CPSC Staff Statement on the

Toxicology Excellence for Risk Assessment Report,

"Final Report for CPSC Task 14"

April 2016

The report, *Final Report for CPSC Task 14*, presents the findings of research conducted by Toxicology Excellence for Risk Assessment ("TERA"), under a contract with the U.S. Consumer Product Safety Commission ("CPSC"). TERA performed this research to summarize available information on the production of engineered wood products (specifically, particleboard, medium-density fiberboard, and hardwood plywood) and the possibility of lead, phthalates or the elements listed in Table 1 of ASTM F963-11[1] ("ASTM elements") above their respective concentration or solubility limits, when used in children's toys or child care articles.

The 10 specified phthalates are:

- DEHP: di-(2-ethylhexyl) phthalate
- DBP: dibutyl phthalate
- BBP: benzyl butyl phthalate
- DINP: diisononyl phthalate
- DIDP: diisodecyl phthalate

[1] *Standard Consumer Safety Specification for Toy Safety*.

- DnOP: di-n-octyl phthalate
- DIBP: diisobutyl phthalate
- DPENP: di-n-pentyl phthalate
- DHEXP: di-n-hexyl phthalate
- DCHP: dicyclohexyl phthalate.

The chemical elements listed in ASTM F963-11 are:

- Antimony
- Arsenic
- Barium
- Cadmium
- Chromium
- Mercury
- Selenium
- Lead.

This research was completed in support of CPSC's work on third party testing burden reduction consistent with assuring compliance. CPSC staff will consider this information in evaluating whether staff could make a recommendation for a Commission determination that the engineered wood products listed do not contain: lead in concentrations above 100 parts-per-million ("ppm,"); any of the ASTM elements in concentrations above their respective solubility limits, or any of the 10 specified phthalates in concentrations above 0.1 percent; and thus, may not require third party testing to assure compliance with sections 101, 106, and 108, respectively, of the Consumer Product Safety Improvement Act of 2008.

This report will be posted on CPSC's website to keep stakeholders informed of the progress of technical research related to the agency's regulatory activities.

TERA

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Final Report for CPSC Task 14

FINAL REPORT
March 25, 2016

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Abbreviations

ASTM	American Society for Testing and Materials
BBP	benzyl butyl phthalate
CAS	Chemical Abstracts Service
CASRN	Chemical Abstracts Service Registry Number
CCA	chromated copper arsenate
CHAP	Chronic Hazard Advisory Panel
CPA	Composite Panel Association
CPSA	Consumer Product Safety Act
CPSIA	Consumer Product Safety Improvement Act
CPSC	Consumer Product Safety Commission
DBP	dibutyl phthalate
DCHP	dicyclohexyl phthalate
DEHP	di-(2-ethylhexyl) phthalate
DHEXP	di-n-hexyl phthalate
DIBP	diisobutyl phthalate
DIDP	diisodecyl phthalate
DINP	diisononyl phthalate
DMDEE	4,4’-(oxydi-2,1-ethanediyl)bismorpholine
DnOP	di-n-octyl phthalate
DPENP	di-n-pentyl phthalate
ECC	Eco-Certified™ Composite
ED-XRF	energy dispersive x-ray fluorescence
EPF	European Panel Federation
EU	European Union
EWP	engineered wood product
FAO	Food and Agriculture Organization
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
HPVA	Hardwood Plywood and Veneer Association
HSDB	Hazardous Substances Data Bank
ICP-MS	inductively coupled plasma mass spectrometry
ICP-OES	inductively coupled plasma optical emission spectrometry
ISO	International Organization for Standardization
LCA	life cycle assessment
LCI	life cycle inventories
LOQ	limit of quantification

MDF	medium density fiberboard
MDI	methylene-diphenyl-diisocyanate
MDPC	methylenediphenyl di(phenylcarbamate)
MF	melamine-formaldehyde
mg/kg	milligrams per kilogram
MSDS	material safety data sheet
MUF	melamine-urea-formaldehyde
NAICS	North American Industry Classification System
ng/g	nanograms per gram
ng/m^3	nanograms per cubic meter
NMA	n-methylolacrylamide
OSB	oriented strand board
OSHA	Occupational Safety and Health Administration
PB	particleboard
PBC	particleboard core
PF	phenol-formaldehyde
pMDI	polymerized methylene-diphenyl-diisocyanate
PP	polypropylene
ppm	parts per million
PRF	phenol-resorcinol-formaldehyde
PU	polyurethane
PVA	polyvinyl acetate
PVC	polyvinyl chloride
RF	resorcinol-formaldehyde
SDS	safety data sheet
SIC	Standard Industrial Classification
TERA	Toxicology Excellence for Risk Assessment
UF	urea-formaldehyde
UK	United Kingdom
USDA	United States Department of Agriculture
US EPA	United States Environmental Protection Agency
WHO	World Health Organization
XRF	x-ray fluorescence

1. Introduction

The Consumer Product Safety Act (CPSA) requires third party testing of children's products for compliance with the applicable children's product safety rules. This report summarizes available information on the production of engineered wood products (specifically - particleboard, medium density fiberboard, and hardwood plywood) and the possibility of the raw materials or finished product containing any of the specified chemical elements or phthalates (listed in Table 1) above their respective solubility or content limits. As defined by the American Home Furnishings Alliance (AHFA), engineered wood (also called composite wood) includes a range of derivative wood products (particleboard, medium density fiberboard, or hardwood plywood) manufactured by bonding primarily cellulosic materials (*e.g.*, wood fibers) with adhesives. The Consumer Product Safety Improvement Act (CPSIA) of 2008 restricts the presence of certain phthalates in children's toys and childcare articles, and the presence of lead in component parts of children's products (with a few exceptions). The CPSIA also requires toys intended for children under the age of six (or toys or toy parts that are likely to be "sucked, mouthed, or ingested") to comply with Section 4.3.5 of ASTM F963-11 (*Heavy Metals)*, of the ASTM International (ASTM, 2011) Standard F963-11, *Standard Consumer Safety Specification for Toy Safety Products* (the Toy Standard). The purpose of this report is to provide the United States Consumer Product Safety Commission (CPSC) staff with information upon which to base a recommendation as to whether specific engineered wood products used for children's products, including toys and childcare articles, can be determined not to contain any of the specified phthalates, lead or other chemical elements in concentrations above the specified limits, and thus, would not require third-party testing to assure compliance with the CPSIA (2008) and the Toy Standard.

Section 108 of the CPSIA (2008) restricts the presence of six phthalates in children's toys and childcare articles: dibutyl phthalate (DBP), benzyl butyl phthalate (BBP), and di-2-ethylhexyl phthalate (DEHP) may not be present in concentrations above 0.1 percent (1000 ppm) in accessible component parts of children's toys and childcare articles; while di-n-octyl phthalate (DnOP), diisononyl phthalate (DINP), and diisodecyl phthalate (DIDP) may not be present in concentrations above 0.1 percent in childcare articles or in mouthable toys. The CPSC Chronic Hazard Advisory Panel (CHAP) recommended that diisobutyl phthalate (DIBP), di-n-pentyl phthalate (DPENP), di-n-hexyl phthalate (DHEXP), and dicyclohexyl phthalate (DCHP) be permanently banned for use in children's toys and childcare articles at concentrations greater than 0.1 percent. This report addresses whether the three specified engineered wood products might contain one or more of these specific phthalates at concentrations above the 1000 ppm limit.

Section 101 of the CPSIA restricts the presence of lead at concentrations greater than 100 ppm in accessible component parts of most children's products. The Toy Standard sets solubility limits for eight chemical elements (antimony, arsenic, barium, cadmium, chromium, lead, mercury, and selenium) in paints, surface coatings, and accessible substrate materials. This report also addresses whether the engineered wood products (*i.e.*, accessible substrate material) might contain lead at concentrations above the specified limit, or one or more of the other elements at levels above the ASTM solubility limits (see Table 1).

Table 1. Specified chemical substances and solubility limits.

Chemical	CASRN[1]	Limit
Specified Phthalates		
DEHP: di-(2-ethylhexl) phthalate	117-81-7	0.1% (1000 ppm)
DBP: dibutyl phthalate	84-74-2	
BBP: benzyl butyl phthalate	85-68-7	
DINP: diisononyl phthalate	28553-12-0, 68515-49-1	
DIDP: diisodecyl phthalate	26761-40-0, 68515-49-1	
DnOP: di-n-octyl phthalate	117-84-0	
DIBP: diisobutyl phthalate	84-69-5	
DPENP: di-n-pentyl phthalate	131-18-0	
DHEXP: di-n-hexyl phthalate	84-75-3	
DCHP: dicyclohexyl phthalate	84-61-7	
ASTM Chemical Elements		
Antimony	7440-36-0	60 ppm
Arsenic	7440-38-2	25 ppm
Barium	7440-39-3	1000 ppm
Cadmium	7440-43-9	75 ppm
Chromium	7440-47-3	60 ppm
Mercury	7439-97-6	60 ppm
Selenium	7782-49-2	500 ppm
Lead	7439-92-1	100 ppm[2]

[1] CASRN or CAS, stands for *Chemical Abstract Service Registry Number.* A CASRN or CAS number is a unique numerical identifier of a chemical substance.
[2] CPSIA section 101 limit for lead content.

The CPSC requested that Toxicology Excellence for Risk Assessment (TERA) investigate the topics below.

- An overview of the materials, other than natural wood or similar natural cellulosic materials (for example, adhesives, resins, and binders), and the processes used worldwide to create engineered wood products.
- Detailed description of the raw materials used worldwide in the production of the materials, other than natural wood or similar natural cellulosic materials, used to make engineered wood products (*e.g.*, adhesives, resins, and binders).
- The proportions of concentrations (or typical ranges) of the wood and non-wood components; for example, the percentage by weight of adhesives and other non-wood materials in each of the three engineered wood product types (*i.e.*, particleboard, medium density fiberboard, and hardwood plywood).
- Detailed description of the manufacturing processes used worldwide to create the materials (adhesives, resins, and binders) and final specified engineered wood products.
- The potential use and description of any recycled materials or other additives in the production of the engineered wood products that could contain lead, the specified phthalates, or the specified chemical elements.

To address this task we methodically searched for evidence and data of potential contamination of these three types of engineered wood products (EWPs) with lead, the specified chemical elements or phthalates in a step-wise fashion. This report is organized into nine sections. First, we briefly describe the literature search and research strategy, along with the types of data sources consulted (details are provided in Appendix I). We then discuss some of the terminology in the engineered wood sector to help define the scope for this research and to clarify some terms. We investigate the possibility for lead, any of the other ASTM elements or specified phthalates to be present in the engineered wood products above their respective solubility or content limits. To supplement this, we identify the raw materials and additives for use in manufacturing each EWP including the resins and additives used in making the adhesives. We then investigate the potential for lead, any of the other ASTM elements, or specified phthalates to be present in those raw materials. For the adhesives, we provide a brief description on why lead, the ASTM elements, and specified phthalates are not likely to be present (Section 8.3). Finally, we look at the possibility for lead, the ASTM elements, or specified phthalates to be introduced into the EWPs from use of recycled raw materials in manufacturing. TERA focused on the materials, other than natural wood or similar cellulosic materials, and the processes used in the manufacture of engineered wood and the non-cellulosic additives.

2. Approach and Methods

For each of the three specified engineered wood products, we investigated how the products are made, what raw materials are used in manufacturing, the proportions of wood and non-wood components, and the potential recycled materials used in production. We also searched for data on concentrations of the substances of interest in the three types of engineered wood products and the most commonly used adhesives and additives. We used a multi-pronged approach to identify available information in order to answer the question of whether engineered wood products (or the adhesives with which they are made) contain the specified phthalates listed in Table 1 (in concentrations over 1000 ppm) or lead (in concentrations over 100 ppm) or any of the other specified ASTM elements (in concentrations exceeding ASTM F963-11 limits shown in Table 1). Our focus was to identify relevant information on the five research topics identified by CPSC in order to address the question of whether engineered wood products, used as substrates in toys or childcare articles, might contain any of the substances in concentrations above the specified limits.

We first researched authoritative sources such as reference books and textbooks, along with Internet resources, for general information about engineered wood products, adhesives, raw materials, manufacturing processes, and the potential use of recycled materials. We utilized this information and consulted technical experts to identify key words for literature searching. We then conducted primary literature searches for research studies and publications. Appendix I provides additional details regarding the literature searches and results, including databases used. Because there is little research on metal/elemental or phthalate contamination of EWPs, we cast a wide net in our searching of the literature and as a result screened thousands of titles and abstracts, with few relevant studies identified. Sometimes these searches also identified patents, and we specifically state when patents are discussed in those sections. Information from patents was only included to provide an indication of new technologies or materials that might suggest future technologies, but these are not expected to be current industry standards or practice (Frazier, personal communication). In addition, we searched for Safety Data Sheets (SDS)[3] for information on raw materials [formerly called Materials Safety Data Sheets (MSDS)]. More details on the specific search strategies and a summary of materials identified in the SDSs are found in Appendix II.

[3] SDS sheets contain information on ingredients that exceed the cut-off limits for concentrations by weight as set by regulatory bodies (Occupational Safety and Health Administration – OSHA; Globally Harmonized System of Classification and Labelling of Chemicals – GHS). These limits are typically ≥1.0% for most ingredients (≥0.1% for carcinogens/mutagens) (UN, 2009). It is also worth noting that Confidential Business Information takes precedence over reporting and proprietary information is commonly omitted.

To address our research task, we reviewed the literature and resources for evidence of potential contamination of the three types of EWPs with the specified elements or phthalates in a step-wise fashion. First, we looked for data on measurements of specified elements or phthalates in the EWPs. As anticipated, we found little information regarding direct evidence and concentrations of the specified elements or phthalates in the EWPs themselves (Section 4). Finding little data for the EWPs themselves, we then sought measurements of specified elements or phthalates in adhesives and waxes most commonly used in EWPs, which meant also identifying the most commonly used adhesives in the EWPs (Section 5 and 6; Appendix II). We identified the raw materials used to make these adhesives, and briefly investigated manufacturing and potential impurities for instances of specified phthalate or ASTM element introduction (Appendix III). We also looked for the presence of phthalates in wood and potential for uptake of phthalates into plants to determine whether phthalates might be found in EWPs originating from raw cellulosic materials (Section 7). The potential for natural wood to contain concentration of the ASTM elements above the solubility limits was addressed under a previous report prepared for CPSC (CPSC, 2015). Lastly, we searched for information on elements and phthalates in recycled materials that might be used to make EWPs (Section 8).

Through our multi-prong approach, we feel confident we have gathered and reported an accurate picture of the EWP raw materials, manufacturing, and potential for contamination with the substances in general. By approaching this research from multiple angles, we were able to locate what we believe is representative information from the available data that provides confidence that we have covered currently used and common adhesives, resins, and raw materials, and the potential for phthalate or ASTM element introduction.

3. Engineered Wood Products

Engineered wood products are composite products made from wooden elements of various sizes, including lumber, veneer, strands, flakes, much smaller particles of wood, and even individual wood cell "fibers." These variously sized wood pieces are bonded together with adhesives to form panel products and lumber-like structural products (Stokke et al., 2014; APA, 2011; US EPA, 2002, 2004; USDA, 2010; Karacabeyli and Douglas, 2013). Often the wooden elements are bonded together with specific "grain" orientations intended to optimize mechanical properties in the composite. The "grain direction" in a piece of wood is that which was parallel to the original tree stem.

The three specified engineered wood products (hardwood plywood, particleboard, and medium density fiberboard) are among multiple types of engineered wood products available. In the

United States, EWPs fall into three manufacturer categories (US EPA, 2004). Hardwood plywood falls within the first category and particleboard (PB) and medium density fiberboard (MDF) fall within the second category. The third category is not relevant to this report.

1. Hardwood Veneer and Plywood (SIC 2435, NAICS 321211)[4]. Example products include hardwood plywood composites, hardwood veneer or plywood, hardwood plywood panels, hardwood or hardwood faced plywood, prefinished hardwood plywood, and hardwood veneer mills.
2. Reconstituted wood products (SIC 2493, NAICS 321219). Example products include bagasse board, flakeboard hardboard, insulating siding, cellular fiber or hard pressed insulation board, fiber lath, medium density fiberboard, particleboard, reconstituted wood panels, oriented strand board (OSB), wafer-board, fiberboard wall tile, and wood fiber wallboard.
3. Structural wood, not classified elsewhere (SIC 2439, NAICS 321213, and NAICS 321214). Example products include glue-laminated or pre-engineered wood arches, fabricated structural wood, finger joint lumber manufacturing, wood I-joists, laminated structural wood, laminated veneer lumber, parallel strand lumber, structural wood (except trusses), and others.

Other wood panel composites include combinations of wood with additional materials, such as inorganics, plastics, fiberglass, and metals (Berglund and Rowell, 2005). These composites can include non-wood or lignocellulosic-mineral composites based on inorganic binders (*e.g.*, cement), natural fiber reinforced polymers, non-woven textile-type composites, polymer-wood composites (polyethylene-wood, polypropylene-wood, polyvinyl chloride-wood), and nanocomposites (USDA, 2010; Berglund and Rowell, 2005). This report focuses on hardwood plywood, medium density fiberboard, and particleboard made from natural wood and does not address these other types of EWPs.

3.1 Terminology

The following is a discussion of definitions and terminology used throughout this report. The Composite Panel Association (CPA) defines medium density fiberboard (MDF) as “a composite panel product typically consisting of cellulosic fibers combined with a synthetic resin or other suitable bonding system and joined together under heat and pressure. Additives may be introduced during manufacturing to impart additional characteristics” (CPA, 2012). Particleboard

[4] SIC: Standard Industrial Classification (SIC); NAICS: North American Industry Classification System (US Department of Commerce, 2015)

(PB) is conceptually similar: “a composite panel product consisting of cellulosic particles of various sizes that are bonded together with a synthetic resin or binder under heat and pressure” (CPA, 2015). Hardwood plywood is defined as “a manufactured panel made up of three or more thin plies of hardwood [veneer] (*e.g.*, red oak) laid on top of each other with the grain of each ply running perpendicular to the one on either side of it” (HPVA, 2015). The Atlantic Plywood Corporation (Atlantic Plywood Corporation, 2013) describes hardwood plywood with a little more detail: “a panel composed of layers of one or more inner plies of wood veneer, medium density fiberboard, PBC [particleboard core], or other core material bonded together with adhesive to a face and back veneer of hardwood or decorative softwood veneer.” Hardwood plywood is distinct from medium density fiberboard and particleboard because the plies comprising the product are large sheets, sheets of veneer, or veneer bonded to a “sheet” of particleboard or medium density fiberboard. Both medium density fiberboard and particleboard can be used as the core material in hardwood plywood. Veneer is a piece of wood that has been peeled or sliced from a log and is typically very thin, on the order of 1/8 inch or less (US EPA, 1995a).

While various classifications exist, composite wood products are most simply described under two general categories, structural and nonstructural. Structural products, like softwood plywood and laminated veneer lumber, are intended to serve as primary load-bearing building elements, in home structures for instance. Structural products are manufactured with structural adhesives that must satisfy certification criteria to be classified as structural adhesives (capable of weather exposure). Nonstructural products, like hardwood plywood, particleboard, and medium density fiberboard, are used to functionalize and/or adorn interior spaces as with cabinets and finish trim. Nonstructural products are typically manufactured with nonstructural adhesives (not capable of weather exposure). Nonstructural products may be manufactured with structural adhesives (typically to reduce formaldehyde emissions), but such products are still considered as nonstructural. Children’s toys (*e.g.*, puzzles, dollhouses, pull toys, toy chests) could be manufactured with either structural or nonstructural composite products, but the latter is most likely.

Adhesive technologies give rise to many terms that may be easily confused and misused. We discuss a number of the standard terminologies and their definitions here.

- “*Adhesive*” is the generic term used to describe a material, typically a liquid that can transform, or cure, into a solid. The term can refer to the applied liquid or the cured solid product (Frihart, 2005).

- "*Adhesive formulations*" contain mixtures of various compounds that affect cost and performance of the final adhesive. While the general formulations may be consistent across the EWP sector, specific adhesive formulations can be highly variable, not only between companies but also from the same company depending on factors such as seasonal weather (*i.e.*, humidity or temperature changes) or moisture content of wood stocks (Frihart, 2005). Adhesives are sometimes formulated with fillers, waxes, and other additives including catalysts, prior to curing into an adhesive.
- The definition and use of "*resin*" differs from source to source. In practice, an uncured formulated adhesive contains the "*resin*" or "*base resin*" materials used to create the cured formulated adhesive (Frihart, 2005; Frazier, personal communication). Adhesion results when separate resins are bonded together as a result of adhesive cure.
- All adhesive formulations contain at least one "*base resin*" (resin) which is typically a synthetic base polymer. The formulated adhesive is often named according to the chemical feedstocks (monomers) used to synthesize the adhesive (Frihart, 2005). For instance, urea-formaldehyde is an adhesive prepared from urea and formaldehyde base resins.
- A resin (base resin) may be used alone (not formulated with other resins or additives) and in this instance the resin may be referred to as a "*binder*."

In order to be consistent throughout this report, the term *adhesive* will refer to a formulated product, while *resin*, or *base resin*, will refer to the base polymers used in adhesive preparation or formulation.

Products such as particleboard and medium density fiberboard are generically classified as "*particulate composites.*" Particulate composites are commonly manufactured using only a base resin (binder); or if formulated, these formulations will not commonly contain fillers and extenders. Adhesive formulations used in particulate composites will contain the base resin, formaldehyde scavengers (compounds like urea that react with formaldehyde and reduce formaldehyde emissions from the finished product), waxes (to impart water resistance), and catalysts (used to accelerate cure). Catalysts increase the reaction rate of the adhesive during the curing process (Frihart, 2005). Catalysts are not consumed in the reaction (Frihart, 2005).

There are other additives found in some adhesive formulations. These can include curing agents (hardeners), fillers, extenders, and solvents present during the polymerization and curing of the adhesives during EWP manufacture.

- "*Curing agents*" (hardeners) are incorporated into the final polymerized adhesive. Curing agents or hardeners may be monomers (or prepolymers) that react with the base resin, and these are typical of two-part adhesives that cure at room temperature (cold-setting thermosets) (Wilson, 2009b). Most cold-setting adhesives contain two parts, the base resin and the curing agent (hardener).
- "*Fillers*" are typically flours of biomass waste like walnut shells or tree bark (Frihart, 2005). Fillers reduce cost and modify adhesive flow properties, giving added body and increased rigidity, reducing flow (viscosity), and influencing wood penetration of the adhesive; these are used in hardwood plywood, but not medium density fiberboard or particleboard (Frihart, 2005).
- "*Extenders*" are similar to fillers in that they are also used to reduce cost and modify flow, but unlike fillers, extenders possess some intrinsic adhesive quality. The most common extender used in wood composites is wheat flour, which is used in urea-formaldehyde resins for hardwood plywood.

Finally, solvents are often used to dissolve the base materials and additives for (typically) spray application, and common solvents include water or methanol (Frihart, 2005). More detail on the typically used resins, fillers, extenders, waxes, and scavengers in these adhesive formulations is provided in Section 6.

3.2 Regulations or Standards

We did not locate any United States or Canadian regulations or standards that specifically set limits on the presence of the specified elements or phthalates in engineered wood products. However, there are limits on uses of chromated copper arsenate (CCA)-treated wood and for formaldehyde emissions from finished EWPs. The US EPA and lumber industry agreed in 2003 to no longer use CCA-treated wood in residential construction (*e.g.*, residential structures such as playground equipment, decks, picnic tables, landscaping features, fences, patios, and walkways) (US EPA, 2003). US EPA has proposed formaldehyde emission standards for composite wood products, such as hardwood plywood, particleboard, and medium density fiberboard (US EPA, 2010).

In the United States, voluntary industry standards for EWPs focus on product performance or grading of boards for consumer end uses; they do not address contamination (Schramm, 2003; USDA, 2010). There are independent third-party testing and certification programs that address environmental or sustainability aspects of product manufacture or content, in order to obtain points toward "green" certifications. We did not find any that address the specified phthalates or elements directly.

In the European Union (EU) there is a voluntary program called Community Ecolabel; the EU Ecolabel for Wooden Furniture limits concentrations of elements in recycled woods used in furniture (EU, 2004). The concentrations are similar to ASTM F963-11 solubility limits, but phthalates are not addressed. Fellin et al. (2014) note that some EU countries have stricter limits, for example, Germany under the Wood Waste Normative. In addition, the European Panel Federation (representing European manufacturers of particleboard, medium density fiberboard, and oriented strand board) has established voluntary industry regulations limiting heavy metals (EPF, 2010a) that are similar to the ASTM limits.

4. Concentrations of Lead, Specified Chemical Elements, and Phthalates in Engineered Wood Products

As described in the Approach and Methods (Section 2 and Appendix I), TERA searched in the primary and secondary literature for the presence or concentrations of the specified elements and phthalates in the three EWPs. Potentially relevant studies (English only) were retrieved and reviewed. We found very few studies and little information on concentrations of the specified elements or phthalates in EWPs. We did not find any studies that measured concentrations above the ASTM solubility limits for the elements, or above 1000 ppm for the phthalates, in an EWP made from virgin timber or fibers. A number of life cycle assessment (LCAs) or life cycle inventories (LCIs) for the specified EWPs were identified and reviewed (*e.g.*, Rivela et al., 2006, 2007; Garcia and Friere, 2011; Iritani et al., 2015; McDevitt and Grigsby, 2014; Wilson et al., 2008a,b). While these provided useful information regarding common adhesives, manufacturing practices, energy consumption, carbon emissions, and in some cases formaldehyde emissions, they did not address concentrations of the specified phthalates and ASTM elements.

We did locate a number of studies that reported concentrations of one or more of the specified elements in EWPs made from CCA-treated wood (*e.g.*, Clausen et al., 2000, 2001; Kartal et al., 2003; Kartal and Clausen, 2001; Munson, 1997; Munson and Kamdem, 1998). The CCA preservative contains chromium and arsenic species, and some of these studies reported concentrations of arsenic and chromium in EWPs above the ASTM limits. Because CCA-treated wood is no longer used in the United States for household products, we did not investigate these studies further.

Another study (Fellin et al., 2014) reported concentrations of barium, cadmium, chromium, and lead above the ASTM limits in EWP wood waste (including particleboard, hardwood plywood, and medium density fiberboard). Because this was waste wood, it is not known how and what the wood might have been contaminated with during its lifecycle and through post-manufacture manipulations (*e.g.*, painting and surface coatings). The results from this study are discussed further in the recycling discussion (Section 8).

Coatings, finishes, and chemical treatments are a potential source of phthalates or elements. Our searching also revealed studies and patents for flame-retardant coatings, some of which contained antimony compounds. US EPA (1995a) notes that most manufacturers do not apply finishes, rather this is typically done by either end users or laminators who then sell the finished product to consumers. The focus of our report is on typical EWPs as produced by the EWP manufacturers, and so we have focused our research on the possibility of the specified elements and phthalates in the typically manufactured board from the factory, without paints, stains, finishes, or special treatments.

4.1 Particleboard

We searched the literature for studies that measured concentrations of the specified elements and phthalates in particleboard. The results of the literature search can be found in Appendix I. We found no potentially relevant studies measuring concentrations of the specified phthalates in particleboard. We identified 13 potentially relevant studies that reported concentrations of one or more of the specified elements in particleboard or recycled wood materials used to make particleboard and reviewed these studies. Three additional studies were identified via tree searching and reviewed. Of the studies identified, only Munson and colleagues reported concentrations of any of the specified elements in particleboard made with untreated woods (Munson, 1997; Munson and Kamdem, 1998). Another study, Wolf et al. (1990), measured concentrations of chromium and arsenic, along with other metals and contaminants, in samples of wood, lacquer, and other agents used to make particleboard, but we were not able to determine additional details including concentrations because only the abstract was available in English.

We also identified a number of United States patents for the development of adhesives for use in particleboard. A patent for a lignin composition used as a phenol-formaldehyde (PF) resin extender reported arsenic, barium, cadmium, chromium, lead, antimony, and selenium impurities (concentrations of each no greater than 0.2%) (Simard et al., 2014). These patents are not common methods and are not typically used in standard manufacture (Frazier, personal communication). Information on patents is only included here to provide an indication of new technologies or materials that might suggest future potential sources of elements or phthalates in EWPs.

Munson and colleagues (Munson, 1997; Munson and Kamdem, 1998)

Munson and colleagues (Munson, 1997; Munson and Kamdem, 1998) studied the use of recycled CCA-treated utility poles to make particleboard, primarily for structural uses. They mixed untreated (virgin) and CCA-treated red pine chips to create particles with 0, 25, 50, 75, and 100% treated wood content. The mixtures were sprayed with phenol-formaldehyde or urea-formaldehyde resin and heat pressed to form ten replicate particleboards per treatment. The particleboards were manufactured with both 4% and 8% resin solids at 2.5, 4, or 6% resin content. The particleboards were then leached in distilled water for 28 days and tested for metal content (chromium, copper, and arsenic oxides). An ASOMA x-ray fluorescence analyzer determined concentrations of chromium and arsenic (and copper) in samples (n=3 per treatment group) of the finished particleboard products. Each of the products made with CCA-treated chips (25, 50, 75, and 100%) had measured concentrations of chromium and arsenic above ASTM limits. Neither arsenic nor chromium was measured in the phenol-formaldehyde particleboard made from virgin wood chips (copper was detected). However, arsenic and chromium (along with copper) were measured at low concentrations (0.04–0.28 ppm and 0.12–0.20 ppm, respectively) in urea-formaldehyde particleboard made from virgin wood chips. The authors concluded that particleboard made with CCA-treated wood chips leached more of the elements than virgin wood chip particleboard, and that those boards with a higher resin content leached less of the elements than those with a lower resin content.

Fellin et al. (2014)

Fellin et al. (2014) conducted elemental analysis on various types of wood residues (including particleboard) from wood recycling plants. They measured concentrations above ASTM solubility limits for several elements. However, as this particleboard was from wood recycling plants, the authors noted that contamination might be due to manufacturing processes such as coating and overlaying. Results of this study are reviewed in the recycling discussion (Section 8).

In summary, we identified little information on measurements of the ASTM elements in particleboard and no studies that measured the specified phthalates. Munson and colleagues (Munson, 1997; Munson and Kamdem, 1998) tested particleboard made from both CCA-treated and untreated wood chips, and measured low concentrations (all less than 0.3 ppm) of arsenic and chromium in the particleboards made from virgin wood chips. Chromium and arsenic were detected in studies investigating particleboard made with CCA-treated wood products (*e.g.*, Munson, 1997; Munson and Kamdem, 1998) and in particleboard that was made with wood waste (Fellin et al., 2014) (discussed in Section 8). Apart from the studies of particleboard wood waste that may have had post-manufacturing treatments and studies using CCA-treated woods in manufacture, the specified phthalates and ASTM elements were not found in concentrations above their limits in particleboard.

4.2 Hardwood Plywood

We searched the literature for studies that measured concentrations of the specified elements and phthalates in hardwood plywood. The results of this search can be found in Appendix I. We found no potentially relevant studies measuring concentrations of the specified phthalates in hardwood plywood. We identified 15 potentially relevant studies that reported concentrations of one or more of the specified elements in hardwood plywood or plywood in general. Only one of these studies, Peltola et al. (2000), investigated elements in plywood made from virgin materials, but all measurements were below the ASTM solubility limits.

We also identified patents for hardwood plywood or decorative uses of plywood. One patent was identified for a binder for use in plywood that contained 1–2 parts by weight of dibutyl phthalate (Chen, 2014). A patent for a lignin composition used as a phenol-formaldehyde (PF) extender reported arsenic, barium, cadmium, chromium, lead, antimony, and selenium impurities (concentrations of each no greater than 0.2%) (Simard et al., 2014). These patents are not common methods and are not typically used in standard manufacture (Frazier, personal communication). Information on patents is only included here to provide an indication of new technologies or materials that might suggest future potential sources of elements or phthalates in EWPs.

Peltola et al. (2000)

Peltola et al. (2000) evaluated plywood (both plain and overlaid plywood) for biodegradability and examined elemental composition, leachate quality, and toxicity to photobacteria. The plain plywood was described as a veneer of birch and spruce with formaldehyde adhesive, while the overlaid plywood was plywood with a phenolic surface film overlay. The samples were first ground to dust particles 1–2 mm in size and then combusted (4 hours at 550 ± 25˚C). The elemental composition analysis was conducted on the ash using inductively coupled plasma mass spectrometry (ICP-MS). The elemental composition analysis identified 12 elements, including chromium, cadmium, and lead. The concentrations of cadmium (0.08 mg/kg), chromium (0.4 mg/kg), and lead (5.1 mg/kg) in plain plywood were all below the ASTM solubility limits. In the overlaid plywood, the concentrations of chromium (<0.3 mg/kg) and lead (3.6 mg/kg) were even lower.

Fellin et al. (2014)

Fellin et al. (2014) conducted elemental analysis on various types of wood residues (including hardwood plywood) from wood recycling plants. They measured concentrations above ASTM solubility limits for several elements. However, as this plywood was from wood recycling plants, the authors noted that contamination might be due to manufacturing processes such as coating and overlaying. Results of this study are reviewed in the recycling discussion (Section 8).

In summary, we identified only one study that measured the ASTM elements in uncontaminated hardwood plywood and no studies that measured the specified phthalates. Peltola et al. (2000) reported concentrations of several of the ASTM elements, all below the solubility limits. Apart from the study by Fellin et al. (2014) of hardwood plywood wood waste that may have had post-manufacturing treatments, the specified phthalates and ASTM elements were not found in concentrations above their limits in hardwood plywood.

4.3 Medium Density Fiberboard

We searched the literature for studies that measured concentrations of the specified elements and phthalates in medium density fiberboard (MDF). The results of this search can be found in Appendix I. We found no potentially relevant studies measuring concentrations of the specified phthalates in MDF. We identified 11 potentially relevant studies that reported concentrations of one or more of the specified elements in MDF, and three additional studies via tree searching. We reviewed each of these studies, but none of them measured any of the specified elements in MDF made from virgin materials.

We also identified a number of United States patents for the development of adhesives for use in medium density fiberboard. At least one of these included metals, specifically antimony and chromium, but the percent concentrations were not provided (Meijer and Flapper, 2013). These patents are not common methods and are not typically used in standard manufacture (Frazier, personal communication). Information on patents is only included here to provide an indication of new technologies or materials that might suggest future potential sources of elements or phthalates in EWPs.

Fellin et al., (2014)

Fellin et al. (2014) conducted elemental analysis on various types of wood residues (including MDF) from wood recycling plants. They measured concentrations above ASTM solubility limits for several elements. However, as the MDF was from wood recycling plants, the authors noted that contamination might be due manufacturing processes such as coating and overlaying. Results of this study are reviewed in the recycling discussion (Section 8).

In summary, no studies were identified that reported the presence of the specified phthalates or elements in medium density fiberboard made with virgin wood. Apart from the study by Fellin et al. (2014) of MDF wood waste that may have had post-manufacturing treatments, the specified phthalates and ASTM elements were not found in concentrations above their limits in medium density fiberboard.

5. Manufacturing of Engineered Wood Products

The basic elements for manufacturing the three types of engineered wood products are similar, with the primary difference relating to the size and shape of the wood fiber (US EPA, 2004; AHFA, 2014a,b). MDF and PB manufacture is most similar; both are particulate cellulosic products where adhesive application requires a blending process (particulates tumbling in and around an adhesive spray). Hardwood plywood manufacture is different because the plies are large sheets (veneer) that pass through an adhesive coating system.

The first step of EWP manufacture is to acquire the raw wood material: logs, veneer, wood chips, wood fiber, *etc.*, and to prepare the material for processing, including sorting and sizing. In PB and MDF, scraps and wood waste can be used for the raw wood materials as well as virgin timber; branches are not typically used. Hardwood plywood requires logs for peeling sheets of veneer. The cellulosic raw material is dried to a specific moisture content, and then adhesives, waxes, and other additives are added, typically as a percent of dry weight of the starting material. These additives are discussed only briefly here. To promote adhesive crosslinking (solidification or curing), catalysts are often added to the adhesives prior to the blending process (Conner, 1996). Fillers and extenders are used only in hardwood plywood. Various scavengers, typically urea/water solutions, can be used to reduce formaldehyde emissions when some formaldehyde-based resins are used. Sizing agents such as petroleum-derived waxes are used to provide short-term resistance to liquid water absorption (USDA, 2010). In the form of molten wax (slack wax) or wax/water emulsions, these sizing agents are commonly used in PB and MDF (not in hardwood plywood). They are typically blended at the same time as the adhesive, perhaps immediately before, during, or immediately after the adhesive, but all within the same blender.

The next stage for MDF and PB manufacture is forming, and this involves air-blowing and/or gravity-feeding adhesive/wood particles into a device that forms the particles into a mat (of uniform thickness and density) that is subsequently hot-pressed. Once loaded into the hot-press, the press plates close to a fixed opening (board thickness) and the thermosetting adhesive cures (solidifies) with hot-press temperatures ranging from about 100°C to 200°C (US EPA, 2004; Stokke et al., 2014). The dynamics of conductive heating, convective heating (steam), compaction pressure, and wood and adhesive chemistry interact to produce the characteristics inherent in the final manufactured composite. The product is cooled and further processed, including trimming, sanding, and cutting to size.

Hardwood plywood differs from PB and MDF in adhesive application, as mentioned, in that forming does not occur. Instead, after adhesive application (commonly with a roll-coater) the various plies are "laid-up," often manually, into stacks, pre-pressed (compacted without heating), and then hot-pressed as above. Cooling and various finishing steps may occur as with PB and MDF. A brief description of the manufacturing steps for each of the specified engineered wood products follows in the below sections (Stokke et al., 2014).

5.1 Particleboard

Particleboard (PB) is an adhesively-bonded wood composite, much like MDF. It is composed of particles made from virgin timber and/or wood residues (or other cellulosics) combined with adhesives, waxes, and other additives, with multiple layers formed into a mat, which is pressed into a board (US EPA, 1995a; USDA, 2010). PB comes in a range of thicknesses and size, ranging from 3/8–1¼ inches thick, 4–5 feet wide, and 8–24 feet long (Wilson, 2008b). To make particleboard, the wood particles are bonded using resins (such as urea-formaldehyde resins). PB usually consists of three to five layers; the faces are usually constructed from fine wood materials with the inner cores constructed from coarser wood materials (USDA, 2010). As specified by the name, the three layer particleboards are made with three layers glued together (USDA, 2010). PB has wide applications in furniture making and interior uses, and the typical resins applied include urea-formaldehyde, melamine-formaldehyde, or melamine-urea-formaldehyde (USDA, 2010). Some manufacturers may use phenol-formaldehyde or polymeric methylene diphenyl diisocyanate [MDI, also known as polymeric methylenebis(phenylisocyanate) (pMDI), polymeric isocyanate, polymeric MDI, or even just isocyanate] as an alternative strategy to reduce formaldehyde emissions, because these are structural resins that do not emit formaldehyde.

5.1.1 Particleboard manufacture

Particleboard is manufactured in a process similar to that used for MDF (US EPA, 1995a; USDA, 2010). The primary steps involved in manufacture of PB are described below (Wilson, 2008b; USDA, 2010; US EPA, 1995a).

- Particle preparation: wood residue storage and sorting by geometry.
- Particle classification: screening and sorting of wood residue is commonly conducted using screens where oversized particles are reduced and used in face and core layers, and undersized (fines) particles are used in the board. Reduction of oversized particles through mechanically milling the wood into uniform size with hammer mills, chippers, ring flakers, ring mills, or hogs.
- Particle drying: drying of particles to a target of about 2–8% moisture content, depending on use in the face or the core and the type of resin formulation.
- Adhesive application: blending with an adhesive/resin, wax, catalyst, and/or scavenger to form discrete droplets onto the wood particles.
- Mat formation: forming blended particles into a flat mat in 3–5 layers, with the ability to adjust moisture and resin content depending on if the layer is a face or core layer.
- Pressing: hot pressing to increase the density and reduce thickness, and for resin curing. Hot pressed panels are then air-cooled.
- Finishing: trimming, sanding, and size cutting. Trim losses can range from 0.5–8%. Sander dust and panel trim can be recycled back through the whole process.

5.1.2 Particleboard raw materials

Wood residues contribute roughly 90% of the weight of particleboard materials and include wood or planar shavings, sawdust, plywood trim, fines, and chips, and may include recycled wood (such as mill residues or waste materials) (USDA, 2010). The potential for natural wood to contain concentrations of the ASTM elements above the solubility limits was addressed under a previous report prepared for CPSC (CPSC, 2015). To evaluate the potential of the wood to contain phthalates, we investigated the potential of trees (and other plants) to take up phthalates and present these findings in Section 7.

To make particleboard, a urea-formaldehyde resin is typically used, along with a catalyst (*e.g.*, ammonium sulfate), and wax (Wilson, 2008b; Berglund and Rowell, 2005). Other resins include melamine-based adhesives that are used in applications that may have a higher exposure to moisture (Berglund and Rowell, 2005) or phenolic or isocyanate-based adhesives (USDA, 2010). Some manufacturers may use phenol-formaldehyde or methylene-diphenyl-diisocyanate (pMDI) as an alternative strategy to reduce formaldehyde emissions. The type of resin used will depend on the end-use of the product (USDA, 2010).

Secondary sources[5] and life cycle assessments (or inventories) provided information regarding types of common adhesives (Conner, 1996; Frazier, 2003; Irle et al., 2012; Rivela et al., 2006; Stark et al., 2011; Wilson, 2008b, 2009b). Information on specific formulations of adhesives used in PB manufacture was not found in the available literature; this information is typically proprietary. To supplement the general information, we searched the Internet for safety data sheets (SDSs) [formerly called material safety data sheets (MSDS)]. SDSs are prepared by manufacturers and include a list of ingredients for a product, as well as safety information. Table 1.3 in Appendix II provides more detailed information on the raw materials identified in the particleboard SDSs. We also obtained information from the Composite Panel Association (CPA) on members' use of binders, resins and other additives, as well as use of recycled sources of wood/fiber and adhesives for PB and MDF (Heroux, personal communication).

Based upon information from these sources, the following are the most commonly used resins in the manufacture of PB:

- Phenol-formaldehyde (uncommon but potential for use),
- Urea-formaldehyde,
- Melamine-urea-formaldehyde,
- Polymeric methylene-diphenyl-diisocyanate (pMDI).

Resins can be used alone or mixed with water, waxes, or catalysts to affect the final properties of the adhesive (US EPA, 1995c, 2004; Rivela et al., 2006; Saravia-Cortex et al., 2013; Stark et al., 2011; Wilson, 2008b). For example, waxes are added for waterproofing and to increase board dimensional stability (US EPA, 1995c; USDA, 2010).

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[5] Secondary sources are defined here as reference and text books, Internet resources, and government and industry reports that contain general information about engineered wood products, adhesives, raw materials, and manufacturing processes. This is in contrast to primary literature, which are the peer-reviewed and published studies generally found using systematic literature searching approaches (See Appendix I).

5.1.3 Typical ranges of the wood and non-wood components in particleboard

The USDA (2010) reports that a typical PB panel is roughly 90% wood by weight, with resin content varying from 4–10% (typical range of 6–9% for urea-formaldehyde resins). The percentage of resin can vary depending on whether it is applied to the outer or inner layers; the outer layers usually receive a higher percentage (~8–15%) than inner layers (~4–8%) (USDA, 2010; Stark et al., 2011). Wilson (2008b) reported that the wood component represents 90%, the resin 9.2%, and that lesser amounts of wax, catalyst, and scavenger make up the remainder of the board weight. Waxes were reported as ranging from 0.3–1% (Stark et al., 2011). Information obtained from the CPA (Heroux, personal communication) reported a somewhat broader range of proportions by weight for composite wood panels (but did not distinguish MDF from PB or other composite panels): wood fiber 80–97%, binder solids 2–18%, emulsified wax solids 0.11–2%, and scavengers 0.1–15%. As noted above, we used the available SDSs to identify the commonly used raw materials in PB; in some cases, the SDSs also provided percentages of raw material by weight. The SDSs for particleboard indicated the following ranges by weight (see Appendix II for details): wood: 60–100%; resins: 0–17% (with a more common application range of 5–11%); waxes: 0.3–1%; and other additives (such as scavengers or additional unspecified materials) contribute up to 2% by weight.

The potential for the primary resins and other additives used to make particleboard to contain any of the selected elements or phthalates is further discussed in Section 6.

5.2 Hardwood Plywood

Hardwood plywood is a specific type of plywood, but the manufacturing information we found generally addressed both hardwood and softwood plywood. In this section, we discuss plywood manufacture in general, but when data are specific for hardwood plywood, it is noted. Note that the terms “hardwood” and “softwood” are botanical designations for angiosperms (*e.g.,* oaks and maples) and gymnosperms (*e.g.,* pines), respectively.

Hardwood plywood is a glued wood panel made up of relatively thin layers of veneer (plies). Hardwood plywood is typically glued veneer made of hardwoods, such as oak, birch, maple, and cherry; softwood plies are from softwoods such as pine, cypress, and cedar (Schramm, 2003; US EPA, 1995a,c). The inner core of hardwood plywood can be made from any number of wood materials, including veneer only (softwood or hardwood), MDF, PB, or alternatives such as agro-fiber based boards (Schramm, 2003; Berglund and Rowell, 2005; USDA, 2010). Most hardwood plywood is made from veneer only, with less made with PB or MDF cores (US EPA, 1995a). Manufacturing of PB and MDF is covered in Sections 5.1.1 and 5.3.1, respectively. Veneer is produced from the tree log either through slicing or through rotary peeling (imagine a roll of toilet paper). Rotary peeling of logs is used to make more than 80% of veneer production (Schramm, 2003). Smaller, imperfect pieces of veneer may be “unitized” into larger sheets. Because veneer is produced from logs, recycled wood does not contribute to veneer production.

5.2.1 Hardwood plywood manufacture

The basic hardwood and softwood plywood manufacturing steps are similar (US EPA, 1995c). The primary steps involved in manufacture of hardwood plywood are described below (Wilson and Sakimoto, 2005; Schramm, 2003; US EPA, 1995c; Stokke et al., 2014; USDA, 2010; Puettmann et al., 2013):

- Debarking: debarking and bucking to remove bark from logs and to cut blocks to size for peeling.
- Conditioning: steaming the log or soaking in heated water, to soften the wood, which improves veneer production.
- Veneer peeling: spinning the log on a rotary lathe while pressing a long sharp blade against the spinning log.
- Veneer clipping: physically clipping the veneer to size and to eliminate defects.
- Veneer drying: drying of veneers to about 3–6% moisture content.
- Veneer preparation, glue application, lay up, and pressing: in these steps, veneers are coated with adhesives and stacked (“laid-up”) for pressing, typically using an alternating grain orientation. Adhesives are typically applied using roll-coaters or other devices. After panel lay-up, the package is pre-pressed (compacted without heating), which facilitates transfer into the hot-press. Once in the hot-press (100–200°C), heat and pressure cure the resin; varying hot-press times according to panel thickness.
- Panel finishing: finishing including trimming, sawing, and sanding. Finishing may include a panel cooling step for hardwood plywood, and this would occur immediately after hot-pressing.

5.2.2 Hardwood plywood raw materials

Hardwood plywood is made up of hardwood veneers and adhesives. The plies that make up hardwood plywood are made of layers of wood veneer from logs of angiosperm trees (*i.e.*, hardwoods) such as oak, birch, maple, and cherry. PB or MDF cores are sometimes used; see Sections 5.1.2 and 5.3.2 for their raw materials. The potential for natural wood to contain concentrations of the ASTM elements above the solubility limits was addressed under a previous report prepared for CPSC (CPSC, 2015). To evaluate the likelihood of the wood to contain phthalates we investigated the potential of trees (and other plants) to take up phthalates and present these findings in Section 7.

Hardwood plywood is made with nonstructural adhesives like polyvinyl acetate (PVA); but most common is urea-formaldehyde. Occasionally, melamine-formaldehyde or melamine fortified urea-formaldehyde adhesives may be used, or soybean flour-based adhesives (Berglund and Rowell, 2005; Schramm, 2003; Stokke et al., 2014; Li et al., 2010). Structural plywood is made with phenol-formaldehyde. However, other structural adhesives could be used to make structural plywood, including various isocyanate containing adhesives (US EPA, 1995c; Stokke et al., 2014).

Catalysts, extenders (*e.g.*, wheat flour), fillers (*e.g.*, ground walnut shell), and water can be added (Schramm, 2003). Typically, the resins are combined (formulated) with these extenders, fillers, and/or catalysts to create the formulated adhesive (Wilson and Sakimoto, 2005; US EPA, 1995c). The purpose of these additives includes controlling the viscosity, increasing the cure rate, and lowering the total cost of production (US EPA, 1995c).

Secondary sources and life cycle assessments (or inventories) provided information regarding types of common adhesives (Berglund and Rowell, 2005; Conner, 1996; Haupt and Sellers, 1994; Irle et al., 2012; Wilson, 2009b; Wilson and Sakimoto, 2005). Information on specific formulations of adhesives used in hardwood plywood manufacture was not found in the available literature; this information is typically proprietary. To supplement the general information, we searched the Internet for safety data sheets (SDSs). Table 1.1 in Appendix II provides more detailed information on raw materials identified in the hardwood plywood safety data sheets. In some cases, the SDSs did not clearly identify whether the product was hardwood or softwood plywood. In some cases, an SDS covered both types; therefore, the information may reflect a mix of hardwood and softwood plywood.

Based upon information from the cited sources, the following are typical resins used in the manufacture of hardwood plywood:

- Phenol-formaldehyde or phenol-resorcinol-formaldehyde (likely for use in structural plywood but potential for application to hardwood plywood),
- Urea-formaldehyde,
- Melamine-formaldehyde,
- Melamine-urea-formaldehyde,
- Polyvinyl acetate.

A relatively new adhesive that was not identified in our searching is a soybean flour-based adhesive (Soyad by Solenis), in which a proprietary petroleum-based crosslinking chemical is blended with soybean flour (Frazier, personal communication; USDA, 2010). Because it was not identified as a typical adhesive, we have not investigated it further.

5.2.3 Typical ranges of the wood and non-wood components in hardwood plywood

The USDA (2010) reports that a typical hardwood plywood panel has resin content varying from 2–10% by weight. We used the available SDSs to identify the commonly used raw materials used in hardwood plywood; in some cases, the SDSs also provided percentages of materials by weight (Appendix II): wood at 75–>99%; resins at 0.02–20% (most common applications range of 1–5%); and other additives (such as fillers) contribute <2% by weight. The potential for the adhesives, base resins, and other additives used to make hardwood plywood to contain any of the selected elements or phthalates is further discussed in Section 6.

5.3 Medium Density Fiberboard

Medium density fiberboard (MDF) is a type of adhesively bonded wood composite made from wood fibers combined with resin, wax, and other additives (Wilson, 2008a). MDF comes in a range of thicknesses, 2–100 mm, and densities, 500–900 kg/m^3 (Stokke et al., 2014). Fiberboard differs from particleboard in that fiberboard uses fibers as opposed to particles[6] and is therefore stronger than particleboard (USDA, 2010). Wood fiber used for manufacturing MDF can be sourced from low value logs, industrial wood residues (*e.g.,* chips, sanderwood, sawdust, shavings, plywood trim), lumber mill residues, scraps and trim from furniture and EWP production, or from urban wood waste (Wilson, 2008a, 2009b; US EPA, 1995c). Other wood input materials include shavings, sawdust, and plywood trim (Wilson, 2008a). While lignocellulosic fibers from wood residues are most often used for MDF, other lignocellulosic fibers used for MDF include agro-fibers and recycled wood (US EPA, 2004). See Section 8 for further discussion on MDF made from recycled materials.

5.3.1 Medium density fiberboard manufacture

MDF is primarily manufactured in a dry process, where resins are added to wood to form mats, but it can also be made in a wet process, where fibers are formed into mats using little adhesive or resin as the fibers themselves are bonded (Berglund and Rowell, 2005). Manufacturing of

[6] Fibers and particles differ in size, where fibers are smaller than particles and are essentially wood cells (USDA, 2010). Particles can be chips, shavings, or sawdust, while fibers are mechanically sheared wood chips and are closer to a pulp than a particle.

MDF includes a number of steps as described below (Wilson, 2009b; Irle et al., 2012; US EPA, 1995c; USDA, 2010):

- Particle preparation: wood residue storage, sorting, and washing or drying. Digesting by steam with pressure to soften the residues.
- Refining: with or without the use of steam (steaming is most common for MDF); pressure is used to mechanically shear the wood into individual wood fibers or fiber bundles (a fiber is a wood cell).
- Adhesive application: discharging the fibers and blending with an adhesive/resin (percent varies from 8–15 depending on grade of panel), and wax, scavenger, or other additive. Additives can also be mixed in during the drying phase. This step differs from the process for particleboard in that the blending is typically conducted prior to drying of the fibers.
- Drying: with air and heat to remove moisture to a target of about 4–9% moisture content.
- Mat formation: forming into a flat mat in one layer.
- Pressing: hot pressing to increase the density and reduce thickness, and for resin curing.
- Conditioning: the panels are loaded into large rotary racks that allow ample airflow so that the panel cools rapidly; this prevents thermal degradation of urea-formaldehyde adhesives.
- Finishing: includes trimming, sanding, size cutting, surface treatment, and embossing the surface to create a texture. Sander dust and panel trim can be recycled back through the whole process.

5.3.2 Medium density fiberboard raw materials

MDF is made from wood fibers mixed with adhesives and other additives. The wood sources for MDF are variable and include wood chips, shavings, and sawdust. The potential for natural wood to contain concentration of the ASTM elements above the solubility limits was addressed under a previous report prepared for CPSC (CPSC, 2015). To evaluate the potential of the wood to contain phthalates, we investigated the potential of trees (and other plants) to take up phthalates and present these findings in Section 7.

To make MDF, common adhesives include urea-formaldehyde, urea-, melamine-, and other formaldehyde-based hybrid adhesives, such as melamine-formaldehyde-urea-formaldehyde blends (Berglund and Rowell, 2005; USDA, 2010). The latest formaldehyde emission regulations have motivated some manufacturers to use structural adhesives like phenol-formaldehyde or polymeric methylene diphenyl diisocyanate (pMDI). In this regard, pMDI is more common than phenol-formaldehyde. Resins can be used alone or mixed with water, waxes, or catalysts to affect the final properties of the adhesive (US EPA, 1995c; Wilson, 2008a). For example, waxes are added for waterproofing and to increase board dimensional stability (US EPA, 1995c; USDA, 2010).

Secondary sources and life cycle assessments (or inventories) provided information regarding types of common adhesives (Berglund and Rowell, 2005; Conner, 1996; Irle et al., 2012; Rivela et al., 2007; Silva et al., 2013a; Stark et al., 2011; Wilson, 2008a, 2009b). Information on specific formulations of adhesives used in MDF manufacture was not found in the available literature; this information is typically proprietary. To supplement the general information, we searched the Internet for safety data sheets (SDSs). Table 1.2 in Appendix II provides more detailed information on raw materials identified in the MDF SDSs. We also obtained information from the Composite Panel Association (CPA) on members' use of binders, resins and other additives, as well as use of recycled sources of wood/fiber and adhesives (Heroux, personal communication).

Based upon information from these sources, the following are typical resins used in manufacture of MDF:

- Phenol-formaldehyde (uncommon, but potentially used for moisture resistance),
- Urea-formaldehyde (most commonly identified),
- Methylene-diphenyl-diisocyanate (pMDI),
- Melamine-formaldehyde,
- Melamine-urea-formaldehyde.

The latest formaldehyde emission regulations have motivated some manufacturers to use structural adhesives like phenol-formaldehyde or polymeric methylene diphenyl diisocyanate. Note that polymeric methylene diphenyl diisocyanate (pMDI) may be identified with a variety of names: pMDI, MDI, polymeric MDI, polymeric methylenebis(phenylisocyanate), polymeric isocyanate, isocyanate, and others. These are the same compound (CAS No. 9016-87-9). For consistency, we use the abbreviation pMDI throughout the rest of this report.

5.3.3 Typical ranges of the wood and non-wood components in MDF

Secondary sources and other reports indicate that a typical MDF panel consists of wood (89%), urea-formaldehyde resin (10%), wax (0.25–1.5%), and urea scavenger (0.2%) of total dry board weight (Wilson, 2009b; Berglund and Rowell, 2005). Other reports state concentrations of adhesives can vary from 8–15% (Irle et al., 2012) or are modeled at 10% (McDevitt and Grigsby, 2014). Waxes were additionally estimated at 0.7% (McDevitt and Grigsby, 2014). Information obtained from the CPA (Heroux, personal communication) reflects a somewhat broader range of proportions by weight for composite wood panels (but did not distinguish MDF from PB or other composite panels): wood fiber 80–97%, binder solids 2–18%, emulsified wax solids 0.11–2%, and scavengers 0.1–15%. We used the available SDSs to identify the commonly used raw materials in MDF; in some cases, the SDS also provided percentages of material by weight (see Appendix II): wood: 73–100%; resins: 0–25% (most common applications range of 5–12%); waxes: <1%; and other additives (unspecified) could contribute 10–30% by weight. The potential for the adhesives, base resins, and other additives used to make MDF to contain any of the selected elements or phthalates is further discussed in Section 6.

6. Adhesive Formulations and Concentrations of Elements and Phthalates

Wood, or wood derived material, is the largest component in an engineered wood product, representing approximately 80–99% of the weight of the finished product. The next most abundant material is the adhesive, comprising up to 25% of the final EWP by weight. Synthetic adhesives are the most highly used adhesives in EWPs (USDA, 2010), although adhesives can also be derived from carbohydrates (*e.g.,* starch, cellulose), proteins from plants (*e.g.,* soybeans), or animal-based proteins [*e.g.,* casein, bones, hides, or lignocellulose (tannins, lignins)] (Pocius, 2012). In North America, the three most common adhesive types for use in PB, MDF, and hardwood plywood are amino-, phenolic-, or isocyanate-based (Stokke et al., 2014) (Table 2). In Europe, urea-formaldehyde (UF) and melamine-urea-formaldehyde (MUF) resins are commonly used for MDF and PB (Alexandropoulos et al., 2005). Of lesser use in the European market are melamine-based resins, phenol-formaldehyde, and pMDI (Alexandropoulos et al., 2005). A number of reports of life cycle assessment (LCAs) or life cycle inventories (LCIs) for the common adhesives were identified and reviewed (*e.g.,* Wilson, 2009a,b; Silva et al., 2013b, 2015). While these provided useful information regarding common additives, manufacturing practices, energy consumption, carbon emissions, and in some cases formaldehyde emissions, they did not address our interest in concentrations of the specified phthalates and ASTM elements.

For adhesives used in EWPs, the actual formulations can be highly complex mixtures that are generally proprietary (Berglund and Rowell, 2005). Specific adhesive formulations can be highly variable among companies and even within a company as adjustments are made for humidity, temperature or changing moisture content of wood stocks (Frihart, 2005). The base resin confers the essential properties of the adhesive, which can be modified with the addition of scavengers, fillers/extenders, and waxes for specific formulations, as previously reported.

Wood adhesives are generally thermosetting organic polymers that cure under heat and pressure (Stokke et al., 2014). The process of adhesive bonding typically involves polymerization and curing (solidification) to form the bond with the surface materials (Frihart, 2005). The methods to activate polymerization can include the addition of heat, change of pH, the addition of a catalyst, or other methods (Frihart, 2005). Some resins cure into a polymer and are supplied in two parts – one part liquid resin that is combined with one part hardener to polymerize during curing (Stokke et al., 2014; Frihart, 2005). Catalysts can be added to affect the rate of polymerization. Catalysts can include ammonium chloride or ammonium sulfate to produce acids, or various metal ions including some of the ASTM elements (as reported in Appendix III) (Frihart, 2005). As noted previously, catalysts are technically expected to be chemically unchanged during the reaction. Specific product formulations with varying percentages of resins and additives are needed depending on product specifications, and so adhesives must be formulated 'just right' (*i.e.*, cannot be too viscous or too brittle for their intended end uses) (Brockman et al., 2008).

Adhesives need to 'set' or cure into a final polymerized product. Methods for curing include polymerization, oxidation, and solvent evaporation (Frihart, 2005). For PVA adhesives, curing involves the loss of solvent; for others, such as formaldehyde-containing adhesives, curing involves polymerization and loss of water; for the pMDI adhesives, setting involves polymerization (Frihart, 2005). In all of these mechanisms, there is no potential for the specified phthalates or ASTM elements to be created. The only way to introduce these compounds is through the addition into the reaction. Based on our research, we identified the adhesives and resins most commonly used in producing EWPs (see Table 2). See the below Sections (6.1–6.4) for each adhesive type and for information on the detection or measurement of the specified phthalates and ASTM elements.

Table 2. Major synthetic resins for use in EWPs.

Adhesive	Name and Base Resins
Amino Resins	Urea-formaldehyde (UF)
	Melamine-formaldehyde (MF)
	Melamine-urea-formaldehyde (MUF)
Phenolic Resins	Phenol-formaldehyde (PF)
	Resorcinol-formaldehyde (RF)
	Phenol-resorcinol-formaldehyde (PRF)
Isocyanate Resins	Polymeric isocyanate (pMDI, MDI, or isocyanate)
Other	Polyvinyl acetate (PVA)

We found mention of some additional resins and adhesives that may be in limited use or in development for future use. Soybean flour-based adhesives are mentioned as alternatives to address formaldehyde emissions. The polyurethane adhesives encompass a wide range of product applications such as coatings (Stokke et al., 2014), but they are less commonly used in wood bonding and so were not included in this report (Frihart, 2005). We also identified a number of patents for novel adhesive formulations. We did not find evidence that any of these patented processes or formulations are in common use and so did not do additional searching for information on raw materials or phthalate or element concentrations in those adhesives.

In the following sections we present information on the adhesives, how they are made, the chemicals used to prepare each adhesive (including base resins), and information from our literature search on concentrations of the specified phthalates and the ASTM elements. Because there is so much variation among formulations, we also searched for concentration information for the base resins and waxes. Details of the literature search are found in Appendix I.

6.1 Amino Resins

Amino resins are termed after the amine group (-NH_2), which is a prominent feature in urea and melamine. Amino resins are thermosetting adhesives, typically water-based, that are prepared from urea and formaldehyde (UF), melamine and formaldehyde (MF), or from melamine, urea, and formaldehyde (MUF). It is worth clarifying here that these individual compounds are referring to the actual monomers (base resins) used to make the adhesives (see Section 3.1 where these terms are defined). MDF and PB are most commonly manufactured with UF, but MUF resins may also be used. The amino resins form highly cross-linked networks, but are not classified as structural resins in North America. While all amino resins are hydrolytically unstable, MF resins are much more water resistant than UF resins. All amino resins exhibit colorless bond lines, which are visually undetectable and aesthetically preferred for many interior applications.

Below is a list of all of the potential chemicals (base resins, catalysts, *etc.*) used in preparation of these amino adhesives (Silva et al., 2013b, 2015; Wilson et al., 2009b; Conner, 1996; Stokke et al., 2014; Irle et al., 2012). Information on manufacture and potential impurities (*i.e.*, phthalates and elements) for each of these is found in Appendix III.

- Urea
- Formaldehyde (formalin, formic acid, paraformaldehyde)
- Melamine
- Boric acid

- Phosphoric acid
- Oxalic acid
- Acid salts of hexamethylenetetramine
- Polyamine hydrochloride salts
- Hydrochloric acid
- Hexamine
- Ammonium chloride
- Ammonium sulfate
- Ammonium nitrate
- Sodium hydroxide
- Methanol
- Water
- Paraffin wax

6.1.1 Urea-formaldehyde (UF)

Urea-formaldehyde resin is the highest production volume adhesive used in the wood industry, chiefly because it is very inexpensive and it cures very rapidly (Frazier, personal communication). This non-structural resin is most commonly employed for PB and MDF manufacture, but has some application in hardwood plywood. UF resin is supplied at neutral pH (~ 7.0) but curing requires acidification using acid catalysts. The most common catalysts used in the United States are ammonium chloride and ammonium sulfate (Stokke et al., 2014). In Europe, catalysts also include ammonium chloride and ammonium sulfate, with a shift towards the sulfate for environmental reasons (Alexandropoulos et al., 2005).

We did not identify any studies that reported phthalates or elements in UF resins. Several patents reported the use of barium as a catalyst in the formation of some UF resins. In one, they describe the use of barium hydroxide (5% by weight) as a catalyst during synthesis of phenolic foam resin (Geng et al., 2014). No information was provided on the potential concentrations of barium that might remain in the resin following catalysis. In theory, catalysts remain chemically unchanged during the reaction but are not removed from the reaction and therefore remain in the adhesive. Catalysts are not incorporated into the polymeric network created by the resin; but the catalyst may remain entrained within the cured adhesive. The relevance of foam resins to the specified EWPs is also unclear.

6.1.2 Melamine-formaldehyde (MF) and melamine-urea-formaldehyde (MUF)

Melamine-formaldehyde resin is substantially more expensive and significantly more water resistant than UF. Unlike UF, MF resins can tolerate limited use in high moisture or high humidity environments (*e.g.*, outdoors) (Stokke et al., 2014). This resin is made with melamine reacted with formaldehyde. As with UF resins, curing (polymerization) may be promoted using an acid catalyst such as ammonium chloride or ammonium sulfate (Stokke et al., 2014; Frihart, 2005).

Melamine-urea-formaldehyde resins may be simple blends of UF and MF, or they may be copolymers where melamine, urea, and formaldehyde are reacted all at once or in careful sequence. In either case, the intention is to improve properties relative to UF and to reduce costs relative to MF (Stokke et al., 2014).

We did not locate any studies that examined phthalate or element concentrations in MF or MUF. Our original search was for melamine as an amino-adhesive, but we did not search for the term “melamine” alone. We conducted an additional literature search for melamine to ensure no primary references were missed in our initial search (see Appendix I). No additional studies were identified, but we did not do an additional search for patents for this term.

6.2 Phenolic Resins

Phenolic resins are heavily used in EWP bonding, as they are waterproof. Due to the dark color of these resins, they are less likely to be used in EWPs with decorative purposes (Stokke et al., 2014). The two types of phenolic resins are resoles and novolacs, with resoles being more important for use in EWPs, and much less use of novolacs for wood adhesive purposes (Stokke et al., 2014). The most common phenolic resoles are phenol-formaldehyde (PF), resorcinol-formaldehyde (RF), and phenol-resorcinol-formaldehyde (PRF), all produced from the corresponding monomers. PF resoles are the most common and least expensive of the phenolic resoles. They cure by the simple application of heat. Because resorcinol is much more reactive than phenol, RF and PRF resoles cure at room temperature (cold-setting). Consequently, RF and PRF resins are two-part systems where a hardener (formaldehyde) is mixed with the base resin and curing rapidly follows. Because resorcinol is very expensive, it is common practice to substitute phenol for a portion of the resorcinol, providing PRF resins that cure at room temperature but at greatly reduced cost in comparison to RF. Aldehydes for polymerization of novolacs include formaldehyde (most common), paraformaldehyde (polymeric formaldehyde), butyraldehyde, glyoxal, and multihydroxymethylketones (Fink, 2013). Metal hydroxide catalysts can also be used and include potassium, sodium, lithium, barium, calcium, and magnesium (Fink, 2013). Each of the phenolic resoles mentioned here are described in greater detail below.

A survey of 13 United States phenol-formaldehyde production plants (representing 62% of PF production in the United States) reported that PF production included phenol and methanol, with a lesser amount of sodium hydroxide and water (Puettmann et al., 2013).

Below is a list of all of the potential chemicals used in preparation of these phenolic adhesives (Puettmann et al., 2013; Haupt and Sellers, 1994; Fink, 2013; Wilson et al., 2009a,b; Pocius, 2012; Stokke et al., 2014; Wang and Zhang, 2011). Information on manufacture and potential impurities (*i.e.*, phthalates and elements) for each of these is found in Appendix III.

- Phenol
- Formaldehyde (paraformaldehyde, formalin)
- Resorcinol
- Methanol
- Butyraldehyde
- Glyoxal
- Multihydroxymethylketones
- Magnesium oxide
- Lithium hydroxide
- Barium hydroxide, barium carbonate
- Magnesium stearate
- Sodium hydroxide
- Hydrogen chloride
- Hydrochloric acid
- Chromium
- Oxalic acid
- Hexamethylene tetramine (uncommon in resoles)
- Ortho esters (uncommon)

6.2.1 Phenol-formaldehyde (PF)

Like all phenolic resoles, PF is a waterproof resin used for structural wood products, including structural plywood, laminated veneer lumber, and OSB (USDA, 2010; Stokke et al., 2014). The dark color of this resin deters its use when visual detection of the bond line would detract from product appearance (such as interior panels and un-upholstered furniture (USDA, 2010; Stokke et al., 2014).

We located studies and patents addressing the use of barium or chromium in some phenol-formaldehyde (PF) resins. A number of patents and studies address barium hydroxide as a catalyst for synthesis of PF resins (Geng et al., 2014; Shrivastava et al., 2012; Wang and Zhang, 2011; Zhang et al., 2009a) and resoles (Bouajila et al., 2002). Only Shrivastava et al. (2012) described concentrations used: 1.68–10.13% barium hydroxide by weight. Another study indicated that barium carbonate has been added to PF resin at a rate of 30g barium carbonate to 100g PF resin to improve heat resistance (Zhang et al., 2009b). Popov et al. (1973) reported that chromium has historically been used as a catalyst in PF resin foams, but concentration information was not provided. We did not find information in our literature or SDS searching to indicate that these catalysts are commonly used.

6.2.2 Resorcinol-based (RF, PRF)

Like all phenolic resins, RF and PRF are waterproof, and have a reddish-brown or black coloration (Stokke et al., 2014). Unlike PF, resorcinol resins are cold-setting (room temperature cure); they are two-part systems that begin curing once the hardener (more formaldehyde) is added. They are typically used for complex assemblies that are not amenable to flat-panel pressing, or for difficult-to-bond products, such as preservative treated woods (Stokke et al., 2014). Resorcinol is much more expensive than phenol, and so expense is reduced by copolymerizing resorcinol, phenol, and formaldehyde (*i.e.,* PRF) in carefully tailored sequences that provide resorcinol end groups that impart rapid reactivity as in RF.

We did not locate any studies on the specified phthalates or ASTM elements in resorcinol-based resins, including phenol-resorcinol-formaldehyde (PRF) resin or resorcinol-formaldehyde (RF) resin.

6.3 Other Resins

6.3.1 Polymeric methylene diphenyl diisocyanate resins (pMDI)

Polymeric methylene diphenyl diisocyanate resins (pMDI) are used principally in the manufacture of rigid insulation foams, which ultimately led to their use as structural resins in wood-based composites (Frazier, 2003). As suggested previously, pMDI suffers from a proliferation of names and identifying acronyms that are often technically incorrect, but firmly entrenched in the industry. One reason for this problem is that pMDI resins do not follow the typical naming convention. For instance, the base resin phenol-formaldehyde is named according to the monomers used to synthesize that resin, phenol and formaldehyde. That is not the case with pMDI where instead names and acronyms attempt to describe the resin structure; and like most resins, the structure is too complex to name simply and correctly. Identified as CAS no.

9016-87-9, this resin called polymeric methylene diphenyl diisocyanate resin, polymethylene polyphenyl isocyanate resin, and also polymeric methylenebis(phenylisocyanate) resin. Other popular names include polymeric isocyanate, or simply, isocyanate. Correct acronyms are pMDI or PMDI; but technically incorrect and popularly misused is the acronym MDI. To make matters worse, pMDI contains a mixture of monomers and oligomers and the monomeric portion is correctly described by the acronym MDI, which stands for methylene diphenyl diisocyanate. The monomeric portion of pMDI contains three isomers, trace quantities of 2,2'-MDI, up to 5% of 2.4'-MDI, and ~95% 4,4'-MDI (Frazier, 2003). Twitchett (1974) reported that pMDI is synthesized from formaldehyde and aniline under aqueous acidic conditions and the resulting polyamine is converted to the final isocyanate by reaction with phosgene. Aspects of pMDI quality include acidic and chlorine containing impurities as related to the efficiency of the phosgenation (Twitchett, 1974), but these impurities are unrelated to the phthalates and chemical elements of concern in this report (Frazier, personal communication).

The pMDI resins are unusual because they are among the few wood bonding resins that are water insoluble. When formaldehyde-free resins are desired, pMDI is sometimes used to make PB and MDF (pMDI is synthesized from formaldehyde; but the final resin is free of formaldehyde). Consequently, PB and MDF manufactured with pMDI could have surface contamination with release agents (which are simple fatty acid salts, waxes, or silicones) (Frazier, 2003). Occasionally, but very uncommon in wood composite manufacture, pMDI resins can be formulated with amine catalysts such as 4,4'-(oxydi-2,1-ethanediyl)bismorpholine (DMDEE).

Below is a list of all of the potential chemicals used in preparation of pMDI (Stokke et al., 2014; Frazier, 2003):

- Phosgene
- Hydrochloric acid
- Formaldehyde
- Aniline
- Antimony trioxide
- 4,4'- methylene diisocyanates
- 2,4'- methylene diisocyanates
- 2,2' - methylene diisocyanates
- 4,4'- (oxydi-2,1-ethanediyl)bismorpholine
- Methylene diphenyl di(phenylcarbamate)

We identified one study regarding the use of antimony as a catalyst in the formation of pMDI. pMDI was prepared using thermal decomposition of methylene diphenyl di(phenylcarbamate) (MDPC) with an antimony trioxide (Sb_20_3) catalyst, but no concentrations were given (Wang et al., 2013). It is not clear how common this methodology is in current manufacturing procedures.

6.3.2 Polyvinyl acetate (PVA)

Polyvinyl acetate (PVA) is commonly used as ‘household glues’ and currently has little application in EWPs (Stokke et al., 2014). However, interest in these resins to replace formaldehyde-releasing resins has led to increased interest for EWP applications (Stokke et al., 2014). None of the SDSs for the three types of EWPs identified use of PVA, however a number of secondary sources note use of PVA in hardwood plywood. Polyvinyl acetate is manufactured through emulsion polymerization of vinyl acetate in water using poly(vinyl alcohol) emulsifiers (Frihart, 2005). However, the most common PVA resins used for wood bonding are so-called “crosslinking PVAs,” which are copolymers of vinyl acetate and N-methylolacrylamide (NMA). When PVA resins are used to make hardwood plywood, crosslinking PVAs are the probable version and these are acid catalyzed, typically with aluminum chloride. The aluminum chloride catalyst may be internal to the resin, or it may be added just prior to adhesive application.

Below is a list of all of the potential chemicals used in preparation of PVA (Frihart, 2005; Stokke et al., 2014; Cameron et al., 1987; Feng et al., 2002):

- Vinyl acetate
- Poly(vinyl alcohol)
- N-methylolacrylamide
- Aluminum chloride
- Aluminum nitrate
- Glyoxal
- Formaldehyde
- Potential phthalates: dibutyl phthalate (DBP), diethyl phthalate, dimethyl phthalate, di(2-ethylhexyl)phthalate (DEHP)

Cameron et al. (1987) noted that PVA can be plasticized with dibutyl, diethyl, and dimethyl phthalate and Stokke et al. (2014) reported the use of DBP. Feng et al. (2002) reported that DEHP is used in the manufacturing of PVA. USDA (2010) suggested that phthalates (such as DBP) are used in PVA manufacture to plasticize the adhesive polymers. Our literature search revealed no information on concentrations of phthalates in PVA and there was no indication in the literature that this is a standard manufacturing procedure. The literature search did not identify any reports of the ASTM elements in PVA resins used for manufacturing engineered wood products. Matoso and Cadore (2008, 2011) tested commercially available PVA-based glues (glue brands or names not specified), for some of the ASTM elements.

Matoso and Cadore (2008, 2011)

Matoso and Cadore (2008) tested three different PVA-based glues. Samples were prepared with a closed vessel microwave digestion procedure and analyzed for arsenic, cadmium, chromium, mercury, lead, and antimony (along with other elements not covered by this report) using an inductively coupled plasma optical emission spectrometer (ICP-OES). The level of each analyte was lower than its limit of quantification (LOQ), except for iron (concentration not reported). Matoso and Cadore (2011) tested seven different commercially available PVA-based glues. Samples were prepared with a closed vessel microwave digestion procedure and analyzed for arsenic, barium, cadmium, chromium, mercury, and lead contamination (along with other elements not specified by CPSC) using ICP-OES. Chromium was detected at 0.3 mg/kg (0.3 ppm) in one of the glue types. All other measurements for arsenic, chromium, barium, cadmium, mercury, and lead were below their LOQ. There are many types of commercially available PVA glues and it is not known whether the glues tested in these studies are similar to those used in EWP production.

6.4 Additives and Raw Materials Used in Adhesives

Depending upon the type of resin and product, scavengers, fillers/extenders, and/or waxes may be used in the adhesive formulation. The manufacturing of the additives was reviewed to assess if there was potential for any of the specified substances to be raw materials or somehow to be created in the manufacturing process. General information on manufacture and potential impurities for each of these products is described in Appendix III, as the information was available from authoritative sources, starting with the Hazardous Substances Data Bank (HSDB) and supplemented from the World Health Organization (WHO) or the Food and Agriculture Organization (FAO). In the case where there was no information available in the HSDB search, and additional investigation through WHO or FAO was unfruitful, we noted as such but did not do additional targeted gap searching due to resource limitations. SDS searching in this case was not helpful as the specifications (impurities) are not available for technical grade products. This is likely because they are not set to certain purity standards as would be done for analytical grades. In addition, the nature of the proprietary adhesive formulations made it difficult to determine the exact additives currently in use in standard manufacturing.

6.4.1 Scavengers

Scavengers, as discussed previously, are agents added to EWPs to reduce the formaldehyde emission when formaldehyde-based adhesives are used. They do this by binding to the resin and thereby reducing formaldehyde release (HBN, 2008). Common scavengers include sodium sulfite melamine, hexamine, anhydrous ammonia or ammonium compounds, and dicyandiamide, as well as some naturally occurring compounds such as tannins (Fink, 2013; HBN, 2008; US EPA, 2002; Que et al., 2007). Some sources (Wilson, 2008a,b) list urea as a scavenger, but it is unclear how the addition of urea as a scavenger differs from urea used as a monomer in the base resin. Information on manufacture and potential impurities (*i.e.*, phthalates and ASTM elements) for each of these common scavengers is found in Appendix III.

- Urea (considered a scavenger by some)
- Sodium sulfite melamine
- Hexamine
- Anhydrous ammonia or ammonium compounds
- Dicyandiamide
- Tannins

6.4.2 Waxes

Wax is one of the most common additives to EWPs. Waxes are added to control water absorption and thickness swell and to add dimensional stability to MDF and PB (USDA, 2010). The waxes are a mixture of petroleum hydrocarbons (paraffins) and are used to lower the absorption of liquid water into the wood composites (US EPA, 2002). Paraffin wax, petroleum slack wax, and emulsified slack wax are commonly used and are essentially the same, other than that paraffin wax is a more refined slack wax (CONCAWE, 1999). Waxes are obtained as a by-product of refining lubricating oil (CONCAWE, 1999). Slack wax is the first by-product removed by filtering the distillate fractions of lubricating oil in a selected solvent (*i.e.*, toluene or methyl ethyl ketone) (CONCAWE, 1999). Slack wax is a waxy oil consisting mostly of paraffinic hydrocarbons (C12–C85) and very few alkylated aromatic hydrocarbons (CONCAWE, 1999). Slack wax is further refined by solvent crystallization, clay treating, and odor removal to create petroleum or paraffin wax (CONCAWE, 1999). Paraffin wax has a crystalline structure and consists of normal alkanes with very few alkylated aromatic hydrocarbons (CONCAWE, 1999).

Because these waxes were known to be common across the specified EWPs and we were able to find specific information on the types used, a full literature search was conducted to identify information related to the concentration of the ASTM elements of specified phthalates in waxes (see Appendix I). The literature search revealed no information regarding possible concentrations of phthalates in waxes, nor did we find any information on ASTM element concentrations in waxes used in the manufacturing engineered wood products. Note that we did not search for patents for waxes or wax additives.

6.4.3 Fillers/Extenders

As described previously, fillers (and extenders) are added to reduce cost and modify the flow properties of a base resin. Fillers in the wood composites industry are lignocellulosic, and typically derived from biomass waste streams such as almond shell, walnut shell, red alder bark, and corn cob residue from furfural production. Wheat flour is occasionally mentioned as a filler, but it is more accurately described as an extender, because unlike fillers, wheat flour possesses some intrinsic adhesive quality; it is sticky when wet. However, most of the fillers identified are cellulosic in nature, such as walnut shell flour, wheat flour (Frihart, 2005), and organic fiber material (Fink, 2013). These fillers and extenders are mostly all cellulosic and those were not discussed further in this report. The non-cellulosic fillers covered in Appendix III include:

- Maleic anhydride-modified poly(propylene)
- Furan oligomers
- Barium carbonate

In the resins and additives, many of the ASTM elements (chromium, arsenic, antimony, barium, mercury, selenium) and lead were identified in processes used in the manufacture (mainly as catalysts) or as potential impurities in the final products (see Appendix III). Cadmium was not identified as a constituent of the adhesive manufacturing processes or as a potential impurity. No information on concentrations exceeding the ASTM elements (or lead) were found, but very few sources reported information on concentrations at all. Because these elements are mainly used as catalysts, they are expected to be chemically unchanged during the reaction. However, during manufacture the catalysts are not removed from the reaction and therefore remain in the adhesive. Catalysts are not incorporated into the polymeric network created by the resin; but the catalyst may remain entrained within the cured resin. In contrast, the specified phthalates, other than dibutyl phthalate (DBP), diethyl phthalate, dimethyl phthalate, and di(2-ethylhexyl)phthalate (DEHP) as mentioned in Section 6.3.2, were not identified in processes used in adhesive manufacture, manufacturing processes, or as potential impurities in the final products.

7. Potential for Uptake of Phthalates into Cellulosics

Particleboard (PB) is composed of particles made from virgin timber and/or wood residues (or other cellulosics). Wood residues include wood or planar shavings, sawdust, plywood trim, fines, and chips, and may include recycled wood (such as mill residues or waste materials) (USDA, 2010). Hardwood plywood is made up of relatively thin layers of veneer (plies), typically made of hardwoods, such as oak, birch, maple, and cherry (Schramm, 2003; US EPA, 1995c). Wood fiber used for manufacturing MDF can be sourced from low value logs, industrial wood residues (*e.g.,* chips, sanderwood, sawdust, shavings, plywood trim), lumber mill residues, or scraps and trim from furniture and EWP production (Wilson, 2008a, 2009b; US EPA, 1995c). While lignocellulosic fibers from wood residues are most often used for MDF, other lignocellulosic fibers used for MDF include agro-fibers and recycled wood (US EPA, 2004).

This report focused on the use of virgin wood and wood residues as a source of cellulosic fiber, as this is the primary source of wood and fiber for EWPs in North America, and we did not investigate other potential cellulosic sources such as agro-fibers. However, data investigating the potential for phthalate uptake in trees was scarce, and so data investigating the potential for phthalate uptake in other plants was reported. It is possible that a number of these non-wood plants could be used in EWP production as agro-fibers, or that uptake into non-tree plants provides evidence for a potential mechanism for uptake into trees. Additionally, the use of recycled wood in EWPs is discussed in detail in Section 8.

7.1 Mechanisms for ASTM Element Uptake in Plants

In a previous task with CPSC, TERA reported on concentrations of the seven ASTM elements in natural wood and addressed plant uptake of elements. This section builds upon that work in that we are investigating the potential for phthalate uptake into wood.

The ASTM elements are ubiquitous in the environment, and plants have the ability to uptake them from environmental media and in some cases to sequester and accumulate them. Typical elemental uptake occurs from the water and soil, with less uptake occurring in the foliage from atmospheric deposition (Suter, 2007). Uptake into plants begins with the transfer of the particle into the root tissues (and occasionally the leaf tissues). Once inside the roots, elements can be sequestered and stored there, or can be transferred (translocated) from the roots into aerial plant tissues, such as stems, trunks, shoots, branches, leaves, and flowers. Accumulation mechanisms are generally plant species and element specific.

In order for uptake to occur, the element must also be bioavailable. Bioavailability of elements in soils is dependent upon a number of factors, such as clay content, organic matter content, pH, cation-exchange capacity, soil and element particle size, salinity, partition coefficients, element solubility and speciation, particle affinity to be bound to soil particles, and others (Suter, 2007; Shaw, 1989; Terry et al., 2000). Overall, environment-specific characteristics play a large part in the bioavailability of the ASTM elements.

Plant uptake is highly variable, and uptake factors (the ratio of concentration of element in plant to the concentration of the element in soil) have been shown to vary significantly (Suter, 2007). Traits of the plant itself can impact its ability to take up and accumulate elements – factors such as plant age, taxonomy, growth stage, root depth, plant genotype and tolerance, and nutrition status (Suter, 2007; Shaw, 1989).

In total, many factors can influence element bioavailability from environmental media, and the ability for plant uptake, the potential for translocation inside the plant, and the ability of a plant to sequester the element. It is likely that many of these mechanisms are applicable to the accumulation of phthalates in other plants and trees as well.

7.2 ATSM Element Concentrations in Trees and Plants

The potential for natural wood to contain concentrations of the ASTM elements (all but lead, which was addressed by CPSC previously) above the solubility limits was addressed under a previous report prepared for CPSC (CPSC, 2015). That report found measurements of the ASTM elements in wood, trees, and other plants.

- Wood – Very few studies were found that measured concentrations of the ASTM elements in wood, tree trunks, or tree rings. None of the measurements were above the solubility limits.
- Trees – Many studies identified and measured the ASTM elements in tree parts other than the trunk. All seven elements were detected in one or more other parts of trees (*e.g.*, roots, shoots, leaves). Evidence was found of concentrations exceeding the solubility limits for all the elements (except barium) in some tree part(s) other than the trunks.

The results of our previous research indicate that there is potential for one or more of the seven ASTM elements to be taken up and be present in plants. A critical question is whether it is plausible that an element could accumulate to levels above the solubility limit.

7.3 Phthalate Concentrations in Plants

The potential for natural wood and trees to contain concentrations of the specified phthalates was investigated. We first sought information on concentrations of the specified phthalates in trees. This search was supplemented with additional searching for information on the potential for uptake of phthalates into plants. We started with a search of PubMed, which identified some data on the potential for phthalate uptake and concentrations in plants but no data on phthalate uptake and concentration specifically in trees. Additional gap searching was conducted using Web of Science and Scopus databases to look for studies on uptake and concentration of phthalates in trees; only one study in trees was uncovered (Wang and Fan, 2014). Details of the literature search strategy and hits are found in Appendix I.

Our search strategy was not intended to identify all available data on phthalate uptake in plants, rather it was meant to see if there is any evidence that phthalates can be taken up by plants and if so, capture the concentrations of phthalates reported. Below we briefly report uptake, concentrations, and translocation factors from those studies we found that reported concentrations of phthalates in trees or plants. Searching of additional databases (*e.g.*, CAB abstracts) may uncover more studies, but we think that what we have located provides general support that phthalates are bioavailable for uptake into plants (and therefore potentially in trees), but that the level of uptake of phthalates is not likely to be above the specified content limit (1000 ppm).

7.3.1 Phthalate uptake in trees

Wang and Fan (2014) measured phthalate levels in the air, soil, and pine needles of Masson pines growing in Nanjing, China and demonstrate that pine needles readily absorb airborne phthalates through their waxy surfaces. Mean concentrations (dry weight) were reported for DBP (0.0903 ± 0.0059 mg/kg), BBP (0.0574 ± 0.0213 mg/kg), and DEHP (0.0193 ± 0.0015 mg/kg). Note that this study provides evidence of phthalate being taken up by trees, but pine needles would not be used as a cellulosic in making the specified EWPs.

7.3.2 Phthalate uptake in plants

With limited data on concentrations of phthalates in trees, we sought information on the potential for plants in general to accumulate phthalates. Sixty-one potentially relevant studies were identified from the PubMed database related to phthalate uptake and concentration in plants. Tree searching identified five additional studies. Twenty-three studies were reviewed in detail. Fourteen studies reported measurements of one or more of the specified phthalates as reported below. Most of the studies centered on phthalate uptake into vegetables and crops and the potential for human exposure from consuming these as food. A few studies investigated the use of plants for phytoremediation of phthalate contamination in the environment. The majority of the studies focused on concentrations of DEHP only.

In a review paper, Staples et al. (1997) investigated the environmental fate of phthalate esters. This paper included a literature review and discussion of terrestrial accumulation, including bioaccumulation in plants. Table 3 reports concentrations and bioaccumulation factors reported in Staples et al. (1997). In general, the authors report that the data suggest that phthalates are taken up into plant species at negligible concentrations.

Table 3. Data reported in Staples et al. (1997) on the concentration and bioaccumulation factors of specific phthalates in plants.

Phthalate	Plant	Plant to soil bioaccumulation factors	Concentration in plant	Reference (all as cited in Staples et al., 1997)
DBP	Corn	<0.002	-	Shea et al., 1982
DBP, DEHP	Barley	-	0.116 mg/kg DBP; 0.530 mg/kg DEHP	Kirchmann and Tengsved, 1991
DBP, DnOP, DEHP	Corn, soybean, wheat, fescue	From <0.001-1; (mostly <0.1)	-	Overcash et al., 1986
DEHP	Lettuce, carrot, chili peppers, tall fescue	-	Not detected	Aranda et al., 1989
DEHP	Barley, potatoes	-	Not detected	Schmitzer et al., 1988

DBP-dibutyl phthalate, DEHP-di-(2-ethylhexl) phthalate, DnOP-di-n-octyl phthalate

We located a number of additional studies that were not cited in Staples et al. (1997). These studies involved a variety of experimental growing conditions and phthalate contamination or exposure levels. For the purposes of this section, we focused on the measured concentrations and translocation factors. Reported measurement of phthalates in the plants used in these studies were all far below 1000 ppm.

Cai et al. (2015)

Cai et al. (2015) investigated DEHP uptake from contaminated soils into various rice cultivars at four different growth stages. None of the reported concentrations of DEHP in various parts of the plants were greater 1000 ppm. Concentrations in roots from normal or hybrid rice plants ranged from 0.26–11.8 mg/kg (dry weight). Concentrations in shoots from normal or hybrid rice plants ranged from 0.40–7.58 mg/kg. During the ripening phase of growth, concentrations of DEHP ranged from 0.12–13.2 mg/kg, with the highest concentrations and variations observed in the stem tissue. The highest reported translocation factors (ratios of DEHP concentration in stems to roots, leaves to stems, or grains to shoots) for normal and hybrid cultivars were 14.55±1.40 from root to stem, 4.67±0.42 from stem to leaf, and 3.73±4.80 from shoot to grain.

Li et al. (2014)

Li et al. (2014) investigated the potential for phytoremediation of phthalate contamination in the environment using pot greenhouse experiments (in eight corn cultivars, alfalfa, ryegrass, and teosinte) with DEHP spiked soil. Concentrations in plant shoots ranged from 0.87–2.46 mg/kg and roots from 0.53–1.86 mg/kg. Translocation factors varied from 0.63–2.31. These authors also calculated maximum shoot concentration factors of 0.094±0.010 (ratio of shoot concentration to soil) and maximum root concentration factors of 0.074±0.004 (ratio of root concentration to soil). The authors reported that these were low values and that uptake and translocation of DEHP from the soil was limited, potentially due to the hydrophobicity of DEHP and the tendency to sorb to soil in the environment.

Fu and Du (2011)

Fu and Du (2011) conducted field studies on the potential for DEHP uptake in potherb mustard, bok choy, celery, spinach, cabbage, leaf of tube, lettuce, garlic, and edible amaranth from use of plastic mulch film used in greenhouses. Concentrations in the edible parts of these plants (from all tested material films, experimental variation of greenhouse height, and use of different aged films) ranged from non-detect to the highest measurement of 36.16±3.13 mg/kg, well below 1000 ppm.

Sun et al. (2015)

Sun et al. (2015) grew lettuce, strawberry, and carrot plants in sand spiked with DEHP for 28-days. The mean concentrations of DEHP ranged from 0.654–1.371 mg/kg (dry weight) in the leaves and roots of all three types of plants.

Several other studies measured DEHP in plants grown in various conditions and either reported no detection of DEHP or concentrations far below the 1000 ppm limit (Gron et al., 2001, as cited in Laturnus et al., 2007; Petersen et al., 2003, as cited in Laturnus et al., 2007; Yin et al., 2003). Other authors report that uptake of DEHP by plants is low when grown in contaminated soil (Kato et al., 1980; Schmitzer et al., 1988; Aranda et al., 1989, as cited in Yin et al., 2003; Sun et al., 2015; Yin et al., 2003).

Cai et al. (2008)

The accumulation of DBP from soil to plant was investigated using five different genotypic (Taiwan filiform-leaf, white-skin filiform-leaf, ensiform green I., Hong Kong white-skin, local white-skin) cultivars of water spinach (Cai et al., 2008). Water spinach has been shown to accumulate significantly higher amounts of metals (*e.g.*, cadmium, copper, and lead) and varying levels of phthalates when used for phytoremediation (Kashem and Singh, 2002; Gothberg et al., 2004; Cai et al., 2003a,b, 2006, as cited in Cai et al., 2008). The maximum accumulated DBP was reported in the ensiform green I cultivar at 16.6 mg/kg. The concentration of accumulated DBP was proportional to the DBP soil concentration with greater concentrations in the shoots for the higher soil concentration groups.

Ma et al. (2013)

Ma et al. (2013) studied the phytoremediation ability of perennial rye grass, tall fescue, and alfalfa alone and in combination for phthalates (including BBP, DEHP, DnOP) using four replicate plots adjacent to a popular e-waste recycling site in China. The shoots of plants were harvested and sampled after two years of growth. Concentrations (dried weight) ranged from approximately 0.9–1.8 mg/kg for BBP, 2.2–4.4 mg/kg for DEHP, and 2.4–4.8 mg/kg for DnOP.

Mo et al. (2009)

Vegetables were sampled for phthalates in the Pearl River Delta region of China (Mo et al., 2009). Eighteen different vegetable varieties were collected from nine different farms. Concentrations (dried weight) ranged from not detected to 9.7 mg/kg for BBP, not detected to 9.3 mg/kg for DEHP, and not detected to 0.47 mg/kg for DnOP.

Wang et al. (2015)

Vegetables and soil from 44 plastic greenhouses in Nanjing City, China were sampled for DEHP, BBP, and DnOP concentrations (Wang et al., 2015). The vegetable species sampled were capsicum, cucumber, Chinese cabbage, radish, green cabbage, lettuce, crown daisy chrysanthemum, celery, spinach, and potherb mustard; each was grown in soil with a plastic mulch film covering the soil surface. Concentrations (dried weight) for vegetables ranged from the level of detection (LOD) to 0.09 mg/kg with a mean of 0.02±0.02 mg/kg for BBP, 0.12–5.82 mg/kg with a mean of 1.37±1.28 mg/kg for DEHP, and LOD–1.37 mg/kg with a mean of 0.31±0.35 mg/kg for DnOP.

Our limited searching identified only one study measuring phthalates in trees, but many more that investigated phthalate uptake by various plants and reported concentrations below 1000 ppm. In the studies we reviewed, the highest reported concentration in any plant was roughly 36 mg/kg.

8. Potential Use of Recycled Materials in EWPs

Production of wood-based panels is increasing and the demand for these products is projected to grow at an average annual rate of 2.7% (UNECE/FAO, 2005, as cited by Saravia-Cortez et al., 2013). There is growing interest and research in using recycled and recovered woods and fibers for engineered wood products to divert wood waste from landfills and reduce natural wood resource consumption (IFC, 2007, as cited in Saravia-Cortez et al., 2013). Research is being conducted to develop products that not only use recycled materials but also can be recycled (USDA, 2010).

8.1 Use of Wood Waste in EWP Production

As discussed above, the primary source of wood and wood fiber for manufacture of particleboard, medium density fiberboard, and hardwood plywood is virgin timber, as well as chips, sanderwood, sawdust, shavings, plywood trim, lumber mill residues, MDF fiber and veneer chips, and scraps and trim from furniture and EWP production (US EPA, 1995c; Heroux, personal communication). Manufacturers of EWPs routinely use pre-consumer and post-industrial recovered wood, including cuttings, scraps, and rejected boards in creation of new product (Varga et al., 2004; Howe et al., 2013). Howe et al. (2013) reports that pre-consumer wood waste has been virtually eliminated in Canada and the United States. The recycling of wood is challenged by issues that are specific to the different kinds of woods to be recycled. Virgin wood, sawn lumber, and post-construction lumber residue can be easily recycled by mechanical means and are excellent feedstocks for engineered woods (USDA, 2002). These pre-consumer and post-industrial recycled inputs are the “raw” materials described in the manufacturing process (see Section 5) and do not introduce any new potential for contamination with the specified elements or phthalates.

Use of materials with recycled content is encouraged and rewarded by many green building and other sustainable and eco-friendly certification programs. Wood products such as medium and high density fiberboard and standard particleboard can readily satisfy requirements through the common use of trim and in-house residues (Howe et al., 2013). The use of recycled materials in production is a trend around the world. For example, the company producing over 90% of Chile's particleboard is producing boards only from industrial by-products to comply with ISO 14001 (Garay, 2012). Nicewicz et al. (2012) reports that approximately 40% of the raw material for fiberboard production in Poland is from wood wastes, including in-house waste, that from sawmills, and from the plywood industry.

A search of the Internet readily identified the availability and promotion of "green" particleboard and medium density fiberboard products made from recycled, recovered, or post-consumer fiber content (*e.g.*, CPA, 2012; Roseburg, 2016; Arauco, 2016; SierraPine, 2016; Collins Pine, 2016) in North America. Manufacturers seek and advertise their green and sustainability certifications to demonstrate that their products meet green standards and goals. Product manufacturers advertise the recycled content of their products; for example, in furniture made with particleboard (Maxon, 2016; NuCraft, 2016). In North America, the Composite Panel Association (CPA) certifies wood or agro-fiber based particleboard, medium density fiberboard, hardboard, engineered wood siding, and engineered wood trim under the Eco-Certified™ Composite (ECC) Sustainability Standard (CPA, 2016). One of the requirements is the use of at least a minimum amount of recycled or recovered fiber. Twenty-four companies are listed as having products certified under the ECC standard (CPA, 2016).

8.2 Post-Consumer Wood Waste

There is also a growing demand for use of post-consumer wood waste, driven by consumer demand and regulatory limits on sending wood waste to landfills. Post-consumer woods are materials that are recovered from their original use and subsequently used for production of EWPs (Bosch et al., 2015). They include recycled cardboard and paper, demolition wood, packaging materials such as pallets and crates, used wood from landscape care (*i.e.*, from urban and highway trees, hedges, and gardens), discarded furniture, and waste wood from industrial, construction, and commercial activities (Bosch et al., 2015; Stark et al., 2011; Howe et al., 2013; US EPA, 2004; Rainier Wood Recyclers, 2006). Howe et al. (2013) reports an annual estimate of 70 million tons of post-consumer wood waste from municipal solid waste, and construction and demolition wood debris in the United States. Hafner et al. (2014) notes that the demand for reclaimed wood products in the building sector will rise in the European Union because the preferred option is reuse and recycling of reclaimed wood.

Wood pallets and shipping containers are a frequent source of reclaimed wood that is generally considered “clean” for recycling. The pallets and containers are ground or chipped to make MDF and particleboard, and to replace or supplement standard pulp (Bush et al., 1996; Nicewicz et al., 2012). Other wood products from deconstructed structures or furniture (many are made from engineered wood) that have outlived their usefulness can also be used as raw material for EWPs (Araman et al., 1998, as cited in MI DEQ, 2007; Lykidis and Grigoriou, 2008; Bosch et al., 2015).

While many manufacturers of MDF and PB routinely incorporate a significant percentage of post-industrial wood waste from their own and other manufacturing, the amount and use of post-consumer recycled fiber is minimal among composite wood producers in the United States (Heroux, personal communication). We were not able to locate information to quantify the prevalence of post-consumer wood materials being used to make engineered woods, but we found several examples of companies who are using post-consumer wood waste to make engineered wood products. For example, Arauco North America lists the percent of recycled content in its domestically produced composite panels and differentiates between recovered and pre- and post-consumer raw materials (Arauco, 2015). The percentage of raw material that is post-consumer ranges from 0–4.61%.

We found mention of other EWP manufacturers with a greater percentage of post-consumer waste wood usage. The US EPA (1995a) discusses a case study of a manufacturer in Oregon that uses wood chips from pallets, shakes, and utility spools to make hardboard. The US EPA report (US EPA, 1995b) indicated that the company’s hardboard product contained 48% urban wood waste, 45% plywood-trim, and 5% virgin wood chips, and noted that the company’s goal was to use 100% urban wood waste. More recently, the company reported using 40,000 tons per year of waste wood that previously was disposed of in landfills or burned (ODEQ, 2016).

8.3 Challenges of Using Post-Consumer Wood Waste

With the increased interest and use of post-consumer recycled materials in EWP production comes the need to address potential contamination in the recycled feedstock, including contamination by the specified elements and phthalates that are the subject of this report. Reclaimed lumber and wood waste may contain various types of contaminants such as surface treatments (*e.g.*, paints, stains), metals, glues and adhesives, glass, paper, plastic, rubber and chemical treatments (Ijeh, 2015). Metals and organics may be present in paints, stains, varnishes, and polishes that are used on wood products (*e.g.*, furniture, window frames) and nails, screws, and other metal hardware might be attached to the recycled and recovered wood (Rowell, 2011;

Jeffrey, 2011; Bradley, 2014). These contaminants are intimately attached to the wood and therefore some contaminants may pass through cleaning systems. When the wood is then chipped or shredded, these materials can contaminate the entire recovered wood stream (Rowell 2011).

Production of EWPs requires careful control of the fiber properties and formulas of resins and other additives to produce consistent quality and meet industry and customer standards. The use of homogenous raw materials produces particleboard with desired qualities of good strength, smooth surfaces, and equal swelling (USDA, 2010). The impact of contaminants, such as paints, needs to be considered with regard to the effect on final product quality (Colak et al., 2011). Just like any fiber source for EWPs, the physical and chemical properties of the recycled sources of fiber must be well-understood to be successful. Using recycled materials for production of EWPs requires testing and quality control to get the ratio of recycled to virgin timber inputs right, as well as to meet product specifications (Saravia-Cortez et al., 2013).

Large quantities of lumber treated with chromated copper arsenate (CCA), creosote, or pentachlorophenol to resist rot and insects are disposed of each year. In the United States, these treated woods are classified as hazardous waste. The presence of arsenic and chromium in CCA-treated woods (as well as creosote and pentachlorophenol treated woods) represents a significant challenge in safely recycling these woods (WRAP, 2016).

8.3.1 Levels of ASTM elements in recycled wood waste

In a study to evaluate the "recyclability" of used wood, Fellin et al. (2014) conducted elemental analysis of wood residues from wood recycling plants using a handheld fast ED-XRF device. This study, while primarily based in Italy, provides some indication of types and levels of contamination in various types of wood waste. In this study, 336 wood specimens were collected from Italian recycling centers (n=268), wood enterprises (n=39), and an on-site field sample (n=1), along with research centers in Canada (n=27) [authors indicated that there were 336 specimens, but individual numbers reported by authors add up to only 335]. Metal hardware pieces were manually removed from the wood samples and then an ED-XRF detector analyzed the wood samples for chlorine and the following elements: antimony, arsenic, barium, bromine, cadmium, chromium, copper, lead, mercury, tantalum, tin, and titanium. Each specimen was analyzed three times with the average of the samples recorded.
Elemental analysis results were compared to EU Community Ecolabel limits (*i.e.*, element

concentrations are less than 25 mg/kg of arsenic, 25 mg/kg of mercury, 25 mg/kg of chromium, 50 mg/kg cadmium, 90 mg/kg lead, and 40 mg/kg copper[7]) (EU, 2004). For all wood products tested, 16% exceeded one or more of the Ecolabel limits, with highest concentrations from lead, chromium, chlorine, copper, cadmium, and mercury. No samples had levels of arsenic over the 25 ppm limit (except a CCA-treated pole). Barium and lead were found in 10–20% of the samples, chromium and cadmium in 3–4%, and antimony, mercury, and arsenic ranged from 0.3–1.2% of samples. Twenty-four percent of furniture and 18% of building materials had one or more elements exceeding the limits. The authors indicated that this may be due to manufacturing processes such as painting, preservation, and overlaying, which are common with furniture and building materials (for example, high levels of titanium may indicate the presence of paint). Most polluted types of wood were particleboard (37% exceeded Ecolabel limits), recycled particleboard (25% exceeded), and plywood (18% exceeded); while fiberboard (MDF and HDF) exceeded limits in 9% of samples. The authors concluded that visual sorting combined with the ED-XRF measuring device was effective in sorting polluted from non-polluted wood wastes, particularly for CCA-treated wood, but was more limited in detecting low concentrations of some other elements including chromium and antimony.

We consulted with CPSC staff regarding accuracy of measurements using ED-XRF (Butturini, personal communication). CPSC uses XRF analysis but requires multiple sample areas (five sample areas are preferred as opposed to three areas used by Fellin and colleagues). This is because an XRF measurement has a small “spot size” and testing more areas helps avoid the presence or absence of a material in a localized area to be misinterpreted as representative of the entire test product or specimen. In addition, the multiple sample areas help reduce noise in these measurements. The ED-XRF is rather indiscriminate in where a detected element is found. When the beam is emitted, anything in the path can reflect back to the detector. However, the beam disperses, and at long distances, the return signal is too low for detection above the noise. CPSC’s ED-XRF test method for certification testing is not approved for composite materials (*e.g.,* plated materials, laminates) because the measurement does not discriminate where along the path an element was detected. Overall, this method can be used to look for elements in wood, but multiple sample areas are needed for manufactured woods. To test the wood substrate accurately, surface coatings need to be removed, and the surface should be washed of potential pollutants before testing.

[77] Ecolabel limits are similar to ASTM solubility limits for the eight elements of interest in our study.

Tables 4-7 below report average concentrations of ASTM elements measured in particleboard, recycled particleboard, plywood, and fiberboard respectively.

Table 4. Contaminants identified in elemental analysis of particleboard samples (n=54) (Fellin et al., 2014). Numbers in bold represent concentrations that exceed ASTM limits.

Element	unit	As	Ba	Cd	Cr	Hg	Pb	Sb	Se
Occurrence	%	0	20	13	2	2	37	4	2
Average concentration	mg/kg	-	**1600**	**100**	**1300**	28	**250**	40	25
Minimum	mg/kg	-	230	56	**1300**	28	8	31	25
Maximum	mg/kg	-	**4300**	**140**	**1300**	28	**3800**	49	25

As-arsenic, Ba-barium, Cd-cadmium, Cr-chromium, Hg-mercury, Pb-lead, Sb-antimony, Se-selenium

Table 5. Contaminants identified in elemental analysis of recycled particleboard samples (n=12) (Fellin et al., 2014). Numbers in bold represent concentrations that exceed ASTM limits.

Element	unit	As	Ba	Cd	Cr	Hg	Pb	Sb	Se
Occurrence	%	0	25	0	8	0	75	0	0
Average concentration	mg/kg	-	370	-	**140**	-	64	-	-
Minimum	mg/kg	-	180	-	**140**	-	6	-	-
Maximum	mg/kg	-	740	-	**140**	-	**200**	-	-

As-arsenic, Ba-barium, Cd-cadmium, Cr-chromium, Hg-mercury, Pb-lead, Sb-antimony, Se-selenium

Table 6. Contaminants identified in elemental analysis of plywood samples (n=44) (Fellin et al., 2014). Numbers in bold represent concentrations that exceed ASTM limits.

Element	unit	As	Ba	Cd	Cr	Hg	Pb	Sb	Se
occurrence	%	0	14	5	11	0	14	2	2
av. Concentration	mg/kg	-	**3200**	**150**	**120**	-	**590**	48	29
min	mg/kg	-	210	32	**100**	-	**230**	48	29
max	mg/kg	-	**13,000**	**260**	**130**	-	**1300**	48	29

As-arsenic, Ba-barium, Cd-cadmium, Cr-chromium, Hg-mercury, Pb-lead, Sb-antimony, Se-selenium

Table 7. Contaminants identified in elemental analysis of fiberboard (medium and high density) samples (n=45) (Fellin et al., 2014). Numbers in bold represent concentrations that exceed ASTM limits.

Element	unit	As	Ba	Cd	Cr	Hg	Pb	Sb	Se
occurrence	%	2	11	0	2	0	11	0	0
av. Concentration	mg/kg	4	**1600**	-	**140**	-	**110**	-	-
min	mg/kg	4	780	-	**140**	-	13	-	-
max	mg/kg	4	**2900**	-	**140**	-	**270**	-	-

As-arsenic, Ba-barium, Cd-cadmium, Cr-chromium, Hg-mercury, Pb-lead, Sb-antimony, Se-selenium

In the United States, there are no federal regulations that limit the level of heavy metals or phthalates in finished EWPs (unless the finished EWPs are incorporated into a toy subject to Section 4.3.5 of ASTM F963-11 or other children's product or childcare article subject to lead or phthalate content requirements), nor are there regulations that limit the use of contaminated wood as a feedstock for EWPs (except for general limitations on uses of creosote, pentachlorophenol, and CCA-treated lumber). Individual states are generally responsible for managing nonhazardous or municipal solid wastes and regulations and guidance can vary from state to state with regard to safe disposal and reuse of various wood wastes (*e.g.*, MI DEQ, 2007; CWC, 1997a,b).

Health Canada does not have specific regulations regarding use of recycled woods for consumer products, except that the products cannot pose a danger to health and safety (Hatlelid, personal communication). Canadian provinces establish waste management plans and regulations (Jeffrey, 2011).

In Europe, the EU Waste Framework Directive requires that by 2020, 70% of a country's construction and demolition waste must be reused or recycled, but each member state sets its own regulations (Jeffrey, 2011). In the EU, wood chips from recycled woods are grouped into categories depending upon the extent of heavy metals and contaminants, with the uncontaminated "green list" chips being used for particleboard and slightly contaminated "yellow list" sometimes used. The "red list" wood chips cannot be recycled but only burned in biomass facilities (Brenner, 2016). The EPF (European Panel Federation, representing European manufacturers of particleboard, MDF, and OSB) has established voluntary industry standards to verify that chemical contaminants are not present in the waste wood used for panel board (EPF, 2010b). The EPF set maximum limit values (g/kg dry panel) for heavy metals in wood-based panels containing recycled wood (EPF, 2010a). The EPF concentrations are based upon the European Toy Safety Standards (EN 71-3:1995) (EPF, 2010a). EN 71-3:1995 standards are similar to ASTM standards.

8.3.2 Identifying and sorting contaminated wood waste

Wood waste processors take various approaches to ensure that their waste woods are not contaminated. For example, one wood recycler in the Pacific Northwest accepts clean urban wood waste, but not treated wood such as that containing creosote, CCA, or pentachlorophenol (Rainier Wood Recyclers, 2006). Another facility explains on their website that they use various testing methods, including outside laboratories to test materials for contaminants (for example, testing painted wood for lead), but notes that they test samples of the materials, and therefore there is always a possibility that there is a portion of untested material within the batch that may have residues of lead paint (Pioneer Millworks, 2016). Waste wood may be sorted by visual and/or mechanical means to identify contaminants, and vendors sell wood recycling sorting equipment that use optical sensors, magnetic, and metal separators (*e.g.*, Sesotec, 2016).

Austin (2008) describes a method of processing waste wood to remove contaminants. The first step removes foreign objects by dumping materials in tanks of water, with the more buoyant wood rising to the top and the other materials sinking to the bottom. The wood moves via conveyor belt and painted or treated woods are separated out; large magnets are used to extract nails and metal pieces. The wood is then ground or chipped and magnets are used again to collect any remaining metal.

Efforts are underway to more easily identify chemicals in recycled wood, for example the Waste & Resources Action Programme (WRAP) in the UK is developing tools to help wood re-processers identify contaminated wood including visual inspection guides and color indicator testing kits (WRAP, 2016). Bouslamti et al. (2012) discussed the inherent high degree of variability of contaminants in recovered and waste wood resulting in the need for a robust analytical sampling protocol to ensure that results of testing for contaminants is as precise as possible. Bradley (2014) reports that research in Germany on X-ray fluorescence analysis, near-infrared spectroscopy, and ion mobility spectrometry is being conducted to help identify contaminants in recycled wood. Once the contaminants are identified, research can be done to identify appropriate supercritical fluid treatments to extract efficiently the contaminants.

8.3.3 Recycling EWPs to make particleboard

Because engineered wood products consist of roughly 90% wood, recovery and recycling of engineered wood products to make new engineered wood, particularly particleboard, is desirable. Researchers have investigated recycling engineered wood product board with mixed success (Lykidis and Grigoriou, 2008; Wan et al., 2014; Roffael et al., 2010). Recycling engineered wood boards is complicated due to the presence of different adhesives, as formaldehyde can be released during recycling (Wan et al., 2014). In addition, some EWPs are treated with fire retardants, moisture resistant chemicals, and other additives that have to be considered in producing particleboard from recycled EWPs.

8.4 Treated Wood with Surface Contamination as Potentially Incompatible for Use in EWPs

There are a few factors that are suggestive of the incompatibility for the presence of the ASTM chemical elements or the specified phthalates in EWP production. Many variables associated with wood surface characteristics can affect the wettability of the surface and the depth of resin penetration into the wood, leading to increased or decreased bonding performance (Stokke et al., 2014). For example, treating wood with CCA modifies the surface of the wood and damages the cell walls, which disrupts the gluing process (Munson, 1997). Munson (1997) also cites a number of researchers who suggest that phenol-formaldehyde resins are incompatible for use with CCA-treated woods (Boggio and Gertjejansen, 1982; Gertjejansen et al., 1988; Vick, 1980; Vick et al., 1990, 1996; all as cited in Munson, 1997); this was reiterated in USDA (2010). These treatments are reported to interfere with the surface contact area for bonding and decrease bond strength (USDA, 2010). Industry and experts suggest that phthalates would not be used in EWP manufacturing because of lack of compatibility with resin formulations (Heroux, personal communication; Frazier, personal communication). These experts also suggest that there is no incentive or reason to add any of the ASTM elements (Heroux, personal communication).

8.5 Wood-Thermoplastic Composites

While beyond the subject of this report, we should mention that wood-thermoplastic composites are gaining in use (Yeh et al., 2009, as cited in Martinez-Lopez et al., 2014; USDA, 2010). These products are made with recycled wood or other cellulosic fibers and thermoplastics such as polypropylene (PP), polystyrene, vinyl, and low- and high-density polyethylene (USDA, 2010; US EPA, 1995c). These composites may also utilize coupling agents or plasticizers to improve bonding and product performance (USDA, 2010; Wambua et al., 2003, as cited in Martinez-Lopez et al., 2014). The inclusion of plastics in composite products introduces the possibility of the composites to contain phthalates if the phthalates were present in the recycled or virgin thermoplastics feedstocks used in production. "Plastic lumber" has been made from ground pallet wood and recovered plastics (*e.g.*, plastic grocery bags) (Bush et al., 1996). Bosch et al. (2015) reports that composites made of wood and plastic have significant market shares in some specific markets.

Various cellulosic materials have been used or investigated, including particleboard residues, Eucalyptus grandis wood, cereal straw, rice hulls/husks, kenaf fibers, and old newspaper fiber, which is mixed with post-consumer plastic such as polypropylene and high density polyethylene (Hillig et al., 2008; Ashori and Nourbakhsh, 2009; Srebrenkoska et al., 2008; USDA, 2010).

US EPA (1995b) demonstrated in the laboratory that wood-plastic composites can be made from a variety of wood wastes and recycled plastics. They report that the properties of the resulting composites were very similar to those made from virgin materials. Ashori and Nourbakhsh (2009) investigated the feasibility of using two types of plastics (PP and high density polyethylene) and old newspaper fiber to manufacture experimental composite panels. They found the resulting panels could be made without significant adverse effect on the panel's properties. Srebrenkoska et al. (2008) investigated PP-based composites (using rice hulls or kenaf fibers) and found their flexural strength and modulus comparable to those of conventional medium-density fiberboards. These authors thought these recycled composites suitable for use indoors or as construction materials.

9. Summary and Discussion of the Potential Evidence for the ASTM Elements or Specified Phthalates to be present in EWPs

The Consumer Product Safety Act (CPSA) requires third party testing of children's products for compliance with the applicable children's product safety rules. This report summarized available information on the production of engineered wood products (EWP) (specifically particleboard, medium density fiberboard, and hardwood plywood) and the possibility of the raw materials or finished product containing any of the specified ASTM elements or phthalates above their respective solubility or concentration limits.

We investigated the possibility that any of the ASTM chemical elements or specified phthalates could be present in the engineered wood products at levels above their respective solubility or concentration limits. We also identified the raw materials used in manufacturing each EWP, including the resins and additives used in making the adhesives, and searched for data on whether any of the ASTM elements or specified phthalates could be present in those raw materials. Finally, we considered the possibility for the ASTM elements or specified phthalates to be introduced into the EWPs from use of recycled raw materials in manufacture.

9.1 Elements and Phthalates in EWPs

We searched in the primary and secondary literature for the presence or concentrations of the specified elements and phthalates in the three types of EWPs.

- Particleboard – We found little information on measurements of the ASTM elements in particleboard and no studies that measured the specified phthalates. Very low concentrations (< 0.3 ppm) of arsenic and chromium were measured in the particleboards made from virgin wood chips (Munson, 1997; Munson and Kamdem, 1998). Chromium and arsenic were detected in particleboard made with CCA-treated wood products (*e.g.*, Munson, 1997; Munson and Kamdem, 1998). Fellin et al. (2014) measured several elements in particleboard wood waste at concentrations above the solubility limits, but the authors noted that the contamination might be due manufacturing processes such as coating and overlaying.
- Hardwood Plywood – We identified only one study that measured the ASTM elements in uncontaminated hardwood plywood and no studies that measured the specified phthalates. Peltola et al. (2000) reported concentrations of several of the ASTM elements, all below the solubility limits. Fellin et al. (2014) measured several elements in hardwood plywood wood waste at concentrations above the solubility limits, but the authors noted that the contamination might be due manufacturing processes such as coating and overlaying.
- Medium Density Fiberboard – We identified no studies that reported the presence of the specified phthalates or ASTM elements in MDF made with virgin wood. Fellin et al. (2014) measured several elements in MDF wood waste at concentrations above the solubility limits, but the authors noted that the contamination might be due manufacturing processes such as coating and overlaying.

9.2 Elements and Phthalates in Adhesives and Additives

We searched for the presence of the specified elements or phthalates in the adhesives, resins, and waxes used in adhesive formulations.

- Urea-formaldehyde – We did not identify any studies that reported phthalates or ASTM elements in UF resins. Several patents reported the use of barium as a catalyst in the formation of some UF resins. In one, they report the concentration of barium hydroxide (5% by weight) added as a catalyst during synthesis of phenolic foam resin (Geng et al., 2014). The relevance of foam resins to the specified EWPs is unclear.

- Melamine-formaldehyde (MF) and melamine-urea-formaldehyde (MUF) – We did not locate any studies that examined phthalates or ASTM element concentrations in MF or MUF. Our original search was for melamine as an amino-adhesive, and we conducted an additional literature search for 'melamine' only to ensure no primary references were missed in our initial search. No additional studies were identified, but this additional search did not include patents.
- Phenol-formaldehyde (PF) – We located studies and patents addressing the use of barium or chromium as catalysts in the formation of some phenol-formaldehyde (PF) resins. We located a number of patents and studies that use barium hydroxide as a catalyst during synthesis of PF resins (Geng et al., 2014; Shrivastava et al., 2012; Wang and Zhang, 2011; Zhang et al., 2009a) and resoles (Bouajila et al., 2002). Only one of these, Shrivastava et al. (2012), described concentrations of 1.68–10.13% barium hydroxide by weight. Other barium compounds, specifically barium carbonate, have been added to PF resin at a rate of 30g barium carbonate to 100g PF resin to improve heat resistance (Zhang et al., 2009b). Popov et al. (1973) reported that chromium has historically been used as a catalyst in PF resin foams, but concentration information was not provided. We did not find information in our literature and SDS searching to indicate how commonly these catalysts are used.
- Resorcinol-based resins (RF, PRF) – We did not locate any studies on the specified phthalates or ASTM elements in resorcinol-based resins, including phenol-resorcinol-formaldehyde (PRF) resin or resorcinol-formaldehyde (RF) resin.
- Polymeric methylene diphenyl diisocyanate resins (pMDI) – We identified one study regarding the use of antimony as a catalyst in the formation of pMDI. Preparation of pMDI was conducted using thermal decomposition of methylenediphenyl di(phenylcarbamate) (MDPC) with an antimony trioxide (Sb_20_3) catalyst, but no concentrations were given (Wang et al., 2013).
- Polyvinyl acetate (PVA) – Cameron et al. (1987) noted that PVA can be plasticized with dibutyl, diethyl, and dimethyl phthalate and Stokke et al. (2014) reported the use of dibutyl phthalate. Feng et al. (2002) reported that di(2-ethylhexyl)phthalate (DEHP) is used in the manufacturing of PVA. USDA (2010) suggested that phthalates (such as dibutyl phthalate) are used in PVA manufacture to plasticize the adhesive polymers. Our literature search revealed no information on concentrations of phthalates in PVA and there was no indication in the literature if this is a standard manufacturing procedure. The literature search did not identify any reports of the ASTM elements in PVA resins used for manufacturing engineered wood products. Matoso and Cadore (2008; 2011) tested

commercially available PVA-based glues (glue brands or names not specified), for some of the ASTM elements. Chromium was detected at 0.3 mg/kg (0.3 ppm) in one of the glue types. All other measurements for arsenic, chromium, barium, cadmium, mercury, and lead were below their limit of quantitation. There are many types of commercially available PVA glues and it is not known whether the glues tested in these studies are similar to those used in EWP production.

- Waxes – The literature search revealed no information regarding possible concentrations of phthalates in waxes, nor did we find any information on ASTM element concentrations in waxes used in the manufacturing engineered wood products. Note that we did not search for patents for wax additives.

We did not find much evidence to suggest that the specified phthalates and elements are likely to be present in any of the commonly used adhesives or waxes at concentrations above 0.1% for the phthalates, and the respective ASTM solubility limits. We found information on use of phthalates in the manufacturing of PVA, but from the information we obtained this resin is not commonly used in EWPs and it is not clear how standard this practice is. While we found several patents that reported use of the ASTM elements as catalysts, these patents are novel formulations that are not likely to represent common industry practice.

In the resins and additives, many of the ASTM elements were identified in processes used in the manufacture (mainly as catalysts) or as potential impurities in the final products (see Appendix III). These ASTM elements include chromium, arsenic, antimony, barium, mercury, selenium, and lead. Cadmium was not identified. No information on concentrations exceeding the solubility limits of the ASTM elements were found, and very few sources reported information on concentrations at all. Because these elements are mainly used as catalysts, they are expected to be chemically unchanged during the reaction. However, these catalysts remain in the adhesive; they are not removed. While the catalyst is not incorporated into the polymeric network created by the resin, the catalyst may remain entrained within the cured adhesive. In contrast, the specified phthalates, other than their mentions in Section 6.3.2, were not identified in processes used in manufacture or as potential impurities in the final products.

9.3 Elements and Phthalates in Wood

The potential for natural wood to contain concentrations of the ASTM elements[8] above the solubility limits was addressed under a previous report prepared for CPSC (CPSC, 2015). That report found the following:

- Wood – Very few studies were found that measured concentrations of the ASTM elements in wood, tree trunks, or tree rings. None of the measurements were above the solubility limits.
- Trees – Many studies identified and measured the ASTM elements in tree parts other than the trunk. All seven elements were detected in one or more other parts of trees (*e.g.*, roots, shoots, leaves). Evidence was found of concentrations exceeding the solubility limits for all the elements (except barium) in some tree part(s) other than the trunks.

The potential for trees and plants to contain concentration of phthalates above the solubility limit was addressed in this report.

- We found only one study, Wang and Fan (2014), that measured phthalate levels in pine needles of Masson pines growing in Nanjing, China and demonstrated that pine needles readily absorb airborne phthalates. However, concentrations were well below the content limits. Note that this study provides evidence of phthalates being taken up by trees, but pine needles would not be used as a cellulosic in making the specified EWPs.
- We found numerous studies investigating phthalate uptake in plants (mainly agricultural crop plants). These studies showed concentrations of DEHP, DnBP, DBP, DEP, DnOP, and BBP in plant tissue showing that phthalates are bioavailable for uptake in plants. However, none of these studies reported concentrations above the 1000 ppm (the highest reported concentration was 36 mg/kg of DEHP).

9.4 Use of Waste Wood

There is increased interest and use of post-consumer recycled materials in EWP production; however, with this comes the need to consider potential contamination in the recycled feedstock, including contamination by the specified elements and phthalates that are the subject of this report. Surface treatments (*e.g.*, paints, stains), metals, glues and adhesives, glass, paper, plastic, rubber, and chemical treatments may contain the elements or phthalates that are intimately bound to the wood. In order to insure EWPs made from used wood fibers do not contain elements or phthalates above the limits, the materials would need to be carefully sorted and tested to be

[8] The previous task did not investigate lead content in wood because the CPSC has previously determined that natural woods do not contain lead in concentrations above the ASTM solubility limit. See 16 C.F.R. 1500.91.

assured that they are not contaminated. We found manufacturer information that indicates that there are some manufacturers using recycled woods to make EWPs, although most of these examples used pallets and containers; these types of wood waste are less likely to be contaminated because they generally are not treated or coated.

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TERA

Final Report for CPSC Task 14

Appendix I: Literature Search Strategy and Data Tables

FINAL Report

March 25, 2016

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INDEPENDENT NON-PROFIT SCIENCE FOR PUBLIC HEALTH PROTECTION

Contents

Appendix I: Literature Search Strategy and Data Tables

1.1 Description of Approach

For each of the three specified engineered wood products (EWPs), we investigated how the products are made, what raw materials are used in their manufacturing, the proportions of wood and non-wood components, and the potential recycled materials used in production. We also searched for data on concentrations of the substances of interest in the raw materials of the three types of engineered wood products. We used a multi-pronged approach to identify available information in order to answer the question of whether engineered wood products (or the raw materials with which they are made) contain lead (in concentrations over 100 ppm), the specified phthalates (in concentrations over 1000 ppm), or any of the specified ASTM elements (in concentrations exceeding the specified limits shown in Table 1 of the main report). Our focus was to identify relevant information on the five research topics identified by CPSC in order to address the question of whether engineered wood products, used as substrates in toys or childcare articles, might contain any of the substances in concentrations above the specified limits.

We first researched authoritative sources such as reference and text books, along with Internet resources, for general information about engineered wood products, adhesives, raw materials, manufacturing processes, and the potential use of recycled materials. We utilized this information and consulted technical experts to identify key words for literature searching. We then conducted primary literature searches for research studies and publications. In addition, we searched for Safety Data Sheets (SDSs) for additional information on raw materials, the typically used materials, and the proportions of these materials in EWPs.

To address our research task, we reviewed the literature and resources for evidence of the potential presence or concentrations of the specified elements or phthalates in the three EWPs in a step-wise fashion. First, we looked for data on measurements of specified elements or phthalates in EWP boards. As anticipated, we found little information regarding direct evidence and concentrations of the specified elements or phthalates in the engineered woods themselves (Section 4). Finding little data on the EWPs themselves, we then sought measurements of specified elements or phthalates in adhesives and waxes and their raw materials (Sections 6 and Appendix III). We also looked at uptake of phthalates into plants to determine whether phthalates might be found in EWPs made with contaminated cellulosic materials (Section 7).

Lastly, we searched for information on elements and phthalates in recycled materials that might be used to make EWPs (Section 8).

This appendix describes how we searched the literature to identify relevant information on the five research topics identified by CPSC, in order to address the question of whether engineered wood products, used as substrates in toys or childcare articles, might contain any of the substances of interest in concentrations above the specified limits.

We sought information from a number of resources and each is described below.

- Authoritative References and Books
- Internet Searches
- Primary Literature
- Trade Organizations
- Safety Data Sheets (SDSs)

1.1.1 Authoritative References and Books

Authoritative sources included reference books [*e.g.*, Introduction to Wood and Natural Fiber Composites (Stokke, 2013); CLT Handbook, U.S. Edition. (Karacabeyli and Douglas, 2013); Research Developments in Wood Engineering and Technology (Aguilera, 2013); Reactive Polymers Fundamentals and Applications: A Concise Guide to Industrial Polymers (Fink, 2013); Encyclopedic Dictionary of Polymers (Gooch, 2007); Handbook of Wood Chemistry and Wood Composites (Rowell, 2012); Handbook of Plasticizers (Wypych, 2012); Aldrich: Handbook of Fine Chemicals and Laboratory Equipment (Sigma-Aldrich, 2004)]. This also included government and industry reports. These were mainly identified through library databases and Internet searching.

1.1.2 Internet Searches

We searched the Internet initially to help understand what data and resources are available to address our needs, and to identify key words for literature searching. We also conducted targeted Internet searches to find information on specific topics and questions that the primary literature search did not identify. These searches included company and trade association web pages, SDSs and manufacturer information sheets, recycling regulations and information, and government reports.

1.1.3 Primary Literature

For each of the three engineered wood products, including adhesives and waxes, and for the use of recycled raw materials, TERA conducted a literature search for primary literature studies that investigated the presence or concentration of the specified elements or phthalates. Because the information for each of the topic areas was diverse, slightly different approaches were undertaken for each search in order to optimize our results.

TERA identified and screened potentially relevant studies for information on concentrations of substances in each material. TERA searched the National Library of Medicine, PubMed, and Toxline databases (http://www.ncbi.nlm.nih.gov/pubmed and http://toxnet.nlm.nih.gov/newtoxnet/toxline.htm), Elsevier's SCOPUS database (http://www.scopus.com/), and Thomson Reuters's Web of Science (WOS) database (http://wokinfo.com/). The keywords searched and resultant hits for each search string are found below. All hits for each search string were recorded, saved, and downloaded into a raw EndNote library. After an initial prescreen to remove duplicates, extraneous, and irrelevant studies, a second, more thorough screening was performed to determine relevancy and likelihood for a study to contain substance concentration information in the materials of interest. This was done for each element and each material group. Once a study was identified as relevant, it was retrieved and data were pulled into a table. Studies were limited to only those available in English.

To determine if recycled woods are used to make the engineered wood products, we searched the SCOPUS and WOS databases for studies on plywood, particleboard, and/or medium density fiberboard (MDF) with wood waste and other related terms. The keywords searched and resultant hits for each search string are found below. Due to the broad nature of the search and the large number of hits from SCOPUS, we limited screening and retrieval to WOS. Screening was conducted as described above.

1.1.4 Trade Organizations

We did not find all of the information in the open literature, particularly specific information on raw materials used in EWPs and their proportions, because either it did not exist, or it was proprietary company information. The published literature only contained general information on ranges of proportions or materials generally used. Because much of the specific information was not available in the primary literature, additional research to gain access to proprietary data was conducted. Several North American trade associations were contacted for industry reports or additional data that they could share [*e.g.*, the Hardwood Plywood & Veneer Association (HPVA) and the Composite Panel Association (CPA)].

The highest producing companies for wood chips and particles, MDF, and hardwood plywood are located in North America, Europe, and China, almost exclusively (FAOSTAT, 2015; Raute, 2011)]. Additionally, searches were conducted to find international trade organizations and at least three were identified: Engineered Wood Products Association of Australia, the International Wood Products Association, and the European Panel Federation. These organizations' web pages were searched for any available information in English to aid in answering the specified research questions regarding composition and raw materials.

The web pages of several trade associations of wood recyclers were also reviewed, including the National Waste and Recycling Association, the Construction & Demolition Recycling Association, the Wood Recyclers Association in Great Britain, and the Alberta Waste Wood Recycling Association.

1.1.5 Safety Data Sheets

As mentioned above, data on raw materials and their proportions in finished products was difficult to find because of the proprietary nature of this data. In order to supplement the general information identified in books and published literature, a detailed Safety Data Sheet (SDS) search was conducted that provided more specific information on the non-wood materials used in EWPs and the proportions of those materials. Due to the large amount of SDSs available, two approaches were undertaken to limit the number of SDSs and to optimize the search. The first approach was to search the (M)SDS database MSDSXchange (http://www.msdsxchange.com/english/) for the specified EWPs (hardwood plywood, MDF, and particleboard). SDSs resulting from these searches were reviewed one by one, ruling out any non-relevant EWPs. There was some difficulty to this approach as some SDSs covered multiple EWPs. Results were recorded in a table and are presented in Appendix II. The second approach was to search the Composite Panel Association for member companies producing hardwood plywood, MDF, and particleboard. Even though the CPA only specifically includes companies producing particleboard and MDF, information was also found through them for companies that produce hardwood plywood, and so we determined that this information was relatively comprehensive of all specified EWPs. Each of the identified companies' websites was visited and SDSs reviewed, and this data was added to the tables in Appendix II.

This approach provided us with the specific data under investigation for this research project. However, it should be noted that this SDS approach likely only covered SDSs from companies and organizations in North America. For example, we searched the International Wood Products Association for manufacturers of the specified EWPs. However, most of the results were North American companies. For the few companies that were identified outside of North America (*e.g.*, Malaysia, China), SDSs could not be found on their webpages.

1.2 Approach for Phthalate Uptake

The search strategy for this piece of the report was considered screening level and not comprehensive of all of the available literature. The search strings and database searches are found below. To mirror the approach of the previous Task 9 (CPSC, 2015), we aimed to first identify concentrations of the specified phthalates in trees themselves that are used to make EWPs. This search was supplemented with additional information from the literature related to the potential for uptake into plants. The initial database searched was PubMed. This search provided some data on the potential for phthalate uptake and concentration in plants, but no data on phthalate uptake and concentration in trees. Additional gap searching was conducted in the Web of Science database and the Scopus database to confirm that there were no missed data for uptake and concentration of phthalates in trees only (this search did not include other types of plants and is why this search was considered screening level).

In reviewing and screening studies for relevance, studies were excluded that studied phthalate concentrations in water or uptake into aquatic biota (including plants). This information was considered non-relevant for the analysis of phthalate uptake into terrestrial plants, although water concentration can be assumed to play a part in the fugacity of phthalates in the environment. Sediment and biodegradation studies, again while potentially informative of environmental presence, were excluded on the basis that the information does not support the identification of phthalate uptake into plants. Other studies that were not relevant were studies related to phthalate concentration in indoor air, homes, dusts, and plastic consumer products. Finally, analysis of phthalates in food were originally viewed, but later removed as there were multiple contamination pathways identified as to how food and foodstuff could be contaminated post-harvesting, and so were not determined adequate predictors of phthalate uptake into plants.

To supplement the data because no studies were identified investigating phthalate uptake in trees, additional searches were conducted in Scopus and Web of Science for information on trees only, as documented below.

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1.4 Key Words and Search Results for Concentrations of Specified Phthalates and ASTM Elements in Engineered Wood Products

1.4.1 Medium Density Fiberboard

Database	Keyword	Query	Results
PubMed	Antimony	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Antimony"[All Fields])	0
Scopus	Antimony	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Antimony"))	1
WOS	Antimony	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Antimony"))	3
PubMed	Arsenic	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Arsenic"[All Fields])	2
Scopus	Arsenic	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Arsenic"))	10
WOS	Arsenic	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Arsenic"))	7
PubMed	Barium	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Barium"[All Fields])	1
Scopus	Barium	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Barium"))	2
WOS	Barium	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Barium"))	5
PubMed	BBP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("benzyl butyl phthalate"[All Fields] OR "BBP"[All Fields] OR "85-68-7"[All Fields])	0
Scopus	BBP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("benzyl butyl phthalate" or "BBP" or "85-68-7"))	0
WOS	BBP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("benzyl butyl phthalate" or "BBP" or "85-68-7"))	0
PubMed	Cadmium	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Cadmium"[MeSH Terms] OR "Cadmium"[All Fields])	0
Scopus	Cadmium	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Cadmium"))	4
WOS	Cadmium	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Cadmium"))	2
PubMed	Chromium	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Chromium"[All Fields])	0
Scopus	Chromium	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Chromium"))	8
WOS	Chromium	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Chromium"))	10
PubMed	DBP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("dibutyl phthalate"[All Fields] OR "DBP"[All Fields] OR "84-74-2"[All Fields])	1
Scopus	DBP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("dibutyl phthalate" or "DBP" or "84-74-2"))	0

WOS	DBP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("dibutyl phthalate" or "DBP" or "84-74-2"))	0
PubMed	DCHP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("dicyclohexyl phthalate"[All Fields] OR "DCHP"[All Fields] OR "84-61-7"[All Fields])	0
Scopus	DCHP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("dicyclohexyl phthalate" or "DCHP" or "84-61-7"))	0
WOS	DCHP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("dicyclohexyl phthalate" or "DCHP" or "84-61-7"))	7
PubMed	DEHP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ((("diagnosis"[Subheading] OR "diagnosis"[All Fields] OR "di"[All Fields]) AND 2-ethylhexl[All Fields] AND ("phthalic acid"[Supplementary Concept] OR "phthalic acid"[All Fields] OR "phthalate"[All Fields])) OR "DEHP"[All Fields] OR "117-81-7"[All Fields])	0
Scopus	DEHP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("di-(2-ethylhexl) phthalate" or "DEHP" or "117-81-7"))	0
WOS	DEHP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("di-(2-ethylhexl) phthalate" or "DEHP" or "117-81-7"))	0
PubMed	DHEXP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("di-n-hexyl phthalate"[All Fields] OR "84-75-3"[All Fields])	0
Scopus	DHEXP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("di-n-hexyl phthalate" or "DHEXP" or "84-75-3"))	0
WOS	DHEXP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("di-n-hexyl phthalate" or "DHEXP" or "84-75-3"))	0
PubMed	DIBP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("diisobutyl phthalate"[All Fields] OR "DIBP"[All Fields] OR "84-69-5"[All Fields])	0
Scopus	DIBP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("diisobutyl phthalate" or "DIBP" or "84-69-5"))	0
WOS	DIBP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("diisobutyl phthalate" or "DIBP" or "84-69-5"))	0
PubMed	DIDP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("diisodecyl phthalate"[All Fields] OR "DIDP"[All Fields] OR "26761-40-0"[All Fields] or "68515-49-1"[All Fields])	0
Scopus	DIDP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("diisodecyl phthalate" or "DIDP" or "26761-40-0" or "68515-49-1"))	0
WOS	DIDP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("diisodecyl phthalate" or "DIDP" or "26761-40-0" or "68515-49-1"))	0
PubMed	DINP	("medium density fiberboard"[All Fields] OR "mdf"[All Fields] OR "medium-density fiberboard"[All Fields]) AND ("Diisononyl phthalate"[All Fields] OR "DINP"[All Fields] OR "28553-12-0"[All Fields] OR "68515-48-0"[All Fields])	0
Scopus	DINP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("diisononyl phthalate" or "DINP" or "28553-12-0" or "68515-48-0"))	0

WOS	DINP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("diisononyl phthalate" or "DINP" or "28553-12-0" or "68515-48-0"))	0
PubMed	DnOP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("di-n-octyl phthalate"[All Fields] OR "DnOP"[All Fields] OR "117-84-0"[All Fields])	0
Scopus	DnOP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("di-n-octyl phthalate" or "DnOP" or "117-84-0"))	0
WOS	DnOP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("di-n-octyl phthalate" or "DnOP" or "117-84-0"))	0
PubMed	DPENP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("di-n-pentyl phthalate"[All Fields] OR "131-18-0"[All Fields])	0
Scopus	DPENP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("di-n-pentyl phthalate" or "DPENP" or "131-18-0"))	0
WOS	DPENP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("di-n-pentyl phthalate" or "DPENP" or "131-18-0"))	0
PubMed	Lead	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Lead"[All Fields])	18
Scopus	Lead	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Lead"))	104
WOS	Lead	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Lead"))	79
Toxline	MDF	medium-density fiberboard	36
PubMed	Mercury	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Mercury"[All Fields])	22
Scopus	Mercury	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Mercury"))	55
WOS	Mercury	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Mercury"))	51
PubMed	Selenium	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Selenium"[All Fields])	0
Scopus	Selenium	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Selenium"))	1
WOS	Selenium	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Selenium"))	4

1.4.1.1 MDF Results Summary

Keyword	**PubMed**	**Scopus**	**Toxline**	**WOS**	**Keyword Total**	**Duplicates Removed**
Antimony	0	1	0	3	4	3
Arsenic	2	10	0	7	19	12
Barium	1	2	0	5	8	6
BBP	0	0	0	0	0	0
Cadmium	0	4	0	2	6	5
Chromium	0	8	0	10	18	13
DBP	1	0	0	0	1	1
DCHP	0	0	0	7	7	7

DEHP	0	0	0	0	0	0
DHEXP	0	0	0	0	0	0
DIBP	0	0	0	0	0	0
DIDP	0	0	0	0	0	0
DINP	0	0	0	0	0	0
DnOP	0	0	0	0	0	0
DPENP	0	0	0	0	0	0
Lead	18	104	0	79	201	136
MDF	0	0	36	0	36	34
Mercury	22	55	0	51	128	62
Selenium	0	1	0	4	5	5
Database Total	**44**	**185**	**36**	**168**	**433**	

1.4.2 Particleboard

Database	**Keyword**	**Query**	**Results**
PubMed	Antimony	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Antimony"[All Fields])	0
PubMed	Arsenic	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Arsenic"[All Fields])	1
PubMed	Barium	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Barium"[All Fields])	0
PubMed	BBP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("benzyl butyl phthalate"[All Fields] OR "BBP"[All Fields] OR "85-68-7"[All Fields])	0
PubMed	Cadmium	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Cadmium"[MeSH Terms] OR "Cadmium"[All Fields])	1
PubMed	Chromium	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Chromium"[All Fields])	0
PubMed	DBP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("dibutyl phthalate"[All Fields] OR "DBP"[All Fields] OR "84-74-2"[All Fields])	0
PubMed	DCHP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("dicyclohexyl phthalate"[All Fields] OR "DCHP"[All Fields] OR "84-61-7"[All Fields])	0
PubMed	DEHP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ((("diagnosis"[Subheading] OR "diagnosis"[All Fields] OR "di"[All Fields]) AND 2-ethylhexl[All Fields] AND ("phthalic acid"[Supplementary Concept] OR "phthalic acid"[All Fields] OR "phthalate"[All Fields])) OR "DEHP"[All Fields] OR "117-81-7"[All Fields])	23
PubMed	DHEXP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("di-n-hexyl phthalate"[All Fields] OR "84-75-3"[All Fields])	0

PubMed	DIBP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("diisobutyl phthalate"[All Fields] OR "DIBP"[All Fields] OR "84-69-5"[All Fields])	0
PubMed	DIDP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("diisodecyl phthalate"[All Fields] OR "DIDP"[All Fields] OR "26761-40-0"[All Fields] or "68515-49-1"[All Fields]))	0
PubMed	DINP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("diisononyl phthalate"[All Fields] OR "DINP"[All Fields] OR "28553-12-0"[All Fields] or "68515-48-1"[All Fields]))	0
PubMed	DnOP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("di-n-octyl phthalate"[All Fields] OR "DnOP"[All Fields] OR "117-84-0"[All Fields])	0
PubMed	DPENP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("di-n-pentyl phthalate"[All Fields] OR "131-18-0"[All Fields])	0
PubMed	Lead	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Lead"[All Fields])	2
PubMed	Mercury	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Mercury"[All Fields])	1
PubMed	Selenium	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Selenium"[All Fields])	0
Scopus	Antimony	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Antimony"))	1
Scopus	Arsenic	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Arsenic"))	0
Scopus	Barium	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Barium"))	1
Scopus	BBP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("benzyl butyl phthalate" or "BBP" or "85-68-7"))	0
Scopus	Cadmium	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Cadmium"))	2
Scopus	Chromium	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Chromium"))	12
Scopus	DBP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("dibutyl phthalate" or "DBP" or "84-74-2"))	0
Scopus	DCHP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("dicyclohexyl phthalate" or "DCHP" or "84-61-7"))	0
Scopus	DEHP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("di-(2-ethylhexl) phthalate" or "DEHP" or "117-81-7"))	0
Scopus	DHEXP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("di-n-hexyl phthalate" or "DHEXP" or "84-75-3"))	0
Scopus	DIBP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("diisobutyl phthalate" or "DIBP" or "84-69-5"))	0

Scopus	DIDP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("diisodecyl phthalate" or "DIDP" or "26761-40-0" or "68515-49-1"))	0
Scopus	DINP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("diisononyl phthalate" or "DINP" or "28553-12-0" or "68515-48-1"))	0
Scopus	DnOP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("di-n-octyl phthalate" or "DnOP" or "117-84-0"))	0
Scopus	DPENP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("di-n-pentyl phthalate" or "DPENP" or "131-18-0"))	0
Scopus	Lead	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Lead"))	77
Scopus	Mercury	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Mercury"))	6
Scopus	Selenium	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Selenium"))	0
Toxline	Particleboard	"Particleboard" OR "Particle-board" OR "Particle board"	194
WOS	Antimony	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Antimony"))	2
WOS	Arsenic	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Arsenic"))	14
WOS	Barium	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Barium"))	3
WOS	BBP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("benzyl butyl phthalate" or "BBP" or "85-68-7"))	0
WOS	Cadmium	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Cadmium"))	3
WOS	Chromium	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Chromium"))	25
WOS	DBP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("dibutyl phthalate" or "DBP" or "84-74-2"))	1
WOS	DCHP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("dicyclohexyl phthalate" or "DCHP" or "84-61-7"))	7
WOS	DEHP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("di-(2-ethylhexl) phthalate" or "DEHP" or "117-81-7"))	0
WOS	DHEXP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("di-n-hexyl phthalate" or "DHEXP" or "84-75-3"))	0
WOS	DIBP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("diisobutyl phthalate" or "DIBP" or "84-69-5"))	0
WOS	DIDP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("diisodecyl phthalate" or "DIDP" or "26761-40-0" or "68515-49-1"))	0
WOS	DINP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("diisononyl phthalate" or "DINP" or "28553-12-0" or "68515-48-1"))	0
WOS	DnOP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("di-n-octyl phthalate" or "DnOP" or "117-84-0"))	0
WOS	DPENP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("di-n-pentyl phthalate" or "DPENP" or "131-18-0"))	0
WOS	Lead	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Lead"))	38

WOS	Mercury	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Mercury"))	7
WOS	Selenium	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Selenium"))	1

1.4.2.1 Particleboard Search Summary

Keyword	PubMed	Scopus	Toxline	WOS	Keyword Total	Duplicates Removed
Antimony	0	1	0	2	3	5
Arsenic	1	0	0	14	15	14
Barium	0	1	0	3	4	4
BBP	0	0	0	0	0	0
Cadmium	1	2	0	3	6	4
Chromium	0	12	0	25	37	31
DBP	0	0	0	1	1	1
DCHP	0	0	0	7	7	7
DEHP	23	0	0	0	23	23
DHEXP	0	0	0	0	0	0
DIBP	0	0	0	0	0	0
DIDP	0	0	0	0	0	0
DINP	0	0	0	0	0	0
DnOP	0	0	0	0	0	0
DPENP	0	0	0	0	0	0
Lead	2	77	0	38	117	102
Mercury	1	6	0	7	14	10
Particleboard	0	0	194	0	194	194
Selenium	0	0	0	1	1	1
Database Total	**28**	**99**	**194**	**101**	**422**	

1.4.3 Plywood

Database	Keyword	Query	Results
PubMed	Antimony	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Antimony"[All Fields] OR "7440-36-0"[All Fields])	0
PubMed	Arsenic	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Arsenic"[All Fields] OR "7440-38-2"[All Fields])	3

PubMed	Barium	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Barium"[All Fields] OR "7440-39-3"[All Fields])	0
PubMed	BBP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("benzyl butyl phthalate"[All Fields] OR "BBP"[All Fields] OR "85-68-7"[All Fields])	0
PubMed	Cadmium	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Cadmium"[All Fields] OR "7440-43-9"[All Fields])	0
PubMed	Chromium	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Chromium"[All Fields] OR "7440-47-3"[All Fields])	1
PubMed	DBP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("dibutyl phthalate"[All Fields] OR "DBP"[All Fields] OR "84-74-2"[All Fields])	0
PubMed	DCHP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("dicyclohexyl phthalate"[All Fields] OR "DCHP"[All Fields] OR "84-61-7"[All Fields])	0
PubMed	DEHP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ((("diagnosis"[Subheading] OR "diagnosis"[All Fields] OR "di"[All Fields]) AND 2-ethylhexl[All Fields] AND ("phthalic acid"[Supplementary Concept] OR "phthalic acid"[All Fields] OR "phthalate"[All Fields])) OR "DEHP"[All Fields] OR "117-81-7"[All Fields])	0
PubMed	DHEXP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("di-n-hexyl phthalate"[All Fields] OR "84-75-3"[All Fields])	0
PubMed	DIBP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("diisobutyl phthalate"[All Fields] OR "DIBP"[All Fields] OR "84-69-5"[All Fields])	0
PubMed	DIDP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("diisodecyl phthalate"[All Fields] OR "DIDP"[All Fields] OR "26761-40-0"[All Fields] OR "68515-49-1"[All Fields])	0
PubMed	DINP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("diisononyl phthalate"[All Fields] OR "DINP"[All Fields] OR "28553-12-0"[All Fields] OR "68515-48-0"[All Fields])	0

PubMed	DnOP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("di-n-octyl phthalate "[All Fields] OR "DnOP"[All Fields] OR "117-84-0"[All Fields])	0
PubMed	DPENP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("di-n-pentyl phthalate "[All Fields] OR "131-18-0"[All Fields])	0
PubMed	Lead	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Lead "[All Fields] OR "7439-92-1"[All Fields])	4
PubMed	Mercury	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Mercury"[All Fields] OR "7439-97-6"[All Fields])	0
PubMed	Selenium	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Selenium"[All Fields] OR "7782-49-2"[All Fields])	0
Scopus	Antimony	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Antimony" or "7440-36-0"))	0
Scopus	Arsenic	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Arsenic" or "7440-38-2"))	7
Scopus	Barium	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Barium" or "7440-39-3"))	5
Scopus	BBP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("benzyl butyl phthalate" or "BBP" or "85-68-7"))	2
Scopus	Cadmium	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Cadmium" or "7440-43-9"))	6
Scopus	Chromium	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Chromium" or "7440-47-3"))	10
Scopus	DBP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("di-2-ethylhexl phthalate" or "DEHP" or "117-81-7"))	0
Scopus	DCHP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("di-n-hexyl phthalate" or "DHEXP" or "84-75-3"))	0
Scopus	DEHP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("di-n-octyl phthalate" or "DnOP" or "117-84-0"))	0
Scopus	DHEXP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("di-n-pentyl phthalate" or "DPENP" or "131-18-0"))	0
Scopus	DIBP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("dibutyl phthalate" or "DBP" or "84-74-2"))	1
Scopus	DIDP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("dicyclohexyl phthalate" or "DCHP" or "84-61-7"))	0

Scopus	DINP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("diisobutyl phthalate" or "DIBP" or "84-69-5"))	0
Scopus	DnOP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("diisodecyl phthalate" or "DIDP" or "26761-40-0" or "68515-49-1"))	0
Scopus	DPENP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("diisononyl phthalate" or "DINP" or "28553-12-0" or "68515-48-0"))	0
Scopus	Lead	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Lead" or "7439-92-1"))	269
Scopus	Mercury	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Mercury" or "7439-97-6"))	5
Scopus	Selenium	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Selenium" or "7782-49-2"))	1
Toxline	Plywood	"Plywood" OR "Laminated Veneer" OR "Wood-based panel" or "Composite panel"	517
WOS	Antimony	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Antimony" or "7440-36-0"))	8
WOS	Arsenic	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Arsenic" or "7440-38-2"))	12
WOS	Barium	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Barium" or "7440-39-3"))	23
WOS	BBP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("benzyl butyl phthalate" or "BBP" or "85-68-7"))	2
WOS	Cadmium	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Cadmium" or "7440-43-9"))	7
WOS	Chromium	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Chromium" or "7440-47-3"))	33
WOS	DBP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("dibutyl phthalate" or "DBP" or "84-74-2"))	10
WOS	DCHP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("dicyclohexyl phthalate" or "DCHP" or "84-61-7"))	8
WOS	DEHP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("di-2-ethylhexl phthalate" or "DEHP" or "117-81-7"))	0
WOS	DHEXP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("di-n-hexyl phthalate" or "DHEXP" or "84-75-3"))	0
WOS	DIBP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("diisobutyl phthalate" or "DIBP" or "84-69-5"))	0
WOS	DIDP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("diisodecyl phthalate" or "DIDP" or "26761-40-0" or "68515-49-1"))	0

WOS	DINP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("diisononyl phthalate" or "DINP" or "28553-12-0" or "68515-48-0"))	0
WOS	DnOP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("di-n-octyl phthalate" or "DnOP" or "117-84-0"))	0
WOS	DPENP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("di-n-pentyl phthalate" or "DPENP" or "131-18-0"))	0
WOS	Lead	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Lead" or "7439-92-1"))	186
WOS	Mercury	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Mercury" or "7439-97-6"))	10
WOS	Selenium	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Selenium" or "7782-49-2"))	2

1.4.3.1 Plywood Search Summary

Keyword	**PubMed**	**Scopus**	**Toxline**	**WOS**	**Keyword Total**	**Duplicates Removed**
Antimony	0	0	0	8	8	8
Arsenic	3	7	0	12	22	20
Barium	0	5	0	23	28	23
BBP	0	2	0	2	4	7
Cadmium	0	6	0	7	13	7
Chromium	1	10	0	33	44	44
DBP	0	0	0	10	10	10
DCHP	0	0	0	8	8	8
DEHP	0	0	0	0	0	0
DHEXP	0	0	0	0	0	0
DIBP	0	1	0	0	1	0
DIDP	0	0	0	0	0	0
DINP	0	0	0	0	0	0
DnOP	0	0	0	0	0	0
DPENP	0	0	0	0	0	0
Lead	4	269	0	186	459	406
Mercury	0	5	0	10	15	15
Plywood, etc.	0	0	517	0	517	466
Selenium	0	1	0	2	3	3
Database Total	**8**	**306**	**517**	**301**	**1132**	

1.5 Key Words and Search Results for Concentrations in Adhesive Formulations and Base Resins

1.5.1 MDI

Database	Keyword	Query	Results
Pubmed	BBP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“benzyl butyl phthalate” OR “BBP” OR “85-68-7”)	0
Pubmed	DBP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”)	2
Pubmed	DCHP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“dicyclohexyl phthalate” OR “DCHP” OR “84-61-7”)	0
Pubmed	DEHP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	3
Pubmed	DHEXP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”)	0
Pubmed	DIBP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”)	0
Pubmed	DIDP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”)	0
Pubmed	DINP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”)	0
Pubmed	DnOP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”)	0
Pubmed	DPENP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”)	0
Pubmed	Antimony	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“antimony” OR “Sb” OR “7440-36-0”)	1
Pubmed	Arsenic	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“arsenic” OR “As” OR “7440-38-2”)	4
Pubmed	Barium	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“barium” OR “Ba” OR “7440-39-3”)	7
Pubmed	Cadmium	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“cadmium” OR “Cd” OR “7440-43-9”)	9
Pubmed	Chromium	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“chromium” OR “Cr” OR “7440-47-3”)	1
Pubmed	Lead	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“lead” OR “Pb” OR “7439-92-1”)	81
Pubmed	Mercury	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“mercury” OR “Hg” OR “7439-97-6”)	14
Pubmed	Selenium	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“selenium” OR “Se” OR “7782-49-2”)	66
Scopus	BBP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("benzyl butyl phthalate" OR "BBP" OR "85-68-7")))	2
Scopus	DBP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("dibutyl phthalate" OR "DBP" OR "84-74-2")))	16
Scopus	DCHP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")))	0

Scopus	DEHP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")))	17
Scopus	DHEXP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")))	0
Scopus	DIBP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("diisobutyl phthalate" OR "DIBP" OR "84-69-5")))	1
Scopus	DIDP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")))	1
Scopus	DINP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")))	2
Scopus	DnOP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")))	2
Scopus	DPENP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")))	0
Scopus	Antimony	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("antimony" OR "Sb" OR "7440-36-0")))	62
Scopus	Arsenic	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("arsenic" OR "7440-38-2")))	45
Scopus	Barium	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("barium" OR "7440-39-3")))	32
Scopus	Cadmium	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("cadmium" OR "7440-43-9")))	77
Scopus	Chromium	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("chromium" OR "7440-47-3")))	92
Scopus	Lead	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("lead" OR "7439-92-1")))	888*
Scopus	Lead	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL ((("lead" AND "metal") OR "7439-92-1")))	153
Scopus	Lead	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("7439-92-1")))	28
Scopus	Mercury	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("mercury" OR "Hg" OR "7439-97-6")))	138
Scopus	Selenium	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("selenium" OR "7782-49-2")))	40
WOS	BBP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (benzyl butyl phthalate OR BBP OR 85-68-7))	1
WOS	DBP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”))	2
WOS	DCHP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7))	0
WOS	DEHP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”))	3
WOS	DHEXP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3))	0
WOS	DIBP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	1
WOS	DIDP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1))	0

WOS	DINP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0))	0
WOS	DnOP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-n-octyl phthalate OR DnOP OR 117-84-0))	0
WOS	DPENP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0))	0
WOS	Antimony	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND ("antimony" OR "Sb" OR "7440-36-0"))	5
WOS	Arsenic	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND ("arsenic" OR "7440-38-2"))	6
WOS	Barium	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND ("barium" OR "7440-39-3"))	1
WOS	Cadmium	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND ("cadmium" OR "7440-43-9"))	3
WOS	Chromium	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND ("chromium" OR "7440-47-3"))	3
WOS	Lead	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND ("lead" OR "7439-92-1"))	141
WOS	Mercury	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND ("mercury" OR "Hg" OR "7439-97-6"))	16
WOS	Selenium	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND ("selenium" OR "7782-49-2"))	2
Toxline	BBP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (benzyl butyl phthalate OR BBP OR 85-68-7)	2
Toxline	DBP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (dibutyl phthalate OR DBP OR 84-74-2)	9
Toxline	DCHP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7)	0
Toxline	DEHP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-2-ethylhexyl phthalate OR DEHP OR 117-81-7)	11
Toxline	DHEXP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3)	0
Toxline	DIBP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (diisobutyl phthalate OR DIBP OR 84-69-5)	0
Toxline	DIDP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1)	2
Toxline	DINP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0)	0
Toxline	DnOP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-n-octyl phthalate OR DnOP OR 117-84-0)	11
Toxline	DPENP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0)	0
Toxline	Antimony	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (antimony OR Sb OR 7440-36-0)	10
Toxline	Arsenic	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (arsenic OR 7440-38-2)	10
Toxline	Barium	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (barium OR 7440-39-3)	5
Toxline	Cadmium	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (cadmium OR Cd OR 7440-43-9)	27
Toxline	Chromium	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (chromium OR 7440-47-3)	11

Toxline	Lead	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (lead OR Pb OR 7439-92-1)	32
Toxline	Mercury	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (mercury OR Hg OR 7439-97-6)	16
Toxline	Selenium	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (selenium OR Se OR 7782-49-2)	10

*search further refined

1.5.2 Melamine

Database	Keyword	Query	Results
Pubmed	BBP	(“Melamine”) AND (“benzyl butyl phthalate” OR “BBP” OR “85-68-7”)	0
Pubmed	DBP	(“Melamine”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”)	1
Pubmed	DCHP	(“Melamine”) AND (“dicyclohexyl phthalate” OR “DCHP” OR “84-61-7”)	0
Pubmed	DEHP	(“Melamine”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	2
Pubmed	DHEXP	(“Melamine”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”)	0
Pubmed	DIBP	(“Melamine”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”)	0
Pubmed	DIDP	(“Melamine”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”)	0
Pubmed	DINP	(“Melamine”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”)	0
Pubmed	DnOP	(“Melamine”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”)	0
Pubmed	DPENP	(“Melamine”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”)	0
Pubmed	Antimony	(“Melamine”) AND (“antimony” OR “Sb” OR “7440-36-0”)	8
Pubmed	Arsenic	(“Melamine”) AND (“arsenic” OR “As” OR “7440-38-2”)	3
Pubmed	Barium	(“Melamine”) AND (“barium” OR “Ba” OR “7440-39-3”)	4
Pubmed	Cadmium	(“Melamine”) AND (“cadmium” OR “Cd” OR “7440-43-9”)	25
Pubmed	Chromium	(“Melamine”) AND (“chromium” OR “Cr” OR “7440-47-3”)	12
Pubmed	Lead	(“Melamine”) AND (“lead” OR “Pb” OR “7439-92-1”)	52
Pubmed	Mercury	(“Melamine”) AND (“mercury” OR “Hg” OR “7439-97-6”)	14
Pubmed	Selenium	(“Melamine”) AND (“selenium” OR “Se” OR “7782-49-2”)	29
Scopus	BBP	("Melamine") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	10
Scopus	DBP	("Melamine") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	52
Scopus	DCHP	("Melamine") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	5
Scopus	DEHP	("Melamine") AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	70
Scopus	DHEXP	("Melamine") AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	1
Scopus	DIBP	("Melamine") AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	4
Scopus	DIDP	("Melamine") AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	3
Scopus	DINP	("Melamine") AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	12
Scopus	DnOP	("Melamine") AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	8
Scopus	DPENP	("Melamine") AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	2
Scopus	Antimony	("Melamine") AND ("antimony" OR "Sb" OR "7440-36-0")	532*
Scopus	Antimony	(("Melamine") AND ("antimony" OR "7440-36-0") NOT wastewater NOT asthma NOT remediation)	313
Scopus	Arsenic	("Melamine") AND ("arsenic" OR "7440-38-2")	511*
Scopus	Arsenic	("Melamine") AND ("arsenic" OR "7440-38-2") AND NOT chelate AND NOT wastewater AND NOT remediation AND NOT asthma	335

Scopus	Barium	("Melamine") AND ("barium" OR "7440-39-3")	211*
Scopus	Barium	(ALL (("Melamine") AND ("barium" OR "7440-39-3")) AND NOT ALL (chelate) AND NOT ALL (remediation) AND NOT ALL (wastewater) AND NOT ALL (asthma))	175
Scopus	Cadmium	(ALL (("Melamine") AND ("cadmium" OR "7440-43-9")) AND NOT ALL (chelate) AND NOT ALL (remediation) AND NOT ALL (wastewater) AND NOT ALL (asthma))	810
Scopus	Chromium	(ALL (("Melamine") AND ("chromium" OR "7440-47-3")) AND NOT ALL (asthma) AND NOT ALL (chelate) AND NOT ALL (wastewater) AND NOT ALL (remediation))	599
Scopus	Lead	("Melamine") AND ("lead" OR "7439-92-1")	2519*
Scopus	Lead	("Melamine") AND (("lead" AND "metal") OR "7439-92-1")	1607*
Scopus	Lead	("Melamine") AND ("7439-92-1")	90
Scopus	Lead	(ALL (("Melamine") AND (("lead" AND "metal") OR "7439-92-1")) AND NOT ALL (asthma) AND NOT ALL (remediation) AND NOT ALL (wastewater) AND NOT ALL (chelate))	1166
Scopus	Mercury	("Melamine") AND ("mercury" OR "Hg" OR "7439-97-6")	1561*
Scopus	Mercury	ALL (("Melamine") AND ("mercury" OR "7439-97-6")) AND NOT ALL (chelate) AND NOT ALL (remediation) AND NOT ALL (asthma) AND NOT ALL (wastewater)	978
Scopus	Selenium	("Melamine") AND ("selenium" OR "7782-49-2")	313*
Scopus	Selenium	(ALL (("Melamine") AND ("selenium" OR "7782-49-2")) AND NOT ALL (asthma) AND NOT ALL (wastewater) AND NOT ALL (remediation) AND NOT ALL (chelate))	226
WOS	BBP	TS=((Melamine) AND (benzyl butyl phthalate OR BBP OR 85-68-7))	7
WOS	DBP	TS=((Melamine) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”))	101
WOS	DCHP	TS=((Melamine) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7))	4
WOS	DEHP	TS=((Melamine) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”))	7
WOS	DHEXP	TS=((Melamine) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3))	0
WOS	DIBP	TS=((Melamine) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	1
WOS	DIDP	TS=((Melamine) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1))	4
WOS	DINP	TS=((Melamine) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0))	8
WOS	DnOP	TS=((Melamine) AND (di-n-octyl phthalate OR DnOP OR 117-84-0))	1
WOS	DPENP	TS=((Melamine) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0))	0
WOS	Antimony	TS=((Melamine) AND (“antimony” OR “7440-36-0”))	396*
WOS	Antimony	TS=((Melamine) AND (“antimony” OR “7440-36-0”)) NOT TS=(wastewater) NOT TS=(asthma) NOT TS=(remediation) NOT TS=(chelate)	392
WOS	Arsenic	TS=((Melamine) AND (“arsenic” OR “7440-38-2”))	22
WOS	Barium	TS=((Melamine) AND (“barium” OR “7440-39-3”))	343*
WOS	Barium	TS=((Melamine) AND (“barium” OR “7440-39-3”)) NOT TS=(asthma) NOT TS=(chelate) NOT TS=(remediation) NOT TS=(wastewater)	343
WOS	Cadmium	TS=((Melamine) AND (“cadmium” OR “7440-43-9”))	88
WOS	Chromium	TS=((Melamine) AND (“chromium” OR “7440-47-3”))	260*
WOS	Chromium	TS=((Melamine) AND (“chromium” OR “7440-47-3”)) NOT TS=(chelate) NOT TS=(asthma) NOT TS=(remediation) NOT TS=(wastewater)	255
WOS	Lead	TS=((Melamine) AND (“lead” OR “7439-92-1”))	445*
WOS	Lead	TS=((Melamine) AND (“lead” OR “7439-92-1”)) NOT TS=(wastewater) NOT TS=(asthma) NOT TS=(chelate) NOT TS=(remediation)	433
WOS	Mercury	TS=((Melamine) AND (“mercury” OR “Hg” OR “7439-97-6”))	133
WOS	Selenium	TS=((Melamine) AND (“selenium” OR “7782-49-2”))	32

Toxline	BBP	(Melamine) AND (benzyl butyl phthalate OR BBP OR 85-68-7)	32
Toxline	DBP	(Melamine) AND (dibutyl phthalate OR DBP OR 84-74-2)	0
Toxline	DCHP	(Melamine) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7)	0
Toxline	DEHP	(Melamine) AND (di-2-ethylhexyl phthalate OR DEHP OR 117-81-7)	39
Toxline	DHEXP	(Melamine) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3)	0
Toxline	DIBP	(Melamine) AND (diisobutyl phthalate OR DIBP OR 84-69-5)	0
Toxline	DIDP	(Melamine) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1)	0
Toxline	DINP	(Melamine) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0)	0
Toxline	DnOP	(Melamine) AND (di-n-octyl phthalate OR DnOP OR 117-84-0)	37
Toxline	DPENP	(Melamine) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0)	0
Toxline	Antimony	(Melamine) AND (antimony OR Sb OR 7440-36-0)	1
Toxline	Arsenic	(Melamine) AND (arsenic OR 7440-38-2)	5
Toxline	Barium	(Melamine) AND (barium OR 7440-39-3)	1
Toxline	Cadmium	(Melamine) AND (cadmium OR Cd OR 7440-43-9)	21
Toxline	Chromium	(Melamine) AND (chromium OR 7440-47-3)	7
Toxline	Lead	(Melamine) AND (lead OR Pb OR 7439-92-1)	24
Toxline	Mercury	(Melamine) AND (mercury OR Hg OR 7439-97-6)	2
Toxline	Selenium	(Melamine) AND (selenium OR Se OR 7782-49-2)	8

*search further refined

1.5.3 Phenol Formaldehyde

Database	Keyword	Search String	Hits
Pubmed	BBP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“benzyl butyl phthalate” OR “BBP” OR “85-68-7”)	0
Pubmed	DBP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”)	0
Pubmed	DCHP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“dicyclohexyl phthalate” OR “DCHP” OR “84-61-7”)	0
Pubmed	DEHP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	1
Pubmed	DHEXP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”)	0
Pubmed	DIBP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”)	0
Pubmed	DIDP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”)	0
Pubmed	DINP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”)	0
Pubmed	DnOP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”)	0
Pubmed	DPENP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”)	0
Pubmed	Antimony	(“Phenol formaldehyde” OR “9003-35-4”) AND (“antimony” OR “Sb” OR “7440-36-0”)	1
Pubmed	Arsenic	(“Phenol formaldehyde” OR “9003-35-4”) AND (“arsenic” OR “As” OR “7440-38-2”)	1
Pubmed	Barium	(“Phenol formaldehyde” OR “9003-35-4”) AND (“barium” OR “Ba” OR “7440-39-3”)	2

Pubmed	Cadmium	(“Phenol formaldehyde” OR “9003-35-4”) AND (“cadmium” OR “Cd” OR “7440-43-9”)	4
Pubmed	Chromium	(“Phenol formaldehyde” OR “9003-35-4”) AND (“chromium” OR “Cr” OR “7440-47-3”)	2
Pubmed	Lead	(“Phenol formaldehyde” OR “9003-35-4”) AND (“lead” OR “Pb” OR “7439-92-1”)	4
Pubmed	Mercury	(“Phenol formaldehyde” OR “9003-35-4”) AND (“mercury” OR “Hg” OR “7439-97-6”)	3
Pubmed	Selenium	(“Phenol formaldehyde” OR “9003-35-4”) AND (“selenium” OR “Se” OR “7782-49-2”)	2
Scopus	BBP	("Phenol formaldehyde" OR "9003-35-4") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	1
Scopus	DBP	("Phenol formaldehyde" OR "9003-35-4") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	10
Scopus	DCHP	("Phenol formaldehyde" OR "9003-35-4") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	0
Scopus	DEHP	("Phenol formaldehyde" OR "9003-35-4") AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	7
Scopus	DHEXP	("Phenol formaldehyde" OR "9003-35-4") AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	0
Scopus	DIBP	("Phenol formaldehyde" OR "9003-35-4") AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	0
Scopus	DIDP	("Phenol formaldehyde" OR "9003-35-4") AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	1
Scopus	DINP	("Phenol formaldehyde" OR "9003-35-4") AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	0
Scopus	DnOP	("Phenol formaldehyde" OR "9003-35-4") AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	0
Scopus	DPENP	("Phenol formaldehyde" OR "9003-35-4") AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	0
Scopus	Antimony	("Phenol formaldehyde" OR "9003-35-4") AND ("antimony" OR "Sb" OR "7440-36-0")	130
Scopus	Arsenic	("Phenol formaldehyde" OR "9003-35-4") AND ("arsenic" OR "7440-38-2")	107
Scopus	Barium	("Phenol formaldehyde" OR "9003-35-4") AND ("barium" OR "7440-39-3")	113
Scopus	Cadmium	("Phenol formaldehyde" OR "9003-35-4") AND ("cadmium" OR "7440-43-9")	252
Scopus	Chromium	("Phenol formaldehyde" OR "9003-35-4") AND ("chromium" OR "7440-47-3")	343
Scopus	Lead	("Phenol formaldehyde" OR "9003-35-4") AND ("lead" OR "7439-92-1")	569*
Scopus	Lead	("Phenol formaldehyde" OR "9003-35-4") AND (("lead" AND "metal") OR "7439-92-1")	310
Scopus	Lead	("Phenol formaldehyde" OR "9003-35-4") AND ("7439-92-1")	15
Scopus	Mercury	("Phenol formaldehyde" OR "9003-35-4") AND ("mercury" OR "Hg" OR "7439-97-6")	248
Scopus	Selenium	("Phenol formaldehyde" OR "9003-35-4") AND ("selenium" OR "7782-49-2")	61
WOS	BBP	TS=((Phenol formaldehyde OR 9003-35-4) AND (benzyl butyl phthalate OR BBP OR 85-68-7))	1
WOS	DBP	TS=((Phenol formaldehyde OR 9003-35-4) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”))	1
WOS	DCHP	TS=((Phenol formaldehyde OR 9003-35-4) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7))	0

WOS	DEHP	TS=((Phenol formaldehyde OR 9003-35-4) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”))	0
WOS	DHEXP	TS=((Phenol formaldehyde OR 9003-35-4) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3))	0
WOS	DIBP	TS=((Phenol formaldehyde OR 9003-35-4) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	0
WOS	DIDP	TS=((Phenol formaldehyde OR 9003-35-4) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1))	0
WOS	DINP	TS=((Phenol formaldehyde OR 9003-35-4) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0))	0
WOS	DnOP	TS=((Phenol formaldehyde OR 9003-35-4) AND (di-n-octyl phthalate OR DnOP OR 117-84-0))	0
WOS	DPENP	TS=((Phenol formaldehyde OR 9003-35-4) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0))	0
WOS	Antimony	TS=((Phenol formaldehyde OR 9003-35-4) AND (“antimony” OR “Sb” OR “7440-36-0”))	6
WOS	Arsenic	TS=((Phenol formaldehyde OR 9003-35-4) AND (“arsenic” OR “7440-38-2”))	10
WOS	Barium	TS=((Phenol formaldehyde OR 9003-35-4) AND (“barium” OR “7440-39-3”))	10
WOS	Cadmium	TS=((Phenol formaldehyde OR 9003-35-4) AND (“cadmium” OR “7440-43-9”))	10
WOS	Chromium	TS=((Phenol formaldehyde OR 9003-35-4) AND (“chromium” OR “7440-47-3”))	25
WOS	Lead	TS=((Phenol formaldehyde OR 9003-35-4) AND (“lead” OR “7439-92-1”))	64
WOS	Mercury	TS=((Phenol formaldehyde OR 9003-35-4) AND (“mercury” OR “Hg” OR “7439-97-6”))	25
WOS	Selenium	TS=((Phenol formaldehyde OR 9003-35-4) AND (“selenium” OR “7782-49-2”))	0
Toxline	BBP	(Phenol formaldehyde OR 9003-35-4) AND (benzyl butyl phthalate OR BBP OR 85-68-7)	9
Toxline	DBP	(Phenol formaldehyde OR 9003-35-4) AND (dibutyl phthalate OR DBP OR 84-74-2)	27
Toxline	DCHP	(Phenol formaldehyde OR 9003-35-4) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7)	0
Toxline	DEHP	(Phenol formaldehyde OR 9003-35-4) AND (di-2-ethylhexyl phthalate OR DEHP OR 117-81-7)	29
Toxline	DHEXP	(Phenol formaldehyde OR 9003-35-4) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3)	0
Toxline	DIBP	(Phenol formaldehyde OR 9003-35-4) AND (diisobutyl phthalate OR DIBP OR 84-69-5)	5
Toxline	DIDP	(Phenol formaldehyde OR 9003-35-4) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1)	2
Toxline	DINP	(Phenol formaldehyde OR 9003-35-4) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0)	0
Toxline	DnOP	(Phenol formaldehyde OR 9003-35-4) AND (di-n-octyl phthalate OR DnOP OR 117-84-0)	34
Toxline	DPENP	(Phenol formaldehyde OR 9003-35-4) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0)	0
Toxline	Antimony	(Phenol formaldehyde OR 9003-35-4) AND (antimony OR Sb OR 7440-36-0)	24
Toxline	Arsenic	(Phenol formaldehyde OR 9003-35-4) AND (arsenic OR 7440-38-2)	52
Toxline	Barium	(Phenol formaldehyde OR 9003-35-4) AND (barium OR 7440-39-3)	13
Toxline	Cadmium	(Phenol formaldehyde OR 9003-35-4) AND (cadmium OR Cd OR 7440-43-9)	77

Toxline	Chromium	(Phenol formaldehyde OR 9003-35-4) AND (chromium OR 7440-47-3)	66
Toxline	Lead	(Phenol formaldehyde OR 9003-35-4) AND (lead OR Pb OR 7439-92-1)	111
Toxline	Mercury	(Phenol formaldehyde OR 9003-35-4) AND (mercury OR Hg OR 7439-97-6)	73
Toxline	Selenium	(Phenol formaldehyde OR 9003-35-4) AND (selenium OR Se OR 7782-49-2)	34

*search further refined

1.5.4 pMDI

Database	Keyword	Query	Results
Pubmed	BBP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	0
Pubmed	DBP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	0
Pubmed	DCHP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	0
Pubmed	DEHP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	0
Pubmed	DHEXP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	0
Pubmed	DIBP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	0
Pubmed	DIDP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	0
Pubmed	DINP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	0
Pubmed	DnOP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	0
Pubmed	DPENP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	0
Pubmed	Antimony	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("antimony" OR "Sb" OR "7440-36-0")	5
Pubmed	Arsenic	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("arsenic" OR "As" OR "7440-38-2")	0
Pubmed	Barium	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("barium" OR "Ba" OR "7440-39-3")	1
Pubmed	Cadmium	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("cadmium" OR "Cd" OR "7440-43-9")	6
Pubmed	Chromium	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("chromium" OR "Cr" OR "7440-47-3")	0
Pubmed	Lead	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("lead" OR "Pb" OR "7439-92-1")	14
Pubmed	Mercury	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("mercury" OR "Hg" OR "7439-97-6")	0
Pubmed	Selenium	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("selenium" OR "Se" OR "7782-49-2")	11
Scopus	BBP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	1

Scopus	DBP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	0
Scopus	DCHP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	0
Scopus	DEHP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	1
Scopus	DHEXP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	0
Scopus	DIBP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	0
Scopus	DIDP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	0
Scopus	DINP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	0
Scopus	DnOP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	0
Scopus	DPENP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	0
Scopus	Antimony	("Polymerized methylene-diphenyl-diisocyanate" OR ("pMDI" NOT inhale) OR "26447-40-5") AND ("antimony" OR "Sb" OR "7440-36-0")	0
Scopus	Arsenic	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("arsenic" OR "As" OR "7440-38-2")	1
Scopus	Barium	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("barium" OR "Ba" OR "7440-39-3")	0
Scopus	Cadmium	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("cadmium" OR "Cd" OR "7440-43-9")	0
Scopus	Chromium	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("chromium" OR "Cr" OR "7440-47-3")	0
Scopus	Lead	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("lead" OR "Pb" OR "7439-92-1")	0
Scopus	Lead	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND (("lead" AND metal) OR "7439-92-1")	0
Scopus	Lead	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("7439-92-1")	0
Scopus	Mercury	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("mercury" OR "Hg" OR "7439-97-6")	0
Scopus	Selenium	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("selenium" OR "Se" OR "7782-49-2")	0
WOS	BBP	TS=(("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7"))	1
WOS	DBP	TS=(("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2"))	0
WOS	DCHP	TS=(("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7"))	0

WOS	DEHP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	0
WOS	DHEXP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”))	0
WOS	DIBP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	0
WOS	DIDP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”))	0
WOS	DINP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”))	0
WOS	DnOP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”))	0
WOS	DPENP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”))	0
WOS	Antimony	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“antimony” OR “Sb” OR “7440-36-0”))	4
WOS	Arsenic	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“arsenic” OR “7440-38-2”))	1
WOS	Barium	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“barium” OR “Ba” OR “7440-39-3”))	2
WOS	Cadmium	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“cadmium” OR “Cd” OR “7440-43-9”))	10
WOS	Chromium	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“chromium” OR “Cr” OR “7440-47-3”))	1
WOS	Lead	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“lead” OR “Pb” OR “7439-92-1”))	25
WOS	Mercury	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“mercury” OR “Hg” OR “7439-97-6”))	0
WOS	Selenium	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“selenium” OR “Se” OR “7782-49-2”))	3
Toxline	BBP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“benzyl butyl phthalate” OR “BBP” OR “85-68-7”)	3
Toxline	DBP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”)	1
Toxline	DCHP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“dicyclohexyl phthalate” OR “DCHP” OR “84-61-7”)	6
Toxline	DEHP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	1
Toxline	DHEXP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”)	7
Toxline	DIBP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”)	2

Toxline	DIDP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”)	1
Toxline	DINP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”)	0
Toxline	DnOP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”)	2
Toxline	DPENP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”)	2
Toxline	Antimony	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“antimony” OR “Sb” OR “7440-36-0”)	1
Toxline	Arsenic	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“arsenic” OR “As” OR “7440-38-2”)	5
Toxline	Barium	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“barium” OR “Ba” OR “7440-39-3”)	2
Toxline	Cadmium	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“cadmium” OR “Cd” OR “7440-43-9”)	5
Toxline	Chromium	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“chromium” OR “Cr” OR “7440-47-3”)	12
Toxline	Lead	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“lead” OR “Pb” OR “7439-92-1”)	5
Toxline	Mercury	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“mercury” OR “Hg” OR “7439-97-6”)	5
Toxline	Selenium	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“selenium” OR “Se” OR “7782-49-2”)	0

1.5.5 Polyvinyl Acetate

Database	Keyword	Query	Results
Pubmed	BBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“benzyl butyl phthalate” OR “BBP” OR “85-68-7”)	2
Pubmed	DBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”)	6
Pubmed	DCHP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“dicyclohexyl phthalate” OR “DCHP” OR “84-61-7”)	0
Pubmed	DEHP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	2
Pubmed	DHEXP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”)	0
Pubmed	DIBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”)	0
Pubmed	DIDP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”)	0
Pubmed	DINP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”)	0
Pubmed	DnOP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”)	0
Pubmed	DPENP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”)	0
Pubmed	Antimony	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“antimony” OR “Sb” OR “7440-36-0”)	8

Pubmed	Arsenic	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“arsenic” OR “As” OR “7440-38-2”)	6
Pubmed	Barium	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“barium” OR “Ba” OR “7440-39-3”)	19
Pubmed	Cadmium	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“cadmium” OR “Cd” OR “7440-43-9”)	77
Pubmed	Chromium	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“chromium” OR “Cr” OR “7440-47-3”)	36
Pubmed	Lead	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“lead” OR “Pb” OR “7439-92-1”)	125
Pubmed	Mercury	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“mercury” OR “Hg” OR “7439-97-6”)	64
Pubmed	Selenium	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“selenium” OR “Se” OR “7782-49-2”)	71
Scopus	BBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	5
Scopus	DBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	122
Scopus	DCHP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	4
Scopus	DEHP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	42
Scopus	DHEXP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	1
Scopus	DIBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	5
Scopus	DIDP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	1
Scopus	DINP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	4
Scopus	DnOP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	3
Scopus	DPENP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	0
Scopus	Antimony	(“polyvinyl acetate” OR “9003-20-7”) AND ("antimony" OR "7440-36-0")	35
Scopus	Arsenic	(“polyvinyl acetate” OR “9003-20-7”) AND ("arsenic" OR "7440-38-2")	33
Scopus	Barium	(“polyvinyl acetate” OR “9003-20-7”) AND ("barium" OR "7440-39-3")	99
Scopus	Cadmium	(“polyvinyl acetate” OR “9003-20-7”) AND ("cadmium" OR "7440-43-9")	94
Scopus	Chromium	(“polyvinyl acetate” OR “9003-20-7”) AND ("chromium" OR "7440-47-3")	104
Scopus	Lead	(“polyvinyl acetate” OR “9003-20-7”) AND ("lead" OR "7439-92-1")	430*
Scopus	Lead	(“polyvinyl acetate” OR “9003-20-7”) AND (("lead" AND "metal") OR "7439-92-1")	145
Scopus	Lead	(“polyvinyl acetate” OR “9003-20-7”) AND ("7439-92-1")	4
Scopus	Mercury	(“polyvinyl acetate” OR “9003-20-7”) AND ("mercury" OR "Hg" OR "7439-97-6")	121
Scopus	Selenium	(“polyvinyl acetate” OR “9003-20-7”) AND ("selenium" OR "7782-49-2")	56
WOS	BBP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (benzyl butyl phthalate OR BBP OR 85-68-7))	2
WOS	DBP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”))	14
WOS	DCHP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7))	1

WOS	DEHP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”))	4
WOS	DHEXP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3))	0
WOS	DIBP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	1
WOS	DIDP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1))	0
WOS	DINP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0))	0
WOS	DnOP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-n-octyl phthalate OR DnOP OR 117-84-0))	1
WOS	DPENP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0))	0
WOS	Antimony	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“antimony” OR “7440-36-0”))	11
WOS	Arsenic	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“arsenic” OR “7440-38-2”))	26
WOS	Barium	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“barium” OR “7440-39-3”))	61
WOS	Cadmium	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“cadmium” OR “7440-43-9”))	127
WOS	Chromium	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“chromium” OR “7440-47-3”))	85
WOS	Lead	TS=((“polyvinyl acetate” OR “9003-20-7”) AND (“lead” OR “7439-92-1”))	21
WOS	Mercury	TS=((“polyvinyl acetate” OR “9003-20-7”) AND (“mercury” OR “7439-97-6”))	9
WOS	Selenium	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“selenium” OR “7782-49-2”))	23
Toxline	BBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (benzyl butyl phthalate OR BBP OR 85-68-7)	4
Toxline	DBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (dibutyl phthalate OR DBP OR 84-74-2)	5
Toxline	DCHP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7)	1
Toxline	DEHP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-2-ethylhexyl phthalate OR DEHP OR 117-81-7)	13
Toxline	DHEXP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3)	0
Toxline	DIBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (diisobutyl phthalate OR DIBP OR 84-69-5)	1
Toxline	DIDP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1)	0
Toxline	DINP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0)	0
Toxline	DnOP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-n-octyl phthalate OR DnOP OR 117-84-0)	2
Toxline	DPENP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0)	0
Toxline	Antimony	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (antimony OR Sb OR 7440-36-0)	4

Toxline	Arsenic	("polyvinyl acetate" OR "PVA" OR "9003-20-7") AND (arsenic OR 7440-38-2)	0
Toxline	Barium	("polyvinyl acetate" OR "PVA" OR "9003-20-7") AND (barium OR 7440-39-3)	1
Toxline	Cadmium	("polyvinyl acetate" OR "PVA" OR "9003-20-7") AND (cadmium OR Cd OR 7440-43-9)	43
Toxline	Chromium	("polyvinyl acetate" OR "PVA" OR "9003-20-7") AND (chromium OR 7440-47-3)	1
Toxline	Lead	("polyvinyl acetate" OR "PVA" OR "9003-20-7") AND (lead OR Pb OR 7439-92-1)	75
Toxline	Mercury	("polyvinyl acetate" OR "PVA" OR "9003-20-7") AND (mercury OR Hg OR 7439-97-6)	5
Toxline	Selenium	("polyvinyl acetate" OR "PVA" OR "9003-20-7") AND (selenium OR Se OR 7782-49-2)	2

*search further refined

1.5.6 Resorcinol

Database	**Keyword**	**Query**	**Results**
Pubmed	BBP	("Resorcinol") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	2
Pubmed	DBP	("Resorcinol") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	6
Pubmed	DCHP	("Resorcinol") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	0
Pubmed	DEHP	("Resorcinol") AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	2
Pubmed	DHEXP	("Resorcinol") AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	0
Pubmed	DIBP	("Resorcinol") AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	0
Pubmed	DIDP	("Resorcinol") AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	3
Pubmed	DINP	("Resorcinol") AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	2
Pubmed	DnOP	("Resorcinol") AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	1
Pubmed	DPENP	("Resorcinol") AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	0
Pubmed	Antimony	("Resorcinol") AND ("antimony" OR "Sb" OR "7440-36-0")	4
Pubmed	Arsenic	("Resorcinol") AND ("arsenic" OR "As" OR "7440-38-2")	3
Pubmed	Barium	("Resorcinol") AND ("barium" OR "Ba" OR "7440-39-3")	5
Pubmed	Cadmium	("Resorcinol") AND ("cadmium" OR "Cd" OR "7440-43-9")	59
Pubmed	Chromium	("Resorcinol") AND ("chromium" OR "Cr" OR "7440-47-3")	14
Pubmed	Lead	("Resorcinol") AND ("lead" OR "Pb" OR "7439-92-1")	70
Pubmed	Mercury	("Resorcinol") AND ("mercury" OR "Hg" OR "7439-97-6")	24
Pubmed	Selenium	("Resorcinol") AND ("selenium" OR "Se" OR "7782-49-2")	29
Scopus	BBP	("Resorcinol") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	10
Scopus	DBP	("Resorcinol") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	115
Scopus	DCHP	("Resorcinol") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	1
Scopus	DEHP	("Resorcinol") AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	34
Scopus	DHEXP	("Resorcinol") AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	0
Scopus	DIBP	("Resorcinol") AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	0

Scopus	DIDP	("Resorcinol") AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	5
Scopus	DINP	("Resorcinol") AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	2
Scopus	DnOP	("Resorcinol") AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	8
Scopus	DPENP	("Resorcinol") AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	0
Scopus	Antimony	("Resorcinol") AND ("antimony" OR "Sb" OR "7440-36-0")	556*
Scopus	Antimony	(("Resorcinol") AND ("antimony" OR "7440-36-0") NOT wastewater NOT asthma NOT remediation)	334
Scopus	Arsenic	("Resorcinol") AND ("arsenic" OR "7440-38-2")	636*
Scopus	Arsenic	("Resorcinol") AND ("arsenic" OR "7440-38-2") AND NOT chelate AND NOT wastewater AND NOT remediation AND NOT asthma	575
Scopus	Barium	("Resorcinol") AND ("barium" OR "7440-39-3")	247
Scopus	Cadmium	("Resorcinol") AND ("cadmium" OR "7440-43-9")	1,964*
Scopus	Cadmium	(ALL ((" Resorcinol") AND ("cadmium" OR "7440-43-9")) AND NOT ALL (chelate) AND NOT ALL (remediation) AND NOT ALL (wastewater) AND NOT ALL (asthma))	1,590
Scopus	Chromium	(ALL ((" Resorcinol ") AND ("chromium" OR "7440-47-3")) AND NOT ALL (asthma) AND NOT ALL (chelate) AND NOT ALL (wastewater) AND NOT ALL (remediation))	1,255
Scopus	Lead	("Resorcinol") AND ("lead" OR "7439-92-1")	3,320*
Scopus	Lead	("Resorcinol") AND (("lead" AND "metal") OR "7439-92-1")	2,109*
Scopus	Lead	("Resorcinol") AND ("7439-92-1")	168
Scopus	Lead	(ALL ((" Resorcinol") AND (("lead" AND "metal") OR "7439-92-1")) AND NOT ALL (asthma) AND NOT ALL (remediation) AND NOT ALL (wastewater) AND NOT ALL (chelate))	1,433
Scopus	Mercury	("Resorcinol") AND ("mercury" OR "Hg" OR "7439-97-6")	1,847*
Scopus	Mercury	ALL ((" Resorcinol") AND ("mercury" OR "7439-97-6")) AND NOT ALL (chelate) AND NOT ALL (remediation) AND NOT ALL (asthma) AND NOT ALL (wastewater)	1,287
Scopus	Selenium	("Resorcinol") AND ("selenium" OR "7782-49-2")	513*
Scopus	Selenium	(ALL ((" Resorcinol") AND ("selenium" OR "7782-49-2")) AND NOT ALL (asthma) AND NOT ALL (wastewater) AND NOT ALL (remediation) AND NOT ALL (chelate))	352
WOS	BBP	TS=((Resorcinol) AND (benzyl butyl phthalate OR BBP OR 85-68-7))	2
WOS	DBP	TS=((Resorcinol) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”))	12
WOS	DCHP	TS=((Resorcinol) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7))	0
WOS	DEHP	TS=((Resorcinol) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”))	2
WOS	DHEXP	TS=((Resorcinol) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3))	0
WOS	DIBP	TS=((Resorcinol) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	0
WOS	DIDP	TS=((Resorcinol) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1))	3
WOS	DINP	TS=((Resorcinol) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0))	2
WOS	DnOP	TS=((Resorcinol) AND (di-n-octyl phthalate OR DnOP OR 117-84-0))	1
WOS	DPENP	TS=((Resorcinol) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0))	0
WOS	Antimony	TS=((Resorcinol) AND (“antimony” OR “7440-36-0”))	10
WOS	Arsenic	TS=((Resorcinol) AND (“arsenic” OR “7440-38-2”))	6
WOS	Barium	TS=((Resorcinol) AND (“barium” OR “7440-39-3”))	3
WOS	Cadmium	TS=((Resorcinol) AND (“cadmium” OR “7440-43-9”))	103
WOS	Chromium	TS=((Resorcinol) AND (“chromium” OR “7440-47-3”))	54

WOS	Lead	TS=((Resorcinol) AND (“lead” OR “7439-92-1”))	177
WOS	Mercury	TS=((Resorcinol) AND (“mercury” OR “Hg” OR “7439-97-6”))	119
WOS	Selenium	TS=((Resorcinol) AND (“selenium” OR “7782-49-2”))	12
Toxline	BBP	(Resorcinol) AND (benzyl butyl phthalate OR BBP OR 85-68-7)	10
Toxline	DBP	(Resorcinol) AND (dibutyl phthalate OR DBP OR 84-74-2)	13
Toxline	DCHP	(Resorcinol) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7)	0
Toxline	DEHP	(Resorcinol) AND (di-2-ethylhexyl phthalate OR DEHP OR 117-81-7)	17
Toxline	DHEXP	(Resorcinol) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3)	1
Toxline	DIBP	(Resorcinol) AND (diisobutyl phthalate OR DIBP OR 84-69-5)	3
Toxline	DIDP	(Resorcinol) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1)	0
Toxline	DINP	(Resorcinol) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0)	0
Toxline	DnOP	(Resorcinol) AND (di-n-octyl phthalate OR DnOP OR 117-84-0)	23
Toxline	DPENP	(Resorcinol) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0)	1
Toxline	Antimony	(Resorcinol) AND (antimony OR Sb OR 7440-36-0)	18
Toxline	Arsenic	(Resorcinol) AND (arsenic OR 7440-38-2)	12
Toxline	Barium	(Resorcinol) AND (barium OR 7440-39-3)	5
Toxline	Cadmium	(Resorcinol) AND (cadmium OR Cd OR 7440-43-9)	37
Toxline	Chromium	(Resorcinol) AND (chromium OR 7440-47-3)	19
Toxline	Lead	(Resorcinol) AND (lead OR Pb OR 7439-92-1)	46
Toxline	Mercury	(Resorcinol) AND (mercury OR Hg OR 7439-97-6)	25
Toxline	Selenium	(Resorcinol) AND (selenium OR Se OR 7782-49-2)	20

*search further refined

1.5.7 Urea Formaldehyde

Database	Keyword	Query	Results
Pubmed	BBP	(“Urea formaldehyde” OR “9011-05-6”) AND (“benzyl butyl phthalate” OR “BBP” OR “85-68-7”)	0
Pubmed	DBP	(“Urea formaldehyde” OR “9011-05-6”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”)	1
Pubmed	DCHP	(“Urea formaldehyde” OR “9011-05-6”) AND (“dicyclohexyl phthalate” OR “DCHP” OR “84-61-7”)	0
Pubmed	DEHP	(“Urea formaldehyde” OR “9011-05-6”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	0
Pubmed	DHEXP	(“Urea formaldehyde” OR “9011-05-6”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”)	0
Pubmed	DIBP	(“Urea formaldehyde” OR “9011-05-6”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”)	0
Pubmed	DIDP	(“Urea formaldehyde” OR “9011-05-6”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”)	0
Pubmed	DINP	(“Urea formaldehyde” OR “9011-05-6”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”)	0
Pubmed	DnOP	(“Urea formaldehyde” OR “9011-05-6”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”)	0
Pubmed	DPENP	(“Urea formaldehyde” OR “9011-05-6”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”)	0
Pubmed	Antimony	(“Urea formaldehyde” OR “9011-05-6”) AND (“antimony” OR “Sb” OR “7440-36-0”)	1
Pubmed	Arsenic	(“Urea formaldehyde” OR “9011-05-6”) AND (“arsenic” OR “As” OR “7440-38-2”)	0
Pubmed	Barium	(“Urea formaldehyde” OR “9011-05-6”) AND (“barium” OR “Ba” OR “7440-39-3”)	2

Pubmed	Cadmium	(“Urea formaldehyde” OR “9011-05-6”) AND (“cadmium” OR “Cd” OR “7440-43-9”)	0
Pubmed	Chromium	(“Urea formaldehyde” OR “9011-05-6”) AND (“chromium” OR “Cr” OR “7440-47-3”)	1
Pubmed	Lead	(“Urea formaldehyde” OR “9011-05-6”) AND (“lead” OR “Pb” OR “7439-92-1”)	7
Pubmed	Mercury	(“Urea formaldehyde” OR “9011-05-6”) AND (“mercury” OR “Hg” OR “7439-97-6”)	1
Pubmed	Selenium	(“Urea formaldehyde” OR “9011-05-6”) AND (“selenium” OR “Se” OR “7782-49-2”)	1
Scopus	BBP	(“Urea formaldehyde” OR “9011-05-6”) AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	0
Scopus	DBP	(“Urea formaldehyde” OR “9011-05-6”) AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	8
Scopus	DCHP	(“Urea formaldehyde” OR “9011-05-6”) AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	0
Scopus	DEHP	(“Urea formaldehyde” OR “9011-05-6”) AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	8
Scopus	DHEXP	(“Urea formaldehyde” OR “9011-05-6”) AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	1
Scopus	DIBP	(“Urea formaldehyde” OR “9011-05-6”) AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	0
Scopus	DIDP	(“Urea formaldehyde” OR “9011-05-6”) AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	1
Scopus	DINP	(“Urea formaldehyde” OR “9011-05-6”) AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	0
Scopus	DnOP	(“Urea formaldehyde” OR “9011-05-6”) AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	1
Scopus	DPENP	(“Urea formaldehyde” OR “9011-05-6”) AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	0
Scopus	Antimony	(“Urea formaldehyde” OR “9011-05-6”) AND ("antimony" OR "Sb" OR "7440-36-0")	46
Scopus	Arsenic	(“Urea formaldehyde” OR “9011-05-6”) AND ("arsenic" OR "7440-38-2")	53
Scopus	Barium	(“Urea formaldehyde” OR “9011-05-6”) AND ("barium" OR "7440-39-3")	46
Scopus	Cadmium	(“Urea formaldehyde” OR “9011-05-6”) AND ("cadmium" OR "7440-43-9")	125
Scopus	Chromium	(“Urea formaldehyde” OR “9011-05-6”) AND ("chromium" OR "7440-47-3")	172
Scopus	Lead	(“Urea formaldehyde” OR “9011-05-6”) AND ("lead" OR "7439-92-1")	339*
Scopus	Lead	(“Urea formaldehyde” OR “9011-05-6”) AND (("lead" AND "metal") OR "7439-92-1")	156
Scopus	Lead	(“Urea formaldehyde” OR “9011-05-6”) AND ("7439-92-1")	13
Scopus	Mercury	(“Urea formaldehyde” OR “9011-05-6”) AND ("mercury" OR "Hg" OR "7439-97-6")	130
Scopus	Selenium	(“Urea formaldehyde” OR “9011-05-6”) AND ("selenium" OR "7782-49-2")	26
WOS	BBP	TS=((Urea formaldehyde OR 9011-05-6) AND (benzyl butyl phthalate OR BBP OR 85-68-7))	0
WOS	DBP	TS=((Urea formaldehyde OR 9011-05-6) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”))	3

WOS	DCHP	TS=((Urea formaldehyde OR 9011-05-6) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7))	0
WOS	DEHP	TS=((Urea formaldehyde OR 9011-05-6) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”))	0
WOS	DHEXP	TS=((Urea formaldehyde OR 9011-05-6) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3))	0
WOS	DIBP	TS=((Urea formaldehyde OR 9011-05-6) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	0
WOS	DIDP	TS=((Urea formaldehyde OR 9011-05-6) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1))	0
WOS	DINP	TS=((Urea formaldehyde OR 9011-05-6) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0))	0
WOS	DnOP	TS=((Urea formaldehyde OR 9011-05-6) AND (di-n-octyl phthalate OR DnOP OR 117-84-0))	0
WOS	DPENP	TS=((Urea formaldehyde OR 9011-05-6) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0))	0
WOS	Antimony	TS=((Urea formaldehyde OR 9011-05-6) AND (“antimony” OR “Sb” OR “7440-36-0”))	2
WOS	Arsenic	TS=((Urea formaldehyde OR 9011-05-6) AND (“arsenic” OR “7440-38-2”))	5
WOS	Barium	TS=((Urea formaldehyde OR 9011-05-6) AND (“barium” OR “7440-39-3”))	0
WOS	Cadmium	TS=((Urea formaldehyde OR 9011-05-6) AND (“cadmium” OR “7440-43-9”))	3
WOS	Chromium	TS=((Urea formaldehyde OR 9011-05-6) AND (“chromium” OR “7440-47-3”))	13
WOS	Lead	TS=((Urea formaldehyde OR 9011-05-6) AND (“lead” OR “7439-92-1”))	30
WOS	Mercury	TS=((Urea formaldehyde OR 9011-05-6) AND (“mercury” OR “Hg” OR “7439-97-6”))	7
WOS	Selenium	TS=((Urea formaldehyde OR 9011-05-6) AND (“selenium” OR “7782-49-2”))	1
Toxline	BBP	(Urea formaldehyde OR 9011-05-6) AND (benzyl butyl phthalate OR BBP OR 85-68-7)	2
Toxline	DBP	(Urea formaldehyde OR 9011-05-6) AND (dibutyl phthalate OR DBP OR 84-74-2)	3
Toxline	DCHP	(Urea formaldehyde OR 9011-05-6) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7)	0
Toxline	DEHP	(Urea formaldehyde OR 9011-05-6) AND (di-2-ethylhexyl phthalate OR DEHP OR 117-81-7)	11
Toxline	DHEXP	(Urea formaldehyde OR 9011-05-6) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3)	0
Toxline	DIBP	(Urea formaldehyde OR 9011-05-6) AND (diisobutyl phthalate OR DIBP OR 84-69-5)	0
Toxline	DIDP	(Urea formaldehyde OR 9011-05-6) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1)	2
Toxline	DINP	(Urea formaldehyde OR 9011-05-6) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0)	0
Toxline	DnOP	(Urea formaldehyde OR 9011-05-6) AND (di-n-octyl phthalate OR DnOP OR 117-84-0)	12
Toxline	DPENP	(Urea formaldehyde OR 9011-05-6) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0)	0
Toxline	Antimony	(Urea formaldehyde OR 9011-05-6) AND (antimony OR Sb OR 7440-36-0)	4
Toxline	Arsenic	(Urea formaldehyde OR 9011-05-6) AND (arsenic OR 7440-38-2)	6
Toxline	Barium	(Urea formaldehyde OR 9011-05-6) AND (barium OR 7440-39-3)	4

Toxline	Cadmium	(Urea formaldehyde OR 9011-05-6) AND (cadmium OR Cd OR 7440-43-9)	10
Toxline	Chromium	(Urea formaldehyde OR 9011-05-6) AND (chromium OR 7440-47-3)	9
Toxline	Lead	(Urea formaldehyde OR 9011-05-6) AND (lead OR Pb OR 7439-92-1)	13
Toxline	Mercury	(Urea formaldehyde OR 9011-05-6) AND (mercury OR Hg OR 7439-97-6)	6
Toxline	Selenium	(Urea formaldehyde OR 9011-05-6) AND (selenium OR Se OR 7782-49-2)	6

*search further refined

1.6 Key Words and Search Results for Concentrations in Waxes

1.6.1 Slack Wax

Database	Keyword	Query	Results
PubMed	Antimony	(("antimony"[MeSH Terms] OR "antimony"[All Fields]) OR 7440-36-0[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Arsenic	(("arsenic"[MeSH Terms] OR "arsenic"[All Fields]) OR 7440-38-2[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Barium	(("barium"[MeSH Terms] OR "barium"[All Fields]) OR 7440-39-3[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	BBP	(("butylbenzyl phthalate"[Supplementary Concept] OR "butylbenzyl phthalate"[All Fields] OR "benzyl butyl phthalate"[All Fields]) OR ("4-boronic acid benzophenone"[Supplementary Concept] OR "4-boronic acid benzophenone"[All Fields] OR "bbp"[All Fields]) OR 85-68-7[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Cadmium	(("cadmium"[MeSH Terms] OR "cadmium"[All Fields]) OR 7440-43-9[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Chromium	(("chromium"[MeSH Terms] OR "chromium"[All Fields]) OR 7440-47-3[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DBP	(("dibutyl phthalate"[MeSH Terms] OR ("dibutyl"[All Fields] AND "phthalate"[All Fields]) OR "dibutyl phthalate"[All Fields]) OR DBP[All Fields] OR 84-74-2[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DCHP	(("dicyclohexyl phthalate"[Supplementary Concept] OR "dicyclohexyl phthalate"[All Fields]) OR ("O, O'-dimethyl-O-(6-chlorobicyclo(3.2.0)heptadiene-1,5-yl)phosphate"[Supplementary Concept] OR "O, O'-dimethyl-O-(6-chlorobicyclo(3.2.0)heptadiene-1,5-yl)phosphate"[All Fields] OR "dchp"[All Fields]) OR 84-61-7[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DEHP	((("diagnosis"[Subheading] OR "diagnosis"[All Fields] OR "di"[All Fields]) AND 2-ethylhexl[All Fields] AND ("phthalic acid"[Supplementary Concept] OR "phthalic acid"[All Fields] OR "phthalate"[All Fields])) OR ("diethylhexyl phthalate"[MeSH Terms] OR ("diethylhexyl"[All Fields] AND "phthalate"[All Fields]) OR "diethylhexyl phthalate"[All Fields] OR "dehp"[All Fields]) OR 117-81-7[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DHEXP	(("di-n-hexyl phthalate"[Supplementary Concept] OR "di-n-hexyl phthalate"[All Fields] OR "di n hexyl phthalate"[All Fields]) OR 84-75-3[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DIBP	(("diisobutyl phthalate"[Supplementary Concept] OR "diisobutyl phthalate"[All Fields]) OR DIBP[All Fields] OR "84-69-5"[EC/RN Number]) AND (slack[All Fields] AND wax[All Fields])	0

PubMed	DIDP	(("diisodecyl phthalate"[Supplementary Concept] OR "diisodecyl phthalate"[All Fields]) OR DIDP[All Fields] OR 26761-40-0[All Fields] OR 68515-49-1[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DINP	(("diisononyl phthalate"[Supplementary Concept] OR "diisononyl phthalate"[All Fields]) OR DINP[All Fields] OR 28553-12-0[All Fields] OR 68515-48-0[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DnOP	(("di-n-octyl phthalate"[Supplementary Concept] OR "di-n-octyl phthalate"[All Fields] OR "di n octyl phthalate"[All Fields]) OR DnOP[All Fields] OR 117-84-0[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DPENP	(("di-n-pentyl phthalate"[Supplementary Concept] OR "di-n-pentyl phthalate"[All Fields] OR "di n pentyl phthalate"[All Fields]) OR "131-18-0"[EC/RN Number]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Lead	(("lead"[MeSH Terms] OR "lead"[All Fields]) OR 7439-92-1[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Mercury	(("mercury"[MeSH Terms] OR "mercury"[All Fields]) OR 7439-97-6[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Selenium	(("selenium"[MeSH Terms] OR "selenium"[All Fields]) OR 7782-49-2[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
Scopus	Antimony	(TITLE-ABS-KEY(Antimony or 7440-36-0) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	Arsenic	(TITLE-ABS-KEY(Arsenic or 7440-38-2) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	Barium	(TITLE-ABS-KEY(Barium or 7440-39-3) AND TITLE-ABS-KEY(Slack wax))	1
Scopus	BBP	(TITLE-ABS-KEY(benzyl butyl phthalate or BBP or 85-68-7) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	Cadmium	(TITLE-ABS-KEY(Cadmium or 7440-43-9) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	Chromium	(TITLE-ABS-KEY(Chromium or 7440-47-3) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DBP	(TITLE-ABS-KEY(dibutyl phthalate or DBP or 84-74-2) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DCHP	(TITLE-ABS-KEY(dicyclohexyl phthalate or DCHP or 84-61-7) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DEHP	(TITLE-ABS-KEY(di-2-ethylhexl phthalate or DEHP or 117-81-7) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DHEXP	(TITLE-ABS-KEY(di-n-hexyl phthalate or DHEXP or 84-75-3) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DIBP	(TITLE-ABS-KEY(diisobutyl phthalate or DIBP or 84-69-5) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DIDP	(TITLE-ABS-KEY(diisodecyl phthalate or DIDP or 26761-40-0 or 68515-49-1) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DINP	(TITLE-ABS-KEY(diisononyl phthalate or DINP or 28553-12-0 or 68515-48-0) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DnOP	(TITLE-ABS-KEY(di-n-octyl phthalate OR dnop OR 117-84-0) AND TITLE-ABS-KEY(slack wax))	0
Scopus	DPENP	(TITLE-ABS-KEY(di-n-pentyl phthalate OR dpenp OR 131-18-0) AND TITLE-ABS-KEY(slack wax))	0
Scopus	Lead	(TITLE-ABS-KEY(lead OR 7439-92-1) AND TITLE-ABS-KEY(slack wax))	1

Scopus	Mercury	(TITLE-ABS-KEY(mercury OR 7439-97-6) AND TITLE-ABS-KEY(slack wax))	1
Scopus	Selenium	(TITLE-ABS-KEY(selenium OR 7782-49-2) AND TITLE-ABS-KEY(slack wax))	0
WOS	Antimony	ts=(Antimony or 7440-36-0) and ts=slack wax	0
WOS	Arsenic	ts=(Arsenic or 7440-38-2) and ts=slack wax	0
WOS	Barium	ts=(Barium or 7440-39-3) and ts=slack wax	0
WOS	BBP	ts=(benzyl butyl phthalate or BBP or 85-68-7) and ts=slack wax	0
WOS	Cadmium	ts=(Cadmium or 7440-43-9) and ts=slack wax	0
WOS	Chromium	ts=(Chromium or 7440-47-3) and ts=slack wax	0
WOS	DBP	ts=(dibutyl phthalate or DBP or 84-74-2) and ts=slack wax	0
WOS	DCHP	ts=(dicyclohexyl phthalate or DCHP or 84-61-7) and ts=slack wax	0
WOS	DEHP	ts=(di-(2-ethylhexl) phthalate or DEHP or 117-81-7) and ts=slack wax	0
WOS	DHEXP	ts=(di-n-hexyl phthalate or DHEXP or 84-75-3) and ts=slack wax	0
WOS	DIBP	ts=(diisobutyl phthalate or DIBP or 84-69-5) and ts=slack wax	0
WOS	DIDP	ts=(diisodecyl phthalate or DIDP or 26761-40-0 or 68515-49-1) and ts=slack wax	0
WOS	DINP	ts=(diisononyl phthalate or DINP or 28553-12-0 or 68515-48-0) and ts=slack wax	0
WOS	DnOP	ts=(di-n-octyl phthalate or DnOP or 117-84-0) and ts=slack wax	0
WOS	DPENP	ts=(di-n-pentyl phthalate or DPENP or 131-18-0) and ts=slack wax	0
WOS	Lead	ts=(Lead or 7439-92-1) and ts=slack wax	1
WOS	Mercury	ts=(Mercury or 7439-97-6) and ts=slack wax	1
WOS	Selenium	ts=(Selenium or 7782-49-2) and ts=slack wax	0

1.6.2 Petroleum Wax

Database	Keyword	Query	Results
PubMed	Antimony	(("antimony"[MeSH Terms] OR "antimony"[All Fields]) OR 7440-36-0[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	Arsenic	(("arsenic"[MeSH Terms] OR "arsenic"[All Fields]) OR 7440-38-2[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	Barium	(("barium"[MeSH Terms] OR "barium"[All Fields]) OR 7440-39-3[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	BBP	(("butylbenzyl phthalate"[Supplementary Concept] OR "butylbenzyl phthalate"[All Fields] OR "benzyl butyl phthalate"[All Fields]) OR ("4-boronic acid benzophenone"[Supplementary Concept] OR "4-boronic acid benzophenone"[All Fields] OR "bbp"[All Fields]) OR 85-68-7[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	Cadmium	(("cadmium"[MeSH Terms] OR "cadmium"[All Fields]) OR 7440-43-9[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	Chromium	(("chromium"[MeSH Terms] OR "chromium"[All Fields]) OR 7440-47-3[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0

PubMed	DBP	(("dibutyl phthalate"[MeSH Terms] OR ("dibutyl"[All Fields] AND "phthalate"[All Fields]) OR "dibutyl phthalate"[All Fields]) OR DBP[All Fields] OR 84-74-2[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DCHP	(("dicyclohexyl phthalate"[Supplementary Concept] OR "dicyclohexyl phthalate"[All Fields]) OR ("O, O'-dimethyl-O-(6-chlorobicyclo(3.2.0)heptadiene-1,5-yl)phosphate"[Supplementary Concept] OR "O, O'-dimethyl-O-(6-chlorobicyclo(3.2.0)heptadiene-1,5-yl)phosphate"[All Fields] OR "dchp"[All Fields]) OR 84-61-7[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DEHP	((("diagnosis"[Subheading] OR "diagnosis"[All Fields] OR "di"[All Fields]) AND 2-ethylhexl[All Fields] AND ("phthalic acid"[Supplementary Concept] OR "phthalic acid"[All Fields] OR "phthalate"[All Fields])) OR ("diethylhexyl phthalate"[MeSH Terms] OR ("diethylhexyl"[All Fields] AND "phthalate"[All Fields]) OR "diethylhexyl phthalate"[All Fields] OR "dehp"[All Fields]) OR 117-81-7[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DHEXP	(("di-n-hexyl phthalate"[Supplementary Concept] OR "di-n-hexyl phthalate"[All Fields] OR "di n hexyl phthalate"[All Fields]) OR 84-75-3[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DIBP	(("diisobutyl phthalate"[Supplementary Concept] OR "diisobutyl phthalate"[All Fields]) OR DIBP[All Fields] OR "84-69-5"[EC/RN Number]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DIDP	(("diisodecyl phthalate"[Supplementary Concept] OR "diisodecyl phthalate"[All Fields]) OR DIDP[All Fields] OR 26761-40-0[All Fields] OR 68515-49-1[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DINP	(("diisononyl phthalate"[Supplementary Concept] OR "diisononyl phthalate"[All Fields]) OR DINP[All Fields] OR 28553-12-0[All Fields] OR 68515-48-0[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DnOP	(("di-n-octyl phthalate"[Supplementary Concept] OR "di-n-octyl phthalate"[All Fields] OR "di n octyl phthalate"[All Fields]) OR DnOP[All Fields] OR 117-84-0[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DPENP	(("di-n-pentyl phthalate"[Supplementary Concept] OR "di-n-pentyl phthalate"[All Fields] OR "di n pentyl phthalate"[All Fields]) OR "131-18-0"[EC/RN Number]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	Lead	(("lead"[MeSH Terms] OR "lead"[All Fields]) OR 7439-92-1[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	1
PubMed	Mercury	(("mercury"[MeSH Terms] OR "mercury"[All Fields]) OR 7439-97-6[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	Selenium	(("selenium"[MeSH Terms] OR "selenium"[All Fields]) OR 7782-49-2[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
Scopus	Antimony	(TITLE-ABS-KEY(Antimony or 7440-36-0) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	Arsenic	(TITLE-ABS-KEY(Arsenic or 7440-38-2) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	Barium	(TITLE-ABS-KEY(Barium or 7440-39-3) AND TITLE-ABS-KEY(petroleum wax))	5
Scopus	BBP	(TITLE-ABS-KEY(benzyl butyl phthalate or BBP or 85-68-7) AND TITLE-ABS-KEY(petroleum wax))	0

Scopus	Cadmium	(TITLE-ABS-KEY(Cadmium or 7440-43-9) AND TITLE-ABS-KEY(petroleum wax))	4
Scopus	Chromium	(TITLE-ABS-KEY(Chromium or 7440-47-3) AND TITLE-ABS-KEY(petroleum wax))	2
Scopus	DBP	(TITLE-ABS-KEY(dibutyl phthalate or DBP or 84-74-2) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DCHP	(TITLE-ABS-KEY(dicyclohexyl phthalate or DCHP or 84-61-7) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DEHP	(TITLE-ABS-KEY(di-2-ethylhexl phthalate or DEHP or 117-81-7) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DHEXP	(TITLE-ABS-KEY(di-n-hexyl phthalate or DHEXP or 84-75-3) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DIBP	(TITLE-ABS-KEY(diisobutyl phthalate or DIBP or 84-69-5) AND TITLE-ABS-KEY(petroleum wax))	1
Scopus	DIDP	(TITLE-ABS-KEY(diisodecyl phthalate or DIDP or 26761-40-0 or 68515-49-1) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DINP	(TITLE-ABS-KEY(diisononyl phthalate or DINP or 28553-12-0 or 68515-48-0) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DnOP	(TITLE-ABS-KEY(di-n-octyl phthalate OR dnop OR 117-84-0) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DPENP	(TITLE-ABS-KEY(di-n-pentyl phthalate OR dpenp OR 131-18-0) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	Lead	(TITLE-ABS-KEY(lead OR 7439-92-1) AND TITLE-ABS-KEY(petroleum wax))	89
Scopus	Mercury	(TITLE-ABS-KEY(mercury OR 7439-97-6) AND TITLE-ABS-KEY(petroleum wax))	4
Scopus	Selenium	(TITLE-ABS-KEY(selenium OR 7782-49-2) AND TITLE-ABS-KEY(petroleum wax))	0
WOS	Antimony	ts=(Antimony or 7440-36-0) and ts=petroleum wax	0
WOS	Arsenic	ts=(Arsenic or 7440-38-2) and ts=petroleum wax	0
WOS	Barium	ts=(Barium or 7440-39-3) and ts=petroleum wax	0
WOS	BBP	ts=(benzyl butyl phthalate or BBP or 85-68-7) and ts=petroleum wax	0
WOS	Cadmium	ts=(Cadmium or 7440-43-9) and ts=petroleum wax	0
WOS	Chromium	ts=(Chromium or 7440-47-3) and ts=petroleum wax	0
WOS	DBP	ts=(dibutyl phthalate or DBP or 84-74-2) and ts=petroleum wax	0
WOS	DCHP	ts=(dicyclohexyl phthalate or DCHP or 84-61-7) and ts=petroleum wax	0
WOS	DEHP	ts=(di-(2-ethylhexl) phthalate or DEHP or 117-81-7) and ts=petroleum wax	0
WOS	DHEXP	ts=(di-n-hexyl phthalate or DHEXP or 84-75-3) and ts=petroleum wax	0
WOS	DIBP	ts=(diisobutyl phthalate or DIBP or 84-69-5) and ts=petroleum wax	0
WOS	DIDP	ts=(diisodecyl phthalate or DIDP or 26761-40-0 or 68515-49-1) and ts=petroleum wax	0
WOS	DINP	ts=(diisononyl phthalate or DINP or 28553-12-0 or 68515-48-0) and ts=petroleum wax	0
WOS	DnOP	ts=(di-n-octyl phthalate or DnOP or 117-84-0) and ts=petroleum wax	0
WOS	DPENP	ts=(di-n-pentyl phthalate or DPENP or 131-18-0) and ts=petroleum wax	0
WOS	Lead	ts=(Lead or 7439-92-1) and ts=petroleum wax	66
WOS	Mercury	ts=(Mercury or 7439-97-6) and ts=petroleum wax	1
WOS	Selenium	ts=(Selenium or 7782-49-2) and ts=petroleum wax	0

1.6.3 Paraffin Wax

Database	Keyword	Query	Results
PubMed	Antimony	(("antimony"[MeSH Terms] OR "antimony"[All Fields]) OR 7440-36-0[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	Arsenic	(("arsenic"[MeSH Terms] OR "arsenic"[All Fields]) OR 7440-38-2[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	Barium	(("barium"[MeSH Terms] OR "barium"[All Fields]) OR 7440-39-3[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	3
PubMed	BBP	(("butylbenzyl phthalate"[Supplementary Concept] OR "butylbenzyl phthalate"[All Fields] OR "benzyl butyl phthalate"[All Fields]) OR ("4-boronic acid benzophenone"[Supplementary Concept] OR "4-boronic acid benzophenone"[All Fields] OR "bbp"[All Fields]) OR 85-68-7[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	Cadmium	(("cadmium"[MeSH Terms] OR "cadmium"[All Fields]) OR 7440-43-9[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	2
PubMed	Chromium	(("chromium"[MeSH Terms] OR "chromium"[All Fields]) OR 7440-47-3[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	2
PubMed	DBP	(("dibutyl phthalate"[MeSH Terms] OR ("dibutyl"[All Fields] AND "phthalate"[All Fields]) OR "dibutyl phthalate"[All Fields]) OR DBP[All Fields] OR 84-74-2[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DCHP	(("dicyclohexyl phthalate"[Supplementary Concept] OR "dicyclohexyl phthalate"[All Fields]) OR ("O, O'-dimethyl-O-(6-chlorobicyclo(3.2.0)heptadiene-1,5-yl)phosphate"[Supplementary Concept] OR "O, O'-dimethyl-O-(6-chlorobicyclo(3.2.0)heptadiene-1,5-yl)phosphate"[All Fields] OR "dchp"[All Fields]) OR 84-61-7[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DEHP	((("diagnosis"[Subheading] OR "diagnosis"[All Fields] OR "di"[All Fields]) AND 2-ethylhexl[All Fields] AND ("phthalic acid"[Supplementary Concept] OR "phthalic acid"[All Fields] OR "phthalate"[All Fields])) OR ("diethylhexyl phthalate"[MeSH Terms] OR ("diethylhexyl"[All Fields] AND "phthalate"[All Fields]) OR "diethylhexyl phthalate"[All Fields] OR "dehp"[All Fields]) OR 117-81-7[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DHEXP	(("di-n-hexyl phthalate"[Supplementary Concept] OR "di-n-hexyl phthalate"[All Fields] OR "di n hexyl phthalate"[All Fields]) OR 84-75-3[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DIBP	(("diisobutyl phthalate"[Supplementary Concept] OR "diisobutyl phthalate"[All Fields]) OR DIBP[All Fields] OR "84-69-5"[EC/RN Number]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DIDP	(("diisodecyl phthalate"[Supplementary Concept] OR "diisodecyl phthalate"[All Fields]) OR DIDP[All Fields] OR 26761-40-0[All Fields] OR 68515-49-1[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0

PubMed	DINP	(("diisononyl phthalate"[Supplementary Concept] OR "diisononyl phthalate"[All Fields]) OR DINP[All Fields] OR 28553-12-0[All Fields] OR 68515-48-0[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DnOP	(("di-n-octyl phthalate"[Supplementary Concept] OR "di-n-octyl phthalate"[All Fields] OR "di n octyl phthalate"[All Fields]) OR DnOP[All Fields] OR 117-84-0[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DPENP	(("di-n-pentyl phthalate"[Supplementary Concept] OR "di-n-pentyl phthalate"[All Fields] OR "di n pentyl phthalate"[All Fields]) OR "131-18-0"[EC/RN Number]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	Lead	(("lead"[MeSH Terms] OR "lead"[All Fields]) OR 7439-92-1[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	19
PubMed	Mercury	(("mercury"[MeSH Terms] OR "mercury"[All Fields]) OR 7439-97-6[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	3
PubMed	Selenium	(("selenium"[MeSH Terms] OR "selenium"[All Fields]) OR 7782-49-2[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	1
Scopus	Antimony	(TITLE-ABS-KEY(Antimony or 7440-36-0) AND TITLE-ABS-KEY(paraffin wax))	9
Scopus	Arsenic	(TITLE-ABS-KEY(Arsenic or 7440-38-2) AND TITLE-ABS-KEY(paraffin wax))	11
Scopus	Barium	(TITLE-ABS-KEY(Barium or 7440-39-3) AND TITLE-ABS-KEY(paraffin wax))	49
Scopus	BBP	(TITLE-ABS-KEY(benzyl butyl phthalate or BBP or 85-68-7) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	Cadmium	(TITLE-ABS-KEY(Cadmium or 7440-43-9) AND TITLE-ABS-KEY(paraffin wax))	35
Scopus	Chromium	(TITLE-ABS-KEY(Chromium or 7440-47-3) AND TITLE-ABS-KEY(paraffin wax))	30
Scopus	DBP	(TITLE-ABS-KEY(dibutyl phthalate or DBP or 84-74-2) AND TITLE-ABS-KEY(paraffin wax))	6
Scopus	DCHP	(TITLE-ABS-KEY(dicyclohexyl phthalate or DCHP or 84-61-7) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	DEHP	(TITLE-ABS-KEY(di-2-ethylhexl phthalate or DEHP or 117-81-7) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	DHEXP	(TITLE-ABS-KEY(di-n-hexyl phthalate or DHEXP or 84-75-3) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	DIBP	(TITLE-ABS-KEY(diisobutyl phthalate or DIBP or 84-69-5) AND TITLE-ABS-KEY(paraffin wax))	1
Scopus	DIDP	(TITLE-ABS-KEY(diisodecyl phthalate or DIDP or 26761-40-0 or 68515-49-1) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	DINP	(TITLE-ABS-KEY(diisononyl phthalate or DINP or 28553-12-0 or 68515-48-0) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	DnOP	(TITLE-ABS-KEY(di-n-octyl phthalate OR dnop OR 117-84-0) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	DPENP	(TITLE-ABS-KEY(di-n-pentyl phthalate OR dpenp OR 131-18-0) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	Lead	((TITLE-ABS-KEY(lead OR 7439-92-1) AND TITLE-ABS-KEY(paraffin wax))) and metal)	62

Scopus	Mercury	(TITLE-ABS-KEY(mercury OR 7439-97-6) AND TITLE-ABS-KEY(paraffin wax))	23
Scopus	Selenium	(TITLE-ABS-KEY(selenium OR 7782-49-2) AND TITLE-ABS-KEY(paraffin wax))	12
WOS	Antimony	ts=(Antimony or 7440-36-0) and ts=paraffin wax	3
WOS	Arsenic	ts=(Arsenic or 7440-38-2) and ts=paraffin wax	1
WOS	Barium	ts=(Barium or 7440-39-3) and ts=paraffin wax	19
WOS	BBP	ts=(benzyl butyl phthalate or BBP or 85-68-7) and ts=paraffin wax	0
WOS	Cadmium	ts=(Cadmium or 7440-43-9) and ts=paraffin wax	4
WOS	Chromium	ts=(Chromium or 7440-47-3) and ts=paraffin wax	4
WOS	DBP	ts=(dibutyl phthalate or DBP or 84-74-2) and ts=paraffin wax	3
WOS	DCHP	ts=(dicyclohexyl phthalate or DCHP or 84-61-7) and ts=paraffin wax	0
WOS	DEHP	ts=(di-(2-ethylhexl) phthalate or DEHP or 117-81-7) and ts=paraffin wax	0
WOS	DHEXP	ts=(di-n-hexyl phthalate or DHEXP or 84-75-3) and ts=paraffin wax	0
WOS	DIBP	ts=(diisobutyl phthalate or DIBP or 84-69-5) and ts=paraffin wax	0
WOS	DIDP	ts=(diisodecyl phthalate or DIDP or 26761-40-0 or 68515-49-1) and ts=paraffin wax	0
WOS	DINP	ts=(diisononyl phthalate or DINP or 28553-12-0 or 68515-48-0) and ts=paraffin wax	0
WOS	DnOP	ts=(di-n-octyl phthalate or DnOP or 117-84-0) and ts=paraffin wax	0
WOS	DPENP	ts=(di-n-pentyl phthalate or DPENP or 131-18-0) and ts=paraffin wax	0
WOS	Lead	ts=(Lead or 7439-92-1) and ts=paraffin wax; Refined by "Metal"	17
WOS	Mercury	ts=(Mercury or 7439-97-6) and ts=paraffin wax	10
WOS	Selenium	ts=(Selenium or 7782-49-2) and ts=paraffin wax	0

1.7 Key Words and Search Results for Recycling Data

Search String	Database	Hits
TS=(particleboard AND ((life cycle inventory) OR (life cycle assessment) OR (life cycle analysis)))	WOS	27
TS=((medium density fiberboard OR MDF) AND ((life cycle inventory) OR (life cycle assessment) OR (life cycle analysis)))	WOS	24
TS=(plywood AND ((life cycle inventory) OR (life cycle assessment) OR (life cycle analysis)))	WOS	21
TS=(particleboard AND ((urban wood waste) OR (industrial wood residue)))	WOS	12
TS=((medium density fiberboard OR MDF) AND ((urban wood waste) OR (industrial wood residue)))	WOS	6
TS=(plywood AND ((urban wood waste) OR (industrial wood residue)))	WOS	12
TS=(particleboard AND ((construction debris) OR (construction waste)))	WOS	20
TS=((medium density fiberboard OR MDF) AND ((construction debris) OR (construction waste)))	WOS	8
TS=(plywood AND ((construction debris) OR (construction waste)))	WOS	18
TS=(particleboard AND ((wood fiber) OR (wood fibre) OR (wood dust) OR (wood shavings) OR (wood trim) OR (wood chip)))	WOS	298*
TS=((medium density fiberboard OR MDF) AND ((wood fiber) OR (wood fibre) OR (wood dust) OR (wood shavings) OR (wood trim) OR (wood chip)))	WOS	374*

TS=(plywood AND ((wood fiber) OR (wood fibre) OR (wood dust) OR (wood shavings) OR (wood trim) OR (wood chip)))	WOS	136*
TS=(particleboard AND ((recycl*) OR (reconstitute*) OR (reuse*) OR (recover*)))	WOS	108
TS=((medium density fiberboard OR MDF) AND ((recycl*) OR (reconstitute*) OR (reuse*) OR (recover*)))	WOS	142
TS=(plywood AND ((recycl*) OR (reconstitute*) OR (reuse*) OR (recover*)))	WOS	104
TS=(particleboard AND ((post-consumer recycled wood) OR (sawdust) OR (deconstruction)))	WOS	31
TS=((medium density fiberboard OR MDF) AND ((post-consumer recycled wood) OR (sawdust) OR (deconstruction)))	WOS	13
TS=(plywood AND ((post-consumer recycled wood) OR (sawdust) OR (deconstruction)))	WOS	19
TS=((plywood OR particleboard OR medium density fiberboard OR MDF) AND ((cradle-to-grave analysis) OR (cradle to grave)))	WOS	1
*did not screen or retrieve – overlaps with individual EWP searches and therefore should not identify anything not already found through those searches.		
SCOPUS – Did not Screen or Retrieve		
(particleboard AND ((life cycle inventory) OR (life cycle assessment) OR (life cycle analysis)))	Scopus	220
((medium density fiberboard OR MDF) AND ((life cycle inventory) OR (life cycle assessment) OR (life cycle analysis)))	Scopus	117
(plywood AND ((life cycle inventory) OR (life cycle assessment) OR (life cycle analysis)))	Scopus	247
(particleboard AND ((urban wood waste) OR (industrial wood residue)))	Scopus	653
((medium density fiberboard OR MDF) AND ((urban wood waste) OR (industrial wood residue)))	Scopus	287
(plywood AND ((urban wood waste) OR (industrial wood residue)))	Scopus	303
(particleboard AND ((construction debris) OR (construction waste)))	Scopus	459
((medium density fiberboard OR MDF) AND ((construction debris) OR (construction waste)))	Scopus	202
(plywood AND ((construction debris) OR (construction waste)))	Scopus	246
(particleboard AND ((wood fiber) OR (wood fibre) OR (wood dust) OR (wood shavings) OR (wood trim) OR (wood chip)))	Scopus	3251
((medium density fiberboard OR MDF) AND ((wood fiber) OR (wood fibre) OR (wood dust) OR (wood shavings) OR (wood trim) OR (wood chip)))	Scopus	1719
(plywood AND ((wood fiber) OR (wood fibre) OR (wood dust) OR (wood shavings) OR (wood trim) OR (wood chip)))	Scopus	2160
(particleboard AND ((recycl*) OR (reconstitute*) OR (reuse*) OR (recover*)))	Scopus	1215
((medium density fiberboard OR MDF) AND ((recycl*) OR (reconstitute*) OR (reuse*) OR (recover*)))	Scopus	541
(plywood AND ((recycl*) OR (reconstitute*) OR (reuse*) OR (recover*)))	Scopus	867
(particleboard AND ((post-consumer recycled wood) OR (sawdust) OR (deconstruction)))	Scopus	291
((medium density fiberboard OR MDF) AND ((post-consumer recycled wood) OR (sawdust) OR (deconstruction)))	Scopus	121
(plywood AND ((post-consumer recycled wood) OR (sawdust) OR (deconstruction)))	Scopus	143
((plywood OR particleboard OR medium density fiberboard OR MDF) AND ((cradle-to-grave analysis) OR (cradle to grave)))	Scopus	7

*search further refined

1.8 Key Words and Search Results for Phthalate Uptake in Trees

1.8.1 Phthalate Uptake in Trees and Plants

Pubmed		
((((di-(2-ethylhexyl) phthalate) OR DEHP) OR 117-81-7) AND tree) AND uptake	1 hit	Saved
((((di-(2-ethylhexyl) phthalate) OR DEHP) OR 117-81-7) AND tree)	3 hits	Saved
(((di-(2-ethylhexyl) phthalate) OR DEHP) OR 117-81-7) AND uptake)	68 hits	Saved
(((dibutyl phthalate) OR DBP) OR 84-74-2) AND uptake)	153 hits	Saved
(((dibutyl phthalate) OR DBP) OR 84-74-2) AND tree)	22 hits	Saved
(((benzyl butyl phthalate) OR BBP) OR 85-68-7) AND tree)	3 hits	Saved
((((benzyl butyl phthalate) OR BBP) OR 85-68-7) AND uptake)	13 hits	Saved
(((((diisononyl phthalate) OR DINP) OR 28553-12-0) OR 68515-49-1) AND uptake)	1 hit	Saved
(((((diisononyl phthalate) OR DINP) OR 28553-12-0) OR 68515-49-1) AND tree)	0 hits	--
(((diisononyl phthalate) OR DINP) AND tree)	0 hits	--
(((diisononyl phthalate) OR DINP) AND uptake)	1 hit (duplicate)	--
((((diisononyl phthalate) OR DINP) OR 28553-12-0) OR 68515-49-1)	227 hits	Saved
(((((diisodecyl phthalate) OR DIDP) OR 26761-40-0) OR 68515-49-1) AND tree)	0 hits	--
(((((diisodecyl phthalate) OR DIDP) OR 26761-40-0) OR 68515-49-1) AND uptake)	1 hit (duplicate)	Saved
(((((diisodecyl phthalate) OR DIDP) OR 26761-40-0) OR 68515-49-1)	127 hits	Saved
((((di-n-octyl phthalate) OR DnOP) OR 117-84-0) AND uptake)	3 hits	Saved
((((di-n-octyl phthalate) OR DnOP) OR 117-84-0) AND tree)	0 hits	--
(((di-n-octyl phthalate) OR DnOP) OR 117-84-0)	153 hits	Saved
((((diisobutyl phthalate) OR DIBP) OR 84-69-5) AND uptake)	6 hits	Saved
((((diisobutyl phthalate) OR DIBP) OR 84-69-5) AND tree)	1 hit	Saved
(((diisobutyl phthalate) OR DIBP) OR 84-69-5)	203 hits	Saved
((((di-n-pentyl phthalate) OR DPENP) OR 131-18-0) AND tree)	0 hits	--
((((di-n-pentyl phthalate) OR DPENP) OR 131-18-0) AND uptake)	0 hits	--
(((di-n-pentyl phthalate) OR DPENP) OR 131-18-0)	0 hits	--
(((di-n-pentyl phthalate) OR 131-18-0) AND tree)	0 hits	--
(((di-n-pentyl phthalate) OR 131-18-0) AND uptake)	0 hits	--
((di-n-pentyl phthalate) OR 131-18-0)	26 hits	Saved
((((di-n-hexyl phthalate) OR DHEXP) OR 84-75-3) AND tree)	0 hits	--
((((di-n-hexyl phthalate) OR DHEXP) OR 84-75-3) AND uptake)	0 hits	--
(((di-n-hexyl phthalate) OR 84-75-3) AND uptake)	0 hits	--
((di-n-hexyl phthalate) OR 84-75-3)	43 hits	Saved
((((dicyclohexyl phthalate) OR DCHP) OR 84-61-7) AND uptake)	1 hit	Saved
((((dicyclohexyl phthalate) OR DCHP) OR 84-61-7) AND tree)	0 hits	--
((dicyclohexyl phthalate) OR 84-61-7)	77 hits	Saved
phthalate AND phytoremediation NOT biodegrad*	2 hits	Saved
phthalate AND phytoremediation	338 hits	Refined
phthalate AND phytoremediation AND plant	56 hits	Saved
(((((di-(2-ethylhexyl) phthalate AND tree) AND uptake)) OR DEHP) OR 117-81-7) AND wood) NOT wood[Author]	8 hits	Saved
Total combined library from endnote		877 reference
Total screened library		207 reference
In depth screen for retrieval (either not in English or not relevant)		61 references

1.8.2 Phthalate Uptake in Trees

Search String	Database	Hits	Retrieved	Database	Hits	Retrieved
DEHP AND phthalate AND tree	WOS	2	0	Scopus	6	0
di- (2-ethylhexyl) phthalate AND tree	WOS	3	0	Scopus	0	0
DBP AND phthalate AND tree	WOS	0	0	Scopus	4	1
dibutyl phthalate AND tree	WOS	3	0	Scopus	10	0 (1 duplicate)
BBP AND phthalate AND tree	WOS	0	0	Scopus	0	0
benzyl butyl phthalate AND tree	WOS	0	0	Scopus	0	0
DINP AND phthalate AND tree	WOS	0	0	Scopus	1	0
diisononyl phthalate AND tree	WOS	0	0	Scopus	2	1
DIDP AND phthalate AND tree	WOS	0	0	Scopus	1	0
diisodecyl phthalate AND tree	WOS	0	0	Scopus	2	0
DnOP AND phthalate AND tree	WOS	0	0	Scopus	0	0
di-n-octyl phthalate AND tree	WOS	1	0	Scopus	1	0
DIBP AND phthalate AND tree	WOS	0	0	Scopus	0	0
diisobutyl phthalate AND tree	WOS	2	0	Scopus	1	0
DPENP AND phthalate AND tree	WOS	0	0	Scopus	0	0
di-n-pentyl phthalate AND tree	WOS	0	0	Scopus	0	0
DHEXP AND phthalate AND tree	WOS	0	0	Scopus	0	0
di-n-hexyl phthalate AND tree	WOS	0	0	Scopus	0	0
DCHP AND phthalate AND tree	WOS	0	0	Scopus	0	0
dicyclohexyl phthalate AND tree	WOS	0	0	Scopus	0	0

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Final Report for CPSC Task 14

Appendix II: SDS Source Information and Materials

FINAL Report

March 25, 2016

Submitted by:

Toxicology Excellence for Risk Assessment

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Contents

1. Appendix II: SDS Source Information and Materials

As noted in Appendix I, data on raw materials and their proportions in finished products was difficult to find because of the proprietary nature of much of this data. In order to supplement the general information identified in books and published literature, a detailed Safety and Data Sheet (SDS) search was conducted that provided more specific information on the non-wood materials used in EWPs and the proportions of those materials. Due to the large amount of SDS sheets available, two approaches were undertaken to limit the number of SDS and to optimize the search. The first approach was to search the (M)SDS database MSDSXchange (http://www.msdsxchange.com/english/) for the specified EWPs (hardwood plywood, medium density fiberboard, and particleboard). SDSs resulting from these searches were reviewed one by one, ruling out any non-relevant EWPs. There was some difficulty to this approach as some SDS covered multiple EWPs, and it was hard to discern which board type the additives applied to. Results for each EWP were recorded in a table and are presented below. The second approach was to search the Composite Panel Association (CPA) for member companies producing hardwood plywood, MDF, and particleboard. Even though the CPA only specifically includes companies producing particleboard and MDF, information was also found through them for companies that produce hardwood plywood, and so we determined that this was relatively comprehensive of all specified EWPs. Each of the identified companies' websites was visited and SDSs reviewed, and this data was added to the tables below.

This approach provided us with the specific data under investigation for this research project, however, it should be noted that this SDS approach likely only covered SDS sheets from companies and organizations in North America. For example, we searched the International Wood Products Association for manufacturers of the specified EWPs. However, most of the results were North American countries. For the few companies that were identified outside of North America (*e.g.*, Malaysia, China), SDS sheets could not be found on their webpages.

1.1 SDS Data for Hardwood Plywood

Material/Product	**Additives**	**Company**
Plywood	Poplar = >87% Ureic formaldehyde resin = <12% Ammonium chloride (extender) = <1%	North American Plywood
Hardwood plywood urea formaldehyde-bonded, melamine urea formaldehyde-bonded, phenol formaldehyde-bonded	Formaldehyde = <1% Hardwood dust, various species = 5-25%	States Industries

Plywood	Wood (wood dust) = 85-99% Polymeric phenol formaldehyde resin solids = 1-15%	Weyerhaeuser Company
Plywood	Wood = 98-99% Phenol formaldehyde resin = 1-2%	Weyerhaeuser Company
Plywood	Softwoods = 85-99% Hardwoods = 0-15% Sodium hydroxide = <1% Formaldehyde gas = <0.1%	International paper
Plywood and composite panels bonded with phenol, melamine, and urea formaldehyde resin systems	Wood solids = 80-95% Cured resin solids = 5-20% Formaldehyde = <0.1% Cured finish (coatings) or melamine surface materials = <1%	Roseburg
Softwood plywood	Wood = 97.8% Phenol formaldehyde resin = 2.1%	American Wood Council; Canadian Wood Council
Phenol-formaldehyde bonded wood products plus a polyurethane film: softwood and hardwood plywood (veneer core), oriented strand board, laminated veneer lumber, wood I-joists, glulam beams	Formaldehyde = <0.1% Solid polyurethane film = 2.67% Wood dust = % not reported	Boise-Cascade
Softwood plywood	Wood = 92-97% Phenol formaldehyde resin = 3-5% Primer = 1% Sealer = 0.5% Medium density overlay = 1%	Roseburg
Hardwood plywood	Wood = 93-95% UF resin = 3-7% UV filler = < 2% Phenol formaldehyde resin = < 3%	Roseburg
Softwood plywood	Wood = 97.8% Phenol formaldehyde resin = 2.1%	American Wood Council; Canadian Wood Council

Softwood plywood, sanded softwood plywood, medium density overlay, high density overlay	Softwood plywood = 88-94% Formaldehyde = <1% Inert filler wheat = 2-4% Water-based acrylic latex = <1%	Westlam Industries Ltd.
Plywood	Wood dust, all soft and hard woods = 99% Phenol-formaldehyde polymer = <1%	Potlatch Corp
Southern yellow pine plywood	Wood/wood dust = 95-97% Phenol formaldehyde resin = 3-5%	Hood Industries, Inc.
UF bonded hardwood Plywood	Wood dust = 96-99% Formaldehyde = <0.1%	Murphy Plywood
Plywood	Southern yellow pine/wood dust = 84-99% Phenolic resin = 0-15%	Roy O Martin
Southern yellow pine plywood	Wood/wood dust = 95-97% Phenol formaldehyde resin = 3-5%	Scotch Plywood Company Inc.
Plywood	Formaldehyde = <0.4 ppm Wood = 87-95%	Tolko Industries Ltd. Plywood Products
Phenol-formaldehyde bonded wood products plus a polyurethane film: softwood and hardwood plywood (veneer core), oriented strand board, laminated veneer lumber, wood I-joists, glulam beams	Formaldehyde = <0.1% Solid polyurethane film = 2.67% Wood dust = N/A	Boise Cascade

N/A = not available

1.2 SDS Data for Medium Density Fiberboard

Material/Product	**Additives**	**Company**
Medium density fiberboard	Urea-formaldehyde resin = 7-10% Wax (paraffin) = <1% (post treatment) ammonia = <1% [wood fiber percentage not given]	Plum Creek Northwest Plywood, Inc.
Medium density fiberboard	Mixed softwood Polymerised resin Paraffin wax Moisture Formaldehyde (≤8mg/100g) [percentages not given]	Medite Europe Ltd
Medium density fiberboard, wood-based panel product	Mixed softwood Urea formaldehyde binder Paraffinic wax Ammonia Formaldehyde (free) [percentages not given]	Medite Corp
Unfinished particleboard and medium density fiberboard panels	Cellulosic materials = 90-93% Polymerized urea formaldehyde resin = 8-11% Formaldehyde = <0.1%	G-P Flakeboard Company
Particleboard, laminated or coated particleboard, laminated or coated MDF	Wood = 80-90% Melamine topcoat = <5% Urea = 0-10% Formaldehyde = <0.1% Cured resin solids = 5-15%	Roseburg
Medium density fiberboard	Formaldehyde = <1 ppm Synthetic binder = (proprietary) Wood dust (and/or ligno-cellulosic fibers) = (proprietary)	Georgia-Pacific Panel Products LLC
Unfinished medium density fiberboard panels	Polymerized urea formaldehyde resin = 0.01-16% Methylene-diphenyl-diisocyanate (MDI) = 0-5% Wood dust/ligno-cellulosic fiber [percentages not given]	SierraPine

Medium density fiberboard and hardboard paneling bonded with urea-formaldehyde resin	Wood/wood dust = 60-100% Formaldehyde = 0-0.1% Urea, polymer with formaldehyde = 1-5% Other components below reportable levels = 10-30%	Georgia-Pacific Panel Products LLC
High density, medium density, and light density fiberboard	Wood dust, soft woods = 88-92% Slack wax, petroleum = <1% Ammonia = <1%	Plum Creek Northwest Plywood, Inc.
Unfinished medium density fiberboard panels	Ligno-cellulosic materials = 75-94% Polymerized urea formaldehyde resin = 6-25%	Masisa/ Timber Products Inc.
Medium density fiberboard	Wood fibers = 73-93% Cured amino resin = 0-17% Cured amino resin = 0-16% Urea = 0-3% Formaldehyde = <0.1%	Arauco-North America
Medium density fiberboard	Formaldehyde = <0.13 ppm Synthetic binder = proprietary Wood dust (and/or ligno-cellulosic fibers) = proprietary	Del-Tin Fiber, LLC
Medium density and high density fiberboard	Formaldehyde = <0.1% Wood (hardwood and softwood of various species) = >90%	Kronospan
Unfinished medium density fiberboard	Ligno-cellulosic materials = 90-93% Polymerized urea formaldehyde resin = 6-12%	West Fraser Mills Ltd.
Unfinished medium density fiberboard	Ligno-cellulosic materials = 90-95% Polymerized methylene-diphenyl-diisocyanate (pMDI) = <10%	West Fraser Mills Ltd.
Unfinished particleboard and medium density fiberboard panels	Cellulosic materials = 90-93% Polymerized urea formaldehyde resin = 8-11% Formaldehyde = <0.1%	G-P Flakeboard Company

1.3 SDS Data for Particleboard

Material/Product	Additives	Company
Particleboard, laminated or coated particleboard, laminated or coated MDF	Wood = 80-90% Melamine topcoat = <5% Urea = 0-10% Formaldehyde = <0.1% Cured resin solids = 5-15%	Roseburg
Particleboard (urea-formaldehyde bonded)	Wood = 95% Formaldehyde = 0.1-0.2%	Roseburg
Particleboard	Wood = 90.2% Urea formaldehyde resin = 9.5% Slack wax = 0.3%	American Wood Council; Canadian Wood Council
Wood products (pMDI bonded)	Wood/wood dust = 60-100% Methylene bisphenol isocyanate (MDI) = 1-5% Polymeric MDI (pMDI) = 1-5% 2,4'-Diphenyl methane diisocyanate = 0.1-1% Other components below reportable levels = 0.5-1.5%	Georgia-Pacific Panel Products LLC
Particleboard	Wood/wood dust = 60-100% Polymeric MDI (pMDI) = <1.0% Formaldehyde = <0.1% Methylene bisphenol isocyanate (MDI) = 0-<1.0% Other components below reportable levels = 1-5% Urea, polymer with formaldehyde = 1-10%	Georgia-Pacific Panel Products LLC
Particleboard, industrial, commercial, underlayment, PB-blend	Wood dust = 60-100% Formaldehyde = <0.1%	Timber Products Company
Particleboard	Wood fibers = 83-92% Cured amino resins = 0-17% Cured amino resins = 0-15% Urea = 0-2% Formaldehyde = <0.1%	Arauco North America
Particleboard	Wood dust = 60-100%	Sierra Pine Composite Solutions

Particleboard, composite panel product	Inland softwoods = 96-98% Hardwoods = 0.0-1.0% pMDI binder = proprietary	Plummer Forest Products
Particle and medium and high density fiber boards, raw and laminated	Formaldehyde = <0.1% Wood dust = N/A	Uniboard
Phase 2 standard CARB particleboards; CARB ULEF particleboards	Wood (woody fibers) = 60-100% Formaldehyde = <0.1% 4,4'-Diphenylmethane diisocyanate = 0-15% Ammonium nitrate = 0.1-15%	Tafisa Canada Inc.
Particleboard	Wood fiber = 95-98% Formaldehyde = <0.1% (0.1% to 0.2% in the board)	Roseburg Forest Products
Unfinished particleboard and medium density fiberboard (MDF) panels	Cellulosic materials = 90-93% Polymerized urea formaldehyde resin = 8-11% Formaldehyde = <0.1%	G-P Flakeboard Company
Unfinished particleboard	Ligno-cellulosic materials = 90-93% Polymerized urea formaldehyde resin = 6-9%	SierraPine Limited
Softwood plywood; composite panel (particleboard)	Wood solids = 80-95% Cured resin solids = 5-20% Formaldehyde = <0.1% Cured finish (coatings) or melamine surface materials = <1%	Roseburg

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Final Report for CPSC Task 14

Appendix III: Manufacturing and Impurities in Raw Materials

FINAL Report

March 25, 2016

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Contents

1. Appendix III: Manufacturing and Impurities in Raw Materials

Polymerization of the binders and resins involves the linking of the initial polymer molecule with the addition of a number of additives, as described in the body of the report. There are also a number of modifiers that may be added during EWP manufacture to impart new properties to the final product. The manufacturing of these materials was also reviewed in order to assess if there was potential for any of the specified substances to be introduced into any of these products or if they were components of the raw materials used in manufacture. General information on manufacture and potential impurities for each of these products is described below, as the information was available from authoritative sources, starting with the Hazardous Substances Data Bank (HSDB) and supplemented from the World Health Organization (WHO) or the Food and Agriculture Organization (FAO) when data were unavailable. It should be noted that there is additional information available if a more detailed company specific/chemical specific search is conducted for these raw materials and adhesives, but we have included only general information here as resources allowed. In the case where there was no information available in the HSDB search, and additional investigation through WHO or FAO was unfruitful, we noted as such but did not do additional targeted gap searching due to resource limitations. SDS searching in this case was not helpful as it appears that for technical grade products the specifications (impurities) are not available because they are not set to certain purity standards as would be done for analytical grades.

Specialty composite materials for use in specialty purposes include those imparted with additives for water resistance, acidity control, fire resistance, insect resistance, and decay resistance (Stark et al., 2011). Because these additives are uncommon and are mostly applied for specialty products, they are unlikely to be present or applied in children's products or toys and so were not covered further in this report.

The information provided below is basic information on the manufacture of the adhesives, the individual starting materials (monomers) used in resin production, along with all potential catalysts, scavengers, and fillers. In an effort to be overly inclusive, all identified additives and resins are covered below. This is in contrast to our main report, which notes only those that are commonly in use or that are only in use for the three specified EWPs.

2. Adhesives

2.1 Amino Resins (Urea-formaldehyde)

The manufacturing process is a two-step reaction. The first is a hydroxymethylation reaction of urea with formaldehyde under neutral to basic conditions and moderate temperature to form various methylol ureas (Stokke et al., 2014). This reaction is driven toward the methylol intermediate with excess formaldehyde, with typical molar ratios of 2.0-2.2 formaldehyde to urea (Stokke et al., 2014). The second step involves condensing these methylol ureas into long strand polymers under acidic conditions and higher heat (Stokke et al., 2014). During this step, excess urea can be added to react excess formaldehyde (Stokke et al., 2014). Additionally, scavengers can be added to control excess formaldehyde (Stokke et al., 2014), but typically just prior to use. Urea-formaldehyde (UF) resin is supplied at neutral pH (~ 7.0) but curing requires acidification.

2.2 Phenols (phenol-formaldehyde)

Phenol-formaldehyde resole resins (PFs) are obtained in a two-step process as the above resins: the first involving the reaction (hydroxylmethylation) of phenol and formaldehyde under alkaline conditions to form monomethylol phenol, followed by the second step of condensing the methylolated intermediates into a moderately polymerized solution (prepolymers) (Stokke et al., 2014; Fink, 2013). These prepolymers are then added to the EWPs for the curing process, which requires heat only (no catalyst) given the reactivity of the prepolymers (Stokke et al., 2014). An accelerator, such as an ortho ester, can be added to speed up the curing process Frihart (2005); however, accelerators in general were suggested to be uncommon by a subject matter expert.

2.3 Isocyanates (pMDI)

The isocyanate resin, pMDI, is synthesized from formaldehyde and aniline under aqueous acid conditions and the resulting polyamine is converted to the final isocyanate by reaction with phosgene (Twitchett, 1974). Aspects of pMDI quality include acidic and chlorine containing impurities as related to the efficiency of the phosgenation (Twitchett, 1974); but these impurities are unrelated to the phthalates and chemical elements of concern in this report (Frazier, personal communication). The pMDI resins are unusual because they are among the few wood bonding resins that are water insoluble. This resin is sometimes used to make PB and MDF when formaldehyde-free resins are desired (pMDI is synthesized from formaldehyde; but the final resin is free of formaldehyde). Consequently, PB and MDF manufactured with pMDI could have surface contamination with release agents (which are simple fatty acid salts, waxes, or silicones) (Frazier, 2004). Occasionally, but very uncommon in wood composite manufacture, pMDI resins will be formulated with amine catalysts such as 4,4’-(oxydi-2,1-ethanediyl) bismorpholine (DMDEE).

2.4 Polyvinyl acetate

Polyvinyl acetate is manufactured through emulsion polymerization of vinyl acetate in water using poly(vinyl alcohol) emulsifiers (Frihart, 2005). However, the most common PVA resins used for wood bonding are so-called “crosslinking PVAs” which are copolymers of vinyl acetate and N-methylolacrylamide (NMA). When PVA resins are used to make hardwood plywood, crosslinking PVAs are the probable type and these are acid catalyzed typically with aluminum chloride. The aluminum chloride catalyst may be internal to the resin, or it may be added just prior to adhesive application.

3. Resins used in Adhesive Manufacture

3.1 Urea (CASRN: 57-13-6)

- Manufacturing (HSDB, 2003a):
  - o A high pressure and high temperature reaction of liquid ammonia and liquid carbon dioxide form ammonium carbamate. At lower pressure, this breaks down into urea and water which can be purified using crystallization.
- Potential impurities (HSDB, 2003a; OECD, 2008):
  - o Biuret (0.3 - 2%), cyanates.
  - o Technical urea analysis as follows: water (0.4 %), free ammonia (0.4 %), and iron (<0.02 %).

3.2 Formaldehyde (CASRN: 50-00-0) (synonyms include formalin)

- Formalin is the aqueous form of formaldehyde.
- Manufacturing (HSDB, 2015a):
  - o Catalytic oxidation method, commonly either using the silver catalyst method or the metal oxide catalyst method.
  - o The silver catalyst method involves using silver crystals or silver gauze, partial oxidation and dehydrogenation with air, steam, and excess methanol at high temperature and high pressure. Purification is done using distillation from reaction products and by-products.
  - o The metal oxide (Formox) method uses a modified iron-molybdenum-vanadium oxide catalyst, oxidation in air, and excess methanol at high temperature and pressure.
- Potential impurities:
  - o Pure formaldehyde tends to polymerize and so is typically sold as a solution with 33-55% formaldehyde in methanol (HSDB, 2015a; OECD, 2002a).
  - o A formaldehyde solution from BASF contained the following reported impurities (OECD, 2002):
    - ▪ Methanol = 0.5-2% w/w
    - ▪ Formic acid = about 0.3% w/w
    - ▪ Iron = <0.0001% w/w

3.3 Paraformaldehyde (CASRN: 30525-89-4)

- Manufacturing (HSDB, 2013a):
  - Paraformaldehyde can be used in the production of phenol, urea, and melamine resins instead of aqueous formaldehyde solutions where the presence of water can be problematic.
  - Paraformaldehyde is industrially manufactured through concentrating aqueous formaldehyde using vacuum conditions at low pressure and variable temperatures. Formaldehyde solutions used can contain formic acid and metal formates with atomic number 23-30 (this includes chromium, among others, as discussed further in the main report).
  - Other methods include fractional condensation of reaction gases, reaction of formaldehyde-containing gas with paraformaldehyde under controlled conditions, or by the introduction of concentrated melt into a cooling liquid (such as benzene, toluene, or cyclohexane) with the addition of acids or alkalis to accelerate polymerization.

- Potential impurities (HSDB, 2013a):
  - Paraformaldehyde can contain 90-93% formaldehyde, up to 9% water, and up to 3% acidity as formic acid (also reported as 0.03%).
  - Other reports of commercial specifications include up to 2% iron and 0.01% ash.

3.4 Phenol (CASRN: 108-95-2)

- Manufacturing (HSDB, 2003b):
  - Cumene oxidation (Hock Process) is the most common method of production in the United States. This involves the production of cumene hydroperoxide through oxidation of cumene and acidic (*e.g.*, sulfuric acid) cleavage/decomposition of cumene hydroperoxide to phenol and acetone.
  - Other methods include:
    - the Dow process (named after Herbert Henry Dow who used it for bromine extraction from brine; later applied to phenol production).
    - includes toluene oxidation to benzoic acid followed by decarboxylation to phenol.

        - benzene sulfonation to benzene sulfonate and heating in an alkali hydroxide to produce phenol dehydrogenation of cyclohexanol-cyclohexanone mixtures.
        - chlorination of benzene followed by steam or alkaline hydrolysis.
- Potential impurities (HSDB, 2003b):
    - Typically sold as liquid in water, oil, or glycerin, or as a mixture. Other compounds were reported as mostly cresols.

3.5 Resorcinol (CASRN: 108-46-3) (synonyms include: 1,3-dihydroxybenzene; 1,3-benzenediol; m-dihydroxybenzene; resorcin)

- Manufacturing (HSDB, 2015b):
    - Continuous sulfonation of benzene with sulfur trioxide or sulfuric acid, and following neutralization with sodium sulfite, soda ash, or sodium hydroxide solution, the sulfonation product (disodium benzene-1,3-disulfonate) is mixed with excess sodium hydroxide and reacted at high heat. The result is a white powder of disodium resorcinate, sodium sulfite, and sodium hydroxide. This reaction product is treated with water to form a saturated solution that is then reacted with sulfur dioxide, sulfuric acid, or hydrochloric acid to give resorcinol. The resorcinol can be extracted using organic solvents such as diisopropyl ether, benzene, 4-methyl-2-pentanone (methyl isobutyl ketone), or others, which are then distilled off to form purified resorcinol.
    - Another method was described of hydroperoxidation of m-diisopropylbenzene in which benzene (or benzene-cumene mixtures) is alkylated with propene using an aluminum chloride-hydrochloric acid catalyst. Para-diisopropylbenzene (p-DiPB) and triisopropylbenzene (TriPB) are then added and isomerized/transalkylated into m-diisopropylbenzene (m-DiPB). The reaction mixture is then fractionated and a radical autoxidation of the m-DiPB fraction is accomplished in reactors under alkaline conditions to yield [1,3-phenylenebis-(1-methylethylidene)]bishydroperoxide (m-diisopropylbenzene dihydroperoxide, DHP). Meta-DHP is then crystallized, centrifuged, dissolved in acetone, and cleaved into resorcinol and acetone. This occurs using an acid catalyst (*e.g.*, sulfuric acid) in boiling acetone. Acetone is then distilled off and further purification can be done using recrystallization or extraction. Alternatively, cleavage of the oxidate can be done using hydrogen peroxide. In this process the byproducts are oxidized to DHP and eventually converted to resorcinol.

    - Resorcinol can be made in other ways, including destructive distillation of brazilin or fusion of galbanum, ammoniac, sagapenum, asafetida, or acroides with caustic potash.
- Potential Impurities:
    - Technical grade resorcinol has a minimum of 99% resorcinol content with small impurities of phenol and catechol. Other reported impurities include other hydroquinone isomers, insoluble matter, acidity, and diresorcinol (HSDB, 2015b).
    - Technical-grade resorcinol was reported with 99.5% resorcinol content with impurities including phenol, catechol, cresols, and 3-mercaptophenol (WHO, 2006).

3.6 4-4'-methylenedianiline isomer (MDA) (CASRN: 101-77-9) (synonyms include: 4,4'-diaminodiphenylmethane)

- Manufacturing:
    - Methods include acid catalyzed (*e.g.*, hydrochloric acid) reaction of aniline and formaldehyde, hydrogenolysis of p,p'-diaminobenzophenone with lithium aluminum hydride or distillation from polymeric 4,4'-diaminodiphenylmethane (HSDB, 2009a; OECD, 2002b).
- Potential impurities (OECD, 2002b):
    - Technical-grade MDA is an isomer mixture containing tri- and polynuclear amines. Typical mixture can include:
        - 4,4'-MDA: 59-61% w/w but highly variable depending on manufacturing method used.
        - MDA polymers: ~ 36% w/w
        - 2,4'-MDA: ~ 3.5% w/w
        - 2,2'-MDA: <0.1% w/w
        - water: <300 ppm
        - aniline: <100 ppm
        - pure 4,4'-MDA can contain traces of 4-amino-4'-methylaminodiphenyl methane.

3.7 4,4’-diphenylmethane diisocyanate (MDI) (CASRN: 101-68-8) (synonyms include: methylene bisphenol isocyanate (MDI), 4,4'-methylenediphenyl diisocyanate)

- Manufacturing (HSDB, 2012a):
    - Methods include condensation of aniline with formaldehyde in the presence of hydrochloric acid. This forms oligomeric di- and polyamines that are then phosgenated to form MDI. This is typically a mixture of isomers that can be controlled through the addition of the starting materials and conditions.
    - Another reported method for pure diphenylmethane 4,4'-diisocyanate also involves condensing aniline and formaldehyde to yield diphenylmethane diamine. Phosgenation of this product then yields aromatic isocyanate MDI.
- Potential impurities (HSDB, 2012a):
    - MDI is typically a mixture of 30-40% diphenylmethane-4,4’-diisocyanate, 2.5-4.0% diphenylmethane-2,4'-diisocyanate, 0.1-0.2 % diphenylmethane-2,2'-diisocyanate, and the remaining 50-60% oligomers; can also be blocked with phenol for some solutions.

3.8 Phosgene (CASRN: 75-44-5)

- Manufacturing (HSDB, 2008a):
    - Phosgene for industrial applications is typically made through the reaction of carbon monoxide and chlorine gas with an activated carbon catalyst. This reaction can also be completed using anhydrous chlorine gas and a majority of the production takes place on-site in the manufacture of polyisocyanates and polycarbonate resins.
    - Non-industrial use methods include combustion of carbon tetrachloride, methylene chloride, trichloroethylene, or butyl chloroformate.
- Potential impurities:
    - Chlorine (free), hydrochloric acid, and sulfur chlorides (HSDB, 2008a).
    - Technical grade phosgene with 95-99% purity can have impurities including nitrogen, carbon monoxide, hydrochloric acid, free chlorine, and sulfur compounds (IPCS, 1998).

3.9 Aniline (CASRN: 62-53-3)

- Manufacturing (HSDB, 2011a):
  - Multiple manufacturing processes include catalytic vapor phase reduction of nitrobenzene with hydrogen, reduction of nitrobenzene with iron filings with an acid catalyst (hydrochloric acid), catalytic reaction of chlorobenzene and aqueous ammonia, and ammonolysis of phenol (Japan).
- Potential impurities:
  - Nitrobenzene, beta-naphthylamine, and 4-aminobiphenyl (pre-1900 A.D.) was reported (HSDB, 2011a).

3.10 Polyvinyl alcohol (CASRN: 9002-89-5)

- Manufacturing (HSDB, 2003c):
  - Includes hydrolysis of polyvinyl acetate by using methanol to replace the acetate groups with hydroxyl groups. Reaction proceeds rapidly in a methanol/methyl acetate mixture using alkali or mineral acid catalysts. Can also proceed in the presence of sodium methylate.
- Potential impurities (FAO, 2004):
  - Sodium acetate, methanol, and methyl acetate.

3.11 Vinyl acetate monomers (CASRN: 108-05-4)

- Manufacturing (HSDB, 2009b):
  - Commonly conducted by reacting acetic acid, ethylene, and oxygen using a noble metal catalyst (zinc salts, zinc acetate, mercury salt, palladium) at high heat and under pressure. The monomer is condensed, scrubbed, and distilled to purify.
  - Other methods include the reaction of ethylene with sodium acetate or using an acetaldehyde/acetic anhydride process to yield ethylidene diacetate, which is then cleaved to form vinyl acetate and acetic acid.
  - A final method was reported using a carbonylation process to react methanol with carbon monoxide to form acetic acid. Methanol and acetic acid are then mixed to form methyl acetate that is further carbonylated to form ethylidene diacetate, which can be pyrolized to vinyl acetate and acetic acid.

- Potential impurities (HSDB, 2009b):
  - Typical USA specifications include acidity (as acetic acid), aldehydes (as acetaldehyde), and water.
  - Typical Western Europe specifications include ethyl acetate, water, methyl acetate, acetaldehyde, and acrolein.
  - Typical Japanese specifications include free acid (as acetic acid), free aldehydes (as acetaldehyde), and moisture.

3.12 Hexamethylenetetramine (CASRN: 100-97-0) (synonyms include methenamine)

- Manufacturing (HSDB, 2003d):
  - Used mainly as an ammonia or formaldehyde donor in the production of phenol or urea-formaldehyde resins.
  - Formed by the action of ammonia on formaldehyde (formalin).
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

3.13 Methanol (CASRN: 67-56-1)

- Manufacturing (HSDB, 2012b):
  - Industrial solvent and raw material for making formaldehyde.
  - Manufactured by exothermically reacting carbon monoxide and hydrogen at high temperature and high pressure. High-pressure processes are catalyzed with copper chromite catalysts; however, it is more commonly manufactured using low-pressure methods catalyzed with copper-zinc oxide and using alumina promoters, and which requires a sulfur-free synthesis gas.
  - Another liquid phase process includes copper-zinc catalysts in hydrocarbon oil and allows for a CO-rich synthesis gas at a lower pressure and high temperature.
  - It was reported that industrial scale methanol is produced exclusively by high, medium, or low-pressure catalytic conversion of synthesis gas.
  - Several other methods were reported including gasification of wood, peat, or lignite, from methane with a molybdenum catalyst, or by partial oxidation of natural gas hydrocarbons.

- Potential impurities:
    - Typical impurities were water, acetone, and ethanol. Others were reported based on product grade, with Grade A methanol having acetone, aldehydes, acetic acid, and water; and Grade AA methanol having the same impurities along with ethanol (HSDB, 2012b).
    - Other reports include water, dimethyl ether, fusel oils, methyl formate, and higher alcohols (HSDB, 2012b; IPCS, 1997).
    - Federal specifications for pure methanol in the United States restrict the presence of most of these impurities (HSDB, 2012b).

3.14 Glyoxal (CASRN: 107-22-2)

- Manufacturing (HSDB, 2006a):
    - Glyoxal can be used industrially in the production of polymers as a cross-linking agent.
    - Glyoxal is manufactured through the oxidation of acetaldehyde with nitric or selenius acid through a continuous process. Once excess acetaldehyde is removed, glyoxal is purified using an ion-exchange resin.
    - Other methods include:
        - heating the polymer with anethole, phenetole, safrole, methyl nonyl ketone, or benzaldehyde.
        - vapor-phase oxidation of ethylene glycol.
        - gas-phase (or liquid phase) oxidation of ethylene glycol by oxygen in the presence of dehydrogenation catalysts (metallic copper or silver) at high temperature.
- Potential impurities:
    - During production, the reaction solution is contaminated with acetic, formic, and glyoxylic acids, which glyoxal is purified from, and which may render the solution acidic (HSDB, 2006a).
    - Some anhydrous forms may include polymerization inhibitors (HSDB, 2006a).
    - The main impurities include (OECD, 2003).
        - traces of formic acid, acetic acid, glyoxylic acid and glycolic acid
        - formaldehyde
        - traces of organic acids
        - 1,2-ethanediol
        - hydroxyacetaldehyde

3.15 N-Methylolacrylamide (NMA) (CASRN: 924-42-5)

- Manufacturing (HSDB, 2003e):
  - Hydroxymethylation of acrylamide and formaldehyde.
- Potential impurities (HSDB, 2003e):
  - None identified in HSDB.

3.16 Butyraldehyde (CASRN: 123-72-8)

- Manufacturing (HSDB, 2009c):
  - Reduction of methyl butyrate or from butyryl chloride.
  - Dry distillation of calcium butyrate and calcium formate.
  - Oxo process combines propylene, carbon monoxide, hydrogen, and a catalyst.
  - Usual processes include catalytic dehydrogenation of butanol, crotonaldehyde, or propene; can also involve acetaldehyde.
- Potential impurities (HSDB, 2009c):
  - Potential for polymerization of butyraldehyde during storage.

3.17 Multihydroxymethylketones

- Manufacturing:
  - None identified in HSDB, WHO, FAO.
  - Fink (2013) reports that multihydroxymethylketones are reaction products of excess formaldehyde and ketones.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4. Catalysts (curing agents, hardeners, accelerators)

Catalysts are used in the manufacture of resins, binders, and adhesives. They influence reaction rate and can also impact the actual properties of the final resin. Catalysts are by definition chemically unchanged during the reaction.

4.1 Magnesium oxide/hydroxide (CASRN: 1309-48-4; 1309-42-8)

- Manufacturing (HSDB, 2012c, 2003f):
  - Limestone is calcined to produce dolomite/dolime that is reacted with magnesium chloride brine to produce magnesium hydroxide and calcium chloride that are then separated.
  - Another method includes thermally decomposing the magnesium chloride brine at high temperature into magnesium oxide and hydrochloric acid. Further processing and different methods produce different reactivity grades.
  - An additional method decarbonates limestone/dolomite to remove all CO_2 and all colloidal particles including salts of other metals resulting in chemically inert magnesia. This is then seeded with magnesium hydroxide to form magnesium hydroxide crystals that are then precipitated, washed, filtered, and further processed.
  - It was noted that the purity of the compound depends on the purity and composition of the natural manesite. It was also noted that the density of the oxide is resultant from the calcining temperature.
- Potential impurities (HSDB, 2012c):
  - Trace impurities were reported as sodium chloride, potassium chloride, and sodium fluoride.

4.2 Magnesium stearate (CASRN: 557-04-0)

- Manufacturing (HSDB, 2005a):
  - Reacting sodium stearate with magnesium sulfate produces magnesium stearate.
- Potential impurities (HSDB, 2005a):
  - Impurities include small amounts of oleate; technical grade magnesium stearate has roughly 7% magnesium oxide.

4.3 Sodium hydroxide (CASRN: 1310-73-2)

- Manufacturing (HSDB, 2012d):
  - There are a number of manufacturing methods reported, including:
    - Formation of caustic soda (solid sodium hydroxide) involves the evaporation of water from sodium hydroxide solution.

        - Another method of causticization involves mixing sodium carbonate with calcium oxide. Calcium carbonate precipitates out and the sodium hydroxide solution is evaporated.
        - Reaction of calcium hydroxide with sodium carbonate.
        - From sodium chloride by electrolysis (reported as most common method for industrial production).
        - From sodium metal and water vapor.
        - A final method was reported as commonly in use in paper pulp plants. This method evaporates waste liquor containing sodium salt and organics. The resulting residue is mixed with ferric oxide forming sodium ferrite that decomposes in water to give sodium hydroxide and ferric oxide.
- Potential impurities (HSDB, 2012d):
    - Common major impurities include sodium chloride, sodium carbonate, sodium sulfate, sodium chlorate, iron, and nickel.
    - The electrolysis method commonly yields excess chlorine and hydrogen in solution.

4.4 Sulfuric acid (7664-93-9)

- Manufacturing (HSDB, 2010):
    - Combustion of elemental sulfur or iron pyrites (sulfur, pyrite, hydrogen sulfide, sulfur-containing smelter gases, or through the use of gypsum) to yield sulfur dioxide. This is catalytically oxidized (with vanadium pentoxide) to sulfur trioxide at high temperatures. After cooling, sulfur trioxide is mixed with sulfuric acid where it bonds with excess water in the acid to form additional sulfuric acid.
    - Also formed by reacting sulfur dioxide with oxygen to form sulfur trioxide and mixing with water.
    - Sulfur dioxide is oxidized with nitrogen oxides to sulfuric acid and water.

- Potential impurities (HSDB, 2010):
    - As reported for technical grade, industry type 66:
        - Non-volatiles – 0.02-0.03 ppm
        - Sulfur dioxide – 40-80 ppm
        - Iron – 50-100 ppm
        - Nitrate – 5-20 ppm

- Also reported impurities of iron, arsenic, sulfur dioxide, nitrogen compounds, chloride, and fluoride.

4.5 Phosphoric acid (CASRN: 7664-38-2)

- Manufacturing (HSDB, 2012e):
    - Vapor phase phosphorus is converted to phosphorus pentoxide through exposure to warm air, and is then treated with water to form phosphoric acid.
    - Phosphate rock (calcium phosphate) is digested in sulfuric acid (occasionally hydrochloric acid). Then phosphoric acid is filtered from the calcium sulfate slurry.
- Potential impurities (HSDB, 2012e):
    - Some inorganic impurities depend on the impurities and composition of the phosphate rock. It was reported that these must be partially or fully removed using precipitation and extraction.
    - Other impurities reported in various technical grades include:
        - Calcium monoxide – 0.06-0.01%
        - Fluoride – 0.8-<0.0001%
        - Aluminum oxide – 1.7-0.0003%
        - Iron oxide – 1.23-0.004%
        - Magnesium oxide – 0.58-0.0002%
        - Potassium oxide – 0.01-0.0007%
        - Sodium oxide – 0.12-0.0025%
        - Silicon dioxide – 0.07-0.0015%
        - Sulfate – 2.2->0.002%

4.6 Hydrochloric acid (CASRN: 7647-01-0)

- Manufacturing (HSDB, 2015c):
    - Produced by direct reaction of hydrogen and chlorine in a combustion chamber at high heat, reaction of metal chlorides and acids, or as a by-product from chemical manufacturing processes (reported that 90% of by-product formation occurs from production of chlorinated solvents, fluorocarbons, isocyanates, organics, magnesium, or vinyl chloride). Hydrogen chloride produced from chlorination can be isolated from gases, isolated and/or purified from distillation, or by aqueous absorption.

- Industrially produced by the Meyer process/Manheim process by reacting sodium chloride (or potassium chloride, sodium bisulfite) and sulfuric acid in a mechanical furnace at high temperatures.
    - Or by the Hargreaves process from reacting sodium chloride, sulfur dioxide, air, and water vapor.
    - Or by burning of chlorine with hydrogen gas.
- Potential impurities (HSDB, 2015c):
    - May contain chlorinated hydrocarbons, inorganic impurities (such as iron).
    - Other reported limits include:
        - Ammonia – 0.003%
        - Free chlorine – 0.0001%
        - Heavy metals – 0.0001%
        - Iron – 0.00002%
        - Sulfate – 0.0001%
        - Sulfite – 0.0001%

4.7 Boric Acid (CASRN: 10043-35-3)

- Manufacturing (HSDB, 2012f):
    - Industrially, borate minerals, brines (such as borax, kernite, colemanite, ascharite, ulexite, hydroboracite, etc.), or sodium- or calcium-containing borate ores are reacted with mineral acids (hydrochloric, sulfuric) and crystalized. Crystals are then filtered, washed, and dried. Reaction can be conducted in weak/strong boric acid liquor at moderate temperatures.
        - The United States commonly uses sodium borate mineral starting materials.
        - Europe commonly uses colemanite starting materials.
    - Can also be manufactured through extraction of borax brines with kerosene chelating agents (2-ethyl-1,3-hexanediol, polyols) and stripping with sulfuric acid.
- Potential impurities (HSDB, 2012f):
    - Boric acid liquor can have high concentrations of sodium sulfate, and technical grade boric acid can contain various metallic impurities carried over from the ore.

4.8 Oxalic acid (CASRN: 144-62-7)

- Manufacturing (HSDB, 2005b):
  - By passing carbon monoxide through concentration sodium hydroxide.
  - By heating sodium formate in the presence of sodium hydroxide/sodium carbonate.
  - Commercial production involves oxidation of starch, sugar, or ethylene glycol using nitric acid.
  - As a co-product in fermenting molasses to citric acid.
  - By fusing cellulose with sodium/potassium hydroxide.
- Potential impurities (HSDB, 2005b):
  - The technical grade was reported as having a chemically pure grade but as not being 100% pure.
  - The commercial product can be a formulation of 71.42% oxalic acid in 28.58% water.
  - None identified in WHO, FAO.

4.9 *p*-Toluenesulfonic acid (CASRN: 104-15-4)

- Manufacturing (HSDB, 2003g):
  - Sulfonation of toluene with sulfuric acid. Can separate toluene from petroleum fractions using this method.
  - At low temperatures, using chlorosulfonic acid with toluene.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.10 Ammonium chloride (CASRN: 12125-02-9)

- Manufacturing (HSDB, 2015d):
  - By neutralization with hydrochloric acid of ammoniacal liquids (derived from coal); recovered through crystallization of ammonium chloride.
  - By absorption of ammonia vapors into hydrochloric acid.
  - As a by-product in the production of sodium bicarbonate, which involves reacting ammonia, carbon dioxide, and sodium chloride in water. Recovery of ammonium chloride by crystallization, separation, washing, and drying, or through distillation

in the presence of lime. Or, by treating spent calcium chloride liquor with ammonia and carbon dioxide, and filtering out the calcium carbonate.

  - By reacting ammonia salt/ammonium sulfate with sodium chloride in a double-decomposition reaction, forming ammonium chloride and sodium salt. Recovery of ammonium chloride through cooling. This is a more economical route to ammonium chloride manufacture.
  - Direct neutralization.
- Potential impurities (HSDB, 2015d):
  - Sodium chloride was reported as the principal impurity.

4.11 Ammonium sulfate (CASRN: 7783-20-2)

- Manufacturing (HSDB, 2015e):
  - By washing coke-oven gas with water, releasing with lime suspension, and introducing into sulfuric acid.
  - Using a saturator and introducing ammonia and sulfuric acid, with crystallization of the salt being continuously discharged.
  - By reacting gypsum with ammonium carbonate solution to form calcium carbonate and ammonium sulfate that is then filtered, acidified using sulfuric acid, and crystalized; or by reacting gypsum with ammonia and carbon dioxide.
  - Formed as a co-product in producing caprolactam, acrylonitrile, methyl methacrylate, formic acid, and acrylamide.
  - Reaction of ammoniacal vapors (derived from coal) reacted with sulfuric acid; recovered through crystallization and drying.
  - By absorption of ammonia vapors into hydrochloric acid.
  - Direct neutralization with sulphuric acid.
- Potential impurities (HSDB, 2015e):
  - It was noted that commercial ammonium sulfate is typically of high purity with heavy metals ≤ 5mg/kg, iron ≤ 5mg/kg, and free acid ≤ 0.01%.

4.12 Ammonium nitrate (CASRN: 6484-52-2)

- Manufacturing (HSDB, 2014a):
  - By neutralizing of aqueous of gaseous ammonia and nitric acid.
  - Treating calcium nitrate tetrahydrate with ammonia and carbon dioxide produces calcium carbonate and ammonium nitrate.

- Potential impurities (HSDB, 2014a):
  - Potential for ammonium phosphate to be used as a stabilizer in solution.
  - None identified in HSDB, WHO, FAO.

4.13 Potassium hydroxide (CASRN: 1310-58-3)

- Manufacturing (HSDB, 2015f):
  - Industrial production involves electrolysis of potassium chloride.
  - By evaporation of potassium hydroxide solution (to create caustic potash).
- Potential impurities (HSDB, 2015f):
  - Sodium oxide, sodium carbonate, sodium chloride, sodium chlorate, ferrous oxide, mercury, sodium sulfate, silicon dioxide, aluminum oxide, calcium oxide, magnesium oxide, manganese, nickel, and copper.

4.14 Lithium hydroxide (CASRN: 7580-67-8)

- Manufacturing:
  - None identified in HSDB, WHO, FAO.
  - Basic process described as a causticization reaction between lime and lithium carbonate in aqueous solution, followed by concentration, crystallization, and purification (Jiang et al., 2014).
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.15 Barium hydroxide (CASRN: 17194-00-2)

- Manufacturing (HSDB, 2015g):
  - By dissolving barium oxide in water followed by crystallization.
  - By precipitation of aqueous barium sulfide using caustic soda.
  - By heating barium sulfide with added carbonic acid to form barium carbonate and superheated steam to form barium hydroxide.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.16 Calcium hydroxide (CASRN: 1305-62-0)

- Manufacturing (HSDB, 2014b):
  - By hydration of lime.
  - Commercially produced by the action of water on calcium oxide.
- Potential impurities (HSDB, 2014b):
  - Calcium carbonate, magnesium salts, iron.

4.17 Calcium oxide (CASRN: 1305-78-8)

- Manufacturing (HSDB, 2014c):
  - By calcination of limestone (calcium carbonate), coal, anthracite, or gypsum until carbon dioxide is driven off.
- Potential impurities (HSDB, 2014c):
  - Calcium carbonate, magnesium, iron, and aluminum oxides.

4.18 Hydrogen peroxide (CASRN: 7722-84-1)

- Manufacturing (HSDB, 2005c):
  - By reduction and oxidation of alkyl anthraquinones (such as 2-ethyl derivatives) in the presence of a palladium catalyst.
  - By treating barium peroxide with acids.
  - By autoxidation of isopropyl alcohol to acetone and hydrogen peroxide.
  - By the conversion of sulfuric acid or acidic ammonium bisulfate electrolytically to peroxydisulfate that can be hydrolyzed to hydrogen peroxide.
  - By electrolysis of potassium bisulfate followed by heating and hydrolysis to liberate water and hydrogen peroxide vapors.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.19 Sodium carbonate (CASRN: 497-19-8)

- Manufacturing (HSDB, 2012g):
  - Trona (sodium sesquicarbonate) is ground and calcined to crude soda ash (sodium carbonate), and can be further refined to monohydrate or anhydrous forms or purified.

    - Sesquicarbonate crystals are formed when crushed ore is dissolved, calcified, and cooled. These crystals can be further process.
    - Solvay process: purified sodium chloride brine is ammoniated and sodium bicarbonate crystals are precipitated by contact with carbon dioxide; the crystals are recovered and the filtrate is calcined to produce sodium carbonate, carbon dioxide, and water vapor. This process was noted as the most utilized process in the world, with the exception of the United States that produces from the minerals that contain sodium bicarbonate.
- Potential impurities (HSDB, 2012g):
    - Sodium chloride, sodium sulfate, calcium carbonate, magnesium carbonate, sodium bicarbonate, iron, chlorine.
    - Impurities from the Solvay process include sodium chloride (0.15%), sodium sulfate (0.02%), ferric oxide (0.002%), calcium oxide (0.01%), magnesium oxide (0.02%).
    - Impurities from the trona process include sodium chloride (0.035%), sodium sulfate (0.1%), ferric oxide (0.001%), calcium oxide (0.01%), magnesium oxide (0.003%).

4.20 Trimethylamine (CASRN: 75-50-3)

- Manufacturing (HSDB, 2009d):
    - By the action of formaldehyde (paraformaldehyde) and formic acid on ammonia (ammonium chloride).
    - Commercially by reacting methanol and ammonia using a catalyst (amorphous silica-alumina) at high temperatures. Yields include mono-, di-, and trimethylamines that can be separated by distillation and ratios of which are dictated by reaction conditions.
- Potential impurities (HSDB, 2009d):
    - Ammonia and formaldehyde.

4.21 2-dimethylamino-2-methyl-1-propanol

- Manufacturing:
    - None identified in HSDB, WHO, FAO.
- Potential impurities:
    - None identified in HSDB, WHO, FAO.

4.22 2-dimethylamino-2-hydroxymethyl-1,3-propanediol

- Manufacturing:
  - None identified in HSDB, WHO, FAO.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.23 Tri(*p*-chlorophenyl)phosphine

- Manufacturing:
  - None identified in HSDB, WHO, FAO.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.24 Tetraalkylammonium hydroxide

- Manufacturing:
  - None identified in HSDB, WHO, FAO.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.25 Triphenylphosphine (CASRN: 603-35-0)

- Manufacturing (HSDB, 2003h):
  - By reaction of phenylmagnesium bromine and phosphorus trichloride.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.26 Chromium (CASRN: 7440-47-3)

- Manufacturing (HSDB, 2005d):
  - From chrome ore (chromite) by silicothermic or aluminothermic processes.
  - Reaction of chromium oxide with aluminum or metallurgical coke.
  - Reaction of ferrochrome, sulfuric acid, and ammonium sulfate.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.27 Antimony/antimony trioxide (CASRN: 7440-36-0; 1309-64-4)

- Manufacturing (HSDB, 2005e, 2013b):
  - Depending on grade of antimony (ore), can be volatized as an oxide, smelted, liquated, or iron precipitated. Some ores can be leached with antimony recovery via electrowinning.
  - Antimony trioxide can be produced through roasting or hydrolysis of antimony trisulfide, burning antimony in oxygen, through alkaline hydrolysis of antimony halides.
  - Other methods include adding ammonium hydroxide to antimony chloride.
- Potential impurities (HSDB, 2005e, 2013b):
  - Lead, arsenic, sulfur, iron, copper.

4.28 Ortho ester

- Manufacturing (HSDB, 2003i):
  - None identified in HSDB, WHO, FAO.
  - By the reaction of alcohols with ketene dimethyl acetal to form mixed ortho esters (Cosgrove and McGeary, 2008).
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.29 Zinc acetate (CASRN: 557-34-6)

- Manufacturing (HSDB, 2006b):
  - From zinc nitrate and acetic anhydride to form the anhydrous salt, or from acetic acid and zinc oxide.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.30 Zinc borate (CASRN: 1332-07-6)

- Manufacturing (HSDB, 2013c):
  - Interaction of zinc oxide slurries with boric acid (borax) or the oxides at high temperature.

- Potential impurities (HSDB, 2013c):
  - Zinc oxide, borate, water, boric anhydride.

4.31 Formic acid (CASRN: 64-18-6)

- Manufacturing (HSDB, 2012h):
  - By carbonylation of methanol with carbon monoxide followed by hydrolysis of methyl formate to form formic acid and methanol. In an alternative method, the ethyl formate is formed and ammonolysis produces formamide, which is hydrolyzed using sulfuric acid to form formic acid and ammonium sulfate. Formic acid can be further purified by distillation.
  - As a by-product of oxidation of hydrocarbons (butane is common in the United States, while naphtha is common in Europe).
  - Reaction of sodium or calcium formate with mineral acids (sulfuric, nitric).
  - As a by-product in the manufacture of acetaldehyde or formaldehyde.
- Potential impurities (HSDB, 2012h):
  - Technical grade reported as < 0.8% acetic acid, < 20ppm chlorides, < 5ppm heavy metals, < 3ppm iron, and < 10ppm sulfates. Commercial grade impurities are similar with the exception of no acetic acid.

5. Scavengers

Scavengers are agents added to EWPs to reduce the formaldehyde emission when formaldehyde based adhesives are used by binding to the resin and reducing formaldehyde release (HBN, 2008). They can be added to the product with the added advantage of lowering formaldehyde emission during manufacture or after the pressing process. Urea is a common scavenger that is effective in lowering formaldehyde emissions (US EPA, 2002). Common scavengers include melamine and hexamine, and anhydrous ammonia or ammonium compounds can be added post-pressing as scavengers. Sodium sulfite is also used as a scavenger (Que et al., 2007). Recently, polyamine compounds are being investigated to modify the urea formaldehyde resin in an effort to lower formaldehyde emissions by improving the stability and durability the urea formaldehyde wood product (Conner, 1996; US EPA, 2002).

Common scavengers in PF resins for reduce formaldehyde emissions include urea (most common), ammonia, melamine, and dicyandiamide, but also some naturally occurring compounds such as tannins (Fink, 2013).

5.1 Melamine (CASRN: 108-78-1)

- Manufacturing (HSDB, 2008b):
  - o Produced from urea in two ways: in the vapor phase, urea with an alumina catalyst at low pressure forms isocyanic acid and is converted to cyanamide then melamine. In the second method, in the liquid phase, urea under high pressure forms cyanuric acid that is reacted with ammonia to form melamine. Both methods are followed by recovery and purification.
- Potential impurities:
  - o None identified in HSDB, WHO, FAO.

5.2 Hexamine (synonyms include hexamethylenetetramine, methenamine)

- See listing above in "Starting Materials and Resins/Adhesives in EWPs."

5.3 Anhydrous ammonia (Ammonium compounds) (CASRN: 7664-41-7)

- Manufacturing (HSDB, 2011b):
  - o Manufactured through reduction (Haber-Bosch) using atmospheric nitrogen and hydrogen (examples: methane, ethylene, naphtha, water gas, producer gas, natural gas) using an iron catalyst.

- Potential impurities:
  - o None identified in HSDB, WHO, FAO.

5.4 Sodium sulphite (CASRN: 7757-83-7)

- Manufacturing (HSDB, 2002a):
  - o By reacting sulfur dioxide with sodium carbonate (bicarbonate, soda ash) in water. The resulting solution of sodium bisulfite can be reacted with additional soda ash.
  - o As a by-product of phenol production.
- Potential impurities:
  - o None identified in HSDB, WHO, FAO.

5.5 Dicyandiamide (cyanoguanidine) (CASRN: 461-58-5)

- Manufacturing (HSDB, 2003j):
  - o By polymerization/dimerization of cyanamide in water in the presence of bases (such as ammonia and alkaline earth hydroxides). Dicyandiamide is then crystallized and separated via centrifugation.
- Potential impurities (HSDB, 2003j):
  - o Commercial grade was reported to have water (0.01%), melamine (0.7%), thiourea (200 ppm), and heavy metals (10 ppm).

5.6 Tannins (tannic acid) (CASRN: 1401-55-4)

- Manufacturing (HSDB, 2002b):
  - o Commercially prepared by solvent extraction from primarily Aleppo gall-nuts (Mediterranean region), tara pods (South America), gall-nuts (Asia), or from excrescences on twigs from Oak species.
- Potential impurities:
  - o None identified in HSDB, WHO, FAO

6. Fillers and Modifiers

In general, fillers are added to reduce cost and shrinkage of the final product during curing. However, most of the fillers identified are cellulosic in nature, such as China clay (kaolin), walnut shell flour, wheat flour (Frihart, 2005), and organic fiber material (Fink, 2013). Other fillers, while non-cellulosic, by nature are highly heterogeneous and therefore difficult to characterize for the purposes here (such as glass fibers and ceramic material). For these reasons, only non-cellulosic and non-fibrous fillers are discussed in detail here.

6.1 Maleic anhydride-modified poly(propylene)

- Manufacturing:
  - o Maleic anhydride (HSDB, 2015h) (CASRN: 108-31-6)
    - ▪ By sublimation of maleic acid under pressure.
    - ▪ Commercially by catalytic vapor-phase oxidation of hydrocarbons (benzene, C-4 hydrocarbons). Example includes reaction of butane with oxygen using vanadium phosphorus oxide catalyst or vanadium pentoxide catalyst.
    - ▪ As a by-product in manufacturing phthalic anhydride.

  - Polypropylene (HSDB, 2003k) (CASRN: 9003-07-0)
    - By polymerization of propylene.
  - Propylene (HSDB, 2006c) (CASRN: 115-07-1)
    - From petroleum oils during gasoline refining, thermal/catalytic cracking of hydrocarbons, or catalytic dehydrogenation of propane.
- Potential impurities:
  - Polypropylene (HSDB, 2003k)
    - Propane, ethane, carbon dioxide.
    - Polymerization grade contains saturates (200 ppm), butylene (20 ppm), ethylene (20 ppm), methylacetylene (10 ppm), oxygen (10 ppm), butadiene (5 ppm), propadiene (5 ppm), carbon monoxide (5 ppm), carbon dioxide (5 ppm), water (5 ppm), hydrogen (5 ppm), and methanol (5 ppm).

6.2 Furan oligomers (CASRN: 110-00-9)

- Manufacturing (HSDB, 2011c):
  - By decarboxylation of 2-furancarboxylic acid.
  - Directly from furfural over soda-lime or dropping furfural on a mixture of sodium and potassium hydroxides.
  - Distillation of furoic acid from furfural.
  - Heating furfural with a palladium catalyst.
  - Oxidization of butanediol by dichromate in acidic solution with subsequent dehydration.
  - Commercially by decarbonylation of furfural and a noble metal catalyst (palladium).
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

6.3 Barium carbonate (CASRN: 513-77-9)

- Manufacturing (HSDB, 2012i)
  - Occurs naturally in nature (witherite).
- Potential impurities (HSDB, 2012i)
  - Commercial grade was reported as having 0.006-0.12% total sulfur.

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HSDB (Hazardous Substances Data Bank). 2003i. Ortho Ester. TOXNET Database, National Library of Medicine (NLM). Bethesda, MD.

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HSDB (Hazardous Substances Data Bank). 2011b. Anhydrous Ammonia. TOXNET Database, National Library of Medicine (NLM). Bethesda, MD.

HSDB (Hazardous Substances Data Bank). 2011c. Furan Oligomers. TOXNET Database, National Library of Medicine (NLM). Bethesda, MD.

HSDB (Hazardous Substances Data Bank). 2012a. 4,4'-Diphenylmethane Diisocyanate. TOXNET Database, National Library of Medicine (NLM). Bethesda, MD.

HSDB (Hazardous Substances Data Bank). 2012b. Methanol. TOXNET Database, National Library of Medicine (NLM). Bethesda, MD.

HSDB (Hazardous Substances Data Bank). 2012c. Magnesium Oxide/Hydroxide. TOXNET Database, National Library of Medicine (NLM). Bethesda, MD.

HSDB (Hazardous Substances Data Bank). 2012d. Sodium Hydroxide. TOXNET Database, National Library of Medicine (NLM). Bethesda, MD.

HSDB (Hazardous Substances Data Bank). 2012e. Phosphoric Acid. TOXNET Database, National Library of Medicine (NLM). Bethesda, MD.

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HSDB (Hazardous Substances Data Bank). 2012g. Sodium Carbonate. TOXNET Database, National Library of Medicine (NLM). Bethesda, MD.

HSDB (Hazardous Substances Data Bank). 2012h. Formic Acid. TOXNET Database, National Library of Medicine (NLM). Bethesda, MD.

HSDB (Hazardous Substances Data Bank). 2012i. Barium Carbonate. TOXNET Database, National Library of Medicine (NLM). Bethesda, MD.

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HSDB (Hazardous Substances Data Bank). 2015d. Ammonium Chloride. TOXNET Database, National Library of Medicine (NLM). Bethesda, MD.

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TERA

Final Report for CPSC Task 14

Appendix I: Literature Search Strategy and Data Tables

INDEPENDENT

NON-PROFIT

SCIENCE

FOR PUBLIC HEALTH PROTECTION

FINAL Report

March 25, 2016

Submitted by:

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Contents

Appendix I: Literature Search Strategy and Data Tables

1.1 Description of Approach

For each of the three specified engineered wood products (EWPs), we investigated how the products are made, what raw materials are used in their manufacturing, the proportions of wood and non-wood components, and the potential recycled materials used in production. We also searched for data on concentrations of the substances of interest in the raw materials of the three types of engineered wood products. We used a multi-pronged approach to identify available information in order to answer the question of whether engineered wood products (or the raw materials with which they are made) contain lead (in concentrations over 100 ppm), the specified phthalates (in concentrations over 1000 ppm), or any of the specified ASTM elements (in concentrations exceeding the specified limits shown in Table 1 of the main report). Our focus was to identify relevant information on the five research topics identified by CPSC in order to address the question of whether engineered wood products, used as substrates in toys or childcare articles, might contain any of the substances in concentrations above the specified limits.

We first researched authoritative sources such as reference and text books, along with Internet resources, for general information about engineered wood products, adhesives, raw materials, manufacturing processes, and the potential use of recycled materials. We utilized this information and consulted technical experts to identify key words for literature searching. We then conducted primary literature searches for research studies and publications. In addition, we searched for Safety Data Sheets (SDSs) for additional information on raw materials, the typically used materials, and the proportions of these materials in EWPs.

To address our research task, we reviewed the literature and resources for evidence of the potential presence or concentrations of the specified elements or phthalates in the three EWPs in a step-wise fashion. First, we looked for data on measurements of specified elements or phthalates in EWP boards. As anticipated, we found little information regarding direct evidence and concentrations of the specified elements or phthalates in the engineered woods themselves (Section 4). Finding little data on the EWPs themselves, we then sought measurements of specified elements or phthalates in adhesives and waxes and their raw materials (Sections 6 and Appendix III). We also looked at uptake of phthalates into plants to determine whether phthalates might be found in EWPs made with contaminated cellulosic materials (Section 7).

Lastly, we searched for information on elements and phthalates in recycled materials that might be used to make EWPs (Section 8).

This appendix describes how we searched the literature to identify relevant information on the five research topics identified by CPSC, in order to address the question of whether engineered wood products, used as substrates in toys or childcare articles, might contain any of the substances of interest in concentrations above the specified limits.

We sought information from a number of resources and each is described below.

- Authoritative References and Books
- Internet Searches
- Primary Literature
- Trade Organizations
- Safety Data Sheets (SDSs)

1.1.1 Authoritative References and Books

Authoritative sources included reference books [*e.g.*, Introduction to Wood and Natural Fiber Composites (Stokke, 2013); CLT Handbook, U.S. Edition. (Karacabeyli and Douglas, 2013); Research Developments in Wood Engineering and Technology (Aguilera, 2013); Reactive Polymers Fundamentals and Applications: A Concise Guide to Industrial Polymers (Fink, 2013); Encyclopedic Dictionary of Polymers (Gooch, 2007); Handbook of Wood Chemistry and Wood Composites (Rowell, 2012); Handbook of Plasticizers (Wypych, 2012); Aldrich: Handbook of Fine Chemicals and Laboratory Equipment (Sigma-Aldrich, 2004)]. This also included government and industry reports. These were mainly identified through library databases and Internet searching.

1.1.2 Internet Searches

We searched the Internet initially to help understand what data and resources are available to address our needs, and to identify key words for literature searching. We also conducted targeted Internet searches to find information on specific topics and questions that the primary literature search did not identify. These searches included company and trade association web pages, SDSs and manufacturer information sheets, recycling regulations and information, and government reports.

1.1.3 Primary Literature

For each of the three engineered wood products, including adhesives and waxes, and for the use of recycled raw materials, TERA conducted a literature search for primary literature studies that investigated the presence or concentration of the specified elements or phthalates. Because the information for each of the topic areas was diverse, slightly different approaches were undertaken for each search in order to optimize our results.

TERA identified and screened potentially relevant studies for information on concentrations of substances in each material. TERA searched the National Library of Medicine, PubMed, and Toxline databases (http://www.ncbi.nlm.nih.gov/pubmed and http://toxnet.nlm.nih.gov/newtoxnet/toxline.htm), Elsevier's SCOPUS database (http://www.scopus.com/), and Thomson Reuters's Web of Science (WOS) database (http://wokinfo.com/). The keywords searched and resultant hits for each search string are found below. All hits for each search string were recorded, saved, and downloaded into a raw EndNote library. After an initial prescreen to remove duplicates, extraneous, and irrelevant studies, a second, more thorough screening was performed to determine relevancy and likelihood for a study to contain substance concentration information in the materials of interest. This was done for each element and each material group. Once a study was identified as relevant, it was retrieved and data were pulled into a table. Studies were limited to only those available in English.

To determine if recycled woods are used to make the engineered wood products, we searched the SCOPUS and WOS databases for studies on plywood, particleboard, and/or medium density fiberboard (MDF) with wood waste and other related terms. The keywords searched and resultant hits for each search string are found below. Due to the broad nature of the search and the large number of hits from SCOPUS, we limited screening and retrieval to WOS. Screening was conducted as described above.

1.1.4 Trade Organizations

We did not find all of the information in the open literature, particularly specific information on raw materials used in EWPs and their proportions, because either it did not exist, or it was proprietary company information. The published literature only contained general information on ranges of proportions or materials generally used. Because much of the specific information was not available in the primary literature, additional research to gain access to proprietary data was conducted. Several North American trade associations were contacted for industry reports or additional data that they could share [*e.g.*, the Hardwood Plywood & Veneer Association (HPVA) and the Composite Panel Association (CPA)].

The highest producing companies for wood chips and particles, MDF, and hardwood plywood are located in North America, Europe, and China, almost exclusively (FAOSTAT, 2015; Raute, 2011)]. Additionally, searches were conducted to find international trade organizations and at least three were identified: Engineered Wood Products Association of Australia, the International Wood Products Association, and the European Panel Federation. These organizations' web pages were searched for any available information in English to aid in answering the specified research questions regarding composition and raw materials.

The web pages of several trade associations of wood recyclers were also reviewed, including the National Waste and Recycling Association, the Construction & Demolition Recycling Association, the Wood Recyclers Association in Great Britain, and the Alberta Waste Wood Recycling Association.

1.1.5 Safety Data Sheets

As mentioned above, data on raw materials and their proportions in finished products was difficult to find because of the proprietary nature of this data. In order to supplement the general information identified in books and published literature, a detailed Safety Data Sheet (SDS) search was conducted that provided more specific information on the non-wood materials used in EWPs and the proportions of those materials. Due to the large amount of SDSs available, two approaches were undertaken to limit the number of SDSs and to optimize the search. The first approach was to search the (M)SDS database MSDSXchange (http://www.msdsxchange.com/english/) for the specified EWPs (hardwood plywood, MDF, and particleboard). SDSs resulting from these searches were reviewed one by one, ruling out any non-relevant EWPs. There was some difficulty to this approach as some SDSs covered multiple EWPs. Results were recorded in a table and are presented in Appendix II. The second approach was to search the Composite Panel Association for member companies producing hardwood plywood, MDF, and particleboard. Even though the CPA only specifically includes companies producing particleboard and MDF, information was also found through them for companies that produce hardwood plywood, and so we determined that this information was relatively comprehensive of all specified EWPs. Each of the identified companies' websites was visited and SDSs reviewed, and this data was added to the tables in Appendix II.

This approach provided us with the specific data under investigation for this research project. However, it should be noted that this SDS approach likely only covered SDSs from companies and organizations in North America. For example, we searched the International Wood Products Association for manufacturers of the specified EWPs. However, most of the results were North American companies. For the few companies that were identified outside of North America (*e.g.*, Malaysia, China), SDSs could not be found on their webpages.

1.2 Approach for Phthalate Uptake

The search strategy for this piece of the report was considered screening level and not comprehensive of all of the available literature. The search strings and database searches are found below. To mirror the approach of the previous Task 9 (CPSC, 2015), we aimed to first identify concentrations of the specified phthalates in trees themselves that are used to make EWPs. This search was supplemented with additional information from the literature related to the potential for uptake into plants. The initial database searched was PubMed. This search provided some data on the potential for phthalate uptake and concentration in plants, but no data on phthalate uptake and concentration in trees. Additional gap searching was conducted in the Web of Science database and the Scopus database to confirm that there were no missed data for uptake and concentration of phthalates in trees only (this search did not include other types of plants and is why this search was considered screening level).

In reviewing and screening studies for relevance, studies were excluded that studied phthalate concentrations in water or uptake into aquatic biota (including plants). This information was considered non-relevant for the analysis of phthalate uptake into terrestrial plants, although water concentration can be assumed to play a part in the fugacity of phthalates in the environment. Sediment and biodegradation studies, again while potentially informative of environmental presence, were excluded on the basis that the information does not support the identification of phthalate uptake into plants. Other studies that were not relevant were studies related to phthalate concentration in indoor air, homes, dusts, and plastic consumer products. Finally, analysis of phthalates in food were originally viewed, but later removed as there were multiple contamination pathways identified as to how food and foodstuff could be contaminated post-harvesting, and so were not determined adequate predictors of phthalate uptake into plants.

To supplement the data because no studies were identified investigating phthalate uptake in trees, additional searches were conducted in Scopus and Web of Science for information on trees only, as documented below.

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1.4 Key Words and Search Results for Concentrations of Specified Phthalates and ASTM Elements in Engineered Wood Products

1.4.1 Medium Density Fiberboard

Database	Keyword	Query	Results
PubMed	Antimony	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Antimony"[All Fields])	0
Scopus	Antimony	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Antimony"))	1
WOS	Antimony	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Antimony"))	3
PubMed	Arsenic	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Arsenic"[All Fields])	2
Scopus	Arsenic	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Arsenic"))	10
WOS	Arsenic	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Arsenic"))	7
PubMed	Barium	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Barium"[All Fields])	1
Scopus	Barium	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Barium"))	2
WOS	Barium	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Barium"))	5
PubMed	BBP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("benzyl butyl phthalate"[All Fields] OR "BBP"[All Fields] OR "85-68-7"[All Fields])	0
Scopus	BBP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("benzyl butyl phthalate" or "BBP" or "85-68-7"))	0
WOS	BBP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("benzyl butyl phthalate" or "BBP" or "85-68-7"))	0
PubMed	Cadmium	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Cadmium"[MeSH Terms] OR "Cadmium"[All Fields])	0
Scopus	Cadmium	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Cadmium"))	4
WOS	Cadmium	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Cadmium"))	2
PubMed	Chromium	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Chromium"[All Fields])	0
Scopus	Chromium	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Chromium"))	8
WOS	Chromium	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Chromium"))	10
PubMed	DBP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("dibutyl phthalate"[All Fields] OR "DBP"[All Fields] OR "84-74-2"[All Fields])	1
Scopus	DBP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("dibutyl phthalate" or "DBP" or "84-74-2"))	0

WOS	DBP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("dibutyl phthalate" or "DBP" or "84-74-2"))	0
PubMed	DCHP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("dicyclohexyl phthalate"[All Fields] OR "DCHP"[All Fields] OR "84-61-7"[All Fields])	0
Scopus	DCHP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("dicyclohexyl phthalate" or "DCHP" or "84-61-7"))	0
WOS	DCHP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("dicyclohexyl phthalate" or "DCHP" or "84-61-7"))	7
PubMed	DEHP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ((("diagnosis"[Subheading] OR "diagnosis"[All Fields] OR "di"[All Fields]) AND 2-ethylhexl[All Fields] AND ("phthalic acid"[Supplementary Concept] OR "phthalic acid"[All Fields] OR "phthalate"[All Fields])) OR "DEHP"[All Fields] OR "117-81-7"[All Fields])	0
Scopus	DEHP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("di-(2-ethylhexl) phthalate" or "DEHP" or "117-81-7"))	0
WOS	DEHP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("di-(2-ethylhexl) phthalate" or "DEHP" or "117-81-7"))	0
PubMed	DHEXP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("di-n-hexyl phthalate"[All Fields] OR "84-75-3"[All Fields])	0
Scopus	DHEXP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("di-n-hexyl phthalate" or "DHEXP" or "84-75-3"))	0
WOS	DHEXP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("di-n-hexyl phthalate" or "DHEXP" or "84-75-3"))	0
PubMed	DIBP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("diisobutyl phthalate"[All Fields] OR "DIBP"[All Fields] OR "84-69-5"[All Fields])	0
Scopus	DIBP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("diisobutyl phthalate" or "DIBP" or "84-69-5"))	0
WOS	DIBP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("diisobutyl phthalate" or "DIBP" or "84-69-5"))	0
PubMed	DIDP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("diisodecyl phthalate"[All Fields] OR "DIDP"[All Fields] OR "26761-40-0"[All Fields] or "68515-49-1"[All Fields])	0
Scopus	DIDP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("diisodecyl phthalate" or "DIDP" or "26761-40-0" or "68515-49-1"))	0
WOS	DIDP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("diisodecyl phthalate" or "DIDP" or "26761-40-0" or "68515-49-1"))	0
PubMed	DINP	("medium density fiberboard"[All Fields] OR "mdf"[All Fields] OR "medium-density fiberboard"[All Fields]) AND ("Diisononyl phthalate"[All Fields] OR "DINP"[All Fields] OR "28553-12-0"[All Fields] OR "68515-48-0"[All Fields])	0
Scopus	DINP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("diisononyl phthalate" or "DINP" or "28553-12-0" or "68515-48-0"))	0

WOS	DINP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("diisononyl phthalate" or "DINP" or "28553-12-0" or "68515-48-0"))	0
PubMed	DnOP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("di-n-octyl phthalate"[All Fields] OR "DnOP"[All Fields] OR "117-84-0"[All Fields])	0
Scopus	DnOP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("di-n-octyl phthalate" or "DnOP" or "117-84-0"))	0
WOS	DnOP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("di-n-octyl phthalate" or "DnOP" or "117-84-0"))	0
PubMed	DPENP	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("di-n-pentyl phthalate"[All Fields] OR "131-18-0"[All Fields])	0
Scopus	DPENP	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("di-n-pentyl phthalate" or "DPENP" or "131-18-0"))	0
WOS	DPENP	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("di-n-pentyl phthalate" or "DPENP" or "131-18-0"))	0
PubMed	Lead	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Lead"[All Fields])	18
Scopus	Lead	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Lead"))	104
WOS	Lead	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Lead"))	79
Toxline	MDF	medium-density fiberboard	36
PubMed	Mercury	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Mercury"[All Fields])	22
Scopus	Mercury	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Mercury"))	55
WOS	Mercury	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Mercury"))	51
PubMed	Selenium	("Medium density fiberboard"[All Fields] OR "MDF"[All Fields] OR "Medium-density fiberboard"[All Fields]) AND ("Selenium"[All Fields])	0
Scopus	Selenium	(TITLE-ABS-KEY ("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND TITLE-ABS-KEY ("Selenium"))	1
WOS	Selenium	(ts=("Medium density fiberboard" OR "MDF" OR "Medium-density fiberboard") AND ts=("Selenium"))	4

1.4.1.1 MDF Results Summary

Keyword	**PubMed**	**Scopus**	**Toxline**	**WOS**	**Keyword Total**	**Duplicates Removed**
Antimony	0	1	0	3	4	3
Arsenic	2	10	0	7	19	12
Barium	1	2	0	5	8	6
BBP	0	0	0	0	0	0
Cadmium	0	4	0	2	6	5
Chromium	0	8	0	10	18	13
DBP	1	0	0	0	1	1
DCHP	0	0	0	7	7	7

DEHP	0	0	0	0	0	0
DHEXP	0	0	0	0	0	0
DIBP	0	0	0	0	0	0
DIDP	0	0	0	0	0	0
DINP	0	0	0	0	0	0
DnOP	0	0	0	0	0	0
DPENP	0	0	0	0	0	0
Lead	18	104	0	79	201	136
MDF	0	0	36	0	36	34
Mercury	22	55	0	51	128	62
Selenium	0	1	0	4	5	5
Database Total	**44**	**185**	**36**	**168**	**433**	

1.4.2 Particleboard

Database	**Keyword**	**Query**	**Results**
PubMed	Antimony	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Antimony"[All Fields])	0
PubMed	Arsenic	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Arsenic"[All Fields])	1
PubMed	Barium	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Barium"[All Fields])	0
PubMed	BBP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("benzyl butyl phthalate"[All Fields] OR "BBP"[All Fields] OR "85-68-7"[All Fields])	0
PubMed	Cadmium	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Cadmium"[MeSH Terms] OR "Cadmium"[All Fields])	1
PubMed	Chromium	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Chromium"[All Fields])	0
PubMed	DBP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("dibutyl phthalate"[All Fields] OR "DBP"[All Fields] OR "84-74-2"[All Fields])	0
PubMed	DCHP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("dicyclohexyl phthalate"[All Fields] OR "DCHP"[All Fields] OR "84-61-7"[All Fields])	0
PubMed	DEHP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ((("diagnosis"[Subheading] OR "diagnosis"[All Fields] OR "di"[All Fields]) AND 2-ethylhexl[All Fields] AND ("phthalic acid"[Supplementary Concept] OR "phthalic acid"[All Fields] OR "phthalate"[All Fields])) OR "DEHP"[All Fields] OR "117-81-7"[All Fields])	23
PubMed	DHEXP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("di-n-hexyl phthalate"[All Fields] OR "84-75-3"[All Fields])	0

PubMed	DIBP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("diisobutyl phthalate"[All Fields] OR "DIBP"[All Fields] OR "84-69-5"[All Fields])	0
PubMed	DIDP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("diisodecyl phthalate"[All Fields] OR "DIDP"[All Fields] OR "26761-40-0"[All Fields] or "68515-49-1"[All Fields]))	0
PubMed	DINP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("diisononyl phthalate"[All Fields] OR "DINP"[All Fields] OR "28553-12-0"[All Fields] or "68515-48-1"[All Fields]))	0
PubMed	DnOP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("di-n-octyl phthalate"[All Fields] OR "DnOP"[All Fields] OR "117-84-0"[All Fields])	0
PubMed	DPENP	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("di-n-pentyl phthalate"[All Fields] OR "131-18-0"[All Fields])	0
PubMed	Lead	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Lead"[All Fields])	2
PubMed	Mercury	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Mercury"[All Fields])	1
PubMed	Selenium	("Particleboard"[All Fields] OR "Particle-board"[All Fields] OR "Particle board"[All Fields]) AND ("Selenium"[All Fields])	0
Scopus	Antimony	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Antimony"))	1
Scopus	Arsenic	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Arsenic"))	0
Scopus	Barium	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Barium"))	1
Scopus	BBP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("benzyl butyl phthalate" or "BBP" or "85-68-7"))	0
Scopus	Cadmium	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Cadmium"))	2
Scopus	Chromium	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Chromium"))	12
Scopus	DBP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("dibutyl phthalate" or "DBP" or "84-74-2"))	0
Scopus	DCHP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("dicyclohexyl phthalate" or "DCHP" or "84-61-7"))	0
Scopus	DEHP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("di-(2-ethylhexl) phthalate" or "DEHP" or "117-81-7"))	0
Scopus	DHEXP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("di-n-hexyl phthalate" or "DHEXP" or "84-75-3"))	0
Scopus	DIBP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("diisobutyl phthalate" or "DIBP" or "84-69-5"))	0

Scopus	DIDP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("diisodecyl phthalate" or "DIDP" or "26761-40-0" or "68515-49-1"))	0
Scopus	DINP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("diisononyl phthalate" or "DINP" or "28553-12-0" or "68515-48-1"))	0
Scopus	DnOP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("di-n-octyl phthalate" or "DnOP" or "117-84-0"))	0
Scopus	DPENP	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("di-n-pentyl phthalate" or "DPENP" or "131-18-0"))	0
Scopus	Lead	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Lead"))	77
Scopus	Mercury	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Mercury"))	6
Scopus	Selenium	(TITLE-ABS-KEY ("Particleboard" OR "Particle-board" OR "Particle board") AND TITLE-ABS-KEY ("Selenium"))	0
Toxline	Particleboard	"Particleboard" OR "Particle-board" OR "Particle board"	194
WOS	Antimony	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Antimony"))	2
WOS	Arsenic	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Arsenic"))	14
WOS	Barium	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Barium"))	3
WOS	BBP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("benzyl butyl phthalate" or "BBP" or "85-68-7"))	0
WOS	Cadmium	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Cadmium"))	3
WOS	Chromium	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Chromium"))	25
WOS	DBP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("dibutyl phthalate" or "DBP" or "84-74-2"))	1
WOS	DCHP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("dicyclohexyl phthalate" or "DCHP" or "84-61-7"))	7
WOS	DEHP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("di-(2-ethylhexl) phthalate" or "DEHP" or "117-81-7"))	0
WOS	DHEXP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("di-n-hexyl phthalate" or "DHEXP" or "84-75-3"))	0
WOS	DIBP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("diisobutyl phthalate" or "DIBP" or "84-69-5"))	0
WOS	DIDP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("diisodecyl phthalate" or "DIDP" or "26761-40-0" or "68515-49-1"))	0
WOS	DINP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("diisononyl phthalate" or "DINP" or "28553-12-0" or "68515-48-1"))	0
WOS	DnOP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("di-n-octyl phthalate" or "DnOP" or "117-84-0"))	0
WOS	DPENP	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("di-n-pentyl phthalate" or "DPENP" or "131-18-0"))	0
WOS	Lead	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Lead"))	38

WOS	Mercury	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Mercury"))	7
WOS	Selenium	(ts=("Particleboard" OR "Particle-board" OR "Particle board") AND ts=("Selenium"))	1

1.4.2.1 Particleboard Search Summary

Keyword	PubMed	Scopus	Toxline	WOS	Keyword Total	Duplicates Removed
Antimony	0	1	0	2	3	5
Arsenic	1	0	0	14	15	14
Barium	0	1	0	3	4	4
BBP	0	0	0	0	0	0
Cadmium	1	2	0	3	6	4
Chromium	0	12	0	25	37	31
DBP	0	0	0	1	1	1
DCHP	0	0	0	7	7	7
DEHP	23	0	0	0	23	23
DHEXP	0	0	0	0	0	0
DIBP	0	0	0	0	0	0
DIDP	0	0	0	0	0	0
DINP	0	0	0	0	0	0
DnOP	0	0	0	0	0	0
DPENP	0	0	0	0	0	0
Lead	2	77	0	38	117	102
Mercury	1	6	0	7	14	10
Particleboard	0	0	194	0	194	194
Selenium	0	0	0	1	1	1
Database Total	**28**	**99**	**194**	**101**	**422**	

1.4.3 Plywood

Database	Keyword	Query	Results
PubMed	Antimony	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Antimony"[All Fields] OR "7440-36-0"[All Fields])	0
PubMed	Arsenic	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Arsenic"[All Fields] OR "7440-38-2"[All Fields])	3

PubMed	Barium	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Barium"[All Fields] OR "7440-39-3"[All Fields])	0
PubMed	BBP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("benzyl butyl phthalate"[All Fields] OR "BBP"[All Fields] OR "85-68-7"[All Fields])	0
PubMed	Cadmium	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Cadmium"[All Fields] OR "7440-43-9"[All Fields])	0
PubMed	Chromium	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Chromium"[All Fields] OR "7440-47-3"[All Fields])	1
PubMed	DBP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("dibutyl phthalate"[All Fields] OR "DBP"[All Fields] OR "84-74-2"[All Fields])	0
PubMed	DCHP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("dicyclohexyl phthalate"[All Fields] OR "DCHP"[All Fields] OR "84-61-7"[All Fields])	0
PubMed	DEHP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ((("diagnosis"[Subheading] OR "diagnosis"[All Fields] OR "di"[All Fields]) AND 2-ethylhexl[All Fields] AND ("phthalic acid"[Supplementary Concept] OR "phthalic acid"[All Fields] OR "phthalate"[All Fields])) OR "DEHP"[All Fields] OR "117-81-7"[All Fields])	0
PubMed	DHEXP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("di-n-hexyl phthalate"[All Fields] OR "84-75-3"[All Fields])	0
PubMed	DIBP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("diisobutyl phthalate"[All Fields] OR "DIBP"[All Fields] OR "84-69-5"[All Fields])	0
PubMed	DIDP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("diisodecyl phthalate"[All Fields] OR "DIDP"[All Fields] OR "26761-40-0"[All Fields] OR "68515-49-1"[All Fields])	0
PubMed	DINP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("diisononyl phthalate"[All Fields] OR "DINP"[All Fields] OR "28553-12-0"[All Fields] OR "68515-48-0"[All Fields])	0

PubMed	DnOP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("di-n-octyl phthalate "[All Fields] OR "DnOP"[All Fields] OR "117-84-0"[All Fields])	0
PubMed	DPENP	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("di-n-pentyl phthalate "[All Fields] OR "131-18-0"[All Fields])	0
PubMed	Lead	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Lead "[All Fields] OR "7439-92-1"[All Fields])	4
PubMed	Mercury	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Mercury"[All Fields] OR "7439-97-6"[All Fields])	0
PubMed	Selenium	(Plywood[All Fields] OR (Laminated[All Fields] AND Veneer[All Fields]) OR (Wood-based[All Fields] AND panel[All Fields]) OR "Composite Panel"[All Fields]) AND ("Selenium"[All Fields] OR "7782-49-2"[All Fields])	0
Scopus	Antimony	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Antimony" or "7440-36-0"))	0
Scopus	Arsenic	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Arsenic" or "7440-38-2"))	7
Scopus	Barium	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Barium" or "7440-39-3"))	5
Scopus	BBP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("benzyl butyl phthalate" or "BBP" or "85-68-7"))	2
Scopus	Cadmium	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Cadmium" or "7440-43-9"))	6
Scopus	Chromium	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Chromium" or "7440-47-3"))	10
Scopus	DBP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("di-2-ethylhexl phthalate" or "DEHP" or "117-81-7"))	0
Scopus	DCHP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("di-n-hexyl phthalate" or "DHEXP" or "84-75-3"))	0
Scopus	DEHP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("di-n-octyl phthalate" or "DnOP" or "117-84-0"))	0
Scopus	DHEXP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("di-n-pentyl phthalate" or "DPENP" or "131-18-0"))	0
Scopus	DIBP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("dibutyl phthalate" or "DBP" or "84-74-2"))	1
Scopus	DIDP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("dicyclohexyl phthalate" or "DCHP" or "84-61-7"))	0

Scopus	DINP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("diisobutyl phthalate" or "DIBP" or "84-69-5"))	0
Scopus	DnOP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("diisodecyl phthalate" or "DIDP" or "26761-40-0" or "68515-49-1"))	0
Scopus	DPENP	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("diisononyl phthalate" or "DINP" or "28553-12-0" or "68515-48-0"))	0
Scopus	Lead	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Lead" or "7439-92-1"))	269
Scopus	Mercury	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Mercury" or "7439-97-6"))	5
Scopus	Selenium	(TITLE-ABS-KEY ("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (TITLE-ABS-KEY ("Selenium" or "7782-49-2"))	1
Toxline	Plywood	"Plywood" OR "Laminated Veneer" OR "Wood-based panel" or "Composite panel"	517
WOS	Antimony	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Antimony" or "7440-36-0"))	8
WOS	Arsenic	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Arsenic" or "7440-38-2"))	12
WOS	Barium	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Barium" or "7440-39-3"))	23
WOS	BBP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("benzyl butyl phthalate" or "BBP" or "85-68-7"))	2
WOS	Cadmium	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Cadmium" or "7440-43-9"))	7
WOS	Chromium	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Chromium" or "7440-47-3"))	33
WOS	DBP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("dibutyl phthalate" or "DBP" or "84-74-2"))	10
WOS	DCHP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("dicyclohexyl phthalate" or "DCHP" or "84-61-7"))	8
WOS	DEHP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("di-2-ethylhexl phthalate" or "DEHP" or "117-81-7"))	0
WOS	DHEXP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("di-n-hexyl phthalate" or "DHEXP" or "84-75-3"))	0
WOS	DIBP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("diisobutyl phthalate" or "DIBP" or "84-69-5"))	0
WOS	DIDP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("diisodecyl phthalate" or "DIDP" or "26761-40-0" or "68515-49-1"))	0

WOS	DINP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("diisononyl phthalate" or "DINP" or "28553-12-0" or "68515-48-0"))	0
WOS	DnOP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("di-n-octyl phthalate" or "DnOP" or "117-84-0"))	0
WOS	DPENP	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("di-n-pentyl phthalate" or "DPENP" or "131-18-0"))	0
WOS	Lead	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Lead" or "7439-92-1"))	186
WOS	Mercury	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Mercury" or "7439-97-6"))	10
WOS	Selenium	(ts=("Plywood" or "Laminated Veneer" or "Wood-based panel" or "Composite Panel")) and (ts=("Selenium" or "7782-49-2"))	2

1.4.3.1 Plywood Search Summary

Keyword	**PubMed**	**Scopus**	**Toxline**	**WOS**	**Keyword Total**	**Duplicates Removed**
Antimony	0	0	0	8	8	8
Arsenic	3	7	0	12	22	20
Barium	0	5	0	23	28	23
BBP	0	2	0	2	4	7
Cadmium	0	6	0	7	13	7
Chromium	1	10	0	33	44	44
DBP	0	0	0	10	10	10
DCHP	0	0	0	8	8	8
DEHP	0	0	0	0	0	0
DHEXP	0	0	0	0	0	0
DIBP	0	1	0	0	1	0
DIDP	0	0	0	0	0	0
DINP	0	0	0	0	0	0
DnOP	0	0	0	0	0	0
DPENP	0	0	0	0	0	0
Lead	4	269	0	186	459	406
Mercury	0	5	0	10	15	15
Plywood, etc.	0	0	517	0	517	466
Selenium	0	1	0	2	3	3
Database Total	**8**	**306**	**517**	**301**	**1132**	

1.5 Key Words and Search Results for Concentrations in Adhesive Formulations and Base Resins

1.5.1 MDI

Database	Keyword	Query	Results
Pubmed	BBP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“benzyl butyl phthalate” OR “BBP” OR “85-68-7”)	0
Pubmed	DBP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”)	2
Pubmed	DCHP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“dicyclohexyl phthalate” OR “DCHP” OR “84-61-7”)	0
Pubmed	DEHP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	3
Pubmed	DHEXP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”)	0
Pubmed	DIBP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”)	0
Pubmed	DIDP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”)	0
Pubmed	DINP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”)	0
Pubmed	DnOP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”)	0
Pubmed	DPENP	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”)	0
Pubmed	Antimony	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“antimony” OR “Sb” OR “7440-36-0”)	1
Pubmed	Arsenic	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“arsenic” OR “As” OR “7440-38-2”)	4
Pubmed	Barium	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“barium” OR “Ba” OR “7440-39-3”)	7
Pubmed	Cadmium	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“cadmium” OR “Cd” OR “7440-43-9”)	9
Pubmed	Chromium	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“chromium” OR “Cr” OR “7440-47-3”)	1
Pubmed	Lead	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“lead” OR “Pb” OR “7439-92-1”)	81
Pubmed	Mercury	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“mercury” OR “Hg” OR “7439-97-6”)	14
Pubmed	Selenium	(“Methylene-diphenyl-diisocyanate” OR “MDI” OR “101-68-8”) AND (“selenium” OR “Se” OR “7782-49-2”)	66
Scopus	BBP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("benzyl butyl phthalate" OR "BBP" OR "85-68-7")))	2
Scopus	DBP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("dibutyl phthalate" OR "DBP" OR "84-74-2")))	16
Scopus	DCHP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")))	0

Scopus	DEHP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")))	17
Scopus	DHEXP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")))	0
Scopus	DIBP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("diisobutyl phthalate" OR "DIBP" OR "84-69-5")))	1
Scopus	DIDP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")))	1
Scopus	DINP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")))	2
Scopus	DnOP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")))	2
Scopus	DPENP	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")))	0
Scopus	Antimony	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("antimony" OR "Sb" OR "7440-36-0")))	62
Scopus	Arsenic	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("arsenic" OR "7440-38-2")))	45
Scopus	Barium	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("barium" OR "7440-39-3")))	32
Scopus	Cadmium	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("cadmium" OR "7440-43-9")))	77
Scopus	Chromium	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("chromium" OR "7440-47-3")))	92
Scopus	Lead	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("lead" OR "7439-92-1")))	888*
Scopus	Lead	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL ((("lead" AND "metal") OR "7439-92-1")))	153
Scopus	Lead	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("7439-92-1")))	28
Scopus	Mercury	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("mercury" OR "Hg" OR "7439-97-6")))	138
Scopus	Selenium	(ALL (("Methylene-diphenyl-diisocyanate" OR "MDI" OR "101-68-8")) AND ALL (("selenium" OR "7782-49-2")))	40
WOS	BBP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (benzyl butyl phthalate OR BBP OR 85-68-7))	1
WOS	DBP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”))	2
WOS	DCHP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7))	0
WOS	DEHP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”))	3
WOS	DHEXP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3))	0
WOS	DIBP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	1
WOS	DIDP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1))	0

WOS	DINP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0))	0
WOS	DnOP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-n-octyl phthalate OR DnOP OR 117-84-0))	0
WOS	DPENP	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0))	0
WOS	Antimony	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“antimony” OR “Sb” OR “7440-36-0”))	5
WOS	Arsenic	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“arsenic” OR “7440-38-2”))	6
WOS	Barium	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“barium” OR “7440-39-3”))	1
WOS	Cadmium	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“cadmium” OR “7440-43-9”))	3
WOS	Chromium	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“chromium” OR “7440-47-3”))	3
WOS	Lead	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“lead” OR “7439-92-1”))	141
WOS	Mercury	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“mercury” OR “Hg” OR “7439-97-6”))	16
WOS	Selenium	TS=((Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (“selenium” OR “7782-49-2”))	2
Toxline	BBP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (benzyl butyl phthalate OR BBP OR 85-68-7)	2
Toxline	DBP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (dibutyl phthalate OR DBP OR 84-74-2)	9
Toxline	DCHP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7)	0
Toxline	DEHP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-2-ethylhexyl phthalate OR DEHP OR 117-81-7)	11
Toxline	DHEXP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3)	0
Toxline	DIBP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (diisobutyl phthalate OR DIBP OR 84-69-5)	0
Toxline	DIDP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1)	2
Toxline	DINP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0)	0
Toxline	DnOP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-n-octyl phthalate OR DnOP OR 117-84-0)	11
Toxline	DPENP	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0)	0
Toxline	Antimony	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (antimony OR Sb OR 7440-36-0)	10
Toxline	Arsenic	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (arsenic OR 7440-38-2)	10
Toxline	Barium	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (barium OR 7440-39-3)	5
Toxline	Cadmium	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (cadmium OR Cd OR 7440-43-9)	27
Toxline	Chromium	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (chromium OR 7440-47-3)	11

Toxline	Lead	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (lead OR Pb OR 7439-92-1)	32
Toxline	Mercury	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (mercury OR Hg OR 7439-97-6)	16
Toxline	Selenium	(Methylene-diphenyl-diisocyanate OR MDI OR 101-68-8) AND (selenium OR Se OR 7782-49-2)	10

*search further refined

1.5.2 Melamine

Database	Keyword	Query	Results
Pubmed	BBP	(“Melamine”) AND (“benzyl butyl phthalate” OR “BBP” OR “85-68-7”)	0
Pubmed	DBP	(“Melamine”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”)	1
Pubmed	DCHP	(“Melamine”) AND (“dicyclohexyl phthalate” OR “DCHP” OR “84-61-7”)	0
Pubmed	DEHP	(“Melamine”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	2
Pubmed	DHEXP	(“Melamine”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”)	0
Pubmed	DIBP	(“Melamine”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”)	0
Pubmed	DIDP	(“Melamine”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”)	0
Pubmed	DINP	(“Melamine”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”)	0
Pubmed	DnOP	(“Melamine”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”)	0
Pubmed	DPENP	(“Melamine”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”)	0
Pubmed	Antimony	(“Melamine”) AND (“antimony” OR “Sb” OR “7440-36-0”)	8
Pubmed	Arsenic	(“Melamine”) AND (“arsenic” OR “As” OR “7440-38-2”)	3
Pubmed	Barium	(“Melamine”) AND (“barium” OR “Ba” OR “7440-39-3”)	4
Pubmed	Cadmium	(“Melamine”) AND (“cadmium” OR “Cd” OR “7440-43-9”)	25
Pubmed	Chromium	(“Melamine”) AND (“chromium” OR “Cr” OR “7440-47-3”)	12
Pubmed	Lead	(“Melamine”) AND (“lead” OR “Pb” OR “7439-92-1”)	52
Pubmed	Mercury	(“Melamine”) AND (“mercury” OR “Hg” OR “7439-97-6”)	14
Pubmed	Selenium	(“Melamine”) AND (“selenium” OR “Se” OR “7782-49-2”)	29
Scopus	BBP	("Melamine") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	10
Scopus	DBP	("Melamine") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	52
Scopus	DCHP	("Melamine") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	5
Scopus	DEHP	("Melamine") AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	70
Scopus	DHEXP	("Melamine") AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	1
Scopus	DIBP	("Melamine") AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	4
Scopus	DIDP	("Melamine") AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	3
Scopus	DINP	("Melamine") AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	12
Scopus	DnOP	("Melamine") AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	8
Scopus	DPENP	("Melamine") AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	2
Scopus	Antimony	("Melamine") AND ("antimony" OR "Sb" OR "7440-36-0")	532*
Scopus	Antimony	(("Melamine") AND ("antimony" OR "7440-36-0") NOT wastewater NOT asthma NOT remediation)	313
Scopus	Arsenic	("Melamine") AND ("arsenic" OR "7440-38-2")	511*
Scopus	Arsenic	("Melamine") AND ("arsenic" OR "7440-38-2") AND NOT chelate AND NOT wastewater AND NOT remediation AND NOT asthma	335

Scopus	Barium	("Melamine") AND ("barium" OR "7440-39-3")	211*
Scopus	Barium	(ALL (("Melamine") AND ("barium" OR "7440-39-3")) AND NOT ALL (chelate) AND NOT ALL (remediation) AND NOT ALL (wastewater) AND NOT ALL (asthma))	175
Scopus	Cadmium	(ALL (("Melamine") AND ("cadmium" OR "7440-43-9")) AND NOT ALL (chelate) AND NOT ALL (remediation) AND NOT ALL (wastewater) AND NOT ALL (asthma))	810
Scopus	Chromium	(ALL (("Melamine") AND ("chromium" OR "7440-47-3")) AND NOT ALL (asthma) AND NOT ALL (chelate) AND NOT ALL (wastewater) AND NOT ALL (remediation))	599
Scopus	Lead	("Melamine") AND ("lead" OR "7439-92-1")	2519*
Scopus	Lead	("Melamine") AND (("lead" AND "metal") OR "7439-92-1")	1607*
Scopus	Lead	("Melamine") AND ("7439-92-1")	90
Scopus	Lead	(ALL (("Melamine") AND (("lead" AND "metal") OR "7439-92-1")) AND NOT ALL (asthma) AND NOT ALL (remediation) AND NOT ALL (wastewater) AND NOT ALL (chelate))	1166
Scopus	Mercury	("Melamine") AND ("mercury" OR "Hg" OR "7439-97-6")	1561*
Scopus	Mercury	ALL (("Melamine") AND ("mercury" OR "7439-97-6")) AND NOT ALL (chelate) AND NOT ALL (remediation) AND NOT ALL (asthma) AND NOT ALL (wastewater)	978
Scopus	Selenium	("Melamine") AND ("selenium" OR "7782-49-2")	313*
Scopus	Selenium	(ALL (("Melamine") AND ("selenium" OR "7782-49-2")) AND NOT ALL (asthma) AND NOT ALL (wastewater) AND NOT ALL (remediation) AND NOT ALL (chelate))	226
WOS	BBP	TS=((Melamine) AND (benzyl butyl phthalate OR BBP OR 85-68-7))	7
WOS	DBP	TS=((Melamine) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”))	101
WOS	DCHP	TS=((Melamine) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7))	4
WOS	DEHP	TS=((Melamine) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”))	7
WOS	DHEXP	TS=((Melamine) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3))	0
WOS	DIBP	TS=((Melamine) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	1
WOS	DIDP	TS=((Melamine) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1))	4
WOS	DINP	TS=((Melamine) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0))	8
WOS	DnOP	TS=((Melamine) AND (di-n-octyl phthalate OR DnOP OR 117-84-0))	1
WOS	DPENP	TS=((Melamine) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0))	0
WOS	Antimony	TS=((Melamine) AND (“antimony” OR “7440-36-0”))	396*
WOS	Antimony	TS=((Melamine) AND (“antimony” OR “7440-36-0”)) NOT TS=(wastewater) NOT TS=(asthma) NOT TS=(remediation) NOT TS=(chelate)	392
WOS	Arsenic	TS=((Melamine) AND (“arsenic” OR “7440-38-2”))	22
WOS	Barium	TS=((Melamine) AND (“barium” OR “7440-39-3”))	343*
WOS	Barium	TS=((Melamine) AND (“barium” OR “7440-39-3”)) NOT TS=(asthma) NOT TS=(chelate) NOT TS=(remediation) NOT TS=(wastewater)	343
WOS	Cadmium	TS=((Melamine) AND (“cadmium” OR “7440-43-9”))	88
WOS	Chromium	TS=((Melamine) AND (“chromium” OR “7440-47-3”))	260*
WOS	Chromium	TS=((Melamine) AND (“chromium” OR “7440-47-3”)) NOT TS=(chelate) NOT TS=(asthma) NOT TS=(remediation) NOT TS=(wastewater)	255
WOS	Lead	TS=((Melamine) AND (“lead” OR “7439-92-1”))	445*
WOS	Lead	TS=((Melamine) AND (“lead” OR “7439-92-1”)) NOT TS=(wastewater) NOT TS=(asthma) NOT TS=(chelate) NOT TS=(remediation)	433
WOS	Mercury	TS=((Melamine) AND (“mercury” OR “Hg” OR “7439-97-6”))	133
WOS	Selenium	TS=((Melamine) AND (“selenium” OR “7782-49-2”))	32

Toxline	BBP	(Melamine) AND (benzyl butyl phthalate OR BBP OR 85-68-7)	32
Toxline	DBP	(Melamine) AND (dibutyl phthalate OR DBP OR 84-74-2)	0
Toxline	DCHP	(Melamine) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7)	0
Toxline	DEHP	(Melamine) AND (di-2-ethylhexyl phthalate OR DEHP OR 117-81-7)	39
Toxline	DHEXP	(Melamine) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3)	0
Toxline	DIBP	(Melamine) AND (diisobutyl phthalate OR DIBP OR 84-69-5)	0
Toxline	DIDP	(Melamine) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1)	0
Toxline	DINP	(Melamine) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0)	0
Toxline	DnOP	(Melamine) AND (di-n-octyl phthalate OR DnOP OR 117-84-0)	37
Toxline	DPENP	(Melamine) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0)	0
Toxline	Antimony	(Melamine) AND (antimony OR Sb OR 7440-36-0)	1
Toxline	Arsenic	(Melamine) AND (arsenic OR 7440-38-2)	5
Toxline	Barium	(Melamine) AND (barium OR 7440-39-3)	1
Toxline	Cadmium	(Melamine) AND (cadmium OR Cd OR 7440-43-9)	21
Toxline	Chromium	(Melamine) AND (chromium OR 7440-47-3)	7
Toxline	Lead	(Melamine) AND (lead OR Pb OR 7439-92-1)	24
Toxline	Mercury	(Melamine) AND (mercury OR Hg OR 7439-97-6)	2
Toxline	Selenium	(Melamine) AND (selenium OR Se OR 7782-49-2)	8

*search further refined

1.5.3 Phenol Formaldehyde

Database	Keyword	Search String	Hits
Pubmed	BBP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“benzyl butyl phthalate” OR “BBP” OR “85-68-7”)	0
Pubmed	DBP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”)	0
Pubmed	DCHP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“dicyclohexyl phthalate” OR “DCHP” OR “84-61-7”)	0
Pubmed	DEHP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	1
Pubmed	DHEXP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”)	0
Pubmed	DIBP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”)	0
Pubmed	DIDP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”)	0
Pubmed	DINP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”)	0
Pubmed	DnOP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”)	0
Pubmed	DPENP	(“Phenol formaldehyde” OR “9003-35-4”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”)	0
Pubmed	Antimony	(“Phenol formaldehyde” OR “9003-35-4”) AND (“antimony” OR “Sb” OR “7440-36-0”)	1
Pubmed	Arsenic	(“Phenol formaldehyde” OR “9003-35-4”) AND (“arsenic” OR “As” OR “7440-38-2”)	1
Pubmed	Barium	(“Phenol formaldehyde” OR “9003-35-4”) AND (“barium” OR “Ba” OR “7440-39-3”)	2

Pubmed	Cadmium	(“Phenol formaldehyde” OR “9003-35-4”) AND (“cadmium” OR “Cd” OR “7440-43-9”)	4
Pubmed	Chromium	(“Phenol formaldehyde” OR “9003-35-4”) AND (“chromium” OR “Cr” OR “7440-47-3”)	2
Pubmed	Lead	(“Phenol formaldehyde” OR “9003-35-4”) AND (“lead” OR “Pb” OR “7439-92-1”)	4
Pubmed	Mercury	(“Phenol formaldehyde” OR “9003-35-4”) AND (“mercury” OR “Hg” OR “7439-97-6”)	3
Pubmed	Selenium	(“Phenol formaldehyde” OR “9003-35-4”) AND (“selenium” OR “Se” OR “7782-49-2”)	2
Scopus	BBP	("Phenol formaldehyde" OR "9003-35-4") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	1
Scopus	DBP	("Phenol formaldehyde" OR "9003-35-4") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	10
Scopus	DCHP	("Phenol formaldehyde" OR "9003-35-4") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	0
Scopus	DEHP	("Phenol formaldehyde" OR "9003-35-4") AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	7
Scopus	DHEXP	("Phenol formaldehyde" OR "9003-35-4") AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	0
Scopus	DIBP	("Phenol formaldehyde" OR "9003-35-4") AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	0
Scopus	DIDP	("Phenol formaldehyde" OR "9003-35-4") AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	1
Scopus	DINP	("Phenol formaldehyde" OR "9003-35-4") AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	0
Scopus	DnOP	("Phenol formaldehyde" OR "9003-35-4") AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	0
Scopus	DPENP	("Phenol formaldehyde" OR "9003-35-4") AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	0
Scopus	Antimony	("Phenol formaldehyde" OR "9003-35-4") AND ("antimony" OR "Sb" OR "7440-36-0")	130
Scopus	Arsenic	("Phenol formaldehyde" OR "9003-35-4") AND ("arsenic" OR "7440-38-2")	107
Scopus	Barium	("Phenol formaldehyde" OR "9003-35-4") AND ("barium" OR "7440-39-3")	113
Scopus	Cadmium	("Phenol formaldehyde" OR "9003-35-4") AND ("cadmium" OR "7440-43-9")	252
Scopus	Chromium	("Phenol formaldehyde" OR "9003-35-4") AND ("chromium" OR "7440-47-3")	343
Scopus	Lead	("Phenol formaldehyde" OR "9003-35-4") AND ("lead" OR "7439-92-1")	569*
Scopus	Lead	("Phenol formaldehyde" OR "9003-35-4") AND (("lead" AND "metal") OR "7439-92-1")	310
Scopus	Lead	("Phenol formaldehyde" OR "9003-35-4") AND ("7439-92-1")	15
Scopus	Mercury	("Phenol formaldehyde" OR "9003-35-4") AND ("mercury" OR "Hg" OR "7439-97-6")	248
Scopus	Selenium	("Phenol formaldehyde" OR "9003-35-4") AND ("selenium" OR "7782-49-2")	61
WOS	BBP	TS=((Phenol formaldehyde OR 9003-35-4) AND (benzyl butyl phthalate OR BBP OR 85-68-7))	1
WOS	DBP	TS=((Phenol formaldehyde OR 9003-35-4) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”))	1
WOS	DCHP	TS=((Phenol formaldehyde OR 9003-35-4) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7))	0

WOS	DEHP	TS=((Phenol formaldehyde OR 9003-35-4) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”))	0
WOS	DHEXP	TS=((Phenol formaldehyde OR 9003-35-4) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3))	0
WOS	DIBP	TS=((Phenol formaldehyde OR 9003-35-4) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	0
WOS	DIDP	TS=((Phenol formaldehyde OR 9003-35-4) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1))	0
WOS	DINP	TS=((Phenol formaldehyde OR 9003-35-4) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0))	0
WOS	DnOP	TS=((Phenol formaldehyde OR 9003-35-4) AND (di-n-octyl phthalate OR DnOP OR 117-84-0))	0
WOS	DPENP	TS=((Phenol formaldehyde OR 9003-35-4) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0))	0
WOS	Antimony	TS=((Phenol formaldehyde OR 9003-35-4) AND (“antimony” OR “Sb” OR “7440-36-0”))	6
WOS	Arsenic	TS=((Phenol formaldehyde OR 9003-35-4) AND (“arsenic” OR “7440-38-2”))	10
WOS	Barium	TS=((Phenol formaldehyde OR 9003-35-4) AND (“barium” OR “7440-39-3”))	10
WOS	Cadmium	TS=((Phenol formaldehyde OR 9003-35-4) AND (“cadmium” OR “7440-43-9”))	10
WOS	Chromium	TS=((Phenol formaldehyde OR 9003-35-4) AND (“chromium” OR “7440-47-3”))	25
WOS	Lead	TS=((Phenol formaldehyde OR 9003-35-4) AND (“lead” OR “7439-92-1”))	64
WOS	Mercury	TS=((Phenol formaldehyde OR 9003-35-4) AND (“mercury” OR “Hg” OR “7439-97-6”))	25
WOS	Selenium	TS=((Phenol formaldehyde OR 9003-35-4) AND (“selenium” OR “7782-49-2”))	0
Toxline	BBP	(Phenol formaldehyde OR 9003-35-4) AND (benzyl butyl phthalate OR BBP OR 85-68-7)	9
Toxline	DBP	(Phenol formaldehyde OR 9003-35-4) AND (dibutyl phthalate OR DBP OR 84-74-2)	27
Toxline	DCHP	(Phenol formaldehyde OR 9003-35-4) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7)	0
Toxline	DEHP	(Phenol formaldehyde OR 9003-35-4) AND (di-2-ethylhexyl phthalate OR DEHP OR 117-81-7)	29
Toxline	DHEXP	(Phenol formaldehyde OR 9003-35-4) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3)	0
Toxline	DIBP	(Phenol formaldehyde OR 9003-35-4) AND (diisobutyl phthalate OR DIBP OR 84-69-5)	5
Toxline	DIDP	(Phenol formaldehyde OR 9003-35-4) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1)	2
Toxline	DINP	(Phenol formaldehyde OR 9003-35-4) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0)	0
Toxline	DnOP	(Phenol formaldehyde OR 9003-35-4) AND (di-n-octyl phthalate OR DnOP OR 117-84-0)	34
Toxline	DPENP	(Phenol formaldehyde OR 9003-35-4) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0)	0
Toxline	Antimony	(Phenol formaldehyde OR 9003-35-4) AND (antimony OR Sb OR 7440-36-0)	24
Toxline	Arsenic	(Phenol formaldehyde OR 9003-35-4) AND (arsenic OR 7440-38-2)	52
Toxline	Barium	(Phenol formaldehyde OR 9003-35-4) AND (barium OR 7440-39-3)	13
Toxline	Cadmium	(Phenol formaldehyde OR 9003-35-4) AND (cadmium OR Cd OR 7440-43-9)	77

Toxline	Chromium	(Phenol formaldehyde OR 9003-35-4) AND (chromium OR 7440-47-3)	66
Toxline	Lead	(Phenol formaldehyde OR 9003-35-4) AND (lead OR Pb OR 7439-92-1)	111
Toxline	Mercury	(Phenol formaldehyde OR 9003-35-4) AND (mercury OR Hg OR 7439-97-6)	73
Toxline	Selenium	(Phenol formaldehyde OR 9003-35-4) AND (selenium OR Se OR 7782-49-2)	34

*search further refined

1.5.4 pMDI

Database	Keyword	Query	Results
Pubmed	BBP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	0
Pubmed	DBP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	0
Pubmed	DCHP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	0
Pubmed	DEHP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	0
Pubmed	DHEXP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	0
Pubmed	DIBP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	0
Pubmed	DIDP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	0
Pubmed	DINP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	0
Pubmed	DnOP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	0
Pubmed	DPENP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	0
Pubmed	Antimony	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("antimony" OR "Sb" OR "7440-36-0")	5
Pubmed	Arsenic	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("arsenic" OR "As" OR "7440-38-2")	0
Pubmed	Barium	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("barium" OR "Ba" OR "7440-39-3")	1
Pubmed	Cadmium	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("cadmium" OR "Cd" OR "7440-43-9")	6
Pubmed	Chromium	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("chromium" OR "Cr" OR "7440-47-3")	0
Pubmed	Lead	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("lead" OR "Pb" OR "7439-92-1")	14
Pubmed	Mercury	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("mercury" OR "Hg" OR "7439-97-6")	0
Pubmed	Selenium	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("selenium" OR "Se" OR "7782-49-2")	11
Scopus	BBP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	1

Scopus	DBP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	0
Scopus	DCHP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	0
Scopus	DEHP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	1
Scopus	DHEXP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	0
Scopus	DIBP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	0
Scopus	DIDP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	0
Scopus	DINP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	0
Scopus	DnOP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	0
Scopus	DPENP	("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	0
Scopus	Antimony	("Polymerized methylene-diphenyl-diisocyanate" OR ("pMDI" NOT inhale) OR "26447-40-5") AND ("antimony" OR "Sb" OR "7440-36-0")	0
Scopus	Arsenic	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("arsenic" OR "As" OR "7440-38-2")	1
Scopus	Barium	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("barium" OR "Ba" OR "7440-39-3")	0
Scopus	Cadmium	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("cadmium" OR "Cd" OR "7440-43-9")	0
Scopus	Chromium	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("chromium" OR "Cr" OR "7440-47-3")	0
Scopus	Lead	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("lead" OR "Pb" OR "7439-92-1")	0
Scopus	Lead	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND (("lead" AND metal) OR "7439-92-1")	0
Scopus	Lead	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("7439-92-1")	0
Scopus	Mercury	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("mercury" OR "Hg" OR "7439-97-6")	0
Scopus	Selenium	("Polymerized methylene-diphenyl-diisocyanate" OR "26447-40-5") AND ("selenium" OR "Se" OR "7782-49-2")	0
WOS	BBP	TS=(("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7"))	1
WOS	DBP	TS=(("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2"))	0
WOS	DCHP	TS=(("Polymerized methylene-diphenyl-diisocyanate" OR "pMDI" OR "26447-40-5") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7"))	0

WOS	DEHP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	0
WOS	DHEXP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”))	0
WOS	DIBP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	0
WOS	DIDP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”))	0
WOS	DINP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”))	0
WOS	DnOP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”))	0
WOS	DPENP	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”))	0
WOS	Antimony	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“antimony” OR “Sb” OR “7440-36-0”))	4
WOS	Arsenic	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“arsenic” OR “7440-38-2”))	1
WOS	Barium	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“barium” OR “Ba” OR “7440-39-3”))	2
WOS	Cadmium	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“cadmium” OR “Cd” OR “7440-43-9”))	10
WOS	Chromium	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“chromium” OR “Cr” OR “7440-47-3”))	1
WOS	Lead	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“lead” OR “Pb” OR “7439-92-1”))	25
WOS	Mercury	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“mercury” OR “Hg” OR “7439-97-6”))	0
WOS	Selenium	TS=((“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“selenium” OR “Se” OR “7782-49-2”))	3
Toxline	BBP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“benzyl butyl phthalate” OR “BBP” OR “85-68-7”)	3
Toxline	DBP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”)	1
Toxline	DCHP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“dicyclohexyl phthalate” OR “DCHP” OR “84-61-7”)	6
Toxline	DEHP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	1
Toxline	DHEXP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”)	7
Toxline	DIBP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”)	2

Toxline	DIDP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”)	1
Toxline	DINP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”)	0
Toxline	DnOP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”)	2
Toxline	DPENP	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”)	2
Toxline	Antimony	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“antimony” OR “Sb” OR “7440-36-0”)	1
Toxline	Arsenic	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“arsenic” OR “As” OR “7440-38-2”)	5
Toxline	Barium	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“barium” OR “Ba” OR “7440-39-3”)	2
Toxline	Cadmium	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“cadmium” OR “Cd” OR “7440-43-9”)	5
Toxline	Chromium	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“chromium” OR “Cr” OR “7440-47-3”)	12
Toxline	Lead	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“lead” OR “Pb” OR “7439-92-1”)	5
Toxline	Mercury	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“mercury” OR “Hg” OR “7439-97-6”)	5
Toxline	Selenium	(“Polymerized methylene-diphenyl-diisocyanate” OR “pMDI” OR “26447-40-5”) AND (“selenium” OR “Se” OR “7782-49-2”)	0

1.5.5 Polyvinyl Acetate

Database	Keyword	Query	Results
Pubmed	BBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“benzyl butyl phthalate” OR “BBP” OR “85-68-7”)	2
Pubmed	DBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”)	6
Pubmed	DCHP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“dicyclohexyl phthalate” OR “DCHP” OR “84-61-7”)	0
Pubmed	DEHP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	2
Pubmed	DHEXP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”)	0
Pubmed	DIBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”)	0
Pubmed	DIDP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”)	0
Pubmed	DINP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”)	0
Pubmed	DnOP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”)	0
Pubmed	DPENP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”)	0
Pubmed	Antimony	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“antimony” OR “Sb” OR “7440-36-0”)	8

Pubmed	Arsenic	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“arsenic” OR “As” OR “7440-38-2”)	6
Pubmed	Barium	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“barium” OR “Ba” OR “7440-39-3”)	19
Pubmed	Cadmium	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“cadmium” OR “Cd” OR “7440-43-9”)	77
Pubmed	Chromium	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“chromium” OR “Cr” OR “7440-47-3”)	36
Pubmed	Lead	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“lead” OR “Pb” OR “7439-92-1”)	125
Pubmed	Mercury	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“mercury” OR “Hg” OR “7439-97-6”)	64
Pubmed	Selenium	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“selenium” OR “Se” OR “7782-49-2”)	71
Scopus	BBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	5
Scopus	DBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	122
Scopus	DCHP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	4
Scopus	DEHP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	42
Scopus	DHEXP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	1
Scopus	DIBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	5
Scopus	DIDP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	1
Scopus	DINP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	4
Scopus	DnOP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	3
Scopus	DPENP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	0
Scopus	Antimony	(“polyvinyl acetate” OR “9003-20-7”) AND ("antimony" OR "7440-36-0")	35
Scopus	Arsenic	(“polyvinyl acetate” OR “9003-20-7”) AND ("arsenic" OR "7440-38-2")	33
Scopus	Barium	(“polyvinyl acetate” OR “9003-20-7”) AND ("barium" OR "7440-39-3")	99
Scopus	Cadmium	(“polyvinyl acetate” OR “9003-20-7”) AND ("cadmium" OR "7440-43-9")	94
Scopus	Chromium	(“polyvinyl acetate” OR “9003-20-7”) AND ("chromium" OR "7440-47-3")	104
Scopus	Lead	(“polyvinyl acetate” OR “9003-20-7”) AND ("lead" OR "7439-92-1")	430*
Scopus	Lead	(“polyvinyl acetate” OR “9003-20-7”) AND (("lead" AND "metal") OR "7439-92-1")	145
Scopus	Lead	(“polyvinyl acetate” OR “9003-20-7”) AND ("7439-92-1")	4
Scopus	Mercury	(“polyvinyl acetate” OR “9003-20-7”) AND ("mercury" OR "Hg" OR "7439-97-6")	121
Scopus	Selenium	(“polyvinyl acetate” OR “9003-20-7”) AND ("selenium" OR "7782-49-2")	56
WOS	BBP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (benzyl butyl phthalate OR BBP OR 85-68-7))	2
WOS	DBP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”))	14
WOS	DCHP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7))	1

WOS	DEHP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”))	4
WOS	DHEXP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3))	0
WOS	DIBP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	1
WOS	DIDP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1))	0
WOS	DINP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0))	0
WOS	DnOP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-n-octyl phthalate OR DnOP OR 117-84-0))	1
WOS	DPENP	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0))	0
WOS	Antimony	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“antimony” OR “7440-36-0”))	11
WOS	Arsenic	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“arsenic” OR “7440-38-2”))	26
WOS	Barium	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“barium” OR “7440-39-3”))	61
WOS	Cadmium	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“cadmium” OR “7440-43-9”))	127
WOS	Chromium	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“chromium” OR “7440-47-3”))	85
WOS	Lead	TS=((“polyvinyl acetate” OR “9003-20-7”) AND (“lead” OR “7439-92-1”))	21
WOS	Mercury	TS=((“polyvinyl acetate” OR “9003-20-7”) AND (“mercury” OR “7439-97-6”))	9
WOS	Selenium	TS=((“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (“selenium” OR “7782-49-2”))	23
Toxline	BBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (benzyl butyl phthalate OR BBP OR 85-68-7)	4
Toxline	DBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (dibutyl phthalate OR DBP OR 84-74-2)	5
Toxline	DCHP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7)	1
Toxline	DEHP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-2-ethylhexyl phthalate OR DEHP OR 117-81-7)	13
Toxline	DHEXP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3)	0
Toxline	DIBP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (diisobutyl phthalate OR DIBP OR 84-69-5)	1
Toxline	DIDP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1)	0
Toxline	DINP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0)	0
Toxline	DnOP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-n-octyl phthalate OR DnOP OR 117-84-0)	2
Toxline	DPENP	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0)	0
Toxline	Antimony	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (antimony OR Sb OR 7440-36-0)	4

Toxline	Arsenic	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (arsenic OR 7440-38-2)	0
Toxline	Barium	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (barium OR 7440-39-3)	1
Toxline	Cadmium	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (cadmium OR Cd OR 7440-43-9)	43
Toxline	Chromium	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (chromium OR 7440-47-3)	1
Toxline	Lead	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (lead OR Pb OR 7439-92-1)	75
Toxline	Mercury	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (mercury OR Hg OR 7439-97-6)	5
Toxline	Selenium	(“polyvinyl acetate” OR “PVA” OR “9003-20-7”) AND (selenium OR Se OR 7782-49-2)	2

*search further refined

1.5.6 Resorcinol

Database	Keyword	Query	Results
Pubmed	BBP	(“Resorcinol”) AND (“benzyl butyl phthalate” OR “BBP” OR “85-68-7”)	2
Pubmed	DBP	(“Resorcinol”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”)	6
Pubmed	DCHP	(“Resorcinol”) AND (“dicyclohexyl phthalate” OR “DCHP” OR “84-61-7”)	0
Pubmed	DEHP	(“Resorcinol”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	2
Pubmed	DHEXP	(“Resorcinol”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”)	0
Pubmed	DIBP	(“Resorcinol”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”)	0
Pubmed	DIDP	(“Resorcinol”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”)	3
Pubmed	DINP	(“Resorcinol”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”)	2
Pubmed	DnOP	(“Resorcinol”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”)	1
Pubmed	DPENP	(“Resorcinol”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”)	0
Pubmed	Antimony	(“Resorcinol”) AND (“antimony” OR “Sb” OR “7440-36-0”)	4
Pubmed	Arsenic	(“Resorcinol”) AND (“arsenic” OR “As” OR “7440-38-2”)	3
Pubmed	Barium	(“Resorcinol”) AND (“barium” OR “Ba” OR “7440-39-3”)	5
Pubmed	Cadmium	(“Resorcinol”) AND (“cadmium” OR “Cd” OR “7440-43-9”)	59
Pubmed	Chromium	(“Resorcinol”) AND (“chromium” OR “Cr” OR “7440-47-3”)	14
Pubmed	Lead	(“Resorcinol”) AND (“lead” OR “Pb” OR “7439-92-1”)	70
Pubmed	Mercury	(“Resorcinol”) AND (“mercury” OR “Hg” OR “7439-97-6”)	24
Pubmed	Selenium	(“Resorcinol”) AND (“selenium” OR “Se” OR “7782-49-2”)	29
Scopus	BBP	("Resorcinol") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	10
Scopus	DBP	("Resorcinol") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	115
Scopus	DCHP	("Resorcinol") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	1
Scopus	DEHP	("Resorcinol") AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	34
Scopus	DHEXP	("Resorcinol") AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	0
Scopus	DIBP	("Resorcinol") AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	0

Scopus	DIDP	("Resorcinol") AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	5
Scopus	DINP	("Resorcinol") AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	2
Scopus	DnOP	("Resorcinol") AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	8
Scopus	DPENP	("Resorcinol") AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	0
Scopus	Antimony	("Resorcinol") AND ("antimony" OR "Sb" OR "7440-36-0")	556*
Scopus	Antimony	(("Resorcinol") AND ("antimony" OR "7440-36-0") NOT wastewater NOT asthma NOT remediation)	334
Scopus	Arsenic	("Resorcinol") AND ("arsenic" OR "7440-38-2")	636*
Scopus	Arsenic	("Resorcinol") AND ("arsenic" OR "7440-38-2") AND NOT chelate AND NOT wastewater AND NOT remediation AND NOT asthma	575
Scopus	Barium	("Resorcinol") AND ("barium" OR "7440-39-3")	247
Scopus	Cadmium	("Resorcinol") AND ("cadmium" OR "7440-43-9")	1,964*
Scopus	Cadmium	(ALL ((" Resorcinol") AND ("cadmium" OR "7440-43-9")) AND NOT ALL (chelate) AND NOT ALL (remediation) AND NOT ALL (wastewater) AND NOT ALL (asthma))	1,590
Scopus	Chromium	(ALL ((" Resorcinol ") AND ("chromium" OR "7440-47-3")) AND NOT ALL (asthma) AND NOT ALL (chelate) AND NOT ALL (wastewater) AND NOT ALL (remediation))	1,255
Scopus	Lead	("Resorcinol") AND ("lead" OR "7439-92-1")	3,320*
Scopus	Lead	("Resorcinol") AND (("lead" AND "metal") OR "7439-92-1")	2,109*
Scopus	Lead	("Resorcinol") AND ("7439-92-1")	168
Scopus	Lead	(ALL ((" Resorcinol") AND (("lead" AND "metal") OR "7439-92-1")) AND NOT ALL (asthma) AND NOT ALL (remediation) AND NOT ALL (wastewater) AND NOT ALL (chelate))	1,433
Scopus	Mercury	("Resorcinol") AND ("mercury" OR "Hg" OR "7439-97-6")	1,847*
Scopus	Mercury	ALL ((" Resorcinol") AND ("mercury" OR "7439-97-6")) AND NOT ALL (chelate) AND NOT ALL (remediation) AND NOT ALL (asthma) AND NOT ALL (wastewater)	1,287
Scopus	Selenium	("Resorcinol") AND ("selenium" OR "7782-49-2")	513*
Scopus	Selenium	(ALL ((" Resorcinol") AND ("selenium" OR "7782-49-2")) AND NOT ALL (asthma) AND NOT ALL (wastewater) AND NOT ALL (remediation) AND NOT ALL (chelate))	352
WOS	BBP	TS=((Resorcinol) AND (benzyl butyl phthalate OR BBP OR 85-68-7))	2
WOS	DBP	TS=((Resorcinol) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”))	12
WOS	DCHP	TS=((Resorcinol) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7))	0
WOS	DEHP	TS=((Resorcinol) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”))	2
WOS	DHEXP	TS=((Resorcinol) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3))	0
WOS	DIBP	TS=((Resorcinol) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	0
WOS	DIDP	TS=((Resorcinol) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1))	3
WOS	DINP	TS=((Resorcinol) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0))	2
WOS	DnOP	TS=((Resorcinol) AND (di-n-octyl phthalate OR DnOP OR 117-84-0))	1
WOS	DPENP	TS=((Resorcinol) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0))	0
WOS	Antimony	TS=((Resorcinol) AND (“antimony” OR “7440-36-0”))	10
WOS	Arsenic	TS=((Resorcinol) AND (“arsenic” OR “7440-38-2”))	6
WOS	Barium	TS=((Resorcinol) AND (“barium” OR “7440-39-3”))	3
WOS	Cadmium	TS=((Resorcinol) AND (“cadmium” OR “7440-43-9”))	103
WOS	Chromium	TS=((Resorcinol) AND (“chromium” OR “7440-47-3”))	54

WOS	Lead	TS=((Resorcinol) AND (“lead” OR “7439-92-1”))	177
WOS	Mercury	TS=((Resorcinol) AND (“mercury” OR “Hg” OR “7439-97-6”))	119
WOS	Selenium	TS=((Resorcinol) AND (“selenium” OR “7782-49-2”))	12
Toxline	BBP	(Resorcinol) AND (benzyl butyl phthalate OR BBP OR 85-68-7)	10
Toxline	DBP	(Resorcinol) AND (dibutyl phthalate OR DBP OR 84-74-2)	13
Toxline	DCHP	(Resorcinol) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7)	0
Toxline	DEHP	(Resorcinol) AND (di-2-ethylhexyl phthalate OR DEHP OR 117-81-7)	17
Toxline	DHEXP	(Resorcinol) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3)	1
Toxline	DIBP	(Resorcinol) AND (diisobutyl phthalate OR DIBP OR 84-69-5)	3
Toxline	DIDP	(Resorcinol) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1)	0
Toxline	DINP	(Resorcinol) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0)	0
Toxline	DnOP	(Resorcinol) AND (di-n-octyl phthalate OR DnOP OR 117-84-0)	23
Toxline	DPENP	(Resorcinol) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0)	1
Toxline	Antimony	(Resorcinol) AND (antimony OR Sb OR 7440-36-0)	18
Toxline	Arsenic	(Resorcinol) AND (arsenic OR 7440-38-2)	12
Toxline	Barium	(Resorcinol) AND (barium OR 7440-39-3)	5
Toxline	Cadmium	(Resorcinol) AND (cadmium OR Cd OR 7440-43-9)	37
Toxline	Chromium	(Resorcinol) AND (chromium OR 7440-47-3)	19
Toxline	Lead	(Resorcinol) AND (lead OR Pb OR 7439-92-1)	46
Toxline	Mercury	(Resorcinol) AND (mercury OR Hg OR 7439-97-6)	25
Toxline	Selenium	(Resorcinol) AND (selenium OR Se OR 7782-49-2)	20

*search further refined

1.5.7 Urea Formaldehyde

Database	Keyword	Query	Results
Pubmed	BBP	(“Urea formaldehyde” OR “9011-05-6”) AND (“benzyl butyl phthalate” OR “BBP” OR “85-68-7”)	0
Pubmed	DBP	(“Urea formaldehyde” OR “9011-05-6”) AND (“dibutyl phthalate” OR “DBP” OR “84-74-2”)	1
Pubmed	DCHP	(“Urea formaldehyde” OR “9011-05-6”) AND (“dicyclohexyl phthalate” OR “DCHP” OR “84-61-7”)	0
Pubmed	DEHP	(“Urea formaldehyde” OR “9011-05-6”) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”)	0
Pubmed	DHEXP	(“Urea formaldehyde” OR “9011-05-6”) AND (“di-n-hexyl phthalate” OR “DHEXP” OR “84-75-3”)	0
Pubmed	DIBP	(“Urea formaldehyde” OR “9011-05-6”) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”)	0
Pubmed	DIDP	(“Urea formaldehyde” OR “9011-05-6”) AND (“diisodecyl phthalate” OR “DIDP” OR “26761-40-0” OR “68515-49-1”)	0
Pubmed	DINP	(“Urea formaldehyde” OR “9011-05-6”) AND (“diisononyl phthalate” OR “DINP” OR “28553-12-0” OR “68515-48-0”)	0
Pubmed	DnOP	(“Urea formaldehyde” OR “9011-05-6”) AND (“di-n-octyl phthalate” OR “DnOP” OR “117-84-0”)	0
Pubmed	DPENP	(“Urea formaldehyde” OR “9011-05-6”) AND (“di-n-pentyl phthalate” OR “DPENP” OR “131-18-0”)	0
Pubmed	Antimony	(“Urea formaldehyde” OR “9011-05-6”) AND (“antimony” OR “Sb” OR “7440-36-0”)	1
Pubmed	Arsenic	(“Urea formaldehyde” OR “9011-05-6”) AND (“arsenic” OR “As” OR “7440-38-2”)	0
Pubmed	Barium	(“Urea formaldehyde” OR “9011-05-6”) AND (“barium” OR “Ba” OR “7440-39-3”)	2

Pubmed	Cadmium	("Urea formaldehyde" OR "9011-05-6") AND ("cadmium" OR "Cd" OR "7440-43-9")	0
Pubmed	Chromium	("Urea formaldehyde" OR "9011-05-6") AND ("chromium" OR "Cr" OR "7440-47-3")	1
Pubmed	Lead	("Urea formaldehyde" OR "9011-05-6") AND ("lead" OR "Pb" OR "7439-92-1")	7
Pubmed	Mercury	("Urea formaldehyde" OR "9011-05-6") AND ("mercury" OR "Hg" OR "7439-97-6")	1
Pubmed	Selenium	("Urea formaldehyde" OR "9011-05-6") AND ("selenium" OR "Se" OR "7782-49-2")	1
Scopus	BBP	("Urea formaldehyde" OR "9011-05-6") AND ("benzyl butyl phthalate" OR "BBP" OR "85-68-7")	0
Scopus	DBP	("Urea formaldehyde" OR "9011-05-6") AND ("dibutyl phthalate" OR "DBP" OR "84-74-2")	8
Scopus	DCHP	("Urea formaldehyde" OR "9011-05-6") AND ("dicyclohexyl phthalate" OR "DCHP" OR "84-61-7")	0
Scopus	DEHP	("Urea formaldehyde" OR "9011-05-6") AND ("di-2-ethylhexyl phthalate" OR "DEHP" OR "117-81-7")	8
Scopus	DHEXP	("Urea formaldehyde" OR "9011-05-6") AND ("di-n-hexyl phthalate" OR "DHEXP" OR "84-75-3")	1
Scopus	DIBP	("Urea formaldehyde" OR "9011-05-6") AND ("diisobutyl phthalate" OR "DIBP" OR "84-69-5")	0
Scopus	DIDP	("Urea formaldehyde" OR "9011-05-6") AND ("diisodecyl phthalate" OR "DIDP" OR "26761-40-0" OR "68515-49-1")	1
Scopus	DINP	("Urea formaldehyde" OR "9011-05-6") AND ("diisononyl phthalate" OR "DINP" OR "28553-12-0" OR "68515-48-0")	0
Scopus	DnOP	("Urea formaldehyde" OR "9011-05-6") AND ("di-n-octyl phthalate" OR "DnOP" OR "117-84-0")	1
Scopus	DPENP	("Urea formaldehyde" OR "9011-05-6") AND ("di-n-pentyl phthalate" OR "DPENP" OR "131-18-0")	0
Scopus	Antimony	("Urea formaldehyde" OR "9011-05-6") AND ("antimony" OR "Sb" OR "7440-36-0")	46
Scopus	Arsenic	("Urea formaldehyde" OR "9011-05-6") AND ("arsenic" OR "7440-38-2")	53
Scopus	Barium	("Urea formaldehyde" OR "9011-05-6") AND ("barium" OR "7440-39-3")	46
Scopus	Cadmium	("Urea formaldehyde" OR "9011-05-6") AND ("cadmium" OR "7440-43-9")	125
Scopus	Chromium	("Urea formaldehyde" OR "9011-05-6") AND ("chromium" OR "7440-47-3")	172
Scopus	Lead	("Urea formaldehyde" OR "9011-05-6") AND ("lead" OR "7439-92-1")	339*
Scopus	Lead	("Urea formaldehyde" OR "9011-05-6") AND (("lead" AND "metal") OR "7439-92-1")	156
Scopus	Lead	("Urea formaldehyde" OR "9011-05-6") AND ("7439-92-1")	13
Scopus	Mercury	("Urea formaldehyde" OR "9011-05-6") AND ("mercury" OR "Hg" OR "7439-97-6")	130
Scopus	Selenium	("Urea formaldehyde" OR "9011-05-6") AND ("selenium" OR "7782-49-2")	26
WOS	BBP	TS=((Urea formaldehyde OR 9011-05-6) AND (benzyl butyl phthalate OR BBP OR 85-68-7))	0
WOS	DBP	TS=((Urea formaldehyde OR 9011-05-6) AND ("dibutyl phthalate" OR "DBP" OR "84-74-2"))	3

WOS	DCHP	TS=((Urea formaldehyde OR 9011-05-6) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7))	0
WOS	DEHP	TS=((Urea formaldehyde OR 9011-05-6) AND (“di-2-ethylhexyl phthalate” OR “DEHP” OR “117-81-7”))	0
WOS	DHEXP	TS=((Urea formaldehyde OR 9011-05-6) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3))	0
WOS	DIBP	TS=((Urea formaldehyde OR 9011-05-6) AND (“diisobutyl phthalate” OR “DIBP” OR “84-69-5”))	0
WOS	DIDP	TS=((Urea formaldehyde OR 9011-05-6) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1))	0
WOS	DINP	TS=((Urea formaldehyde OR 9011-05-6) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0))	0
WOS	DnOP	TS=((Urea formaldehyde OR 9011-05-6) AND (di-n-octyl phthalate OR DnOP OR 117-84-0))	0
WOS	DPENP	TS=((Urea formaldehyde OR 9011-05-6) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0))	0
WOS	Antimony	TS=((Urea formaldehyde OR 9011-05-6) AND (“antimony” OR “Sb” OR “7440-36-0”))	2
WOS	Arsenic	TS=((Urea formaldehyde OR 9011-05-6) AND (“arsenic” OR “7440-38-2”))	5
WOS	Barium	TS=((Urea formaldehyde OR 9011-05-6) AND (“barium” OR “7440-39-3”))	0
WOS	Cadmium	TS=((Urea formaldehyde OR 9011-05-6) AND (“cadmium” OR “7440-43-9”))	3
WOS	Chromium	TS=((Urea formaldehyde OR 9011-05-6) AND (“chromium” OR “7440-47-3”))	13
WOS	Lead	TS=((Urea formaldehyde OR 9011-05-6) AND (“lead” OR “7439-92-1”))	30
WOS	Mercury	TS=((Urea formaldehyde OR 9011-05-6) AND (“mercury” OR “Hg” OR “7439-97-6”))	7
WOS	Selenium	TS=((Urea formaldehyde OR 9011-05-6) AND (“selenium” OR “7782-49-2”))	1
Toxline	BBP	(Urea formaldehyde OR 9011-05-6) AND (benzyl butyl phthalate OR BBP OR 85-68-7)	2
Toxline	DBP	(Urea formaldehyde OR 9011-05-6) AND (dibutyl phthalate OR DBP OR 84-74-2)	3
Toxline	DCHP	(Urea formaldehyde OR 9011-05-6) AND (dicyclohexyl phthalate OR DCHP OR 84-61-7)	0
Toxline	DEHP	(Urea formaldehyde OR 9011-05-6) AND (di-2-ethylhexyl phthalate OR DEHP OR 117-81-7)	11
Toxline	DHEXP	(Urea formaldehyde OR 9011-05-6) AND (di-n-hexyl phthalate OR DHEXP OR 84-75-3)	0
Toxline	DIBP	(Urea formaldehyde OR 9011-05-6) AND (diisobutyl phthalate OR DIBP OR 84-69-5)	0
Toxline	DIDP	(Urea formaldehyde OR 9011-05-6) AND (diisodecyl phthalate OR DIDP OR 26761-40-0 OR 68515-49-1)	2
Toxline	DINP	(Urea formaldehyde OR 9011-05-6) AND (diisononyl phthalate OR DINP OR 28553-12-0 OR 68515-48-0)	0
Toxline	DnOP	(Urea formaldehyde OR 9011-05-6) AND (di-n-octyl phthalate OR DnOP OR 117-84-0)	12
Toxline	DPENP	(Urea formaldehyde OR 9011-05-6) AND (di-n-pentyl phthalate OR DPENP OR 131-18-0)	0
Toxline	Antimony	(Urea formaldehyde OR 9011-05-6) AND (antimony OR Sb OR 7440-36-0)	4
Toxline	Arsenic	(Urea formaldehyde OR 9011-05-6) AND (arsenic OR 7440-38-2)	6
Toxline	Barium	(Urea formaldehyde OR 9011-05-6) AND (barium OR 7440-39-3)	4

Toxline	Cadmium	(Urea formaldehyde OR 9011-05-6) AND (cadmium OR Cd OR 7440-43-9)	10
Toxline	Chromium	(Urea formaldehyde OR 9011-05-6) AND (chromium OR 7440-47-3)	9
Toxline	Lead	(Urea formaldehyde OR 9011-05-6) AND (lead OR Pb OR 7439-92-1)	13
Toxline	Mercury	(Urea formaldehyde OR 9011-05-6) AND (mercury OR Hg OR 7439-97-6)	6
Toxline	Selenium	(Urea formaldehyde OR 9011-05-6) AND (selenium OR Se OR 7782-49-2)	6

*search further refined

1.6 Key Words and Search Results for Concentrations in Waxes

1.6.1 Slack Wax

Database	Keyword	Query	Results
PubMed	Antimony	(("antimony"[MeSH Terms] OR "antimony"[All Fields]) OR 7440-36-0[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Arsenic	(("arsenic"[MeSH Terms] OR "arsenic"[All Fields]) OR 7440-38-2[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Barium	(("barium"[MeSH Terms] OR "barium"[All Fields]) OR 7440-39-3[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	BBP	(("butylbenzyl phthalate"[Supplementary Concept] OR "butylbenzyl phthalate"[All Fields] OR "benzyl butyl phthalate"[All Fields]) OR ("4-boronic acid benzophenone"[Supplementary Concept] OR "4-boronic acid benzophenone"[All Fields] OR "bbp"[All Fields]) OR 85-68-7[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Cadmium	(("cadmium"[MeSH Terms] OR "cadmium"[All Fields]) OR 7440-43-9[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Chromium	(("chromium"[MeSH Terms] OR "chromium"[All Fields]) OR 7440-47-3[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DBP	(("dibutyl phthalate"[MeSH Terms] OR ("dibutyl"[All Fields] AND "phthalate"[All Fields]) OR "dibutyl phthalate"[All Fields]) OR DBP[All Fields] OR 84-74-2[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DCHP	(("dicyclohexyl phthalate"[Supplementary Concept] OR "dicyclohexyl phthalate"[All Fields]) OR ("O, O'-dimethyl-O-(6-chlorobicyclo(3.2.0)heptadiene-1,5-yl)phosphate"[Supplementary Concept] OR "O, O'-dimethyl-O-(6-chlorobicyclo(3.2.0)heptadiene-1,5-yl)phosphate"[All Fields] OR "dchp"[All Fields]) OR 84-61-7[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DEHP	((("diagnosis"[Subheading] OR "diagnosis"[All Fields] OR "di"[All Fields]) AND 2-ethylhexl[All Fields] AND ("phthalic acid"[Supplementary Concept] OR "phthalic acid"[All Fields] OR "phthalate"[All Fields])) OR ("diethylhexyl phthalate"[MeSH Terms] OR ("diethylhexyl"[All Fields] AND "phthalate"[All Fields]) OR "diethylhexyl phthalate"[All Fields] OR "dehp"[All Fields]) OR 117-81-7[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DHEXP	(("di-n-hexyl phthalate"[Supplementary Concept] OR "di-n-hexyl phthalate"[All Fields] OR "di n hexyl phthalate"[All Fields]) OR 84-75-3[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DIBP	(("diisobutyl phthalate"[Supplementary Concept] OR "diisobutyl phthalate"[All Fields]) OR DIBP[All Fields] OR "84-69-5"[EC/RN Number]) AND (slack[All Fields] AND wax[All Fields])	0

PubMed	DIDP	(("diisodecyl phthalate"[Supplementary Concept] OR "diisodecyl phthalate"[All Fields]) OR DIDP[All Fields] OR 26761-40-0[All Fields] OR 68515-49-1[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DINP	(("diisononyl phthalate"[Supplementary Concept] OR "diisononyl phthalate"[All Fields]) OR DINP[All Fields] OR 28553-12-0[All Fields] OR 68515-48-0[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DnOP	(("di-n-octyl phthalate"[Supplementary Concept] OR "di-n-octyl phthalate"[All Fields] OR "di n octyl phthalate"[All Fields]) OR DnOP[All Fields] OR 117-84-0[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	DPENP	(("di-n-pentyl phthalate"[Supplementary Concept] OR "di-n-pentyl phthalate"[All Fields] OR "di n pentyl phthalate"[All Fields]) OR "131-18-0"[EC/RN Number]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Lead	(("lead"[MeSH Terms] OR "lead"[All Fields]) OR 7439-92-1[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Mercury	(("mercury"[MeSH Terms] OR "mercury"[All Fields]) OR 7439-97-6[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
PubMed	Selenium	(("selenium"[MeSH Terms] OR "selenium"[All Fields]) OR 7782-49-2[All Fields]) AND (slack[All Fields] AND wax[All Fields])	0
Scopus	Antimony	(TITLE-ABS-KEY(Antimony or 7440-36-0) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	Arsenic	(TITLE-ABS-KEY(Arsenic or 7440-38-2) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	Barium	(TITLE-ABS-KEY(Barium or 7440-39-3) AND TITLE-ABS-KEY(Slack wax))	1
Scopus	BBP	(TITLE-ABS-KEY(benzyl butyl phthalate or BBP or 85-68-7) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	Cadmium	(TITLE-ABS-KEY(Cadmium or 7440-43-9) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	Chromium	(TITLE-ABS-KEY(Chromium or 7440-47-3) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DBP	(TITLE-ABS-KEY(dibutyl phthalate or DBP or 84-74-2) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DCHP	(TITLE-ABS-KEY(dicyclohexyl phthalate or DCHP or 84-61-7) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DEHP	(TITLE-ABS-KEY(di-2-ethylhexl phthalate or DEHP or 117-81-7) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DHEXP	(TITLE-ABS-KEY(di-n-hexyl phthalate or DHEXP or 84-75-3) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DIBP	(TITLE-ABS-KEY(diisobutyl phthalate or DIBP or 84-69-5) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DIDP	(TITLE-ABS-KEY(diisodecyl phthalate or DIDP or 26761-40-0 or 68515-49-1) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DINP	(TITLE-ABS-KEY(diisononyl phthalate or DINP or 28553-12-0 or 68515-48-0) AND TITLE-ABS-KEY(Slack wax))	0
Scopus	DnOP	(TITLE-ABS-KEY(di-n-octyl phthalate OR dnop OR 117-84-0) AND TITLE-ABS-KEY(slack wax))	0
Scopus	DPENP	(TITLE-ABS-KEY(di-n-pentyl phthalate OR dpenp OR 131-18-0) AND TITLE-ABS-KEY(slack wax))	0
Scopus	Lead	(TITLE-ABS-KEY(lead OR 7439-92-1) AND TITLE-ABS-KEY(slack wax))	1

Scopus	Mercury	(TITLE-ABS-KEY(mercury OR 7439-97-6) AND TITLE-ABS-KEY(slack wax))	1
Scopus	Selenium	(TITLE-ABS-KEY(selenium OR 7782-49-2) AND TITLE-ABS-KEY(slack wax))	0
WOS	Antimony	ts=(Antimony or 7440-36-0) and ts=slack wax	0
WOS	Arsenic	ts=(Arsenic or 7440-38-2) and ts=slack wax	0
WOS	Barium	ts=(Barium or 7440-39-3) and ts=slack wax	0
WOS	BBP	ts=(benzyl butyl phthalate or BBP or 85-68-7) and ts=slack wax	0
WOS	Cadmium	ts=(Cadmium or 7440-43-9) and ts=slack wax	0
WOS	Chromium	ts=(Chromium or 7440-47-3) and ts=slack wax	0
WOS	DBP	ts=(dibutyl phthalate or DBP or 84-74-2) and ts=slack wax	0
WOS	DCHP	ts=(dicyclohexyl phthalate or DCHP or 84-61-7) and ts=slack wax	0
WOS	DEHP	ts=(di-(2-ethylhexl) phthalate or DEHP or 117-81-7) and ts=slack wax	0
WOS	DHEXP	ts=(di-n-hexyl phthalate or DHEXP or 84-75-3) and ts=slack wax	0
WOS	DIBP	ts=(diisobutyl phthalate or DIBP or 84-69-5) and ts=slack wax	0
WOS	DIDP	ts=(diisodecyl phthalate or DIDP or 26761-40-0 or 68515-49-1) and ts=slack wax	0
WOS	DINP	ts=(diisononyl phthalate or DINP or 28553-12-0 or 68515-48-0) and ts=slack wax	0
WOS	DnOP	ts=(di-n-octyl phthalate or DnOP or 117-84-0) and ts=slack wax	0
WOS	DPENP	ts=(di-n-pentyl phthalate or DPENP or 131-18-0) and ts=slack wax	0
WOS	Lead	ts=(Lead or 7439-92-1) and ts=slack wax	1
WOS	Mercury	ts=(Mercury or 7439-97-6) and ts=slack wax	1
WOS	Selenium	ts=(Selenium or 7782-49-2) and ts=slack wax	0

1.6.2 Petroleum Wax

Database	Keyword	Query	Results
PubMed	Antimony	(("antimony"[MeSH Terms] OR "antimony"[All Fields]) OR 7440-36-0[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	Arsenic	(("arsenic"[MeSH Terms] OR "arsenic"[All Fields]) OR 7440-38-2[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	Barium	(("barium"[MeSH Terms] OR "barium"[All Fields]) OR 7440-39-3[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	BBP	(("butylbenzyl phthalate"[Supplementary Concept] OR "butylbenzyl phthalate"[All Fields] OR "benzyl butyl phthalate"[All Fields]) OR ("4-boronic acid benzophenone"[Supplementary Concept] OR "4-boronic acid benzophenone"[All Fields] OR "bbp"[All Fields]) OR 85-68-7[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	Cadmium	(("cadmium"[MeSH Terms] OR "cadmium"[All Fields]) OR 7440-43-9[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	Chromium	(("chromium"[MeSH Terms] OR "chromium"[All Fields]) OR 7440-47-3[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0

PubMed	DBP	(("dibutyl phthalate"[MeSH Terms] OR ("dibutyl"[All Fields] AND "phthalate"[All Fields]) OR "dibutyl phthalate"[All Fields]) OR DBP[All Fields] OR 84-74-2[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DCHP	(("dicyclohexyl phthalate"[Supplementary Concept] OR "dicyclohexyl phthalate"[All Fields]) OR ("O, O'-dimethyl-O-(6-chlorobicyclo(3.2.0)heptadiene-1,5-yl)phosphate"[Supplementary Concept] OR "O, O'-dimethyl-O-(6-chlorobicyclo(3.2.0)heptadiene-1,5-yl)phosphate"[All Fields] OR "dchp"[All Fields]) OR 84-61-7[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DEHP	((("diagnosis"[Subheading] OR "diagnosis"[All Fields] OR "di"[All Fields]) AND 2-ethylhexl[All Fields] AND ("phthalic acid"[Supplementary Concept] OR "phthalic acid"[All Fields] OR "phthalate"[All Fields])) OR ("diethylhexyl phthalate"[MeSH Terms] OR ("diethylhexyl"[All Fields] AND "phthalate"[All Fields]) OR "diethylhexyl phthalate"[All Fields] OR "dehp"[All Fields]) OR 117-81-7[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DHEXP	(("di-n-hexyl phthalate"[Supplementary Concept] OR "di-n-hexyl phthalate"[All Fields] OR "di n hexyl phthalate"[All Fields]) OR 84-75-3[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DIBP	(("diisobutyl phthalate"[Supplementary Concept] OR "diisobutyl phthalate"[All Fields]) OR DIBP[All Fields] OR "84-69-5"[EC/RN Number]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DIDP	(("diisodecyl phthalate"[Supplementary Concept] OR "diisodecyl phthalate"[All Fields]) OR DIDP[All Fields] OR 26761-40-0[All Fields] OR 68515-49-1[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DINP	(("diisononyl phthalate"[Supplementary Concept] OR "diisononyl phthalate"[All Fields]) OR DINP[All Fields] OR 28553-12-0[All Fields] OR 68515-48-0[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DnOP	(("di-n-octyl phthalate"[Supplementary Concept] OR "di-n-octyl phthalate"[All Fields] OR "di n octyl phthalate"[All Fields]) OR DnOP[All Fields] OR 117-84-0[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	DPENP	(("di-n-pentyl phthalate"[Supplementary Concept] OR "di-n-pentyl phthalate"[All Fields] OR "di n pentyl phthalate"[All Fields]) OR "131-18-0"[EC/RN Number]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	Lead	(("lead"[MeSH Terms] OR "lead"[All Fields]) OR 7439-92-1[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	1
PubMed	Mercury	(("mercury"[MeSH Terms] OR "mercury"[All Fields]) OR 7439-97-6[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
PubMed	Selenium	(("selenium"[MeSH Terms] OR "selenium"[All Fields]) OR 7782-49-2[All Fields]) AND (petroleum[All Fields] AND wax[All Fields])	0
Scopus	Antimony	(TITLE-ABS-KEY(Antimony or 7440-36-0) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	Arsenic	(TITLE-ABS-KEY(Arsenic or 7440-38-2) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	Barium	(TITLE-ABS-KEY(Barium or 7440-39-3) AND TITLE-ABS-KEY(petroleum wax))	5
Scopus	BBP	(TITLE-ABS-KEY(benzyl butyl phthalate or BBP or 85-68-7) AND TITLE-ABS-KEY(petroleum wax))	0

Scopus	Cadmium	(TITLE-ABS-KEY(Cadmium or 7440-43-9) AND TITLE-ABS-KEY(petroleum wax))	4
Scopus	Chromium	(TITLE-ABS-KEY(Chromium or 7440-47-3) AND TITLE-ABS-KEY(petroleum wax))	2
Scopus	DBP	(TITLE-ABS-KEY(dibutyl phthalate or DBP or 84-74-2) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DCHP	(TITLE-ABS-KEY(dicyclohexyl phthalate or DCHP or 84-61-7) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DEHP	(TITLE-ABS-KEY(di-2-ethylhexl phthalate or DEHP or 117-81-7) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DHEXP	(TITLE-ABS-KEY(di-n-hexyl phthalate or DHEXP or 84-75-3) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DIBP	(TITLE-ABS-KEY(diisobutyl phthalate or DIBP or 84-69-5) AND TITLE-ABS-KEY(petroleum wax))	1
Scopus	DIDP	(TITLE-ABS-KEY(diisodecyl phthalate or DIDP or 26761-40-0 or 68515-49-1) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DINP	(TITLE-ABS-KEY(diisononyl phthalate or DINP or 28553-12-0 or 68515-48-0) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DnOP	(TITLE-ABS-KEY(di-n-octyl phthalate OR dnop OR 117-84-0) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	DPENP	(TITLE-ABS-KEY(di-n-pentyl phthalate OR dpenp OR 131-18-0) AND TITLE-ABS-KEY(petroleum wax))	0
Scopus	Lead	(TITLE-ABS-KEY(lead OR 7439-92-1) AND TITLE-ABS-KEY(petroleum wax))	89
Scopus	Mercury	(TITLE-ABS-KEY(mercury OR 7439-97-6) AND TITLE-ABS-KEY(petroleum wax))	4
Scopus	Selenium	(TITLE-ABS-KEY(selenium OR 7782-49-2) AND TITLE-ABS-KEY(petroleum wax))	0
WOS	Antimony	ts=(Antimony or 7440-36-0) and ts=petroleum wax	0
WOS	Arsenic	ts=(Arsenic or 7440-38-2) and ts=petroleum wax	0
WOS	Barium	ts=(Barium or 7440-39-3) and ts=petroleum wax	0
WOS	BBP	ts=(benzyl butyl phthalate or BBP or 85-68-7) and ts=petroleum wax	0
WOS	Cadmium	ts=(Cadmium or 7440-43-9) and ts=petroleum wax	0
WOS	Chromium	ts=(Chromium or 7440-47-3) and ts=petroleum wax	0
WOS	DBP	ts=(dibutyl phthalate or DBP or 84-74-2) and ts=petroleum wax	0
WOS	DCHP	ts=(dicyclohexyl phthalate or DCHP or 84-61-7) and ts=petroleum wax	0
WOS	DEHP	ts=(di-(2-ethylhexl) phthalate or DEHP or 117-81-7) and ts=petroleum wax	0
WOS	DHEXP	ts=(di-n-hexyl phthalate or DHEXP or 84-75-3) and ts=petroleum wax	0
WOS	DIBP	ts=(diisobutyl phthalate or DIBP or 84-69-5) and ts=petroleum wax	0
WOS	DIDP	ts=(diisodecyl phthalate or DIDP or 26761-40-0 or 68515-49-1) and ts=petroleum wax	0
WOS	DINP	ts=(diisononyl phthalate or DINP or 28553-12-0 or 68515-48-0) and ts=petroleum wax	0
WOS	DnOP	ts=(di-n-octyl phthalate or DnOP or 117-84-0) and ts=petroleum wax	0
WOS	DPENP	ts=(di-n-pentyl phthalate or DPENP or 131-18-0) and ts=petroleum wax	0
WOS	Lead	ts=(Lead or 7439-92-1) and ts=petroleum wax	66
WOS	Mercury	ts=(Mercury or 7439-97-6) and ts=petroleum wax	1
WOS	Selenium	ts=(Selenium or 7782-49-2) and ts=petroleum wax	0

1.6.3 Paraffin Wax

Database	Keyword	Query	Results
PubMed	Antimony	(("antimony"[MeSH Terms] OR "antimony"[All Fields]) OR 7440-36-0[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	Arsenic	(("arsenic"[MeSH Terms] OR "arsenic"[All Fields]) OR 7440-38-2[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	Barium	(("barium"[MeSH Terms] OR "barium"[All Fields]) OR 7440-39-3[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	3
PubMed	BBP	(("butylbenzyl phthalate"[Supplementary Concept] OR "butylbenzyl phthalate"[All Fields] OR "benzyl butyl phthalate"[All Fields]) OR ("4-boronic acid benzophenone"[Supplementary Concept] OR "4-boronic acid benzophenone"[All Fields] OR "bbp"[All Fields]) OR 85-68-7[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	Cadmium	(("cadmium"[MeSH Terms] OR "cadmium"[All Fields]) OR 7440-43-9[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	2
PubMed	Chromium	(("chromium"[MeSH Terms] OR "chromium"[All Fields]) OR 7440-47-3[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	2
PubMed	DBP	(("dibutyl phthalate"[MeSH Terms] OR ("dibutyl"[All Fields] AND "phthalate"[All Fields]) OR "dibutyl phthalate"[All Fields]) OR DBP[All Fields] OR 84-74-2[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DCHP	(("dicyclohexyl phthalate"[Supplementary Concept] OR "dicyclohexyl phthalate"[All Fields]) OR ("O, O'-dimethyl-O-(6-chlorobicyclo(3.2.0)heptadiene-1,5-yl)phosphate"[Supplementary Concept] OR "O, O'-dimethyl-O-(6-chlorobicyclo(3.2.0)heptadiene-1,5-yl)phosphate"[All Fields] OR "dchp"[All Fields]) OR 84-61-7[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DEHP	((("diagnosis"[Subheading] OR "diagnosis"[All Fields] OR "di"[All Fields]) AND 2-ethylhexl[All Fields] AND ("phthalic acid"[Supplementary Concept] OR "phthalic acid"[All Fields] OR "phthalate"[All Fields])) OR ("diethylhexyl phthalate"[MeSH Terms] OR ("diethylhexyl"[All Fields] AND "phthalate"[All Fields]) OR "diethylhexyl phthalate"[All Fields] OR "dehp"[All Fields]) OR 117-81-7[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DHEXP	(("di-n-hexyl phthalate"[Supplementary Concept] OR "di-n-hexyl phthalate"[All Fields] OR "di n hexyl phthalate"[All Fields]) OR 84-75-3[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DIBP	(("diisobutyl phthalate"[Supplementary Concept] OR "diisobutyl phthalate"[All Fields]) OR DIBP[All Fields] OR "84-69-5"[EC/RN Number]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DIDP	(("diisodecyl phthalate"[Supplementary Concept] OR "diisodecyl phthalate"[All Fields]) OR DIDP[All Fields] OR 26761-40-0[All Fields] OR 68515-49-1[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0

PubMed	DINP	(("diisononyl phthalate"[Supplementary Concept] OR "diisononyl phthalate"[All Fields]) OR DINP[All Fields] OR 28553-12-0[All Fields] OR 68515-48-0[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DnOP	(("di-n-octyl phthalate"[Supplementary Concept] OR "di-n-octyl phthalate"[All Fields] OR "di n octyl phthalate"[All Fields]) OR DnOP[All Fields] OR 117-84-0[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	DPENP	(("di-n-pentyl phthalate"[Supplementary Concept] OR "di-n-pentyl phthalate"[All Fields] OR "di n pentyl phthalate"[All Fields]) OR "131-18-0"[EC/RN Number]) AND (paraffin[All Fields] AND wax[All Fields])	0
PubMed	Lead	(("lead"[MeSH Terms] OR "lead"[All Fields]) OR 7439-92-1[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	19
PubMed	Mercury	(("mercury"[MeSH Terms] OR "mercury"[All Fields]) OR 7439-97-6[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	3
PubMed	Selenium	(("selenium"[MeSH Terms] OR "selenium"[All Fields]) OR 7782-49-2[All Fields]) AND (paraffin[All Fields] AND wax[All Fields])	1
Scopus	Antimony	(TITLE-ABS-KEY(Antimony or 7440-36-0) AND TITLE-ABS-KEY(paraffin wax))	9
Scopus	Arsenic	(TITLE-ABS-KEY(Arsenic or 7440-38-2) AND TITLE-ABS-KEY(paraffin wax))	11
Scopus	Barium	(TITLE-ABS-KEY(Barium or 7440-39-3) AND TITLE-ABS-KEY(paraffin wax))	49
Scopus	BBP	(TITLE-ABS-KEY(benzyl butyl phthalate or BBP or 85-68-7) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	Cadmium	(TITLE-ABS-KEY(Cadmium or 7440-43-9) AND TITLE-ABS-KEY(paraffin wax))	35
Scopus	Chromium	(TITLE-ABS-KEY(Chromium or 7440-47-3) AND TITLE-ABS-KEY(paraffin wax))	30
Scopus	DBP	(TITLE-ABS-KEY(dibutyl phthalate or DBP or 84-74-2) AND TITLE-ABS-KEY(paraffin wax))	6
Scopus	DCHP	(TITLE-ABS-KEY(dicyclohexyl phthalate or DCHP or 84-61-7) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	DEHP	(TITLE-ABS-KEY(di-2-ethylhexl phthalate or DEHP or 117-81-7) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	DHEXP	(TITLE-ABS-KEY(di-n-hexyl phthalate or DHEXP or 84-75-3) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	DIBP	(TITLE-ABS-KEY(diisobutyl phthalate or DIBP or 84-69-5) AND TITLE-ABS-KEY(paraffin wax))	1
Scopus	DIDP	(TITLE-ABS-KEY(diisodecyl phthalate or DIDP or 26761-40-0 or 68515-49-1) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	DINP	(TITLE-ABS-KEY(diisononyl phthalate or DINP or 28553-12-0 or 68515-48-0) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	DnOP	(TITLE-ABS-KEY(di-n-octyl phthalate OR dnop OR 117-84-0) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	DPENP	(TITLE-ABS-KEY(di-n-pentyl phthalate OR dpenp OR 131-18-0) AND TITLE-ABS-KEY(paraffin wax))	0
Scopus	Lead	((TITLE-ABS-KEY(lead OR 7439-92-1) AND TITLE-ABS-KEY(paraffin wax))) and metal)	62

Scopus	Mercury	(TITLE-ABS-KEY(mercury OR 7439-97-6) AND TITLE-ABS-KEY(paraffin wax))	23
Scopus	Selenium	(TITLE-ABS-KEY(selenium OR 7782-49-2) AND TITLE-ABS-KEY(paraffin wax))	12
WOS	Antimony	ts=(Antimony or 7440-36-0) and ts=paraffin wax	3
WOS	Arsenic	ts=(Arsenic or 7440-38-2) and ts=paraffin wax	1
WOS	Barium	ts=(Barium or 7440-39-3) and ts=paraffin wax	19
WOS	BBP	ts=(benzyl butyl phthalate or BBP or 85-68-7) and ts=paraffin wax	0
WOS	Cadmium	ts=(Cadmium or 7440-43-9) and ts=paraffin wax	4
WOS	Chromium	ts=(Chromium or 7440-47-3) and ts=paraffin wax	4
WOS	DBP	ts=(dibutyl phthalate or DBP or 84-74-2) and ts=paraffin wax	3
WOS	DCHP	ts=(dicyclohexyl phthalate or DCHP or 84-61-7) and ts=paraffin wax	0
WOS	DEHP	ts=(di-(2-ethylhexl) phthalate or DEHP or 117-81-7) and ts=paraffin wax	0
WOS	DHEXP	ts=(di-n-hexyl phthalate or DHEXP or 84-75-3) and ts=paraffin wax	0
WOS	DIBP	ts=(diisobutyl phthalate or DIBP or 84-69-5) and ts=paraffin wax	0
WOS	DIDP	ts=(diisodecyl phthalate or DIDP or 26761-40-0 or 68515-49-1) and ts=paraffin wax	0
WOS	DINP	ts=(diisononyl phthalate or DINP or 28553-12-0 or 68515-48-0) and ts=paraffin wax	0
WOS	DnOP	ts=(di-n-octyl phthalate or DnOP or 117-84-0) and ts=paraffin wax	0
WOS	DPENP	ts=(di-n-pentyl phthalate or DPENP or 131-18-0) and ts=paraffin wax	0
WOS	Lead	ts=(Lead or 7439-92-1) and ts=paraffin wax; Refined by "Metal"	17
WOS	Mercury	ts=(Mercury or 7439-97-6) and ts=paraffin wax	10
WOS	Selenium	ts=(Selenium or 7782-49-2) and ts=paraffin wax	0

1.7 Key Words and Search Results for Recycling Data

Search String	Database	Hits
TS=(particleboard AND ((life cycle inventory) OR (life cycle assessment) OR (life cycle analysis)))	WOS	27
TS=((medium density fiberboard OR MDF) AND ((life cycle inventory) OR (life cycle assessment) OR (life cycle analysis)))	WOS	24
TS=(plywood AND ((life cycle inventory) OR (life cycle assessment) OR (life cycle analysis)))	WOS	21
TS=(particleboard AND ((urban wood waste) OR (industrial wood residue)))	WOS	12
TS=((medium density fiberboard OR MDF) AND ((urban wood waste) OR (industrial wood residue)))	WOS	6
TS=(plywood AND ((urban wood waste) OR (industrial wood residue)))	WOS	12
TS=(particleboard AND ((construction debris) OR (construction waste)))	WOS	20
TS=((medium density fiberboard OR MDF) AND ((construction debris) OR (construction waste)))	WOS	8
TS=(plywood AND ((construction debris) OR (construction waste)))	WOS	18
TS=(particleboard AND ((wood fiber) OR (wood fibre) OR (wood dust) OR (wood shavings) OR (wood trim) OR (wood chip)))	WOS	298*
TS=((medium density fiberboard OR MDF) AND ((wood fiber) OR (wood fibre) OR (wood dust) OR (wood shavings) OR (wood trim) OR (wood chip)))	WOS	374*

TS=(plywood AND ((wood fiber) OR (wood fibre) OR (wood dust) OR (wood shavings) OR (wood trim) OR (wood chip)))	WOS	136*
TS=(particleboard AND ((recycl*) OR (reconstitute*) OR (reuse*) OR (recover*)))	WOS	108
TS=((medium density fiberboard OR MDF) AND ((recycl*) OR (reconstitute*) OR (reuse*) OR (recover*)))	WOS	142
TS=(plywood AND ((recycl*) OR (reconstitute*) OR (reuse*) OR (recover*)))	WOS	104
TS=(particleboard AND ((post-consumer recycled wood) OR (sawdust) OR (deconstruction)))	WOS	31
TS=((medium density fiberboard OR MDF) AND ((post-consumer recycled wood) OR (sawdust) OR (deconstruction)))	WOS	13
TS=(plywood AND ((post-consumer recycled wood) OR (sawdust) OR (deconstruction)))	WOS	19
TS=((plywood OR particleboard OR medium density fiberboard OR MDF) AND ((cradle-to-grave analysis) OR (cradle to grave)))	WOS	1
*did not screen or retrieve – overlaps with individual EWP searches and therefore should not identify anything not already found through those searches.		
SCOPUS – Did not Screen or Retrieve		
(particleboard AND ((life cycle inventory) OR (life cycle assessment) OR (life cycle analysis)))	Scopus	220
((medium density fiberboard OR MDF) AND ((life cycle inventory) OR (life cycle assessment) OR (life cycle analysis)))	Scopus	117
(plywood AND ((life cycle inventory) OR (life cycle assessment) OR (life cycle analysis)))	Scopus	247
(particleboard AND ((urban wood waste) OR (industrial wood residue)))	Scopus	653
((medium density fiberboard OR MDF) AND ((urban wood waste) OR (industrial wood residue)))	Scopus	287
(plywood AND ((urban wood waste) OR (industrial wood residue)))	Scopus	303
(particleboard AND ((construction debris) OR (construction waste)))	Scopus	459
((medium density fiberboard OR MDF) AND ((construction debris) OR (construction waste)))	Scopus	202
(plywood AND ((construction debris) OR (construction waste)))	Scopus	246
(particleboard AND ((wood fiber) OR (wood fibre) OR (wood dust) OR (wood shavings) OR (wood trim) OR (wood chip)))	Scopus	3251
((medium density fiberboard OR MDF) AND ((wood fiber) OR (wood fibre) OR (wood dust) OR (wood shavings) OR (wood trim) OR (wood chip)))	Scopus	1719
(plywood AND ((wood fiber) OR (wood fibre) OR (wood dust) OR (wood shavings) OR (wood trim) OR (wood chip)))	Scopus	2160
(particleboard AND ((recycl*) OR (reconstitute*) OR (reuse*) OR (recover*)))	Scopus	1215
((medium density fiberboard OR MDF) AND ((recycl*) OR (reconstitute*) OR (reuse*) OR (recover*)))	Scopus	541
(plywood AND ((recycl*) OR (reconstitute*) OR (reuse*) OR (recover*)))	Scopus	867
(particleboard AND ((post-consumer recycled wood) OR (sawdust) OR (deconstruction)))	Scopus	291
((medium density fiberboard OR MDF) AND ((post-consumer recycled wood) OR (sawdust) OR (deconstruction)))	Scopus	121
(plywood AND ((post-consumer recycled wood) OR (sawdust) OR (deconstruction)))	Scopus	143
((plywood OR particleboard OR medium density fiberboard OR MDF) AND ((cradle-to-grave analysis) OR (cradle to grave)))	Scopus	7

*search further refined

1.8 Key Words and Search Results for Phthalate Uptake in Trees

1.8.1 Phthalate Uptake in Trees and Plants

Pubmed		
((((di-(2-ethylhexyl) phthalate) OR DEHP) OR 117-81-7) AND tree) AND uptake	1 hit	Saved
((((di-(2-ethylhexyl) phthalate) OR DEHP) OR 117-81-7) AND tree)	3 hits	Saved
(((di-(2-ethylhexyl) phthalate) OR DEHP) OR 117-81-7) AND uptake)	68 hits	Saved
(((dibutyl phthalate) OR DBP) OR 84-74-2) AND uptake)	153 hits	Saved
(((dibutyl phthalate) OR DBP) OR 84-74-2) AND tree)	22 hits	Saved
(((benzyl butyl phthalate) OR BBP) OR 85-68-7) AND tree)	3 hits	Saved
((((benzyl butyl phthalate) OR BBP) OR 85-68-7) AND uptake)	13 hits	Saved
(((((diisononyl phthalate) OR DINP) OR 28553-12-0) OR 68515-49-1) AND uptake)	1 hit	Saved
(((((diisononyl phthalate) OR DINP) OR 28553-12-0) OR 68515-49-1) AND tree)	0 hits	--
(((diisononyl phthalate) OR DINP) AND tree)	0 hits	--
(((diisononyl phthalate) OR DINP) AND uptake)	1 hit (duplicate)	--
((((diisononyl phthalate) OR DINP) OR 28553-12-0) OR 68515-49-1)	227 hits	Saved
(((((diisodecyl phthalate) OR DIDP) OR 26761-40-0) OR 68515-49-1) AND tree)	0 hits	--
(((((diisodecyl phthalate) OR DIDP) OR 26761-40-0) OR 68515-49-1) AND uptake)	1 hit (duplicate)	Saved
(((((diisodecyl phthalate) OR DIDP) OR 26761-40-0) OR 68515-49-1)	127 hits	Saved
((((di-n-octyl phthalate) OR DnOP) OR 117-84-0) AND uptake)	3 hits	Saved
((((di-n-octyl phthalate) OR DnOP) OR 117-84-0) AND tree)	0 hits	--
(((di-n-octyl phthalate) OR DnOP) OR 117-84-0)	153 hits	Saved
((((diisobutyl phthalate) OR DIBP) OR 84-69-5) AND uptake)	6 hits	Saved
((((diisobutyl phthalate) OR DIBP) OR 84-69-5) AND tree)	1 hit	Saved
(((diisobutyl phthalate) OR DIBP) OR 84-69-5)	203 hits	Saved
((((di-n-pentyl phthalate) OR DPENP) OR 131-18-0) AND tree)	0 hits	--
((((di-n-pentyl phthalate) OR DPENP) OR 131-18-0) AND uptake)	0 hits	--
(((di-n-pentyl phthalate) OR DPENP) OR 131-18-0)	0 hits	--
(((di-n-pentyl phthalate) OR 131-18-0) AND tree)	0 hits	--
(((di-n-pentyl phthalate) OR 131-18-0) AND uptake)	0 hits	--
((di-n-pentyl phthalate) OR 131-18-0)	26 hits	Saved
((((di-n-hexyl phthalate) OR DHEXP) OR 84-75-3) AND tree)	0 hits	--
((((di-n-hexyl phthalate) OR DHEXP) OR 84-75-3) AND uptake)	0 hits	--
(((di-n-hexyl phthalate) OR 84-75-3) AND uptake)	0 hits	--
((di-n-hexyl phthalate) OR 84-75-3)	43 hits	Saved
((((dicyclohexyl phthalate) OR DCHP) OR 84-61-7) AND uptake)	1 hit	Saved
((((dicyclohexyl phthalate) OR DCHP) OR 84-61-7) AND tree)	0 hits	--
((dicyclohexyl phthalate) OR 84-61-7)	77 hits	Saved
phthalate AND phytoremediation NOT biodegrad*	2 hits	Saved
phthalate AND phytoremediation	338 hits	Refined
phthalate AND phytoremediation AND plant	56 hits	Saved
(((((di-(2-ethylhexyl) phthalate AND tree) AND uptake)) OR DEHP) OR 117-81-7) AND wood) NOT wood[Author]	8 hits	Saved
Total combined library from endnote		877 reference
Total screened library		207 reference
In depth screen for retrieval (either not in English or not relevant)		61 references

1.8.2 Phthalate Uptake in Trees

Search String	Database	Hits	Retrieved	Database	Hits	Retrieved
DEHP AND phthalate AND tree	WOS	2	0	Scopus	6	0
di- (2-ethylhexyl) phthalate AND tree	WOS	3	0	Scopus	0	0
DBP AND phthalate AND tree	WOS	0	0	Scopus	4	1
dibutyl phthalate AND tree	WOS	3	0	Scopus	10	0 (1 duplicate)
BBP AND phthalate AND tree	WOS	0	0	Scopus	0	0
benzyl butyl phthalate AND tree	WOS	0	0	Scopus	0	0
DINP AND phthalate AND tree	WOS	0	0	Scopus	1	0
diisononyl phthalate AND tree	WOS	0	0	Scopus	2	1
DIDP AND phthalate AND tree	WOS	0	0	Scopus	1	0
diisodecyl phthalate AND tree	WOS	0	0	Scopus	2	0
DnOP AND phthalate AND tree	WOS	0	0	Scopus	0	0
di-n-octyl phthalate AND tree	WOS	1	0	Scopus	1	0
DIBP AND phthalate AND tree	WOS	0	0	Scopus	0	0
diisobutyl phthalate AND tree	WOS	2	0	Scopus	1	0
DPENP AND phthalate AND tree	WOS	0	0	Scopus	0	0
di-n-pentyl phthalate AND tree	WOS	0	0	Scopus	0	0
DHEXP AND phthalate AND tree	WOS	0	0	Scopus	0	0
di-n-hexyl phthalate AND tree	WOS	0	0	Scopus	0	0
DCHP AND phthalate AND tree	WOS	0	0	Scopus	0	0
dicyclohexyl phthalate AND tree	WOS	0	0	Scopus	0	0

TERA

Final Report for CPSC Task 14

Appendix II: SDS Source Information and Materials

FINAL Report

March 25, 2016

Submitted by:

Toxicology Excellence for Risk Assessment

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INDEPENDENT NON-PROFIT SCIENCE FOR PUBLIC HEALTH PROTECTION

Contents

1. Appendix II: SDS Source Information and Materials

As noted in Appendix I, data on raw materials and their proportions in finished products was difficult to find because of the proprietary nature of much of this data. In order to supplement the general information identified in books and published literature, a detailed Safety and Data Sheet (SDS) search was conducted that provided more specific information on the non-wood materials used in EWPs and the proportions of those materials. Due to the large amount of SDS sheets available, two approaches were undertaken to limit the number of SDS and to optimize the search. The first approach was to search the (M)SDS database MSDSXchange (http://www.msdsxchange.com/english/) for the specified EWPs (hardwood plywood, medium density fiberboard, and particleboard). SDSs resulting from these searches were reviewed one by one, ruling out any non-relevant EWPs. There was some difficulty to this approach as some SDS covered multiple EWPs, and it was hard to discern which board type the additives applied to. Results for each EWP were recorded in a table and are presented below. The second approach was to search the Composite Panel Association (CPA) for member companies producing hardwood plywood, MDF, and particleboard. Even though the CPA only specifically includes companies producing particleboard and MDF, information was also found through them for companies that produce hardwood plywood, and so we determined that this was relatively comprehensive of all specified EWPs. Each of the identified companies' websites was visited and SDSs reviewed, and this data was added to the tables below.

This approach provided us with the specific data under investigation for this research project, however, it should be noted that this SDS approach likely only covered SDS sheets from companies and organizations in North America. For example, we searched the International Wood Products Association for manufacturers of the specified EWPs. However, most of the results were North American countries. For the few companies that were identified outside of North America (*e.g.*, Malaysia, China), SDS sheets could not be found on their webpages.

1.1 SDS Data for Hardwood Plywood

Material/Product	**Additives**	**Company**
Plywood	Poplar = >87% Ureic formaldehyde resin = <12% Ammonium chloride (extender) = <1%	North American Plywood
Hardwood plywood urea formaldehyde-bonded, melamine urea formaldehyde-bonded, phenol formaldehyde-bonded	Formaldehyde = <1% Hardwood dust, various species = 5-25%	States Industries

Plywood	Wood (wood dust) = 85-99% Polymeric phenol formaldehyde resin solids = 1-15%	Weyerhaeuser Company
Plywood	Wood = 98-99% Phenol formaldehyde resin = 1-2%	Weyerhaeuser Company
Plywood	Softwoods = 85-99% Hardwoods = 0-15% Sodium hydroxide = <1% Formaldehyde gas = <0.1%	International paper
Plywood and composite panels bonded with phenol, melamine, and urea formaldehyde resin systems	Wood solids = 80-95% Cured resin solids = 5-20% Formaldehyde = <0.1% Cured finish (coatings) or melamine surface materials = <1%	Roseburg
Softwood plywood	Wood = 97.8% Phenol formaldehyde resin = 2.1%	American Wood Council; Canadian Wood Council
Phenol-formaldehyde bonded wood products plus a polyurethane film: softwood and hardwood plywood (veneer core), oriented strand board, laminated veneer lumber, wood I-joists, glulam beams	Formaldehyde = <0.1% Solid polyurethane film = 2.67% Wood dust = % not reported	Boise-Cascade
Softwood plywood	Wood = 92-97% Phenol formaldehyde resin = 3-5% Primer = 1% Sealer = 0.5% Medium density overlay = 1%	Roseburg
Hardwood plywood	Wood = 93-95% UF resin = 3-7% UV filler = < 2% Phenol formaldehyde resin = < 3%	Roseburg
Softwood plywood	Wood = 97.8% Phenol formaldehyde resin = 2.1%	American Wood Council; Canadian Wood Council

Softwood plywood, sanded softwood plywood, medium density overlay, high density overlay	Softwood plywood = 88-94% Formaldehyde = <1% Inert filler wheat = 2-4% Water-based acrylic latex = <1%	Westlam Industries Ltd.
Plywood	Wood dust, all soft and hard woods = 99% Phenol-formaldehyde polymer = <1%	Potlatch Corp
Southern yellow pine plywood	Wood/wood dust = 95-97% Phenol formaldehyde resin = 3-5%	Hood Industries, Inc.
UF bonded hardwood Plywood	Wood dust = 96-99% Formaldehyde = <0.1%	Murphy Plywood
Plywood	Southern yellow pine/wood dust = 84-99% Phenolic resin = 0-15%	Roy O Martin
Southern yellow pine plywood	Wood/wood dust = 95-97% Phenol formaldehyde resin = 3-5%	Scotch Plywood Company Inc.
Plywood	Formaldehyde = <0.4 ppm Wood = 87-95%	Tolko Industries Ltd. Plywood Products
Phenol-formaldehyde bonded wood products plus a polyurethane film: softwood and hardwood plywood (veneer core), oriented strand board, laminated veneer lumber, wood I-joists, glulam beams	Formaldehyde = <0.1% Solid polyurethane film = 2.67% Wood dust = N/A	Boise Cascade

N/A = not available

1.2 SDS Data for Medium Density Fiberboard

Material/Product	Additives	Company
Medium density fiberboard	Urea-formaldehyde resin = 7-10% Wax (paraffin) = <1% (post treatment) ammonia = <1% [wood fiber percentage not given]	Plum Creek Northwest Plywood, Inc.
Medium density fiberboard	Mixed softwood Polymerised resin Paraffin wax Moisture Formaldehyde (≤8mg/100g) [percentages not given]	Medite Europe Ltd
Medium density fiberboard, wood-based panel product	Mixed softwood Urea formaldehyde binder Paraffinic wax Ammonia Formaldehyde (free) [percentages not given]	Medite Corp
Unfinished particleboard and medium density fiberboard panels	Cellulosic materials = 90-93% Polymerized urea formaldehyde resin = 8-11% Formaldehyde = <0.1%	G-P Flakeboard Company
Particleboard, laminated or coated particleboard, laminated or coated MDF	Wood = 80-90% Melamine topcoat = <5% Urea = 0-10% Formaldehyde = <0.1% Cured resin solids = 5-15%	Roseburg
Medium density fiberboard	Formaldehyde = <1 ppm Synthetic binder = (proprietary) Wood dust (and/or ligno-cellulosic fibers) = (proprietary)	Georgia-Pacific Panel Products LLC
Unfinished medium density fiberboard panels	Polymerized urea formaldehyde resin = 0.01-16% Methylene-diphenyl-diisocyanate (MDI) = 0-5% Wood dust/ligno-cellulosic fiber [percentages not given]	SierraPine

Medium density fiberboard and hardboard paneling bonded with urea-formaldehyde resin	Wood/wood dust = 60-100% Formaldehyde = 0-0.1% Urea, polymer with formaldehyde = 1-5% Other components below reportable levels = 10-30%	Georgia-Pacific Panel Products LLC
High density, medium density, and light density fiberboard	Wood dust, soft woods = 88-92% Slack wax, petroleum = <1% Ammonia = <1%	Plum Creek Northwest Plywood, Inc.
Unfinished medium density fiberboard panels	Ligno-cellulosic materials = 75-94% Polymerized urea formaldehyde resin = 6-25%	Masisa/ Timber Products Inc.
Medium density fiberboard	Wood fibers = 73-93% Cured amino resin = 0-17% Cured amino resin = 0-16% Urea = 0-3% Formaldehyde = <0.1%	Arauco-North America
Medium density fiberboard	Formaldehyde = <0.13 ppm Synthetic binder = proprietary Wood dust (and/or ligno-cellulosic fibers) = proprietary	Del-Tin Fiber, LLC
Medium density and high density fiberboard	Formaldehyde = <0.1% Wood (hardwood and softwood of various species) = >90%	Kronospan
Unfinished medium density fiberboard	Ligno-cellulosic materials = 90-93% Polymerized urea formaldehyde resin = 6-12%	West Fraser Mills Ltd.
Unfinished medium density fiberboard	Ligno-cellulosic materials = 90-95% Polymerized methylene-diphenyl-diisocyanate (pMDI) = <10%	West Fraser Mills Ltd.
Unfinished particleboard and medium density fiberboard panels	Cellulosic materials = 90-93% Polymerized urea formaldehyde resin = 8-11% Formaldehyde = <0.1%	G-P Flakeboard Company

1.3 SDS Data for Particleboard

Material/Product	Additives	Company
Particleboard, laminated or coated particleboard, laminated or coated MDF	Wood = 80-90% Melamine topcoat = <5% Urea = 0-10% Formaldehyde = <0.1% Cured resin solids = 5-15%	Roseburg
Particleboard (urea-formaldehyde bonded)	Wood = 95% Formaldehyde = 0.1-0.2%	Roseburg
Particleboard	Wood = 90.2% Urea formaldehyde resin = 9.5% Slack wax = 0.3%	American Wood Council; Canadian Wood Council
Wood products (pMDI bonded)	Wood/wood dust = 60-100% Methylene bisphenol isocyanate (MDI) = 1-5% Polymeric MDI (pMDI) = 1-5% 2,4'-Diphenyl methane diisocyanate = 0.1-1% Other components below reportable levels = 0.5-1.5%	Georgia-Pacific Panel Products LLC
Particleboard	Wood/wood dust = 60-100% Polymeric MDI (pMDI) = <1.0% Formaldehyde = <0.1% Methylene bisphenol isocyanate (MDI) = 0-<1.0% Other components below reportable levels = 1-5% Urea, polymer with formaldehyde = 1-10%	Georgia-Pacific Panel Products LLC
Particleboard, industrial, commercial, underlayment, PB-blend	Wood dust = 60-100% Formaldehyde = <0.1%	Timber Products Company
Particleboard	Wood fibers = 83-92% Cured amino resins = 0-17% Cured amino resins = 0-15% Urea = 0-2% Formaldehyde = <0.1%	Arauco North America
Particleboard	Wood dust = 60-100%	Sierra Pine Composite Solutions

Particleboard, composite panel product	Inland softwoods = 96-98% Hardwoods = 0.0-1.0% pMDI binder = proprietary	Plummer Forest Products
Particle and medium and high density fiber boards, raw and laminated	Formaldehyde = <0.1% Wood dust = N/A	Uniboard
Phase 2 standard CARB particleboards; CARB ULEF particleboards	Wood (woody fibers) = 60-100% Formaldehyde = <0.1% 4,4'-Diphenylmethane diisocyanate = 0-15% Ammonium nitrate = 0.1-15%	Tafisa Canada Inc.
Particleboard	Wood fiber = 95-98% Formaldehyde = <0.1% (0.1% to 0.2% in the board)	Roseburg Forest Products
Unfinished particleboard and medium density fiberboard (MDF) panels	Cellulosic materials = 90-93% Polymerized urea formaldehyde resin = 8-11% Formaldehyde = <0.1%	G-P Flakeboard Company
Unfinished particleboard	Ligno-cellulosic materials = 90-93% Polymerized urea formaldehyde resin = 6-9%	SierraPine Limited
Softwood plywood; composite panel (particleboard)	Wood solids = 80-95% Cured resin solids = 5-20% Formaldehyde = <0.1% Cured finish (coatings) or melamine surface materials = <1%	Roseburg

TERA

Final Report for CPSC Task 14

Appendix III: Manufacturing and Impurities in Raw Materials

FINAL Report

March 25, 2016

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Contents

1. Appendix III: Manufacturing and Impurities in Raw Materials

Polymerization of the binders and resins involves the linking of the initial polymer molecule with the addition of a number of additives, as described in the body of the report. There are also a number of modifiers that may be added during EWP manufacture to impart new properties to the final product. The manufacturing of these materials was also reviewed in order to assess if there was potential for any of the specified substances to be introduced into any of these products or if they were components of the raw materials used in manufacture. General information on manufacture and potential impurities for each of these products is described below, as the information was available from authoritative sources, starting with the Hazardous Substances Data Bank (HSDB) and supplemented from the World Health Organization (WHO) or the Food and Agriculture Organization (FAO) when data were unavailable. It should be noted that there is additional information available if a more detailed company specific/chemical specific search is conducted for these raw materials and adhesives, but we have included only general information here as resources allowed. In the case where there was no information available in the HSDB search, and additional investigation through WHO or FAO was unfruitful, we noted as such but did not do additional targeted gap searching due to resource limitations. SDS searching in this case was not helpful as it appears that for technical grade products the specifications (impurities) are not available because they are not set to certain purity standards as would be done for analytical grades.

Specialty composite materials for use in specialty purposes include those imparted with additives for water resistance, acidity control, fire resistance, insect resistance, and decay resistance (Stark et al., 2011). Because these additives are uncommon and are mostly applied for specialty products, they are unlikely to be present or applied in children’s products or toys and so were not covered further in this report.

The information provided below is basic information on the manufacture of the adhesives, the individual starting materials (monomers) used in resin production, along with all potential catalysts, scavengers, and fillers. In an effort to be overly inclusive, all identified additives and resins are covered below. This is in contrast to our main report, which notes only those that are commonly in use or that are only in use for the three specified EWPs.

2. Adhesives

2.1 Amino Resins (Urea-formaldehyde)

The manufacturing process is a two-step reaction. The first is a hydroxymethylation reaction of urea with formaldehyde under neutral to basic conditions and moderate temperature to form various methylol ureas (Stokke et al., 2014). This reaction is driven toward the methylol intermediate with excess formaldehyde, with typical molar ratios of 2.0-2.2 formaldehyde to urea (Stokke et al., 2014). The second step involves condensing these methylol ureas into long strand polymers under acidic conditions and higher heat (Stokke et al., 2014). During this step, excess urea can be added to react excess formaldehyde (Stokke et al., 2014). Additionally, scavengers can be added to control excess formaldehyde (Stokke et al., 2014), but typically just prior to use. Urea-formaldehyde (UF) resin is supplied at neutral pH (~ 7.0) but curing requires acidification.

2.2 Phenols (phenol-formaldehyde)

Phenol-formaldehyde resole resins (PFs) are obtained in a two-step process as the above resins: the first involving the reaction (hydroxylmethylation) of phenol and formaldehyde under alkaline conditions to form monomethylol phenol, followed by the second step of condensing the methylolated intermediates into a moderately polymerized solution (prepolymers) (Stokke et al., 2014; Fink, 2013). These prepolymers are then added to the EWPs for the curing process, which requires heat only (no catalyst) given the reactivity of the prepolymers (Stokke et al., 2014). An accelerator, such as an ortho ester, can be added to speed up the curing process Frihart (2005); however, accelerators in general were suggested to be uncommon by a subject matter expert.

2.3 Isocyanates (pMDI)

The isocyanate resin, pMDI, is synthesized from formaldehyde and aniline under aqueous acid conditions and the resulting polyamine is converted to the final isocyanate by reaction with phosgene (Twitchett, 1974). Aspects of pMDI quality include acidic and chlorine containing impurities as related to the efficiency of the phosgenation (Twitchett, 1974); but these impurities are unrelated to the phthalates and chemical elements of concern in this report (Frazier, personal communication). The pMDI resins are unusual because they are among the few wood bonding resins that are water insoluble. This resin is sometimes used to make PB and MDF when formaldehyde-free resins are desired (pMDI is synthesized from formaldehyde; but the final resin is free of formaldehyde). Consequently, PB and MDF manufactured with pMDI could have surface contamination with release agents (which are simple fatty acid salts, waxes, or silicones) (Frazier, 2004). Occasionally, but very uncommon in wood composite manufacture, pMDI resins will be formulated with amine catalysts such as 4,4'-(oxydi-2,1-ethanediyl) bismorpholine (DMDEE).

2.4 Polyvinyl acetate

Polyvinyl acetate is manufactured through emulsion polymerization of vinyl acetate in water using poly(vinyl alcohol) emulsifiers (Frihart, 2005). However, the most common PVA resins used for wood bonding are so-called "crosslinking PVAs" which are copolymers of vinyl acetate and N-methylolacrylamide (NMA). When PVA resins are used to make hardwood plywood, crosslinking PVAs are the probable type and these are acid catalyzed typically with aluminum chloride. The aluminum chloride catalyst may be internal to the resin, or it may be added just prior to adhesive application.

3. Resins used in Adhesive Manufacture

3.1 Urea (CASRN: 57-13-6)

- Manufacturing (HSDB, 2003a):
  - A high pressure and high temperature reaction of liquid ammonia and liquid carbon dioxide form ammonium carbamate. At lower pressure, this breaks down into urea and water which can be purified using crystallization.
- Potential impurities (HSDB, 2003a; OECD, 2008):
  - Biuret (0.3 - 2%), cyanates.
  - Technical urea analysis as follows: water (0.4 %), free ammonia (0.4 %), and iron (<0.02 %).

3.2 Formaldehyde (CASRN: 50-00-0) (synonyms include formalin)

- Formalin is the aqueous form of formaldehyde.
- Manufacturing (HSDB, 2015a):
  - Catalytic oxidation method, commonly either using the silver catalyst method or the metal oxide catalyst method.
  - The silver catalyst method involves using silver crystals or silver gauze, partial oxidation and dehydrogenation with air, steam, and excess methanol at high temperature and high pressure. Purification is done using distillation from reaction products and by-products.
  - The metal oxide (Formox) method uses a modified iron-molybdenum-vanadium oxide catalyst, oxidation in air, and excess methanol at high temperature and pressure.
- Potential impurities:
  - Pure formaldehyde tends to polymerize and so is typically sold as a solution with 33-55% formaldehyde in methanol (HSDB, 2015a; OECD, 2002a).
  - A formaldehyde solution from BASF contained the following reported impurities (OECD, 2002):
    - Methanol = 0.5-2% w/w
    - Formic acid = about 0.3% w/w
    - Iron = <0.0001% w/w

3.3 Paraformaldehyde (CASRN: 30525-89-4)

- Manufacturing (HSDB, 2013a):
  - Paraformaldehyde can be used in the production of phenol, urea, and melamine resins instead of aqueous formaldehyde solutions where the presence of water can be problematic.
  - Paraformaldehyde is industrially manufactured through concentrating aqueous formaldehyde using vacuum conditions at low pressure and variable temperatures. Formaldehyde solutions used can contain formic acid and metal formates with atomic number 23-30 (this includes chromium, among others, as discussed further in the main report).
  - Other methods include fractional condensation of reaction gases, reaction of formaldehyde-containing gas with paraformaldehyde under controlled conditions, or by the introduction of concentrated melt into a cooling liquid (such as benzene, toluene, or cyclohexane) with the addition of acids or alkalis to accelerate polymerization.

- Potential impurities (HSDB, 2013a):
  - Paraformaldehyde can contain 90-93% formaldehyde, up to 9% water, and up to 3% acidity as formic acid (also reported as 0.03%).
  - Other reports of commercial specifications include up to 2% iron and 0.01% ash.

3.4 Phenol (CASRN: 108-95-2)

- Manufacturing (HSDB, 2003b):
  - Cumene oxidation (Hock Process) is the most common method of production in the United States. This involves the production of cumene hydroperoxide through oxidation of cumene and acidic (*e.g.*, sulfuric acid) cleavage/decomposition of cumene hydroperoxide to phenol and acetone.
  - Other methods include:
    - the Dow process (named after Herbert Henry Dow who used it for bromine extraction from brine; later applied to phenol production).
    - includes toluene oxidation to benzoic acid followed by decarboxylation to phenol.

        - benzene sulfonation to benzene sulfonate and heating in an alkali hydroxide to produce phenol dehydrogenation of cyclohexanol-cyclohexanone mixtures.
        - chlorination of benzene followed by steam or alkaline hydrolysis.
- Potential impurities (HSDB, 2003b):
    - Typically sold as liquid in water, oil, or glycerin, or as a mixture. Other compounds were reported as mostly cresols.

3.5 Resorcinol (CASRN: 108-46-3) (synonyms include: 1,3-dihydroxybenzene; 1,3-benzenediol; m-dihydroxybenzene; resorcin)

- Manufacturing (HSDB, 2015b):
    - Continuous sulfonation of benzene with sulfur trioxide or sulfuric acid, and following neutralization with sodium sulfite, soda ash, or sodium hydroxide solution, the sulfonation product (disodium benzene-1,3-disulfonate) is mixed with excess sodium hydroxide and reacted at high heat. The result is a white powder of disodium resorcinate, sodium sulfite, and sodium hydroxide. This reaction product is treated with water to form a saturated solution that is then reacted with sulfur dioxide, sulfuric acid, or hydrochloric acid to give resorcinol. The resorcinol can be extracted using organic solvents such as diisopropyl ether, benzene, 4-methyl-2-pentanone (methyl isobutyl ketone), or others, which are then distilled off to form purified resorcinol.
    - Another method was described of hydroperoxidation of m-diisopropylbenzene in which benzene (or benzene-cumene mixtures) is alkylated with propene using an aluminum chloride-hydrochloric acid catalyst. Para-diisopropylbenzene (p-DiPB) and triisopropylbenzene (TriPB) are then added and isomerized/transalkylated into m-diisopropylbenzene (m-DiPB). The reaction mixture is then fractionated and a radical autoxidation of the m-DiPB fraction is accomplished in reactors under alkaline conditions to yield [1,3-phenylenebis-(1-methylethylidene)]bishydroperoxide (m-diisopropylbenzene dihydroperoxide, DHP). Meta-DHP is then crystallized, centrifuged, dissolved in acetone, and cleaved into resorcinol and acetone. This occurs using an acid catalyst (*e.g.*, sulfuric acid) in boiling acetone. Acetone is then distilled off and further purification can be done using recrystallization or extraction. Alternatively, cleavage of the oxidate can be done using hydrogen peroxide. In this process the byproducts are oxidized to DHP and eventually converted to resorcinol.

- Resorcinol can be made in other ways, including destructive distillation of brazilin or fusion of galbanum, ammoniac, sagapenum, asafetida, or acroides with caustic potash.

- Potential Impurities:
  - Technical grade resorcinol has a minimum of 99% resorcinol content with small impurities of phenol and catechol. Other reported impurities include other hydroquinone isomers, insoluble matter, acidity, and diresorcinol (HSDB, 2015b).
  - Technical-grade resorcinol was reported with 99.5% resorcinol content with impurities including phenol, catechol, cresols, and 3-mercaptophenol (WHO, 2006).

3.6 4-4'-methylenedianiline isomer (MDA) (CASRN: 101-77-9) (synonyms include: 4,4'-diaminodiphenylmethane)

- Manufacturing:
  - Methods include acid catalyzed (*e.g.*, hydrochloric acid) reaction of aniline and formaldehyde, hydrogenolysis of p,p'-diaminobenzophenone with lithium aluminum hydride or distillation from polymeric 4,4'-diaminodiphenylmethane (HSDB, 2009a; OECD, 2002b).
- Potential impurities (OECD, 2002b):
  - Technical-grade MDA is an isomer mixture containing tri- and polynuclear amines. Typical mixture can include:
    - 4,4'-MDA: 59-61% w/w but highly variable depending on manufacturing method used.
    - MDA polymers: ~ 36% w/w
    - 2,4'-MDA: ~ 3.5% w/w
    - 2,2'-MDA: <0.1% w/w
    - water: <300 ppm
    - aniline: <100 ppm
    - pure 4,4'-MDA can contain traces of 4-amino-4'-methylaminodiphenyl methane.

3.7 4,4’-diphenylmethane diisocyanate (MDI) (CASRN: 101-68-8) (synonyms include: methylene bisphenol isocyanate (MDI), 4,4'-methylenediphenyl diisocyanate)

- Manufacturing (HSDB, 2012a):
    - Methods include condensation of aniline with formaldehyde in the presence of hydrochloric acid. This forms oligomeric di- and polyamines that are then phosgenated to form MDI. This is typically a mixture of isomers that can be controlled through the addition of the starting materials and conditions.
    - Another reported method for pure diphenylmethane 4,4'-diisocyanate also involves condensing aniline and formaldehyde to yield diphenylmethane diamine. Phosgenation of this product then yields aromatic isocyanate MDI.
- Potential impurities (HSDB, 2012a):
    - MDI is typically a mixture of 30-40% diphenylmethane-4,4’-diisocyanate, 2.5-4.0% diphenylmethane-2,4'-diisocyanate, 0.1-0.2 % diphenylmethane-2,2'-diisocyanate, and the remaining 50-60% oligomers; can also be blocked with phenol for some solutions.

3.8 Phosgene (CASRN: 75-44-5)

- Manufacturing (HSDB, 2008a):
    - Phosgene for industrial applications is typically made through the reaction of carbon monoxide and chlorine gas with an activated carbon catalyst. This reaction can also be completed using anhydrous chlorine gas and a majority of the production takes place on-site in the manufacture of polyisocyanates and polycarbonate resins.
    - Non-industrial use methods include combustion of carbon tetrachloride, methylene chloride, trichloroethylene, or butyl chloroformate.
- Potential impurities:
    - Chlorine (free), hydrochloric acid, and sulfur chlorides (HSDB, 2008a).
    - Technical grade phosgene with 95-99% purity can have impurities including nitrogen, carbon monoxide, hydrochloric acid, free chlorine, and sulfur compounds (IPCS, 1998).

3.9 Aniline (CASRN: 62-53-3)

- Manufacturing (HSDB, 2011a):
    - Multiple manufacturing processes include catalytic vapor phase reduction of nitrobenzene with hydrogen, reduction of nitrobenzene with iron filings with an acid catalyst (hydrochloric acid), catalytic reaction of chlorobenzene and aqueous ammonia, and ammonolysis of phenol (Japan).
- Potential impurities:
    - Nitrobenzene, beta-naphthylamine, and 4-aminobiphenyl (pre-1900 A.D.) was reported (HSDB, 2011a).

3.10 Polyvinyl alcohol (CASRN: 9002-89-5)

- Manufacturing (HSDB, 2003c):
    - Includes hydrolysis of polyvinyl acetate by using methanol to replace the acetate groups with hydroxyl groups. Reaction proceeds rapidly in a methanol/methyl acetate mixture using alkali or mineral acid catalysts. Can also proceed in the presence of sodium methylate.
- Potential impurities (FAO, 2004):
    - Sodium acetate, methanol, and methyl acetate.

3.11 Vinyl acetate monomers (CASRN: 108-05-4)

- Manufacturing (HSDB, 2009b):
    - Commonly conducted by reacting acetic acid, ethylene, and oxygen using a noble metal catalyst (zinc salts, zinc acetate, mercury salt, palladium) at high heat and under pressure. The monomer is condensed, scrubbed, and distilled to purify.
    - Other methods include the reaction of ethylene with sodium acetate or using an acetaldehyde/acetic anhydride process to yield ethylidene diacetate, which is then cleaved to form vinyl acetate and acetic acid.
    - A final method was reported using a carbonylation process to react methanol with carbon monoxide to form acetic acid. Methanol and acetic acid are then mixed to form methyl acetate that is further carbonylated to form ethylidene diacetate, which can be pyrolized to vinyl acetate and acetic acid.

- Potential impurities (HSDB, 2009b):
  - Typical USA specifications include acidity (as acetic acid), aldehydes (as acetaldehyde), and water.
  - Typical Western Europe specifications include ethyl acetate, water, methyl acetate, acetaldehyde, and acrolein.
  - Typical Japanese specifications include free acid (as acetic acid), free aldehydes (as acetaldehyde), and moisture.

3.12 Hexamethylenetetramine (CASRN: 100-97-0) (synonyms include methenamine)

- Manufacturing (HSDB, 2003d):
  - Used mainly as an ammonia or formaldehyde donor in the production of phenol or urea-formaldehyde resins.
  - Formed by the action of ammonia on formaldehyde (formalin).
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

3.13 Methanol (CASRN: 67-56-1)

- Manufacturing (HSDB, 2012b):
  - Industrial solvent and raw material for making formaldehyde.
  - Manufactured by exothermically reacting carbon monoxide and hydrogen at high temperature and high pressure. High-pressure processes are catalyzed with copper chromite catalysts; however, it is more commonly manufactured using low-pressure methods catalyzed with copper-zinc oxide and using alumina promoters, and which requires a sulfur-free synthesis gas.
  - Another liquid phase process includes copper-zinc catalysts in hydrocarbon oil and allows for a CO-rich synthesis gas at a lower pressure and high temperature.
  - It was reported that industrial scale methanol is produced exclusively by high, medium, or low-pressure catalytic conversion of synthesis gas.
  - Several other methods were reported including gasification of wood, peat, or lignite, from methane with a molybdenum catalyst, or by partial oxidation of natural gas hydrocarbons.

- Potential impurities:
    - Typical impurities were water, acetone, and ethanol. Others were reported based on product grade, with Grade A methanol having acetone, aldehydes, acetic acid, and water; and Grade AA methanol having the same impurities along with ethanol (HSDB, 2012b).
    - Other reports include water, dimethyl ether, fusel oils, methyl formate, and higher alcohols (HSDB, 2012b; IPCS, 1997).
    - Federal specifications for pure methanol in the United States restrict the presence of most of these impurities (HSDB, 2012b).

3.14 Glyoxal (CASRN: 107-22-2)

- Manufacturing (HSDB, 2006a):
    - Glyoxal can be used industrially in the production of polymers as a cross-linking agent.
    - Glyoxal is manufactured through the oxidation of acetaldehyde with nitric or selenius acid through a continuous process. Once excess acetaldehyde is removed, glyoxal is purified using an ion-exchange resin.
    - Other methods include:
        - heating the polymer with anethole, phenetole, safrole, methyl nonyl ketone, or benzaldehyde.
        - vapor-phase oxidation of ethylene glycol.
        - gas-phase (or liquid phase) oxidation of ethylene glycol by oxygen in the presence of dehydrogenation catalysts (metallic copper or silver) at high temperature.
- Potential impurities:
    - During production, the reaction solution is contaminated with acetic, formic, and glyoxylic acids, which glyoxal is purified from, and which may render the solution acidic (HSDB, 2006a).
    - Some anhydrous forms may include polymerization inhibitors (HSDB, 2006a).
    - The main impurities include (OECD, 2003).
        - traces of formic acid, acetic acid, glyoxylic acid and glycolic acid
        - formaldehyde
        - traces of organic acids
        - 1,2-ethanediol
        - hydroxyacetaldehyde

3.15 N-Methylolacrylamide (NMA) (CASRN: 924-42-5)

- Manufacturing (HSDB, 2003e):
  - Hydroxymethylation of acrylamide and formaldehyde.
- Potential impurities (HSDB, 2003e):
  - None identified in HSDB.

3.16 Butyraldehyde (CASRN: 123-72-8)

- Manufacturing (HSDB, 2009c):
  - Reduction of methyl butyrate or from butyryl chloride.
  - Dry distillation of calcium butyrate and calcium formate.
  - Oxo process combines propylene, carbon monoxide, hydrogen, and a catalyst.
  - Usual processes include catalytic dehydrogenation of butanol, crotonaldehyde, or propene; can also involve acetaldehyde.
- Potential impurities (HSDB, 2009c):
  - Potential for polymerization of butyraldehyde during storage.

3.17 Multihydroxymethylketones

- Manufacturing:
  - None identified in HSDB, WHO, FAO.
  - Fink (2013) reports that multihydroxymethylketones are reaction products of excess formaldehyde and ketones.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4. Catalysts (curing agents, hardeners, accelerators)

Catalysts are used in the manufacture of resins, binders, and adhesives. They influence reaction rate and can also impact the actual properties of the final resin. Catalysts are by definition chemically unchanged during the reaction.

4.1 Magnesium oxide/hydroxide (CASRN: 1309-48-4; 1309-42-8)

- Manufacturing (HSDB, 2012c, 2003f):
  - Limestone is calcined to produce dolomite/dolime that is reacted with magnesium chloride brine to produce magnesium hydroxide and calcium chloride that are then separated.
  - Another method includes thermally decomposing the magnesium chloride brine at high temperature into magnesium oxide and hydrochloric acid. Further processing and different methods produce different reactivity grades.
  - An additional method decarbonates limestone/dolomite to remove all CO_2 and all colloidal particles including salts of other metals resulting in chemically inert magnesia. This is then seeded with magnesium hydroxide to form magnesium hydroxide crystals that are then precipitated, washed, filtered, and further processed.
  - It was noted that the purity of the compound depends on the purity and composition of the natural manesite. It was also noted that the density of the oxide is resultant from the calcining temperature.
- Potential impurities (HSDB, 2012c):
  - Trace impurities were reported as sodium chloride, potassium chloride, and sodium fluoride.

4.2 Magnesium stearate (CASRN: 557-04-0)

- Manufacturing (HSDB, 2005a):
  - Reacting sodium stearate with magnesium sulfate produces magnesium stearate.
- Potential impurities (HSDB, 2005a):
  - Impurities include small amounts of oleate; technical grade magnesium stearate has roughly 7% magnesium oxide.

4.3 Sodium hydroxide (CASRN: 1310-73-2)

- Manufacturing (HSDB, 2012d):
  - There are a number of manufacturing methods reported, including:
    - Formation of caustic soda (solid sodium hydroxide) involves the evaporation of water from sodium hydroxide solution.

        - Another method of causticization involves mixing sodium carbonate with calcium oxide. Calcium carbonate precipitates out and the sodium hydroxide solution is evaporated.
        - Reaction of calcium hydroxide with sodium carbonate.
        - From sodium chloride by electrolysis (reported as most common method for industrial production).
        - From sodium metal and water vapor.
        - A final method was reported as commonly in use in paper pulp plants. This method evaporates waste liquor containing sodium salt and organics. The resulting residue is mixed with ferric oxide forming sodium ferrite that decomposes in water to give sodium hydroxide and ferric oxide.
- Potential impurities (HSDB, 2012d):
    - Common major impurities include sodium chloride, sodium carbonate, sodium sulfate, sodium chlorate, iron, and nickel.
    - The electrolysis method commonly yields excess chlorine and hydrogen in solution.

4.4 Sulfuric acid (7664-93-9)

- Manufacturing (HSDB, 2010):
    - Combustion of elemental sulfur or iron pyrites (sulfur, pyrite, hydrogen sulfide, sulfur-containing smelter gases, or through the use of gypsum) to yield sulfur dioxide. This is catalytically oxidized (with vanadium pentoxide) to sulfur trioxide at high temperatures. After cooling, sulfur trioxide is mixed with sulfuric acid where it bonds with excess water in the acid to form additional sulfuric acid.
    - Also formed by reacting sulfur dioxide with oxygen to form sulfur trioxide and mixing with water.
    - Sulfur dioxide is oxidized with nitrogen oxides to sulfuric acid and water.

- Potential impurities (HSDB, 2010):
    - As reported for technical grade, industry type 66:
        - Non-volatiles – 0.02-0.03 ppm
        - Sulfur dioxide – 40-80 ppm
        - Iron – 50-100 ppm
        - Nitrate – 5-20 ppm

    - Also reported impurities of iron, arsenic, sulfur dioxide, nitrogen compounds, chloride, and fluoride.

4.5 Phosphoric acid (CASRN: 7664-38-2)

- Manufacturing (HSDB, 2012e):
    - Vapor phase phosphorus is converted to phosphorus pentoxide through exposure to warm air, and is then treated with water to form phosphoric acid.
    - Phosphate rock (calcium phosphate) is digested in sulfuric acid (occasionally hydrochloric acid). Then phosphoric acid is filtered from the calcium sulfate slurry.
- Potential impurities (HSDB, 2012e):
    - Some inorganic impurities depend on the impurities and composition of the phosphate rock. It was reported that these must be partially or fully removed using precipitation and extraction.
    - Other impurities reported in various technical grades include:
        - Calcium monoxide – 0.06-0.01%
        - Fluoride – 0.8-<0.0001%
        - Aluminum oxide – 1.7-0.0003%
        - Iron oxide – 1.23-0.004%
        - Magnesium oxide – 0.58-0.0002%
        - Potassium oxide – 0.01-0.0007%
        - Sodium oxide – 0.12-0.0025%
        - Silicon dioxide – 0.07-0.0015%
        - Sulfate – 2.2->0.002%

4.6 Hydrochloric acid (CASRN: 7647-01-0)

- Manufacturing (HSDB, 2015c):
    - Produced by direct reaction of hydrogen and chlorine in a combustion chamber at high heat, reaction of metal chlorides and acids, or as a by-product from chemical manufacturing processes (reported that 90% of by-product formation occurs from production of chlorinated solvents, fluorocarbons, isocyanates, organics, magnesium, or vinyl chloride). Hydrogen chloride produced from chlorination can be isolated from gases, isolated and/or purified from distillation, or by aqueous absorption.

- Industrially produced by the Meyer process/Manheim process by reacting sodium chloride (or potassium chloride, sodium bisulfite) and sulfuric acid in a mechanical furnace at high temperatures.
    - Or by the Hargreaves process from reacting sodium chloride, sulfur dioxide, air, and water vapor.
    - Or by burning of chlorine with hydrogen gas.
- Potential impurities (HSDB, 2015c):
    - May contain chlorinated hydrocarbons, inorganic impurities (such as iron).
    - Other reported limits include:
        - Ammonia – 0.003%
        - Free chlorine – 0.0001%
        - Heavy metals – 0.0001%
        - Iron – 0.00002%
        - Sulfate – 0.0001%
        - Sulfite – 0.0001%

4.7 Boric Acid (CASRN: 10043-35-3)

- Manufacturing (HSDB, 2012f):
    - Industrially, borate minerals, brines (such as borax, kernite, colemanite, ascharite, ulexite, hydroboracite, etc.), or sodium- or calcium-containing borate ores are reacted with mineral acids (hydrochloric, sulfuric) and crystalized. Crystals are then filtered, washed, and dried. Reaction can be conducted in weak/strong boric acid liquor at moderate temperatures.
        - The United States commonly uses sodium borate mineral starting materials.
        - Europe commonly uses colemanite starting materials.
    - Can also be manufactured through extraction of borax brines with kerosene chelating agents (2-ethyl-1,3-hexanediol, polyols) and stripping with sulfuric acid.
- Potential impurities (HSDB, 2012f):
    - Boric acid liquor can have high concentrations of sodium sulfate, and technical grade boric acid can contain various metallic impurities carried over from the ore.

4.8 Oxalic acid (CASRN: 144-62-7)

- Manufacturing (HSDB, 2005b):
    - By passing carbon monoxide through concentration sodium hydroxide.
    - By heating sodium formate in the presence of sodium hydroxide/sodium carbonate.
    - Commercial production involves oxidation of starch, sugar, or ethylene glycol using nitric acid.
    - As a co-product in fermenting molasses to citric acid.
    - By fusing cellulose with sodium/potassium hydroxide.
- Potential impurities (HSDB, 2005b):
    - The technical grade was reported as having a chemically pure grade but as not being 100% pure.
    - The commercial product can be a formulation of 71.42% oxalic acid in 28.58% water.
    - None identified in WHO, FAO.

4.9 *p*-Toluenesulfonic acid (CASRN: 104-15-4)

- Manufacturing (HSDB, 2003g):
    - Sulfonation of toluene with sulfuric acid. Can separate toluene from petroleum fractions using this method.
    - At low temperatures, using chlorosulfonic acid with toluene.
- Potential impurities:
    - None identified in HSDB, WHO, FAO.

4.10 Ammonium chloride (CASRN: 12125-02-9)

- Manufacturing (HSDB, 2015d):
    - By neutralization with hydrochloric acid of ammoniacal liquids (derived from coal); recovered through crystallization of ammonium chloride.
    - By absorption of ammonia vapors into hydrochloric acid.
    - As a by-product in the production of sodium bicarbonate, which involves reacting ammonia, carbon dioxide, and sodium chloride in water. Recovery of ammonium chloride by crystallization, separation, washing, and drying, or through distillation

in the presence of lime. Or, by treating spent calcium chloride liquor with ammonia and carbon dioxide, and filtering out the calcium carbonate.

  - By reacting ammonia salt/ammonium sulfate with sodium chloride in a double-decomposition reaction, forming ammonium chloride and sodium salt. Recovery of ammonium chloride through cooling. This is a more economical route to ammonium chloride manufacture.
  - Direct neutralization.
- Potential impurities (HSDB, 2015d):
  - Sodium chloride was reported as the principal impurity.

4.11 Ammonium sulfate (CASRN: 7783-20-2)

- Manufacturing (HSDB, 2015e):
  - By washing coke-oven gas with water, releasing with lime suspension, and introducing into sulfuric acid.
  - Using a saturator and introducing ammonia and sulfuric acid, with crystallization of the salt being continuously discharged.
  - By reacting gypsum with ammonium carbonate solution to form calcium carbonate and ammonium sulfate that is then filtered, acidified using sulfuric acid, and crystalized; or by reacting gypsum with ammonia and carbon dioxide.
  - Formed as a co-product in producing caprolactam, acrylonitrile, methyl methacrylate, formic acid, and acrylamide.
  - Reaction of ammoniacal vapors (derived from coal) reacted with sulfuric acid; recovered through crystallization and drying.
  - By absorption of ammonia vapors into hydrochloric acid.
  - Direct neutralization with sulphuric acid.
- Potential impurities (HSDB, 2015e):
  - It was noted that commercial ammonium sulfate is typically of high purity with heavy metals ≤ 5mg/kg, iron ≤ 5mg/kg, and free acid ≤ 0.01%.

4.12 Ammonium nitrate (CASRN: 6484-52-2)

- Manufacturing (HSDB, 2014a):
  - By neutralizing of aqueous of gaseous ammonia and nitric acid.
  - Treating calcium nitrate tetrahydrate with ammonia and carbon dioxide produces calcium carbonate and ammonium nitrate.

- Potential impurities (HSDB, 2014a):
  - Potential for ammonium phosphate to be used as a stabilizer in solution.
  - None identified in HSDB, WHO, FAO.

4.13 Potassium hydroxide (CASRN: 1310-58-3)

- Manufacturing (HSDB, 2015f):
  - Industrial production involves electrolysis of potassium chloride.
  - By evaporation of potassium hydroxide solution (to create caustic potash).
- Potential impurities (HSDB, 2015f):
  - Sodium oxide, sodium carbonate, sodium chloride, sodium chlorate, ferrous oxide, mercury, sodium sulfate, silicon dioxide, aluminum oxide, calcium oxide, magnesium oxide, manganese, nickel, and copper.

4.14 Lithium hydroxide (CASRN: 7580-67-8)

- Manufacturing:
  - None identified in HSDB, WHO, FAO.
  - Basic process described as a causticization reaction between lime and lithium carbonate in aqueous solution, followed by concentration, crystallization, and purification (Jiang et al., 2014).
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.15 Barium hydroxide (CASRN: 17194-00-2)

- Manufacturing (HSDB, 2015g):
  - By dissolving barium oxide in water followed by crystallization.
  - By precipitation of aqueous barium sulfide using caustic soda.
  - By heating barium sulfide with added carbonic acid to form barium carbonate and superheated steam to form barium hydroxide.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.16 Calcium hydroxide (CASRN: 1305-62-0)

- Manufacturing (HSDB, 2014b):
  - By hydration of lime.
  - Commercially produced by the action of water on calcium oxide.
- Potential impurities (HSDB, 2014b):
  - Calcium carbonate, magnesium salts, iron.

4.17 Calcium oxide (CASRN: 1305-78-8)

- Manufacturing (HSDB, 2014c):
  - By calcination of limestone (calcium carbonate), coal, anthracite, or gypsum until carbon dioxide is driven off.
- Potential impurities (HSDB, 2014c):
  - Calcium carbonate, magnesium, iron, and aluminum oxides.

4.18 Hydrogen peroxide (CASRN: 7722-84-1)

- Manufacturing (HSDB, 2005c):
  - By reduction and oxidation of alkyl anthraquinones (such as 2-ethyl derivatives) in the presence of a palladium catalyst.
  - By treating barium peroxide with acids.
  - By autoxidation of isopropyl alcohol to acetone and hydrogen peroxide.
  - By the conversion of sulfuric acid or acidic ammonium bisulfate electrolytically to peroxydisulfate that can be hydrolyzed to hydrogen peroxide.
  - By electrolysis of potassium bisulfate followed by heating and hydrolysis to liberate water and hydrogen peroxide vapors.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.19 Sodium carbonate (CASRN: 497-19-8)

- Manufacturing (HSDB, 2012g):
  - Trona (sodium sesquicarbonate) is ground and calcined to crude soda ash (sodium carbonate), and can be further refined to monohydrate or anhydrous forms or purified.

    - Sesquicarbonate crystals are formed when crushed ore is dissolved, calcified, and cooled. These crystals can be further process.
    - Solvay process: purified sodium chloride brine is ammoniated and sodium bicarbonate crystals are precipitated by contact with carbon dioxide; the crystals are recovered and the filtrate is calcined to produce sodium carbonate, carbon dioxide, and water vapor. This process was noted as the most utilized process in the world, with the exception of the United States that produces from the minerals that contain sodium bicarbonate.
- Potential impurities (HSDB, 2012g):
    - Sodium chloride, sodium sulfate, calcium carbonate, magnesium carbonate, sodium bicarbonate, iron, chlorine.
    - Impurities from the Solvay process include sodium chloride (0.15%), sodium sulfate (0.02%), ferric oxide (0.002%), calcium oxide (0.01%), magnesium oxide (0.02%).
    - Impurities from the trona process include sodium chloride (0.035%), sodium sulfate (0.1%), ferric oxide (0.001%), calcium oxide (0.01%), magnesium oxide (0.003%).

4.20 Trimethylamine (CASRN: 75-50-3)

- Manufacturing (HSDB, 2009d):
    - By the action of formaldehyde (paraformaldehyde) and formic acid on ammonia (ammonium chloride).
    - Commercially by reacting methanol and ammonia using a catalyst (amorphous silica-alumina) at high temperatures. Yields include mono-, di-, and trimethylamines that can be separated by distillation and ratios of which are dictated by reaction conditions.
- Potential impurities (HSDB, 2009d):
    - Ammonia and formaldehyde.

4.21 2-dimethylamino-2-methyl-1-propanol

- Manufacturing:
    - None identified in HSDB, WHO, FAO.
- Potential impurities:
    - None identified in HSDB, WHO, FAO.

4.22 2-dimethylamino-2-hydroxymethyl-1,3-propanediol

- Manufacturing:
  - None identified in HSDB, WHO, FAO.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.23 Tri(*p*-chlorophenyl)phosphine

- Manufacturing:
  - None identified in HSDB, WHO, FAO.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.24 Tetraalkylammonium hydroxide

- Manufacturing:
  - None identified in HSDB, WHO, FAO.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.25 Triphenylphosphine (CASRN: 603-35-0)

- Manufacturing (HSDB, 2003h):
  - By reaction of phenylmagnesium bromine and phosphorus trichloride.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.26 Chromium (CASRN: 7440-47-3)

- Manufacturing (HSDB, 2005d):
  - From chrome ore (chromite) by silicothermic or aluminothermic processes.
  - Reaction of chromium oxide with aluminum or metallurgical coke.
  - Reaction of ferrochrome, sulfuric acid, and ammonium sulfate.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.27 Antimony/antimony trioxide (CASRN: 7440-36-0; 1309-64-4)

- Manufacturing (HSDB, 2005e, 2013b):
  - Depending on grade of antimony (ore), can be volatized as an oxide, smelted, liquated, or iron precipitated. Some ores can be leached with antimony recovery via electrowinning.
  - Antimony trioxide can be produced through roasting or hydrolysis of antimony trisulfide, burning antimony in oxygen, through alkaline hydrolysis of antimony halides.
  - Other methods include adding ammonium hydroxide to antimony chloride.
- Potential impurities (HSDB, 2005e, 2013b):
  - Lead, arsenic, sulfur, iron, copper.

4.28 Ortho ester

- Manufacturing (HSDB, 2003i):
  - None identified in HSDB, WHO, FAO.
  - By the reaction of alcohols with ketene dimethyl acetal to form mixed ortho esters (Cosgrove and McGeary, 2008).
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.29 Zinc acetate (CASRN: 557-34-6)

- Manufacturing (HSDB, 2006b):
  - From zinc nitrate and acetic anhydride to form the anhydrous salt, or from acetic acid and zinc oxide.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

4.30 Zinc borate (CASRN: 1332-07-6)

- Manufacturing (HSDB, 2013c):
  - Interaction of zinc oxide slurries with boric acid (borax) or the oxides at high temperature.

- Potential impurities (HSDB, 2013c):
    - Zinc oxide, borate, water, boric anhydride.

4.31 Formic acid (CASRN: 64-18-6)

- Manufacturing (HSDB, 2012h):
    - By carbonylation of methanol with carbon monoxide followed by hydrolysis of methyl formate to form formic acid and methanol. In an alternative method, the ethyl formate is formed and ammonolysis produces formamide, which is hydrolyzed using sulfuric acid to form formic acid and ammonium sulfate. Formic acid can be further purified by distillation.
    - As a by-product of oxidation of hydrocarbons (butane is common in the United States, while naphtha is common in Europe).
    - Reaction of sodium or calcium formate with mineral acids (sulfuric, nitric).
    - As a by-product in the manufacture of acetaldehyde or formaldehyde.
- Potential impurities (HSDB, 2012h):
    - Technical grade reported as < 0.8% acetic acid, < 20ppm chlorides, < 5ppm heavy metals, < 3ppm iron, and < 10ppm sulfates. Commercial grade impurities are similar with the exception of no acetic acid.

5. Scavengers

Scavengers are agents added to EWPs to reduce the formaldehyde emission when formaldehyde based adhesives are used by binding to the resin and reducing formaldehyde release (HBN, 2008). They can be added to the product with the added advantage of lowering formaldehyde emission during manufacture or after the pressing process. Urea is a common scavenger that is effective in lowering formaldehyde emissions (US EPA, 2002). Common scavengers include melamine and hexamine, and anhydrous ammonia or ammonium compounds can be added post-pressing as scavengers. Sodium sulfite is also used as a scavenger (Que et al., 2007). Recently, polyamine compounds are being investigated to modify the urea formaldehyde resin in an effort to lower formaldehyde emissions by improving the stability and durability the urea formaldehyde wood product (Conner, 1996; US EPA, 2002).

Common scavengers in PF resins for reduce formaldehyde emissions include urea (most common), ammonia, melamine, and dicyandiamide, but also some naturally occurring compounds such as tannins (Fink, 2013).

5.1 Melamine (CASRN: 108-78-1)

- Manufacturing (HSDB, 2008b):
  - Produced from urea in two ways: in the vapor phase, urea with an alumina catalyst at low pressure forms isocyanic acid and is converted to cyanamide then melamine. In the second method, in the liquid phase, urea under high pressure forms cyanuric acid that is reacted with ammonia to form melamine. Both methods are followed by recovery and purification.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

5.2 Hexamine (synonyms include hexamethylenetetramine, methenamine)

- See listing above in “Starting Materials and Resins/Adhesives in EWPs.”

5.3 Anhydrous ammonia (Ammonium compounds) (CASRN: 7664-41-7)

- Manufacturing (HSDB, 2011b):
  - Manufactured through reduction (Haber-Bosch) using atmospheric nitrogen and hydrogen (examples: methane, ethylene, naphtha, water gas, producer gas, natural gas) using an iron catalyst.

- Potential impurities:
  - None identified in HSDB, WHO, FAO.

5.4 Sodium sulphite (CASRN: 7757-83-7)

- Manufacturing (HSDB, 2002a):
  - By reacting sulfur dioxide with sodium carbonate (bicarbonate, soda ash) in water. The resulting solution of sodium bisulfite can be reacted with additional soda ash.
  - As a by-product of phenol production.
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

5.5 Dicyandiamide (cyanoguanidine) (CASRN: 461-58-5)

- Manufacturing (HSDB, 2003j):
  - By polymerization/dimerization of cyanamide in water in the presence of bases (such as ammonia and alkaline earth hydroxides). Dicyandiamide is then crystallized and separated via centrifugation.
- Potential impurities (HSDB, 2003j):
  - Commercial grade was reported to have water (0.01%), melamine (0.7%), thiourea (200 ppm), and heavy metals (10 ppm).

5.6 Tannins (tannic acid) (CASRN: 1401-55-4)

- Manufacturing (HSDB, 2002b):
  - Commercially prepared by solvent extraction from primarily Aleppo gall-nuts (Mediterranean region), tara pods (South America), gall-nuts (Asia), or from excrescences on twigs from Oak species.
- Potential impurities:
  - None identified in HSDB, WHO, FAO

6. Fillers and Modifiers

In general, fillers are added to reduce cost and shrinkage of the final product during curing. However, most of the fillers identified are cellulosic in nature, such as China clay (kaolin), walnut shell flour, wheat flour (Frihart, 2005), and organic fiber material (Fink, 2013). Other fillers, while non-cellulosic, by nature are highly heterogeneous and therefore difficult to characterize for the purposes here (such as glass fibers and ceramic material). For these reasons, only non-cellulosic and non-fibrous fillers are discussed in detail here.

6.1 Maleic anhydride-modified poly(propylene)

- Manufacturing:
  - Maleic anhydride (HSDB, 2015h) (CASRN: 108-31-6)
    - By sublimation of maleic acid under pressure.
    - Commercially by catalytic vapor-phase oxidation of hydrocarbons (benzene, C-4 hydrocarbons). Example includes reaction of butane with oxygen using vanadium phosphorus oxide catalyst or vanadium pentoxide catalyst.
    - As a by-product in manufacturing phthalic anhydride.

- Polypropylene (HSDB, 2003k) (CASRN: 9003-07-0)
    - By polymerization of propylene.
  - Propylene (HSDB, 2006c) (CASRN: 115-07-1)
    - From petroleum oils during gasoline refining, thermal/catalytic cracking of hydrocarbons, or catalytic dehydrogenation of propane.
- Potential impurities:
  - Polypropylene (HSDB, 2003k)
    - Propane, ethane, carbon dioxide.
    - Polymerization grade contains saturates (200 ppm), butylene (20 ppm), ethylene (20 ppm), methylacetylene (10 ppm), oxygen (10 ppm), butadiene (5 ppm), propadiene (5 ppm), carbon monoxide (5 ppm), carbon dioxide (5 ppm), water (5 ppm), hydrogen (5 ppm), and methanol (5 ppm).

6.2 Furan oligomers (CASRN: 110-00-9)

- Manufacturing (HSDB, 2011c):
  - By decarboxylation of 2-furancarboxylic acid.
  - Directly from furfural over soda-lime or dropping furfural on a mixture of sodium and potassium hydroxides.
  - Distillation of furoic acid from furfural.
  - Heating furfural with a palladium catalyst.
  - Oxidization of butanediol by dichromate in acidic solution with subsequent dehydration.
  - Commercially by decarbonylation of furfural and a noble metal catalyst (palladium).
- Potential impurities:
  - None identified in HSDB, WHO, FAO.

6.3 Barium carbonate (CASRN: 513-77-9)

- Manufacturing (HSDB, 2012i)
  - Occurs naturally in nature (witherite).
- Potential impurities (HSDB, 2012i)
  - Commercial grade was reported as having 0.006-0.12% total sulfur.

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