Bisphenol A Alternatives in Thermal Paper

Chapter 2

Products and Materials: BPA in Thermal Paper

FINAL REPORT

August 2015
[Supercedes version dated January 2014]

U.S. Environmental Protection Agency

Table of Contents

List of Acronyms and Abbreviations

AIM	Analog Identification Methodology
ACR	Acute to Chronic Ratio
ADME	Absorption, Distribution, Metabolism, and Excretion
AIST	Advanced Industrial Science and Technology
ASTM	American Society for Testing and Materials
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BMD	Benchmark Dose
BMDL	Benchmark Dose Lower-confidence Limit
BPA	Bisphenol A
BPS	Bisphenol S
BOD	Biochemical Oxygen Demand
CASRN	Chemical Abstracts Service Registry Number
CDC	Centers for Disease Control and Prevention
CHO	Chinese Hamster Ovary Cells
ChV	Chronic Value
CPSC	Consumer Product Safety Commission
CVL	Crystal Violet Lactone
DfE	Design for the Environment
DOC	Dissolved Organic Carbon
dpi	Dots per inch
EC_{50}	Half Maximal Effective Concentration
ECHA	European Chemicals Agency
ECOSAR	Ecological Structure Activity Relationships
EDSP	Endocrine Disruptor Screening Program
EEC	European Economic Community
Eh	Redox potential
EKG	Electrocardiogram
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EPI	Estimations Program Interface
ERMA	Environmental Risk Management Authority
EU	European Union
EWG	Environmental Working Group
FDA	U.S. Food and Drug Administration
GHS	Globally Harmonized System of Classification and Labeling of Chemicals
GLP	Good Laboratory Practice
HGPRT	Hypoxanthine-Guanine Phosphoribosyl-Transferase
HIPAA	Health Insurance Portability and Accountability Act of 1996
HPLC	High Performance Liquid Chromatography
HPV	High Production Volume
HSDB	Hazardous Substances Data Bank
IARC	International Agency for Research on Cancer
IR	Infrared

IRIS	Integrated Risk Information System
IUCLID	International Uniform Chemical Information Database
K_{oc}	Soil adsorption coefficient
K_{ow}	Octanol/water partition coefficient
LC_{50}	Median Lethal Concentration
LCA	Life-cycle Assessment
LD_{50}	Median Lethal Dose
LD	Lactation Day
LFL	Lower Limit of Flammability
LOAEL	Lowest Observed Adverse Effect Level
LOEC	Lowest Observed Effective Concentration
MDI	Mean Daily Intake
MF	Molecular Formula
MITI	Japanese Ministry of International Trade and Industry
MW	Molecular Weight
MSDS	Material Safety Data Sheet
NAICS	North American Industry Classification System
NES	No Effects at Saturation
NGO	Non-Governmental Organization
NHANES	National Health and Nutrition Examination Survey
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NIOSH	National Institute for Occupational Safety and Health
NIR	Near Infrared
NOAEL	No Observed Adverse Effect Level
NOEC	No Observed Effect Concentration
NOEL	No Observed Effect Level
NTP	National Toxicology Program
OECD	Organisation for Economic Cooperation and Development
OPPT	Office of Pollution Prevention and Toxics
P2	Pollution Prevention
PBB	Poly-Brominated Biphenyls
PBDE	Polybrominated Diphenyl Ether
PBT Profiler	Persistent, Bioaccumulative, and Toxic (PBT) Chemical Profiler
PMN	Premanufacture Notice
PNEC	Predicted No Effect Concentration
POS	Point-of-sale
ppb	parts per billion
ppm	parts per million
PVC	Polyvinyl Chloride
REACH	**R**egistration, **E**valuation, **A**uthorisation and Restriction of **Ch**emical substances
RoHS	Restriction of Hazardous Substances
SAR	Structure Activity Relationship
SCAS	Semi-Continuous Activated Sludge
SF	Sustainable Futures
SMILES	Simplified Molecular-Input Line-Entry System
SPARC	Sparc Performs Automated Reasoning in Chemistry

TDI	Total Daily Intake
TOC	Total Organic Carbon
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
QSAR	Quantitative Structure Activity Relationships
UFL	Upper Limit of Flammability
USGS	U.S. Geological Survey
WHO	World Health Organization
WWTP	Wastewater Treatment Plant

2. Products and Materials: BPA in Thermal Paper

Bisphenol A (BPA) is one of the highest production volume chemicals in the world. Global production capacity of BPA was about 5,160 kilotons in 2008 (Chemical Weekly 2009). The U.S. alone had a production capacity of 1,226 kilotons of BPA in 2008. In 2008, Europe's estimated annual production capacity was 1,438 kilotons (Chemical Weekly 2009), up from 1,150 kilotons/year in 2005/2006 (JRC-IHCP 2010).

BPA is found in a diverse array of products in addition to thermal paper. One of the main uses of BPA is in polycarbonate plastics and in epoxy resins. Applications of polycarbonates include reusable food and drink containers such as plastic bottles, optical media such as CDs and DVDs, automotive and other transport equipment, sports safety equipment, glazing, and polycarbonate blends in the electronics industry (OECD 2002; Polycarbonate/BPA Global Group 2011). Applications of epoxy resins containing BPA include lacquers in protective coatings in food cans and water pipes, structural composites, electrical laminates such as for printed circuit boards, composites, electrical applications, as well as paints, adhesives, and other protective coatings such as dental sealants (OECD 2002; Polycarbonate/BPA Global Group 2011). BPA is used in the production of polyester resins, polysulfone resins, polyacrylate resins, and flame retardants (NTP-CERHR 2008). It is also contained in polyvinyl chloride (PVC) plastics and foundry castings (U.S. EPA 2010).

BPA is synthesized by the condensation of phenol and acetone in the presence of an acid catalyst (e.g., hydrogen chloride) and a promoter (e.g., methyl mercaptan). This condensation reaction yields two grades of BPA, both of which may be used in the manufacture of thermal paper (ICIS 2011; S. MacNeil, personal communication, November 28, 2011).

This chapter describes BPA's use as a developer, as well as the thermal paper applications in which BPA is often used. Thermal printing technology is described in Chapter 3.

2.1 BPA as a Developer in Thermal Paper

BPA is widely used as a developer in thermal paper because it is efficacious, available, and affordable (Mendum, Stoler et al. 2011). Although there are currently no estimates for the amount of BPA used in thermal paper in the U.S., the amount of BPA used in Europe in 2005/2006 in thermal paper amounted to 1.89 kilotons (JRC-IHCP 2010). This accounts for roughly 0.2 percent of total European BPA consumption (JRC-IHCP 2010).

In a sample of ten twelve-inch blank cash register receipts from businesses in suburban Boston, Mendum et al. (2011) found that eight receipts had quantifiable concentrations of BPA (level of quantification 26 µg/g); detectable BPA varied from 3 to 19 mg per 12-inch receipt. Mendum et al. identified three categories for the amount of BPA in thermal paper: full BPA content (9-19mg/12 inches), low BPA content (1-3 mg/12 inches), and BPA-free paper (below the detection limit) (2011).

In a larger study, 103 thermal receipt papers from 58 locations in the U.S., Japan, Korea, and Vietnam were tested (Liao and Kannan 2011). BPA was found in 94 percent of the receipts, ranging from below the level of quantification (1 ng/g in this study) to 13.9 mg/g (geometric mean: 0.211 mg/g). Some receipt papers claimed to be "BPA-free," as specifically printed on the receipt paper, but all of these receipt papers contained hundreds of µg/g levels of BPA

(geometric mean: 217µg/g). Of the receipt papers collected in the U.S., 100 percent of them contained BPA. BPA was not detected in any of the six samples from Japan, likely due to the 2001 Japanese phase-out of BPA in thermal paper.

2.2 Thermal Paper Uses

Thermal paper has extensive applications, with the most common uses including: point-of-sale (POS) receipts, labels, tickets, and print-outs from recording devices. POS receipts include sales receipts from cash registers, ATMs, and banks. Labels printed on thermal paper include labels on prescriptions, industrial barcodes, packaged items such as supermarket foods (e.g., deli meats, cheese, bulk items) and retail shelf labels. Tickets for transportation (e.g., airlines, trains), entertainment (e.g., cinema, theatre, gaming, sporting events, amusement parks, arenas, and museums), parking tickets, and tickets from kiosks are all common applications of thermal paper (Nashua Corporation 2008). Ultrasound, electrocardiogram (EKG), and printouts from other laboratory recorders are also common examples of thermal printing (JPI Healthcare n.d.). Testing of thermal paper used in medical applications, such as EKG printouts, indicates that it is made with bisphenol S (J. Warner, personal communication, March 1, 2011).

According to European estimates, POS receipts account for only half of thermal paper sold. Nearly one-third of thermal paper is used in self-adhesive labels in applications such as deli trays, shipping labels, luggage tags, etc. Lottery tickets account for 10 percent of thermal paper applications and another 10 percent for fax paper (JRC-IHCP 2010).

References

Chemical Weekly (2009). Bisphenol-A: A Techno-Commercial Profile. **September 1, 2009:** 205-211.

ICIS (2011). Bisphenol A (BPA) Production and Manufacturing Information.

Joint Research Centre-Institute for Health and Consumer Protection (JRC-IHCP) (2010). European Union Risk Assessment Report, 4,4'-Isopropylidenediphenol (Bisphenol-A).

JPI Healthcare. (n.d.). "Ultrasound Paper." from http://www.jpihealthcare.com/ultrasound-paper.

Liao, C. and K. Kannan (2011). "Widespread Occurence of Bisphenol A in Paper and Paper Products: Implications for Human Exposure." Environ. Sci. Technol. **45**: 9372-9379.

Mendum, T., E. Stoler, et al. (2011). "Concentration of bisphenol A in thermal paper." Green Chemistry Letters and Reviews **4**(1): 81-86.

Nashua Corporation. (2008). "Label Products." from http://nashua.com/prodandservices/labelproducts.aspx?selected=labeltrans.

National Toxicology Program-Center for the Evaluation of Risks to Human Reproduction (NTP-CERHR) (2008). NTP-CERHR Monograph on the Potential Human Reproductive and Developmental Effects of Bisphenol A. U.S. Department of Health and Human Services.

Organisation for Economic Co-operation and Development (OECD) (2002). "SIDS Initial Assessment Profile." Existing Chemicals Database **SIAM 14**: 26-28.

Polycarbonate/BPA Global Group. (2011). "Bisphenol A." from http://bisphenol-a.org/.

U.S. Environmental Protection Agency (U.S. EPA) (2010). Bisphenol A Action Plan.