

# Analysis of Quality Management, Industrial Safety and Environmental Performance in the Home Appliances Industries, Bogotá-Colombia

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The present paper identifies environmental and industrial safety aspects generated during the production processes of two home appliances companies located in Bogotá. Essential quality tools were used, such as the Deming cycle and some of the seven (7) quality control tools, since it allows a more specific and complete approach to industrial problems. In addition, there is a methodology used to generate preventive strategies in these companies that mitigate workers' health and safety effects and optimize resources, raw materials, and costs (López, 2016).

The analysis results evidenced that the companies generate a high environmental impact despite the controls that the department of environmental management takes. The two companies are producing a total of annual waste, reported as follows: 1.188 t that are usable, 1.45 t of non-usable, 2.85t of hazardous matters, 3.15t of waste electrical and electronic equipment (WEEE), as well as NOX, CO<sub>2</sub> and VOC atmospheric emissions. Consequently, the environment and the health of workers are affected. In addition, the tools applied demonstrated that the final waste has correct disposal. Finally, the opportunities for business improvement in occupational safety and health and environmental management systems were proposed (Gracia et al, 2018).

**Keywords:** quality control tools, Deming cycle, environmental management, industrial safety, home appliance industries.

## 1. Introduction

The city of Bogotá D.C., being one of the cities with an industrial epicenter in Colombia, presents an important environmental problem due to the negative impacts on natural resources. According to statistics, Bogotá generates approximately 6200 tons of solid waste per day, with the industrial sector contributing significantly. (Ardila, 2011). Furthermore, the manufacturing industry of household appliances in Bogotá is of great importance for its large production volumes due to the country's high demand and rapid transition from small to medium-sized enterprises.

On the other hand, the companies of the household appliances sector in Bogotá D.C. present different problems to implementing and maintaining environmental management systems because their productive activities generate environmental pollution by the inadequate management of resources, the use of chemical substances, and raw materials that create smog and affect the health of workers. Therefore, according to the above, these companies must improve their processes to mitigate the environmental impact generated, developing practices that help improve these effects. However, among the most reiterative arguments of the managers of these industries before the barriers to demonstrate improvements in their environmental performance, allowing them to obtain certification in standards such as ISO 14001:2015, are lack of financial resources, lack of knowledge of how to implement the bar, or even declare that voluntarily do not want to manage their companies under this type of standards.

When companies are not certified in environmental management systems and safety and health at work, it triggers a series of undesirable effects in the medium term as; low-quality processes, instability in customer relations, lower profitability, limitations to do business with large companies, losing the opportunity to be recognized for controlling the environmental impact.

Considering the importance of this issue for companies' sustainability, the District Secretariat of Environment of Bogota D.C. provides free support to industries to strengthen environmental self-regulation through the District Environmental Excellence Program PREAD, which requires rational use of natural resources and elimination of any pollutant load. This program encourages and gives reputational and economic benefits to registered companies, mitigating their pollution and contributing to the environment.

This contribution is the result of the research carried out in two companies of the household appliances sector in Bogotá, D.C., registered in the PREAD program. Written in the PREAD program, significant environmental impacts were analyzed. Furthermore, the causes that led these companies to fail to maintain environmental management systems and health and safety at work were evaluated, to formulate solution strategies for these industries to improve their performance and subsequently achieve certification. For this purpose, the authors applied quality management tools and cleaner production tools to analyze environmental and health problems associated with companies in the household appliances sector. Additionally, to solve the issues explored in the industry's understudy, it was necessary the design specific strategies for continuous improvement.

## **2. Materials and methods**

The present study was conducted in two industries of the household appliances sector voluntarily enrolled in the District Environmental Excellence Program (PREAD) in Bogotá D.C. Applying the Kaizen method and using the "PDCA" approach: Plan, Do, Check, and Act (Alvarado and Pumisacho, 2017), the following techniques were developed: The diagnostic stage identified the leading environmental aspects, critical points of waste and forms of residual pollution in the companies of the study using cleaner production tools, such as flow analysis, Eco-balances, Ecomaps and the Matrix Material, Energy, Waste- MED (Van Fan, et al., 2020) developed during several visits to the companies using checklists and interviews with key personnel, through which information was obtained from the development of the production process. Secondly, once the primary sources of contamination and generators of affectation to the health of workers were identified, the state of implementation of environmental management and aspects related to occupational health and safety in these companies was analyzed, for which quality tools such as cause, and effect diagram and affinity diagram were elaborated. Finally, the necessary improvement actions were established for the studied companies using the Failure Mode and Effects Analysis (FMEA) methodology.

## **3. Results and Analysis**

### **3.1 Diagnosis of critical points of the production processes**

The study starts with formulating two cleaner production tools for the two companies studied: Process Flow Analysis, Material Energy Waste Matrix - MED, Eco balance, and Ecomaps. The tools show that their final waste is being disposed of correctly. However, the information obtained during the visits shows a high environmental impact despite the environmental management department's controls. The two companies generate a total annual waste: 1.188t of usable waste, 1.45t of non-usable waste, 2.85 t of hazardous waste, 3.15t of WEEE, and atmospheric emissions: NOX, CO<sub>2</sub>, and VOC.

The results are also in line with those of the study on the life cycle of desktop computers in China by Duan et al. in 2008, which revealed the problems associated with greenhouse gas emissions and energy consumption from computer production. Figure 1 shows the graphical scheme of the Eco balance (Murakami, et al., 2019) to produce 18000 desktop computers.

### **3.2 Application of quality tools**

To find the root causes of the study's most recurrent environmental management and occupational health and safety problems, companies and their possible opportunities for improving quality tools were necessary, such as the cause-and-effect diagram and affinity diagram. (Gutiérrez, 2010)

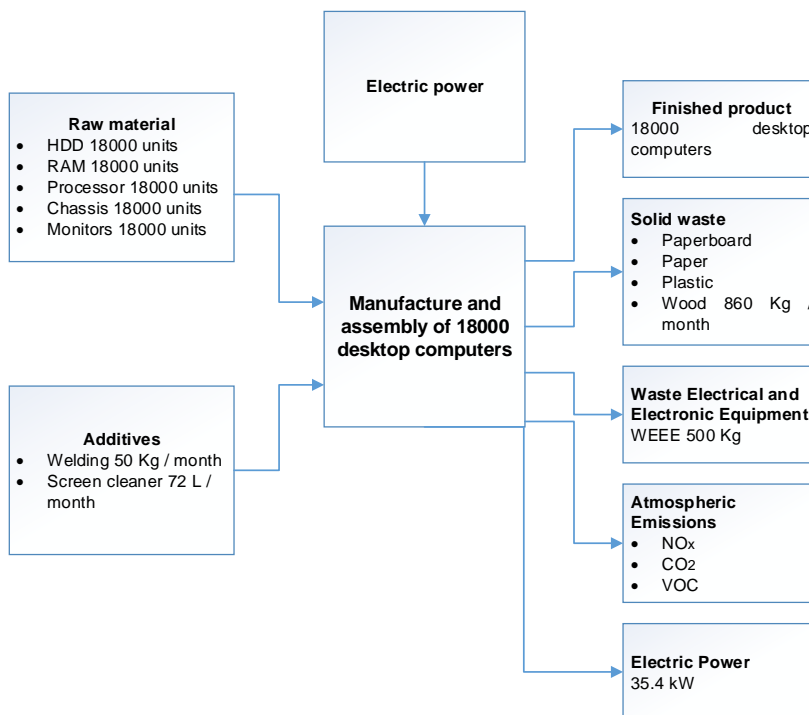


Figure 1: Encapsulating manufacture and assembly of 18000 desktop computers

By analyzing the environmental impacts of the manufacture and assembly of 18,000 desktop computers, it was possible to detail the input and output elements of the process, identifying the leading causes of pollution, on which the company should focus its integrated management strategies. These results are consistent with the life cycle analysis study of desktop computer display production, conducted by Socolof, Overly, and Geibig in 2005, where high environmental impacts related to energy consumption, toxic waste generation are highlighted as necessary. Based on Ishikawa's (1986) PCDA (Plan, Do, Check, Act) cycle, a fishbone diagram was developed to capture all the possible causes of the problem graphically and was constructed following the method described in Camison et al., (2006). Figure 2 shows the application of the Ishikawa diagram (Abbasi, et al., 2020) to analyze the impacts generated to the environment and the health of individuals by the manufacture and assembly of desktop computers.

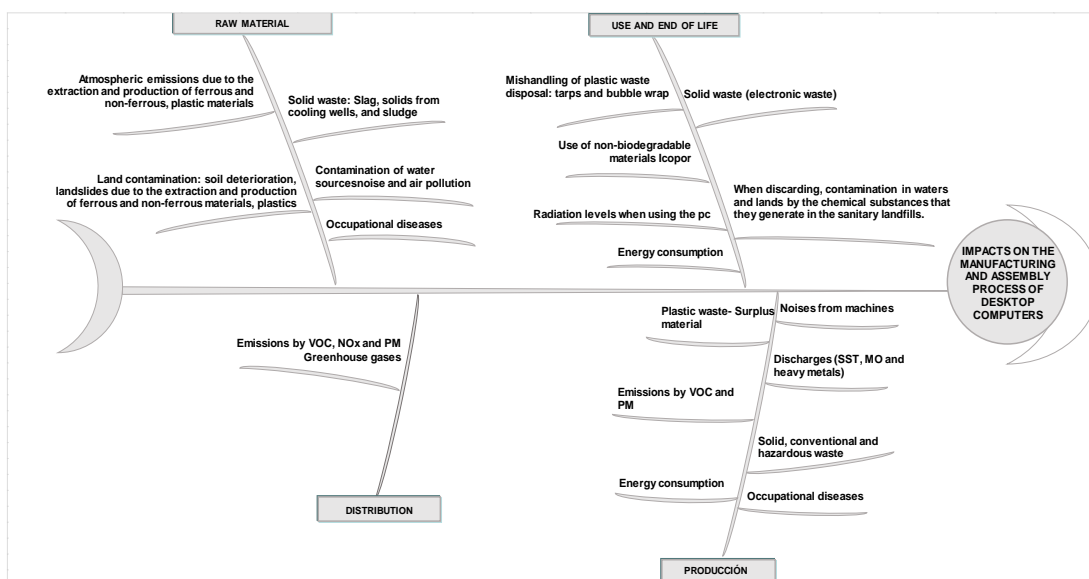


Figure 2: Cause and effect diagram of desktop computer production

Figure 3 details the affinity diagram that was built together with the staff of the organizations participating in the study and where ideas for improvement solutions to the main problems of greater complexity emerged, designed to contribute more to the sustainability of technology companies, to reduce the effects of lead, arsenic, mercury, copper, (Escolar,2018; Marmo & Dansi, 2018) chromium and gases such as carbon trifluoride used in plasma screens.

The affinity diagram was used, as it is a tool that synthesizes a set of verbal data (ideas, opinions), grouping them according to the relationship they have with each other; for this purpose, work sessions were held with the companies' collaborators, and brainstorming sessions were carried out. This tool is based on the principle that many of these data are related so that they can be gathered under a few general ideas, and therefore, it is used in the public planning stage of the Integrated Management System. This tool was applied because it is very effective when the problem is complex and was carried out following the methodological steps of (Vilar, 1998; Straker, 1995). Thirty-five employees actively participated in the brainstorming sessions and completed the survey questionnaires.

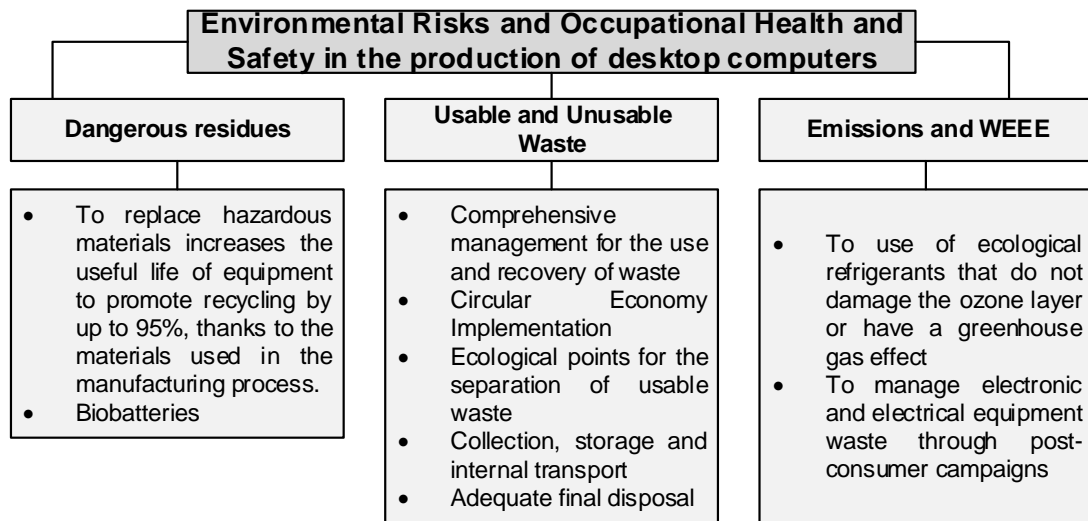


Figure 3: Affinity Diagram for Environmental Risks and Occupational Safety and Health for the production of desktop computers

### 3.3 Corrective action analysis

The industries of household appliances studied must apply corrective actions in all anomalous situations found to stop generating negative impacts on workers' health and environmental impacts. On the other hand, the not correction will increase distancing them from the possibility of demonstrating better ecological and occupational performance and thus achieving certifications of international standards. To correct this situation was necessary to develop a Failure Mode Analysis and the effects of the process (Fernandez, 2019).

Table 1 presents the FMEA performed for desktop computers' manufacturing and assembly process. For calculating the risk priority number RPN, the following scale includes 1 to 3 low, 4 to 6 medium, 7 to 9, high, and 10, extreme. The RPN multiples each failure mode and effect's severity, occurrence, and detection rating.

The household appliance manufacturing sector presents opportunities for improvement in the implementation of eco-design, which promotes preventive control from the beginning of the product life cycle. (Hoof, 2015). As for the physical facilities of their production plants, the suggestion is to invest with a view to savings, obtaining not only economic but also environmental benefits, with changes such as the implementation of solar panels for power supply in the luminaire, a physical restructuring with improvements in ventilation systems and access to natural light, high-tech machinery that mitigates the carbon footprint.

Furthermore, as an opportunity for improvement, it is advisable to have early management of their suppliers to identify in a preventive way the ecological line that manages their inputs and materials of the main product to be manufactured by the companies studied. In addition, implementing preventive programs to continuously promote the inclusion of employees training on the classification and disposal of waste leads the staff to generate an ecological commitment within their role in the company and self-care and prevention of occupational diseases.

Table 1: Failure Mode and Effects Analysis (FMEA) desktop computer manufacturing and assembly process

Failure mode	Failure Effect	Causes	Proposed control	Severity	Occurrence	Detection	Risk Priority Number
Equipment generated noise	Noise pollution	Adverse effects on the physical, mental, and hearing health of the operators.	To use corresponding protective equipment. Maintenance in noise control.	5	6	5	150
Consumption of raw materials and inputs	Use of natural resources	Depletion of natural resources	To buy raw materials that help conserve natural resources.	8	8	7	448
Water consumption	Use of natural resources	Depletion of natural resources	Water-saving and efficient use program	4	5	3	60
Electric power consumption	Use of natural resources	Depletion of natural resources	Energy-saving and efficient use program	9	9	8	648
Extraction and processing of raw materials (ferrous, non-ferrous, precious, and plastic metals)	Atmospheric emission	They emit toxic gases and vapors that are harmful to the environment and the health of workers	Continuous monitoring	9	9	9	729
Emissions by VOC, CO2	Atmospheric emission	Respiratory diseases. Degradation of the ozone layer	To make strategic plans to control gases	7	8	4	224
Solid waste	Contamination of soil, water sources, and groundwater	Deterioration of soil and water quality. Decrease in the useful life of landfills.	To adapt environmental policy guidelines for the integral management of solid waste. Use biodegradable materials. Give good use of reuse	10	10	10	1000
Sewage water	Contamination of soils and water sources	The quality of the environment decreases. Health illnesses of workers	To implement a wastewater treatment plant. Rainwater harvesting system	6	8	6	288

#### 4. Conclusions

Appliance companies in Bogota should use methods and techniques to prevent and minimize environmental impacts based on the design of processes and technologies available for waste treatment (Boltic & Ruzic, 2013). The difficulty evidenced that companies have to maintain an environmental management system within their processes (Colin C.J., et.al, 2014), so you must generate production strategies that optimize resources and reduce production costs caused by waste. It is of great importance to maintain a culture of good manufacturing practices that create greater welfare for workers and contribute to companies in this sector to formulate, implement and maintain environmental management systems ISO 14001.

Finally, the participation of companies in the household appliances sector in the PREAD program encourages industry managers and their human resources to seek sustainable and healthy practices.

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### References

- Abbasi O., Noorzai E., Gharouni K., Golabchi M., 2020, Exploring the Causes of Delays in Construction Industry Using a Cause-and-Effect Diagram: Case Study for Iran, *Journal of Architectural Engineering*, 26,3.
- Alvarado R., Pumisacho Á., 2017, Prácticas de mejora continua, con enfoque Kaizen, en empresas del Distrito Metropolitano de Quito: Un estudio exploratorio, *Intangible Capital*, 13,2, 479-497
- Ardila G., 2011, Does an environmental policy exist in Bogotá? Main environmental problems. Institute of Urban Studies National University of Colombia, Bogotá.
- Boltic Z., Ruzic N., 2013, Cleaner production aspects tablet coating process in pharmaceutical industry: problem of VOCs emission, Elsevier, 8.
- Camison C., Cruz S., González T., 2006, *Gestión de la Calidad: conceptos, enfoques, modelos y sistemas*, Pearson Educación, S. A, Madrid.
- Colin C.J., Chen L., Chwen S., 2014, The link between eco-innovation and business performance, *Journal of Cleaner Production*, 85.
- Duan H., Eugster M., Hischer R., Streicher-Porte M., Li J., 2009, Life cycle assessment study of a Chinese desktop personal computer, *Science of the total environment*, 407,1755–1764
- Escolar A., 2018, Lead, Arsenic, Cadmium and Mercury: Effects and studies in Colombia, (Degree thesis) Universidad de Los Andes.
- Fernandez J.M., 2019, Failure mode and effect analysis (FMEA) (Research paper), Universidad Privada del Norte.
- Gracia J., Lara L., Quintero P., Santis A., 2018, Formulation of Strategies for the Implementation of Integral Management System Based on ISO 9001:2015 and 14001:2015 in the Company Surtiapiques (Bogotá-Colombia), *Chemical Engineering Transactions*, 67, 559-564.
- Gutiérrez H., 2010, Total Quality and Productivity, <[http://xlibros.com/wpcontent/uploads/2014/04/Calidad-total-y-productividad-3edi-Gutierrez\\_redacted.pdf](http://xlibros.com/wpcontent/uploads/2014/04/Calidad-total-y-productividad-3edi-Gutierrez_redacted.pdf)> accessed 21.08.2021.
- Hoof, B. et.al., 2015, Cleaner production tools, Alfaomega, Bogotá.
- Marmo L., Danzi E., 2018, Metal Waste Dusts from Mechanical Workings – Explosibility Parameters Investigation, *Chemical engineering transactions*, 67, 205.
- Murakami S., Nakatani J., Nakajima K., *et al.*, 2019, EcoBalance 2018, Nexus of ideas: innovation by linking through life cycle thinking (9-12 October 2018, Tokyo, Japan), *Int J Life Cycle Assess*, 24, 1544-1552.
- López P., 2016, Tools for quality improvement, Confemetal Foundation, Madrid, Spain, 247.
- Socolof M., Overly J., Geibig J., 2005, Environmental life-cycle impacts of CRT and LCD desktop computer displays, *Journal of Cleaner Production*, 13, 1281-1294.
- Straker D., 1995, *A toolbook for Quality Improvement and Problem Solving*, Prentice Hall, UK.
- Van Fan Y., Huin Ch J., Klemes J., Sabev P., Lui X., 2020, Optimisation and process design tools for cleaner production, *Journal of Cleaner Production*, 247,20.
- Vilar J F., 1998, *Las 7 nuevas herramientas para la mejora de la calidad*, Fundación Confemetal, Madrid.