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Abstract

Purpose – The purpose of this paper is to present a case report involving environmental performance analysis of a big Brazilian graphic company.

Design/methodology/approach – An "environmental performance indicator" (I_{epa}) was developed, which is calculated taking into consideration the weighting of potential environmental impact of each residue/sub-product generated, the relative spatial dispersion which each residue/sub-product can reach and adequacy evaluation of final allocation accomplished by the company for each residue/sub-product.

Findings – Despite the evidence that the corporations emit gases generated by the burning of volatile organic compounds to the atmosphere, the result obtained is favorable to enterprise, largely, due to the adequate allocation given to industrial effluent, which is the waste with the largest share on I_{epa} (50.2 percent). Industrial effluent is collected by a company licensed by Environmental Sanitation Company of the state of São Paulo, which is an environmentally adequate practice. The result of $I_{epa} = 90.8$ percent is explained by the large amount of CO_2 emitted by the operations into the atmosphere throughout the year.

Practical implications – The method used can be applied to measure the environmental impact generated by any business of a graphic service sector.

Originality/value – The authors observed, in the specialized literature, a small number of works dealing with the environmental management of graphic sector companies, as well as methodologies for assessing the environmental performance of companies through environmental performance indicators. The originality of the work is in the developed method, which takes into account: the potential impact of each residue/sub-product generated; the amount of each residue/sub-product generated in a given time period; the dispersion that each residue/sub-product can attain; and the evaluation of eventual allocation of each residue/sub-product.

Keywords Environmental management, Printing, Environmental analysis index, Environmental indicators, Environmental development, Graphic sector

Paper type Case study

1. Introduction

Printing process is considered an industrial procedure quite diverse and highly polluting. It serves to all other economic segments including individual printing, public services, financial sector, all types of service providers, manufacturing industries, besides servicing companies that solely work on graphic printing such as newspapers, magazines and advertising companies. In other words, this process is part of people's lives and businesses (Kiurski *et al.*, 2012). Although it massively demands paper, which consumes forest wood in its manufacturing, wood extractions do not always follow responsible and sustainable environmental management practices.

Printing production consumes various petroleum-derived inputs such as organic solvents, inks, varnishes, cleaning agents, among others. These liquid materials generate various potentially toxic by-products, consisting mainly of volatile organic compounds (VOC). Significant amounts of evaporated toluene, ethylbenzene, xylenes, alcohols and other airborne organic mixtures are released to the indoor air of the printing industry buildings. The chemical vapor composition greatly depends on the sort of printing machinery, cleaning and drying procedures, substrates and end-use applications. In a programmed screen-printing engine, the inks are dried by polymerization with UV lamps and releases low

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VOC gases into the indoor printing environment. Nevertheless, in a semi-automatic screen-printing process, the inks are dried by evaporation producing significantly higher quantities of VOCs. Other printing processes and operations that may cause major unsafe emissions comprise ink preparing, varnishing and cleaning (Kiurski *et al.*, 2011).

Under a cleaner production (CP) scope, it becomes essential to search for production goals engaged with environmental issues, which suggests establishing some performance indicators to show potential impacts of industrial operations on the environment. Bearing in mind that the various functional areas of a business have different impacts on the environment, environmental performance assessment (EPA) indicators should take into account produced goods specificity and the nature of adopted processes, once each business type generates and discards a wide range of chemicals, gases, particulate materials, metals, solvents, organic compounds, among others (Rebelato *et al.*, 2013). As a corollary, an EPA application demands knowledge on each step of all processing procedure to identify all of the generated wastes, so that one can point their effects against the environment.

In view of the above, this research issue lies in how to build a methodologically valid structure for the environmental performance evaluation of companies from the printing industry segment based on the disposal suitability of the wastes and by-products generated.

In accord with the research problem, this study has the objective to conduct a case report about environmental performance of a Brazilian graphic company located in the state of São Paulo (Brazil). In order to accomplish this goal, an index was developed, which represents a single percentage point of how environmentally adequate is the allocation of all residues/sub-products generated in operational activities. Therefore, this study is relevant because it contributes to a reflection on negative environmental impacts caused by such business activity, as well as developing methods to measure environmental performance of the printing industry with further contribution in controlling the generation of wastes and by-products. This deeper analysis on the environmental impacts generated by the printing industry can serve as a theoretical basis for other business sectors.

2. Method

First, it must be elucidated that the term "residue" is conceptualized and will be henceforth employed as any remainder derived from manufacturing that is not characterized as a sub-product, either a gas, or a liquid effluent or a solid. Second, in order to be regarded as a sub-product, according to Fipa (2007), the remainder originated in manufacturing requires harmony with three conditions: there must be probability of future employment for it; possibility of direct employment with its current shape, which means, without going through alterations; and be integrated part of a continuous production process.

Complementary, it is highlighted that a sub-product can be considered also a pollutant, once a polluting material is a material or substance that do not accommodate to a natural system in case of introduction of a quantity exceeding the natural system's assimilation capacity.

The research method employed in this study was composed by five stages as follows:

(1) Mapping of productive stages of the printing process – at this stage the identification and study of the unit processing operations to transform paper into finished goods was held such as business cards, brochures, stickers, brochures, magazines, books, newspapers.

(2) Quantitative weighting of environmental impact referring to each residue/sub-product identified in the previous stage – in this stage the method improved analytic

hierarchy process (IAHP) was applied, a supporting tool for decisions about complex issues. IAHP is a variant of the conventional method analytic hierarchy process (AHP) developed by Thomas L. Saaty (2008). In the original version of AHP, the method requires pairwise comparison of various alternatives with respect to each of the attributes and a pairwise comparison of attributes themselves. The size and number of the comparison matrices increases rapidly as the number of alternatives and/or attributes increases (Rao, 2013). This can be placed as one of the major problems with the conventional AHP technique, in other words, a quadratic increase in the number of comparisons depending on the number of alternatives (more precisely, ([$n \times (n-1)/2$]). Five to seven alternatives is quite an acceptable case. However, with more of this, it is desirable to have effective methods of reducing the number or time needed for pairwise comparisons, even with the inevitable loss of some accuracy (Roodchenko and Banin, 2015). In order to achieve results faster and to deal with the original AHP method weakness, it was chosen MindDecider software (www.minddecider.com). This tool has an interesting option that is to enable the so-called "auto-solve dependencies," which drastically reduces the number of questions based on the previously entered correlation significances. For example (Roodchenko and Banin, 2015), if the user enters the following proportions during the binary comparison: A < B and C > B, the "auto solve" makes a logical assumption that A < C. Alternatively, when it was entered: A < B and B = C, "auto solve" formulates that A < C. Thus, depending on a comparison order auto-solve function can reduce the number of requests up to nearly linear in the most appropriate case.

(3) Development of Environmental Performance Analysis Index (I_{epa}) – this index was developed with the aim of representing, in a single percentage value, how intensely the allocation of the set of all residues/sub-products generated in production is environmentally adequate. The I_{epa} was judged in a way to be directly proportional:

- to relative environmental impact of each residue/sub-product originated in production, once the nature between them is extremely diverse;
- to relative quantity of each residue/sub-product generated in a given time period, once there are residues/sub-products with high relative quantity, such as molding sand, and low relative quantity such as resin batches;
- to relative geographic coverage or relative spatial dispersion that each residue/sub-product can reach, once each of them is capable to attain a distinct extension in accordance with processing technology, composition and physical condition; and
- to categorical evaluation of final allocation adequacy practiced by the company for each residue/sub-product, once organizations can employ adequate or inadequate methods in the final allocation.

The general formula of I_{epa} is defined as follows:

$$I_{\text{epa}} = \sum_{i=1}^{n} \left[\frac{\left(V_{(a)i} Q_i A_i\right)}{\sum_{j=1}^{n} \left(V_{(a)j} Q_j A_j\right)} k_i \right] \times 100 \tag{1}$$

where n is the number of residues or sub-products generated and $V_{(a)i}$ the value of analyzed alternative (previously presented in item c). In this case, it is the relative weight of potential environmental impact of each residue/sub-product i; Q_i the relative quantity of each residue/sub-product i generated is expressed as follows:

$$Q_i = \frac{b_i}{\sum_{j=1}^{n} b_j} \times 100 \tag{2}$$

where b_i is the absolute quantity (produced per week, month or year) of each residue/sub-product i; A_i the impact relative coverage of each residue/sub-product is expressed as follows:

$$A_i = \frac{x_i}{\sum_{j=1}^{n} x_j} \times 100 \tag{3}$$

where x is the value (1, 2, 3) assigned according to impact geographic coverage of each residue/sub-product based on Table I. In Equation (1), k_i is the categorical evaluation of allocation adequacy of each residue/sub-product i practiced by the company. In order to have an environmentally adequate final allocation, $k=1$. In the opposite case, $k=0$. Since "environmentally adequate final allocation" is conceptualized as allocation of production remnants that includes reuse, recycling, composting, recovery and energy production or different allocations that will not lead to damages or risks to public health or safety and minimize unfavorable environmental impacts (Lei 12305, 2010).

(4) Data collection – this stage was carried out by observing the studied place and gathering documented information of the company, such as produced quantities of each residue/sub-product and final allocation given to each of them.

(5) Final results quantification – this stage was conducted through analysis of obtained data and computation of necessary parameters to I_{epa} calculation.

3. EPA

The EPA is crucial since it provides information that help companies to prioritize environmental aspects by means of reducing impacts caused during operations. Even though a holistic environmental assessment is not a new idea, being originated in 1973, it is no easy task to identify and evaluate holistically the risks that pollution arising from industrial activities can cause to the society and the environment. These impacts may be direct, indirect and cumulative (Salter and Ford, 2001). Until now, pollution incidents from factories or purely local effects have not had enough attention from the pertinent literature, since the consequences are limited. However, even small incidents can result in large toxicological problems to the surrounding communities.

Over the decades, several studies have been performed both for knowledge and for the evaluation of environmental management practices. In 1984, the Responsible Care Program was established in Canada, which was considered by Culley (1998) as the first formal environmental management model. This model was a formal action by the Chemical Manufacturers Association and consisted primarily of Guiding Principles (purposes),

Table I.
Criteria used in evaluation of impact coverage of each residue/sub-product

x	1	2	3
Criterion	The impact is local, the effects affect the production place and its surroundings	The impact is regional, it is relevant beyond the surroundings of the production place	The impact is strategic, its effects might have relevant effects coverage in national or global scope

Management Practices codes with generic goals that allow each organization to establish the ways of achieving them, Public Advisory Panel composed of members from different areas that cooperate with the chemical industry in developing management practices and helping to understand the community's concerns, and Leadership groups with executives of companies that fit the principles of responsible care for the discussion of experiences, exchange of information and identification of needs for improvement and mutual assistance.

Hunt and Auster (1990) focused on the environmental concern of companies and proposed a model of five stages to classify the studied companies, which might be from a start-up business, without any environmental concern, to a proactive company, which is highly committed to the issue. For Maimon (1994), evaluating the environmental performance of a company can be analyzed based on three typical stages. The first would be the adaptation of the company to the market regulations and demands, embodying pollution control equipment to the output lines, without changing the production structure and the final product (these are technologies known as end of pipe). In the second stage, the performed adaptations are required regarding the environmental issue, which modifies the processes and/or products (including packaging) to prevent pollution and problems that undermine the achievement of business strategy. The last stage is highlighted by anticipation of the environmental problems that may further occur, i.e. adopting a proactive behavior and searching for business eco excellence. Donaire (1994) proposed an analysis into three stages that often can occur simultaneously. The first stage consists of taking environmental control actions at the output line, such as chimneys and sewers, however, keeping the existing structure. In the second stage, such actions are taken for processes to mitigate environmental pressures, recycling materials and streamlined energy inputs. Finally, in the third stage, the company adopts goals for a high environmental performance, in general under consumer market pressure, which supervises as legal agents do. The model developed by Sanches (2000) elects two types of integration of the environmental variable to the company. The first states that environmental issues generate extra operational costs, being a barrier to the business expansion. Yet the second is the opposite, being a proactive environmental management, in which the ecological dimension is taken as a profit generator. At this stage, a technical group of experts and a management system (environmental department) are incorporated to the process, having the role of promoting better company's relationship with the natural environment through assessment and control of potential impacts. Corazza (2003) proposed that the production unit structure could be changed in two ways to deal with the environmental management. The first one corresponds to a specific integration of the environmental variable, i.e. the punctual creation of a function, position or environment department, setting the centralization of this environmental initiation and hence becoming a less efficient and proactive environmental management system. The second way is a matrix integration, in which there is a mobilization of internal sectors, involving mainly the areas of human resources, production, management as well as research and development. To achieve excellence in environmental compliance, this integration is commonly driven by the deployment of systems based on the ISO 14000 series standards, which guide the company to a continuous and growing search for environmental quality.

Günes *et al.* (2008) sampled polluted water from Ergene river basin in Turkey; they observed high concentrations of chromium, sulfides, ammonia, high biochemical oxygen demand and high chemical oxygen demand, concluding that the water is highly toxic to human health. RPS (2008) reported a health risk evaluation carried on emissions from industrial chimneys; this evaluation was performed directly by air inhalation and indirectly by contaminated food ingestion. The assessment presented the constructs: cancer risk estimates, risk estimates related to exposure to contaminants, risk estimates associated with respiratory tract, lead exposure level estimates, infant exposure by breastfeeding, estimates of soil concentrations from most affected receptors, and concentration of metals in food.

Strezov *et al.* (2013) developed sustainability indicators for iron and steel production and compared with power generation and food production industries. Liu *et al.* (2013) reported that crops in China are contaminated by heavy metals from traffic smoke, mining and local industries. A total of 268 samples of plants were collected and concentrations of metals and heavy metals were found there. The results from health risk assessment showed that fields near mining areas and landfills have proven to be inadequate for growing vegetables, given carcinogenic contamination by lead, chromium, arsenic, cadmium and mercury. Kubota and Rosa (2013) proposed, after thorough literature search, the integration between the theory of inventive problem solving (TRIZ) and the CP strategies to build a new method aimed at reducing effluents, wastes and gas emissions from companies. Samuel *et al.* (2013) created key indicators for a sustainable production in a Malaysian petrochemical industry; these indexes were based on indicators developed by the global reporting initiative and the Lowell Center for Sustainable Production.

In a quantitative assessment, there is the methodological proposal of Tahir and Darton (2010), which suggests a broader vision for environmental performance measurements of a business, being divided into five steps: business overview, sustainability definition and derivation of business prospects, setting limits to the analyzed system, development of indicators and metrics, and checking and modifications.

With regard to the selection and definition of specific environmental indicators, several studies have been published over the past few decades. In the same line, we can find the studies developed by Thoresen (1999) and Jasch (2000). The ISO 14000 series itself has, from the ISO 14031 (International Organization for Standardization, 2013a) standards and ISO 14034 (International Organization for Standardization, 2013b), a set of recommendations for the choice of environmental indicators. In this context, Perotto *et al.* (2008) pointed out that the selection of environmental performance indicators should take into consideration the products produced and the production process features associated with them, suggesting a careful survey of these factors as a prerequisite to set indicators able to measure the environmental performance of a company.

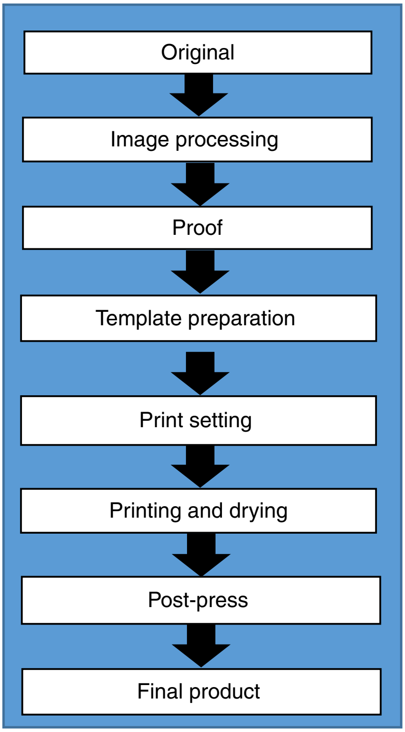
4. Printing process and the generated residues/sub-products

Figure 1 briefly presents the printing process stage "offset." It begins with an order entry, that is, at this stage a first contact with the customer is made, the product is designed, quotted and the project is approved. In some cases, such as magazine, books and newspapers, material editing had already been pre-defined by the publisher. The second stage is image processing, which is carried in the prepress and premedia. Graphic designers manipulate the image to be inserted into plotters (print run model to be printed in the rotary or flat machines), and later being burned onto a plate recording. The third step is the proof, which is the initial model, being used as a matrix for comparison with other units of the product; thus, this printing is used as a template. In this step, metal plates are printed with images and inked for further transferring to an intermediate cylinder (blanket) from which the image is reprinted onto the substrate (paper for example). Print setting is the step performed right after the start of printing to reach color quality and overtone. The following step is printing and drying. Thereafter, water-based varnish or UV light is applied on the printed material. The penultimate step is the post-printing, which consists of a finishing sector, where it is cut and assembled. Finally, the final product is stored or directly dispatched.

Table II shows the residues/sub-products generated by the printing production, their respective compositions and the activities that have potential impact.

5. Results and discussion

The case report was taken from a company founded approximately 35 years ago. It operates in São Paulo State, Brazil, has around 23,000 m^2 of built area, and acts at printing and



Source: Adapted from Companhia de Tecnologia de Saneamento Ambiental (2003, p. 21)

Figure 1.
Simplified flowchart of the printing process "offset"

supply chain sectors. The study was conducted between January and July of 2015. The company has a capacity of printing 23 million copies a month, and owns several certifications, among which we may cite ISO 14001:2008 and ISO 9001:2004. Waste management is accomplished by an environment-responsible team, which controls production volume, sales or waste disposals, and preparation of documents for transport within the state legal requirements, besides taking account of the "Waste Allocation Certificates" that charges waste transport by contracted carriers.

Before IAHP analysis, a hierarchical structure was designated, which was guided by the three key environmental compartments: soil, water and atmosphere. These three entities set the evaluation criteria, which were used as benchmarks on pairwise weighting of the 21 residues/sub-products generated during the printing process. Figure 2 illustrates this hierarchical structure.

The pairwise weightings were carried by a focus group (Stewart and Shamdasani, 2015), which was composed of four experts from the environmental management area who know the features of wastes generated during the printing process. All of them have been working in this industry for a period of at least three years. Table III presents the skills of the expert team.

By the above-mentioned software application, the relative weighting was obtained among the three criteria "impact on atmosphere," "impact on water" and "impact on soil," taking into account the potential risks regularly caused by the residues/sub-products from printing companies. Figure 3 shows the results obtained.

Residues/ sub-products	Activity	Composition	Potential impact
Industrial wastewater	Plate burning and printing	Liquid with potassium sulfate (10%); hydroquinone (7%); diethylene glycol (2%); sodium carbonate (1%); potassium citrate (10%); aluminum nitrate (20%); trisodium phosphate (20%); water (30%)	Potentially polluting liquid waste to soil and surface water and/or groundwater
Sludge from drying beds of STP	Domestic wastewater treatment (sewage)	Organic material	Potentially polluting solid waste to soil and surface water and/or groundwater
Contaminated mix[a]	The entire production process	Plastic acetate (77%), silver (3%), vinyl acetate (11 to 12%), biocide additives (2 to 3%), scrapes, plastic and PVC	Potentially polluting solid waste to soil and surface water and/or groundwater
Aqueous liquid waste contaminated by solvents	Printing: blanket and plate washing	Pigment, varnish, ethanol, isopropyl acetate/*n*-propyl, wax, fatty acids, ammonia, resin and water with arsenic, chlorides, nickel and isopropyl alcohol (pH = 8.24)	Potentially polluting liquid waste to soil and surface water and/or groundwater
Painting sludge	Printing	Vegetable oil-based, refined mineral-based and aliphatic hydrocarbon-based inks, resin, pigment, zirconium naphthenates and octanates, manganese, cobalt and polyethylene based wax	Potentially polluting liquid waste to soil and surface water and/or groundwater
Batteries	Produced in the entire company	Cadmium, nickel and metal cartridge	Potentially polluting solid waste to soil and surface water and/or groundwater
Technological waste[b]	Produced in the entire company	Electronic components, printed circuit board and plastics	Potentially polluting solid waste to soil and surface water and/or groundwater
Industrial towel, uniforms and PPE contaminated by solvents, ink, oil, grease and other chemicals	The whole production process	Fabrics, oils and inks	Potentially polluting solid waste to soil and surface water and/or groundwater
Fluorescent bulbs	Lighting system of all company	Glass, mercury and sodium	Potentially polluting solid waste to soil and surface water and/or groundwater
Healthcare waste – outpatient[c]	Outpatient	Bandages, cotton, syringes, needles and vials	Potentially polluting solid waste to soil and surface water and/or groundwater
Lubricating oil/ burnt oil	Maintenance of machinery and power generators	Organic acids, ketones, polynuclear aromatic compounds, resins, lacquers and metals (lead, chromium, barium, cadmium)	Potentially polluting liquid waste to soil and surface water and/or groundwater
Metal scraps	Produced in the entire company	Iron and steel	Potentially polluting solid waste to soil and surface water and/or groundwater
Copper scraps	Electrical service	Copper (99%) and other metals (1%)	Potentially polluting solid waste to soil and surface water and/or groundwater

(*continued*)

Table II. Residues/sub-products typically generated during the printing process, their composition, production stage and potential impact

Residues/ sub-products	Activity	Composition	Potential impact
Aluminum plates	Plate burning and printing	Aluminum (99%) and other metals (1%)	Potentially polluting solid waste to soil and surface water and/or groundwater
Paper offcuts	Produced in the entire company	Cellulose fiber	Potentially polluting solid waste to soil and surface water and/or groundwater
Plastics	Produced in the entire company	Plastic resin	Potentially polluting solid waste to soil and surface water and/or groundwater
Organic waste	Cafeterias and eateries	Organic material and fibers	Potentially polluting solid waste to soil and surface water and/or groundwater
Sanitary effluent	Restrooms and kitchen	Organic material	Potentially polluting solid waste to soil and surface water and/or groundwater
Wood and pallet scraps	The entire production process	Fiber and organic material	Potentially polluting solid waste to soil and surface water and/or groundwater
Tires	Forklift truck servicing	Natural rubber, synthetic rubber, oil, steel and sulfur	Potentially polluting solid waste to soil and surface water and/or groundwater
CO_2 from VOC combustion	Print settings, printing, drying and post-press	CO_2 gas	Potentially polluting gas to the atmosphere

Notes: [a]The contaminated mix waste is composed of residues from adhesives and various resins; flexographic rubber dust; cyrel and blankets; film waste, photolith, laminates and astralon; needled-felt filter residue from industrial and graphic origin; contaminated laminate scraps and plastic blanket; paper scraps contaminated with silicone, glue, resin, ink and solvents; plastic packaging contaminated with chemicals other than pesticides, empty and non-clean; and sawdust waste contaminated with soluble oil, among others; [b]the technological waste consists of electronic devices, computers, printed circuit boards, telephone switchboards, etc; [c]the healthcare service wastes (outpatient) consist of contaminated syringes and needles, bandages, worn ribbons and adhesive tapes, expired medications, medicine packaging, among others

Table II.

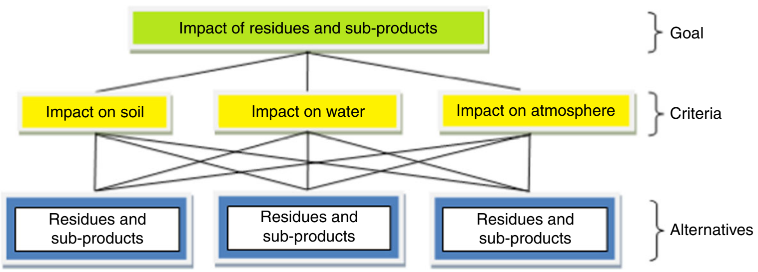


Figure 2. Hierarchical structure for weighting of the residues/sub-products generated by printing process

Regarding the quantitative weight of relative environmental impact for each alternative (residues/sub-products), it was taken as hypothesis that each of them had been released directly into the environment (air, water, soil) and improperly (i.e. without any previous treatment). For example, for the pairwise comparison of the aqueous liquid waste contaminated by solvents vs industrial wastewater, concerning water impacts, we took as hypothesis that both wastewaters were directly discharged into watercourses. In this case, the focus-group team considered a ratio of 5:1; therefore, the aqueous liquid was taken as strongly dominant against the wastewater. Even though the Company of Environmental Sanitation Technology (Cetesb) from São Paulo state considers both wastes as hazardous, the aqueous liquid has most polluting elements in its composition like pigment, wax, resin, arsenic and nickel. On the other hand, the industrial wastewater is composed of elements that are considered soil nutrients, such as potassium nitrate and aluminum phosphate. Figure 4 illustrates the results graph, showing the ratio ($R_{a(i)}$) of each residue/sub-product. These ratios are determined based on the highest weighted result. It can be seen that the highest $R_{a(i)}$ was achieved by industrial wastewater (100 percent); so the experts took it as the most impacting waste to the environment.

Table IV complements Figure 4, presenting ascending quantitative results of $V_{a(i)}$. It should be noted that $V_{a(i)}$ is the complement of $R_{a(i)}$, that is, $V_{a(i)} = 1 - R_{a(i)}$.

The graphic analysis shows that the eight most outstanding wastes were domestic wastewater (5.235 percent), painting sludge (5.830 percent), contaminated mix (5.889 percent), lubricant/burnt oil (6.365 percent), contaminated towel/uniform and PPE (6.425 percent), fluorescent bulbs (6.484 percent), batteries (6.901 percent) and industrial wastewater (7.198 percent).

The domestic wastewater is hazardous to public health inasmuch, as have pathogenic microorganisms that can propagate in water intended for human consumption. The organic matter in this waste can lead to dissolved oxygen depletion, impairing life of other aquatic organisms. Nitrate (NO_3^-) and phosphate (PO_4^{3-}) were also present, causing the eutrophication of the aquatic medium.

Refractory organic compounds and metals such as lead (Pb), chromium (Cr), cadmium (Cd) and silver (Ag), among others are found in wastes like painting sludge, contaminated mix, lubricant/burnt oil as well as contaminated towels, uniforms and PPE. These refractory organic pollutants are commonly known as recalcitrant, since they are non-biodegradable or present slow biodegradation rate. In the case of lubricants and burnt oil, which are petroleum derivatives, the major harmful effects of improper disposal are

Table III.
Skills of the experts that worked on the evaluations of environmental impact

Expert	Printing process experience	Environmental management experience	Education
A	4 years	3 years	Business administrator
B	4 years	4 years	Chemist
C	3 years	7 years	Environmental engineer
D	6 years	11 years	Business administrator

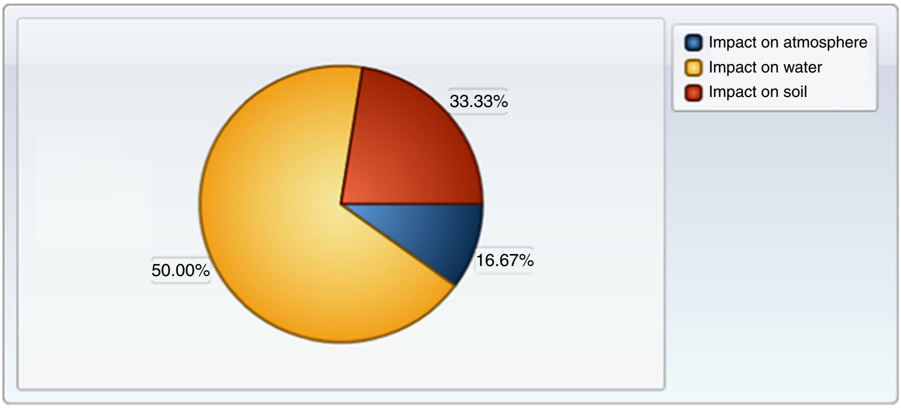


Figure 3.
Pie chart corresponding to the potential impact relative weight of residues/sub-products generated by printing industry against atmosphere, water and soil environments

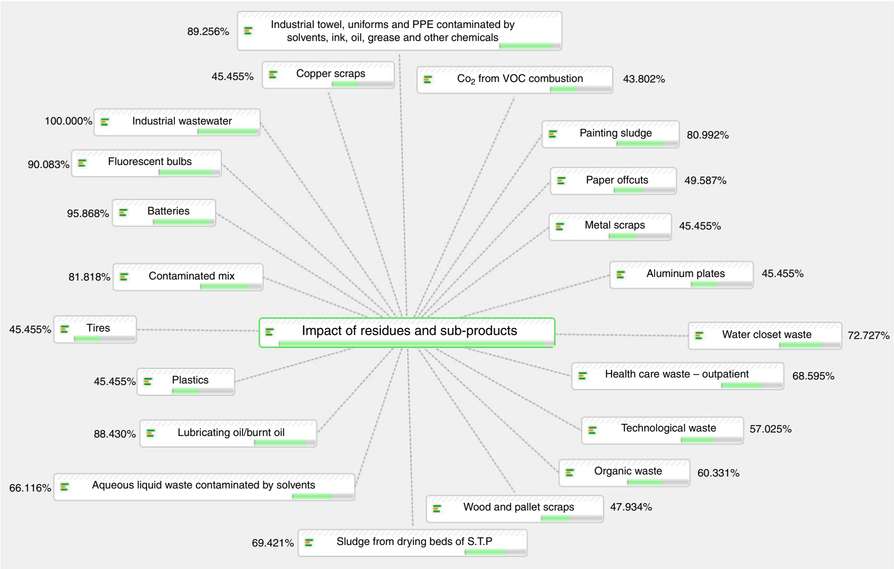


Figure 4.
The $R_{a(i)}$ ration of each residue/sub-product

Residues/sub-products	Relative weighting ($V_{a(i)}$)(%)
CO_2 from VOC burning	3.153
Metal scraps	3.272
Aluminum plates	3.272
Plastics	3.272
Tires	3.272
Copper scraps	3.272
Wood and pallet scraps	3.450
Paper offcuts	3.569
Technological waste	4.105
Organic waste	4.343
Wastewater with solvent	4.759
Healthcare service wastes	4.938
Sludge from drying beds of STP	4.997
Sanitary effluent (water closet waste)	5.235
Painting sludge	5.830
Contaminated mix	5.889
Lubricant/burnt oil	6.365
Contaminated towel, uniform and PPE	6.425
Fluorescent bulbs	6.484
Batteries	6.901
Industrial wastewater	7.198

Table IV.
Potential impact of each waste/by-product ($V_{(a)i}$) corresponding to Figure 4

hindrance to gas exchange between the water and the atmosphere by film formed on the water surface, plant stomata sealing aside from damages on animal respiratory organs, root waterproofing and toxic effects against several organisms. The aforementioned metals can cause damage to health due to their toxicity and carcinogenic, mutagenic or teratogenic potentials. Aquatic organisms may or may not be sensitive to these metals; however, these elements bioaccumulate, which enhances the harmful effects throughout the food chain, endangering organisms at the top of it (Braga *et al.*, 2005).

Among the mercury lamps, fluorescent bulbs are major polluters and when improperly discarded, represent an environmental risk due to their high mercury content (Hg) able to spread throughout the environment. The Hg introduced in these lamps manufacturing can undergo oxidation and gain mobility within the environment (Durão Júnior *et al.*, 2008). At toxic concentrations but non-lethal, it breaks down brain enzymatic and metabolic processes, causing shyness, loss of memory and psychopathological symptoms such as fear, insomnia, irritability, depression, tremor and insanity, which combined are called erethism (Bernhoft, 2012). The element also causes kidneys damage, blindness, chromosome breakage and results in teratogenesis (Lenzi *et al.*, 2009).

Gradual leakage of toxic metals from batteries can directly reach the lithosphere. About 80 percent of the produced batteries are built-in and are made of hazardous components of environmental persistence, besides deposition and concentration within sediments and wastes, as well as bioaccumulation of cadmium and nickel in animals and plants (Martinelli *et al.*, 2014). Cadmium (Cd) is a highly toxic element that harms humans, animals and plants (Jarup and Akesson, 2009). In humans, Cd can cause hypertension, stomach and liver diseases, emphysema, cataract forming, muscle atrophy, bone porosity, heart diseases, cancer, memory and cognitive changes (Fernandes and Mainier, 2014). The effluent or industrial waste from plate burning and printing are composed of aluminum nitrate ($Al(NO_3)_3$) and trisodium phosphate (Na_3PO_4) which are sources of nutrients (NO_3^- and PO_4^{3-}), which can cause eutrophication of water bodies if released into reservoirs without treatment (Braga *et al.*, 2005).

Shortly after the relative weighting of each residue/sub-product potential environmental impact, it was identified the absolute quantity (b_i) generated by the company's printing process. From that, the relative quantities (Q_i) were calculated. Thereupon, relative coverage (A_i) and categorical evaluation (K_i) were defined. Table V displays the allocation of each residue/sub-product adopted by the company with the corresponding categorical evaluation that was represented by K_i. A zero value was assigned only for K_i of CO_2 from VOC

Residue/sub-product	Company's allocation	*Ki*
Wastewater with solvent	Licensed company	1
Lubricant/burnt oil	Marketing	1
Fluorescent bulbs	Licensed company	1
Contaminated towels, uniforms and PPE	Licensed company (sanitization and treatment)	1
Contaminated mix	Licensed company	1
Batteries	Licensed company	1
Technological waste	Marketing	1
Industrial wastewater	Licensed company	1
Healthcare service waste	Licensed company	1
Painting sludge	Licensed company	1
Sanitary effluent (water closet waste)	Biological treatment at STP and following launch into surface water	1
Organic waste	Landfill licensed by Cetesb	1
Sludge from drying beds of STP	Landfill licensed by Cetesb	1
CO_2 from VOC burning	Atmospheric emissions	0
Copper scraps	Marketing	1
Tires	There is a tire disposal site in the city (Ecopoint). The materials are recycled by the local Department of the Environment	1
Plastics	Marketing	1
Aluminum plates	Marketing	1
Metal scraps	Marketing	1
Wood and pallet scraps	Marketing	1
Paper offcuts	Marketing	1

Table V.
Final destination of each residue/sub-product and their respective categorical evaluation (K_i)

burning. In other words, except for that waste, the discharging of all other residues/sub-products was considered environment friendly.

In this company, a few wastes are stored at specific sites and, after reaching certain amount, they are driven to the waste center or released to collection. A company licensed by the Cetesb agency collects this material. Such collection company recycles, process, treats and treats each residue/sub-product for the proper final destination. Some examples include industrial wastewater and mix contaminated. The first is packaged in unique and waterproof metal tanks. Yet the second is conditioned in waterproof metal dump buckets placed at specific sites within the production area; they are all covered and have waterproof floors. Once filled, the waste is taken to the waste center.

The printing company has a device at its web-offset machines called "after-burn," which promotes post-burning of VOC generated during process, turning them into carbon dioxide. The furnaces for burning of such gases are fed by liquefied petroleum gas instead of electrical power, which enhances the CO_2 emissions.

Table VI presents results of $V_{(a)i}$, b_i, Q_i, A_i and I_{epa} in the studied company. It is noteworthy mention that the company achieved a 90.8 percent I_{epa}, meaning that 90.8 percent of the residues/sub-products have environment-friendly destination based on EPA analysis. Even though the Brazilian legislation does not oppose the release of combustion gases directly into atmosphere, CO_2 emissions received a zero scoring by the categorical evaluation (K_i), regarding its allocation adequacy. It is because the carbon dioxide is a greenhouse gas and, therefore, contributes to global warming.

It was noted that the relative amount (Q_i) of the domestic wastewater produced corresponds to approximately 39.00 percent of the absolute amount of residues/sub-products,

Waste/ by-product	Relative weighting ($V_{(a)i}$) (%)	Absolute quantity (bi) (ton/year)	Relative quantity (Q_i) (%)	Relative coverage (A_i) (%)	Categorical evaluation (K_i)	$\left[\frac{(V_{(a)i}Q_iA_i)}{\sum_{j=1}^{n}(V_{(a)j}Q_jA_j)}k_i\right] \times 100$
CO_2 from VOC burning	3.153	2678.47	7.92703	8.11	0	0.00000%
Metal scraps	3.272	3.95	0.01169	2.70	1	0.00469%
Aluminum plates	3.272	104.46	0.30915	2.70	1	0.12402%
Plastics	3.272	47.31	0.14002	2.70	1	0.05617%
Tires	3.272	0.10	0.00030	2.70	1	0.00012%
Copper scraps	3.272	0.63	0.00186	2.70	1	0.00075%
Wood and pallet scraps	3.450	265.20	0.78487	2.70	1	0.33200%
Paper offcuts	3.569	12321.00	36.46446	2.70	1	15.95629%
Technological waste	4.105	1.75	0.00518	5.41	1	0.00522%
Organic waste	4.343	123.60	0.36580	5.41	1	0.39028%
Wastewater with solvent	4.759	5.77	0.01708	5.41	1	0.01996%
Healthcare service wastes	4.938	0.01	0.00002	5.41	1	0.00002%
Sludge from drying beds of STP	4.997	15.52	0.04593	5.41	1	0.05639%
Sanitary effluent (water closet waste)	5.235	13.200.00	39.06589	5.41	1	50.24160%
Painting sludge	5.830	14.43	0.04271	5.41	1	0.06117%
Contaminated mix	5.889	64.81	0.19181	5.41	1	0.27750%
Lubricant/burnt oil	6.365	0.50	0.00148	5.41	1	0.00231%
Contaminated towel, uniform and PPE	6.425	4620.00	13.67306	5.41	1	21.58182%
Fluorescent bulbs	6.484	0.40	0.00118	8.11	1	0.00283%
Batteries	6.901	1.50	0.00444	5.41	1	0.00753%
Industrial wastewater	7.198	320.00	0.94705	5.41	1	1.67469%
	100.0	33,789.41	100.0	100.0	$I_{\text{epa}}=$	90.8%

Table VI. Results of $V_{(a)i}$, b_i, Q_i, A_i and I_{epa} in studied company which has a 50.2 percent weight in the I_{epa}. The number of employees in the company and required physical structure of the facilities explain that fact. This way, given the large number of employees (about 800), the company has 80 toilets and changing rooms with ten showers, plus a dining room that perform fruit and vegetable washing and has a capacity for 800 meals per day. Thus, the treatment of this effluent requires a great retention capacity of about 400,000 liters, while industrial wastewater is treated every eight days, on average, at plant units that receive around 6,000 liters.

6. Last remarks

This study had the objective to conduct a case report about environmental performance of a Brazilian graphic company. In order to accomplish this goal, an index called I_{epa} was developed, which represents a single percentage point, of how environmentally adequate is the allocation of all residues/sub-products generated in operational activities.

The developed method is based on the presupposition that the effort efficiency measurement of environmental management of a company will be directly proportional to the efficiency rating of environmental adequacy of allocations given to generated residues/sub-products.

The determination of I_{epa} considered the relative weighting of potential impact of each residue/sub-product generated by foundry industry; the relative quantity of each residue/sub-product generated in a given time period; the relative dispersion that each residue/sub-product can reach; and the adequacy evaluation of final allocation of each residue/sub-product practiced by the company.

The environmental impact weighting of residues/sub-products set of graphic services might be considered a complex problem, as its causes and effects can only be noticed through reflection and require deductive view assisted by experience, which means, through previous involvement with the concerned variables. The problem involves residues/sub-products with great differences of physical and chemical nature; several harmful effects that can be caused in case of inappropriate allocation into different natural environments (water, soil and atmosphere) and alterations that these effects can have over time.

The conducted evaluation among the residues/sub-products considered the most impacting to the environment, verified that a much higher relative impact occurs on water rather than soil or atmosphere. Printing process has high potential for contamination of surface and groundwater sources, medium potential for soil contamination and little potential for contamination of the atmosphere. The eight wastes with greater environmental impact are as follows: sanitary effluent; painting sludge; contaminated mix; lubricant/burnt oil; contaminated towel, uniform and PPE; fluorescent bulbs; batteries; and industrial wastewater.

Regarding the storage, treatment, disposal and destination of residues/sub-products, the company achieved an index I_{epa} of 90.8 percent, which means that 90.8 percent of the wastes have environment friendly disposal. It means that only 9.2 percent of allocations were considered inadequate. This percentage is related to the VOC burning generated gases, which cause the greenhouse effect. However, despite being an environmentally inadequate practice, this is legally accepted.

Based on what was discussed above and considering that the currently available technologies for CO_2 capturing from industrial combustion are extremely expensive – which could economically hinders business, the company should not be charged of negligence or intentional environmental damage by the waste treatment inevitably discarded.

The proposed indicator I_{epa} was established for the graphic service companies and cannot be used for other sectors.

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