon as the minimum storage quantity is reached, are sold to a few middlemen working in João Pessoa. There are not specific agreements with those middlemen because the market is very liquid and prices for each sold material are discussed and agreed from time to time. Table 2 contains mean prices of the main materials sold by the cooperative; variability of prices is

included in $\pm 20\%$. Parallel to the beginning of the commercial activity, a brochure explaining COREMM activity and what kinds of waste could be exploited was distributed to local population. This action, aimed to improve the environmental awareness and sensitivity of local people, has given good results early: scavengers started to collect directly from homes developing a door-to-door collection service.

Table 2. Mean prices of the main materials sold by the cooperative to the middlemen.

Material	Price
White paper	0.70 R\$/kg
Mixed paper	0.15 R\$/kg
Cardboard	0.30 R\$/kg
White o transparen plastic	0.60 R\$/kg
Mixed plastic	0.40 R\$/kg
Glass	0.30 R\$/kg
Aluminum	2.10 R\$/kg
Copper	9.00 R\$/kg
Iron	0.20 R\$/kg
Glass bottle (1 L)	0.45 R\$/each
Glass bottle (0.33 L)	0.20 R\$/each
Broken glass	0.80 R\$/kg

The collected amounts of waste are not sufficient to guarantee the Cooperative self-sustainability and some improvements are in evaluation, as the cooperation with local industries and with local municipality. This study aimed to offer ideas for the improvement of the plant and the overall performances of the cooperative; basing on acquired information and analysis of the waste locally produced.

Independent studies by different researchers agree on the definition of a mean composition municipal waste collected at Marcos Moura and Tibiri Districts. This composition shows a wide prevalence of the organic fraction, as shown in Table 3 [19].

Table 3. Mean MSW composition at Marcos Moura and Tibiri Districts.

Fraction	Marcos Moura	Tibiri
Organic	79%	79%
Plastic	13%	6%
Paper-cardboard	3%	10%
Glass	2%	1%
Metals	1%	2%
Other	2%	2%

An idea, yet partial, of the composition of waste as generated by commercial or entrepreneurial activities was detected by an on-site evaluation performed by a questionnaire. Seven activities answered the questions. In all these cases, reported in Table 4, the organic fraction was excluded from the evaluation.

Table 4. Waste produced by local activities.

Activity	Composition %				
	Plastic	Paper-paperboard	Glass	Metals	Others
Bicycles repair	79%	4%	0%	17%	0%
Bar	31%	5%	64%	0%	0%
Mini market	34%	61%	0%	4%	0%
Hardware/construction store	48%	50%	0%	2%	0%
Electric/electronic repair	2%	0%	0%	59%	39%
Mechanical	95%	5%	0%	0%	0%
Furniture factory	36%	64%	0%	0%	0%

On this basis, and after evaluating local situation, CeTamb and other Partners prepared several proposals to improve the performances of COREMM both at a managerial and a technical level.

According to a managing point of view, the experience gained on site showed the necessity of a professional employee who takes care purely of commercial activities of the COREMM. As already mentioned, the impossibility of selling directly to big companies, and the passage through an intermediary, represents a serious limitation for the potential revenues of the cooperative. According to data obtained by colloquies with the commercial directors of a few big companies, the prices paid by them for recovered material are even twice those paid by the intermediaries, but the quality of materials must be very good, meaning they must be clean and sorted very well (e.g., according to polymer and color for plastic).

At the same time a technical director is fundamental to supervise all the processing phases at the plant. The presence of a coordinator could help the scavengers to do a better job, guaranteeing a better quality of collected and sorted materials

The first economical evaluation of the benefits, considering the introduction of the two new professional profiles (commercial and technical superintendents) foresees an increasing of gain for the Catadores, expected in about 30%.

Another aspect that should be improved is the door-to-door waste collection from local families: that activity already started with the distribution of a brochure but is still subject to improvement.

From a technical point of view, the working procedures should be improved by the realization of new structures and the improvement of some processing phases. In particular it is foreseen the introduction of a new manual selection desk to sort the entering waste: plastic, glass, paper, paperboard and metals. Sorted materials could be stored in a specific area located outside the warehouse, where it is possible to accumulate a sufficient amount of material to be conveniently processed afterward. As already mentioned, a big problem noted is the impossibility of storing an elevate quantity of recovered material as the selling of a bigger quantity is more convenient for both scavengers and buyers.

In this way, recovered materials could be processed properly, according to necessities and possibilities: for example, for recovered plastic materials (bottles, containers, *etc.*) the separation according to the polymer type (polyethylene terephthalate—PET, high density polyethylene—HDPE, polystyrene—PS, polypropylene—PP) and after that by the color, is foreseen. The well-sorted material could be washed, grinded by a small electrical rotating and easy-managing blade grinder and then sold.

As concerns glass, a manual separation of entering material in order to separate flat glasses (windows, car glasses, *etc.*) from other glasses (bulbs) and colored glasses (typically bottles) is necessary. For this kind of recovered material, the washing process is particularly important, because it helps the separation of other parts as caps, plastic parts, paper labels, *etc.*

Sorted material could be grinded and wrapped by a small concrete mixer. This device, which has already been tested, allows the dimensional reduction of the recovered glass and fills big-bags or other containers with the required amount of recovered waste.

The processing of paper is the one that requires the minimum technical upgrading being based, almost totally, on the manual separation between paper and paperboard directly recoverable and other types (as Tetrapack) that require further washing or sorting treatment.

The processing of the different kind of metals recovered at the site could be based on the separation, by a manually operated magnet, among iron and non-iron metals. A further step foresees the separation between metals that can be pressed (cans) or not. As already mentioned, an hydraulic press capable of producing bales of cans is present at the plant,

All the materials, after recovery and processing are stored outside the warehouse, are divided into categories and then sold.

The last proposed upgrading foresees the recovery and process of WEEEs (Waste from Electric and Electronic Equipments) as, in particular, CRT monitors from personal computers and TV sets (following the European experience) [20]. The treatment of this kind of waste would allow the recovery, at the same time, of different types of material: plastic, glass and metals from electronic parts. Among metals several interesting fractions are surely present (copper, silver, gold, *etc.*).

4. Conclusions

The proposed actions, well integrated into a wider framework of social inclusion and recovery of the poorest groups of local population, are aimed at a specific environmental target, that is the improvement of waste collection in a poor area of Santa Rita, Brazil. The creation of a local cooperative of scavengers and the beginning of its activity already showed first positive results: a small increase of catadores earnings, the improvement, at local scale, of the waste collection service of exploitable fractions of MSW, a greater environmental awareness in local population who are directly involved in the different phases of the process, the possibility for scavengers to operate with safer conditions and equipment and to see an improvement in their social and working conditions.

The plant, the warehouse and the equipment used appear highly sustainable from an environmental, technical and economic point of view; however, the analysis of local conditions and the comprehension of its problems permitted the individuation of possible further improvements for the COREMM cooperative, always respecting local potentialities and resources.

This experience has provided interesting and stimulating results, so that the hypothesis to replicate it in other similar realities should be taken into account. Starting from the existing organizational structure, *i.e.*, the cooperative, and identifying areas for improvement that are practical and economically viable for the organization (e.g., the development of new equipment, the reorganization of the activities, the insertion of new technical and commercial profiles), the working conditions of Catadores can be improved and their revenues can increase greatly, up to 50%.

Further steps of this work could be the evaluation in the mid-term (one-two years) of the proposed improvements and the replication of this experience in other Brazilian realities.

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Conflict of Interest

The authors declare no conflict of interest.

References and Notes

1. Rothic, K.H.; Zhao, Y.; Dong, J. Municipal solid waste management challenges in developing countries—Kenyan case study. *Waste Manage.* **2006**, *26*, 92–100.
2. Collivignarelli, C.; Vaccari, M.; Di Bella, V.; Giardina, D. Techno-economic evaluation for the improvement of MSW collection in Somaliland and Puntland. *Waste Manage. Res.* **2011**, *29*, 521–531.
3. Collivignarelli, M.C.; De Felice, V.; Di Bella, V.; Sorlini, S.; Torretta, V.; Vaccari, M. Assessment of sanitary infrastructures and polluting loads in Pojuca river (Brazil). *Water Pract. Technol.* **2012**, *7*, doi:10.2166/wpt.2012.044.
4. Wilson, D.C.; Velis, C.; Cheeseman, C.R. Role of informal sector recycling in waste management in developing countries. *Habitat Int.* **2006**, *30*, 797–808.
5. Coelho, D.B.; Godoy, A.S. From waste pickers to cooperated recyclers: A solidary enterprise case study. *Revista de Administração Pública* **2011**, *45*, 721–724.
6. Vaccari, M.; Di Bella, V.; Vitali, F.; Collivignarelli, C. From mixed to sorted collection of solid waste: Benefits for small towns in Bosnia and Herzegovina. *Waste Manage.* **2012**, in press.
7. Santos, G.O.; da Silva, L.F.F. What garbage represents for municipal collectors and recyclers in Fortaleza, State of Ceará (Brazil). *Ciênc. saúde coletiva.* **2011**, *16*, 3413–3419.
8. Medina, M. World's largest and most dynamic scavenger movement. *BioCycle* **2010**, *51*, 32–33.
9. Tremblay, C.; Gutberlet, J. Empowerment through participation assessing the voices of leaders recycling cooperatives in São Paulo, Brazil. *Commun. Dev. J.* **2010**, *47*, 282–302.
10. Foster-Fishman, P.; Nowell, B.; Deacon, Z.; Nievar, M.A.; McCann, P. Using methods that matter: The impact of reflection, dialogue, and voice. *Am. J. Commun. Psychol.* **2005**, *36*, 275–291.
11. Torretta, V.; Conti, F.; Leonardi, M.; Ruggieri, G. Energy recovery from sludges and sustainable development: A Tanzanian case study. *Sustainability* **2012**, *4*, 2662–2671.
12. Schmid, A.L. Introdução à metodologia da pesquisa. Paraná, UFPR, 2006. Available online: <http://www.burle.arquit.ufpr.br/> (accessed on 19 October 2012).

13. de Aquino, I.F.; de Castilho, A.B.; de Lorenzi Pires, T.S. Organizing a network of scavenger cooperatives in the reverse production chain of the metropolitan area of Florianopolis: An alternative for aggregating value. *Gest. Prod.* **2009**, *16*, 15–24.
14. IBGE. Desenvolvimento sustentavel. Available online: <http://www.ibge.gov.br/home/> (accessed on 19 October 2012)
15. Severo da Silva, J. *Estudo do Reaproveitamento dos Resíduos Industriais na Região Metropolitana de João Pessoa*; Universidad Federal da Paraíba: João Pessoa, Brazil, 2004.
16. Coutinho Nóbrega, C. *Risultati Ricerca sulla Produzione di Rifiuti Solidi nel Municipio di Santa Rita*; Universidad Federal de Campina Grande: Campina, Grande, Brazil, 2002.
17. Coutinho Nóbrega, C. *Viabilidade Econômica, com Valoração Ambiental e Social, de Sistemas de Coleta Seletiva de Resíduos Sólidos Domiciliares—Estudo de Caso: João Pessoa/PB*; Universidad Federal de Campina Grande: Campina Grande, Brazil, 2003.
18. Ratto, P. *Riciclaggio dei Rifiuti nella Municipalità di Santa Rita (Paraíba, Brasile)*; Università degli studi di Brescia Facoltà di ingegneria: Brescia, Italy, 2010.
19. Grehs, B.C.; Campêllo, A.A.; Ataíde, C.G. Problemática dos resíduos sólidos urbanos do Município de João Pessoa: Aplicação do Modelo P-E-R. *Qualit@s Revista Eletrônica* **2010**, *8*. Available online: <http://revista.uepb.edu.br/index.php/qualitas/article/viewFile/661/360> (accessed on 19 October 2012).
20. Torretta, V.; Istrate, I.; Rada, E.C.; Ragazzi, M. Management of waste electrical and electronic equipment in two EU countries: A comparison. *Waste Manage.* **2012**, doi:10.1016/j.wasman.2012.07.029.

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