

FLAME RETARDANT CHEMICALS: TECHNOLOGIES AND GLOBAL MARKETS



CHM014M
April 2015

Marcanne Green
Project Analyst

ISBN: 1-62296-080-7



BCC Research
49 Walnut Park, Building 2
Wellesley, MA 02481 USA
866-285-7215 (toll-free within the USA),
or (+1) 781-489-7301
www.bccresearch.com
information@bccresearch.com

TABLE OF CONTENTS

| TOPIC | PAGE NO. |
|---|-----------------|
| CHAPTER 1 INTRODUCTION | 2 |
| STUDY GOAL AND OBJECTIVES | 2 |
| REASONS FOR DOING THE STUDY | 2 |
| INTENDED AUDIENCE | 3 |
| SCOPE OF REPORT | 3 |
| METHODOLOGY | 3 |
| BCC RESEARCH | 3 |
| INFORMATION SOURCES | 4 |
| ANALYST'S CREDENTIALS | 4 |
| RELATED BCC RESEARCH REPORTS | 4 |
| BCC RESEARCH WEBSITE | 5 |
| DISCLAIMER | 5 |
| CHAPTER 2 SUMMARY | 7 |
| <i>SUMMARY TABLE GLOBAL CONSUMPTION OF FLAME RETARDANT CHEMICALS, THROUGH 2019 (MILLION POUNDS)</i> | 7 |
| <i>SUMMARY FIGURE GLOBAL CONSUMPTION OF FLAME RETARDANT CHEMICALS, 2012-2019 (MILLION POUNDS)</i> | 7 |
| CHAPTER 3 INDUSTRY OVERVIEW | 10 |
| IMPORTANCE OF THE INDUSTRY | 10 |
| FLAME RETARDANCY BASICS | 10 |
| TERMINOLOGY | 11 |
| MECHANISMS OF BURNING | 11 |
| <i>TABLE 1 ADDITIVES/MODIFIERS FOR CONTROLLING BURNING</i> | 12 |
| FLAME RETARDANT CONCEPTS | 12 |
| PHYSICAL DILUTION | 13 |
| CHEMICAL INTERFERENCES | 13 |
| INERT GAS DILUTION | 14 |
| THERMAL QUENCHING | 14 |
| PROTECTIVE COATINGS | 14 |
| GENERALLY ACCEPTED MECHANISMS OF FLAME RETARDANT CONTROL | 15 |
| <i>TABLE 2 FLAME RETARDANTS AND GENERALLY ACCEPTED MECHANISMS OF CONTROL</i> | 15 |
| TYPES OF FLAME RETARDANTS | 15 |
| ADDITIVE FLAME RETARDANTS | 15 |
| <i>TABLE 3 ADDITIVES/MODIFIERS FOR CONTROL OF BURNING</i> | 16 |
| REACTIVE FLAME RETARDANTS | 16 |
| SYNERGISTIC FLAME RETARDANTS | 17 |
| <i>TABLE 4 REPRESENTATIVE SYNERGISTIC FLAME RETARDANT COMBINATIONS (%)</i> | 17 |
| DIVERSITY OF FLAME-RETARDED PRODUCTS | 17 |
| <i>TABLE 5 FLAME RETARDANTS AND PRODUCTS WHERE THEY ARE COMMONLY USED</i> | 18 |
| COMBINED CLASSIFICATION SYSTEM FOR FLAME RETARDANT CHEMICALS | 19 |
| <i>TABLE 6 COMMON CLASSIFICATION SYSTEM FOR FLAME RETARDANT CHEMICALS</i> | 19 |
| <i>TABLE 7 LEADING CAUSES OF U.S. RESIDENTIAL FIRES (%)</i> | 19 |

| TOPIC | PAGE NO. |
|--|-----------------|
| TESTING | 20 |
| TESTING GOALS | 20 |
| <i>TABLE 8 GOALS OF SIMULATED FIRE CONDITIONS TESTS</i> | 20 |
| TYPES OF TESTING | 21 |
| Small-Scale Testing | 21 |
| Limiting Oxygen Index (LOI) | 21 |
| <i>TABLE 9 OXYGEN INDICES OF SOME COMMON MATERIALS</i> | 21 |
| Cone Calorimeter | 22 |
| <i>TABLE 10 CONE CALORIMETRY PARAMETERS AND VALUES</i> | 23 |
| Medium-Scale Testing | 23 |
| Large-Scale Testing | 23 |
| UL-94 | 24 |
| <i>TABLE 11 UL-94 BURN TEST RATINGS</i> | 24 |
| Additional Tests | 24 |
| INDUSTRY ENVIRONMENT | 25 |
| THE NEGATIVE VIEW OF FLAME RETARDANT CHEMICALS | 26 |
| U.S. REGULATIONS RESTRICTING USE OF CERTAIN FLAME RETARDANTS | 27 |
| EPA REGULATIONS | 27 |
| TOXIC SUBSTANCES CONTROL ACT (TSCA) | 28 |
| U.S. LAWS | 29 |
| STATE LAWS | 29 |
| <i>TABLE 12 PROPOSED FLAME RETARDANT CHEMICALS BEING LIMITED/PROHIBITED FROM CHILDREN'S PRODUCTS</i> | 32 |
| EUROPEAN RESTRICTIONS ON FLAME RETARDANTS | 33 |
| WEEE AND ROHS | 33 |
| REACH | 34 |
| SIGNIFICANT ORGANIZATIONS REGULATING FIRE CONTROL | 34 |
| NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST) | 34 |
| INTERNATIONAL CODE COUNCIL (ICC) AND THE INTERNATIONAL BUILDING CODE (IBC) | 35 |
| U.S. FEDERAL AVIATION REGULATIONS | 35 |
| UPHOLSTERY REGULATION | 36 |
| NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH) AND OSHA | 36 |
| OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) | 37 |
| OSHA Standards | 37 |
| OSHA 29 CFR 1910.132 | 37 |
| OSHA CFR 29 1910.269- Protection from Flames and Electric Arcs | 38 |
| ROLE OF NON-FEDERAL AGENCIES | 38 |
| National Fire Protection Association (NFPA) | 39 |
| <i>TABLE 13 NFPA GUIDELINES AND STANDARDS</i> | 39 |
| <i>TABLE 14 AGENCIES INVOLVED IN ESTABLISHING FLAME RETARDANT AND PROTECTIVE STANDARDS</i> | 40 |
| ASTM International | 41 |
| ASTM Standards | 41 |
| <i>TABLE 15 ASTM STANDARDS APPLICABLE TO THE FLAME RETARDANT INDUSTRY</i> | 41 |
| American National Standards Institute (ANSI) | 43 |
| Underwriters Laboratories Inc. | 44 |

| TOPIC | PAGE NO. |
|---|-----------------|
| OTHER ORGANIZATIONS OF INTEREST | 44 |
| American Chemistry Council | 44 |
| European Flame Retardants Association (EFRA) | 44 |
| Fire Safety Platform Secretariat | 44 |
| Groupement Technique Francais Contre L'Incendie | 45 |
| National Association of State Fire Marshals | 45 |
| INTERNATIONAL REGULATIONS ON USE OF FLAME RETARDANTS | 45 |
| ASIAN REGULATIONS | 45 |
| The Japanese Chemical Substances Control Law (CSCL) | 45 |
| Chinese Flame Retardant Society | 45 |
| SPECIFIC EUROPEAN REGULATIONS | 46 |
| European Committee for Standardization | 46 |
| ISO TC61 Committee Standards | 46 |
| The Department for Business, Innovation & Skills (BIS) | 47 |
| The British Standards Institution (BSI) | 47 |
| Voluntary Emissions Control Action Programme (VECAP) | 47 |
| STRATEGIES AND OPPORTUNITIES | 48 |
| DRIVING FORCES | 49 |
| TABLE 16 MARKET SHARE BY INDUSTRY, 2012 (% , BASED ON \$) | 50 |
| FIGURE 1 MARKET SHARE BY INDUSTRY, 2012 (% , BASED ON \$) | 51 |
| CHAPTER 4 FLAME RETARDANT CHEMICALS | 54 |
| CHEMICALS THAT ARE FLAME RETARDANT | 54 |
| TABLE 17 CHEMICALS COMMONLY USED AS FLAME RETARDANTS | 54 |
| TABLE 18 SIGNIFICANT FLAME RETARDANT CHEMICALS | 55 |
| TABLE 19 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS BY CHEMICAL, THROUGH 2019 (\$ MILLIONS) | 56 |
| FIGURE 2 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS, 2012-2019 (\$ MILLIONS) | 56 |
| ALUMINUM TRIHYDRATE | 57 |
| BAUXITE/ALUMINUM TRIHYDRATE SOURCES | 57 |
| TABLE 20 BAUXITE/ALUMINUM RESOURCES WORLDWIDE (%) | 58 |
| TABLE 21 WORLD BAUXITE MINE PRODUCTION AND RESERVES, 2012-2014 (THOUSAND METRIC DRY TONS) | 58 |
| ALUMINUM TRIHYDRATE GRADES | 59 |
| CONSUMPTION OF ALUMINUM TRIHYDRATE AS A FLAME RETARDANT | 59 |
| TABLE 22 GLOBAL MARKET FOR ALUMINUM TRIHYDRATE, THROUGH 2019 (\$ MILLIONS) | 60 |
| PRICES OF ATH | 60 |
| TABLE 23 GLOBAL MARKET FOR ALUMINUM TRIHYDRATE FLAME RETARDANT CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS) | 60 |
| ANTIMONY OXIDE | 61 |
| FIGURE 3 REACTIONS OF ANTIMONY TRIOXIDE WITH HALOGENS | 61 |
| PRODUCTION AND CONSUMPTION OF ANTIMONY OXIDE | 62 |
| TABLE 24 WORLD ANTIMONY OXIDE MINE PRODUCTION AND RESERVES, 2012-2014 | 62 |
| TABLE 25 GLOBAL CONSUMPTION OF ANTIMONY OXIDE, THROUGH 2019 (MILLION POUNDS) | 63 |
| TABLE 26 GLOBAL MARKET FOR ANTIMONY OXIDE, THROUGH 2019 (\$ MILLIONS) | 63 |

| TOPIC | PAGE NO. |
|--|-----------------|
| <i>TABLE 27 GLOBAL MARKET FOR ANTIMONY OXIDE FLAME RETARDANT CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS)</i> | 64 |
| BROMINE-BASED COMPOUNDS | 64 |
| <i>TABLE 28 GLOBAL CONSUMPTION OF BROMINE-BASED FLAME RETARDANTS IN ELECTRICAL/ELECTRONIC COMPONENTS, 2014 (%)</i> | 65 |
| TYPES OF BROMINE-BASED FLAME RETARDANTS | 66 |
| <i>TABLE 29 TYPES OF AROMATIC BROMINE-BASED FLAME RETARDANT COMPOUNDS</i> | 66 |
| <i>TABLE 30 SIGNIFICANT AROMATIC BROMINE-BASED FLAME RETARDANT COMPOUNDS</i> | 67 |
| <i>TABLE 31 SIGNIFICANT TYPES OF ALIPHATIC BROMINE-BASED FLAME RETARDANT COMPOUNDS</i> | 67 |
| CONSUMPTION OF BROMINE-BASED FLAME RETARDANTS | 68 |
| <i>TABLE 33 GLOBAL CONSUMPTION OF BROMINE-BASED FLAME RETARDANTS, THROUGH 2019 (MILLION POUNDS)</i> | 68 |
| <i>TABLE 34 GLOBAL MARKET FOR FLAME RETARDANT BROMINE-BASED CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS)</i> | 69 |
| <i>FIGURE 4 GLOBAL MARKET FOR FLAME RETARDANT BROMINE-BASED CHEMICALS BY END USE, 2012-2019 (\$ MILLIONS)</i> | 69 |
| <i>TABLE 35 GLOBAL CONSUMPTION OF FLAME RETARDANT BROMINE-BASED CHEMICALS BY END USE, THROUGH 2019 (MILLIONS POUNDS)</i> | 70 |
| CHLORINE-BASED FLAME RETARDANT COMPOUNDS | 71 |
| CHLORINE-BASED FLAME RETARDANT PROPERTIES | 71 |
| SOURCES OF CHLORINE | 72 |
| CHLORINE-BASED FLAME RETARDANT TYPES | 72 |
| DECHLORANE PLUS | 73 |
| CONSUMPTION OF CHLORINE-BASED FLAME RETARDANTS | 73 |
| <i>TABLE 36 GLOBAL CONSUMPTION OF CHLORINE-BASED FLAME RETARDANTS, THROUGH 2019 (MILLION POUNDS)</i> | 74 |
| MAGNESIUM HYDROXIDE | 74 |
| MAGNESIUM HYDROXIDE PROPERTIES | 74 |
| SOURCES OF MAGNESIUM HYDROXIDE | 74 |
| MAGNESIUM HYDROXIDE GRADES | 75 |
| CONSUMPTION OF MAGNESIUM HYDROXIDE AS A FLAME RETARDANT | 75 |
| <i>TABLE 37 GLOBAL MARKET FOR MAGNESIUM HYDROXIDE FLAME RETARDANT CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS)</i> | 75 |
| MELAMINE-BASED FLAME RETARDANTS | 76 |
| MELAMINE HOMOLOGUES | 78 |
| <i>TABLE 38 COMMON MELAMINE-BASED FLAME RETARDANT CHEMICALS</i> | 78 |
| <i>TABLE 39 GLOBAL MARKET FOR MELAMINE FLAME RETARDANT CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS)</i> | 78 |
| <i>FIGURE 5 GLOBAL MARKET FOR MELAMINE FLAME RETARDANT CHEMICALS BY END USE, 2012-2019 (\$ MILLIONS)</i> | 78 |
| PHOSPHORUS-BASED FLAME RETARDANTS | 79 |
| PHOSPHATES | 80 |
| PHOSPHONATES AND PHOSPHINATES | 80 |
| RED PHOSPHORUS | 80 |
| AMMONIUM POLYPHOSPHATE | 81 |
| CONSUMPTION OF PHOSPHOROUS-BASED FLAME RETARDANTS | 81 |
| <i>TABLE 40 GLOBAL MARKET FOR PHOSPHORUS-BASED FLAME RETARDANT CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS)</i> | 82 |

| TOPIC | PAGE NO. |
|--|-----------------|
| OTHER FLAME RETARDANTS | 82 |
| BORON-BASED FIRE RETARDANTS | 83 |
| Boron Sources | 83 |
| MOLYBDENUM-BASED FIRE RETARDANTS | 83 |
| Molybdenum Properties | 84 |
| Molybdate Smoke Suppression | 84 |
| Molybdenum Sources | 84 |
| NANOCOMPOSITE FLAME RETARDANT CHEMICALS | 84 |
| Nanocomposites in Packaging | 85 |
| Nanocomposites in Foams | 85 |
| IN SITU POLYMERIZATION | 86 |
| GRAPHITE-BASED FLAME RETARDANT CHEMICALS | 86 |
| DUST-FREE SUSTAINABLE POLYMERIC FLAME RETARDANT SYSTEMS | 87 |
| GLOBAL MARKET FOR OTHER FLAME RETARDANT CHEMICALS | 87 |
| <i>TABLE 41 GLOBAL MARKET FOR OTHER FLAME RETARDANT CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS)</i> | 88 |
| <i>FIGURE 6 GLOBAL MARKET FOR OTHER FLAME RETARDANT CHEMICALS BY END USE, 2012-2019 (\$ MILLIONS)</i> | 88 |
| PRODUCTS THAT ARE SMOKE AND FLAME RETARDED | 89 |
| <i>TABLE 42 MAJOR MARKETS USING FLAME RETARDANT CHEMICALS</i> | 89 |
| <i>TABLE 43 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS BY APPLICATION, THROUGH 2019 (\$ MILLIONS)</i> | 89 |
| <i>FIGURE 7 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS BY APPLICATION, 2012-2019 (\$ MILLIONS)</i> | 90 |
| PLASTICS | 90 |
| <i>TABLE 44 WORLDWIDE PLASTICS PRODUCTION ESTIMATE, THROUGH 2019 (MILLION POUNDS)</i> | 91 |
| <i>TABLE 45 FLAME RETARDANTS IN PLASTICS, 2019 (% OF TOTAL MILLION POUNDS)</i> | 92 |
| FLAME RETARDANT METHODS USED FOR PLASTICS | 92 |
| <i>TABLE 46 METHODS OF FLAME-RETARDING POLYMERS</i> | 93 |
| <i>TABLE 47 CRITERIA FOR SELECTING FLAME RETARDANT CHEMICALS</i> | 93 |
| <i>TABLE 48 TYPES OF PLASTICS THAT USE FLAME RETARDANT CHEMICALS</i> | 94 |
| FORECAST FOR FLAME RETARDANT CHEMICALS IN PLASTICS CONSUMPTION | 95 |
| <i>TABLE 49 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN PLASTICS BY CHEMICAL, THROUGH 2019 (\$ MILLIONS)</i> | 95 |
| AVAILABLE PLASTICS STATISTICS | 96 |
| <i>TABLE 50 PLASTIC PRODUCTION BY MARKET SECTOR, 2014 AND 2019 (% OF MILLION POUNDS)</i> | 97 |
| ACRYLICS | 97 |
| EPOXY RESINS | 98 |
| NYLONS | 99 |
| Other Chemicals in Nylons | 99 |
| PHENOLICS | 100 |
| POLYCARBONATES | 100 |
| POLYESTERS | 101 |
| POLYETHYLENES/POLYPROPYLENES | 102 |
| POLYURETHANE | 102 |
| POLYVINYL CHLORIDE (PVC) | 103 |

| TOPIC | PAGE NO. |
|---|----------|
| STYRENES | 103 |
| TEXTILES | 104 |
| TEXTILE CLASSIFICATIONS | 104 |
| Non-Durable | 105 |
| Semi-Durable | 105 |
| Durable | 105 |
| Nomex | 105 |
| TYPES OF TEXTILES | 106 |
| Natural Fibers | 106 |
| Synthetic Fabrics | 107 |
| Blended Fabrics | 108 |
| GLOBAL MARKET SIZE OF FLAME RETARDANT CHEMICALS IN TEXTILES | 108 |
| <i>TABLE 51 TEXTILE-RELATED INDUSTRIES AND THEIR GROWTH RATES (%)</i> | 108 |
| <i>TABLE 52 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN TEXTILES BY CHEMICAL, THROUGH 2019 (\$ MILLIONS)</i> | 109 |
| <i>TABLE 53 GLOBAL CONSUMPTION OF FLAME RETARDANTS USED IN TEXTILES BY TYPE OF CHEMICAL, 2019 (%)</i> | 110 |
| WOOD/PAPER | 110 |
| GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS IN WOOD/PAPER | 110 |
| <i>TABLE 54 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN WOOD/PAPER BY CHEMICAL, THROUGH 2019 (\$ MILLIONS)</i> | 111 |
| <i>TABLE 55 GLOBAL CONSUMPTION OF FLAME RETARDANT CHEMICALS USED IN WOOD/PAPER BY CHEMICAL, THROUGH 2019 (MILLION POUNDS)</i> | 112 |
| COATINGS/PAINTS | 112 |
| GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS IN COATINGS/PAINTS | 112 |
| <i>TABLE 56 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN PAINTS/COATINGS BY CHEMICAL, THROUGH 2019 (\$ MILLIONS)</i> | 113 |
| COATINGS/CONSTRUCTION | 113 |
| GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS IN COATINGS/CONSTRUCTION | 113 |
| <i>TABLE 57 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN COATINGS/CONSTRUCTION BY CHEMICAL, THROUGH 2019 (\$ MILLIONS)</i> | 114 |
| <i>TABLE 58 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN COATINGS/CONSTRUCTION BY REGION, 2019 (%)</i> | 114 |
| COATINGS/DECORATIONS | 115 |
| VALUE OF FLAME RETARDANT CHEMICALS IN COATINGS/DECORATIONS | 115 |
| <i>TABLE 59 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN COATINGS/DECORATIONS BY CHEMICAL, THROUGH 2019 (\$ MILLIONS)</i> | 115 |
| <i>TABLE 60 GLOBAL CONSUMPTION OF FLAME RETARDANT CHEMICALS USED IN COATINGS/DECORATIONS BY CHEMICAL, THROUGH 2019 (MILLION POUNDS)</i> | 116 |
| TECHNOLOGY | 116 |
| DOW POLYFR | 117 |
| CHEMTURA | 118 |
| ALBEMARLE | 118 |
| ICL | 118 |
| FIRE-RETARDANT GELS | 119 |
| CARBON NANOTUBES (CNTS) | 119 |
| NANOCOATING COMPRISED OF POSITIVELY CHARGED CHITOSAN (CH) AND ANIONIC POLY (VINYL SULFONIC ACID SODIUM SALT) | 120 |

| TOPIC | PAGE NO. |
|--|----------|
| CLAY, CRAB SHELLS AND DNA BASED "GREEN" FIRE RETARDANTS | 121 |
| BIO-INSPIRED COATINGS ON FLEXIBLE POLYURETHANE FOAM | 121 |
| OCEAN BACTERIA PRODUCE FLAME RETARDANTS | 121 |
| INDIA GOVERNMENT ADDING FLAME RETARDANTS TO MILITARY UNIFORMS | 122 |
| BASF NEW ULTRAMID A3U42G6 HALOGEN FREE FLAME RETARDANT | 122 |
| SONY LAUNCHES EXTERNAL SALES OF SORPLAS FLAME-RETARDANT RECYCLED PLASTIC MATERIAL | 123 |
| RESEARCHERS CREATE DAIRY-BASED FLAME RETARDANT | 123 |
| PATENT ACTIVITY | 124 |
| <i>TABLE 61 LIST OF APPLICABLE PATENTS</i> | 124 |
| CHAPTER 5 LEADING COMPANIES IN FLAME RETARDANT CHEMICALS | 131 |
| ALBEMARLE CORP. | 131 |
| <i>TABLE 62 ALBEMARLE'S MAJOR FLAME RETARDANT PRODUCT LINES</i> | 131 |
| <i>TABLE 63 ALBEMARLE CORP. KEY EXECUTIVES</i> | 132 |
| CHEMTURA CORP. | 132 |
| GREAT LAKES SOLUTIONS (PART OF CHEMTURA) | 132 |
| <i>TABLE 64 SELECT FLAME RETARDANT PRODUCT LINES FROM GREAT LAKES SOLUTIONS (A CHEMTURA COMPANY)</i> | 133 |
| ISRAEL CHEMICALS LTD. | 134 |
| ISRAEL CHEMICALS LTD. PERFORMANCE PRODUCTS LP | 134 |
| AKZO NOBEL N.V. | 135 |
| International Protective Coatings Corp. | 135 |
| ALMATIS GMBH (PART OF ALMATIS HOLDINGS GMBH) | 135 |
| AMCOL INTERNATIONAL CORP. | 135 |
| AMPACET CORP. | 136 |
| AMSPEC CHEMICAL CORP. | 136 |
| ARKEMA SA | 136 |
| Arkema USA (part of Arkema SA) | 136 |
| BARRICADE INTERNATIONAL INC. | 136 |
| BASF SE | 136 |
| BAYER AG | 137 |
| CIBA (PART OF BASF CORP.) | 137 |
| CLARIANT AG | 137 |
| Clariant Specialty Chemicals | 137 |
| DAIHACHI CHEMICAL INDUSTRY CO. LTD. | 137 |
| DOVER CHEMICAL CORP. | 138 |
| FREEPORT-MCMORAN COPPER AND GOLD INC. | 138 |
| Climax Molybdenum Co. (Part of Freeport McMoRan Copper and Gold) | 138 |
| ICC INDUSTRIES INC. | 138 |
| INTERPLASTIC CORP. | 138 |
| J.M. HUBER CORP. | 138 |
| Huber Engineered Materials (Part of J.M. Huber Corp.) | 139 |
| KYOWA CHEMICAL INDUSTRY CO. LTD. | 139 |
| LANXESS | 139 |
| LHOIST SA | 139 |
| Franklin Industrial Minerals (Part of Lhoist SA) | 139 |

| TOPIC | PAGE NO. |
|---|-----------------|
| MARTIN MARIETTA MATERIALS INC. | 140 |
| Martin Marietta Magnesia Specialties Llc. (Part of Martin Marietta Materials Inc.) | 140 |
| NYACOL NANO TECHNOLOGIES INC. | 140 |
| OCCIDENTAL CHEMICAL CORP. | 140 |
| RIO TINTO ALCAN CANADA LTD. | 140 |
| R.J. MARSHALL CO. | 141 |
| ROCKWOOD CLAY ADDITIVES LTD./SOUTHERN CLAY PRODUCTS | 141 |
| SHERWIN-WILLIAMS CO. | 141 |
| SOLVAY RHODIA | 141 |
| SUPRESTA LLC | 141 |
| TOR MINERALS INTERNATIONAL INC. | 142 |
| TOSOH CORP. | 142 |
| Tosoh USA Inc. (Part of Tosoh Corp.) | 142 |
| U.S. ANTIMONY SALES CORP. | 142 |
| U.S. BORAX INC. | 142 |
| VELSICOL CHEMICAL LLC | 143 |
| MISCELLANEOUS FLAME RETARDANT COMPANIES | 143 |
| APEXICAL INC. | 143 |
| CHINA NATIONAL CHEMICAL CONSTRUCTION | 143 |
| CYTEC INDUSTRIES INC. | 143 |
| DAIHACHI CHEMICAL INDUSTRY | 144 |
| DOW CHEMICAL CO. | 144 |
| DUPONT | 144 |
| ITALMATCH CHEMICALS SPA | 144 |
| NABALTEC | 144 |
| NIHON SEIKO LTD. | 145 |
| SAKAMOTO YAKUJIN KOGYO CO. LTD. | 145 |
| SPARTAN FLAME RETARDANTS | 145 |
| TATEHO CHEMICAL INDUSTRIES CO. LTD., A SUBSIDIARY OF AIR WATER WORKS | 145 |
| OTHER ORGANIZATIONS | 145 |
| AZONETWORK UK LTD. | 145 |
| BUREAU OF ELECTRONIC AND APPLIANCE REPAIR, HOME FURNISHINGS AND THERMAL INSULATION | 146 |
| CENTERS FOR DISEASE CONTROL AND PREVENTION | 146 |
| FLAME RETARDANTS-ONLINE | 146 |
| INTERNATIONAL ORGANIZATION OF FIRE AND RESCUE SERVICES | 146 |
| JAPAN FIRE RETARDANT ASSOCIATION (JFRA) | 146 |
| CHAPTER 6 APPENDIX | 148 |
| <i>TABLE 65 WORLDWIDE BAUXITE MINE PRODUCTION AND RESERVES (THOUSAND METRIC DRY TONS)</i> | 148 |

LIST OF TABLES

| TABLE HEADING | PAGE NO. |
|---|-----------------|
| SUMMARY TABLE GLOBAL CONSUMPTION OF FLAME RETARDANT CHEMICALS, THROUGH 2019 (MILLION POUNDS) | 7 |
| TABLE 1 ADDITIVES/MODIFIERS FOR CONTROLLING BURNING | 12 |
| TABLE 2 FLAME RETARDANTS AND GENERALLY ACCEPTED MECHANISMS OF CONTROL | 15 |
| TABLE 3 ADDITIVES/MODIFIERS FOR CONTROL OF BURNING | 16 |
| TABLE 4 REPRESENTATIVE SYNERGISTIC FLAME RETARDANT COMBINATIONS (%) | 17 |
| TABLE 5 FLAME RETARDANTS AND PRODUCTS WHERE THEY ARE COMMONLY USED | 18 |
| TABLE 6 COMMON CLASSIFICATION SYSTEM FOR FLAME RETARDANT CHEMICALS | 19 |
| TABLE 7 LEADING CAUSES OF U.S. RESIDENTIAL FIRES (%) | 19 |
| TABLE 8 GOALS OF SIMULATED FIRE CONDITIONS TESTS | 20 |
| TABLE 9 OXYGEN INDICES OF SOME COMMON MATERIALS | 21 |
| TABLE 10 CONE CALORIMETRY PARAMETERS AND VALUES | 23 |
| TABLE 11 UL-94 BURN TEST RATINGS | 24 |
| TABLE 12 PROPOSED FLAME RETARDANT CHEMICALS BEING LIMITED/PROHIBITED FROM CHILDREN'S PRODUCTS | 32 |
| TABLE 13 NFPA GUIDELINES AND STANDARDS | 39 |
| TABLE 14 AGENCIES INVOLVED IN ESTABLISHING FLAME RETARDANT AND PROTECTIVE STANDARDS | 40 |
| TABLE 15 ASTM STANDARDS APPLICABLE TO THE FLAME RETARDANT INDUSTRY | 41 |
| TABLE 16 MARKET SHARE BY INDUSTRY, 2012 (% , BASED ON \$) | 50 |
| TABLE 17 CHEMICALS COMMONLY USED AS FLAME RETARDANTS | 54 |
| TABLE 18 SIGNIFICANT FLAME RETARDANT CHEMICALS | 55 |
| TABLE 19 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS BY CHEMICAL, THROUGH 2019 (\$ MILLIONS) | 56 |
| TABLE 20 BAUXITE/ALUMINUM RESOURCES WORLDWIDE (%) | 58 |
| TABLE 21 WORLD BAUXITE MINE PRODUCTION AND RESERVES, 2012-2014 (THOUSAND METRIC DRY TONS) | 58 |
| TABLE 22 GLOBAL MARKET FOR ALUMINUM TRIHYDRATE, THROUGH 2019 (\$ MILLIONS) | 60 |
| TABLE 23 GLOBAL MARKET FOR ALUMINUM TRIHYDRATE FLAME RETARDANT CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS) | 60 |
| TABLE 24 WORLD ANTIMONY OXIDE MINE PRODUCTION AND RESERVES, 2012-2014 | 62 |
| TABLE 25 GLOBAL CONSUMPTION OF ANTIMONY OXIDE, THROUGH 2019 (MILLION POUNDS) | 63 |
| TABLE 26 GLOBAL MARKET FOR ANTIMONY OXIDE, THROUGH 2019 (\$ MILLIONS) | 63 |
| TABLE 27 GLOBAL MARKET FOR ANTIMONY OXIDE FLAME RETARDANT CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS) | 64 |
| TABLE 28 GLOBAL CONSUMPTION OF BROMINE-BASED FLAME RETARDANTS IN ELECTRICAL/ELECTRONIC COMPONENTS, 2014 (%) | 65 |
| TABLE 29 TYPES OF AROMATIC BROMINE-BASED FLAME RETARDANT COMPOUNDS | 66 |
| TABLE 30 SIGNIFICANT AROMATIC BROMINE-BASED FLAME RETARDANT COMPOUNDS | 67 |
| TABLE 31 SIGNIFICANT TYPES OF ALIPHATIC BROMINE-BASED FLAME RETARDANT COMPOUNDS | 67 |
| TABLE 33 GLOBAL CONSUMPTION OF BROMINE-BASED FLAME RETARDANTS, THROUGH 2019 (MILLION POUNDS) | 68 |
| TABLE 34 GLOBAL MARKET FOR FLAME RETARDANT BROMINE-BASED CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS) | 69 |

| TABLE HEADING | PAGE NO. |
|--|-----------------|
| TABLE 35 GLOBAL CONSUMPTION OF FLAME RETARDANT BROMINE-BASED CHEMICALS BY END USE, THROUGH 2019 (MILLIONS POUNDS) | 70 |
| TABLE 36 GLOBAL CONSUMPTION OF CHLORINE-BASED FLAME RETARDANTS, THROUGH 2019 (MILLION POUNDS) | 74 |
| TABLE 37 GLOBAL MARKET FOR MAGNESIUM HYDROXIDE FLAME RETARDANT CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS) | 75 |
| TABLE 38 COMMON MELAMINE-BASED FLAME RETARDANT CHEMICALS | 78 |
| TABLE 39 GLOBAL MARKET FOR MELAMINE FLAME RETARDANT CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS) | 78 |
| TABLE 40 GLOBAL MARKET FOR PHOSPHORUS-BASED FLAME RETARDANT CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS) | 82 |
| TABLE 41 GLOBAL MARKET FOR OTHER FLAME RETARDANT CHEMICALS BY END USE, THROUGH 2019 (\$ MILLIONS) | 88 |
| TABLE 42 MAJOR MARKETS USING FLAME RETARDANT CHEMICALS | 89 |
| TABLE 43 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS BY APPLICATION, THROUGH 2019 (\$ MILLIONS) | 89 |
| TABLE 44 WORLDWIDE PLASTICS PRODUCTION ESTIMATE, THROUGH 2019 (MILLION POUNDS) | 91 |
| TABLE 45 FLAME RETARDANTS IN PLASTICS, 2019 (% OF TOTAL MILLION POUNDS) | 92 |
| TABLE 46 METHODS OF FLAME-RETARDING POLYMERS | 93 |
| TABLE 47 CRITERIA FOR SELECTING FLAME RETARDANT CHEMICALS | 93 |
| TABLE 48 TYPES OF PLASTICS THAT USE FLAME RETARDANT CHEMICALS | 94 |
| TABLE 49 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN PLASTICS BY CHEMICAL, THROUGH 2019 (\$ MILLIONS) | 95 |
| TABLE 50 PLASTIC PRODUCTION BY MARKET SECTOR, 2014 AND 2019 (% OF MILLION POUNDS) | 97 |
| TABLE 51 TEXTILE-RELATED INDUSTRIES AND THEIR GROWTH RATES (%) | 108 |
| TABLE 52 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN TEXTILES BY CHEMICAL, THROUGH 2019 (\$ MILLIONS) | 109 |
| TABLE 53 GLOBAL CONSUMPTION OF FLAME RETARDANTS USED IN TEXTILES BY TYPE OF CHEMICAL, 2019 (%) | 110 |
| TABLE 54 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN WOOD/PAPER BY CHEMICAL, THROUGH 2019 (\$ MILLIONS) | 111 |
| TABLE 55 GLOBAL CONSUMPTION OF FLAME RETARDANT CHEMICALS USED IN WOOD/PAPER BY CHEMICAL, THROUGH 2019 (MILLION POUNDS) | 112 |
| TABLE 56 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN PAINTS/COATINGS BY CHEMICAL, THROUGH 2019 (\$ MILLIONS) | 113 |
| TABLE 57 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN COATINGS/CONSTRUCTION BY CHEMICAL, THROUGH 2019 (\$ MILLIONS) | 114 |
| TABLE 58 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN COATINGS/CONSTRUCTION BY REGION, 2019 (%) | 114 |
| TABLE 59 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS USED IN COATINGS/DECORATIONS BY CHEMICAL, THROUGH 2019 (\$ MILLIONS) | 115 |
| TABLE 60 GLOBAL CONSUMPTION OF FLAME RETARDANT CHEMICALS USED IN COATINGS/DECORATIONS BY CHEMICAL, THROUGH 2019 (MILLION POUNDS) | 116 |
| TABLE 61 LIST OF APPLICABLE PATENTS | 124 |
| TABLE 62 ALBEMARLE'S MAJOR FLAME RETARDANT PRODUCT LINES | 131 |
| TABLE 63 ALBEMARLE CORP. KEY EXECUTIVES | 132 |
| TABLE 64 SELECT FLAME RETARDANT PRODUCT LINES FROM GREAT LAKES SOLUTIONS (A CHEMTURA COMPANY) | 133 |

| TABLE HEADING | PAGE NO. |
|--|-----------------|
| TABLE 65 WORLDWIDE BAUXITE MINE PRODUCTION AND RESERVES (THOUSAND METRIC DRY TONS) | 148 |

LIST OF FIGURES

| FIGURE TITLE | PAGE NO. |
|--|-----------------|
| SUMMARY FIGURE GLOBAL CONSUMPTION OF FLAME RETARDANT CHEMICALS, 2012-2019 (MILLION POUNDS) | 7 |
| FIGURE 1 MARKET SHARE BY INDUSTRY, 2012 (% , BASED ON \$) | 51 |
| FIGURE 2 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS, 2012-2019 (\$ MILLIONS) | 56 |
| FIGURE 3 REACTIONS OF ANTIMONY TRIOXIDE WITH HALOGENS | 61 |
| FIGURE 4 GLOBAL MARKET FOR FLAME RETARDANT BROMINE-BASED CHEMICALS BY END USE, 2012-2019 (\$ MILLIONS) | 69 |
| FIGURE 5 GLOBAL MARKET FOR MELAMINE FLAME RETARDANT CHEMICALS BY END USE, 2012-2019 (\$ MILLIONS) | 78 |
| FIGURE 6 GLOBAL MARKET FOR OTHER FLAME RETARDANT CHEMICALS BY END USE, 2012-2019 (\$ MILLIONS) | 88 |
| FIGURE 7 GLOBAL MARKET FOR FLAME RETARDANT CHEMICALS BY APPLICATION, 2012-2019 (\$ MILLIONS) | 90 |