ENVIRONMENTAL ADJUSTMENT: THE "FIVE STEPS METHOD" APPLIED TO THE CERAMIC TILE INDUSTRY

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(*) Visiting Research Fellowship - CNPq Process No: 301372/96-9

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1. ABSTRACT

The techno-scientific knowledge of the ceramic tile production process, studied from an environmental point of view, can reduce the amount of waste to levels below current ones. Besides, it allows the re-use of water, an optimized use of energy and of raw materials, decreasing waste volumes, and consequently lowering costs. The routes that lead to the environmental adjustment are not intrinsically complicated. It requires planning and organization of procedures, establishment of feasible goals, identification of the causes. In this way the simplest problems are solved first, followed by more complex ones, implementing corrective actions. The "Five Steps Method" was developed and applied, based on methodically organizing actions to achieve the environmental adjustment. A sequence of procedures, divided into five steps, applied to a specific industrial establishment, allowed the definition of priorities regarding the points that needed to be worked out, once they had been identified, through a gravity X frequency matrix. Two critical points were identified, two significant points, two points with "reduced effect", and two points with marginal "effects". The critical points were detected in the glaze preparation and decoration section and in the decoration line. The "significant" points were detected in the kiln section and air filter system. For each of these points correction actions and controls were suggested and applied

to decrease the generation of solid wastes. The qualitative and quantitative data obtained were registered on forms specifically developed for each of the five steps, guiding the implementation of corrective actions. In this way, the environmental aspects of the production process were documented, supplying a realistic position of the studied industry in relation to the environment. The "Five Steps Method" is a management tool for continuous improvement, supplying information and guiding the application of corrective measures.

2. INTRODUCTION

One of the strongest demands in an enterprise, in order to face a competitive market and worried with the environmental aspects, is its environmental adjustment. To reach this target planning and organization of procedures are needed, setting feasible goals, identifying the causes, at first looking to solve the simplest problems and implement corrective actions.

To accomplish the evaluation of environmental impacts of an enterprise it is important to know the production process and its peculiarities, so that the evaluation criteria to be specified are compatible with the risks and complexity of the appraised facilities. This knowledge can be acquired by means of detailed surveying of the production sequence, so that no information is left without being considered (FERRARI, 2000). This procedure is the same adopted in an environmental audit for evaluation of the series of Standards ISO 14.000 (BATALAS, 1996).

In this context, the methodology of the Five Steps was developed for environmental adjustment, applied here in the evaluation of the ceramic tile production process, though it could equally be applied to any other sector, after taking into account the specific characters of each.

This method is not enough to achieve the environmental certification for the enterprise; even so it precedes it. It constitutes a management tool and guide toward continuous improvement, because it records and organizes the data obtained on appropriate data sheets for each step. The Five Steps Method will indicate an up to date position of the enterprise in relation to the environment, supplying data to map the production process, from an environmental point of view. It will enable hierarchizing the problems related to the wastes generated in the different stages relative to its pollutant effects. This information will form the basis for the proposals of specific corrective actions for each observed nonconformity, besides the follow-up of its efficiency, by means of the comparison of the data obtained in the routine evaluations. The Five Steps Method for environmental adaptation allows the company to accomplish the identification of the environmental aspects, based on the applicable legal requirements, establishing practices and procedures keeping in mind eco-management and pollution prevention.

3. METHODOLOGY

The Five Steps Method for environmental adjustment is a set of actions that facilitates the identification of the environmental problems of an industry. Following each one of the steps it is possible to establish how the industry is polluting, and obtain information on which places in the production process are generating wastes. It allows identifying which

of these generate dangerous wastes, the amount of generated waste and, mainly, helps in taking decisions to control and decrease the environmental impacts of the enterprise. Figure 1 displays the organization of the method applied to an industry.

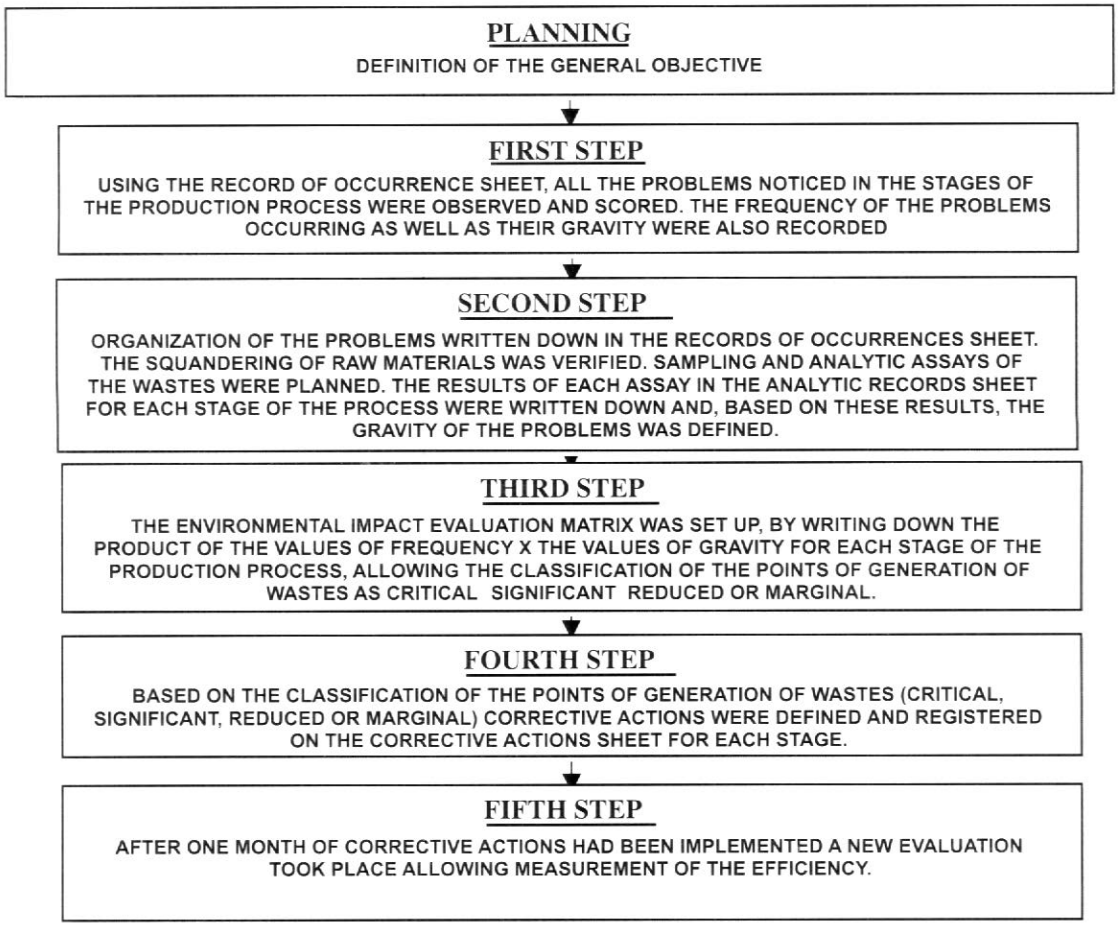


Figure 1: Schematic flow diagram of the organization of the Five Steps Method.

4. APPLICATION OF THE METHOD

4.1. PLANNING

In order to achieve the environmental adaptation of the industry the following general objective was set: "to establish the updated position of the enterprise in relation to the environment." With the purpose of reaching it, actions were defined, organized in the five steps establishing, for each one, intermediate objectives and targets.

Step 1: Identification of the points of generation of wastes
Step 2: Characterization of the wastes
Step 3: Identification of the pollution effect of each point
Step 4: Establishment of corrective actions
Step 5: Follow-up

With this, it was possible to organize the information and, at the same time, to document the environmental aspects of each stage of the production process, backing up the environmental control of the process for its continuous environmental improvement.

4,2 FIRST STEP: IDENTIFICATION OF THE POINTS OF GENERATION OF WASTES

The objective of the first step was to identifying the wastes generated in each stage of the production process, to survey the environmental aspects of the production process. The observations were written down on the **Records of Occurrence Sheet** exemplified by the figure 2.

RECORDS OF OCCURRENCE SHEET N° 08

COMPANY:	CTI-25/01
ADDRESS:	XXXXXX
RESPONSIBLE FOR THE EVALUATION:	Paulo Miranda — Signature:
DATE: 03-07-2001	HOUR: 1:45pm
SECTION:	Silkscreen
STAGE:	Decoration line
SECTION S ENCHARGED:	XXXXX
PRODUCT (NAME OR CODE):	XXXXXX
TYPE OF GENERATED RESIDUE	(X) S LID — (X) LIQUID — ( ) GASEOUS

DESCRIPTION OF OBSERVED OCCURRENCES

- It was noticed, over the whole extension of the decoration line, misalignments and differences among adjacent segments of belts. The accentuated differences, with different speeds among aside segments, occasionally causes fall of pieces, especially in the curves.
- At the stage of glaze application it was verified that the applied material was dripping over the belts and falling on the floor, besides dirtying the inferior surface of the pieces, facilitating the impregnation of the belts and/or becoming attached to the kiln rolls.
- The liquid effluent generated by the equipment s wash and the solid residues generated by broken pieces are drained to the same canal, increasing, this way, the volume of solid residues.

Figure 2: Record of Occurrences Sheet for registration of environmental irregularities and of other important aspects.

Using the **Records of Occurrence Sheet** (figure 2) the non-conformities were logged, from an environmental point of view, of each stage of the production process, organized in tables 1 and 2.

This information, scored in the Records of Occurrence Sheet, elaborated for each stage of the production process, laid the basis for the definition of the evaluation parameters relative to the frequency and gravity of each occurrence. It contributed to the establishment of criteria to take decisions for the implementation of corrective actions and control of losses, as well as in the elaboration of a sampling planning for the characterization of the wastes.

STAGES OF THE PROCESS	OBSERVATIONS	GRAVITY and FREQUENCY
Provisioning of the Silos	During the discharge of the ceramic mass to supply the silos, the generation of particulate material in significant amounts occurs, largely due to blockages. The cause of these blockages can be the formation of crusts of raw materials in the internal walls of the tank of the truck and in the hoses that go to the silos, due to eventual humidity increases in the mass.	Concerning gravity, it was considered that there is moderate generation of wastes, which can be recycled. Concerning frequency, it was observed that it occurs sometimes in the course of the process.
Silos	In the internal walls of the silos incrusted material can form. The removal of this material from the internal walls of the silos can generate waste, which will be discarded in older open pit clay mine.	Moderate generation of wastes, which would not be re-used, was found. The observed frequency was considered to only occur sometimes during the activities of the production process
Belt to press	Generation of very fine particulate material.	With regard to gravity, during this stage it was verified, that a small generation of dust occurs. With regard to frequency it is considered to happen permanently after initiating the activity.
Sleeve Filter System	The system of capture of the dust particles generated during pressing of the pieces is efficient, though the collected material is discarded in old mining sites, together with other materials, not being re-used, thus generating pollution not only in collecting, but also during transportation and in final disposition.	It was observed that there is moderate generation of wastes, occurring several times in the course of the production process.
Presses	The wastes of the sieve close to the presses are picked up in a wheelbarrow and discarded with the other wastes.	The generation of these wastes was considered worthless, happening several times during the process
Kiln	Due to misalignment of the belts breakage of unfired pieces occurred, considered as non-toxic wastes, during the transport.	In this stage, it was noticed that there is moderate generation of wastes. With regard to frequency, it was noticed that it happened several times in the course of the process.

Table 1: Organization of the observations noted in the records of occurrences elaborated for each stage of the process of ceramic tile production.

STAGES OF THE PROCESS	OBSERVATIONS	GRAVITY is FREQUENCY
Preparation of inks and glazes	• The washing of the mills happens after each change of colour of the decoration mass, generating liquid effluents and solid wastes with presence of toxic metals. • The provisioning of the decoration lines with pastes and engobes is made by vessels with agitation equipment. The transportation of these vessels causes eventual spills.	The observed gravity was that there is squandering of raw material, happening several times in the course of the process.
Decoration line	• There were noticed, in the whole extension of the decoration line, height differences among the belts and misalignment among the segments of adjacent belts. The accentuated differences, with different speeds among the segments caused pieces to fall, especially in the curves. • In the engobe application stage, it was verified that the applied material was dripping over the belts, falling on the floor, besides dirtying the bottom part of the pieces, so that it could impregnate the belts and the kiln rollers. • The liquid effluent and the solid wastes generated by the washing of the equipment are captured by the drainage canal, contaminating broken pieces thus increasing the volume of wastes. • There is not a system to collect the splashes over the whole extension of the transportation belt that cross the application cabin, nor a protection system on drainage canals to avoid the entrance to the system of treatment of liquid effluents of broken decorated pieces. • It was still observed that the vessels with engobe and pastes for provisioning the decoration line became overfilled, facilitating material spills.	In each one of these observations there is raw material squandering. Considering that the decoration line is a continuous activity, it was considered that the observed non-conformities happen permanently after starting the production activities.

Table 2: Organization of the observations registered in the Occurrence Sheet elaborated for each stage of the process of Ceramic tiles production. (Continuation of the table 1)

4.3 SECOND STEP: CHARACTERIZATION OF THE WASTES

The objective of this step was to characterize solid wastes and liquid effluents generated in different stages of the production process, and compare to the values established by the legislation concerning the concentration of toxic metals. The obtained results above the legislation (SÃO PAULO, 1976; ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS, ABNT NBR 1004, 1995) were organized in the **Analytic Records Sheet**, according to figure 3. It shows quantitative data, the evaluation parameters concerning the gravity related to these wastes, complementing the information of the occurrence records.

ANALYTIC RECORD SHEET N°. 01

COMPANY: CTI-25/01 DATE: 03-16-2001

Responsible for evaluation: Kátia Ferrari Signature: Hour: 2:30 pm

STAGE	RESIDUE		TYPE OF ASSEY	VALUES	ESTABLISHED MAXIMUM VALUES	OBSERVATIONS
Decoration line	SOLIDS	Process				
		scraping	FRX	7441 $mg.kg^{-1}$	1000 $mg.kg^{-1}$	lead
	LIQUIDS	Wash				
		of the line	AA	0,6 $mg.L^{-1}$	0,5 $mg.L^{-1}$	lead
	GASEOUS					

Figure 3: Analytic Record Sheet for organization and classification of the wastes according to legislation.

4.4 THIRD STEP: IDENTIFICATION OF THE POLLUTANT EFFECT OF EACH STAGE

The objective of this third step was to establish an order of priority to the points of generation of wastes of each stage of the production process.

The hierarchy of the waste generation points was found after the definition of the pollutant effect of each one of these points. The pollutant effect was defined relating the frequency which the problems happen (table 3) with the gravity of these problems (table 4).

Weight	Description
5	It happens permanently when initiate the activity.
4	It will happen several times in the course of the process.
3	It will sometimes happen in the course of the process.
2	It is not expected to happen during the process (although there is some possibility).
1	It can be assumed that it won't happen during the process.

Source: (FERRARI et al., 1999)

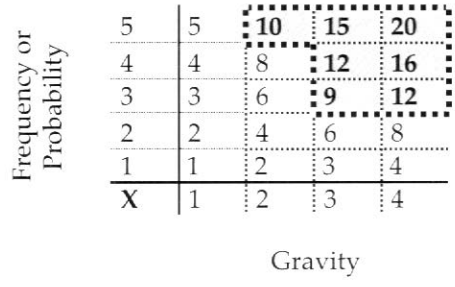
Table 3: Frequency levels or probability of occurrence of negative environmental impacts.

Weight	Description
4	Concentrations of toxic metals a great deal above the maximum limits established by legislation / notable squander of raw materials.
3	Squander of raw materials / concentrations of toxic metals a little above the maximum limits established by legislation.
2	Moderate generation of wastes / Concentrations of toxic metals about the maximum limits established by the legislation.
1	Concentrations of toxic metals below the maximum limits established by the legislation / negligible generation of wastes / Re-use of the wastes.

Source: (FERRARI et al., 1999)

Table 4: Categories of gravity of the negative environmental impacts.

To define the pollutant effect one should multiply the weight of the frequency by the weight of the gravity category attributed to the same waste that is being evaluated. The Risk Matrix (MOURA, 1998) presented at figure 4 relates the frequency weights to gravity weights.



Source–(MOURA, 1998)

Figure 4: Risk Matrix

The product, obtained by the multiplication of the weight of the frequency by the weight of the gravity, will indicate one of the four classifications for the pollutant effect:

Critical effect: equal or superior to 9 points
Significant effect: inferior to 9 and superior to 6 points
Reduced effect: equal or inferior to 6 and equal or superior to 4 points
Marginal effect: inferior to 4 points

As an example the determination of the pollutant effect is presented, based on the levels of Frequency and Gravity using the Risk Matrix:

Considering a stage where raw material squander occurs (attributed gravity with weight 3), several times in the course of the process (attributed frequency with weight 3). Applying these weights to the Risk Matrix gives the characterization of a pollutant effect classified as **Critical** (value 9), as illustrated by the figure 5:

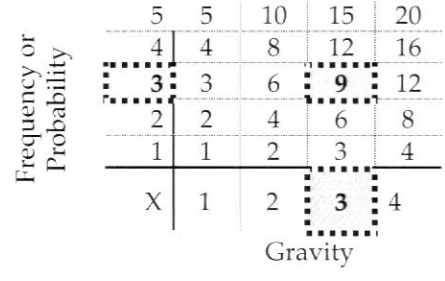


Figure 5: Simulation of the use of the Risk Matrix for obtaining the pollutant effect in agreement with the approaches specified for the levels of Frequency and of Gravity

Applying the established criteria to gravity and frequency in the **Environmental Impacts Evaluation Matrix** for the evaluation of the process of production of ceramic tiles, based on the notes registered on the Occurrences **Sheet** and on the **Analytic Records Sheet**, yields the classification of the stages concerning the pollutant effect, as presented in the table 5.

STAGES OF THE PROCESS	EVALUATION (GRAVITY X FREQUENCY)	PRODUCT	CLASSIFICATION
Provisioning of the Silos	Moderate generation of wastes (weight 2), that can be re-used, happening sometimes in the course of the process (weight 3).	6	Reduced Effect
Silos	Moderate generation of wastes (weight 2), however it is not expected to occur along the process (although there is some possibility). (Weight 2).	4	Marginal Effect
Belt to Press	Worthless generation of wastes (very fine particles) (weight 1), happening permanently once initiated the activity (weight 5).	5	Reduced Effect
Sleeve Filter System	Moderate generation of wastes (weight 2), happening several times in the course of the process (weight 4)	8	Significant Effect
Presses	Worthless generation of wastes (weight 1), happening several times during the process (weight 4).	4	Marginal Effect
Kilns	Moderate generation of wastes (weight 2) that happens several times in the course of the process (weight 4).	8	Significant Effect
Preparation of inks and glazings	Squander of raw materials, presenting concentrations of toxic metals a little above the maximum limits established by legislation. (Weight 3), happening several times in the course of the process (weight 4).	12	Critical Effect
Decoration line	Squander of raw materials, presenting concentrations of toxic metals a little above the maximum limits established by legislation. (Weight 3), happening permanently once initiate the activity (weight 5).	15	Critical Effect

Table 5: Classification of the stages of the process of production of ceramic tiles relative to the pollutant effect, established according to the gravity data and observed frequency.

Organizing this information in the **Environmental Impacts Evaluation Matrix** (figure 6) gives the ranking of the points of generation of wastes. It will supply an environmental mapping of the production process according to the classification of each stage considering the degree of contribution of its pollutant effect: critical, significant, reduced or marginal (FERRARI et al., 1999). In this way it will provide the basis for specific corrective actions for each observed nonconformity.

ENVIRONMENTAL IMPACTS EVALUATION MATRIX N° 001

COMPANY: CTI-25/01

ADDRESS: XXXXXXXXXX

RESPONSIBLE FOR THE EVALUATION: Paulo Miranda and Kátia Ferrari Signature:

DATE: 03-20-2001 HOUR: 3:00 pm

ENVIRONMENTAL PARAMETERS / STAGES OF THE PROCESS	RESIDUES							EFFECT'S CLASSIFICATION			
	LIQUID			GASEOUS		SOLID					
	COLOR	SOLIDS IN SUSPENSION	TOXICANT METALS	VERY FINE PARTICULES	GASES OF COMBUSTION	DANGEROUS RESIDUES	NON DANGEROUS RESIDUES	CRITICAL	SIGNIFICANT	REDUCED	MARGINAL
PROVISIONING OF THE SILOS				6			6			X	
SILOS				4			4				X
BELTS TOTHE PRESSES				5			5			X	
SLEEVE FILTER PRESSES				8			8		X		
PRESSES							4				X
STOVES							8		X		
PREPARATION OF COLORS AN GLAZES			12			12		X			
DECORATION LINE			15			15		X			

Figure 6: Environmental Impacts Evaluation Matrix.

4.5 FOURTH STEP: ESTABLISHMENT OF CORRECTIVE ACTIONS

In the fourth step, the objective was establishing corrective actions to attenuate the pollutant effect identified in each stage of the production process, to decrease the squander of raw materials. Figure 7 presents the proposed **Corrective Actions Sheet.**

In this Sheet the observed environmental problems and the indication of the correctives actions were described so they could be implemented in the production process. These actions were based on the information acquired in each one of the previous steps, mainly, the information on the hierarchy and the classification of the pollutant effects of each stage.

CORRECTIVE ACTIONS SHEET		Nº: 08
COMPANY: CTI-25/01	DATE: 03-23-2001	
Responsible for the evaluation: Paulo Miranda and Kátia Ferrari	Signature:	Hour: 9:00 am
STAGE	OBSERVED PROBLEMS AND THE CORRECTIVE ACTIONS	
Decoration line	1. Correct differences and misalignments and adjust the speeds among the segments of the belts of the whole production line; 2. Adjust the flow of provisioning of the engobe; 3. Create a protection for the drainage canals to avoid entrance of decorated broken pieces 4. Define and monitor a maximum level for the provisioning of the vessels, in way to avoid material spill; 5. Articulate with the glaze and ink suppliers the production of materials with low lead grades	

Figure 7: Corrective Actions Sheet for description of the observed environmental problems and the indication of the corrective actions.

Table 6 presents a synthesis of the corrective actions suggested for the stages of the production process with the respective effect classification: critical, significant and reduced.

POLLUTANT EFFECT	CORRECTIVE ACTIONS
Critical effects	1. Installation of an automatic closed circuit system for the supply of the decoration lines. 2. Definition, for each mill, of a glaze pattern, with the addition of colouring matters after milling, directly in the recipients that provision the line, eliminating the washing of the mills 3. Correct differences and misalignments and adjust the speeds among the segments of the belts of the whole production line; 4. Adjust the flow of provisioning of the engobe; 5. Installation of "big bags" under the cabins of application of enamels during its wash in order to catch the solid wastes. 6. Define and monitor a maximum level for the provisioning of the vessels, in way to avoid material spill; 7. Articulate with the glaze and ink suppliers the production of materials with low lead grades.
Significant effects	1. Implant a recovery system of the very fine material captured by the sleeve filters to be incorporate in the ceramic mass; 2. Adjust the misalignments of the belts and table after the kiln. Incorporate to the ceramic mass, the generated waste resultant of the falling of pieces.
Reduced effects	1. Improve the maintenance of the hoses of provisioning of the silos to identify and to eliminate the leak points; 2. Project a confinement system for the belts that feed the presses. 3. Project system of recovery of the very fine material collected in the sleeves, in the provisioning of the silos and in the belts of provisioning of the presses, to allow that the recovered material can be incorporated to the milling system, or offered for sale.

Table 6: Synthesis of the corrective actions suggested for each stage of the production process with the pollutant effect classification: Critical, Significant and Reduced.

The first corrective actions implemented looked for to solve the simplest and low cost problems, this way achieving improvement results and contributing to decrease some of the effects initially classified, as significant or critical.

4.6 FIFTH STEP: FOLLOW-UP

In search of the continuous improvement of the environmental quality of the production process the last step had as objective to verify the efficiency of the actions implemented. It is aimed to reach continuous improvement of the environmental quality of the production process and keep actualized the position of the enterprise in relation to the environment. The follow-up was accomplished by comparing the data scored in the first evaluation with the data obtained by the second evaluation, performed one month after the proposed actions implantation. Table 7 presents the results of the corrective actions applied to the stages classified as critical.

STAGES OF THE PROCESS	CORRECTIVE ACTIONS IMPLEMENTED	RESULT
Preparation of inks and glazings	• Definition, for each mill, of a glaze pattern, with addition of colouring matters after milling directly in the vessels that supply the line, eliminating some washing of the mills	Average reduction of 50% of the solid wastes generated in this stage
Decoration line	• Definition and monitoring a maximum level for the provisioning of the vessels, avoiding material spilling; • Adjustment of the glaze application flow and adaptation of equipment to collect the excess of glaze, avoiding squander. • Installation of "big bag" under the cabins of application of enamels during its wash; • Correction of height differences and misalignments of belts and adjustment of the belts speeds of contiguous belts segments over the whole production line.	Average 90 kg/day recovery and re-use of synthetic raw material (glazes and inks)

Table 7: Results of the corrective actions applied in the stages classified as critical pollutant effect, verified after one month after implementation of actions.

The results of the corrective actions in these stages were reflected in a 70% decrease of the total solid waste generated by the production process in the first month of follow-up, tending to increase the performance as other actions, now under planning studies, are implemented.

5. FINAL CONSIDERATIONS

The Five Steps Method, developed and applied for the ceramic industry, by means of its data sheets, demonstrated to be a method of easy application, without need of high investments.

This method promotes a complete and integrated evaluation of the production process, facilitating the establishment of corrective actions for the environmental adaptation, followed by the verification of the efficiency of these actions by means of a continuous follow-up, besides promoting changes in the production process, correcting losses and avoiding squander, consequently, REDUCING COSTS.

These measures will make the enterprise more competitive, because they have in mind the concept of pollution prevention.

6. GRATEFULNESS

The authors express their gratefulness to:

- Conselho Nacional de Desenvolvimento Científico e Tecnológico–CNPq and to the Fundação de Amparo à Pesquisa do Estado de São Paulo–FAPESP for the financial support;

- Laboratório de Geoquímica–LABOGEO of the Department of Petrologia and Metalogenia of the Instituto de Geociências e Ciência Exatas da Universidade Estadual de São Paulo–UNESP, campus Rio Claro, for the accomplishment of the fluorescence of rays X assays;

- To the Laboratório do Projeto Gálio of the Departamento de Engenharia de Minas of the Escola Politécnica of the Universidade de São Paulo - USP, for the accomplishment of the atomic absorption spectrometry analysis.

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