 

# Environmental Considerations Relevant to Electrophotographic Toner Cartridges

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## Abstract

This paper explores environmental considerations connected with materials which may be used in desktop electrophotographic toner cartridges. Such considerations include materials constraints, indoor air quality, and end-of-life disposition and recycling. Materials content is constrained both by regulation and public perception. As examples, the issues surrounding carbon black, azocolorants, and heavy metals are discussed. Indoor air quality is an emerging issue of public concern. Measurement of printer emissions is expected to be a growing area of focus within the printing industry. Design-for-Environment (DfE) reduces the environmental impacts caused by a product by altering its engineering design and materials. Some examples of proven DfE applications are presented. One application of DfE is the design of toner cartridges to be recyclable. Design issues surrounding end-of-life returns and recycling will also be explored.

## Introduction

Little has been written in the technical literature on the subject of toner cartridge design and relevant environmental considerations. As consumers and manufacturers become increasingly aware of environmental issues, and as regulations become more stringent, this area of study deserves greater attention. The purpose of this paper is to identify and describe environmental issues that may affect the electrophotographic printer industry. Three topics have been selected as illustrative: materials constraints, indoor air quality, and design for recyclability. The topics selected cover many but not all of the environmental considerations possible in toner cartridge design and manufacture.

### Materials Constraints

Three examples will be used to illustrate materials constraint issues: the toxicological classification of carbon black, the restriction of azocolorants in ecolabel criteria, and the restriction of heavy metals by regulation.

### Carbon Black

Carbon black (CAS# 1333-86-4) is a finely divided form of carbon made by the incomplete combustion of liquid or gaseous hydrocarbons. It is sometimes used in the printing industry as a pigment and conducting filler for some inks and toners. In April 1996, based on a review of existing literature, one international agency, the International Agency for Research on Cancer (IARC), changed its carcinogen rating for carbon black from a Group 3 classification (not classifiable as to its carcinogenicity in humans) to a Group 2B classification (possibly carcinogenic to humans). This is a controversial change. Although epidemiological studies suggest that there is inadequate evidence of carcinogenicity in humans, studies using rats indicate carbon black might cause lung cancer in rats. The risk may be attributed to the polycyclic aromatic hydrocarbons (PAHs) present in the carbon black. Since IARC was unable to state with confidence that the mechanisms of carcinogenicity in rats do not also operate in exposed humans, carbon black was evaluated by IARC as a Group 2B substance.[1]

This new classification means that producers of substances containing carbon black will include the “possibly carcinogenic to humans” classification in hazard communications on carbon black in conformance with the U.S. Hazard Communication Standard and the Canadian Workplace Hazardous Materials Information System (WHMIS) regulations. Furthermore, the classification may increase the probability for future regulations concerning carbon black. For example, in the U.S., the California Office of Environmental Health Hazard Assessment (OEHHA) is considering the addition of carbon black to the Proposition 65 list of chemicals that are known to cause cancer. In Europe, authorities in Denmark are considering a requirement to label preparations that contain carbon black in quantities >0.1% by weight as carcinogenic. Warning labels such as these have the potential to be sales inhibitors, and additional regulatory developments may follow in other regions.

While there may be black colorants that could be chemical substitutes for carbon black, these have not been evaluated with respect to environmental safety and may impact printer performance. Meanwhile, the carbon black manufacturing industry contends that any carcinogenic activity induced in rat inhalation studies is a result of an overload mechanism in the lungs in which insoluble particles cannot be expelled. Several chronic health hazard studies have been initiated in an attempt to better understand this anticipated biological response in rats. These studies are being closely monitored by the printer industry.

**Azocolorants**

Materials restrictions may also be set in the form of ecolabel criteria. Although not compulsory, an environmental label, or ecolabel, can be viewed by consumers as a seal of approval for environmentally preferable products, and can therefore be attractive for marketing purposes. Governments and some industries as well as individual customers use ecolabels as purchasing criteria, thus restricting the use of products without ecolabels.

Most ecolabels are designed to convey information to consumers in a simple yet objective way, enabling them to more easily consider environmental concerns in their purchasing decisions. A good example is Germany's Blue Angel ecolabel, first developed in 1978. As of 1999, Blue Angel criteria have been developed for about 88 product groups, including printers (RAL UZ 85).

Blue Angel criteria include a number of materials restrictions. For example, Criterion 3.16.2 for toner/ink states that, "No azocolorants (dyes and pigments) may be used which as amine components contain substances which according to the MAK-value list are classified as carcinogenic or suspected of being carcinogenic (MAK III1, MAK III2, MAK III3) (cf. Chapter III "Special Substance Groups" of the MAK-value list)."[2] An azocolorant is any dye or pigment that has an azo functional group (-N=N-) in it. Blue Angel disallows any azocolorant when specific amine functional groups are attached regardless of the chemical activity of the functional groups. The possible amines that cause an azocolorant to fail Blue Angel are listed in the German MAK-value list.[3] For toner, compliance verification for this criterion requires both (1) a statement from the supplier, and (2) negative results of the Ames-Test.

As a final note on azocolorants, the European Commission at the time of this writing is close to finalizing draft legislation that will introduce a ban on several hundred azo dyes throughout the European Union. Although the scope of the draft currently does not include toner/ink, Germany and Austria are pushing for the prohibition to cover all products colored with azo dyes that can release aromatic amines.[4] Thus, selection of azocolorants for toner/ink may ultimately be constrained by regulation, regardless of whether or not the Blue Angel ecolabel is an objective for the product.

**Heavy Metals**

The term "heavy metals" is generally interpreted as those metallic elements with densities greater than five times the density of water. The semi-metallic elements boron, arsenic, selenium, and tellurium are often included in this classification. Certain heavy metals, such as cadmium and copper, are used in pigment manufacture. These metals and their compounds can affect the health of people who inhale fine particles or ingest them in liquids and foods. Special environmental concern arises when materials containing these metals are disposed of near water bodies that receive heavy concentrations of acid rain. The increased acidity makes the metals more soluble and, as a result, they can be consumed in drinking water or are taken in by aquatic life.

In Europe, use of certain heavy metals including cadmium, lead, and mercury is restricted, and bans on these metals are being considered by the European Commission. In the U.S., wastes containing heavy metals in quantities above applicable threshold limit values are considered hazardous, and as such, are regulated under both U.S. EPA regulations and the more stringent Title 22 of the California Code of Regulations. For California Title 22, toxicity is established by assessing the properties of the waste, including metal content and acute aquatic toxicity. The metal content of a waste is determined by using a Waste Extraction Test (WET). Acute aquatic toxicity, which is often affected by the presence of heavy metals, particularly copper, is determined by using one of several State-approved test methods.[5]

In addition to the environmental implications of a hazardous waste classification, the resulting treatment and handling requirements are generally viewed unfavorably by end-users. For these reasons, elimination or reduction of heavy metals in toner cartridges to below threshold limit values is a way of designing products to satisfy local markets. As an example, selenium used in photoconductive print drum coatings was successfully eliminated throughout the toner cartridge manufacturing industry. Typically an organic coating on an aluminum substrate is now used. In the case that a hazardous waste classification is unavoidable, an alternative that is sometimes possible is to provide customers with an end-of-life solution to dispose of the hazardous waste in an easy, environmentally responsible manner.

**Indoor Air Quality**

Indoor air quality is an emerging issue. Certain recent studies conducted by the U.S. Environmental Protection Agency (EPA) and the National Institute of Occupational Safety and Health (NIOSH) have identified office equipment, as a source of indoor air pollution.[6] In response to this concern, Underwriters Laboratories (UL), the National Science Foundation (NSF) and other scientific research organizations are developing proposals for office equipment emissions standards (e.g., UL 2117, "Safety for Indoor Air Emissions of Equipment…"). Existing regulations relevant to indoor air quality include the U.S. Occupational Safety and Health Act (OSHA), which establishes maximum workplace airborne contaminant concentrations, and California Proposition 65, which requires warning labels on products with the potential to expose humans to carcinogens and reproductive toxins above threshold levels. In addition, Section 3.17 of the voluntary Blue Angel ecolabel specifies limits for emissions of ozone, particulates, and styrene from laser printers.[7]

Three recent articles in a popular German tabloid, ComputerBild, have heightened the concern over indoor air quality in Europe. These articles detail the results of printer emissions tests conducted by the Landesgewerbeanstalt (LGA) in Bavaria. The first article, entitled “Dicke Luft (Thick Air),” reports on volatile organic compounds (VOCs), ozone, and dust emissions during printer operation. The test methodologies used are not well documented. Of particular emphasis in this article is benzene, an EPA Class A “known human carcinogen.” LGA’s analysis for a particular printer yielded results for benzene of 27 $\mu g/cm^3$ for a 30 square meter office. For comparison, a highest average daily value of 9 $\mu g/cm^3$ for heavy traffic in the Karlsplatz in Munich is cited.[8] Two subsequent related articles have appeared in *ComputerBild,* one comparing emissions among color laser printers and the other comparing emissions from personal laser printers with emissions from inkjet printers.[9-10] These articles focus on styrene, a carcinogen classified in EPA’s Toxic Release Inventory (TRI). Although the results published for both styrene and benzene are well below any established threshold limit values, the articles have generated considerable public interest in printer emissions issues in Europe. Printer manufacturers must develop strategies to address these customer concerns and should identify opportunities to reduce off-gassing components and prepare for anticipated standards.

Ozone, an allotropic form of oxygen, is an oxidant gas which alters pulmonary immunologic response and may demonstrate other cellular changes. The EPA has an established limit of 0.12 ppm. The American Conference of Government Industrial Hygienists (ACGIH) recommends a threshold limit value (TLV) of 1.0 ppm (0.2 $mg/m^3$) for light work conditions)Printer technologies on the market today rely on the use of contact charging systems which reduce the amount of ozone produced. Filters in the printer containing carbon are often used to remove the ozone from the air stream entering the office environment. Changing charging systems and the use of carbon filtration has reduced ozone in the office environment where laser printers are in use. Attributed to these control technologies, many printing systems today typically generate negligible levels of ozone.

Airborne particulate material serves as a last example of indoor air quality issues. Electrophotographic printing systems may have several sources of airborne particle material in this size range. The largest common source is paper. High quality papers contain filler materials, which include finely divided clays and organic material. Increasing printing speeds results in more paper being subjected to the mechanical flexing of the paper as it traverses the paper path. This can result in significant amounts of fiber dust and fine particle material accumulating in and around the printer. Emission of these particles is controlled by air flow and filtration.

Dry toner and toner or ink residues can also be a source of fine particle material. Over spray or leakage of dry toners may contribute to printer particle emissions. Current toner formulations frequently fall in the size range of 4 to 10 microns. Most current printing systems are tested to characterize these emission concentrations and compare them to existing work standards.

Design considerations such as the use of seals, better control of charge on toner in the electrophotographic process and air flow control measures are used to reduce the amount of airborne particle material associated with printing on modern systems.

**Design for Recyclability**

In addition to being part of many printer manufacturers’ corporate citizenship policies, environmental programs are playing an increasing role in helping to differentiate products and support product sales. Recycling programs for imaging supplies are particularly attractive because they can provide customers with end-of-life solutions in which they may directly participate in an easy and cost effective manner. These programs also have the potential for substantially reducing the environmental impact of the printing system.

Legislation in Europe is pending that would require manufacturers of IT equipment, including printers and toner cartridges, to accept used equipment free of charge and to set up collection and recycling systems to process returned equipment. The current draft proposal for a Directive on Waste Electrical and Electronic Equipment (WEEE) contains provisions that address materials restrictions and recycled plastic content as well as returns rates, recycling rates, and program availability. Materials restrictions include the phase out of lead, mercury, cadmium, hexavalent chromium and halogenated flame retardants. Member States are directed to enact legislation on public procurement to encourage producers of electrical and electronic equipment to increase recycled materials content. The rate of component, material and substance re-use and recycling for consumables is mandated to reach a minimum of 70 % by weight.[11] It is likely that additional legislation concerning returns and recycling will follow.

To cope with this pending legislation and to maximize manufacturers’ ability to recycle IT equipment, there are several generally recognized guidelines to consider when designing printers and their consumables. These include eliminating or minimizing potentially hazardous materials, minimizing the number of material types, maximizing recyclable materials, marking plastics with resin identification information, avoiding glue and other adhesives, and minimizing the number of connectors. In addition, specific consumable design criteria for the Blue Angel ecolabel are provided in Blue Angel Section 3.13.1, Recyclable Design of Consumables.[12] Following Design-for-Environment (DfE) guidelines can reduce the need for waste treatment operations and the administrative burdens associated with hazardous waste, reduce the number of process steps and associated costs, and improve ease of disassembly and materials sorting.

## Summary

Numerous environmental issues must be considered when designing electrophotographic toner cartridges. These include materials content restrictions, indoor air quality concerns, and end-of-life disposal. Materials content may be constrained by either regulation or public perception. Carbon black and heavy metals are two examples of materials that are regulated, while azocolorants are currently restricted only by voluntary ecolabel criteria. Printer emissions and indoor air quality issues are growing areas of public concern. Leading printer manufacturers are developing strategies for emissions testing to address customer concerns and identify opportunities to reduce off-gassing. End-of-life disposal solutions for toner cartridges are driven both by customer demand and anticipated legislation that will require manufacturers to take back used consumables for recycling. Proven DfE methodology can maximize a manufacturer's ability to efficiently recycle returned consumables.

## References

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## Biography

Susanne Gallivan received her M.S. degree in Physics from Washington State University in 1994. From 1994-1997 she worked at the Hanford Nuclear Site on various U.S. Department of Energy environmental restoration projects. She joined Hewlett-Packard in 1997, where her work has primarily focused on regulatory compliance, Design-for-Environment (DfE), and environmental program development for HP LaserJet printer supplies.

Quintin Phillips received his MS degree in Environmental Chemistry and Statistics from Brigham Young University in 1980. He has worked for IBM and Hewlett-Packard in the areas of contamination control, clean room and equipment design, CFC elimination and most recently in electrophotographic process and toner cartridge development.