

Blending Processing of Industrial Residues: A Specific Case of an Enterprise Located in the Municipality of Belo Horizonte, MG, Brazil

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Abstract—Residues are produced in all stages of human activities in terms of composition and volume which vary according to consumption practices and to production methods. Forms of significant harm to the environment are associated to volume of generated material as well as to improper disposal of solid wastes, whose negative effects are noticed more frequently in the long term. The solution to this problem constitutes a challenge to the government, industry and society, because they involve economic, social, environmental and, especially, awareness of the population in general. The main concerns are focused on the impact it can have on human health and on the environment (soil, water, air and sights). The hazardous waste produced mainly by industry, are particularly worrisome because, when improperly managed, they become a serious threat to the environment. In view of this issue, this study aimed to evaluate the management system of solid waste of a co-processing industrial waste company, to propose improvements to the rejects generation management in a specific step of the Blending production process.

Keywords— Blending, environment, industrial residues.

I. INTRODUCTION

DEVELOPING countries face several difficulties associated to residues management. In some cases residues are poured directly into the sewage pipeline, or even buried or disposed on the ground and quite frequently burned, generating serious problems to the atmosphere, to the soil as well as to the underground aquifers and a continuous health and life quality deterioration to the local population. Under these conditions, toxic substances are generated by low biodegradable substances, reaching the environment and so the food producing system, being harmful to animals and humans.

Brazil produces millions of tons of industrial residues per year from which only one million ton is directed to known destination. Serious problems have generated important solutions and opportunities which initiatives were based on the hierarchy of residues management focused on controls as well as on environmental impact minimization. The enterprise

under consideration offers environmental solutions to the industrial residues generated at cement furnaces. Residues are forward to definite destination since the enterprise accounts with laboratories, treatment stations facilities to observe the ISO 9001 (quality) as well as ISO 14001 (environment) norms, exerting safe work and providing health conditions of high standards as well. It is of common agreement that the conciliation between growth and environmental preservation converges to the Industrial Ecology and Sustainability. Industrial Ecology objectives include resources optimization, to complete the energy and material cycle, to minimize pollution and emission, to introduce or to modify the activities to avoid the resources intensive use and to eliminate or to reduce the dependency on non renewable energy sources. Simultaneous processing is viewed as an ideal alternative toward the industrial residues elimination. It consists in destroying the residues through high temperature in *Clínquer* furnaces which are legally certified as well as authorized to that operation with energy and minerals harnessing with no further residues generation. Nowadays the process exhibited by the enterprise “Y” accounts with the generation of a major amount of residues in one of its phases during the *Blending* production (process of mixing solid and paste residues in compartments – grinded coal rejects) of industrial residues constitutes a major environmental problem due to the large generated volume.

Based on the identification of the above described problems it was decided to create a studying group to analyze, to characterize and to suggest viable solutions to the waste generate during the *Blending* process at the “Y” enterprise.

II. THEORETICAL BACKGROUND

A. Economical Development versus Sustainable Development.

The sustainable development concept was presented by the World Committee for the Environment in April of 1987 at the UN General Meeting. The most important document generated by that committee was named “Our Common Future Report” also known as “Brundtland Report” in which the sustainable development is presented as “the development which fulfills the present necessities without impeding the future generations to fulfill their own needs” [14].

[1] stated that, actually, sustainable development catalyzes a set of themes which express the yearnings and aspirations of the contemporaneous society which could be divided into the

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diverse social compartments which composes the globalized world. That same author states that the sustainable development involves interdisciplinary activities as its evolution induces the people to work under three macro themes which composes the known “*Triple bottom line*”, i.e., environmental issues, social issues as well as economical issues. The synergy among these aspects permeates the application of the sustainable development concept or, in other words, sustainability, wherever it is being applied, at governmental level, in the civil society or at enterprise domain.

B. Environmental Impacts

According to the Environmental National Committee resolution [5], in the paragraph 001/86, article 1º, the term environmental impact is defined as all the physical, chemical and biological alterations on the environment caused by material or energy form generated by human activities which directly or indirectly affects human health, population wellness and environmental quality. [12] states that the Evaluation of Environmental Impact (EEI) should be understood as a pre-emptive instrument of public policy which turn efficient only if is taken as a decision maker tool. A project conception and planning tool in order to effectuate a sustainable development should overcome the developing process showed as a synonym of economical growth ignoring the environmental, cultural, political as well as social issues.

Based on these considerations it should be emphasized that if large economical, touristic, industrial or real state projects, in smaller or in larger scale have been or will be implanted under the scope of this subject matter, they can be analyzed through the harm or through the benefits generate from such venture. Beyond the impact to the natural environment, by no means a venture implantation would avoid cultural and social disorganization to the local population which is interpreted as new consumption habits, financial needs and the abandonment of traditional productive practices.

C. Solid Waste

The solid waste concept as defined by the Brazilian Regulation Norms [3] say: “solid wastes are material components encountered in solid or in semi solid state generated from products use or transformation. Part of these wastes is produced in great urban centers, originated mainly from domestic houses, schools, industry and civil constructions which are composed of recyclable materials which can be directed to the producing chain, generating income to the workers, profit to the enterprises and mainly residues disposed to the environment”. [19]. states that the of normally solid residues resulting from human and animal activities are rejecting material, however they are still of some value.

D. Residues Classification

In order to follow the Brazilian Regulation Norms (NBR - 10.004/04 [3] residues are classified as follows:

- a) Class I residues – dangerous.
- b) Class II residues – not dangerous.
 - Class IIA residues – not inert.
 - Class IIB residues – inert.

Class I residues – Dangerous. Due to their characteristics as inflammability, corrosivity, reactivity, toxicity and pathogenicity, they are considered harmful to the public health, contributing to, or provoking mortality increase or even causing adverse effects in the environment if handled or disposed without adequacy.

Class II Residues – not dangerous. They do not present dangerous characteristics. Examples, wood, plastics, card board, paper, sugarcane bagasse, etc.

Class II A Residues – not inert. These residues may present biodegradable, combustible or water soluble characteristics. They are inert in terms of the above referred norm.

Class II B Residues – inert. Any residue which representative sample was taken as prescribed by the ABNT NBR 10007 norm if set in dynamic or static contact with distilled or deionized water at room temperature, as ruled by the ABNT NBR 10006 norm, none of their constituent turn soluble at concentrations greater than the potable water patterns, excepting for color, turbidity, hardness and taste.

E. Solid Industrial Residues

Industrial solid residues deserve appropriate treatment which is associated to the collecting, conditioning, transportation as well as destination procedures due to their highly harmful characteristics to living individuals. It is observed that beyond the produced quantity and the selected treating technology, the solution of the industrial residues problems should obey the legislation as well as the treatment place [16].

Industrial solid residues are classified by the Brazilian Association of Technical Norms (ABNT) as three main classes, as Class I – dangerous, Class II – not inert and Class III – inert. [7] states that industrial residues can be divided into *organic* residues (solid, liquid and gaseous) and *inorganic*. Solid residues belonging to Class I exhibit no commercial value, deserving disposal. In the USA, residues are listed according to the *Environmental Protection Agency* (EPA) or if they show one of the four characteristics as inflammability, reactivity, corrosivity and toxicity the residue is classified as *dangerous* [10].

F. Residues Co-processing

The first residue burning in Clinquer producing furnaces took place in the 70th decade. In Canada tests were carried with chloride residues through moisturized process. In France and in Sweden tests were carried in 1978 also with chloride residues [9].

Burning practices of industrial residues in cement furnaces took place in the year of 1979 from which it has been adopted in all over the world [13].

Estimates reveal an amount of 400.000 metric tons of tires burned in the European Union in the year of 1997 and 600.000 metric tons of liquid residues employed as alternative fuel source to feed Clinquer furnaces in cement factories.

[18] reported that burning practices started in the year of 1980 in Japan and in 1990 close to 26 kinds of industrial residues have been burned, saving 110 000 metric tons of coal.

Industrial residues of different origin have contributed as alternative energy source in rotative furnaces for Clinquer and cement production to recuperate the material instead of forward them to simple disposal. That procedure can be considered correct if harm to the environment, to the public health, to safety, equipment deterioration and Clinquer/cement contamination are avoided.

The application of residues in furnaces faces environmental laws as well as the Clinquer fabrication process restrictions. The residue qualification as fuel substitute is close associated to the thermal energy liberation during the combustion process and its application as raw material should consider calcium aluminum, silicium and iron contents.

Residues injection timing into the furnace depends on its application. Residues applied as raw material substitutes are introduced into the mill together with the remaining material. However, the residues used as fuel substitutes are injected at flame nozzle or into the smoke box, depending on the material characteristics. Fig. 1 illustrates the residues injection during the cement fabrication.

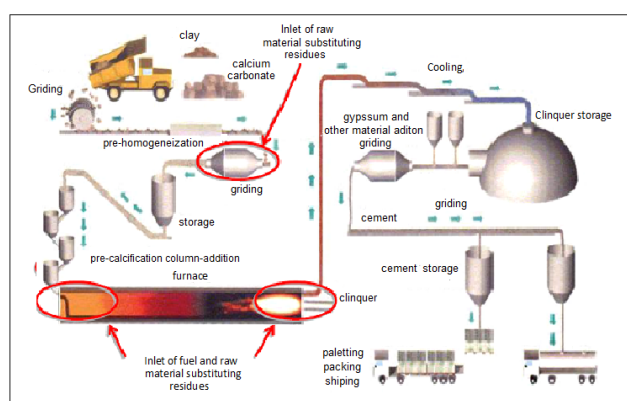


Fig. 1 Cement co-processing diagram. Source:MARINGOLO, 2001.

G. Industrial Solid Residues Already used in Co-processing

It can be mentioned, as example, some residues as painting and oily clogs, mud generated at the Sludge Treatment Station (ETE), plastics and contaminated papers, tires, etc. Table I exemplifies some of co-processing residues encountered at national industries [9].

TABLE I
CO-PROCESSING RESIDUES

Sector	Residues
Siderurgy	Feeding Clogs, emulsions and residual oils, greases, slags
Surface Treatment	Mud, varnish and painting clogs
Aluminum	Aluminum clogs, sodium oxalate clogs, Skimming clogs.
Ruber	Tires, metal spares and barbs
Petroleum Chemistry	Solvents, neutral clogs, petroleum clogs, phosphate clogs, acid clogs, catalizers.

Automobile Industry	Painting clogs, solvent clogs, phosphate clogs, plastics and sheets.
Packs	PET, plastics excepting PVC
Civil Construction	Housing construction junks

Source: [9].

H. National and International Residues Co-processing Scenery

Brazilian cement industry includes 58 units spread throughout the country which is divided into 10 groups and from which 11 of them are devoted to milling process and 47 to fabrication. From that total number, only 32 of them hold legal state permission for residues co-processing and the remaining units are undergoing through the legal allowance procedure. National residues generation is estimated in 2.7 millions of metric tons, observing that the cement industry co-process 800 thousand of metric tons per year which corresponds to 30% of the total. It is expected to rise that Fig 1 to 1.5 millions of metric tons in [4] Table II exhibits data of thermal substitution in cement furnaces in overall the world.

TABLE II
PERCENTAGE OF THERMAL RESIDUES SUBSTITUTION AROUND THE WORLD

Country	% of Thermal Substitution By Residues
USA	25%
France	32%
Germany	42%
Norway	45%
Switzerland	47%

Source: [4]

I. Incident Legislature

As stated by the National Environment Council [5], *co-processing* is a name given to the industrial residues destination by thermal destruction at high temperatures during Clinquer fabrication which are properly prepared, taking advantage of generated thermal energy as well as of the mineral fraction as raw material.

J. Residues Processing

In order to increase co-processing capacity as well as to lower down furnaces operational disturbances, residues can be previously blended to obtain the *blends* which chemical compounds and thermal power are homogenized. Two types of blends are commonly produced ("Y" enterprise + GTZ):

a) Solids – obtained by mixing solid and paste residues of calcium carbonate powder, saw dust or grinded coal, which is named MR 10 (fine solid of granulometry number 10), MR 100 (coarse solid with granulometry number 100) and MR 200 (sieve rejected material holding granulometry number 200).

b) Relifuel – obtained from the homogenization of liquid residues.

III. MATERIAL AND METHODS

A. Sampling

Five samples were collected from the material being directed to the furnace during the blending sieving process at 3 hours interval each reading. These samples were collected for three weeks to quantify the rejected material MR 200 which is generated during the blending sieving.

B. Data collection procedure

Data were collected through the identification of the material belonging to the rejects during a full processing residues producing period. Rejecting materials generated by the customers of the Enterprise Y had been analyzed because an excessive amount of rejects MR200 had been encountered at the blending production final steps. Field workers were interviewed on appropriate formulary for previous identification of impacting residues on rejects generation.

C. Data Analysis Method

Information was organized by means of the Pareto's diagram. "The Diagram of Pareto is a graphic representation which permits the identification of the most important causes of a problem, establishing the priorities toward a solution. In that kind of diagram, the problem causing factors are listed in a sequence of importance, showing by that way, the ideal sequence toward the problem solution [2]. Information was classified based on residue type and quantity generated during the sampling period under consideration, identifying also the customer. .

D. Organizational Study

Enterprise Y offers environmental solutions from the industrial residues co-processing technology in the cement furnaces. Laboratory and Treatment Stations support associated to the official authorities supervision, the Enterprise Y to guarantee appropriate destination to the industrial residues. The operation follows the Integrated Management System adopted by the Enterprise X as well as the World Co-processing Policy and it is certificated by the ISO 9001 (quality) and by the ISO 14001 (environment).

The enterprise under study is located in the Belo Horizonte Metropolitan area, in the State of Minas Gerais. Enterprise Y accounts with 37 workers, with the Enterprise X plus 03 extra workers, adding up to 40 collaborating personnel. Enterprise Y is located in an area of 48,857 m² which is inside of the Cement Industrial Area exhibiting a total area of 5,535.41 m²

IV. RESULTS

A. Enterprise Productive Processing

The residues co-processing system diagram flux of the Enterprise located in Belo Horizonte Metropolitan Area is detailed as follows.

a) Characterization. Reception of residues samples collected at the generator followed by analysis to confirm and/or to characterize the material in the enterprise laboratory.

b) Licensing. Documents elaboration to obtain the license of the residues from official authorities.

c) Management at the origin. Residues management at the generator, supporting its identification, internal transportation,

issuing of documentation of safety, proper conditioning and loading.

d) Logistics. Identification of enterprises specialized in harmful material transportation, accounting with specific equipment as well as with trained personnel to handle the residues to guarantee the material transportation from the origin to destination trajectory. If the transportation service is contracted by the residue generating enterprise, the enterprise X will offer orientation and adequate indications according to the needs of each enterprise.

e) Residues treatment and improvement. Handling, characterization, control, improvement and homogenization and/or residues preparation to adequate them for co-processing in the cement furnaces.

f) Co-processing. Techniques for residues thermal destruction in high temperature Clinquer furnaces, properly prepared for that activity as well as properly officially permitted, employing the generated energy and the mineral fraction as raw material.

g) Certificate of thermal destruction (CDT). The Integrated Residues Management System cycle is completed with CDT issue which guarantees the proper residue destination.

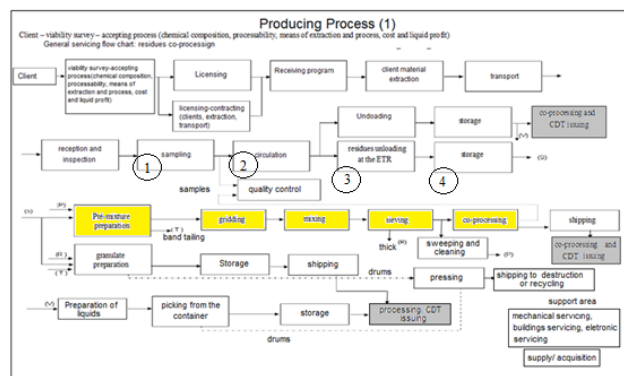


Fig. 2 Processing and co-processing diagram. Source: X Enterprise SGI manual, 2011

Residues processing is illustrated on the diagram of the Fig. 2. Blending processing 1,2,3 and 4 are viewed in the macro format as well as in yellow color and amplified on Fig. 3.

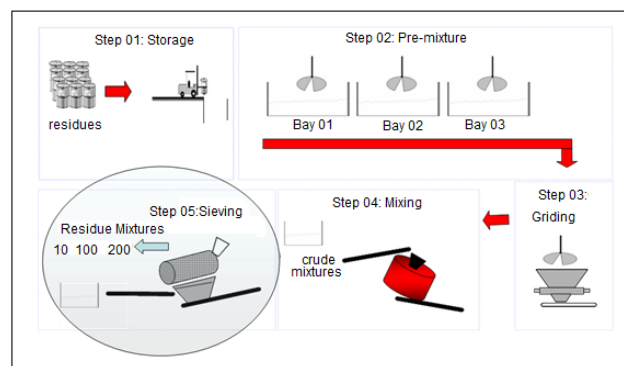


Fig. 3 Co-processing diagram

It can be observed on Fig. 3 at the step 1 in the blending preparation diagram that 04 bay of 200m³ each are employed and 03 of them are used for liquid-paste residues transport in container wagons or in dumping wagons up to the unit. In one of these bays used to produce the blending which receives diverse residues in containers of 200 liters, the presence of plastic residues are noted due to the packing method applied to avoid the contact of the material with the container.

At the step 2, in the flow diagram the ST's (grinding solids), are constituted by material like papers, plastics, oil contaminated wood pieces, greases and solvents which are grinded to reduce its granulometry. At this step a grinder of 30 metric ton/hour is employed.

At step 3 on the preparation flux diagram, the paste and grinded residues mixing and sieving procedures take place.

At step 4 in the preparation flux diagram the material is sieved to prepare the MR 200 material sieving as well as the material which is the object of this study.

B. Rejected material MR 200 identification and quantification

Five samples were collected at each 03 hours interval for one week at the sieving step of the blending being forwarded to the cement furnace. Collected samples exhibited similar behavior. Table III displays the characteristics of the collected material generated during only one collection of 03 hours.

TABLE III
ENCOUNTERED RESIDUE DISTRIBUTION IN THE MR 200 MATERIAL

Material	Quantity in metric tons	%	Accumulated (%)
Stones over 200 cm	19	59,38	59,38
Mr 100	7	21,88	81,26
Metal	5	15,63	96,89
Wood	0,85	2,66	99,55
Plastics	0,15	0,45	100

Table III shows the encountered material as well as the corresponding quantity and some useful characteristics.

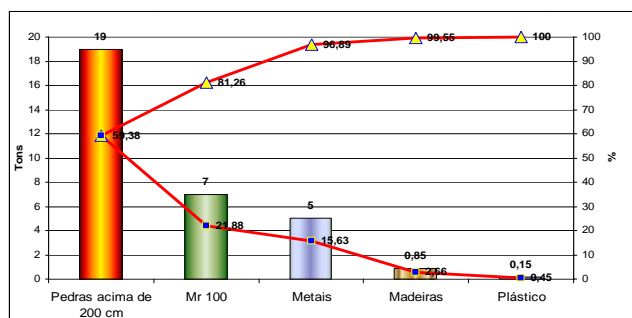


Fig. 4 Pareto's graphic for the rejected material MR 200 quantity and identification.

Fig. 4 presents the identification and quantity of the material encountered at the final blending sieving step by

means of the Pareto's graphic. This information is considered important for this study, also referring to Table II.



Fig. 5 Instrument applied in sample collection (shoveling machine)

The employed equipment is shown on Fig. 5 which is "L60" shoveling machine model of 3.6 metric tons capacity monitored with an electronic instrument for automatic weighing.



Fig. 6 MR 200 rejecting material which consists holds granulometry larger than 200 mm.

The material collected at the final blending sieving step, named MR 200 can be observed on Fig. 6.

Blending preparation requires four bays of 200m³ each. Three of these bays are used for liquid-paste material which is transported to the enterprise facilities by tank vehicles or by dumping wagon.

It has been also identified the presence of plastic packing employed to keep the material inside the containers.

C. Method of Interviewing the Workers

Information collection included visits to the area under study as well as the identification of the possibilities MR 200 generation reduction.

Workers interview were held during the current production process which included the ground workers, loading shovel operators, production leaders, which hold, all of them, knowledge on the production system and on the causes of MR 200 generation. These interviews are detailed on the questionnaire form for field research.

D. MR 200 rejecting material re-processing viability evaluation.

The examination of enterprise documents revealed the viability of reducing the MR 200 material at the initial phase of the process.

TABLE IV

FUEL EMPLOYED TO GENERATE 145,000 METRIC TONS OF CLINQUER

Fuel Employed To Generate 145,000 Metric Tons Of Clinquer			
fuel	metric tons	%	% kcal/ kg
imported/national cok	9338	42,02	61,7
	8873	39,93	33,09
other fuels	2596	11,68	3,36
mr 100	1416	6,37	1,85
total	22223	100	100

Table IV details the quantities of the fuels employed to produce 145,000 metric tons of Clinquer for cement production.

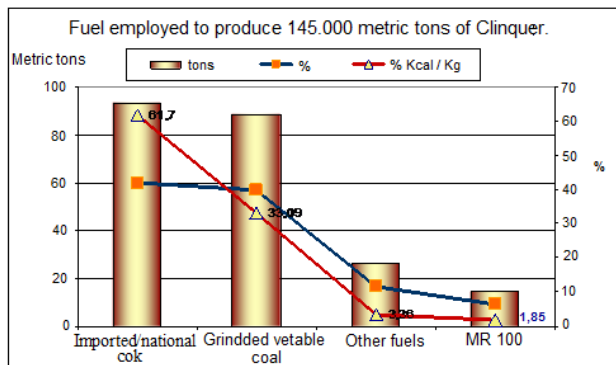


Fig. 7 Fuel employed to produce 145,000 metric tons of Clinquer.

The graph displayed on the Fig. 7 list the contribution of each kind of fuel to produce 145,000 metric tons of Clinquer. It should be considered that the MT 100 also offers thermal contribution to the furnace.

Table V details the cost of each fuel according to the information written on the Production Formulaire (Anex A). It can be observed the MR 100 cost in respect to the cok.

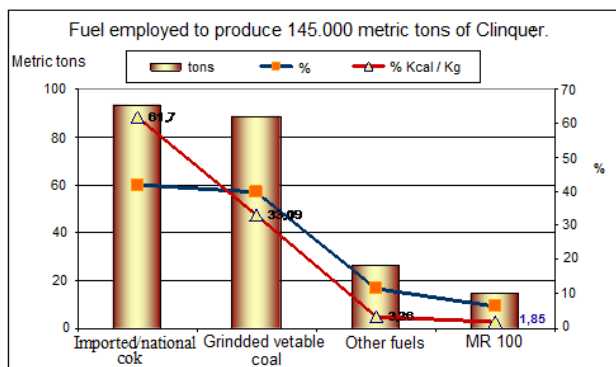


Fig. 8. Cost associated to each kind of fuel and the quantity added to the furnace to produce 145, 00 metric tons of Clinquer.

The graph displayed on Fig. 8 shows the cost associated to each kind of fuel as well as the quantity added to the furnace to produce 145, 00 metric tons of Clinquer.

TABLE V

FUEL COST FOR PRODUCTION OF 145,000 METRIC TONS OF CLINQUER

Fuel Costs Associated To The Generation Of 145,000 Metric Tons Of Clinquer			
Fuel	Metric Tons	R\$ / ton	Total Cost
Imported/Nati			
onal Cok	9338	460	R\$ 4.295.480,00
	8873	150	R\$ 1.330.950,00
Mr 100	1416	450	R\$ 637.200,00
Total	19627	1060	R\$ 6.263.630,00

TABLE VI

COST LIST ASSOCIATED TO THE TREATMENT OF THE MR 200 MATERIAL

MR 100 and MR 200	Tons dia	Tons mês	R\$ Mês
Consumption of MR			
100 no F (?)	59	1446	R\$ 637.200,00
MR 100 generated on the rejecting material	18,66	448	R\$ 201.600,00
MR 200 treatment cost	85	2047,8	R\$ 184.320,00

It is observed on Table VI the treatment required by the MR 200 material is lower than the benefits generated in adding it into the furnace, considering a 24 days month.

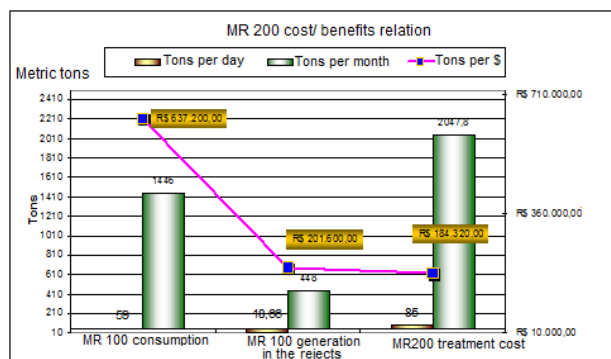


Fig. 9 Cost and benefits associated to the MR 200 treatment

It can be observed from the Fig. 9 the cost associated to the MR 200 treatment is lower than the benefits of the material reuse by its injection into the furnace which generates a gain on R\$ 17000.00 at each 24 producing days of work.

E Proposal for MR 200 Generation Reduction and Recycling.

Changing opportunities have been identified through the applied questionnaires during the personnel interview. Proposed solutions toward these opportunities associated to the MR 200 reuse can be divided into two categories, as follows.

F. Proactive Solutions

The study of the costumers which directly contributes to the MR 200 generation fits into the proactive solutions. These costumers were analyzed through the cost/benefits relation of the received amount of MR 200 material and the generated MR amount that should be treated. It has been noticed that the MR 200 treatment reaches the value of R\$ 90.00 per metric ton meanwhile these material are received with the price

varying from R\$ 35.00 to R\$ 120.00 per metric ton, indicating an economy viability study, or even to brake the contract with these enterprises.

A second proposed solution suggests the residue quality control by sieving and separating the material which contributes to the MR 200 generation. As example, the material received from known clients should be sieved and to separate the material exhibiting granulometry larger than 200 mm right at the beginning of the process

These actions would avoid the generation of 19 metric tons of MR 200 in the final process and it also generates income because product discarding together with theses rejects will be avoided.

Another suggestion indicates the use of a single bay to concentrate the material coming from costumers which generate MR 200, preventing contamination of the remaining bays with materials which slow down the operating flow.

G. Reactive Solutions

One of the reactive solutions suggests the installation of grinder to treat the MR 200 referring to the material holding components of size higher than 200 mm. Another reactive solution suggests the installation of metal detectors to discard metallic pieces before sieving, living only plastics, wood, stoners in order to improve the grinding process. That solution should undergo through an cost/benefit analysis to evaluate the installation costs of new equipments as associated to the MR 200 treatment cost.

V. CONCLUSION

The natural resources o four planet had been used by the mankind at unsustainable levels. Next generations will not be able to use natural resources and to discard the residues as the nowadays practices are carried. If the ecological conscientization are not included into the enterprises goals, government and population will experience growth rate restricted by resources limitations, as well as by growing difficulties in meeting the demands for material and energetic resources. Resources use will be also limited by the environment capacity in assimilating the resources generated. The author had the opportunity to interact with the objective of this research work, i.e., the MR 200, observing what actually occurs in the generation of that phenomenon. The operation personal engagement in the work proposal was greater than it was expected.

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