White Paper

Printing Inks and the Environment

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Introduction

According to EPA's National Emissions Inventories (NEI), the domestic printing industry ranks fifth in volatile organic compounds (VOC's) emissions among major industries. To put this ranking in perspective, consider that the automobile industry ranks sixth, behind printing.

Pollution emitted from the U.S. printing industry is dispersed among 34,146 firms, with 70% of them employing less than 10 employees (Bureau of Labor Statistics, 2006). When non-employers and printing-related support activities are included, the number climbs to 65,735 organizations. The small size of most printing shops allows them to be exempt from federal regulations under the Appropriations Act (although more stringent statewide regulations may be in effect). If a business emits 20 or fewer pounds of VOC's per day, they are exempt from obtaining a Minor Facility Registration from the U.S. EPA. Reducing pollution in the printing industry is a unique challenge, as change is voluntary for the majority of print shops. Pollution from the printing industry, primarily emissions from varnish preparation, is disperse and difficult to track. Finally, small-scale printers rarely have the capital available for improvements or process reengineering, adding difficulty to advancements in environmental stewardship.

Environmental Concerns

There are four primary components of printing inks: varnish (sometimes referred to as the "vehicle"), solvent, colorant (may include heavy metals), and additives, each presenting their own unique environmental hazards and challenges.

Varnishes and Solvents: Varnish preparation is the greatest source of emissions from the printing industry. Depending on the compound, ink varnish is heated to 200-600°F for 8-12 hours. Odorous emission are released during the heating and cooling processes of the varnish, which includes resins, drying oils, petroleum oils, and solvents. Common solvents include butanol, ethanol, glycol ethers, heptane, hexane, methanol, mineral spirits, toluene, and xylene (for an expanded list, see appendix, fig. 1) (New York State Department of Environmental Conservation Pollution Prevention Unit, 1997). Most conventional solvents used in the printing industry are VOC's, and account for the majority of the 101,537 tons of VOC's emitted per year by the printing industry (EPA, 1995). VOC emissions from the printing industry are the fiftth largest of 18 industrial sectors tabulated by the EPA, placing it just below the fabricated metals industry and ahead of the motor vehicles, bodies, parts, and accessories industry (for a complete list of industries and their associated emissions factors, see appendix, fig. 2).

VOC's present numerous health concerns and, when in the presence of sufficient UV radiation, contribute to ground-level ozone formation, which is an irritant, a contributor to smog, and a possible carcinogen (Jacobson, 2002). Many VOC's are irritants to the skin, eyes, lungs, and throat (particularly for those with asthma), and are known to contribute to neurological damage and birth defects (CICAD, 1999-2006). While the health effects of different VOC's are, for the most part, similar, some compounds are particularly damaging and some have unique health effects, such as carcinogenicity. For an expanded list of the effects of VOC's and heavy metals, visit TOXNET at http://toxnet.nlm.nih.gov/, which includes more than a dozen databases, including the Developmental and Reproductive Toxicology database (DART) and the Integrated Risk Information System (IRIS).

Colorant and Heavy Metals: Heavy metals in the printing industry have been reduced significantly in the past 20 years, but many are still in use. For example, titanium oxide, chromate, molybdenum, and iron are used as pigments; cobalt and manganese are used as driers; titanium oxide is used for pearlescent pigments; and aluminum and brass are used in metallic inks (Society of British Printing Ink Manufacturers, 1993). Heavy metals pose unique and serious environmental problems. One concern is the ability of heavy metals to leech into ground water, which could lead to serious health issues in both humans and wildlife. A more potent pathway, however, is the inhalation of finely ground metals, such as those created in ink manufacturing. Neurological damage is the most serious risk heavy metals may have on human health, although some compounds have also shown to be carcinogenic, aggravate asthma, decrease sexual potency, and contribute to birth defects (CICAD, 1999).

Additives: Although additives typically comprise less than 10% of the total ink, depending on their purpose, they can still contribute to environmental pollution. Among other uses, additives are used as optical brighteners, driers, defoaming agents, adhesion promoters, and anti-skinning agents. Some of these agents are harmless, such as organic waxes used to improve the water repellency of ink, but others, such as resin used to promote adhesion and heavy metals used to catalyze drying, pose similar risks as those compounds described above (Erhan et al., 1997).

Emission Control

Waste gas treatment in commercial printing is essential to remove dust, aerosols, and volatile compounds. Cleaning processes of particular importance to the printing industry include physical adsorption to solid materials, thermal after-burning, catalytic conversion, and bioactive filters or scrubbers. If used successfully, environmental controls may reduce VOC's by more than 90% and nearly eliminate particulate matter from escaping. Dust removal devices include cyclones, wet dust scrubbers, filters, and electrical precipitators. Vapor removing devices include condensation, absorption, adsorption, thermal treatment ("after-burning"), catalytic conversion, and bioactive scrubbers and filters. While these technologies are appealing, the costs associated with emissions control often place the latest technologies out of reach for the average printer (see appendix, fig. 3).

Alternative Inks

Vegetable Oil and Water-based Inks: Although conventional inks pose environmental difficulties to both the air and water, there are alternatives that are less damaging. Vegetable oil-based inks reduce or eliminate mineral oils in inks, conserving non-renewable reserves and reducing VOC emissions. Generally, vegetable oil-based inks perform equally well as their competitors in sheet-fed offset lithography printing. However, in web-offset printing, problems arise due to the higher heat of vaporization required for vegetable oils when compared to conventional mineral oils. The temperature of the web must be raised from an average of 250°F to 300°F, which is expensive and disadvantageous to the environment. Vegetable oil-based inks have gained the greatest acceptance and use in the newsprint industry, where they are not only considered environmentally friendly, but also of greater quality. Domestically, most vegetable oil-based inks originate from soybeans, as soybean farmers are important to the American economy and soy oil esters have similar characteristics on press as mineral oils.

While vegetable oil-based inks are most appropriate for lithographic printers, water-based inks have proven to be suitable for gravure, screen, and flexographic printing. The greatest advantage of water-based inks is the significant reduction of solvent emissions; however, solvent emissions are not always eliminated, as it is a common practice to add a small amount of ethanol or iso-propanol to the blend. Challenges printers face when using water-based inks include longer drying times and difficulties resulting from the high surface tension of water.

***Radiation-Curing Inks**:* Radiation-curing inks are a second class of alternative inks. These inks typically do not contain solvents. Although this process results in a significant decrease in VOC emissions, UV-curing systems pose their own unique problems. For example, they require the use of acrylate resins, which are irritants and UV radiation is damaging to the skin and UV radiators produce ozone from atmospheric oxygen. Additionally, UV-curing systems "dry" only if they are bombarded with UV light, and UV radiators consume high amounts of energy.

Electron beam-curing is an alternative to UV-curing, but still doesn't eliminate environmental risks and challenges. For example, electron beam curing devices produce X-rays, requiring lavish shielding to protect the operators. This process is also extremely expensive and cannot be used for mass printing, which limits this method to special purpose applications."

Ink Optimization Software

Regardless of the ink being used, ink optimization software, such as FineEye Color Solutions' ICEsaver software (http://www.fineeyecolor.com/icesaver.html), provides a valid and valuable way to reduce printing emissions and costs. Although various approaches may differ, all optimization solutions share the common characteristic of reducing CMY values in a digital image while increasing black. Ink optimization can reduce the overall ink demand by as much as 40%.

As long as the quality of the resulting printed product is not compromised, printers can use ink optimization software to proactively reduce hazardous emissions while also increasing bottom line profits. Additionally, reducing the ink film thickness on paper also introduces less ink into landfills and lowers the amount of solvents needed to de-ink paper in the recycling process.

Current Industry Efforts

Printing partnership programs sponsored by the EPA's Design for the Environment (DfE) program (http://www.epa.gov/dfe/) are examples of current efforts to reduce the negative effects of the printing industry on the environment. The DfE, which offers partnerships in a number of industries, primarily focuses on environmental education, offering reports and other documents to assist business owners to employ cleaner business practices. The goal of the DfE is to "promote integrating cleaner, cheaper, and smarter solutions into everyday business practices" (EPA, 2007). The printing partnerships focus on identifying and informing the industry about chemical risks in ink; facilitating the use and formulation of cleaner inks; promoting blanket washes that contain fewer VOC's; and encouraging safe workplace practices to minimize exposure to relevant chemicals.

The Sustainable Green Printing (SGP) Partnership (http://www.sgppartnership.org/) held its first stakeholders meeting on November 27, 2007 in Arlington, VA. Representatives from the Printing Industries of America/Graphic Arts Technical Foundation (PIA/GATF), the Specialty

Graphic Imaging Association (SGIA), the Flexographic Technical Association (FTA), environmental groups, and key government agencies were in attendance to take the first steps towards a national registry program for green and sustainable printing practices. Each of the printing industry organizations mentioned also now offer their own educational resources and programs geared toward improving environmental awareness.

Appendix

Fig. 1: Common solvents used in commercial inks:

Butanol (butyl alcohol)	Ethanol (ethyl alcohol)	Ethyl acetate
Ethylene glycol	Glycol esters	Glycol ethers
Glycol ether esters	Heptane	Hexane
Isoctanol (isooctyl alcohol)	Isopropanol	Isopropyl acetate
Methanol (methyl alcohol)	Methyl chloroform	Methyl isobutyl ketone
Methyl ethyl ketone	Mineral spirits	Normal propyl acetate
Napthas	Propanol (propyl alcohol)	Stoddard solvent
Toluene	Xylene	

Source: EPA, 1995
To learn more about the health effects of these solvents, visit TOXNET at http://toxnet.nlm.nih.gov/

Fig. 2: VOC releases by industry sector (short tons/year):

Industry Sector	VOC emissions
1. Petroleum refining	369,058
2. Organic chemicals	201,888
3. Rubber/plastics	140,741
4. Fabricated metal	102,186
5. Printing	**101,537**
6. Motor vehicles	101,275
7. Pulp and paper	96,875
8. Iron and steel	82,292
9. Furniture/fixtures	59,426

Industry Sector	VOC emissions
10. Inorganic chemicals	52,091
11. Lumber production	41,423
12. Stone/clay/concrete	30,262
13. Nonferrous metals	27,375
14. Dry cleaning	7,310
15. Electronic components	4,854
16. Nonmetal mining	1,736
17. Metal mining	1,283
18. Computer/office equip.	0

Source: EPA Office of Air and Radiation, AIRS Database

Fig. 3: Cost estimations of emissions control:

Treatment type	Purchase cost (USD)	Operating cost ($/yr)
adsorption	$150,000	$60,000
thermal	$190,000	$75,000
catalytic	$340,000	$50,000
bioactive	$150,000	$45,000

Based on 5,000 m^3/hour
Source: Woche der Druckindustrie (The Printing Industry's Week), 1994

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