Cleaner production applied to low tech electronic enterprises

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Abstract

The printed circuit board (PCB) industries around the world were significantly improved with simple water minimization techniques based on Cleaner Production. This work analyzed benchmarks from PCBs approaches in lower tech devices enterprises. It was observed that unprivileged common alternatives can present reasonable solutions lower tech devices lower tech devices.

Keywords: Cleaner Production, Industrial Symbiosis, Management System

INTRODUCTION

Every year, the electronic sector shows a huge demand for technological improvements that require innovation and significant changes on production techniques. A meaningful example is the Moore's law that suggests the continuous decrease of the minimal dimensions of every integrated circuit and "More than Moore" technology that pursue new materials for the development of new devices (Heath 2005). However, several production processes still deal with big (tenths of micron) dimensions. Thus, from small didactic tools such as photocells or simple integrated devices to complex electronic systems as electronic nose or flexible screen-printed touch sensors and chips for energy harvesting (Dahiya 2015), the use of conventional wet processes is still possible and usually also means lower costs, although water consumption and waste generation are major concerns (Adner 2015).

Those processes are essentially meant to change surfaces in three different ways: deposition or etch material surface aside the protection of predefined areas for etching take place. This is quite similar to the ones currently used in metal finishing industries all around the world. On such industries, metal contamination in water and soil always was a topmost issue; therefore, In the past decades cleaner production projects were proposed and implemented around the world. In general, these projects attended several distinct enterprises, some of them even localized in different countries. One interesting example was described by Reeve (2007) regarding Australasia region; in 1998 benchmarking in the metal finishing industry was prosecuted, due to the UK Government request and UNEP support, and an industry guide of the best available systems for depositing zinc on steel was produced. After that, in 2000 another study defined "methodology for environmental benchmarking in a specific industry sector".

Printed circuit board (PCB) can be considered as a special area, due to the requests of electronic devices such as material electric properties within the metal finishing industry. Furthermore, some decades ago PCBs factories were also significantly improved with simple water and waste minimization techniques based on Cleaner Production Concepts (Chang, McCoy 1990). Many of these attempts counted on EPA actions and generated industries guides and reports that spread all around the world (Freeman, 1994).

In Brazil, similar efforts were carried out and usually also involved government environmental agencies. Ferreira (2016) described one of these programs, developed by the São Paulo State Government in the 1990's, in order to emphasize the industrial partnership that came out and resulted in the creation of a company called Centralsuper. The company belonged to employers' association of metal finishing industries and aimed to handle all sludge produced by these industries in the São Paulo State. A decade later, Centralsuper joined a technological research institute and created a new company that initiated sludge plasma treatment, a more environmental correct procedure. São Paulo environmental agency, called CETESB, also provided a series of cleaner production guides for metal finishing that considered specificities of production areas, such as jewelry (Pacheco 2002) (Santos 2005).

Thus, this work aimed to analyze the possibility of benchmarking from PCBs approaches on water optimization in small enterprises producing lower tech devices, such as power diodes.

METHODOLOGY

This work uses the case study methodology. Therefore, one small enterprise on the electronic sector was analyzed in the whole cycle of power diodes production regarding water consumption. After that, pollution prevention opportunities were listed and the short term applications were tested in laboratory and pilot conditions. Finally, at least one production set was obtained with the minimization conditions established.

Power diodes production is one of the oldest functions in the microelectronics area but also one of the most neglected regarding cleaner production strategies, which explains the reason why it was chosen for this study. Furthermore, microelectronics usually requires high purity level for all material inputs, especially water and chemical reactants. Thus, any improvement in reuse or recycling on such condition means a huge economical impact.

RESULTS AND DISCUSSIONS

The first audit in the case study enterprise immediately provided a complex scenario of water use and discharge, and Table 1 summarizes it. The following points were observed: 1) there are four different cleanliness levels on such enterprises; deionized (di.) water, tap water, aqueous solutions and waste water, 2) the main consumption and cost are due to processes that require di. water, although the consumption is not high, 3) the very high consumption of tap water suggests the development of recycling solutions, especially if the consequent decrease on sludge formation is take into account, 4) on the other hand, aqueous solution is not a meaningful issue. For those reasons, the primary actions taken were reduction on di water use – with the consequent decrease in tap water consumption monitored - and recycling of waste water.

Table 1 - Water cleanliness levels on case study enterprise and parameters (issues) that affect reuse and recycling

Water cleanliness levels	Parameter		
	Economical	Environmental	Consumption
DI.	Purchase Production Treatment	Waste generation: Process water discharge Resins for water treatment	Medium
Tap water	Purchase Treatment	Process water discharge	Very high
Waste water	Treatment	Sludge waste generation	High
Aqueous solution	Purchase Production Treatment	Waste generation	Low

Then, the main strategies for reduction of water consumption on PCB industries were considered and tested in every wet procedure/process. The strategies used on PCB industries and the corresponding availability analysis for the case study enterprise essentially are:

1) <u>Continuous use of cleanliness water</u>: each aqueous solution must be removed by the corresponding solvent, i.e. di. water, before the sample being processed reaches the next step. For PCB industries almost all aqueous solution can be processed this way, but silicon surface has unique properties that narrow this option only to the last wet steps. It is worth noting that the case study already used such procedure.

2) Air spray: water is sprayed in small drops instead of using complete dip on di. water reactor. Again, that is not possible due to silicon surface properties.

3) Decrease on volumetric flow: this option required the evaluation of the reactors design; therefore, simulation and laboratory tests were carried out in order to optimize such devices for minimum dimensions, which assure lower water flow to carry on the sample cleanliness. It was verified that reactors could be downsized and pilot tests showed a di. water economy of 26% minimum. It is worth noting that increasing on water turbulence by nitrogen jets could decrease water consumption up to 50% but it was no implemented due to economic constraints, although there are no technical reasons that advise against it.

The most important action carried out for water minimization was also the simplest one. Since for most parameters di. water is cleaner than tap water, the less pollutant processes were segregated from wastewater treatment and the corresponding wastewater was added to the beginning of di, production cycle. This action allows reduction on water consumption up to 63%.

Finally, it is worth noticing that discharged wastewater still remains clean enough to be recycled on low severe conditions, such as galvanic processes quite common on packaging area of same industries, which means up to 75% of water could be spared on such arrangement. The remaining 25% lost on water input is mainly due to di. water production equipment that dispense water with high amount of soluble ions. Nonetheless, this remained discharged water might be used on industrial symbiosis provided the enterprise was located near less restrictive industries, such as paper recycling.

Finally, it is important to observe that these changes required implementing a lot of educational procedures before the main stakeholders agreed with such implementation. This is quite common on this industrial sector due to the high level of purity required in order to obtain high quality and reproducible devices.

CONCLUSION

Although the huge technological improvements on the electronic sector decreased the minimal dimensions to the nanoscale on many devices, several production processes still deal with tenths of microns. Such processes usually make use of wet treatments that are quite similar to the ones developed to printed circuit board (PCB) industries, which means they could be optimized used conventional approach for water consumption reduction. Therefore, using PCB industries as benchmarking this work aimed to analyze water optimization in small enterprises producing lower tech devices. It was observed that unprivileged common alternatives can be a reasonable solution for those enterprises. Although electronic sector is quite demanding on purity and process regulations, there are hidden opportunities that could be assessed by benchmarking.

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