STRATEGIES FOR INNOVATION IN CONSTRUCTION DEMOLITION WASTE MANAGEMENT IN BRAZIL

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Abstract
The paper aims to present the strategies for innovation in construction and demolition waste management in Brazil and to compare them with international ones. The CDW traditional management is very costly to local authorities including several environmental impacts. The Brazilian experience shows that a policy based only on regulation of CDW transportation and landfilling is not totally efficient in controlling illegal dumping. The policy has to be complemented with a network of transfer stations, which cuts down the transportation costs, making illegal dumping less attractive. Despite CDW landfills being a feasible option in small towns, recycling will be a very important tool in big cities like São Paulo.

The new policy, as presented by National Resolution 307, is rapidly changing the actual situation, mainly in major cities. In the near future the major market for CDW recycled aggregate will be in road paving activities, but the development of new applications for such materials will be necessary in order to obtain massive recycling and to avoid using sanitary landfills for CDW.

The existence of a comprehensive set of research results demonstrating the social cost of CDW mismanagement as well as material wastage rates was crucial because it produced public awareness to the problem and enhanced the discussion within the supply chain. The importance of research on public policy formulation and technological and scientific approaches were presented.

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1 Introduction

The construbusiness is responsible for 15.5% of the Brazilian GNP (CONSTRUBUSINESS, 2003). The sector causes relevant environmental impacts in Brazil by the intensive use of non-renewable raw materials, energy and landfills. The Brazilian Portland cement industry alone is responsible for about 12% of the total CO_2 released (John, 2000). As an example, sand consumption is near 12 million m³/year in the Metropolitan Region of São Paulo city and the transport activity represents 1.35 million trips/year (Rangel et al., 1997; Coelho, 2001).

The Brazilian society has been giving special attention to CDW in recent years due to the economical effects from illegal dumped waste in urban areas. The estimated construction and demolition waste (CDW) per capita generation rate is around 500 kg/year, which means a total of 68.5 million tons/year. In fact, CDW represents the largest amount of municipal solid waste (in mass). Nevertheless, CDW has long been ignored in most waste related policies.

Without any management scheme, most CDW is illegally dumped in public areas or privately operated dumping sites (Pinto, 1999). CDW illegal dumping creates several impacts. It has been associated with the proliferation of pests (rats and poisonous insects, among others), and landscape polluting. Fly tipping on streets sometimes obstructs traffic. In medium-size to large cities, removing and disposing of illegally dumped CDW in public areas is costly too. In São Paulo city, removing illegally dumped CDW and transporting it to regular landfills costs nearly US$ 19 million/year, according to local authority reports, and an important fraction of the CDW generated is exported to neighboring cities. Sometimes, illegal CDW landfills can cause accidents like the landslide above the Nova República shantytown in São Paulo that killed 14 people in 1989.

Nevertheless, CDW transportation and management, both legal and illegal, is a profitable business. The revenues of this industry are around US $40 million/year[1] in São Paulo city alone. In this metropolitan area the price for removing and dumping a CDW 4m^3 skip container can be as much as US $25,00. There are around 700 companies (SIERESP, 2003), which are responsible for, roughly, 2.000 waste removal trips each working day.

2 Historical background

Research about CDW recycling started in de middle 1980’s with the pioneer work of Pinto (1986).

The same author started in the end of the 1980´s to investigate materials wastage in building sites and CDW management schemes for cities. In the beginning of the 1990´s a CDW management scheme was first introduced in cities like São Paulo and Belo Horizonte. This scheme included publicly owned

[1] US $1 = R$3

CDW recycling plants and a CDW landfill. In São Paulo city a newly elected mayor interrupted the operation of the recycling plant in 1995.

In 1998 the Brazilian Program on Housing Quality and Productivity (PBQP-H) was created. It brought together representatives of all branches of the construction supply chain and researchers. This program succeeded in creating a new approach within the construction supply chain. One of the successful results was the introduction of a quality management system in building companies that was adopted by a large number of companies nationwide.

A landmark was a national diagnostic on materials wastage rates in building sites (Souza et al., 1999). This research revealed very high wastage rates and received broad coverage by the media, and increased the awareness within the construction production chain as well as among authorities and consumers.

In the year 2000 the Environmental Chamber of the Construction Industry of the State of São Paulo was created. From this initiative, a Technical Group on Construction and Demolition Waste[2] was formed. This group comprising representatives of the local authorities, environmental agencies, building contractors, materials producers, CDW transportation companies and researchers, has been successful in preparing draft standards and promoting municipal and state regulations on different aspects of CDW management, including transfer station operations and CDW landfill design and operations.

3 National Resolution on CDW Management

In the year 2000 the National Council on the Environment (CONAMA) created a technical group made up of representatives from the supply chain and environmental NGOs to elaborate a National Regulation on Construction and Demolition Waste management. The resolution was approved in 2002 (CONAMA resolution 307).

The main aim of the resolution was to reduce CDW generation, reduce illegal dumping and promote recycling. The CDW management was based on supply chain responsibility like that found abroad (Schultmann *et al.,* 2001). The resolution will become valid after July 2004. It states that:

a) Dumping CDW in sanitary landfills is prohibited,
b) Local authorities are responsible for operating CDW management schemes which should be able to receive both low volume generators and high volume generators of CDW;
c) Each construction or demolition site must submit a CDW management plan of operation to local authorities; and
d) Material producers, building contractors and CDW transportation companies are co-responsible for managing CDW.

The resolution classifies CDW in four different classes:

a) Class A: CDW such as rocks, ceramics and cement-based materials which are recyclable as aggregate.
b) Class B: CDW such as metal scraps, glass, plastics and wood, which are recyclable.
c) Class C: CDW such as gypsum plasterboard, which, at present, is not being recycled in Brazil due to the lack of that technology.
d) Class D: hazardous materials such as hydro carbonated compounds, asbestos, sulphates etc from CDW.

Only class A waste can be dumped at CDW landfills. The others must be recycled or dumped at an adequate landfill. So CDW sorting is mandatory.

The resolution has intensified the developments of CDW management in Brazil. At present, local authorities all over the country are implementing CDW management schemes. Among them 12 cities are already operating schemes which include recycling plants. The resulting aggregate is mostly used as road sub-base. Building contractors are sorting CDW at site. Small entrepreneurs are starting CDW transfer stations and sorting operations generating income.

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[2] http://www.sindusconsp.com.br/CAMARA_AMBIENTAL/camara_ambiental.htm

4 Strategies for Sustainable CDW Management

The strategies worldwide combine legislation and regulations in order to introduce formal CDW management schemes (Symonds, 1999; Hendriks, 2000).

4.1 Preventing illegal dumping

In Brazil as in other countries, fly tipping has been a problem for long time, especially in situations where transportation distances from generator to landfill are long and transportation costs weigh heavily.

So the creation of a network of CDW transfer stations dense enough to decrease transportation costs thereby making illegal dumping less attractive is certainly a key measure in reducing this activity. Normally there are two different sub-nets of transfer stations. One is devoted to collecting low volumes of CDW (no trucks allowed) and the other receives both low and high-volumes of CDW. São Paulo City Council produced the first municipal regulation for CDW transfer stations in Brazil (SIERESP, 2003).

Additionally, there is a need for some regulation of the CDW transportation services. Such regulations should require the transfer stations to issue a document declaring that the waste has been properly delivered. This document would return to the waste generator and could be used as proof of compliance. The São Paulo City Council started the CDW regulatory process by requiring registration of transportation companies in 1999 (decree 37.952/99). Without the existence of the transfer station networks this regulation would not be effective in reducing illegal dumping.

Although a majority of the transfer stations is publicly owned, private companies or cooperatives can also operate them. The privately owned transfer stations charge for each container received and also profit from the selling of recyclable materials. In São Paulo city there are two publicly owned, free of charge, high-volume transfer stations (each with a capacity of 1.250 ton/day) and, at least, one small privately owned station (Ferraz et al., 2001). Sometimes a introduction of a public transfer station causes the private one to bankrupt.

Brazilian experience has shown that the cost of operating a publicly owned, free-of-charge transfer station network can be lower than the cost of collecting and removing illegally dumped CDW.

4.2 CDW sorting

CDW can be a mixture of different materials, including contaminants coming from outside the construction and demolition sites because many times the containers are placed in the street near the site. So, CDW sorting is a requirement for recycling. Figure 1 shows CDW class A is the most common composition as in many other countries (Hendriks, 2000). Other phases include gypsum, paper, soil and other building materials.

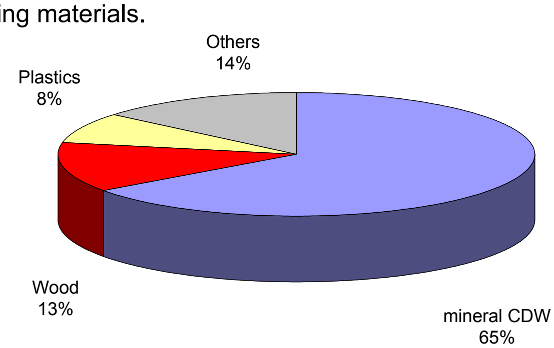

Figure 1 Typical CDW composition in Brazil (Ferraz *et al*., 2001)

Brazilian legislation does not require CDW sorting at the building or demolition site allowing the job to be carried out by transfer stations, that charges for the service. Only class A waste is allowed to be dumped in CDW landfills. Figure 2 shows a small privately owned transfer station that operates in São Paulo. The price for receiving CDW is between US $ 1 and 6.

Metal scraps, plastics, paper and wood components are sold to different recycling businesses. Class A waste is delivered to a recycling plant to be transformed into aggregate for road bases or backfilling (Pinto, 1999) or dumped in a publicly owned free of charge CDW landfill.

Figure 2 Wood being sorted at a CDW transfer station in São Paulo. Source: Pinto, T.P.

The most valuable recycled product at a transfer station is the metal scrap and the least valuable one is the CDW class A (Ferraz *et al*., 2001).

4.3 CDW management in demolition

It has been estimated that around 50% of CDW class A comes from construction sites similar to those in China (Pinto, 1999; Poon *et al*., 2001). In European countries, demolition waste comprises the major part of CDW (Symonds, 1999). However, most of the Brazilian demolition waste most likely comes from small maintenance activities such as replacing ceramic tiles, removing partition walls, etc carried out by professionals with no technical supervision.

Selective demolition is a practice used only in the demolition of old, relatively small houses. Components such as wood doors, floors, windows, steel fences, old bricks and ceramic roof tiles are sold for reuse to dealers of second-hand materials who re-sell them at a profitable margin. This activity has also been reported to exist in Turkey (Elias-Ozkan, 2001). In some cities, local authorities operate second hand material and components stores offering cheap construction materials to the economically disadvantaged. Such materials have also recently come into fashion and are being used for decoration purposes in the construction of prestigious residences. In the city of Londrina, a medium size town located in the southern region of Brazil, 71% of the analyzed demolition sites practiced selective demolition and waste collection (Angulo, 1998).

In terms of demolition technology, there are national companies[3], which are equipped to sort concrete components from building structures as in European countries (Hendriks, 2000; Kowalczyk et al., 2002). However, waste generated by demolition of concrete pavement, which is a significant source of waste in some countries, is relatively new in Brazil and is still rare as demolition waste. The national standard of use of CDW recycled aggregate in concrete is currently (dez 2003) under discussion and should result in further demands on concrete sorting and recycling.

At present, there is no specific policy for demolition practices or the second-hand material market.

4.4 CDW management and waste reduction at the building sites

All building sites are required by law to submit CDW management plans for each job.

There are many companies developing CDW management schemes aiming to reduce waste generation. When adequate space is available the management scheme normally include sorting CDW on site (Figure 3), which permits better the estimation of wastage rates for different materials (Vasconcellos, 2003).

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[3] http://www.demolidoradiez.com.br/

Figure 3 Selective construction waste collection in national building site. Source: Vasconcellos, F.

In building sites, plastics, scrap metal and paper are collected free of charge and sold to recycling companies and the remaining material (class A) can either be used as backfill on site or transported at a reduced volume.

Around 50% of the national generated construction waste is produced by the formal building construction sector (Vasconcellos, 2003). The informal (do-it-yourself) sector, which is important and produces most of the low-cost houses in Brazil, is responsible for a significant part of building material consumption such as cement and bricks. However, at present, there is no CDW generation data or policy for this sector (STI/MDIC, 2003).

4.5 CDW recycling class A

Brazilian national average CDW (class A) recycling is still low, but there are some cities like Belo Horizonte where the recycling rate is probably around 25% of the total CDW generated.

Local authorities own the major part of Brazilian class A CDW recycling plants. Public investments in CDW recycling plants are not so significant and they can be re-paid through a reduction in the cost of removing the illegally dumped CDW as well as by reducing the city's consumption of natural aggregates.

The aggregate produced by the São Paulo recycling plant (Itaquera) is either consumed by the city or sold at, or lower than, cost (less than US$ 1/metric ton) as in the Belo Horizonte recycling plants (Pampulha/Estoril). The cost of aggregate production is near US$ 2/metric ton and exempt from public fees because most of the recycling plants belong to the public sector or are virtually controlled by it.

The Table 1 shows a resume of some national recycling plants describing the applied technology. In Brazil, the sorting out of CDW fraction not suited to aggregate production is usually done by hand at horizontal piles or hand separated on conveyor belts. Sometimes a magnetic separator is available to collect steel. In Europe, the use of mechanical equipment like Soortermart[4] (before grinding) and wind sifting (after grinding) is common.

The use of wet processing in a private CDW recycling plant (Socorro/SP) is being investigated in order to reduce the organic fraction and the fine material content (lower than .15 mm) from CDW recycled sand. The researchers intend to improve aggregate quality and to control mortar performance by reducing the variability of the fine material parameter. Other uses of CDW are being investigated such as in mortar rendering.

In most Brazilian recycling plants, class A CDW is further classified into two sub-classes: Red (visually red appearance, composed of masonry with concrete or ceramic block and mortar, soils, etc and Grey (visually grey appearance, composed of concrete and other cement based materials). The general opinion is that Grey CDW has better quality because it is composed mostly of concrete, but our previous results have shown that this is not necessarily true in all situations (Figure 4).

[4] http://www.thole.nl/products/engels/bt_engl.htm

Table 1 Some national recycling plants and applied recycling technology.

Recycling plant	Grinding	Sieving	Concentration	Others
Santo André – piloto/SP	Impact (10 t/h)	Screenings (12,7 mm)	Hand sorting (before grinding)	Conveyor belts
São Paulo (Itaquera)/SP	Impact (100 t/h)	Screenings (40, 20 and 4,8 mm)	Hand sorting (before/after grinding) Magnetic separation	Conveyor belts
Vinhedo/SP	Jaw crusher (62 t/h)	Screenings (12,7, 9,5 and 4,8 mm)	Hand sorting (before grinding)	Conveyor belts Dust control
Londrina/PR	Impact	Screenings	Hand sorting (before grinding)	Conveyor belts
Belo Horizonte (Pampulha)/MG	Impact (30 t/h)	Screenings	Hand sorting in piles	Wetting in arrival Screening
Belo Horizonte (Estoril)/MG	Impact (15 t/h)	Nd	Hand sorting in piles (before grinding)	Wetting in arrival
Ribeirão Preto/SP[1]	Impact (30 t/h)	Nd	Hand sorting (before grinding) Magnetic separation	Conveyor belts Dust control
Socorro/SP (Private sector)	Jaw Crusher (2,5 t/h)	Screenings (20, 4,8 and 1,2 mm)	Hand sorting (before grinding) Magnetic separation	Conveyor belts, Impact mill Screw washer

[1] Zordan (1997).

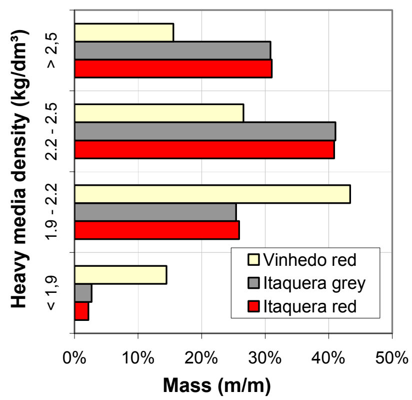
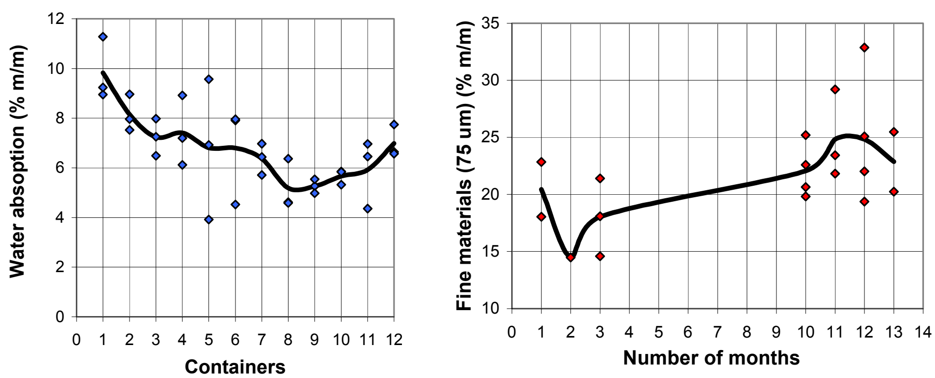


Figure 4 Mass balance analysis from CDW coarse aggregate samples obtained from heavy media separation from two different Brazilian recycling plants located in the São Paulo state (Angulo et al., 2003).

The recycled CDW aggregate produced in Brazil presents highly variable characteristics (Angulo, 2000), which is similar to that of European countries (FHA, 2000). Figure 5 shows variability of the resulting aggregates from two different recycling plants.



(a) (b)

Figure 5 Water absorption coarse aggregate inside and between containers – Santo André recycling plant (Angulo, 2000) (a) and average content of material passing 75um sieve in fine recycled aggregate in Socorro recycling plant (Miranda et al., 2002) (b).

Recycled coarse CDW aggregate can present a relatively high content of contamination (Figure 6).

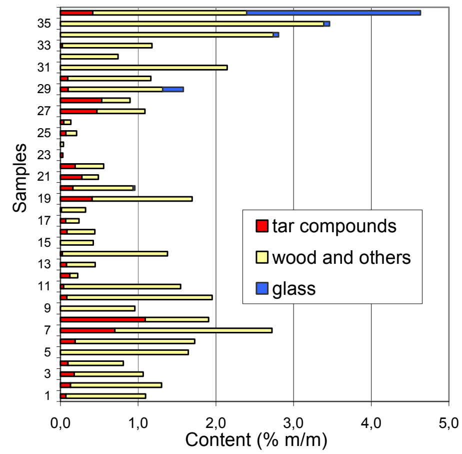


Figure 6 Contaminants of coarse CDW recycled aggregate by hand sorting. Santo André recycling plant (Angulo, 2000).

With the current recycling technology only a small fraction of the produced aggregate will be suitable for structural concrete production (Angulo; John, 2002). So, changes in CDW management and recycling plant technology are pre-conditions for the exploitation of this market.

4.6 Managing gypsum waste

Despite the fact that national class A CDW has an average concentration of sulphates as low as 0.18-0.27 (% m/m), the use of gypsum plaster and plasterboard compounds has been increasing very fast in the last few years. Also, there is always a possibility of a higher concentration of sulphates from statistical analysis, which can be potentially dangerous in recycled aggregate.

The estimated gypsum waste generation in the São Paulo Metropolitan area is more than sixty thousand metric tons from building construction activities alone. Data from a national assessment of material wastage in building sites revealed that 88% of this total is due to wastage resulting from the application of gypsum paste as rendering (Figure 7).

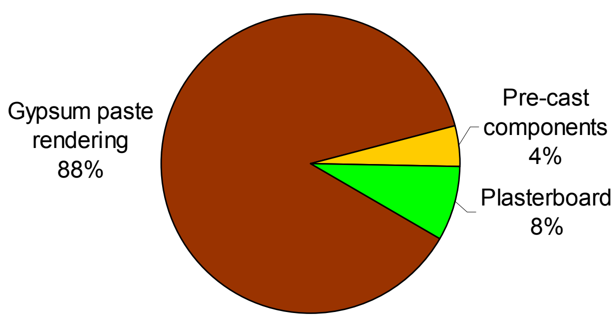


Figure 7 Generation of gypsum waste during building construction activities.

After this data was collected, gypsum producers introduced gypsum formulations with better rheology and setting time, causing a great reduction in gypsum wastage at building sites.

Recycling gypsum waste such as fertilizer, raw material for cement production and for the production of plasterboard and gypsum plaster can be feasible in the southern regions of Brazil because the cost of transporting gypsum from the northeast quarry to the south represents 90% of the total cost. However, in those northern regions, which have quarries, gypsum recycling will probably not be economically feasible.

The gypsum industry is composed of well-structured, international groups and small-scale companies. Both sectors have aligned with the Environmental Chamber of the Construction Industry of the State of São Paulo and have contributed with recycling alternatives. The major consumption however remains from small-scale companies and a simplified process of recycling is being developed between the sector and the university.

4.7 CDW landfill

Dumping CDW waste in sanitary landfills will be prohibited. Class A CDW landfilling (only mineral fraction, without gypsum) is probably a feasible option in small towns where natural aggregates are cheap, areas suitable for landfills are easily available and CDW generation is low. In larger cities as São Paulo this is not the best option, because there is a lack of suitable areas and natural aggregates are more expensive. The scarcity of suitable areas and a lack of recycling options in São Paulo city transformed an old, 100-meter deep quarry used as CDW landfill into an 80-meter high artificial hill (Figure 8).

(a) (b)

Figure 8 Itatinga, CDW class A landfill, São Paulo city. (a) during the execution and (b) after of the finalization. Source: John, V.M. and Fialho, M. A. respectively.

As part of the regulation process, the requirements for approval of a CDW class A landfill have been greatly simplified. No lining is required. For landfills with volumes lower than 10,000 m³, underground and superficial water monitoring is not required, but the control of CDW origin is mandatory.

Currently there is a discussion in progress on the dumping of gypsum waste in landfills. The European Union Council Decision of December 19, 2002 prohibits the dumping of gypsum waste wherever there is any organic waste, probably due to the risk of H_2S gas generation (Environment Agency, 2002).

4.8 Taxation of landfills and natural aggregate production

In China, the UK and some other countries, landfill taxes have been adopted as a tool for improving CDW management practices (Poon et al., 2001; Hobbs; Harley, 2002). In Brazil, a strategy of landfill regulation taxes could also contribute efficiently to the management process of CDW.

4.9 CDW related standards

A set of CDW management standards are currently being developed, including:

a) design and operation of CDW landfills;
b) design and operation of transfer stations;
c) design and operation class A, CDW recycling plants;
d) use of CDW recycled aggregate in paving works; and
e) use of CDW recycled aggregate in concrete components.

4.10 Research needs

Worldwide research on CDW recycling has primarily been focused on concrete waste recycling in a effort to produce an aggregate suitable for use in concrete. Even though the available research is undeniably important there is still a great need for new approaches in this research, such as:

- Development of new markets for mineral fraction (raw material industrial uses);
- Development of cheap, fast and more efficient CDW aggregate quality control tools, allowing for the selection of use based on product characteristics;

- Influence of aggregate characteristics on its performance in different applications, such as road base, mortar, concrete components etc;
- Investigation of management practices for dangerous waste, such as paint;
- Reducing materials wastage in building sites;
- Investigation of gypsum waste management alternatives, including gypsum landfill regulations;
- Evaluation of the environmental impacts of the new CDW landfill regulations;
- Development of life-cycle analysis comparing recycled CDW aggregates with natural aggregates.

5 Conclusions

Brazilian strategies for innovation in construction and demolition waste management were presented and compared with data from other countries. Research needs were also described.

CDW traditional management leads to a high rate of illegal dumping, which is very costly to local authorities reducing the amount of money available to other public services.

The Brazilian experience has shown that management policy based entirely on regulation of CDW transportation and landfilling is not in itself enough to control illegal dumping. This policy must be complemented with a network of transfer stations, which cuts down on the transportation costs making illegal dumping less attractive.

Landfilling is probably a feasible option in small towns where natural aggregates are cheap, areas suitable to be landfills are easily available and generation of CDW is low. In big cities like São Paulo though, recycling will be a very important tool because there are few available landfill areas and natural aggregates are expensive.

In the near future the major market for CDW recycled aggregate will be in road pavement activities, but the development of new applications for such material will be necessary.

The new policy, as presented by National Resolution 307, is rapidly changing the actual situation, mainly in major cities. We consider that the active participation of all elements within the supply chain in the discussion of this policy has been a key factor in its success. The introduction of alternatives for reducing gypsum waste generation after one such discussion by those in the supply chain is a good example of the possibilities offered by such an approach.

The existence of a comprehensive set of research results demonstrating the social cost of CDW mismanagement as well as material wastage rates was also crucial because it produced public awareness to the problem and facilitated the discussion within the supply chain. This fact shows the importance of research on the formulation of public policies, especially in environmental related areas.

Finally, there is a great need for further and innovative research in this field, particularly in developing new markets for CDW mineral phases.

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