CHEMICAL ADDITIVES FOR THE PLASTICS INDUSTRY

Properties, Applications, Toxicologies

by

Radian Corporation

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McLean, Virginia

NOYES DATA CORPORATION

Park Ridge, New Jersey, U.S.A.

1987

Library of Congress Catalog Card Number 86-31155
ISBN: 0-8155-1114-0
Printed in the United States

Published in the United States of America by
Noyes Data Corporation
Mill Road, Park Ridge, New Jersey 07656

10 9 8 7 6 5 4 3 2 1

Library of Congress Cataloging-in-Publication Data

Chemical additives for the plastics industry.

Bibliography: p.
Includes index.
1. Plastics--Additives. I. Radian Corporation.
TP1142.C47 1987 668.4'11 86-31155
ISBN 0-8155-1114-0

Foreword

This book describes in detail each chemical additive used in the plastics industry. It analyzes the chemicals used as additives in polymer manufacturing and the processing of plastics, environmental releases of these chemicals, and possible occupational exposures to them.

Since World War II, the development and growth of the use of plastics has been phenomenal. The technology for the manufacture of polymers and plastic products has expanded into the most important of the chemical-based industries, producing new products for new uses at a remarkably high rate. Plastics additives have played a critical and complex role in this growth. The emphasis is on identification of the additives used and discussion of their functions, properties, and applications.

The plastics additives are presented by major functional groups of chemicals, which are further subdivided into chemically-, functionally-, or physically-similar chemicals. An overview of each major functional group includes the properties and application of the subclasses, their environmental impacts, and possible occupational exposures. Common worker exposure practices for each functional group are also presented.

A series of appendices details the physical and chemical properties and polymer application of each chemical within the functional groups; the industrial, commercial, and consumer uses and consumption volumes for each chemical, and data on toxicological and worker exposure concerns for each chemical. The 17 sections of this book give substantial information on the broad spectrum of plastics additives.

The information in the book is from *Industrial Process Profiles for Environmental Use: Plastics Additives,* prepared by Radian Corporation for the U.S. Environmental Protection Agency, July 1985.

Two companion volumes, *Polymer Manufacturing—Technology and Health Effects* and *Plastics Processing—Technology and Health Effects*, are also available from Noyes.

The table of contents is organized in such a way as to serve as a subject index and provides easy access to the information contained in the book.

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NOTICE

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1. Industry Description

INTRODUCTION

Since World War II, the development and growth of the use of plastics has been phenomenal. The technology for the manufacture of polymers and plastic products has expanded into the most important of the chemical-based industries, producing new products for new uses at a remarkably high rate. Plastic additives have played a critical and complex role in this growth.

The purpose of this report is to put additives used in the manufacture of plastic products in perspective for environmental and health impact analysis. It focuses on the use of chemicals rather than on the evaluation of manufacturing processes and the impact of process operations on health and the environment. More specifically, the emphasis here is on identification of the additives used and discussion of their functions, properties, and applications.

Consideration is given to the potential for environmental impact or harmful human exposure associated with the use of various additives. However, because of the large number of compounds involved (more than 2,000 specific chemicals in the 16 categories identified below), the discussion is, by necessity, somewhat general. The main objective is to provide a sound basis for more detailed analyses of individual compounds that may prove to be of interest. Although the objective was to be as specific and quantitative as possible, the proprietary nature of the industry at times presented some difficulty in that certain additives were designated only by trade names. Even so, it was possible in most cases at least to characterize the product by a generic chemical classification.

For the purposes of this report, plastics additives are defined as chemicals used to polymerize, process, or modify the properties of a plastic. As such, they include all chemicals used in plastics except monomers, polymers, copolymers, and physical mixtures of two polymeric components.

Many additives provide more than one function in polymers. They may act as both heat stabilizers and plasticizers, both as colorants and UV stabilizers, or as flame retardants and fillers. Clearly, the division between functional groups of additives is not clearcut. The division between polymer and additive may be equally vague. Cure agents for thermosetting resins, for

example, are incorporated in the polymer backbone. This document makes a distinction for curing agents that are chemically bonded to the polymer; they are considered additives if used at concentrations below 25 parts per hundred parts of resin. Chemicals used in polymerization above this concentration are defined as monomers.

Although individual additives may be multi-functional and can be classified in numerous ways (as shown in Table 1), four basic groups that consist of 16 categories and about 100 subcategories are considered in this report. These include:

- polymerization aids;
- processing aids;
- stabilizers; and
- end-use modifying additives.

The four basic categories are generally relatable to specific process steps. Polymerization aids are used to facilitate the reaction of monomers to produce resins. Processing aids such as lubricants, etc., are used in forming plastic products. Stabilizers increase the lifespan of resin and plastics products, preventing their degradation by environmental factors. They may be incorporated into the plastic during either production or processing, depending upon the product's susceptibility to deterioration and the environment(s) to which it is subjected. The end-use modifying additives are generally incorporated in the plastic during processing. These additives modify the properties of the polymer, making the plastic suitable for its end use and/or reducing product cost.

The remainder of this section provides a discussion of the additives industry that considers the relationship between polymers and additives and the marketing of additives, a summary of the environmental impacts associated with additive use, and an overview of possible exposure of workers to additives.

The succeeding sections of this report (Sections 2 through 17) present the major functional additive classes (in alphabetical order). Included in each section is the overview of the class, a summary of the application of particular additive groups to polymers, and (where available) an indication of the consumption volumes within the subgroups of the class. The general properties of each of the subgroups within the class are presented along with an analysis of the environmental impact of each functional group. Summaries of worker exposure concerns are also presented. Each section refers to a series of three appendices containing tabulated data for the specific additives. These appendices, referred to in the text by table letter and number, detail the specific chemicals used as additives within the functional groups, their physical and chemical properties, polymer application, uses, consumption volumes, toxicity, and worker exposure concerns.

TABLE 1. SUMMARY OF ADDITIVE FUNCTIONAL GROUPS

POLYMERIZATION AIDS:

Catalysts alter the rate of polymerization reactions without themselves being chemically changed. (Catalysts for polyolefin, thermoplastic polyester, polycarbonate, polyamide, polyphenylene oxide, and polyacetal resins; catalyst neutralizers.)

Curing Agents and Catalysts for Thermosetting Resins achieve polymerization of thermosetting resins through incorporation in the polymer backbone or through catalysis. (Catalysts for alkyds and polyurethanes; cure agents for amino, epoxy, and phenolic resins; neutralizers; deactivators; and stabilizers.)

Free Radical Initiators act as sources of unpaired electrons to initiate polymerization by forming reactive sites for the monomer or polymer chain. (Peroxides, azo compounds, inorganics, activators, and inhibitors.)

Solution Modifiers and Other Polymerization Aids are chemicals used to control molecular weight during polymerization and/or to maintain the polymer in solution. (Acids, bases, buffers, chain transfer agents, coagulants, crosslinking agents, defoamants, emulsifiers, feed stream desiccants, inert gases, protective colloids, solvents, and thickeners.)

PROCESSING AIDS:

Lubricants and Other Processing Aids improve the processing and/or end use performance characteristics of plastics. (Fatty acids and alcohols, fatty acid amides, fatty acid esters, metallic soaps, paraffin waxes, other synthetic polymerics, and inorganics.)

Blowing Agents and Other Additives for Foamed Plastics produce porous polymers. Blowing agents are converted to gases during processing and form the cellular component of the plastic. Other additives aid in forming and maintaining cell structure. (Physical blowing agents, chemical blowing agents, blowing agent catalysts, surfactants, and nucleating agents.)

STABILIZERS:

Antioxidants inhibit or reduce the rate of oxidative degradation of polymers at ambient or elevated temperatures. They extend service life and increase processing stability. (Phenolics, aromatic amines, thioesters, phosphites, and miscellaneous antioxidants.)

Heat Stabilizers inhibit or retard the degradation of halogenated polymers and copolymers, particularly polyvinyl chloride. (Mixed metal stabilizers, organotin and mercaptotin compounds, lead salts, antimony mercaptides, and miscellaneous stabilizers.)

(Continued)

TABLE 1 (Continued)

Preservatives prevent the biological degradation of plastics by microorganisms. (Bactericides, bacteriostats, fungicides, and fungistats.)

Ultraviolet Stabilizers inhibit or reduce degradation of polymers resulting from ultraviolet radiation. (Benzophenones, benzotriazoles, nickel organics, and miscellaneous stabilizers.)

END-USE MODIFYING ADDITIVES:

Antistatic Agents reduce the accumulation or increase the rate of dissipation of electrical charge on the surface of polymers. (Amines, quaternary ammonium compounds, anionic surface active agents, and miscellaneous antistats.)

Colorants impart hue (shade), value (brightness), and chroma (intensity or strength of color) to plastics. (Inorganic pigments, organic pigments, dyes, optical brightners, fluorescents, metallics, phosphorescents, and pearlescents.)

Coupling Agents improve polymer-mineral surface bonds for filled and reinforced products. (Silanes, titanates, and miscellaneous wetting agents.)

Fillers and Reinforcers are inert solids added to plastics to lower the product's cost and/or enhance its properties. (Inorganic extenders, organic extenders, inorganic fibers, and organic fibers.)

Flame Retardants reduce the combustibility of plastics. (Inorganics, nonreactive organics, and reactive organics.)

Plasticizers impart flexibility to resins. (Phthalates, trimellitates, epoxidized esters, polyesters, phosphates, linear esters, extenders, and miscellaneous plasticizers.)

INDUSTRY DISCUSSION

Additives come from a wide variety of sources, many being derived from industrial organic chemicals. These include the plasticizers, solvents, antioxidants, and flame retardants. Many fillers and reinforcers are derived from the mining and minerals industry, and others may be byproducts of agricultural production. Preservatives originate in the pesticides industry, whereas many lubricants are produced in the petroleum industry. Colorants originate in the dyes and pigments industry.

These additives are produced by a wide variety of companies for a wide variety of customers other than those that make plastic products. The subsections that follow consider the role of additives and how they are marketed.

Additive-Polymer Relationship

Overall, additives account for 20 percent by weight of the total volume of plastic products marketed. The consumption and value of sales for various classes are shown in Table 2. These data, though incomplete, show the dominance of a few categories as far as volume is concerned. In addition, the data indicate the general level of total production and provide an indication of the importance of additives in the chemical industry.

The sales data shown for 9 of the 16 additives totaled almost 1.8×10^9, an amount equivalent to almost 5 percent of the total sales of 37.0×10^9 for all plastic products in 1981.

The polymers used to produce plastic products have very different additive requirements. For example, in 1982, acrylonitrile-butadiene-styrene (ABS) constituted only 2 percent of the total plastics market, but this plastic used 30 percent of the antioxidants.[47, 151] By way of contrast, about half of the basic polymers generally incorporate no antioxidant. Polyvinyl chloride provides another example of the differences in additive requirements. This product incorporates plasticizers in amounts as high as 40 percent by weight, but many polymers require none at all. The variability in polymer requirements is further illustrated by flame retardants. Polyurethane foams, because of their susceptibility to combustion and because of their widespread use in furniture cushioning and building products, use up to 40 weight percent flame retardant in building products.[190] Table 3 presents the major functional groups of additives and the polymers in which they are used. The polymer applications shown are for the most heavily used additive classes only. Other minor applications are presented in the sections for individual functional groups.

TABLE 2. CONSUMPTION AND SALES OF ADDITIVES

Additive Class	1982 Thousand Metric Tons	1982 Distribution By Weight	1980 Sales 10^6
Antioxidants	14.0	0.4	37
Antistatic Agents	2.8	0.1	7
Blowing Agents	53.4 (1980)	1.4	148
Catalysts	*	*	*
Colorants	146.6	3.9	124
Coupling Agents	2.5 (1979)	<0.1	*
Cure Agents (Urethane Catalysts only)	2.3	<0.1	*
Fillers and Reinforcers	2,655.2	70.6	*
Flame Retardants	171.0	4.6	327
Free Radical Initiators (Peroxides only)	15.0	0.4	76
Heat Stabilizers	35.4	1.0	140
Lubricants and Mold Release Agents	37.8	1.0	70
Plasticizers	624.0	16.6	775
Preservatives	*	*	*
Solution Modifiers	*	*	*
UV Stabilizers	2.1	<0.1	48
TOTAL	3,762.1	100.0	1,752

* - Unknown.

Sources: Curry, Susan and Susan Rich, The Kline Guide to the Chemical Industry, 1980.
Modern Plastics, July 1979, p. 49.
Modern Plastics, July 1982, p. 44.
Modern Plastics, September 1982, p. 55.