# LAYOUT MODEL OF PRODUCTIVE SYSTEMS FOR INORGANIC SOLID WASTE RECYCLING PLANTS FOR SMALL MUNICIPALITIES


## ABSTRACT

In the past, garbage was not a problem so emphasized by society, however, the significant increase in consumption has made waste management one of the main areas of study throughout the world. This study aimed to identify, describe and compare models of layout of the production system of recycling plants, thus providing better prospects in the design of these much needed projects in the cities of the new sustainable society that wants to build. The main object of study is the layout models of productive systems for recycling plants in order to identify, describe and compare them. To this end, we used bibliographic or secondary data, in books, periodicals, and dissertations on the theme in question. The main result was to scan the literature, with subsequent identification and description of 04 (four) layout models for recycling plants. When reviewing Layouts broached, it can be seen that there are some similarities and differences between them. It is expected that the theoretical background, results and discussions presented in this study may support further studies on the physical arrangement ideal for implementation of recycling plants for small municipalities.



**KEYWORDS:** Inorganic Solid Waste; Recycling; Recycling Plants; Layout.


# MODELO DE LAYOUT DE SISTEMA PRODUTIVO PARA USINAS DE RECICLAGEM DE RESÍDUOS INORGÂNICOS SÓLIDOS PARA PEQUENOS MUNICÍPIOS


## RESUMO

No passado o lixo não era um problema tão enfatizado pela sociedade, no entanto, o aumento significativo do consumo tornou a gestão de resíduos uma das principais áreas de estudo por todo mundo. Este estudo teve como objetivo identificar, descrever e comparar modelos de layout (arranjo físico) do sistema produtivo de usinas de reciclagem, proporcionando assim, melhores perspectivas na concepção destes empreendimentos tão necessários nas cidades da nova sociedade sustentável que se deseja construir. O objeto principal de estudo são os modelos de layout (arranjo físico) de sistemas produtivos de usinas de reciclagem, visando identificá-los, descrevê-los e compará-los. Para tal, foram utilizados dados bibliográficos ou secundários, em livros, periódicos, e dissertações, que abordem a temática em questão. O principal resultado da pesquisa foi a varredura na literatura, com conseqüente identificação e descrição de 04 (quatro) modelos de layout para usinas de reciclagem. Ao analisar os Layouts abordados, pode-se perceber que existem algumas semelhanças e diferenças entre eles. Espera-se que o referencial bibliográfico, os resultados e discussões apresentados neste trabalho possam subsidiar novos estudos sobre o arranjo físico ideal para implementação de Usinas de Reciclagem para pequenos municípios.



**PALAVRAS-CHAVE**: Resíduos inorgânicos sólidos; Reciclagem; Usinas de reciclagem; Arranjo Físico.



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## INTRODUCTION

In conformity to Athayde Jr., Nobrega and Onofre (2009, p.01), long time ago, garbage was not seen as a problem, because it was generated in a smaller quantity, and its major part was composed by biodegradable materials, easily transformed by nature. However, lately, population has increased sharply, migrated from country to cities, their habits changed, gone to consume more industrialized products, and, with that, long life packs, plastic bags, styrofoam, cans, among others, went to take part of garbage; materials which take a long time to be degraded, but, on the other hand, can be recycled.

According to Pereira (2005, p.19), the importance of holding studies and discussions on solid waste problem indicates improvements in garbage treatment and its adequate final destination. Despite of the struggles, it´s known that the matter is complex, demanding several areas of knowledge performance, considering environmental, social and economical matters, in an interdisciplinary way that integrates urbanization, environment and sustainable development.

Oliveira highlights (2007, p.202), the big quantity of produced garbage, especially in the cities, is one of the crucial concerns in the world today. The industrialization process made man modify the space quicker, controlling the forces of nature and producing the necessary means to the capitalist society formation, today, essentially focused on consumption.

According to Cavalcanti et al. (2007, p.100), the technological advancements brought important contributions which made possible the globalized development in the present society. This development resulted in a rampant running of the capitalist system creating a distance between man/nature.

> By passing years, civilization was getting more complex, behaving as if divorcing from the natural world was possible. The first concern was about the construction of an extremely rational, planned, controlled and manufactured world. As long as this complexity has been increasing, we have been keeping away from our roots with the land and losing the integration link with the rest of nature. Machado (2004, p.82, *apud* CAVALCANTI et al. 2007, p.101).

As described by Taguchi (2001, *apud* JUNKES, 2002, p.34), reusing and recycling are much old practices; the antique times ´scrap ironers` collected swords from the battle fields to produce new weapons. Cities did not have public services for garbage collection and it was only in 1869 that the Town Hall of São Paulo decided to hire cart-drivers to collect the houses garbage.

In conformity to Wells (1997, *apud* JUNKES, 2002, P.35), the first actions for garbage recycling associated to garbage collection programmes came up in the country since the ending of the 70´s, where the Prefecture of Pindamonhagaba, in São Paulo State, was pioneer with one experience introduced in 1978, and the collection was held with the support of animal draft two-wheeled carts.

> Recycling process has been already used in Brazil and in several parts of the world by the processing industry, where a well conducted program trends to develop in population a new consciousness about matters which involves economy and environmental preservation, the citizen stowing the waste from his house goes

> to put himself as a bigger and more established integral piece of a whole system of environment preservation than a mere spectator of all the campaigns commonly disseminated in favor of his own species´ preservation. Pereira, (2000, *apud* JUNKES, 2002, p.35).

Corresponding to Alencar (2005, p.101), recycling is the “result of a number of activities by which the materials that would become or that are in the garbage are turned aside, collected, separated and processed for being used as raw material in new products manufacturing”. The author affirms that recycling can be considered also garbage separation and processing for a later reuse.

This study aimed to identify, describe and compare models of layout of the production system of recycling plants, thus providing better prospects in the design of these much needed projects in the cities of the new sustainable society that wants to build.

## METODOLOGY

The main object of study is the models of layout of productive systems of recycling plants, aiming to identify, describe and compare them. In order to, bibliographical or secondary references, in books, newspapers, and dissertations, that broach the subject in question, were used.

> The bibliographical research broaches every bibliography already launched related to the studied subject, from spare publications, newsletters, newspapers, magazines, books, researches, monographs, theses, cartographic materials and means of oral communication: radio broadcast, magnetic tape recording and audiovisual ways: films and television (MARCONI; LAKATOS, 2009, p.57).

The collected data were accurately analyzed and the selection of the bibliographical information passed through a critical review, aiming to minimize possible contradictions to the desired result was achieved.

## THEORETICAL REVIEW

### Garbage in Cities

From the historical point of view, according to Dias (2000, *apud* JUNKES, 2002, p.24), “garbage came up in the day men began to live in groups, setting themselves in determined places and giving up nomadic habits to look for food or being cattle shepherds”. Thereafter, processes to eliminate waste became a motif of concern, although the solutions only aimed to move the produced residues to places far away from primitive human agglomerations.

Fernandes (2007, p.38) understands that:

> Garbage is today one of the most serious social problems that the cities face and also a determinant factor for a healthy environment. Only providing urban cleaning services does not solve the problem. Garbage is one of the biggest problems that threaten life on the planet, because, besides polluting the soil, the water and the

> air, also attracts animals that transmit diseases. Opposite to the primitive tribes, that only produced what they needed to survive, we live in a consumer society, where people have value for the amount of goods they own.

Baptista (2001, *apud* PONTES; CARDOSO, 2006, p.02), solid waste present a very large meaning, taking part of it every and any kind of solid or semi-solid waste produced by man during the development of his professional, social, leisure, cultural activities, etc.

According to the NBR 10.004 (1987), *apud* MUÑOZ, 2002, p.04) the solid waste can be defined as:

> Those solid and semi-solid wastes that result from community´s activities: industrial, residential, from hospitals, commercial, from services, from sweeping, agricultural. Also are included in this definition the lakes from water treatment system, those generated inside equipments and installations for pollution controlling as also specific liquids which particularities make their discharge in the public sewerage system or bodies of water unviable, or demand for it, technical and economically unviable solutions face to the best available technology.

In conformity to the CONAMA Resolution 05 (1993, *apud* MUÑOZ, 2002, p.05), the Health Services Residues (HSR) are defined as "residues generated in hospitals, drugstores, laboratories, medical, odontological and veterinary rooms, blood and milk banks, besides rail-motor stations, ports and airports".

As asserted by Pontes and Cardoso (2006, p.02), garbage is everything which remains from any duty. It can be a result of our residential duty (sweeping, remains of food, remains of packs), in communities and enterprises (waste papers on the ground, gums, plastic cups, popsicle sticks, cigarette butts, leaves and branches) or in industrial processes (rubber, paper, pasteboard, wood, scrap irons, cables, industrial thins, remains of civil architecture, refractories, etc.).

> There is a basic difference between the terms Garbage and Solid Residue; while the first does not have any value, being necessary its discard, the second one can present economic value added, being possible to stimulate its use within an appropriate productive process. But this comparison can only be considered if garbage is seen as no use material, what, undoubtedly happened some decades ago, Demajorovic (*apud* PONTES; CARDOSO, 2006, p.02).

It is inevitable the garbage production in the cities because of the consumption culture. According to IBGE (2006, *apud* BELLINI; MUCELIN, 2008, p.113):

> Brazil is constituted of 5.507 municipal districts and in the last National Sanitation Research, held in 2000 by IBGE, it was registered that only 33% (1.814) of the 5.475 municipal districts collected the whole amount of the residential residues generated in the urban houses of their territories. The data revealed that Brazil produced daily 228.413 solid waste tones daily. This implies a production of 1,2 kg/inhabitant.

As described by Delmont (2007, p.18), the duty of define waste is not one of the simplest, many others manners of classification were prepared to help in their management processes. According to the Handbook of Integrated Solid Waste Management of IBAM (2001, *apud* DELMONT, 2007, p.18), "there are two more common manners to classify the solid waste:

considering the potential risks of environment contamination and about the nature or residues origin.

In conformity to IPT/CEMPRE (2000, *apud* SAVI, 2005, p.37-38), the residues can be classified according to Table 01. Regarding the generation cause, according to Baptista (2001, *apud* PONTES; CARDOSO, 2006 p.03), all the real estates placed in the municipal district produce solid waste. Therefore, Magera (2003, *apud* SAVI, 2005, p.39), points out another manner of classification of the solid waste, regarding their origin according to Table 02.

**Table 01:** Classification of the residues regarding their physical characteristics and chemical composition:

| | |
|---|---|
| **PHYSICAL CHARACTERISTICS** | **Dry:** papers, plastics, metals, processed leather, fabrics, glasses, wood, handkerchiefs, paper towels, cigarettes butts, Styrofoam, lamps, paraffin, ceramics, porcelain, foams, corks; |
| | **Wet:** remains of aliments, peels and husks of fruits and greens, eggs, legumes, spoiled food, etc.. |
| **CHEMICAL COMPOSITION** | **Organic:** composed by coffee and tea powder, threads of hair, remains of aliments, peels and husks of fruits and greens, eggs, legumes, spoiled food, bones, remains of pruned gardens; |
| | **Inorganic:** composed by manufactured products like plastics, glasses, rubbers, metals (aluminum, iron, etc.), fabrics, Styrofoam, lamps, candles, paraffin, ceramics, porcelain, foams, corks, etc.. |

**Source:** adapted from IPT/CEMPRE (2000, *apud* SAVI, 2005, p.37-38).

**Table 02**: Classification of garbage regarding its origin.

| CLASSIFICATION | FORMATION |
|---|---|
| **HOUSEHOLD** | The one originated in everyday life, produced in residences, consisted basically of remains of aliments, peels of fruits and greens, packs, etc.; |
| **COMMERCIAL** | The one originated in several commercial and services establishments like Banks, financial institutions, supermarkets, offices, etc.; |
| **INDUSTRIAL** | Generally it is consisted of manufacturing process chips, waste of several industry lines; |
| **MEDICAL** | Originated in ambulatories, hospitals, laboratories, it is constituted of septic waste like: syringe, gauzes, removed tissues, etc.; |
| **PUBLIC** | The one originated from the urban sanitation, public roads sweeping, beach cleaning, free markets cleaning, etc.; |
| **AGRICULTURAL** | It is composed of agricultural activities and livestock waste, where can be included also the packaging of fertilizers and pesticides that, generally, are highly toxic and must have a different destination from the rest of the packaging used in farming; |
| **NUCLEAR** | It is composed of radioactive fuel rods that remains from nuclear plants, which final destinations are not known still today; |
| **RUBBISH** | It is formed of waste normally originated in civil architecture, composed of demolition materials or remains of construction materials like: tiles, metals, cement, bricks, etc. |

**Source:** adapted from Magera (2003, *apud* SAVI, 2005, p.39-40).

Another form of waste classification according to ABNT (*apud* PONTES; CARDOSO, 2006, p.02-03), the Solid Waste can be classified in three classes, shown in Table 3.

Population growth, over-consumption, inconsequential waste and industrial development have contributed to the increase of solid waste quantity generated. Consequently, the solid residues, in the form of garbage, have been turning into a high difficult problem to be solved for the major part of the municipal districts and a grave sanitary and environmental problem for population, according to Ruberg and Philippi (2001, *apud* PONTES; CARDOSO, 2006, p.06). According to Pontes e Cardoso (2006, p.08), the residues more produced in the cities are presented in Table 04.

**Table 03**: Solid Waste Classification.

| CLASS | TYPE | CLASSIFICATION |
|---|---|---|
| **CLASS I** | DANGEROUS WASTE | Residues which cannot be placed on the ground without using practices protectives to avoid risks to the public health and environment. Examples: paint sludge, electroplating sludge, Waste Health Services (WHS), solvents, substances containing heavy metals and chlorinated, others. |
| **CLASS II** | NON-INERT WASTE | Those residues which cannot be placed on the ground, however, must receive added care. Example: urban household waste (domiciliate and commercial), ferrous and nonferrous scraps, paper, plastic, wood, others. |
| **CLASS III** | INERT WASTE | They are residues which when adequately placed on the ground do not cause risks to the public health and environment. Example: broken glasses, rubbish from civil architecture, refractories, others. |

**Source:** adapted from ABNT (*apud* PONTES; CARDOSO, 2006, p.02-03).

**Table 04**: Garbage Composition Weighted Average in 33 Brazilian Cities

| COMPONENT | WEIGHT PERCENT (%) |
|---|---|
| Plastics | 3,83 |
| PET | 1,50 |
| Paper | 3,00 |
| Pastboard | 10,18 |
| Organic Material | 34,40 |
| Aluminum | 0,22 |
| Steel Can | 3,20 |
| Glasses | 3,07 |
| Others | 40,60 |
| Totals | 100,0 |

**Source:** Adapted from Nardim, Prochnik and Carvalho (2000, *apud* PONTES; CARDOSO, 2006, p.8).

### Inorganic Solid Waste and Forms of Treatment

According to Reichert (1999, apud JUNKES, 2002, p.29), the correct management of solid waste is certainly one of the main challenges in this millennium beginning. Tight and isolated solutions which do not consider the waste matter from the generation till its final destination, passing through its treatment, even being good in the beginning, do not succeed in solving the problem as a whole.

According to Charnock and Wells (1985, *apud* MUÑOZ, 2002, p.07), there are three basic forms adopted by urban society to discharge and treat the solid waste: dumps or sewers, controlled landfill and sanitary landfill. Continuing, Muñoz (2002, p.10) broaches another form of treatment which is the recycling process. Finally, the National Health Foundation (BRASIL, 2006, p.266) broaches that incineration must be included too.

According to Serra et al. (1998, *apud* MUÑOZ, 2002, p.08), the dumps or sewers result from simple discharge of waste in the open without considering: the site in which the discharging is made, the percolation of the liquids derived from waste decomposition, the liberation of gases in the atmosphere and the proliferation of insects, rodents and other animals that can transmit diseases to man.

For Calderoni (1997, *apud* SAVI, 2005, p.53), dumps, also known as sewers, are places where a simple waste discharge without technical control occur. This is the most harmful form to human being and environment, because in these places, generally, it is established an informal economy resulted from the picking of the recyclable material, and more, the raising of domestic animals, which are possibly destined to human consumption such as: birds, cattle and porks.

In conformity to Muñoz (2002, p.08-09), controlled landfill differs from dumps only because the waste is not disposed in the open, being covered with earth periodically. The soil is not waterproofed, not always has a system of draining for the percolated liquids, capture of gases formed by the decomposition of the organic material neither.

The controlled landfill is one technique of disposing the solid waste on the ground, aiming the minimization of environmental impacts. This method comprehends some principles of engineer to confine the solid waste, covering them with a layer of inert material in the conclusion of each working day, National Health Foundation (BRASIL, 2006, p.267).

According to Muñoz (2002, p.09), sanitary landfill refers to an installation previously planned for a posterior disposition of solid waste, in order not to cause damage or hazards to the environment and public health. Other concepts can be seen in literature, namely:

> Sanitary landfill – the waste is placed in trenches, lined with plastic sheeting, compacted in layers in suitable land, for being covered with inert material, generally, the proper earth. Over time, all the material is decomposed and becomes part of the soil. The land is waterproofed to allow that the liquids and the gases resulted from the decomposition suffered under the soil, by the mainly action of bacteria, be drained and treated, to avoid environment contamination. There is still a lack of sanitary landfills in Brazil. (Alencar, 2005, p.100).
>
> Sanitary landfill of urban solid waste is the technique of urban solid waste disposal on the ground, in order to minimize environmental impacts, method which comprehends principles of engineer to confine solid waste to the smallest site and reduce it to the smallest possible volume, covering it with a layer of earth on each working day conclusion or by shorter intervals, if necessary. (BRASIL, 2006, p.267).

For Cerqueira and Alves (1999, *apud* MUÑOZ, 2002, p.10), the incineration, process of residues treatment through oxidation at high temperatures, under certain controlled conditions, is considered one of the techniques more adequate for the treatment of the health services waste. The National Health Foundation (BRASIL, 2006, p.266) gives the concept:

> Incineration is the process of oxidation at high temperatures, with gases burning between 1.000°C and 1.450°C, in time to four seconds, and occur in well-designed and correctly operated installations where there is the materials process and

> destruction of the microorganisms of the solid waste, aiming, essentially, the reduction of its volume to 5% and, its weight, from 10% to 15% of initial values.

Continuing, the National Health Foundation (BRASIL, 2006, p.266), yet affirms that the slags and ashes generated in the process are totally inert, and receive precautions for packaging, storage, identification, transportation and adequate final destination. According to Scarlato and Pontin (1992, *apud* ALENCAR, 2005, p.100), where:

> Incineration or waste burning – greatly reduces the volume and the waste mass and virtually eliminates the risk of diseases. The medical waste is generally incinerated, as also the dead animals collected in the streets. The ashes which remain, present mass much smaller than the original waste and are inert, being its destination much simpler and less dangerous than the raw garbage, being able to be sent to the landfills without risks.

In conformity to IPT/CEMPRE (2000, *apud* DELMONT, 2007, p.25), the recycling process is "the result of activities which aim to minimize or divert the waste from its final destination for being used as secondary raw material for goods manufacturing, that were produced with virgin material before".

In conformity to Pontes e Cardoso (2006, p.03), recycling is a "process which has gained considerable space and which priority function is to promote the recuperation of materials considered solid waste, processing them to raw materials to be used in reprocessing processes.

Finally, Medina (2007, *apud* DELMONT, 2007, p.25) defines the recycling process as "the process of secondary raw materials production from industrial rubbish (residues) and end of life products (scrap irons) to introduce them in the productive process.

According to Ruberg, Aguiar and Philippi Jr (2000, *apud* MARTINS, 2005, p.29), the process of recycling materials consider, generally, three phases, in conformity to Table 05.

**Table 05**: Recycling process.

| PHASE | PROCESS |
|---|---|
| I | The selective collection, that can be door to door, that is, the raising of recyclable materials by the municipal public cleaning services, by private enterprises, by street collectors, or another entities, directly in the household. Collection can occur alternatively with population´s participation; in this kind of process, kits of containers are set in several parts of the city by the municipal public power, so that the population deposits the recyclables there. |
| II | Sorting and pre-processing of recyclable material in sheds, plants; in this phase –post-collection – the selection of the inorganic materials, according to their types, and one preliminary processing, consisted of washing, pressing and baling, is done. The materials considered non-potentially recyclable, like some inorganic ones which are not sold yet to recycling industries due to feasibility issues, or even organic materials which come mixed to the "recyclable ones", constitute the rubbish not useful, generally discarded in landfills after selection; |
| III | The processing of the material in a recycling industry, modifying its physical characteristics, resulting in the production of a new product. |

**Source:** Martins (2005, p.29).

According to Reis et al. (2000, *apud* JUNKES, 2002, p.30) one of the basic factors for the success of the urban solid waste treatment is the existence of collection programmes differentiated such as: the segregated collection, consisting in the separation for type of material in the moment of the residue generation and the selective collection, used to name the collection of recyclable materials, despite that demands a great investment on environmental education, once people begin to separate the residues in their houses due to consciousness.

### Recycling Plants as a Means of Inorganic Waste Treatment

According to Pontes and Cardoso (2006, p.06), in Brazil, the waste processing began 30 years ago, and is becoming a very important ally in the Urban Cleaning System (UCS). Authors report that also, “becomes important, today, to know the process of one plant of urban waste recycling and composting (PWRC), inserted in the management system and its behavior.

According to Junkes (2002, p.48), the sorting and composting plants, many times qualified as sorting sheds, can have their layout varied so much according to the scheme of the recyclables reception and separation. As there is not a static standard, the classic phases according to Reichert (1999, *apud* JUNKES, 2002, p.48), are: reception/storage, separation (by belt conveyors, bins and pressing/baling).

In conformity to Silva et al. (2003, p.102), Sorting Plants receive the residues without any kind of selective collection and the whole separation of them is taken in the proper plant. Besides the shed as the working place and one area for the residues packaging, the minimum equipment for the assembly of the sorting center are the rolling mats of the residues, bombina specific to each type of material and presses for baling.

According to Pontes and Cardoso (2006, p.06), the sequence of the PWRC operation inserted in the Integrated Solid Waste System presents as following: generation (garbage); household collection; treatment (PWRC), (separation of materials); recyclable material, (to be reused); composting (use in fertilization) and rubbish and final discards, (for landfills).

Pontes and Cardoso (2006, p.06) report that is possible to define one PWRC as “being a center of waste sorting and composting, in its organic and inorganic functions”.

> The establishment of a PWRC enables the creation of jobs directly proportional to the total demand of waste generated in the city, minimizes the discharge in landfills due to the usage of existing recyclable materials, minimizes the contamination of the environment due to the waste reduction sent to sanitary landfills, minimizes the diseases transmission linked to waste, minimizes the necessity of withdrawing or extraction of raw material from nature due to the use of recyclable materials and the minimization of floods with barriers drops due to the more normal waste collection in streets and barriers (PONTES and CARDOSO, 2006, p.07)

However, Pontes and Cardoso (2006, p.04) report that nowadays there are three recycling models for the waste treatment, adopted regularly in the world, according to Table 06.

According to Bley Jr. (2001, *apud* Junkes, 2002, p.53), the great justification to construct plants are the direct advantages of sanitation with reduction of volumes to be landed. He still affirms that another advantage is the access to the scrap iron materials, that after classified and decontaminated, go to the recycling, opening a new economic cycle for the raw materials which would be landed and mainly reduce the environmental impacts.

**Table 06:** Recycling Models.

| MODEL | DESCRIPTION |
|---|---|
| **MECHANIC RECYCLING** | The one which presents one or several operational processes (washing, crushing, grinding, agglomeration, agglutination, extrusion, graining, casting, others), aiming the reuse of determined solid waste to produce consumption goods (secondary products). |
| **CHEMICAL RECYCLING** | The one which comes from the technological process held from the conversion of the solid waste into primary raw materials. This method has been already used for the conversion of plastics into petrochemical raw materials (gas, kerosene, diesel, others) by specific chemical reactions. |
| **ENERGETIC RECYCLING** | The one held aiming the recuperation of part of the heat energy contained in the constituents of solid waste considered fuel and/or putrescible. |

**Source:** Adapted from Pontes and Cardoso (2006, p.04).

**Table 07:** Characteristics of one sorting and composting unit and of the tailings landfill for communities of 10.000 Inhabitants.

| | STRUCTURE, MATERIALS AND FUTURE TAXES | AREA IN m² AND COSTS |
|---|---|---|
| **Basic Models of the Unit** | Administration building.<br>Waste reception and sorting. Deposit for the recyclables.<br>Yard for composting.<br>Rubbish landfill. | |
| **Project Área in m2** | Constructions.<br>Yard for composting<br>Added projects<br>Rubbish landfill | 250 m2<br>3.500 m2<br>500 m2<br>600 m2 |
| **Equipments and Civil Works (costs US$)** | Tap power<br>Sorting belt conveyor<br>Hydraulic press<br>Civil works | 1.200<br>2.800<br>8.000<br>35.000 |
| **Operational Costs (Montly US$)** | Wages, taxes, energy, water and maintenance of 10 employees. | 4.200 |
| **Benefits** | Extinction of the city dump, average monthly treatment of 18 tons of municipal waste, average monthly production (06 tons of organic compost, 2.5 tons of recyclable materials, 04 tons of rubbishes), generating 10 direct jobs and 50 indirect, health environmental, economic and social improvements. | |

**Source:** Pereira (1999, *apud* Junkes 2002, p.54).

## *Layout* of Productive System

According to Corrêa and Corrêa (2009, p.398), the place of an operation affects both its competitive capacity and another internal and external aspects. Continuing, Gaither and Frazier affirm (1999, *apud* BÓSOLI et al. 2009, p.03), that planning the layout implies practices and strategies for organizations. The sufficient supply in the production capacity, the reduction of materials costs and handling, the guarantee of places to machinery, the high use of resources and manpower, and the reduction of investment are the main aims of this kind of planning.

Marinho, Sousa and Vargas (2006, p.02) report that the layout elaboration of an operation is basically important, once the layout determines the form and appearance of a productive operation and determines the flow of resources throughout the production process. Yet, they broach that a poorly prepared *Layout* can generate a number of problems for the operation like: unnecessary storages, long or confusing flows, extra displacements, customers´ queues and high production times.

According to Slack (2002, *apud* MARINHO, SOUSA and VARGAS 2006, p.03), the major part of the layouts, in practice, derives from only four basic types, they are: positional layout, layout by process, cell layout and layout by product.

Corrêa and Corrêa (2009, p.407), one operation layout is the manner in which the resources which occupy space inside an installation of one operation are physically disposable.

Slack et al. (2002, *apud* PEINADO; GRAEML, 2007, p.199) define layout of a productive operation as a concern with the physical location of the transforming resources. In a simply way, defining layout is "to decide where to keep all the installations, machinery, equipments and production staff."

Gaither and Frazier (2001, *apud* PEINADO; GRAEML, 2007, p.199) describe that defining layout means:

> Planning the location of all the machines, utilities, working stations, areas of customers´ services, areas of materials storage, corridors, toilets, cafeterias, drinking fountains, internal partitions, offices and computer rooms and also the materials and building users´ flowing standards.

As described by Norões, Gadelha and Gadelha describe (2008, p.03), the layout by product, linear or even online is the kind of layout in which the product moves itself and the machines are kept fixed. The machines are placed according to the operations sequence and these ones are done according to the sequence established without alternative ways.

Peinado and Graeml (2007, p.203) report the advantages of the layout by product or online, as a "possibility of mass production with big productivity, engine load and consumption of material along this line of production and easier productivity control".

Layout by Process has this denomination because according to Slack et al. (1999, p.164, *apud* RIBEIRO et al., 2006, p.04), "the needs and conveniences of the transforming resources that constitute the process in the operation dominate the decision over the layout". This kind of layout keeps all the similar resources of the operation close to each other; this is more convenient so that the use of the transforming resources is optimized.

In conformity to Peinado and Graeml (2007, p.212), layout by process or functional layout:

> It arranges, in the same area, all the processes and equipments of the same type and function. That is why it is known as functional layout too. This layout also can arrange similar operations or assemblies in the same area. The materials and the products displace themselves searching for the different processes of each area needed. It is a different layout easily found in services providers and commercial organizations.

For Martins and Laugeni (1999, *apud* RIBEIRO et al., 2006, p.04), this process presents the following characteristics: flexibility to meet to market changing, long flow inside the factory, provides working satisfaction, more adequate for diversified productions in medium or small quantities and meet to diversified products throughout time.

However, Peinado and Graeml (2007, p.213) broach the advantages of the layout by process or functional layout, "great flexibility to meet to market changing, good level of motivation, meets to diversified products in varied quantities at the same time, lower investment for the industrial park installation and higher product margin.

In conformity to Peinado and Graeml (2007, p.225), the cell layout:

> It seeks to unite the advantages of the layout by process to the advantages of the payout by product. The cell of the manufacture consists in arrange in one place, known as cell, different machines which are able to produce the whole product. The material displaces itself inside the cell seeking for the necessary processes, but the displacement occurs online.

According to Ribeiro et al. (2006, p.04), Cell Layout is called like this because all the necessary resources for a specific operation are disposable in groups, that is, consists in displace in one place the machines or equipments which will be used for the whole product manufacturing.

However, Peinado and Graeml (2007, p.2270 comment the advantages of the cell layout: "higher flexibility of the batch sizes per product, decrease of material transporting and storage". According to Peinado and Graeml (2007, p.228), layout by fixed position is "that one where the product, that is the material to be processed, remains stopped in one determined position and the transforming resources are displaced around it, performing the necessary operations".

On the other hand, according to Norões, Gadelha and GAdelha (2008, p.03), the positional layout or fixed position layout is used when the product remains fixed (for example, ships, airplanes, buildings construction) while the workers, the machines, the equipments and the raw materials move. In this case, the movement must be the minimum. Everything must be closer to the product.

For Gaiter and Irazier (2001, *apud* RIBEIRO et al., 2006, p.03), some characteristics of this type of layout: it is not repetitive, for a unique product, in small or one only unit and minimizes the needed quantity of the product movement.

According to Marinho, Sousa and Vargas (2006, p.02), the basic aims of the layout are: total integration of all the factors which affect the layout; materials movement in minimum distances, work flowing throughout the factory, all the space effectively used, satisfaction and safety for the employees, a flexible arrange that can be readjusted, minimize processing expenses, material transporting and storage throughout the production.

## RESULTS AND DISCUSSIONS

According to Savi (2005, p.48), the most important aspect in the implementation phase of a Sorting Center is, undoubtedly the choice of the implementation area, that is, the geographical and physical space for the project. In Table 08, the items which must be considered for this choice are shown.

**Table 08:** The items which must be considered for that choice are introduced below.

| ITENS | DESCRIPTION |
|---|---|
| I | Intern physical space for equipments location; |
| II | Area for reception and dispatch; |
| III | Area for processed material storages; |
| IV | Space for materials and people´s movement; |
| V | Proper ventilation; |
| VI | Dimensioned grid to supply the equipment consumption; |
| VI | Firefighting equipment, hydrants and extinguishers; |
| VIII | Proper light, preferably natural; |
| IX | Physical and structural conditions of the implementation place; |
| X | Easy location, as close as possible to the buyers (less transporting cost); |
| XI | Area reserved for administration/office. |

**Source:** Adapted from Savi (2005, p.48).

Model of the productive system layout of a sorting center, according to Savi (2005, p.50), in conformity to Figure 01. For Castro (2001, *apud* SAVI, 2005, p.49), the process which involves the plants can be divided in Reception and Storage, material Sorting (manual or mechanized), Grinding and biological Treatment (normal or accelerated) of the organic materials (composting).

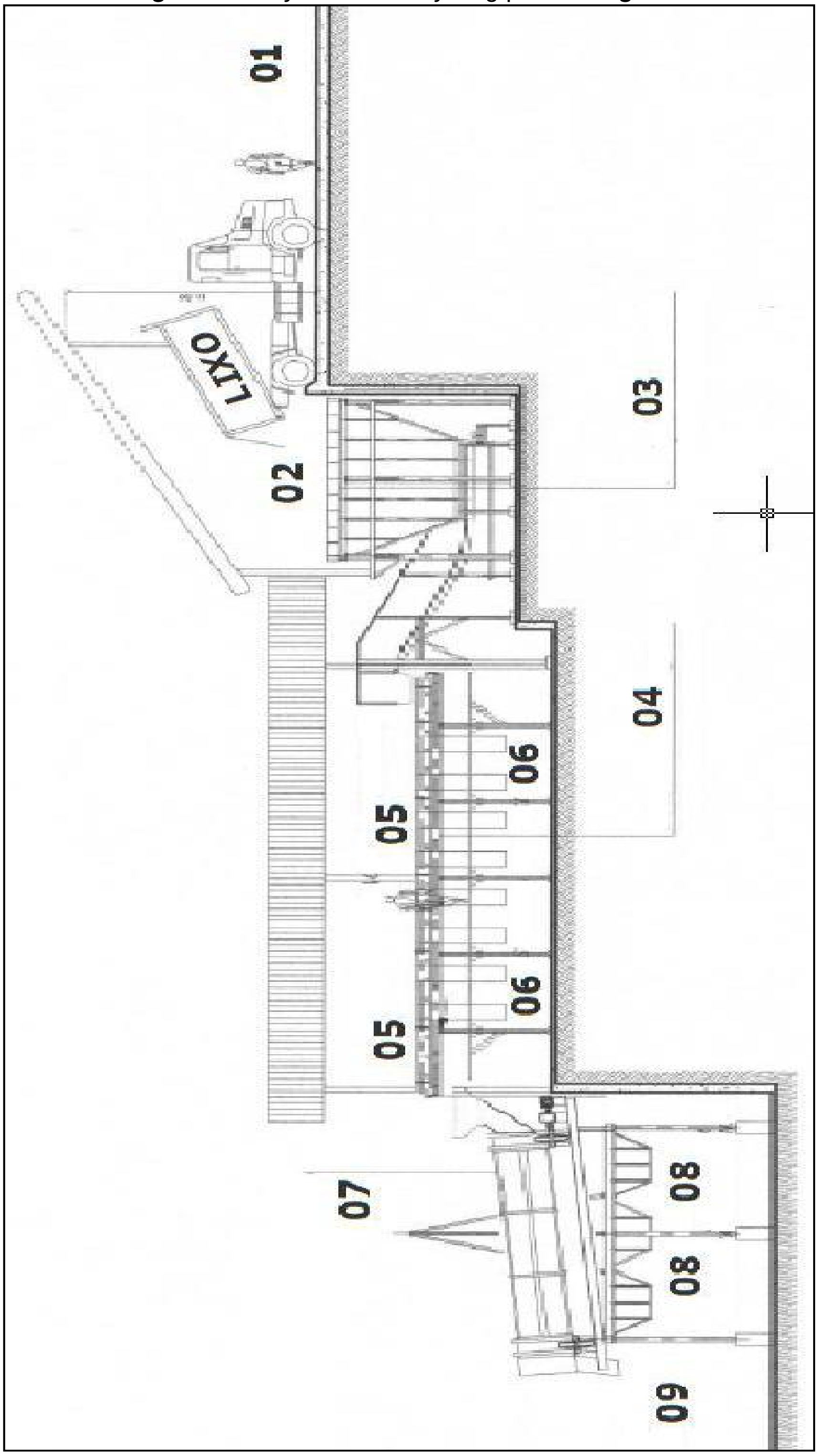
According to Savi (2005, p.49), the waste reception is made by the collection trucks discharge in paved yards or reception areas, in special devices, like covered moats for manure picking and drainage, with vertical walls in one side and inclined ones in the other to encourage the disposal of the reception hoppers with a minimum slope of 60° to the horizontal. The yard storage, like the reception moat, is designed due to the nominal capacity, previewing a minimum reserve for three storage days.

The sorting center is the place where the separation of the several waste fractions is made. The main equipment is the sorting belt conveyor coated with rubber slipping by of end to end allowing so the removal of the recyclable materials, IPT/CEMPRE (*apud* SAVI, 2000, p.49).

In conformity to Savi (2005, p.49), the waste sorting can be done manually - run on belt conveyors with working width of 1m and speed between 6 and 12 m / min, with variable speed, where the workers, placed side by side of the mats, remove manually the recyclable residues. The mechanized system is made by special equipments like electromagnet, rotating and vibrating screens, cyclones, vacuum cleaners, floaters, etc. In some plants, the sorting is made by the two methods.

Savi (2005, p.51), it is important to highlight the separation mat must contain a magnetic separator (electromagnetic) in its end to retain objects like batteries, metals, caps, aiming one better quality of the organic composting.

**Figure 01**: Layout of a Recycling plants. **Legend**[1]




**Source:** Adapted from the Prefecture of the Municipality of Adamantina (*apud* SAVI, 005, p.50).

A sorting shed is useful, even in the case of segregation at source by the dry/wet systems, since there will be a separation of the dry, (papers, plastics, glasses, etc.), wet (fractions of

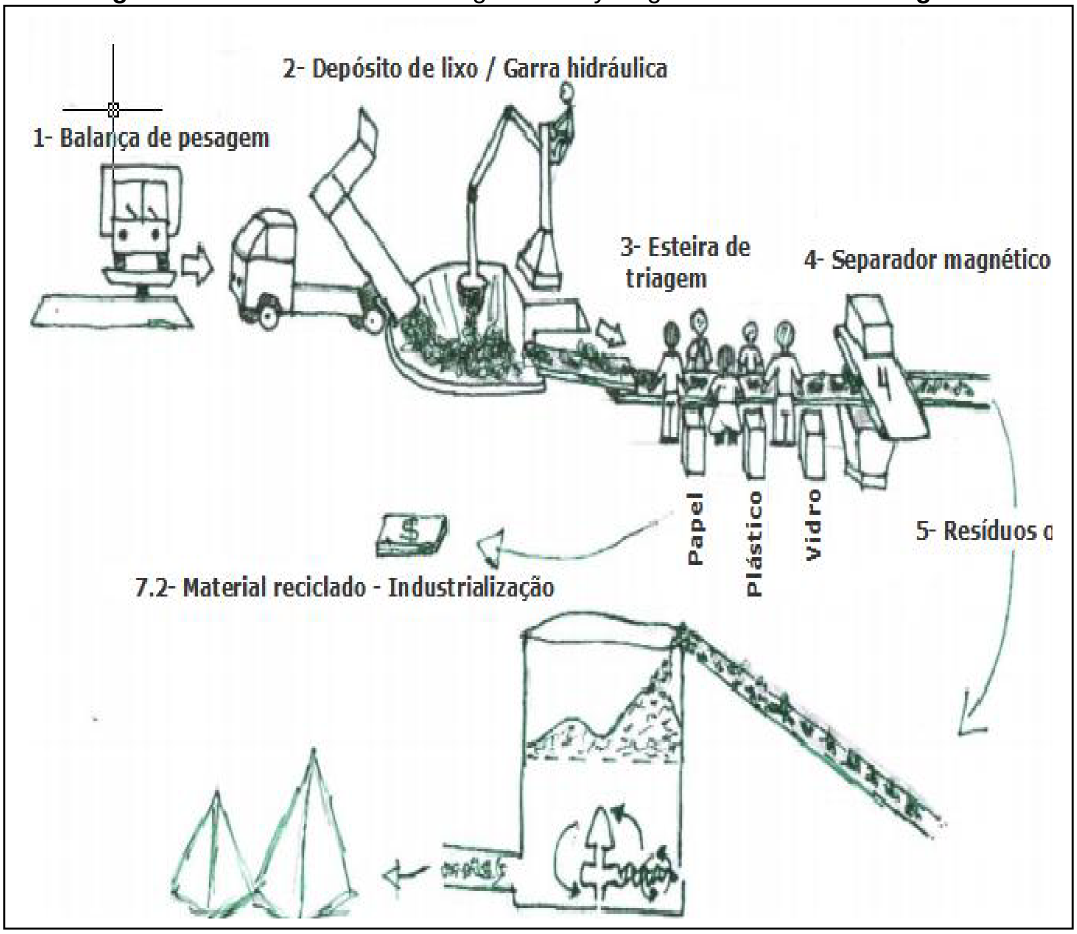
[1] 1) Reception yard; 2) Hopper; 3) Silo with existing metal belt conveyor; 4) picking and sorting belt conveyor in place; 5) sorting recyclable belt conveyor; 6) output materials for recycling; 7) AR (1) existing; 8) output material for composting organic fertilizer; and 9) out of material for sanitary landfill.

organics) and others (rubbish). In conformity to CEMPRE (1999, p.12, *apud* SAVI 2005, p.51). Continuing, Savi (200, p.51), highlights that graining is held in mills specially constructed to process waste. There are several types of mills, where the most used is the hammer one. Some processing systems do not present this equipment.

In the composting process occurs the aerobic decomposition of the organic material through the action of microbial biological agents in the presence of oxygen, being natural or accelerated, according to the definition of the handbook of CEMPRE/IPT (2000, *apud* SAVI 2005, p.51).

Another model found in literature, according to Teobaldo Neto and Nishiyama (2005, p.132), is the Scheme of the Sorting and Recycling Plant of Uberaba, as can be verified in the Picture 02.

**Figure 02:** Scheme of the Sorting and Recycling Plant of Uberaba. **Legend**[2]




**Source:** Adapted from Teobaldo Neto and Nishiyama (2005, p.132).

Teobaldo Neto and Nishiyama (2005, p.131) describe the working system, that is illustrated through scheme represented in the Picture 02. In the first stage, waste is discharged inside the moat of the first deposit with capacity of approximately 500 tons. A hydraulic claw with capacity of

[2] (1) Weighing scale; (2) Waste deposit/hydraulic claw; (3) Sorting belt conveyor; (4) Magnetic separator; (5) Inorganic residues; (6) Biodigester (French system); (7.1) Recycled material – Organic compound; (7.2) Recycled material - Industrialization.

de 1,5 tons feed the waste separation belt conveyor. According to Teobaldo Neto and Nishiyama (2004, p.132), from then waste goes to a rotating circular sieve with a mesh of 20 x 20 cm and tear-bags tips. Following, it is leaded to two picking sieves with 13 meters long where it is segregated manually in the types: pasteboard, paper, thin plastic, other plastic packs, aluminum, metal, glass, copper and rubbish in general (cloths, tires, wood, etc.).

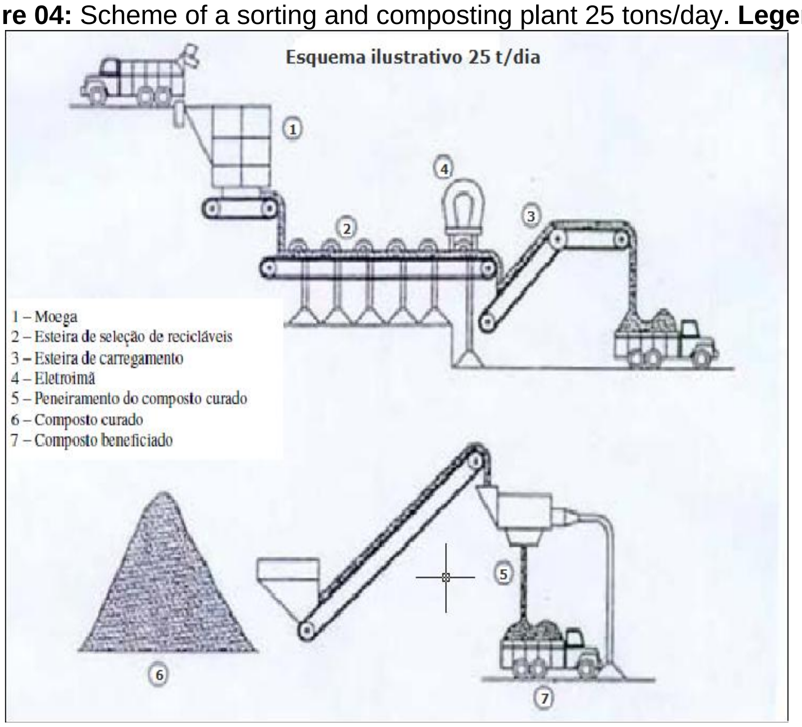
Also in Theobaldo Neto and Nishiyama (2005, p.132): following, waste passes through an electromagnetic where is the retention of all the existing ferrous material is made. In the sequence the residues pass through a fine screening using a variable mesh of 12 to 18 mm and internal scraper separating organic compound on one side and on the other hand, fine tailings.

Finally, Teobaldo Neto and Nishiyama (2005, p.132) add that the organic residues pass through the biodigester, prototype of a French plant, where they undergo anaerobic bacterial action under controlled conditions of temperature and pressure. They are then placed in windrows and 45 days after they are sold.

Model of layout of productive system based on the enterprise VALTEC Machinery Industry LTD., requested by Socio-Environmental Institute Tree (2009), envisioned in Figure 03.

Other model found in bibliography according to Junkes (2002, p.50), this is the scheme of a sorting and composting plant 25 tons/day, as can be verified in Figure 04.

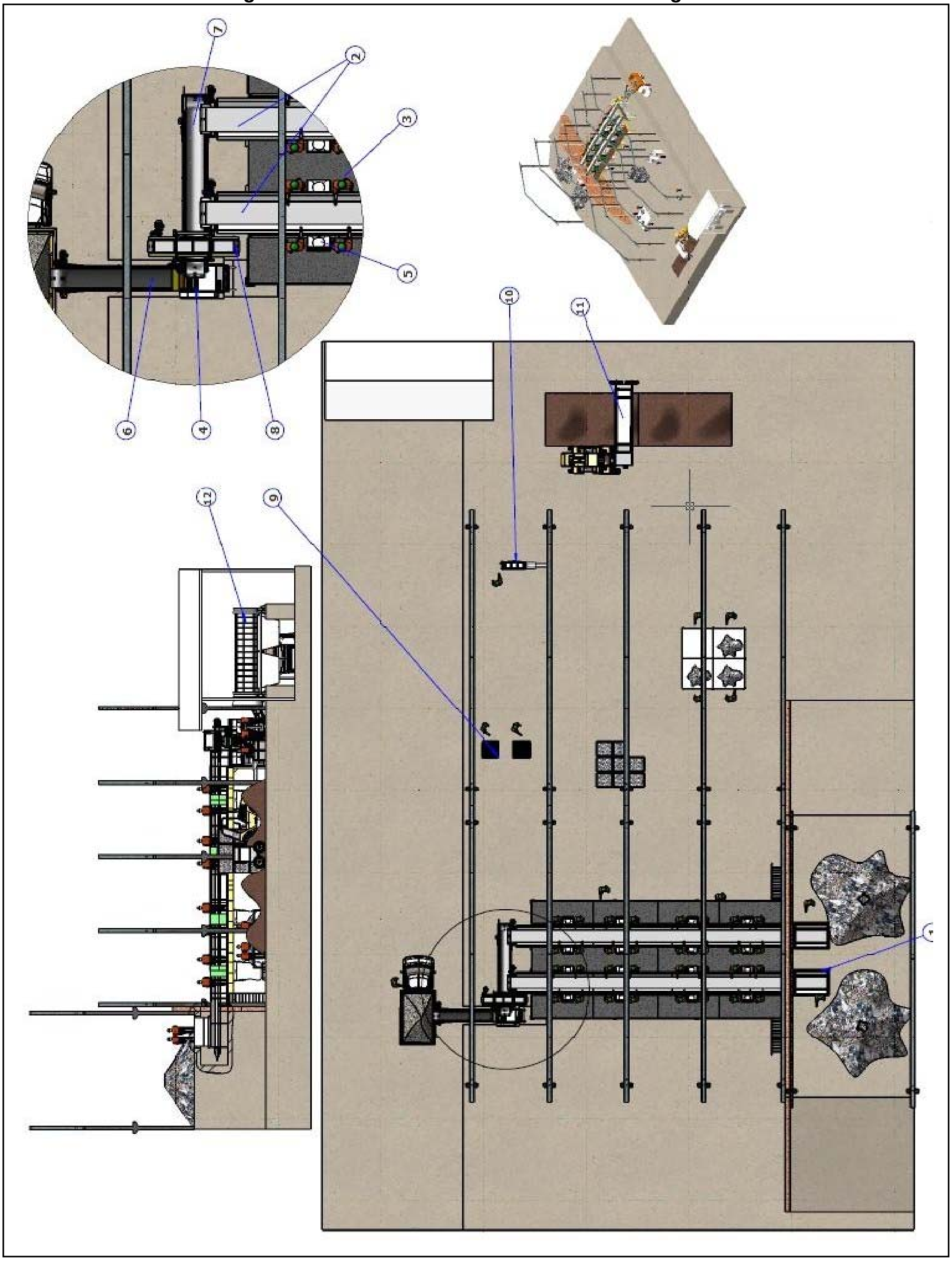
**Figure 04:** Scheme of a sorting and composting plant 25 tons/day. **Legend**[3]




**Source:** Adapted from IPT (1993, *apud* Junkes 2002, p.50).

[3] (1) Hopper; (2) Recyclable selection belt conveyors; (3) Loading belt conveyor; (4) Electromagnetic; (5) Screening of the cured compound; (6) Cured compound; (7) Processed compound.

**Figure 03:** Urban waste line of classification. **Legend**[4]




**Source:** adapted from enterprise VALTEC Machinery Industry LTD., requested by Socio-Environmental Institute Tree (2009).

4 1) Ramp input; 2) 800x20000mm selecting belt conveyor; 3) Suspension platform; 4) Mill MV800; 5) 500x500x6000mm selector spouts; 6) "V" 5000x6000mm output belt conveyor; 7) 400x2000mm mill feeding belt conveyor; 8) Suspended magnetic belt conveyor; 9) 15 ton vertical – weigh 600x400x950mm hydraulic press; 10) 25 ton Horizontal for cans and iron 350x350mm hydraulic press; 11) Composting equipment (material revolving); 12) Screen for standardization of waste composting.

There are a number of factors which must be considered for the installation of a sorting and composting plant according to D´Almeida (2000 *apud* Junkes 2002, p.49), as also some recommendations about industrial subject due to the quantity of waste generated and collected.

D´Almeida (2000 *apud* Junkes 2002, p.49), describes the schemed system working in figure 04. The waste is directly discharged into a hopper that feeds the sorting belt conveyor from where the recyclables are collected. There must be a magnetic device in the end of the belt conveyor to remove metals. The residues not separated, rich in organic material, go to the composting yard, where must stay about 90 days in windrows periodically revolved; this is named artisan compound.

## FINAL CONSIDERATIONS

Four layout models of productive systems for Recycling Plants were identified and described. Figure 01Layout of one Sorting Center adapted from the Prefecture of the Municipality of Adamantina (*apud* SAVI, 2005), the other Figure 02 Scheme of the Sorting and Composting Plant of Uberaba adapted from Teobaldo Neto e Nishiyama (2005), Figure 03 Line of classification for urban waste adapted from enterprise Valtec Machinery Industry LTD., requested by Socio-Environmental Institute Tree (2009), finally Figure 04 Scheme of one sorting and composting plant adapted from IPT (1993, *apud* Junkes 2002).

Analyzing the broached Layouts, it can be seen that exist some similarities and differences among them. Comparing the figure 01 with the others, it was possible to notice the lack of the hydraulic press, the biodigester and the composting yard. In the figure 02, comparing with the others, it can be seen the lack of some items, that is, the reception yard, the mill, the hydraulic press, the composting yard and the material output for sanitary landfill. However, the hopper is substituted by a waste deposit and the bin with a metallic belt conveyor by a hydraulic claw; it´s worthy to highlight that there´s no need of weigh scale for trucks. Comparing the figure 03 with the others, it was evident the lack of the reception yard, the hopper, the magnetic separator, the biodigester and the composting yard. Finally, it was noticeable in the figure 04 the lack of the reception yard, the hydraulic claw or metallic belt conveyor, biodigester, the hydraulic press and the material output for sanitary landfill.

It is expected that the bibliographic references, results and discussions presented in this study may support further studies on the physical layout ideal for implementing recycling plant for small municipalities. The approaches presented here do not limit the possibilities of existence of other forms of layout (physical layout), but only introduces the subject, due to the perceived lack of literature on the subject.

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