INDUSTRIAL SOLID WASTE MANAGEMENT IN A METALLURGICAL PLANT: EFFECTS OF ENVIRONMENTAL REARRANGEMENT AND FEEDBACK

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ABSTRACT

Objective: To evaluate the effect of a contingency arrangement (environmental rearrangement and feedback presentation) in a metallurgical company to increase the likelihood of proper disposal and separation of industrial solid waste.

Theoretical Framework: The incorrect disposal of solid waste in companies produces a series of environmental damages and significantly hampers the effectiveness of reverse logistics.

Method: Two owners and all employees of a metallurgical company in Paraná, Brazil, participated. The procedure consisted of three stages: (1) analysis and detailed description of the current disposal conditions before the intervention; (2) strategic rearrangement of containers for waste disposal location, accompanied by a weekly record of the types of waste discarded during the intervention; and (3) installation of informative signs providing monthly feedback on the quantity of waste discarded.

Results and Conclusion: The structural rearrangement of the environment, with the strategic placement of containers in easily accessible locations and the inclusion of signs identifying the types of waste in each of them, coupled with regular feedback on the quantity of waste disposal from the metallurgical plant, resulted in a highly effective management of solid waste in the company. We concluded that the intervention improved the company’s industrial solid waste management and expanded the reverse logistics practice.

Implications of the Research: The intervention contributed to local-level management, which could inspire similar changes in the socio-environmental management practices of other organizations.

Originality/value: The study contributes to scientific advancement by proposing the contingency arrangement based on Behavior Analysis principles.

Keywords: Solid Waste, Metallurgical Industry, Recycling, Applied Behavior Analysis.
Método: Participaram dois sócios e os funcionários de uma metalúrgica do Paraná, Brasil. O procedimento teve três etapas: (1) análise e descrição das condições de descarte vigentes antes da intervenção; (2) rearranjo estratégico da disposição de contentores destinados ao descarte de resíduos, acompanhado de um registro semanal dos tipos de resíduos descartados ao longo da intervenção; e (3) inserção de placas informativas com o fornecimento de feedbacks referentes à quantidade de resíduos descartados mensalmente.

Resultados e conclusão: O rearranjo estrutural do ambiente, com a colocação estratégica dos contentores de resíduos em locais de fácil acesso e a inclusão das placas identificando os tipos de resíduos em cada um deles, aliado ao feedback proporcionou uma gestão eficaz dos resíduos sólidos na metalúrgica. Conclui-se que a intervenção contribuiu para a melhoria da gestão de resíduos sólidos industriais da empresa e ampliou a logística reversa praticada.

Implicações da pesquisa: A intervenção fomentou contribuições de ordem gerencial em um âmbito local, a qual pode inspirar modificações semelhantes nas práticas de gestão socioambiental de outras organizações.

Originalidade/valor: O estudo contribui para o avanço da ciência com a proposição do arranjo de contingências baseado em princípios da Análise do Comportamento.


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1 INTRODUCTION

Some of the main raw materials used in metallurgical plants, such as various types of steel (galvanized, black, laminated, etc.), categorized as ferrous metals, can represent a significant environmental risk if their waste is disposed of incorrectly. The metal decomposition time is estimated to be more than 100 years (Brazil, 2005). According to IBGE, industrial production in the metallurgical sector has increased by 11.7% in the last 12 months (until the latest update, May 3, 2022; IBGE, 2022). The metallurgical industry still produces other types of waste, such as paper, cardboard, plastic, glass, wood, and organic. Proper disposal of this waste is also fundamental for maintaining ecosystems in equilibrium and preventing damage to public health and other species (Artaxo, 2020). According to Artaxo, the imbalance in the relations between ecosystems is often related to biodiversity loss and has a great influence on climate changes, besides being connected to the appearance and propagation of new diseases. Thus, reducing consumption and recycling waste are crucial to preventing this imbalance.

In Brazil, the National Policy on Solid Waste (PNRS), established by Law 12,305 on August 2, 2010, aims to prevent environmental damage and promote changes in the waste sector to increase environmental protection and promote reverse economy (Ferreira et al., 2021). Significant changes have occurred in the funding and research on the topic, but the lack of institutional capacity, adequate waste management, and economic instruments to drive best practices and services are still challenges to be overcome (Ferreira et al., 2021; Nascimento et al. 2022). The Brazilian Association of Public Cleaning Companies and Special Waste released a panorama regarding solid waste management in 2022 (ABRELPE, 2022), indicating a coverage deficit in the country’s regular collection services, an initial step necessary to promote an adequate waste management system, including Urban Solid Waste, Health Service Waste, and Construction and Demolition Waste. According to ABRELPE, only 3% of the waste produced annually by Brazilian citizens is recycled, and each citizen produces 381 kg of waste...
annually. In addition, 4,183 municipalities were collected selectively in 2020, representing 75.1% of the total Brazilian municipalities.

Selective waste collection makes the benefits of recycling possible: waste reuse and reduction, energy saving and conservation, gas emissions reduction, natural resources preservation and rational use, and public health and primary sanitation problems reduction (Souza et al., 2015). Reused waste can replace various original materials, as the life cycle of products does not end with consumer disposal. On the other hand, the losses of inadequate waste disposal can be: (a) at the societal level, such as population life quality decrease, mainly of the population that resides close to the places of disposal; (b) at the environmental level, such as visual pollution, soil contamination or flooding in periods of rain; and (c) at the economic level, such as the devaluation of disposal areas and these areas recovery costs (Marques Neto et al., 2004). Even so, according to Nogueira et al. (2020), solid waste management in Brazil “demands support from the government, in the legal level for the creation of public policies, and from society” (p. 48), in such a way that all Brazilians are involved and must modify their behavior about solid waste management.

Businesses waste management can be pursued by combining changes in antecedent and consequent environmental variables, as contextualized in this article’s theoretical framework. The effect of the interventions can be analyzed through the product generated, that is, by observing the waste discarded and sent for recycling. Thus, behavioral science can approach the social agenda of environmental preservation, especially where waste disposal is inadequate and damages the population. Given this context and resources, the objective of the present study was to evaluate the effect of contingency arrangements (environmental rearrangement and feedback) on a metallurgical plant to increase industrial solid waste proper separation and dispatch to recycling.

2 THEORETICAL FRAMEWORKS

Promoting behavioral changes is essential to perform functional analyses to identify motivational variables, antecedents, and the consequences of the responses emitted (Michael, 2000; Skinner, 1953; see also Moreira & Medeiros, 2018). A systematic review of the empirical literature on pro-environmental behavior (Gelino et al., 2021) searched for articles related to environmental sustainability issues and behavior analysis. The 50 papers selected were characterized and grouped according to the types of interventions carried out: 40% of the studies manipulated consequences to change behavior, with the most frequent being the delivery of incentives; 34% of the studies provided information and feedback about the participants’ performance; and 20% of the studies carried out informational and educational operations to change behavior. Therefore, antecedent and consequent variables management were the most used procedures for promoting pro-environmental behavior.

For example, Austin et al. (1993) evaluated the effect of information signs on the behavior of professors, staff, and graduate students at two departments of a Florida university. The intervention involved the arrangement of two signs (one labeled “waste” and the other labeled “recyclable materials”), each indicating the items that could be disposed of in the containers present in the environment. Data analysis was performed by counting the number of discarded recyclable materials. The study results showed that signaling increased recycling behavior, with an improvement of 54% from baseline. These data showed that it is feasible to carry out interventions aimed at environmental preservation by placing instructions for proper waste disposal.

Another empirical study that focused on the business context was developed by Florián et al. (2023), in which solid waste management in a restaurant was evaluated, and technical and
administrative alternatives were proposed to reduce waste, in addition to promoting a pro-environmental culture among employees and customers. Based on a survey of the solid waste produced, a proposal for overall waste management was drawn up, with environmental monitoring and identifying effectiveness indicators. In addition, adaptations were made to the restaurant premises, and an ecological indicators matrix was created. It was found that 86% of the restaurant waste was reusable/recyclable materials such as paper, cardboard, textiles, handkerchiefs, napkins, glass, plastic, and organic, which can be used efficiently and have their use reduced.

### 3 METHOD

In the present study, a single case design was used, comparing the effect of an intervention regarding solid waste management in a metallurgical plant, comparing the conditions before and during an intervention, in which two variables were manipulated - the environmental arrangement and the introduction of feedback signs.

#### 3.1 Setting and Participants

The study was conducted in a metallurgical company manufacturing agricultural equipment for post-harvest grain processing. Office and production sector activities (cutting, machining, stamping, welding, and painting) and any disposal of personal protective equipment (PPE) are the sources of waste in the metallurgy. Ten employees of the company and the two owners participated in the study. Participants age ranged from 24 to 61 years (see Table 1).

<table>
<thead>
<tr>
<th>Participant/Owner</th>
<th>Job/Profession</th>
<th>Age</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1</td>
<td>Engineer</td>
<td>58</td>
<td>M</td>
</tr>
<tr>
<td>O2</td>
<td>Administrator</td>
<td>55</td>
<td>F</td>
</tr>
<tr>
<td>P1</td>
<td>Welder</td>
<td>61</td>
<td>M</td>
</tr>
<tr>
<td>P2</td>
<td>Production Owner</td>
<td>50</td>
<td>M</td>
</tr>
<tr>
<td>P3</td>
<td>Welder</td>
<td>45</td>
<td>M</td>
</tr>
<tr>
<td>P4</td>
<td>Welder</td>
<td>38</td>
<td>M</td>
</tr>
<tr>
<td>P5</td>
<td>Welder</td>
<td>27</td>
<td>M</td>
</tr>
<tr>
<td>P6</td>
<td>Machine Operator</td>
<td>27</td>
<td>M</td>
</tr>
<tr>
<td>P7</td>
<td>Machine Operator</td>
<td>27</td>
<td>M</td>
</tr>
<tr>
<td>P8</td>
<td>Production Auxiliary</td>
<td>27</td>
<td>M</td>
</tr>
<tr>
<td>P9</td>
<td>Welder</td>
<td>24</td>
<td>M</td>
</tr>
<tr>
<td>P10</td>
<td>Production Auxiliary</td>
<td>23</td>
<td>M</td>
</tr>
</tbody>
</table>

**Source:** Prepared by the authors.

Figure 1 represents the plant floor plan: at the top is the inner area, and at the bottom is the outer area (courtyard). The figure shows the locations of containers designated for industrial waste (green points) and the improvised disposal sites (in red) before the intervention. At the green spots in the inner area, there were six overlapping waste containers (see Figures 2a and 2b), and at the green dot in the outer space, a dumpster for the disposal of ferrous waste (see Figure 2c). In the improvised disposal sites were containers such as wheelbarrows and paint cans. There were places where the waste remained on the floor (see Figures 2c, 2d, 2f).
3.2 Materials

Mobile phones were used to take photos and record data. The images were used to estimate discarded waste volume based on the dumpster and waste container measures (95 cm x 95 cm x 60 cm). In addition, were employed: a computer to store and organize the photos; four A4-sheet-size printed plasticized signs with the name of each type of residue, with the color that represents the; a printer; and a whiteboard (1.1 m x 1 m).
3.3 Procedure

The initial contact with the metallurgical company was made by the first author, who requested participation in the research, clarified any questions, and requested the signature of the Free and Informed Consent Agreement. The procedure was carried out in three stages.

Stage 1: The stage consisted of a weekly survey of waste disposal environmental conditions in the metallurgical company, as well as data recording via photos over a period of one month. The waste discarded in the various locations of the factory was visually inspected, and estimates were made of the volume of trash dumped in the six containers (Figures 2a and 2b) based on their capacities (0.55 m³). Waste scattered by the factory in improvised locations was not included in the pre-intervention data registry because evaluating it as recyclable waste was impossible. The weight of the waste classified as ferrous metals discarded in the dumpster was obtained from the junkyard company that bought it. A representation of the ideal environmental arrangement plan (Figure 3) was made before the intervention, considering the number of containers available in the factory and the most suitable position according to the production process.

Figure 2 Waste containers distributed in the metallurgical plant before intervention
Source: Prepared by the authors.
Stage 2: consisted of an intervention with changes in the disposition of solid waste disposal containers (side by side instead of stacked), the rearrangement of their location on the factory floor, and the replacement of signs indicating which waste to dispose of in each container. Four designated containers for the disposal of metal, plastic, paper/cardboard, and wood waste were relocated (see Figure 4). The containers have been repositioned to be closer to the production process. New signs indicating the type of waste to be discarded were printed with a color background representing the kind of waste to be discarded, according to CONAMA Resolution nº 275 of April 25, 2001. One of the company owners suggested painting one of the containers yellow, which would be used for discarding the ferrous metals inside the factory before they were taken to the dumpster. The dumpster for ferrous material disposal remained in its previous location, in the plant’s yard. Data on waste disposal was recorded weekly, as in the previous stage, and lasted two months.
The owners decided to paint three other containers that remained in the yard, increasing the availability of containers for the specific and suitable destination. As can be seen in Figure 5, they were painted blue (Figure 5a), red (Figure 5b), and black (Figure 5c). In addition, the employees spontaneously separated a container for discarding Styrofoam (Figure 5d) and a can of paint for discarding gloves and dirty fabrics.
Implementing what was planned depended on the company’s possibilities to make the changes proposed in the project. Figure 6 presents the metallurgical plant floor plan with the final arrangement of waste disposal containers. A comparison of Figures 3 and 6 highlights the difference between the ideal plan established at the beginning of the intervention and that executed during Stage 2.

![Figure 6](image)

**Figure 6.** Plant floor plan indicating the final location of solid waste containers.  
**Source:** Prepared by the authors.

Stage 3: the whiteboard was introduced in the employee convenience area (Figure 7), indicating the amount of waste separated correctly in the containers per month for three months. That information consisted in providing feedback on their waste separation. The board informed how many m³ of plastic, wood, and paper/cardboard and how many kg of ferrous metals were destined for recycling. It was suggested to the company’s management that the feedback board be maintained and updated after the end of the study to follow up the process over the years.
4 RESULTS

At the start of the intervention, waste containers were stacked in the center of the plant (with white nameplates) in improvised containers, and the waste was not properly separated, as shown in Figure 2. Table 2 presents the production sites/process, the waste generated, and its destination before and after the intervention. Before the intervention, several recyclable products, such as paper/cardboard, plastic, and paint cans, were destined for the landfill. However, the company already destined various residues for recycling, mainly ferrous metals, which were sold to a junkyard, where these residues were reused or sent for recycling. Eventually, wood was donated to independent waste pickers or reused in the metallurgical plant itself.

Throughout Stages 2 and 3, the amount of waste discarded into the containers was estimated from the maximum volume each container/dumpster supported. In addition, the photographic record made it possible to compare the successive months. Table 3 presents the quantities of waste discarded in the containers shown in Figures 2a, 2b, and 2c in the pre-intervention Stage 1 period (Month 1). During the intervention, the waste discarded in the containers of Figures 4 and 5 and sent for recycling was registered during Stage 2 (Months 2 and 3) and after the introduction of the feedback sign placed in the employee’s convenience area (Month 4, 5 and 6; Stage 3).

In the pre-intervention period (Month 1), 1.32 m³ of waste (plastic, wood, paper, and cardboard) was disposed of in a mixed manner. In the initial two months of the intervention, shortly after the relocation of the containers, the company’s employees and owners cleaned up the whole area of the metallurgical plant, discarding in the relocated containers the waste that had accumulated in the factory and that one who could be sent for recycling. This resulted in an average discarding of 1.25 m³ of plastic, 0.65 m³ of wood, 0.76 m³ of paper/cardboard, and 2,066 kg of ferrous metal per month. The feedback board, as planned, was made available in the employee’s convenience area at the beginning of Month 4, with a reduction in the amount of plastic and ferrous metal waste discarded in that month and in subsequent months compared to Months 2 and 3, to an average of 0.8 m³ of plastic and 1,461 kg of ferrous metal per month.
The volume of paper/cardboard and wood discarded in Months 4 and 5 was similar to that in Months 2 and 3, but there was a reduction in Month 6, to a total of 0.2 m³ paper/cardboard and 0.4 m³ wood.

Table 2 Production site/process, solid waste generated, and the destination before and after the intervention

<table>
<thead>
<tr>
<th>Production Site/Process</th>
<th>Generated Product</th>
<th>Destination before Intervention</th>
<th>Destination after Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>Paper, cardboard, and plastic</td>
<td>Landfill</td>
<td>Municipality selective collection for recycling</td>
</tr>
<tr>
<td>Employees</td>
<td>Aprons, goggles, cartridges, cream, old gloves, hoses, masks, glasses, earplugs, PPE leftovers, food waste and sandpaper</td>
<td>Landfill</td>
<td>Landfill</td>
</tr>
<tr>
<td>Cutting</td>
<td>Wood, plastic or cardboard packages, steel sheet refinish, and small pieces</td>
<td>Wood packages: new boxes and supports or donations to waste pickers Plastic and cardboard: landfill Steel sheet refinish and small pieces: junkyard</td>
<td>Wood packages: new packages and supports or donations to waste pickers Plastic and cardboard: landfill Steel sheet refinish and small pieces: junkyard</td>
</tr>
<tr>
<td>Machining</td>
<td>Steel holes. Circular steel waste.</td>
<td>Junkyard</td>
<td>Junkyard</td>
</tr>
<tr>
<td>Fold</td>
<td>No waste. Circular steel waste.</td>
<td>Junkyard</td>
<td>Junkyard</td>
</tr>
<tr>
<td>Welding</td>
<td>Sandpapers, roughing disks, cutting disks, iron dust or filings</td>
<td>Junkyard</td>
<td>Junkyard</td>
</tr>
<tr>
<td>Painting</td>
<td>Ink powder, oil-soiled tow (dirty cloth flap), tiner and paint cans</td>
<td>Landfill</td>
<td>Landfill</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors.

Table 3 Volume or weight of waste disposed of in plastic, wood, paper/cardboard, and ferrous metal containers during pre-intervention (Month 1) and intervention periods (Months 2 to 6)

<table>
<thead>
<tr>
<th>Waste</th>
<th>Pre-Intervention</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Month 1</td>
<td>Month 2</td>
</tr>
<tr>
<td>Plastic</td>
<td>1.32 m³</td>
<td>1.2 m³</td>
</tr>
<tr>
<td>Wood</td>
<td>0.64 m³</td>
<td>0.66 m³</td>
</tr>
<tr>
<td>Paper/Cardboard</td>
<td>0.71 m³</td>
<td>0.81 m³</td>
</tr>
<tr>
<td>Ferrous metal</td>
<td>4000kg*</td>
<td>2,056 kg</td>
</tr>
</tbody>
</table>

Note: * Before the intervention, the dumpster with ferrous metal contained the accumulated waste for 3 months. Source: Prepared by the authors.

5 DISCUSSION

The present study aimed to evaluate the effect of a contingency arrangement on a metallurgical plant (environmental rearrangement and feedback) to increase industrial solid waste proper separation and dispatch to recycling. At first, the use of 19 containers distributed in the plant was conceived. However, the containers owned by the company were large and heavy and had to be moved with the aid of a forklift truck. That is, it would be necessary for an
employee to stop his production process activities to implement the environmental change. Due to a shortage of workforce and time, relocating all the containers was impossible. Containers that were not used for the disposal of waste remained distributed in the yard and were used for different purposes, for example, to store raw material or to support metal sheets (sheets for the construction of silos). It was recommended that the company consider the rearrangement of the other waste containers following the ideal design in the future, as shown in Figure 3.

After the intervention, it was possible to observe that the employees started to separate the waste according to its type (paper/cardboard, plastic, and wood). There was an improvement in the separation of the ferrous metals that were already separated before the intervention. A similar result was observed in the study by Austin et al. (1993), in which signs labeled “Trash” and “Recyclables” (which specified the materials that could be disposed of in the recycling containers) increased the behavior of proper waste disposal in two university departments. The results of the present study are in line with Florian et al. (2023) proposal, which characterized waste management in a restaurant and elaborated “an environmental monitoring plan with effectiveness indicators” (p. 1). The authors concluded that the opportunities for improvement in waste management generate “a positive impact by reducing the amount of waste going to the landfill; moreover, with the increase of recycled waste and the efficient use of single-use elements, it generates a reduction in costs” (p. 10).

In the plant participating in the present study, inadequate disposal with various types of waste mixed was, in part, a result of the initial arrangement of the containers, both concerning the location within the factory and the fact that they were stacked (three in each pile), even though they had signs indicating waste types that should be discarded in each one. With the arrangement of the containers side-by-side (see Figure 4) and the placement of signs with standardized colors for the type of waste to be discarded in each one (according to CONAMA Resolution nº 275, of April 25, 2001), employees started to separate the waste properly, allowing for the correct waste destination for recycling. The company was already disposing of ferrous metal waste (such as rubbish bins, thinning disks, cutting disks, iron powder, or filings) for recycling in junk yards, but with the intervention, all the ferrous metal started being disposed of in the dumpster, no longer parts of it being discarded on the floor next to where it was generated.

At the beginning of the intervention, other behavior motivated by the intervention proposal was observed as soon as the containers were repositioned. One of the owners suggested painting one of the containers yellow since there was paint of this color available at the plant, and that color represents a container for discarding the ferrous metals. According to this owner, he would have liked to paint all the containers, but there was no staff or time to do so. Another behavior observed was that before the rearrangement of the containers, there were discussions between the owners about the waste destination for recycling. Both were more interested and willing to talk about the matter and to make arrangements for proper waste disposal in the metallurgical plant, showing that the proposal functioned as a motivating operation (cf. Michael, 2000), both about the behaviors that made the environmental rearrangement possible and to related verbal behaviors.

During the intervention, a dumpster was hired where the wood accumulated in the factory was discarded and destined for a company specialized in solid waste management. With the new container arrangement, it was found that the disposal increased in the initial months of the intervention, and the proper separation of the waste was carried out, with no further mixing of the waste. One aspect of the results to be highlighted is that in the initial months of the intervention, the company’s owners and employees cleaned the whole plant’s space, removing and discarding waste accumulated and disposed of it in various improvised locations/containers. This contributed to a sharp increase in the volume of waste dumped in the
initial two months of the intervention, except for ferrous waste, which was accumulated for two months (see Figure 2c). The movement in the initial months to clean up the plant may explain the greater amount of waste discarded in the initial two months of intervention before the feedback sign placement. Hence, the effects of the feedback sign introduction may have been masked.

Proper waste separation and dispatch for recycling, as well as the verbalizations on the theme, make it possible to affirm that the intervention based on Behavior Analysis principles aimed at the development of pro-environmental behaviors corroborated the results of studies such as those reviewed by Gelino et al. (2021), allowing to reduce the incorrect disposal of solid waste that represents, as Marques Neto et al. (2004) highlighted, an environmental problem.

As for the study’s limitations, it should be considered that the containers were quite large, taking a few weeks to fill, which did not allow for a more precise assessment of the amount of waste produced per week. Thus, future studies using this type of container could maintain data collection for more than six months and employ other forms of measurement. The containers in the form of large cans (red and blue) introduced into the metallurgical plant were 1.5 m high, and emptying them required time and effort. Therefore, future interventions such as the present study could employ more practical containers - smaller and with wheels. It is also recommended that emphasis be placed on the introduction of a hazardous/contaminated waste container (orange container), the disposal of ink-soiled fabrics, gloves, etc., and the correct disposal of such waste.

6 CLOSING REMARKS

This study contributed to the management of industrial solid waste in a metallurgical plant. The company was already practicing what can be identified as a reverse economy (cf. Ferreira et al., 2021), as ferrous metals were sold to a junkyard, causing waste of this type to be fully recycled. The rearrangement of the environment with the placement of containers in more accessible places and signs with the names of the waste with standardized colors, however, fostered an even more effective and wide management of the company’s solid waste. Furthermore, despite the lack of a systematic evaluation of the verbal behavior of the participants, recycling has become a theme discussed and a concern of the company’s owners. This suggests the possibility that participants (owners, and employees) may generalize such practices to other environments, be they business or domestic.

This study further contributes to the advancement of science by proposing a management procedure based on principles of Behavior Analysis. Improved waste management has contributed to reducing the amount of waste going to landfills, reducing the negative environmental impact of waste generation. In addition, with the increase in the shipment of waste for recycling, the need to extract natural resources has been reduced, characterizing a practice of reverse economy. In this way, the applied intervention fostered contributions of a managerial nature in a local environment, which may inspire similar changes in the practices of socio-environmental management of other organizations.

REFERENCES

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