

Are there any environmentally friendly printing principles? Environmental issues linked to document printing

Petre Ogruțan

Transilvania University of Brașov, Faculty of Electrical Engineering and Computer Science, Brașov, Romania. Corresponding author: P. Ogruțan, petre.ogrutan@unitbv.ro

Abstract. Modern world needs printed documents increasingly more and one of the biggest ecological challenges linked to the printing equipment is the large amount of consumed toner and ink cartridges discarded in the environment. The paper sets out a comparison among the main current printing principles with their features, it highlights the waste material policy, it analyses electrophotographic, ink jet, thermal printing and a newly applied environmentally friendly principle, namely solid ink printing. The paper also sets out methods and initiatives of mitigating the amount of waste materials discarded in the environment, it analyses the policy of the manufacturing companies in this industry and discusses the users' responsibility.

Key Words: ink, waste material, printer, environment.

Introduction. Modern world needs printed documents increasingly more. The complexity of the manufacturing systems, of those that provide quality in all fields, the service management and diversification, the quality standards implementation are processes that use printed documents more and more. Document printing by current printers gives rise to a large amount of waste materials, mainly composed of toner cartridges, ink cartridges and broken printers (Ogrutan et al 2010). There are many initiatives for mitigating the printing costs, which also leads to a reduction of the amount of trash. There are software programmes for managing document printing at the level of a company, like the one presented by Kalochristianakis et al (2013). The initiatives aiming at cost diminishment usually lead to positive effects upon the environment, the typical example being energy savings (Slocum 2004). The European Community has preoccupations in this regard, one of them being to ECO Label mark out the printing pieces of equipment that have the best environment protection performances. The criteria analysed for printing, copiers and multifunctional devices are sustainability, recyclability, the consumption of energy, the execution without hazardous substances (for instance ROHS - Restriction of Hazardous Substances Directive 2002/95/EC for electronic boards), the consumable materials, the gas, electromagnetic field and noise exhaustions (Kougoulis et al 2012; EU Ecolabel Regulation 66 2010).

One of the greatest challenges linked to the printing equipment is the large amount of discarded toner and ink cartridges. Ruan et al (2011) suggest a manufacturing line for separating the toner cartridge components. The separation percentage points for iron, toner, aluminium and plastic are 98.4%, 95%, 97.5% and 98.8%, respectively. The separation by means of the suggested line is far superior to manual disassembling and separation, both in terms of time and of performance. Toner cartridge remanufacture is an old preoccupation (Nakada 1999). By remanufacturing, the cartridges are filled with toner and some used components may be replaced, thus obtaining cartridges with a lesser quality than the new ones, but a whole lot cheaper.

As regards electronic waste material recycling, there are certain original initiatives, like Lucena's (2011), who suggests the integration of certain components from the printing equipment into modules for pupils' and academic students' education. He suggests the utilisation of sensors, mechanisms and motors, which, if integrated into modules with microcontrollers, can become working platforms with an educational potential. Another original initiative is Suwa's (2005), who suggests the utilisation of a natural toner, cartridge dumping thus affecting the environment less.

The printer manufacturers partly took the responsibility of protecting the environment. In this respect, HP initiated the action of taking over used cartridges (HP Product Return and Recycling 2014). Within this program HP announces: "We are

committed to helping our customers recycle responsibly, recovering 2.8 billion pounds of products since 1987. More than 75% of our ink cartridges and 24% of HP LaserJet toner cartridges are now manufactured with 'closed loop' recycled plastic."

The distribution companies also render free of charge services of taking over exhausted consumable materials and out of order electronic appliances. The supermarkets and the sanitation companies take over WEEE (Waste Electrical and Electronic Equipment Directive is the European Community directive 2002/96/EC), according to the data from ECOTIC's website. ECOTIC is a non-profit organisation that takes over in Romania the responsibilities that rest with the electrical and electronic equipment manufacturers and importers, in order to reach the yearly goals linked to WEEE collection, reutilisation, recycling and valorisation.

The European Community makes efforts in this regard, by creating the European Association of Electrical and Electronic Waste Take Back Systems, which in 2010 drew up the WEELABEX (WEE Label of Excellence) document, which sets out basic principles for electronic trash collection, sorting and storing (Weelabex 2014). The printer cartridges, as consumable materials within electronic devices, fall into the electronic trash category and are subjected to the same regulations, such as the obligation of being stored in waterproof premises, for environment protection purposes.

Our paper briefly sets out the functional principles of printing for the most widely spread printers and analyses the same from the standpoint of their impact upon the environment. A new principle of printing with no negative impact upon the environment is analysed and compared to the classic printing principles. The paper suggests solutions for choosing the best printing system from the environmental point of view and critically analyses the policy of the printing equipment manufacturers, the conclusions outlining the latter's responsibility.

In addition, users may contribute to the mitigation of the amount of waste materials by only printing really necessary documents. Many companies gave up certain printed documents and only use the electronic format.

Classic printing principles and their impact upon the environment. The very first printer is said to have been designed by Charles Babbage in 1822, as a component of a mechanical calculator. The first printers offered commercially were the ones with impact. They dominated the market for a long time owing to their cheap consumable materials. However, the low printing quality, the slow printing speed and the big noise generated by printing led to their replacement.

At present time, the most printing pieces of equipment are created according to the electrophotographic, ink jet or thermal principle. The electrophotographic one is illustrated in Figure 1a.

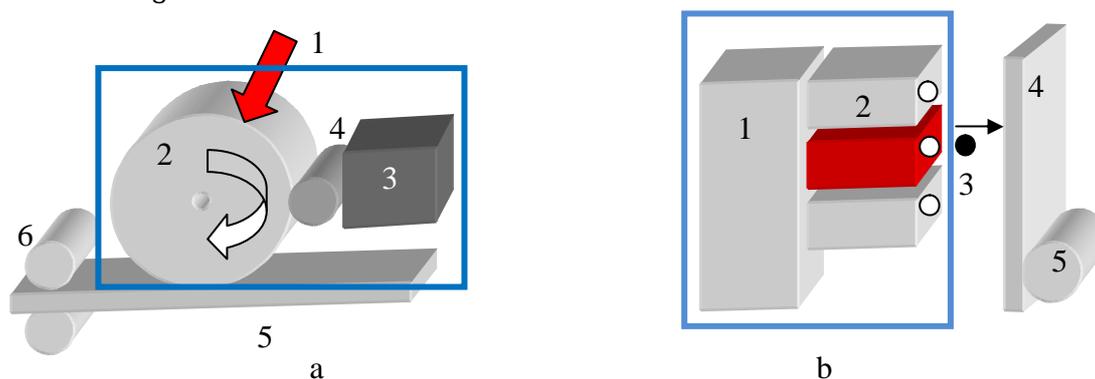


Figure 1. The principle of electrophotographic printing (a) and ink jet printing (b).

A source of light 1, which can be a swept laser or a series of light-emitting diodes, punctually discharges an electrostatically charged photosensitive drum 2, drawing a virtual image of the page to be printed. The toner from reservoir 3 is transferred by means of a transfer drum 4 on the discharged surface of the drum. The image is transferred onto paper 5 and fastened onto oven 6 by melting. A colour image is created

in the same way, except that the three fundamental colours and black are laid down by means of 4 sets of drums and toner reservoirs. For most electrophotographic printers, toner exhaustion means the need of replacing the toner reservoir, the drum and the transfer roller (in the blue frame). An exception is the Brother company, which developed a system that only exchanges the toner reservoir.

The principle of ink jet printing is set out in Figure 1b : from an ink reservoir, the ink enters the drop forming chambers 2. These chambers compose the printing head. By piezoelectrically bending the chamber wall or by heating the wall until the boiling point of the ink, one drop of ink 3 is splashed on paper 4. After printing a column of points, the head shifts and writes down the next column. At the end of the row, the paper is shifted by means of drum 5 and the next row is written down. In case of the jet printers, the ink reservoir or the reservoir and the printing head are exchanged.

Ogrutan' et al's paper (2010) assessed the amount of consumed cartridges that are disposed of or recycled. The obtained value, i.e. 25000 t of cartridges per year only from the printers of one manufacturer, means an impressive quantity.

By acting in a highly competitive market, the printer manufacturers have searched all the time for means of reducing the visible prices for the client upon purchasing a printer. The buying operation creates a link between the manufacturer and the seller, because printers need consumable materials ; this link does not exist in case of most electronic products. By customising the consumable materials, the manufacturers thought that every client would buy a certain amount of consumable materials only from the manufacturer, therefore the cost addition to the printer can be little. This trend became more conspicuous in time, toward selling printers and consumable materials, in certain cases, under the manufacturing price, with a significant addition.

The reaction of the free market to consumable material prices above the normal ones was rapid. There appeared companies that began manufacturing cartridges called 'compatible', often using components from used cartridges, thus producing remanufactured cartridges. The effect upon the environment was positive, but no so upon the printer manufacturers. The price of such a cartridge ranges between 25% and 50% of an original cartridge price.

The well established manufacturers of printing equipment defend their economic interests and took several measures for increasing the number of original cartridges sold:

- the new cartridges are endowed with a protection microcontroller;
- upon delivery, the printers are equipped with low capacity cartridges, termed 'start cartridges';
- low capacity cartridges were designed, in order to come up with acceptable prices;
- each new model of printer uses its own type of cartridge.

In order to alert the user that the toner life from the cartridge will end up soon, the manufacturers mounted a microcontroller on the cartridge – Figure 2, its role being to count the pages and of alerting the user. As a consequence, the cartridge cannot be refilled and no remanufactured cartridge may be bought. Certain types of printers only announce the toner life end, others reduce their functionality, such as certain multifunctional devices that no longer can print the received faxes and others no longer enable printing.



Figure 2. Chip mounted on the cartridge.

Another important aspect is that the consumable material running out alert by counting the hard copies is made long before it actually runs out. Many times, upon filling a cartridge, one notices that it still has plenty of toner. The alert may be accompanied by a partial loss of functionality.

In order to equip the new printers with short service life cartridges and in order to win the low income natural persons and companies market, cartridges with a small amount of consumable material were developed. In order to be mounted in the same space designed for large cartridges, the toner reservoir of the small ones has another shape, with an indentation, like in Figure 3.

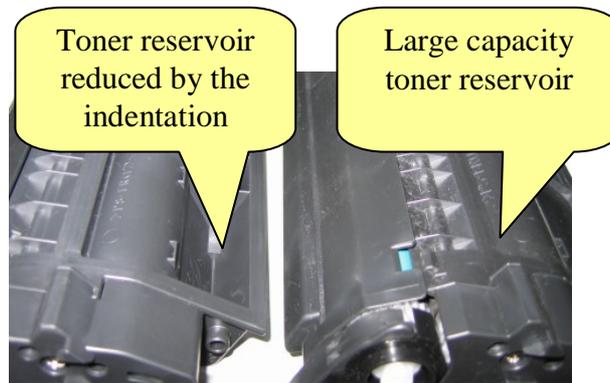


Figure 3. Two toner cartridges for the same printer: a small capacity one (left) and a large capacity one (right).

For instance, the situation of the low capacity (2300 pages) HP CE505A cartridges, which cost € 58, and the large capacity (6500 pages) CE 505x ones, which cost € 105, can be analysed. Around 100 g of toner (€ 1) can be used to print 1000 pages, so the price difference between the cartridges could only be € 4. The € 47 selling price difference clearly shows that there is no connection between the cost price and the selling price.

The existence of the cartridges with a lower content of toner can be said to be favourable to buyers, because they are cheaper, and to the printer manufacturers, because they sell more cartridges, but it is detrimental to the environment. Buyers should become more aware and to protect the environment by dumping as few cartridges as possible and by purchasing large capacity cartridges, which would be favourable from the financial view point as well. Thus, in the previous example with the € 58 cartridge, € 2.5 / 100 pages are spent and with the € 105 one, € 1.6/100 pages are spent. This idea can be traced in Slocum (2004).

Printing principles with a reduced impact upon the environment: thermal printing and solid ink printing. Thermal printers are less widely spread than the electrophotographic ones or the ink ones, they are smaller-sized and are therefore used as fax machines, notebook, telephone printers or for bar code printing. Theoretically speaking, there is a matrix of processor-controlled miniature resistors that quickly get heated up and cooled off, respectively.

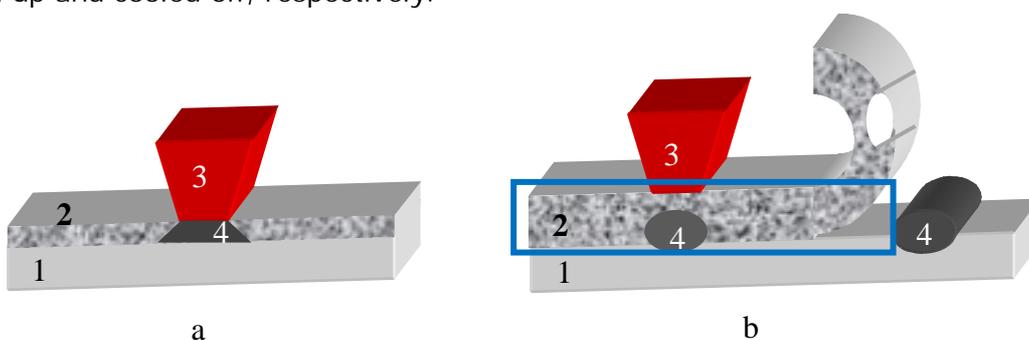


Figure 4. The principle of direct thermal printing (a) and of thermal printing by transfer (b).

Direct thermal printing on photosensitive paper – Figure 4a – is monochromatic printing, used especially for fax machines. Paper 1 is special, paint and acid 2 being laid on the photosensitive side. In the point heated by thermal head 3, the ink and the acid get combined and form a dark coloured point 4.

Thermal printing by transfer uses ordinary paper 1 and a film with paint 2. In case of heating a point by thermal head 3, the wax film gets melted and the paint is laid on the paper in points 4.

Direct thermal printing does not generate trash and the printing speed is low. In time, the thermal paper gets coloured and the contrast decreases. Thermal printing by transfer uses, as consumable materials, the film with paint, which is discarded after utilisation.

A relatively new printing principle, which is not yet widely spread, is solid ink printing. In 1986, Tektronix introduced the principle of printing by solid ink, which is melted, thus entering the writing head. Unlike the liquid ink, which has to dry up on the paper, the melted ink gets solidified much quicker, thus increasing the printing rate. The first variants of printers used a writing head directly on the paper, just like the liquid ink printers, which is a solution with many disadvantages. In 1995, Tektronix implemented indirect printing, which is used in current printers – Figure 5 (Jaeger 2014). In reservoir 1, the solid ink is melted and it feeds the printing head 2. The printing head 2, heated at a lower temperature than the reservoir, prints the coloured ink drops 3 in the fundamental colours and gets melted on drum 4. The drum is heated at a lower temperature than the printing head and the drops form a semisolid layer on its surface. This layer gets transferred onto the paper and the paper is heated and pressed, thus making the ink get printed on the paper.

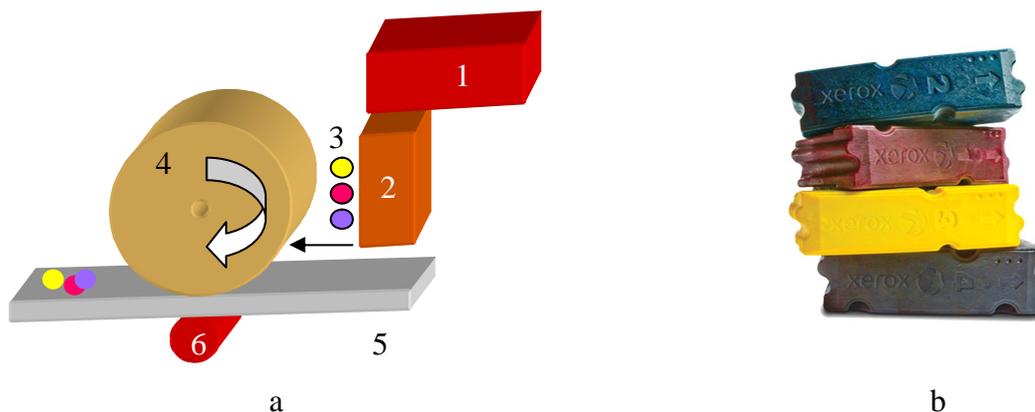


Figure 5. The principle of indirect printing by solid ink (a) and the solid ink (source: www.xerox.de) (b).

The advantage of this kind of printing is the absence of waste materials, thus making it the environmentally friendliest printing manner. The printing speed is high, reaching the Xerox ColorQube 8570 reference printing model of 40 pages per minute. The shortcomings consist in the need for a 12-15 minute turn on and turn off time, in a period of time needed for the solid ink to get melted and in the printer price, which is pretty high, namely between 700 and 2500 dollars. The printer must not be moved during running.

In 2000, Xerox bought Tektronix' printers division and in 2011 Xerox was awarded the Best Eco-Friendly Ink Technology prize, which was justified by the fact that printing takes place cartridge-free, the consumable materials get run out entirely, the ink is not toxic, and printing generates 90 % fewer waste materials than electrophotographic printing.

Discussions. Table 1 is a centralising one, comparatively showing a few printers based on various printing principles and their main characteristics. The feature aimed at in this paper is the amount of waste materials generated upon printing, however the table also contains prices, which are very important to the users. Both the prices of the printers and

of the consumable materials are relative, depending on suppliers, the quantity, the purchasing time and so forth. The costs of the consumable materials are provided for one hundred printed pages.

Table 1

Comparison between few printers based on various printing principles and their main characteristics

No.	Printing principle	Printer and printer price [€]	Consumable material	Number of printed pages	Cost/ a hundred pages [€]	Waste materials
1	Ink	HP Photosmart, 57	CC641 black	200	9.5	yes
2	Electrophotografic	HP 2035 Laser, 200	CE505A	2300	2.5	yes
3	Electrophotografic	HP 2035 Laser, 200	CE505x	6500	1.6	yes
4	Electrophotografic	Canon IR, 700	EXV14	8300	0.37	yes
5	Thermal	Brother MFC 1025, 150	Transfer film PC 201	400	5	no
6	Solid ink	Xerox ColorQube, 500	Stick	4300	1	no

Before the appearance of solid ink printing, the only printing with few scraps was thermal printing. The low printing speed and the relatively high costs of the consumable materials hindered this method from getting spread for large amounts of printing. The appearance of solid ink printing, which is an environmentally friendly printing with low costs for waste materials, is about to incline the balance towards ecological printing, notably in case of large amounts of printing. The small users that print little will keep on preferring ink jet printing, on account of the low price of the printing equipment.

A justified question is whether the amount of scraps generated upon printing depends on the printing principle. The above description of the printing principles shows that electrophotografic printing and ink printing generate large amounts of waste materials and that thermal printing and solid ink one give rise to far lower quantities. According to the analysis from this article one can assert that waste materials do not depend on the principle, but on the financial interest of the manufacturers of selling cartridges. Given this financial interest, one produces cartridges with protection electronic circuits or with small capacities. The functional principle does not hinder the printer manufacturers to design a large capacity toner or ink reservoir. An example that confirms these allegations is CISS (continuous ink supply system) printing, where the ink jet printers are attached a feeding system from large capacity reservoirs. One may thus conclude that the commercial interests are opposed to the environmental protection ones.

Manufacturers oppose themselves to the utilisation of compatible, far cheaper cartridges, for reasons easy to understand. The LaserJet trial (2008), made by the Four Elements company for HP, shows that the utilisation of original cartridges instead of remanufactured ones provides a more reduced impact upon the environment, which is a debatable conclusion. The total amount of trash remained after the remanufactured cartridges utilisation is 44 % greater, the trial conclusion supporting HP's financial interests.

The large producers of printers and consumable materials released on the market cheap models of printers with cartridges with a smaller and smaller capacity and without the possibility of refilling, consequently with negative effects upon the environment. Initiatives of taking over the used cartridges free of charge have obviously come up,

however the calculations from Ogrutan et al (2010) show an approximate amount of used cartridges far greater than the amount of cartridges declared as having been taken over.

Conclusions. As expected, the printer manufacturers prioritise profit. Nonetheless, the pressure of society, of public opinion and of the ecological organisations, as well as the costs linked to used cartridge recycling, were factors that led to looking for environmentally friendly printing principles. The appearance of solid ink printing may be an answer to the necessity of ecologic printing, however this remains to be seen in the future.

What can each of us, users, do for limiting the number of discarded cartridges ? Upon buying a printer, users should consider certain selection criteria, namely the degree of environmental pollution, apart from the equipment price and the consumable materials price. Purchasing from the dealers that take over used cartridges for recycling purposes and that give over the used one upon changing the cartridge would be beneficial for the environment. The selection of a printer with increasingly large capacity cartridges, possibly with refillable cartridges, is more and more difficult nowadays. On the long run, the care about the environment is also doubled by the economic advantages, so if a more expensive equipment with larger capacity cartridges is chosen, the price per page will decrease.

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Author:

Petre Ogruțan, Transilvania University of Brașov, Faculty of Electrical Engineering and Computer Science, Politehnicii str., no. 1, Brașov, Romania, e-mail: petre.ogrutan@unitbv.ro

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