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# FORMALDEHYDE IN TEXTILES

While Levels in  
Clothing Generally  
Appear to Be Low,  
Allergic Contact  
Dermatitis Is a Health  
Issue for Some People



GAO

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Highlights of [GAO-10-875](#), a report to congressional committees

## Why GAO Did This Study

Formaldehyde—one of the most widely produced chemicals in the world—is used in many products, including disinfectants, pressed-wood, and clothing and other textiles. Exposure to this chemical, which has been linked to adverse health effects for more than 30 years, typically occurs through inhalation and dermal (skin) contact. Formaldehyde can be used to enhance wrinkle resistance in some clothing and textiles, especially those made of cotton. The Consumer Product Safety Commission reviewed formaldehyde in clothing in the 1980s and determined that the levels found did not pose a public health concern. At that time, most clothing sold in the United States was made here—but the market has changed such that most U.S. clothing is now made in other countries. This market change has raised anew questions about the levels of formaldehyde in clothing.

In response to a mandate in the Consumer Product Safety Improvement Act of 2008, this report provides information on what is known about (1) the health risks of exposure to formaldehyde, particularly from clothing, and (2) the levels of formaldehyde in clothing sold in the United States. GAO analyzed government reviews and the medical literature, as well as studies on levels of formaldehyde in clothing, and had a sample of 180 textiles—primarily clothing—tested for formaldehyde by an accredited laboratory. While illustrative of formaldehyde levels that may be found in clothing, the test results from GAO's sample cannot be projected to all clothing sold in the United States. This report contains no recommendations.

[View GAO-10-875 or key components.](#)  
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## FORMALDEHYDE IN TEXTILES

### While Levels in Clothing Generally Appear to Be Low, Allergic Contact Dermatitis Is a Health Issue for Some People

#### What GAO Found

The potential health risks associated with formaldehyde vary, depending largely on the means of exposure (e.g., inhalation or dermal contact), the concentration of the formaldehyde, and the duration of exposure. Inhaled formaldehyde may cause such effects as nausea, exacerbation of asthma, and cellular changes that may lead to the development of tumors. In fact, comprehensive reviews by the Department of Health and Human Services, the Environmental Protection Agency, and the World Health Organization have found that chronic inhalation exposure to formaldehyde may cause cancer. However, the health risk of greatest concern associated with formaldehyde in clothing—*allergic* contact dermatitis—stems from dermal exposure. A form of eczema, allergic contact dermatitis affects the immune system and produces reactions characterized by rashes, blisters, and flaky, dry skin that can itch or burn. Another potential health effect from dermal exposure to formaldehyde—*irritant* contact dermatitis—is also a form of eczema and has similar symptoms; however, this condition does not affect the immune system. Avoiding clothing containing formaldehyde is typically effective at preventing allergic and irritant contact dermatitis and relieving symptoms, but doing so can be difficult as clothing labels do not identify items treated with or containing formaldehyde. Washing clothing before it is worn often reduces formaldehyde levels but is not always successful. In some cases, avoiding or relieving allergic contact dermatitis requires more drastic measures, such as taking medications with potentially serious side effects. Finally, consumers may also experience dermal exposure to formaldehyde by using some cosmetics and skin care products, such as shampoos and sunscreens that contain formaldehyde.

Comprehensive data on formaldehyde levels in clothing sold in the United States are not publicly available. While formaldehyde levels in clothing are not regulated in the United States, the apparel industry reports that 13 countries have laws or regulations that limit formaldehyde levels in clothing. Most of the 180 items GAO had tested had formaldehyde levels that were below the most stringent of these industry-identified regulatory limits. GAO's test results are similar to those of recent studies of formaldehyde levels in clothing by the European Union, New Zealand, and Australia—that is, most items were found to meet the most stringent limits. Moreover, government studies we reviewed showed a decline in the formaldehyde levels in clothing since the 1980s, and the levels reported in these studies are generally consistent with the decline in levels reported in the medical literature. This decline is associated with the development and use of low-formaldehyde technologies (resins) in manufacturing clothing, which has been encouraged by such factors as the identification of formaldehyde as a probable human carcinogen via inhalation; the promulgation of federal regulations protecting workers from inhalation exposure to formaldehyde; and limits on formaldehyde levels that some U.S. retailers have established for clothing they sell.

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### Abbreviations

AATCC test	American Association of Textile Chemists and Colorists 112 test
CPSC	Consumer Product Safety Commission
DMDHEU	dimethylol dihydroxy ethylene urea
EPA	Environmental Protection Agency
HHS	Department of Health and Human Services
IARC	International Agency for Research on Cancer
ISO	International Organization for Standardization
Japanese test	Japanese Law 112 test
OSHA	Occupational Safety and Health Administration
USDA	Department of Agriculture
WHO	World Health Organization

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United States Government Accountability Office  
Washington, DC 20548

August 13, 2010

The Honorable Jay Rockefeller  
Chairman  
The Honorable Kay Bailey Hutchison  
Ranking Member  
Committee on Commerce, Science  
and Transportation  
United States Senate

The Honorable Henry A. Waxman  
Chairman  
The Honorable Joe Barton  
Ranking Member  
Committee on Energy and Commerce  
House of Representatives

Formaldehyde is a colorless, pungent-smelling chemical well known for its use as a preservative and disinfectant in laboratories and mortuaries but is also widely used in consumer products such as pressed-wood products, glues and adhesives, cosmetics, and clothing and other textiles. Some clothing—generally garments made of cotton and other natural fibers—is treated with resins<sup>1</sup> containing formaldehyde primarily to enhance wrinkle resistance. Formaldehyde is toxic and has been linked to serious adverse health effects, including cancer, and some federal agencies have regulations that limit human exposure, which occurs primarily through inhalation and dermal (skin) contact. Regarding inhalation exposure, the Environmental Protection Agency (EPA) regulates formaldehyde emissions to the ambient air from both industrial sources and vehicles under the Clean Air Act, and the Department of Labor’s Occupational Safety and Health Administration (OSHA) has standards in place that limit employee exposure to formaldehyde emissions in the workplace. Regarding dermal exposure to textiles, formaldehyde levels in clothing and other textiles that come into contact with the skin are not regulated. The Consumer Product Safety Commission (CPSC), which is charged with protecting the public from unreasonable risks of serious injury or death

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<sup>1</sup>In this report, the term “resin” encompasses both the older resin technologies that may release high levels of formaldehyde and the more recent cross-linking agents that may release little to no formaldehyde.

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from consumer products, including clothing, reviewed formaldehyde in clothing sold in the United States in the 1980s and found that formaldehyde levels were sufficiently low so as not to be a public health concern.<sup>2</sup>

At the time of the CPSC review, most textiles sold in the United States were also manufactured in the United States. However, the market for textiles has changed significantly in recent years, raising questions about what the current levels of formaldehyde in clothing are. Currently, most clothing sold in the United States is imported from other countries, particularly from China, Vietnam, and other countries in Asia, as well as from countries in Central America. In 2008, for example, nearly 35 percent of clothing imported into the United States was manufactured in China, up from about 6 percent in 2000. Moreover, in contrast with the United States, some countries, including China, have established legal limits on the levels of formaldehyde that clothing may contain. For example, China and Japan have similar restrictions on levels of formaldehyde that may be contained in infant and other clothing that comes into direct contact with the skin. Further, the level of formaldehyde in clothing depends largely on the variability in the way the manufacturing process is conducted. For example, formaldehyde levels can vary among the same type and make of clothing because of, among other things, differences in the type of resin used and the ways it is applied.

Section 234 of the Consumer Product Safety Improvement Act of 2008 requires GAO to conduct a study on the use of formaldehyde in the manufacturing of textiles and apparel.<sup>3</sup> This report provides information on what is known about (1) the health risks from exposure to formaldehyde, particularly from clothing, and (2) the levels of formaldehyde found in clothing sold in the United States. To determine what is known about the health risks from exposure to formaldehyde, we analyzed comprehensive government reviews of the health effects of exposure to formaldehyde and conducted a literature review of articles in

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<sup>2</sup>Formaldehyde is one of five substances CPSC has identified as a strong sensitizer—a substance that can cause hypersensitivity through recurring contact—under the Federal Hazardous Substances Act. Therefore, formaldehyde and any products containing 1 percent of formaldehyde or more (10,000 parts per million) are required to bear a warning label. The 1 percent refers to the concentration of formaldehyde in solutions and products, not in the air. This reporting level for formaldehyde far exceeds amounts likely to be found in clothing.

<sup>3</sup>Pub. L. No. 110-314, § 234 (2008).

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medical, textile, and environmental journals and books published from 1980 through April 2010 (see app. I for more information on this research).<sup>4</sup> To determine what is known about the levels of formaldehyde found in clothing sold in the United States, we analyzed information about (1) the use of formaldehyde-containing resins in clothing, (2) formaldehyde levels in clothing reported in government studies, and (3) relevant voluntary labeling programs, corporate limits, and regulatory limits for formaldehyde levels in clothing in the United States and other countries. Because of complexities in obtaining English translations of formaldehyde laws and regulations in other countries and confirming their application within the context of these countries' legal systems, we relied primarily on the American Apparel and Footwear Association for information on formaldehyde limits set in other countries, including the limits identified as the most stringent.<sup>5</sup> In addition, using an accredited commercial laboratory, we tested a nonprobability sample<sup>6</sup> of 180 textile items—primarily clothing (165) and some bed linens (15)—purchased from selected U.S. retailers in six metropolitan areas: Boston, Chicago, Dallas, Los Angeles, Seattle, and Washington, D.C. We selected low- or moderately priced items. We compared our test results with the most stringent regulatory limits for formaldehyde in clothing and other textiles established in other countries, as identified by the American Apparel and Footwear Association. The results from testing our nonprobability sample are illustrative of formaldehyde levels that may be found in some clothing and are not projectable to clothing sold in the United States in general. Throughout our review, we consulted with CPSC on our methodology and to obtain relevant background information stemming from the agency's mission to ensure consumer protection. Appendix II provides a more detailed description of our scope and methodology. We conducted this performance audit from September 2009 to August 2010 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained

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<sup>4</sup>Most of the relevant articles identified from our literature review were from medical journals or addressed medical issues, and in this report, we use the term "medical literature" to refer to the articles.

<sup>5</sup>American Apparel and Footwear Association, *Restricted Substance List*, Release 6 (2010).

<sup>6</sup>A nonprobability sample is a sample in which some items in the population have no chance, or an unknown chance, of being selected. Results from nonprobability samples cannot be used to make inferences about a population.

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## Background

Formaldehyde—one of the most widely produced and used chemicals in the world—is a water-soluble gas often used in a water-based solution (aqueous form) as a disinfectant or tissue preservative. In terms of toxicity, ingestion by an adult of as little as 1 ounce of a solution containing 37 percent formaldehyde has been reported to be lethal.<sup>7</sup> Formaldehyde is also used in other forms, including resins, that combine formaldehyde with other compounds. Aqueous formaldehyde and products containing formaldehyde tend to emit some formaldehyde into the air. Formaldehyde is also produced naturally in the environment and is found in low levels in people and most living things. In addition, formaldehyde is a by-product of combustion processes, such as wood burning and cigarette smoking. When formaldehyde is exposed to air, it begins to break down and dissipate.

The Department of Health and Human Services (HHS) reports that average levels of formaldehyde in outdoor air are often less than 0.01 parts of formaldehyde per million parts of air, and the average levels in indoor air in homes are often less than 0.04 parts per million.<sup>8</sup> Major sources of formaldehyde in outdoor air are man-made, such as power plants, manufacturing facilities, incinerators, and automobile exhaust. Formaldehyde levels in outdoor air are often found to be higher near some industry facilities and in heavily populated urban areas. In addition, people exposed to formaldehyde at work—such as medical personnel, embalmers, cabinetmakers, and textile plant employees—may be exposed to higher levels of formaldehyde. In general, the highest levels of airborne formaldehyde are detected indoors, where it can be released from various building materials, consumer products, and tobacco smoke.

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<sup>7</sup>*Medical Management Guidelines for Formaldehyde* (Atlanta: U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Feb. 7, 2008), <http://www.atsdr.cdc.gov/mhmi/mmg111.html> (accessed Aug. 5, 2009).

<sup>8</sup>U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program, *Report on Carcinogens, Background Document for Formaldehyde* (Research Triangle Park, North Carolina, 2010).



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Because formaldehyde is highly toxic, it is regulated by various federal and state agencies to protect human health and the environment.<sup>9</sup> For example, EPA lists formaldehyde as a hazardous air pollutant under the Clean Air Act and as a hazardous waste under the Resource Conservation and Recovery Act. Other agencies, such as OSHA and the Department of Housing and Urban Development, regulate airborne formaldehyde concentrations in the workplace and in manufactured homes, and the Food and Drug Administration limits the food-related use of formaldehyde to packaging components. In addition, California regulates formaldehyde emissions from composite wood products to protect human health from airborne exposure to formaldehyde.<sup>10</sup> According to an official from the California Environmental Protection Agency, the agency found that emissions from textiles commonly found in the home, such as draperies, dissipate quickly, whereas emissions from composite wood products are higher and remain relatively constant over time.

Formaldehyde-containing resins have been used in clothing and other textiles since the mid-1920s primarily to impart durable press characteristics to fabrics made from natural fibers, especially plant-based fibers such as cotton.<sup>11</sup> These resins may also provide other easy-care benefits, such as shrink resistance and color fastness.<sup>12</sup> The use of these resins in cotton clothing and other textiles became more prevalent in the 1950s and 1960s to compete with the increased use of synthetic fabrics, which often provided durable press characteristics. Under certain

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<sup>9</sup>In this report, we use the terms “toxic” and “highly toxic” as they are used by EPA’s Toxics Release Inventory Program and HHS’s Agency for Toxic Substances and Disease Registry, respectively.

<sup>10</sup>EPA initiated an advanced notice of a proposed rulemaking in December 2008 indicating that the agency intends to investigate whether and what type of federal regulation or other action might be appropriate to protect against the risks posed by formaldehyde emitted from composite and pressed-wood products. Furthermore, on July 7, 2010, the Formaldehyde Standards for Composite Wood Act was signed into federal law. The new law amends the Toxic Substances Control Act to establish standards for emissions of formaldehyde from hardwood plywood, medium-density fiberboard, and particleboard. EPA must promulgate regulations to implement the standards by January 2013.

<sup>11</sup>In this report, “durable press” is used to encompass terms such as wrinkle resistant, wrinkle free, noniron, no iron, and easy care. The durable press fabric characteristic applies to items treated to retain their shape and pressed appearance after many uses, washing, and tumble drying. All-synthetic fabrics, such as 100 percent polyester, are inherently durable press and do not need to be treated.

<sup>12</sup>Formaldehyde may also be used in binders for prints, in various coatings such as fire retardant chemicals, and for other purposes.

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conditions, formaldehyde-containing resins may chemically degrade and release (off gas) free formaldehyde, including when exposed to high temperature and humidity.

The level of formaldehyde in clothing identified by testing and the level of formaldehyde that may be emitted by that clothing into the air will vary under different conditions—especially heat and humidity—and the test method used. Formaldehyde release mechanisms are numerous and complex, and emissions of formaldehyde from fabrics are much lower than the levels found in the fabrics by testing. Several analytical tests may be used to identify the levels of formaldehyde in clothing and other textiles. Test results are generally expressed as micrograms of formaldehyde per gram of fabric—typically either as microgram per gram or as parts per million.

The two analytical tests now commonly used in the textile industry to identify levels of formaldehyde in clothing and textiles are the Japanese Industrial Standard L 1041 test, also known as the Japanese Law 112 test (Japanese test), and the American Association of Textile Chemists and Colorists 112 test (AATCC test).<sup>13</sup> The Japanese test was developed to measure the amount of formaldehyde that may be released by clothing and other textiles that may come into contact with the skin, and the AATCC test was developed to measure the amount of formaldehyde that may be released from clothing and other textiles during extended storage or hot and humid conditions.<sup>14</sup> Because of different testing specifications, as well as variables related to the particular formaldehyde resins used, formaldehyde levels measured by the two tests are not comparable, and the results from the Japanese test cannot be used to predict what the results would be under the AATCC test and vice versa.<sup>15</sup> Regarding the tests performed on our sample of clothing and bed linens, the laboratory

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<sup>13</sup>The International Organization for Standardization (ISO) has equivalent tests: ISO 14184-1 Textiles—Determination of Formaldehyde—Part 1: Free and Hydrolyzed Formaldehyde (Water Extraction Method), which is equivalent to the Japanese test; and ISO 14184-2 Textiles—Determination of Formaldehyde—Part 2: Released Formaldehyde (Vapour Absorption Method), which is equivalent to the AATCC test.

<sup>14</sup>Formaldehyde Release from Fabric, Determination of: Sealed Jar Method, AATCC Test Method 112-2008.

<sup>15</sup>In general, the AATCC test results in higher formaldehyde levels than the Japanese test—except at low formaldehyde levels, such as 30 parts per million or less—although the difference between the formaldehyde levels measured by the two tests depends, in part, on the type of fabric and resin used.

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tested all of them using the Japanese test and a subset of them using the AATCC test. According to the American Apparel and Footwear Association, the Japanese test is used to determine whether formaldehyde levels in clothing are consistent with levels cited in international regulations. In addition, most of the U.S. retailers that provided us with information on internal corporate limits use the Japanese test or its equivalent. Further, the Japanese test was more frequently used in the studies we identified that conducted formaldehyde testing in clothing and other textiles.

The American Apparel and Footwear Association has identified the most stringent regulatory limits for formaldehyde in clothing and home textiles in other countries for its members that may wish to sell their products internationally.<sup>16</sup> The most stringent formaldehyde limits identified use the Japanese (or equivalent) test as a basis for measurement and are

- not detectable (defined as less than 20 parts per million) for products intended for children younger than 3 years of age,
- less than 75 parts per million for products that come into direct contact with the skin for children who are 3 years of age and older and for adults, and
- less than 300 parts per million for products that do not come into direct contact with the skin—e.g., outerwear—for children who are 3 years of age and older and for adults.

Some countries do not limit formaldehyde levels in clothing but require disclosure in labels if formaldehyde levels exceed specified amounts.<sup>17</sup> Further, some countries and private entities offer “eco labels” for clothing and other textiles, if their formaldehyde levels—as well as levels of other chemicals—are within specified ranges. Appendix III provides more

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<sup>16</sup>In the *Restricted Substance List*, the American Apparel and Footwear Association, a national trade association, provides information about the regulatory limits for various substances in countries in which its members may operate. The *Restricted Substance List* identifies Austria, China, Finland, France, Germany, Japan, Lithuania, the Netherlands, New Zealand, Norway, Poland, Russia, and South Korea as countries that regulate formaldehyde in apparel, home textiles, and footwear products.

<sup>17</sup>Information on countries that require disclosure was compiled by the Hong Kong Standards and Testing Centre, a laboratory that provides formaldehyde testing services according to international standards and regulations.

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information on voluntary labeling programs. Finally, while the United States does not legally limit formaldehyde levels in clothing, some U.S. retailers have set internal corporate limits on formaldehyde in clothing.

In the mid-1980s, most of the clothing sold in the United States was also manufactured in the United States and its territories. However, imports of clothing and other textiles from other countries now make up a majority of U.S. sales. Although textile industries are dispersed throughout the world, China is now the world's largest producer and exporter of clothing and textiles. Much of China's growth occurred during the 10-year phaseout of textile quotas under the 1995 World Trade Organization Agreement on Textiles and Clothing, which was completed on January 1, 2005.<sup>18</sup> As of 2008, China accounted for the largest share of total U.S. clothing imports—34.3 percent, an increase from 6.5 percent in 1999. Vietnam and Bangladesh rank second and third at 6.7 percent and 6.3 percent, respectively. Appendix IV provides additional information on the 10 countries that exported the most clothing to the United States in 2008.

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## Formaldehyde Poses Different Health Risks Depending on the Type and Extent of Exposure

Key government reviews on the health effects of exposure to formaldehyde, including those conducted by EPA, HHS, and the World Health Organization (WHO), have concluded that chronic inhalation exposure to formaldehyde may cause cancer. Regarding exposure to formaldehyde in clothing, the health risk of greatest concern identified in key government reviews and in the medical literature is allergic contact dermatitis.

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### Key Government Reviews Have Concluded That Chronic Inhalation Exposure to Formaldehyde May Cause Cancer

The potential health risks from exposure to formaldehyde vary depending on the means of exposure (inhalation, dermal, ingestion, or eye contact), the concentration of formaldehyde, and the duration of exposure, among other factors. Inhaled formaldehyde may cause such effects as (1) discomfort or nausea stemming from the chemical's pungent odor; (2) irritation of the eyes, nose, and throat; (3) exacerbation of asthma; and (4) changes at the cellular level that may lead to the development of tumors. In fact, several comprehensive government reviews of the health risks of

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<sup>18</sup>Various international agreements (or quotas) capping textile and apparel imports into the United States were put in place, in part, to attempt to curb the trend toward offshore production, which many U.S. manufacturers were using in order to control costs. The World Trade Organization agreement was put in place to lift these quotas.

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exposure to formaldehyde have found that chronic inhalation exposure to formaldehyde may cause cancer.

Concerns about the health risks of exposure to formaldehyde were heightened in 1979 when the Chemical Industry Institute of Toxicology<sup>19</sup> reported that formaldehyde caused nasal cancer in laboratory rats. Since then, government and industry entities have extensively studied the potential human health risks of inhalation exposure to this commonly used chemical. Concerns about formaldehyde are based on its cancer-causing potential in humans as well as its irritant properties. Research efforts on inhalation exposure have focused on indoor air levels of formaldehyde, where concentrations are known to be higher, and in particular on exposure in occupational settings. These research efforts include long-term epidemiological studies conducted on workplace exposure. For example, the largest study to date was conducted by the National Cancer Institute, which has tracked close to 26,000 workers employed in 10 different formaldehyde-producing or -using plants since the 1960s; the latest update to this study was published in 2009. Similarly, HHS's National Institute for Occupational Safety and Health has studied about 11,000 textile workers exposed to formaldehyde in the workplace. These studies have suggested that formaldehyde exposure is associated with nasopharyngeal cancer and possibly with cancers of the hematopoietic and lymphatic systems, particularly myeloid leukemia.<sup>20</sup>

Based on these and other studies, at least three government entities—EPA, HHS, and WHO—have conducted comprehensive reviews of the health effects of formaldehyde. For example, in 2005, the HHS's National Toxicology Program<sup>21</sup> concluded that chronically inhaled formaldehyde is reasonably anticipated to be a human carcinogen; the agency is currently considering upgrading this designation to “known to be a human carcinogen.”<sup>22</sup> Similarly, beginning in 1987, EPA classified inhaled

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<sup>19</sup>This organization is now called the Hamner Institutes for Health Sciences.

<sup>20</sup>The hematopoietic and lymphatic systems are, among other things, involved in the production of blood and in the immune system function.

<sup>21</sup>U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program, *Report on Carcinogens, 11th Edition* (Research Triangle Park, North Carolina, 2005).

<sup>22</sup>74 *Fed. Reg.* 67883 (Dec. 21, 2009).

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formaldehyde as a probable human carcinogen<sup>23</sup> and in June 2010 released a revised draft assessment classifying it as a known human carcinogen.<sup>24</sup> The draft EPA assessment is undergoing a review by the National Academies,<sup>25</sup> one of several key steps the agency must take prior to finalizing the assessment. In addition, in 2006, WHO's International Agency for Research on Cancer (IARC) reclassified formaldehyde from "probably carcinogenic to humans," a classification based on its 1995 assessment, to "carcinogenic to humans."<sup>26</sup> For the 2006 classification, IARC found sufficient evidence that formaldehyde causes nasopharyngeal cancer in humans, limited evidence for cancer of the nasal cavity and paranasal sinuses, and strong but not sufficient evidence for leukemia. In 2009, IARC's Cancer Monograph Working Group determined on the basis of additional epidemiological studies that there was sufficient evidence to associate formaldehyde exposure with leukemia.<sup>27</sup> This finding will be published in an upcoming IARC monograph.

Most studies supporting a link between exposure to formaldehyde and an increased risk of cancer studied workers exposed to formaldehyde occupationally, rather than people exposed to formaldehyde in consumer products, although people may be exposed to formaldehyde in consumer goods, such as pressed-wood products and textiles, that may "off gas" formaldehyde indoors. While EPA is required to develop regulations establishing standards for emissions of formaldehyde from hardwood plywood, medium-density fiberboard, and particleboard under July 2010 amendments to the Toxic Substances Control Act, the comprehensive

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<sup>23</sup>EPA, Office of Pesticides and Toxic Substances, *Assessment of Health Risks to Garment Workers and Certain Home Residents From Exposure to Formaldehyde* (Washington, D.C., 1987); and *Integrated Risk Information System, Formaldehyde (CASRN 50-00-0)* (Washington, D.C.: EPA), <http://www.epa.gov/ncea/iris/subst/0419.htm> (downloaded Dec. 9, 2009).

<sup>24</sup>EPA, *IRIS Toxicological Review of Formaldehyde—Inhalation Assessment (External Review Draft)* (Washington, D.C., June 2010).

<sup>25</sup>The National Academies comprises four organizations: the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine, and the National Research Council.

<sup>26</sup>World Health Organization, International Agency for Research on Cancer, *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 88, Formaldehyde, 2-Butoxyethanol and 1-tert-Butoxypropan-2-ol* (Lyon, France, 2006).

<sup>27</sup>Robert Baan et al. "A Review of Human Carcinogens—Part F: Chemical Agents and Related Occupations," *The Lancet Oncology*, vol. 10, issue 12 (2009).

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government studies we reviewed do not indicate that formaldehyde levels in clothing present an inhalation health risk to consumers.

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### The Health Risk of Greatest Concern Associated with Dermal Exposure to Formaldehyde in Clothing Is Allergic Contact Dermatitis

Regarding exposure to formaldehyde in clothing, CPSC officials said that, on the basis of research the agency conducted in the 1980s,<sup>28</sup> (1) there were no data indicating that formaldehyde in clothing and other textiles could penetrate the skin and cause cancer and (2) levels of formaldehyde found in clothing did not pose an acute or chronic health hazard to consumers. As a result, CPSC concluded that a regulatory standard was not needed for levels of formaldehyde in clothing and other textiles or for emissions of formaldehyde from these items. Further, the United States has no other legal limit on the level of formaldehyde that may be found in clothing and other textiles.

Based on our review of the medical literature, the health risk of greatest concern associated with formaldehyde in clothing—*allergic* contact dermatitis—stems from dermal exposure.<sup>29</sup> A form of eczema, allergic contact dermatitis produces reactions characterized by rashes, discoloration (particularly redness), swelling, blisters, scaling, and flaky dry skin that can itch or burn. These reactions are often very painful and can last indefinitely if left untreated. The reactions can be exacerbated by heat, humidity, friction, and perspiration and are usually worse where clothing fits closely. In some cases, repeated scratching of the affected area can lead to patches of tough, leathery skin. Allergic contact dermatitis also affects the immune system. Another potential health effect from dermal exposure to formaldehyde in clothing—*irritant* contact dermatitis—is also a form of eczema and has similar symptoms; however, this condition does not affect the immune system.

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<sup>28</sup>Department of Energy, Oak Ridge National Laboratory, *Formaldehyde Release From Durable-Press Apparel Textiles, Final Project Report to the U.S. Consumer Product Safety Commission* (Oak Ridge, Tennessee, 1985).

<sup>29</sup>Dermal exposure occurs when skin comes in contact with free formaldehyde in textiles. Formaldehyde in clothing may be either bound or free, and it is the skin contact with free formaldehyde that is associated with the negative health effects. Free formaldehyde occurs when there is an incomplete binding process between the formaldehyde-based resin and the clothing fibers or when the resin decomposes. Unless otherwise noted in this report, references to the health effects associated with formaldehyde in clothing or textiles refer to free formaldehyde.

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Formaldehyde is classified as a “strong sensitizer”—a substance that can cause hypersensitivity through recurring or prolonged contact. According to the medical literature, people with allergic contact dermatitis caused by contact with formaldehyde in clothing have generally become hypersensitive to the chemical through previous exposure. The test used to determine whether an individual has allergic contact dermatitis does not identify the level of formaldehyde in clothing that would trigger this condition. Although the estimates vary widely, the medical literature suggests that the amount of formaldehyde in clothing needed to trigger an allergic contact dermatitis reaction in sensitized individuals can be as little as 30 parts per million. The amount of formaldehyde in clothing that would cause a reaction is an area needing further research, according to a 2009 medical journal article by experts on contact dermatitis.<sup>30</sup>

Some of the medical literature has estimated the number of people with allergic and irritant contact dermatitis caused by dermal exposure to formaldehyde. This literature focuses on subpopulations of patients—those with eczema—and therefore the results cannot be generalized to the rest of the population. For example, one study reported that 9.2 percent of patients suspected of having contact dermatitis tested positive to a diagnostic skin test—called a patch test—that applied a 1 percent formaldehyde solution to the skin to test for any dermal reaction. Other studies estimate that between 1.2 percent and 2.3 percent of people with eczema have dermatitis related to formaldehyde in their clothing. Some of the medical literature suggests that allergic contact dermatitis may be underreported because medical practitioners might not distinguish it from cases of dermatitis with other causes, because of differences in how patch testing is conducted to determine dermatitis, and because some individuals may attempt to treat the condition themselves without seeking medical attention or are reluctant to make the number of visits to the doctor necessary to make a reliable diagnosis.

Avoiding clothing containing formaldehyde is typically effective at preventing allergic or irritant contact dermatitis and at relieving symptoms, but doing so may be difficult because labels for clothing sold in the United States generally do not provide information on formaldehyde content or on whether the clothing item was treated with formaldehyde.

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<sup>30</sup>Anton C. De Groot and Howard I. Maibach, “Does Allergic Contact Dermatitis from Formaldehyde in Clothes Treated with Durable-Press Chemical Finishes Exist in the USA?” *Contact Dermatitis*, vol. 62, no. 3 (2009).



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One dermatologist with whom we spoke published an article that identifies some clothing companies that report using little or no formaldehyde in their clothing.<sup>31</sup> Also, a number of medical articles recommend that patients allergic to formaldehyde wash articles of clothing before wearing them to reduce the level of formaldehyde to which they may be exposed. The success of this technique in limiting exposure to formaldehyde in clothing may vary, however. For example, studies conducted by the Department of Agriculture (USDA) Agricultural Research Service report that the effect of laundering on formaldehyde levels depends on the type of resin that is applied to the clothing as well as on other factors, such as the alkalinity and hardness of the water and whether bleach is used. Other studies report that while formaldehyde levels may decline initially after washing, the levels may start increasing again after multiple washes. One publication explains that while washing clothing does remove some formaldehyde, levels may increase again over time as the resin is broken down by, among other things, washing and ironing.<sup>32</sup> Additionally, certain clothing items, such as hats, are generally not washed before being worn.

In some cases, more drastic measures may be necessary to avoid allergic contact dermatitis. Some researchers suggest that some patients may need to change occupations or job responsibilities to avoid contact with formaldehyde-containing products. If wearing clothing with formaldehyde cannot be avoided, some researchers suggest wearing synthetic or silk undergarments to act as a barrier between the skin and the clothing. When avoidance is not feasible or does not sufficiently relieve symptoms for those with allergic contact dermatitis, other treatment options include strong oral or topical medications, including immunosuppressive agents that may have serious side effects. Topical medications should be used with caution because some of these medications may actually contain formaldehyde, which could potentially perpetuate or worsen the reaction. Finally, we note that consumers may also experience dermal exposure to formaldehyde by using some cosmetics and skin care products, such as some shampoos and sunscreens that contain formaldehyde.

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<sup>31</sup>Ryan M. Carlson, Mary C. Smith, and Susan T. Nedorost, "Diagnosis and Treatment of Dermatitis Due to Formaldehyde Resins in Clothing," *Dermatitis*, vol. 15, no. 4 (2004).

<sup>32</sup>Etain Cronin, *Contact Dermatitis* (New York City: Churchill Livingstone, 1980).

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## While Comprehensive Data Are Not Available, Recent Studies Suggest That Formaldehyde Levels in Clothing Are Generally Low and Have Declined over Time

In the absence of U.S. regulation of formaldehyde levels in clothing, and associated compliance testing, comprehensive data on the levels of formaldehyde in clothing sold in the United States are not publicly available.<sup>33</sup> Tests conducted by an accredited commercial laboratory of 180 items we purchased in stores across the country indicate that formaldehyde levels in most of the items are low or not detectable. Moreover, these test results indicate that the levels of formaldehyde found in most of these items would meet the most stringent regulatory standards set by other countries as identified by the American Apparel and Footwear Association: not detectable in clothing and other items for infants and toddlers younger than 3 years of age and less than 75 parts per million for clothing and other items that come into direct contact with the skin for adults and for children 3 years of age and older.<sup>34</sup> However, 10 of the items exceeded these limits, with formaldehyde levels ranging from 75.4 to 206.1 parts per million. As table 1 shows, nine of these items exceeded the limits for adults and for children 3 years of age and older, and one item—a sheet for a child’s crib—exceeded the limit for infants and toddlers younger than 3 years of age as well as that for adults and for children 3 years of age and older. More than half of the items we had tested that exceeded these limits were labeled as having fabric performance characteristics related to durable press, which may indicate the use of resins that contain formaldehyde and can alert consumers who wish to avoid formaldehyde in clothing.<sup>35</sup> Both domestic and imported clothing and bed linens had formaldehyde levels that exceeded the limits identified by the apparel industry. Appendix V provides more complete information on the items we had tested.

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<sup>33</sup>While a national regulation of formaldehyde in clothing would not necessarily produce comprehensive data on levels in clothing, such data are unlikely to be compiled without a requirement to do so.

<sup>34</sup>We considered all items in our sample to come into direct contact with the skin, although some textile industry standards consider bed linens for older children and adults to be subject to the formaldehyde limits applicable to items that do not come into direct contact with the skin.

<sup>35</sup>We are using “durable press” to include terms such as wrinkle resistant, wrinkle free, noniron, no iron, and easy care.

**Table 1: Ten Items Sold in the United States That Exceeded the Most Stringent Regulatory Standards for Formaldehyde Identified by the American Apparel and Footwear Association**

Item type	Fiber content identified on label	Fabric performance characteristic identified on label or packaging	Country identified on label	Target customer	Formaldehyde level in parts per million <sup>a</sup>
Dress shirt	100% cotton	Wrinkle free	China	Men	206.1
Hat	100% cotton exclusive of decoration	None identified	China	Boys 3 years of age and older	192.6
Bed linens (pillow cases)	60% cotton, 40% polyester	Soft finish, easy care	Bahrain	Adults or children 3 years of age and older	189.6
Khakis	100% cotton	No iron, permanent crease	India	Men	169.6
Dress shirt	60% cotton, 40% polyester	None identified	China	Boys 3 years of age and older	95.1
Bed linens (pillow cases)	100% cotton	Wrinkle free, easy care, no ironing needed, eco-friendly	USA; fabric imported from Pakistan	Adults or children 3 years of age and older	93.8
Dress shirt	100% cotton	Noniron	Indonesia	Men	92.6
Bed linens (pillow cases)	100% cotton	Wrinkle free performance	Pakistan	Adults or children 3 years of age and older	89.3
Bed linens (crib sheet)	100% cotton	Preshrunk	Thailand	Infants/toddlers <sup>b</sup>	85.4
U.S. military combat uniform pants	50% cotton, 50% nylon	None identified	USA	Women	75.4

Source: GAO analysis of information provided on items' labels or packaging and test data from an accredited commercial laboratory.

<sup>a</sup>These formaldehyde levels were determined using the Japanese test.

<sup>b</sup>Infants/toddlers refers to children younger than 3 years of age.

In 2007, the European Union and New Zealand government conducted studies of formaldehyde levels in clothing using methodologies similar to ours and also found that most clothing items tested had levels of formaldehyde that were low or not detectable.<sup>36,37</sup> Specifically, the European Union found that

<sup>36</sup>European Commission Directorate General Joint Research Centre, Physical and Chemical Exposure Unit, Chemical Release from Textiles, *European Survey on the Release of Formaldehyde from Textiles* (Ispra, Italy, 2007).

<sup>37</sup>*Evaluation of Alleged Unacceptable Formaldehyde Levels in Clothing* (Wellington, New Zealand: New Zealand Ministry of Consumer Affairs, Oct. 17, 2007), <http://www.consumeraffairs.govt.nz/legislation-policy/policy-reports-and-papers/reports> (accessed Oct. 22, 2009). The New Zealand government also received information from four retailers that tested 203 items. One item, a preproduction fabric, was found to be above the acceptable level, which was defined by New Zealand to be 100 parts per million.

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212 of 221 items tested either had formaldehyde levels below 75 parts per million for adults and older children or levels that were not detectable for infants. Of the 9 items that exceeded these levels, 5 were either dress shirts labeled as “easy care” or T-shirts. Moreover, our analysis of the New Zealand government study showed that 96 of 99 items tested had formaldehyde levels below 75 parts per million; the 3 exceptions were men’s dress or casual pants. A more limited study of 10 clothing items, conducted in 2007 by the Australian government, reported that all 10 items had formaldehyde levels that were not detectable.<sup>38</sup> These studies, as well as our own test results, provide important data on levels of formaldehyde that may be found in clothing, but these data cannot be projected to clothing in general.

Regarding the decline in levels of formaldehyde in clothing over time, government studies we reviewed have reported decreasing levels since the 1960s. While researchers have used various test methods in the past, which has limited comparisons of formaldehyde levels in clothing over time, the available data on formaldehyde levels in items tested show a decline over time. For example, the USDA Agricultural Research Service reported that in the early 1960s formaldehyde levels in clothing were found to be generally above 3,000 parts per million using the AATCC test.<sup>39</sup> However, tests conducted in the early 1980s by the textile industry showed that formaldehyde levels in clothing were generally below 500 parts per million using the AATCC test. Further, tests conducted by government entities in Australia, Denmark, the European Union, Finland, New Zealand, and the United States from 1984 to 2010—more often using the Japanese test—show that the percentage of items with formaldehyde levels greater than 100 parts per million has generally declined (see table 2). For example, although in 1985 67 percent of items tested by CPSC<sup>40</sup> had levels of formaldehyde above 100 parts per million using the Japanese test, studies since 2003 have shown that 2 percent or less of the items tested using the Japanese test had formaldehyde levels above 100 parts per million. Similarly, the maximum formaldehyde level identified in any item in each study has generally declined.

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<sup>38</sup>*No Formaldehyde Found in Clothing*, Australian Competition and Consumer Commission, (October 17, 2007), <http://www.accc.gov.au/content/index.phtml?itemId=801314> (accessed Aug. 5, 2009).

<sup>39</sup>B.A. Kottes Andrews, “Wrinkle Resistant Cotton and Formaldehyde Release,” *Colourage Annual* (1995).

<sup>40</sup>*Formaldehyde Release from Durable-Press Apparel Textiles, Final Project Report to the U.S. Consumer Product Safety Commission* (1985).

**Table 2: Levels of Formaldehyde in Clothing and Other Textiles Reported in Government Studies, 1984-2010**

Source	Year tested	Type of items tested	Number of items tested	Percentage of items tested with greater than 100 parts per million of formaldehyde		Maximum level of formaldehyde identified in any item (parts per million)	
				Japanese test <sup>a</sup>	AATCC test <sup>a</sup>	Japanese test <sup>a</sup>	AATCC test <sup>a</sup>
CPSC <sup>b</sup>	1984-1985	Clothing and bed linens	12	67	92	736.6	2,897
Tampere Regional Institute of Occupational Health, Finland	1986-1987	Clothing, home textiles, and cotton fabrics	20	50	90	855	1,680
Tampere Regional Institute of Occupational Health, Finland	1987-1994	Fabrics, textiles	144	11	<sup>c</sup>	2,000	<sup>c</sup>
Finnish Customs Laboratory	1988	Imported textiles	2,719	12	<sup>c</sup>	2,200	<sup>c</sup>
Finnish Customs Laboratory	1989	Imported textiles	1,922	7	<sup>c</sup>	1,050	<sup>c</sup>
Finnish Customs Laboratory	1990	Imported textiles	1,547	11	<sup>c</sup>	1,500	<sup>c</sup>
Finnish Customs Laboratory	1991	Imported textiles	2,173	9	<sup>c</sup>	805	<sup>c</sup>
Finnish Customs Laboratory	1992	Imported textiles	1,407	10	<sup>c</sup>	1,319	<sup>c</sup>
Finnish Customs Laboratory	1993	Imported textiles	1,680	5	<sup>c</sup>	643	<sup>c</sup>
Danish Ministry of Environment and Energy	2003 <sup>d</sup>	Clothing and home textiles	10	0	<sup>c</sup>	82	<sup>c</sup>
New Zealand Ministry of Consumer Affairs	2007	Clothing, home textiles, and footwear	99	2	<sup>c</sup>	250	<sup>c</sup>
Australian Competition and Consumer Commission	2007	Clothing	10	0	0	Not detectable	Not detectable
European Union	2007	Clothing and home textiles	221 items (Japanese test); 127 items (AATCC test)	1	9	162.5	397.3
GAO	2010	Clothing and bed linens	180 items (Japanese test); 21 items (AATCC test)	2	10	206.1	550.7

Sources: Government-sponsored or -supported studies and GAO analysis of test data from an accredited commercial laboratory.

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<sup>a</sup>Or an equivalent test method.

<sup>b</sup>CPSC-sponsored study tested a subset (12 items) of its full sample using the Japanese and AATCC tests. The entire sample of 180 clothing and bed linens was tested using a proprietary method developed by the Department of Energy's Oak Ridge National Laboratory, which conducted the testing. Based on this test method, 14 percent of the items had more than 100 parts per million of formaldehyde, and the maximum formaldehyde level identified in an item was 940.2 parts per million.

<sup>c</sup>Only the Japanese or Japanese-equivalent tests were used in this study.

<sup>d</sup>This is the year the report was published.

The levels of formaldehyde found in these studies are generally consistent with information reported since the 1980s in the medical literature and trade publications that documents a decline in formaldehyde levels in clothing since that time. This decline is associated with the development and use of low-formaldehyde resins in manufacturing clothing, which has been encouraged by such key factors as the following: (1) the identification of formaldehyde as a probable human carcinogen via inhalation and the promulgation of regulations by OSHA to protect workers, such as those in textile factories, from exposure to formaldehyde; (2) legal limits on the levels of formaldehyde in clothing and other textiles adopted in other countries; (3) limits on formaldehyde levels that some U.S. retailers have established for clothing they sell; and (4) the textile industry's development of improved resins that provide durable press characteristics but release less formaldehyde.

More specifically, as discussed earlier, formaldehyde was classified as a probable human carcinogen in the 1980s based on animal and human studies showing that airborne formaldehyde exposure is associated with certain types of cancer. In 1987 and 1992, OSHA decreased the permissible airborne exposure level of formaldehyde in the workplace. The current OSHA regulation, among other things, limits airborne exposure to 0.75 parts of formaldehyde per million parts of air.<sup>41</sup> While this regulation primarily addresses the airborne concentration of formaldehyde to which workers—such as those in textile factories—may be exposed, several

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<sup>41</sup>The current OSHA regulation, among other things, limits airborne exposure to 0.75 parts of formaldehyde per million parts of air over an 8-hour workday; sets a short-term exposure limit of 2 parts of formaldehyde per million parts of air; and includes a hazard communication requirement pertaining to formaldehyde gas, all mixtures or solutions composed of greater than 0.1 percent formaldehyde (equivalent to 1,000 parts per million), and materials capable of releasing formaldehyde into the air, under reasonably foreseeable conditions of use, at concentrations reaching or exceeding 0.1 parts per million. The National Institute for Occupational Safety and Health has established nonenforceable guidelines for formaldehyde exposure and recommends an occupational exposure limit over an 8-hour workday of 0.016 parts per million and a 15-minute ceiling of 0.1 parts per million in the air.

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government studies and the medical literature have noted that OSHA regulations have encouraged lower formaldehyde levels in clothing and other textiles. Information provided in a Finnish Regional Institute of Occupational Health study illustrates the relationship between the levels of formaldehyde being applied to textiles in the workplace and airborne formaldehyde emissions in the factory. The Finnish study reported that formaldehyde levels in textiles should be under 200 parts per million<sup>42</sup> to ensure airborne formaldehyde emission levels in factories remain below 1 part per million under adverse conditions such as low ventilation and high humidity.<sup>43</sup>

Another factor that may have encouraged the use of lower levels of formaldehyde in clothing is the adoption in other countries of legal limits on formaldehyde in clothing and textiles and on the airborne levels of formaldehyde in the workplace. For example, according to HHS's National Institute for Occupational Safety and Health, over 20 countries have established occupational exposure limits to protect workers, including those in the textile industry.<sup>44</sup> In addition, the European Union's European Scientific Committee on Occupational Exposure Limits has issued provisional occupational exposure limits for formaldehyde. Further, according to the American Apparel and Footwear Association, 13 countries regulate the level of formaldehyde in clothing.<sup>45</sup> Another factor that may limit formaldehyde levels in clothing is the use of voluntary labeling programs such as the Oeko-Tex® Standard 100 label.<sup>46</sup> Such labels may be displayed by clothing and other textile items that meet certain

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<sup>42</sup>This formaldehyde level in textiles is based on the Japanese test.

<sup>43</sup>Eero Priha, "Are Textile Formaldehyde Regulations Reasonable? Experiences from the Finnish Textile and Clothing Industries," *Regulatory Toxicology and Pharmacology*, 22, 243-249 (1995).

<sup>44</sup>Department of Health and Human Services, National Institute for Occupational Safety and Health, *The Registry of Toxic Effects of Chemical Substances, No. LP8925000, CAS No. 50-00-0* (Washington, D.C., 2009).

<sup>45</sup>The countries the American Apparel and Footwear Association identifies as having regulatory standards for formaldehyde in clothing and other textiles are Austria, China, Finland, France, Germany, Japan, Lithuania, the Netherlands, New Zealand, Norway, Poland, Russia, and South Korea.

<sup>46</sup>The Austrian Textile Research Institute and the German Research Institute Hohenstein jointly developed the Oeko-Tex® Standard 100 in 1992. The International Oeko-Tex® Association, which includes 14 textile research and test institutes in Europe and Japan, is responsible for the independent tests for harmful substances according to Oeko-Tex® Standard 100.

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limits on formaldehyde and other substances. Appendix III provides more information on voluntary labeling programs.

In addition, while there are no legal limits on the levels of formaldehyde in clothing in the United States, some U.S. retailers have established their own corporate limits on formaldehyde in clothing and bed linens. These corporate formaldehyde limits are generally considered proprietary, although some may be disclosed upon request. We obtained information on corporate limits for formaldehyde in clothing established by 14 U.S.-based retailers.<sup>47</sup> Many of these limits were set within the last 10 years, although one was set as early as 1995. In some cases, the limits established by retailers apply only to private store brands and not to national brands, some of which may establish their own limits. Some of the 14 retailers told us they review regulations adopted in other countries to inform their own corporate limits or to comply with regulations in countries where they operate.

Table 3 shows the corporate limits for formaldehyde in clothing and bed linens sold in the United States that we obtained from 14 retailers. The retailers' limits vary both by age and item category. For example, a retailer may have limits for clothing and bed linens for infants and toddlers but not for clothing or bed linens for adults.

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<sup>47</sup>We requested information on corporate limits on formaldehyde in clothing and other textiles, if any, from 16 publicly traded U.S.-based clothing retailers. One of the 14 retailers responding reported that it had not established formaldehyde limits. For one of the two retailers that did not respond, we were able to obtain, from its Web site, information about the corporate limits it has established.



**Table 3: Formaldehyde Limits Set by 14 U.S. Retailers for Clothing and Bed Linens**

Formaldehyde limits <sup>a,b</sup>	Number of retailers reporting formaldehyde limits, by category					
	Clothing for infants/toddlers	Bed linens for infants/toddlers	Clothing for children	Bed linens for children	Clothing for adults	Bed linens for adults
None	0	1	0	1	3	3
<250 parts per million	0	1	0	1	0	1
<200 parts per million <sup>c</sup>	1	1	1	1	1	2
<150 parts per million	0	1	0	1	0	1 <sup>c</sup>
<100 parts per million	0	0	1	1	2	1
<75 parts per million	2	4	11 <sup>d</sup>	9 <sup>d</sup>	8 <sup>d</sup>	6 <sup>c</sup>
<20 parts per million	11 <sup>c</sup>	6 <sup>d</sup>	1	0	0	0
Number of retailers reporting limits	14	14	14	14	14	14

Source: GAO analysis of data from 14 U.S. retailers.

Notes: Retailers' age designations for infants/toddlers and children vary.

<sup>a</sup>Unless otherwise noted, retailers reported using the Japanese test.

<sup>b</sup>Formaldehyde limits for clothing are applicable to clothing that comes in direct contact with the skin.

<sup>c</sup>One retailer determines compliance with this limit using the AATCC test.

<sup>d</sup>Two retailers determine compliance with this limit using the AATCC test.

However, retailers may use their corporate limits more as guidelines than as absolute compliance limits. For example, one retailer told us that when its test results for formaldehyde content exceed corporate limits, the company may conduct additional testing to determine the extent of the problem to inform its response. In contrast, this retailer told us that if a single sample exceeds a U.S. regulatory standard—for example, for lead in clothing—the company rejects the entire shipment. Another retailer told us the company complies with Japan's formaldehyde limit—the most stringent—when selling products in Japan but has established a less stringent limit for clothing sold in the United States.

Finally, another factor that may have contributed to lower levels of formaldehyde in clothing, according to government and trade publications, is industry actions to address concerns about some formaldehyde-containing resins. The older resins, such as urea formaldehyde and melamine formaldehyde, impart durable press characteristics to clothing but also tend to release more formaldehyde during the manufacture, storage, retailing, and use of fabrics and clothing than newer resins because they are less chemically stable. In addition, the older resins can also stiffen fabric, degrade after repeated washing, damage fabrics if chlorine bleach is used, and cause the fabrics to emit a noticeable odor.

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The development and use of newer resins in clothing production to impart durable press characteristics have addressed some of these issues as well as reduced the level of formaldehyde in clothing. These newer resins, also called cross-linking agents, became widely used in the 1980s. For example, dimethylol dihydroxy ethylene urea (DMDHEU) and its derivatives are reported to be the most commonly used resins today. Fabrics finished with DMDHEU may release moderate amounts of formaldehyde but can be modified to release low to ultra-low levels.<sup>48</sup> Newer resins that do not contain formaldehyde have also been developed, but they are not as widely used because of their higher cost; some may also have negative effects on fabrics.

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## Agency Comments and Our Evaluation

We provided a draft of this report to the Chairman, CPSC, for review and comment. CPSC provided technical comments, which we have incorporated, as appropriate.

We are sending copies of this report to the appropriate congressional committees; the Chairman, CPSC; and other interested parties. The report is also available at no charge on the GAO Web site at <http://www.gao.gov>.

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<sup>48</sup>According to medical literature, moderate amounts of formaldehyde are defined as between 1,000 and 100 parts per million, while low and ultra-low levels are below 100 parts per million, based on the AATCC test.

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If you or your staff have any questions about this report, please contact me at (202) 512-3841 or [stephensonj@gao.gov](mailto:stephensonj@gao.gov). Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix VI.

A handwritten signature in black ink, reading "John B. Stephenson". The signature is written in a cursive style with a long horizontal flourish at the end.

John B. Stephenson  
Director, Natural Resources  
and Environment

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# Appendix I: Government Reviews of the General Health Effects of Exposure to Formaldehyde and Medical Literature on the Health Effects of Formaldehyde in Textiles

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Following is more detailed information on the sources we used in our analysis to determine what is known about the health effects of exposure to formaldehyde.

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Health Effects of Formaldehyde in Textiles**

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**Appendix I: Government Reviews of the  
General Health Effects of Exposure to  
Formaldehyde and Medical Literature on the  
Health Effects of Formaldehyde in Textiles**

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# Appendix II: Objectives, Scope, and Methodology

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Section 234 of the Consumer Product Safety Improvement Act of 2008 requires GAO to conduct a study on the use of formaldehyde in the manufacturing of textiles and apparel.<sup>1</sup> This report provides information on what is known about (1) the health risks from exposure to formaldehyde, particularly from clothing, and (2) the levels of formaldehyde found in clothing sold in the United States. Throughout our review, we consulted with the Consumer Product Safety Commission (CPSC) on our methodology and to obtain relevant background information stemming from the agency's mission to ensure consumer protection.

To determine what is known about the health effects of exposure to formaldehyde, particularly from clothing, we conducted literature reviews on both the general health effects of formaldehyde and the health effects of exposure to formaldehyde in clothing. For the general health effects, we summarized the findings of several comprehensive government reviews, including (1) the Health and Human Services' (HHS) 2005 National Toxicology Program report on carcinogens (currently being updated),<sup>2</sup> (2) HHS's Agency for Toxic Substances and Disease Registry 1999 toxicological profile for formaldehyde,<sup>3</sup> (3) the Environmental Protection Agency's (EPA) 1991 Integrated Risk Information System formaldehyde assessment<sup>4</sup> and the 2010 draft update,<sup>5</sup> (4) the 2006 monograph on formaldehyde prepared by the World Health Organization's International Agency for Research on Cancer,<sup>6</sup> and (5) the Organisation for Economic

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<sup>1</sup>Pub. L. No. 110-314, § 234 (2008).

<sup>2</sup>U.S. Department of Health and Human Services, National Toxicology Program, *Report on Carcinogens, 11th Edition* (Research Triangle Park, North Carolina, 2005).

<sup>3</sup>U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, *Toxicological Profile for Formaldehyde* (Atlanta, Georgia, 1999).

<sup>4</sup>*Integrated Risk Information System, Formaldehyde (CASRN 50-00-0)* (Washington, D.C.: EPA), <http://www.epa.gov/ncea/iris/subst/0419.htm> (downloaded Dec. 9, 2009).

<sup>5</sup>U.S. Environmental Protection Agency, *External Review Draft: Toxicological Review of Formaldehyde—Inhalation Assessment, in Support of Summary Information on the Integrated Risk Information System, Volume I of IV* (Washington, D.C., June 2010).

<sup>6</sup>World Health Organization, International Agency for Research on Cancer, *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 88, Formaldehyde, 2-Butoxyethanol and 1-tert-Butoxypropan-2-ol* (Lyon, France, 2006).

Co-operation and Development's 2002 Screening Information Data Set for formaldehyde.<sup>7</sup>

To determine the health effects of exposure to formaldehyde in clothing, we reviewed and summarized the findings of over 40 relevant articles published from 1980 to April 2010 primarily in medical journals, but also in textile industry and environmental journals and books. We targeted reviews and meta-analyses, rather than individual studies, published in English but also included articles presenting original research, such as clinical studies. In addition, we interviewed and obtained studies from medical professionals, officials from the Department of Agriculture (USDA) and CPSC, and representatives from industry organizations such as the American Apparel and Footwear Association, Cotton Incorporated, and the Formaldehyde Council, Inc.

To determine what is known about the levels of formaldehyde found in clothing sold in the United States, we analyzed information on formaldehyde-containing resins and formaldehyde levels in clothing from government studies, patent applications, and trade publications; interviewed officials from government agencies including USDA's Agricultural Research Service, industry associations, retailers, testing laboratories, and academia, as well the medical profession; and contracted with an accredited commercial laboratory to test the formaldehyde levels in a nonprobability sample<sup>8</sup> of 180 articles of clothing (165) and bed linens (15).

For our nonprobability sample, we purchased clothing and bed linens from 10 national retailers, two military facilities, and a store selling children's scout uniforms. In March 2010, our staff purchased items in six major metropolitan areas: Boston, Chicago, Dallas, Los Angeles, Seattle, and Washington, D.C. Our sample was approximately evenly split by gender and included items worn by adults and children. We purchased only items that come into direct contact with the skin; we did not buy outerwear such as jackets or coats. We used clothing sizes to determine whether clothing was intended for children 3 years of age and older. We also considered

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<sup>7</sup>Organisation for Economic Co-operation and Development, *SIDS Initial Assessment Report for 14th SIAM, Formaldehyde (CAS No. 50-00-0)* (Paris, France, 2002).

<sup>8</sup>A nonprobability sample is a sample in which some items in the population have no chance, or an unknown chance, of being selected. Results from nonprobability samples cannot be used to make inferences about a population.

crib sheets and cloth diapers to be intended for use by infants and toddlers. The results from testing our nonprobability sample are illustrative of formaldehyde levels that may be found in some clothing and are not projectable to clothing sold in the United States in general.

We selected items that were likely to contain formaldehyde, such as those made from plant-based fibers, like cotton, that are likely to be treated for durable press. Almost all of the items in the sample were made from 50 percent or more natural (mostly plant-based) fibers. About 76 percent of the items were made from 90 percent or more cotton. About a fifth of the items were labeled as being treated for durable press, including bed linens and career apparel such as dress shirts. We also included some commonly worn items, such as T-shirts and jeans, based on a review of Department of Commerce data for volumes of clothing and bed linens imported or produced in the United States. We selected low- or moderately priced items. Most of the items in our sample were imported; however, we also made an effort to ensure that about 10 percent of them were American made.

An accredited commercial laboratory tested the items for formaldehyde. The laboratory is accredited by, among others, the American Association of Textile Chemists and Colorists and the American Association for Laboratory Accreditation.<sup>9</sup> To prepare items for shipment, we placed each one in its own zippered plastic bag shortly after its purchase to avoid cross-contamination from other items or packaging materials. Samples received by the laboratory were cut, weighed, and kept wrapped in foil inside a plastic bag until the formaldehyde test was run.

The laboratory tested the items using two test methods commonly used by the textile industry—the Japanese Industrial Standard L 1041 test, also known as the Japanese Law 112 test (Japanese test), and the American Association of Textile Chemists and Colorists 112 test (AATCC test). Results from the Japanese test and the AATCC test are not comparable because, for example, they use different testing specifications. The procedure the laboratory used for the Japanese test included placing 1 gram of the sample in a stoppered flask with 100 mL of water and immersing it in a bath of 40°C water for 1 hour. The procedure the

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<sup>9</sup>The American Association for Laboratory Accreditation bases its accreditation on the International Organization for Standardization (ISO) 17025:2005, *General requirements for the competence of testing and calibration laboratories*.

laboratory used for the AATCC test included suspending 1 gram of the sample in a sealed jar above 50 mL of water. The jar was kept in an oven at 49°C for 20 hours and then cooled at room temperature for 30 minutes. For both tests, an acetyl acetone reagent was added as the next step, and the solution was heated at 40°C for 30 minutes and allowed to cool at room temperature for 30 minutes. The laboratory ran quality control tests for each batch of samples.

We had each of the 180 items tested using the Japanese test and a smaller number using the AATCC test because most of the regulatory and corporate formaldehyde limits we identified used the Japanese test or its equivalent. According to the American Apparel and Footwear Association, this test or its equivalent is used to determine whether formaldehyde levels in clothing are consistent with levels cited in international formaldehyde regulations, which we used as a basis of comparison for our own test results. Also, the Japanese test was more frequently used in the government studies we identified that conducted formaldehyde testing in clothing and other textiles. In addition, most of the U.S. retailers that provided us with information on internal corporate limits on formaldehyde in clothing, and the voluntary labeling programs we identified, use the Japanese test or its equivalent. We tested 21 of the 180 items using both the Japanese test and the AATCC test. This latter test is used by some U.S. retailers that have established corporate limits on formaldehyde and has been used in some studies cited in government reviews, trade publications, and the medical literature. The 21 items tested by both methods were selected to include a similar mix of clothing and bed linens as the overall sample.

If items contained more than one type of fabric that could potentially contain varying levels of formaldehyde, the laboratory tested a composite sample that included equal amounts of these fabrics. Decorative elements that do not come into direct skin contact, such as sequins, were not included as part of the composite. This composite approach would tend to result in formaldehyde levels falling between the highest and lowest levels in the different fabrics.

In addition, we contacted U.S.-based, publicly owned retailers to determine if they have internal corporate limits for formaldehyde in clothing. We contacted 16 retailers and received responses from 14, of which 13 had limits. We also found information on the Internet on the limits set by one of the two retailers that did not respond.

To identify regulatory and voluntary labeling programs that may be used in other countries as well as relevant studies on the levels of formaldehyde in clothing, we contacted government and European Union officials and conducted Internet searches. We identified a number of countries that have regulatory standards for formaldehyde in textiles as well as voluntary labeling programs. Because of complexities in obtaining translations of other countries' formaldehyde laws and regulations into English and confirming their application within the context of these countries' legal systems, we relied primarily on the American Apparel and Footwear Association for information on formaldehyde limits set in other countries, including the limits identified as the most stringent.<sup>10</sup> We obtained information on international worker safety standards for formaldehyde primarily from a report by HHS's National Institute for Occupational Safety and Health.

We conducted this performance audit from September 2009 to August 2010 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

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<sup>10</sup>American Apparel and Footwear Association, *Restricted Substance List*, Release 6 (2010).

# Appendix III: Voluntary Labeling Programs

Table 4 lists examples of voluntary labeling programs, which are primarily used in other countries.<sup>1</sup> Clothing and other items meeting the specified limits for formaldehyde and other substances would typically display a label indicating their compliance. The formaldehyde limits in the table are those applicable to clothing and other textiles that come into direct contact with the skin.

**Table 4: Examples of Voluntary Labeling Programs**

Governing body	Label name	Formaldehyde limit for infants/toddlers, <sup>a</sup> in parts per million	Formaldehyde limit for children and adults, in parts per million	Test method specified (or equivalent)
European Union	European Ecolabel	20	30	Japanese test
Good Environmental Choice Australia Ltd	Australian Ecolabel	30	30	Japanese or AATCC tests <sup>b</sup>
International Association for Research and Testing in the Field of Textile Ecology	Oeko-Tex® Standard 100	Not detectable <sup>c</sup>	75	Japanese test
International Working Group on Global Organic Textile Standard	Global Organic Textile Standard	Any level prohibited	Any level prohibited	Not specified
New Zealand Ecolabelling Trust	Environmental Choice New Zealand	30	30	Japanese test

Source: GAO analysis of voluntary labeling programs.

<sup>a</sup>The transition from limits applicable to infants/toddlers to those for children and adults, where applicable, is 3 years of age.

<sup>b</sup>Or certified according to the most recent Oeko-Tex® Standard 100.

<sup>c</sup>Formaldehyde limit listed as “not detectable” is 16 parts per million.

<sup>1</sup>We have identified a few U.S.-based retailers that comply with some voluntary programs, but they do not generally sell individual items that are labeled to indicate compliance.

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# Appendix IV: Top Ten Exporters of Clothing to the United States in 2008

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<b>Country</b>	<b>Percentage of total U.S. imports<sup>a</sup></b>
China	34.3
Vietnam	6.7
Bangladesh	6.3
Honduras	5.9
Indonesia	4.8
Mexico	4.6
Cambodia	3.9
India	3.9
El Salvador	3.7
Pakistan	3.1

Source: GAO analysis of the Department of Commerce Office for Textiles and Apparel data.

Notes: Data include all apparel imports under notional category 1.

<sup>a</sup>By square meter equivalents.

# Appendix V: Results of Formaldehyde Tests for a Sample of Clothing and Bed Linens Sold in the United States

Table 5 shows the results of tests we had performed on 180 items—165 articles of clothing and 15 bed linen items.

**Table 5: Information on Items Sold in the United States and Tested for Formaldehyde Levels, 2010**

Comparison to most stringent regulatory standards for formaldehyde <sup>a</sup>	Item type	Fiber content identified on label	Fabric performance characteristic identified on label or packaging	Country identified on label	Target customer	Formaldehyde level in parts per million <sup>b</sup>	
						Japanese test	AATCC test
Exceeds	Dress shirt	100% cotton	Wrinkle free	China	Men	206.1	<sup>c</sup>
Exceeds	Hat	100% cotton exclusive of decoration	None identified	China	Boys 3 years of age and older	192.6	<sup>c</sup>
Exceeds	Bed linens (pillow cases)	60% cotton, 40% polyester	Soft finish, easy care	Bahrain	Adults or children 3 years of age and older	189.6	550.7
Exceeds	Khakis	100% cotton	No iron, permanent crease	India	Men	169.6	<sup>c</sup>
Exceeds	Dress shirt	60% cotton, 40% polyester	None identified	China	Boys 3 years of age and older	95.1	<sup>c</sup>
Exceeds	Bed linens (pillow cases)	100% cotton	Wrinkle free, easy care, no ironing needed, eco-friendly	USA of fabric imported from Pakistan	Adults or children 3 years of age and older	93.8	<sup>c</sup>
Exceeds	Dress shirt	100% cotton	Noniron	Indonesia	Men	92.6	<sup>c</sup>
Exceeds	Bed linens (pillow cases)	100% cotton	Wrinkle free performance	Pakistan	Adults or children 3 years of age and older	89.3	<sup>c</sup>
Exceeds	Bed linens (crib sheet)	100% cotton	Preshrunk	Thailand	Infants/toddlers <sup>d</sup>	85.4	<sup>c</sup>
Exceeds	U.S. military combat uniform pants	50% cotton, 50% nylon	None identified	USA	Women	75.4	205.5
Meets	Bed linens (pillow cases)	100% cotton	None identified	China	Adults or children 3 years of age and older	72.4	<sup>c</sup>
Meets	U.S. military combat uniform pants	50% cotton, 50% nylon	Insect repellent	USA	Men	71.0	<sup>c</sup>



**Appendix V: Results of Formaldehyde Tests  
for a Sample of Clothing and Bed Linens Sold  
in the United States**

Comparison to most stringent regulatory standards for formaldehyde <sup>a</sup>	Item type	Fiber content identified on label	Fabric performance characteristic identified on label or packaging	Country identified on label	Target customer	Formaldehyde level in parts per million <sup>b</sup>	
						Japanese test	AATCC test
Meets	Dress shirt	100% cotton	Noniron, stain resistant	Indonesia	Men	63.0	<sup>c</sup>
Meets	U.S. military combat uniform shirt	50% cotton, 50% nylon	None identified	USA	Women	57.8	<sup>c</sup>
Meets	Dress pants	100% cotton	No iron, permanent crease	Vietnam	Men	54.3	<sup>c</sup>
Meets	Hat	79% cotton, 19% polyester, 2% other	None identified	China	Women	50.1	<sup>c</sup>
Meets	Bed linens (pillow cases)	100% cotton	Wrinkle free, bleach friendly	India	Adults or children 3 years of age and older	47.9	<sup>c</sup>
Meets	Khakis	100% cotton	Wrinkle free, easy care	Dominican Republic	Boys 3 years of age and older	45.9	<sup>c</sup>
Meets	Polo shirt	100% cotton	Minimal shrinkage, fade and pill resistant, nonroll collar	Pakistan	Men	45.5	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	USA	Women	42.5	32.7
Meets	Dress pants	100% worsted wool (polyester lining)	Wrinkle and stain resistant	Mexico	Men	41.7	<sup>c</sup>
Meets	Dress shirt	100% cotton	Noniron, stain resistant	Honduras	Men	38.0	<sup>c</sup>
Meets	Dress shirt	100% cotton	Easy iron	Bangladesh	Men	37.2	<sup>c</sup>
Meets	Bed linens (sham)	60% cotton, 40% polyester	None identified	Pakistan	Boys 3 years of age and older	35.9	<sup>c</sup>
Meets	Dress shirt	100% cotton	Wrinkle resist	Bangladesh	Men	32.7	<sup>c</sup>
Meets	Jeans	98% cotton, 2% spandex	None identified	China	Women	24.0	<sup>c</sup>
Meets	Khakis	100% cotton	Stain resistant, wrinkle free	Assembled in Nicaragua	Men	23.7	43.2
Meets	Blouse	69% cotton, 27% nylon, 4% spandex	None identified	China	Women	23.5	<sup>c</sup>

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						Japanese test	AATCC test
Meets	Dress shirt	60% cotton, 40% polyester	Easy care, wrinkle resist	Bangladesh	Men	22.5	33.1
Meets	Hat	100% cotton	None identified	China	Women	22.5	<sup>c</sup>
Meets	Khakis	100% cotton	No iron, wrinkle free, easy care	Bangladesh	Men	22.4	<sup>c</sup>
Meets	Scout skirt	100% cotton	None identified	USA	Girls 3 years of age and older	21.6	<sup>c</sup>
Meets	Sweatpants	100% cotton	None identified	Honduras	Men	21.0	<sup>c</sup>
Meets	Khakis	97% cotton, 3% elastane	None identified	India	Women	20.5	<sup>c</sup>
Meets	U.S. military dress uniform shirt	65% polyester, 35% cotton	None identified	USA	Women	20.3	<sup>c</sup>
Meets	Pajamas	100% cotton	None identified	Thailand	Infants/toddlers <sup>d</sup>	Not detectable	24.1
Meets	Dress shirt	60% cotton, 40% polyester	Wrinkle free, stain repellent	Vietnam	Men	Not detectable	21.8
Meets	Dress pants	90% cotton, 10% cashmere	None identified	USA of imported fabric	Boys 3 years of age and older	Not detectable	21.1
Meets	Underwear	100% cotton	None identified	India	Women	Not detectable	14.0
Meets	Bed linens (crib sheet)	100% cotton sateen	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	13.8
Meets	Dress pants	100% cotton	Shrink resistant, wrinkle resistant, stain repellent, soil release	Vietnam	Men	Not detectable	11.1
Meets	Dress	54% cotton, 45% polyester, 1% metallic. Lining: 65% polyester, 35% cotton	None identified	Bangladesh	Girls 3 years of age and older	Not detectable	11.0
Meets	Bed linens (crib sheet)	100% cotton	Easy care	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Cargo pants	100% cotton	None identified	Kenya	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Cargo pants	100% cotton	None identified	Indonesia	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>

**Appendix V: Results of Formaldehyde Tests  
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Comparison to most stringent regulatory standards for formaldehyde <sup>a</sup>	Item type	Fiber content identified on label	Fabric performance characteristic identified on label or packaging	Country identified on label	Target customer	Formaldehyde level in parts per million <sup>b</sup>	
						Japanese test	AATCC test
Meets	Cloth diapers	100% cotton	Extra absorbent and quick drying	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Cloth diapers	100% cotton	Extra absorbent and quick drying	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Hat	100% cotton	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Hat	100% cotton exclusive of decoration	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Jeans	100% cotton exclusive of decoration	None identified	Indonesia	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Jeans	99% cotton, 1% spandex	None identified	Bangladesh	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Pajamas	100% cotton	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Pajamas	100% cotton	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Pajamas	100% cotton exclusive of decoration	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Romper	100% combed cotton	None identified	USA	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Romper	100% cotton	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Romper	100% cotton	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Romper	100% cotton	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Set (dress and leggings)	100% cotton	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	Not detectable
Meets	Set (romper, pants, and bib)	100% cotton/80% cotton, 20% polyester	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Set (top and bottom)	100% cotton	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Set (top and bottom)	100% cotton	None identified	Thailand	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>

**Appendix V: Results of Formaldehyde Tests  
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Comparison to most stringent regulatory standards for formaldehyde <sup>a</sup>	Item type	Fiber content identified on label	Fabric performance characteristic identified on label or packaging	Country identified on label	Target customer	Formaldehyde level in parts per million <sup>b</sup>	
						Japanese test	AATCC test
Meets	Set (top and bottom)	Shell: 100% cotton exclusive of decoration	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Set (tops and bottom)	100% cotton	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Socks	82% cotton, 15% nylon, 2% spandex, 1% rubber	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Sweatpants	100% cotton	None identified	Bangladesh	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Sweatpants	100% cotton	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	China	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	El Salvador	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	Guatemala	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	Guatemala	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	Thailand	Infants/toddlers <sup>d</sup>	Not detectable	<sup>c</sup>
Meets	Bed linens (pillow cases)	60% cotton, 40% polyester	None identified	Pakistan	Boys 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Cargo pants	100% cotton	None identified	Bangladesh	Boys 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Dress pants	55% linen, 45% rayon	None identified	China	Boys 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Jeans	100% cotton	None identified	Bangladesh	Boys 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Pajamas	100% cotton	None identified	China	Boys 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Polo shirt	100% organic cotton	None identified	India	Boys 3 years of age and older	Not detectable	<sup>c</sup>

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Comparison to most stringent regulatory standards for formaldehyde <sup>a</sup>	Item type	Fiber content identified on label	Fabric performance characteristic identified on label or packaging	Country identified on label	Target customer	Formaldehyde level in parts per million <sup>b</sup>	
						Japanese test	AATCC test
Meets	Polo shirt	60% cotton, 40% polyester	None identified	Lesotho	Boys 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Scout pants	67% cotton, 33% polyester	None identified	USA	Boys 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Scout shirt	67% cotton, 33% polyester	None identified	Bangladesh	Boys 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Sweatpants (shorts)	100% cotton	None identified	Vietnam	Boys 3 years of age and older	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	Honduras	Boys 3 years of age and older	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	Honduras	Boys 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Underwear	100% cotton	None identified	China	Boys 3 years of age and older	Not detectable	Not detectable
Meets	Bed linens (pillow cases)	60% cotton, 40% polyester	None identified	Pakistan	Girls 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Blouse	100% cotton	None identified	China	Girls 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Bra	95% cotton, 5% spandex	None identified	Bangladesh	Girls 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Bra	95% cotton, 5% spandex, inner cup: 100% polyester (padded)	None identified	China	Girls 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Dress	100% cotton	None identified	Vietnam	Girls 3 years of age and older	Not detectable	<sup>c</sup>

**Appendix V: Results of Formaldehyde Tests  
for a Sample of Clothing and Bed Linens Sold  
in the United States**

Comparison to most stringent regulatory standards for formaldehyde <sup>a</sup>	Item type	Fiber content identified on label	Fabric performance characteristic identified on label or packaging	Country identified on label	Target customer	Formaldehyde level in parts per million <sup>b</sup>	
						Japanese test	AATCC test
Meets	Dress	100% cotton. Mesh—100% polyester, exclusive of decoration	None identified	China	Girls 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Dress pants	97% cotton, 3% spandex	None identified	China	Girls 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Jeans	56% ramie, 25% cotton, 18% polyester, 1% spandex	None identified	China	Girls 3 years of age and older	Not detectable	Not detectable
Meets	Khakis	100% cotton	None identified	Bangladesh	Girls 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Polo shirt	100% cotton exclusive of decoration	None identified	Vietnam	Girls 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Scout shirt	65% polyester, 35% cotton	None identified	USA	Girls 3 years of age and older	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	Mexico of USA Parts	Girls 3 years of age and older	Not detectable	<sup>c</sup>
Meets	T-shirt	95% cotton, 5% spandex	None identified	USA	Girls 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Underwear	95% cotton, 5% spandex	None identified	China	Girls 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Bed linens (fitted sheet)	100% cotton exclusive of decoration	None identified	China	Adults or children 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Bed linens (flat sheet)	60% pima cotton, 40% polyester	Easy care	China	Adults or children 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Bed linens (pillow cases)	100% cotton	None identified	China	Adults or children 3 years of age and older	Not detectable	<sup>c</sup>

**Appendix V: Results of Formaldehyde Tests  
for a Sample of Clothing and Bed Linens Sold  
in the United States**

Comparison to most stringent regulatory standards for formaldehyde <sup>a</sup>	Item type	Fiber content identified on label	Fabric performance characteristic identified on label or packaging	Country identified on label	Target customer	Formaldehyde level in parts per million <sup>b</sup>	
						Japanese test	AATCC test
Meets	Bed linens (pillow cases)	60% cotton, 40% polyester	Easy care, wrinkle resistant	China	Adults or children 3 years of age and older	Not detectable	<sup>c</sup>
Meets	Cargo pants	100% cotton	None identified	Egypt	Men	Not detectable	<sup>c</sup>
Meets	Dress pants	100% wool	None identified	Vietnam	Men	Not detectable	<sup>c</sup>
Meets	Dress pants	60% cotton, 40% polyester	Easy care	Bangladesh	Men	Not detectable	<sup>c</sup>
Meets	Dress pants	Shell: 100% cotton	None identified	China	Men	Not detectable	<sup>c</sup>
Meets	Dress shirt	100% cotton	Easy iron	Bangladesh	Men	Not detectable	<sup>c</sup>
Meets	Dress shirt	100% cotton	Easy care	Bangladesh	Men	Not detectable	<sup>c</sup>
Meets	Dress shirt	100% cotton	None identified	USA	Men	Not detectable	<sup>c</sup>
Meets	Dress shirt	55% cotton, 45% polyester	Wrinkle free	Vietnam	Men	Not detectable	<sup>c</sup>
Meets	Dress shirt	60% cotton, 40% polyester exclusive of decoration	Easy care	Bangladesh	Men	Not detectable	<sup>c</sup>
Meets	Hat	100% cotton	Moisture management	China	Men	Not detectable	<sup>c</sup>
Meets	Hat	100% cotton exclusive of decoration	None identified	China	Men	Not detectable	<sup>c</sup>
Meets	Hat	97% cotton, 3% P.U. spandex	None identified	Bangladesh	Men	Not detectable	Not detectable
Meets	Jeans	100% Cotton	None identified	India	Men	Not detectable	<sup>c</sup>
Meets	Jeans	100% cotton	None identified	Mexico	Men	Not detectable	<sup>c</sup>
Meets	Jeans	100% cotton	None identified	Mexico	Men	Not detectable	<sup>c</sup>
Meets	Khakis	100% combed cotton	Wrinkle resistant	Bangladesh	Men	Not detectable	<sup>c</sup>
Meets	Khakis	100% combed cotton	None identified	USA	Men	Not detectable	<sup>c</sup>
Meets	Khakis	100% cotton	No iron, wrinkle free, permanent crease, polished finish	Vietnam	Men	Not detectable	<sup>c</sup>

**Appendix V: Results of Formaldehyde Tests  
for a Sample of Clothing and Bed Linens Sold  
in the United States**

Comparison to most stringent regulatory standards for formaldehyde <sup>a</sup>	Item type	Fiber content identified on label	Fabric performance characteristic identified on label or packaging	Country identified on label	Target customer	Formaldehyde level in parts per million <sup>b</sup>	
						Japanese test	AATCC test
Meets	Khakis	100% cotton	Shrink resistant, wrinkle resistant, stain repellent, soil release	Vietnam	Men	Not detectable	<sup>c</sup>
Meets	Pajama pants	100% cotton	None identified	Cambodia	Men	Not detectable	<sup>c</sup>
Meets	Polo shirt	100% cotton	None identified	India	Men	Not detectable	<sup>c</sup>
Meets	Polo shirt	100% cotton exclusive of decoration	None identified	India	Men	Not detectable	<sup>c</sup>
Meets	Polo shirt	60% cotton, 40% polyester	Easy care	Indonesia	Men	Not detectable	<sup>c</sup>
Meets	Polo shirt	65% cotton, 35% polyester	Easy care, wrinkle resistant, super soft touch	China	Men	Not detectable	<sup>c</sup>
Meets	Socks	84% cotton, 15% nylon, 1% spandex	None identified	USA	Men	Not detectable	<sup>c</sup>
Meets	Sweatpants (shorts)	100% cotton	None identified	Honduras	Men	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	China	Men	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	Mexico	Men	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	Pakistan	Men	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	USA	Men	Not detectable	<sup>c</sup>
Meets	U.S. military combat uniform shirt	50% cotton, 50% nylon	Insect repellent	USA	Men	Not detectable	<sup>c</sup>
Meets	U.S. military dress uniform shirt	75% polyester, 25% wool	None identified	USA	Men	Not detectable	<sup>c</sup>
Meets	Underwear	100% combed cotton	Antimicrobial, pre-shrunk	Bangladesh	Men	Not detectable	<sup>c</sup>
Meets	Underwear	100% cotton	None identified	Bangladesh	Men	Not detectable	<sup>c</sup>
Meets	Underwear	100% cotton	None identified	Honduras	Men	Not detectable	<sup>c</sup>
Meets	Blouse	100% cotton	None identified	Indonesia	Women	Not detectable	Not detectable
Meets	Blouse	65% cotton, 35% silk	None identified	China	Women	Not detectable	<sup>c</sup>
Meets	Blouse	68% cotton, 28% nylon, 4% spandex	None identified	China	Women	Not detectable	<sup>c</sup>



**Appendix V: Results of Formaldehyde Tests  
for a Sample of Clothing and Bed Linens Sold  
in the United States**

Comparison to most stringent regulatory standards for formaldehyde <sup>a</sup>	Item type	Fiber content identified on label	Fabric performance characteristic identified on label or packaging	Country identified on label	Target customer	Formaldehyde level in parts per million <sup>b</sup>	
						Japanese test	AATCC test
Meets	Bra	95% cotton, 5% lycra	None identified	Bangladesh	Women	Not detectable	<sup>c</sup>
Meets	Bra	Body/cup: 80% nylon, 20% lycra. Back lining: 84% polyester, 16% lycra	None identified	China	Women	Not detectable	Not detectable
Meets	Cargo pants	97% cotton, 3% spandex	None identified	China	Women	Not detectable	<sup>c</sup>
Meets	Cargo pants	98% cotton, 2% spandex	None identified	Bangladesh	Women	Not detectable	<sup>c</sup>
Meets	Dress	100% cotton	None identified	China	Women	Not detectable	<sup>c</sup>
Meets	Dress	100% cotton	None identified	Indonesia	Women	Not detectable	<sup>c</sup>
Meets	Dress pants	54% linen, 44% cotton, 2% spandex	None identified	Vietnam	Women	Not detectable	<sup>c</sup>
Meets	Dress pants	97% cotton, 3% spandex	None identified	Vietnam	Women	Not detectable	<sup>c</sup>
Meets	Dress pants	97% wool, 3% spandex	None identified	China	Women	Not detectable	<sup>c</sup>
Meets	Dress pants	98% cotton, 2% spandex	None identified	China	Women	Not detectable	<sup>c</sup>
Meets	Dress shirt	100% cotton	None identified	Bangladesh	Women	Not detectable	<sup>c</sup>
Meets	Dress shirt	100% cotton	None identified	Sri Lanka	Women	Not detectable	<sup>c</sup>
Meets	Dress shirt	100% cotton	None identified	USA	Women	Not detectable	<sup>c</sup>
Meets	Dress shirt	60% cotton, 37% polyester, 3% spandex	Easy care	China	Women	Not detectable	<sup>c</sup>
Meets	Dress shirt	96% cotton, 4% spandex	None identified	Bangladesh	Women	Not detectable	<sup>c</sup>
Meets	Dress shirt	96% cotton, 4% spandex	None identified	China	Women	Not detectable	Not detectable
Meets	Dress shirt	97% cotton, 3% spandex	None identified	China	Women	Not detectable	<sup>c</sup>
Meets	Dress shirt	97% cotton, 3% spandex	None identified	China	Women	Not detectable	<sup>c</sup>
Meets	Dress shirt	97% cotton, 3% spandex	None identified	Indonesia	Women	Not detectable	<sup>c</sup>

**Appendix V: Results of Formaldehyde Tests  
for a Sample of Clothing and Bed Linens Sold  
in the United States**

Comparison to most stringent regulatory standards for formaldehyde <sup>a</sup>	Item type	Fiber content identified on label	Fabric performance characteristic identified on label or packaging	Country identified on label	Target customer	Formaldehyde level in parts per million <sup>b</sup>	
						Japanese test	AATCC test
Meets	Dress skirt	71% polyester, 26% rayon, 3% spandex	Washable stretch, minimum care required	China	Women	Not detectable	<sup>c</sup>
Meets	Dress skirt	97% cotton, 3% spandex	None identified	Sri Lanka	Women	Not detectable	Not detectable
Meets	Jeans	100% cotton	None identified	USA	Women	Not detectable	<sup>c</sup>
Meets	Khakis	96% cotton, 4% spandex	None identified	Indonesia	Women	Not detectable	<sup>c</sup>
Meets	Khakis	97% cotton, 3% spandex	None identified	Vietnam	Women	Not detectable	<sup>c</sup>
Meets	Khakis	97% cotton, 3% spandex	None identified	China	Women	Not detectable	<sup>c</sup>
Meets	Khakis	98% cotton, 2% spandex	None identified	China	Women	Not detectable	<sup>c</sup>
Meets	Khakis	98% cotton, 2% spandex	None identified	Vietnam	Women	Not detectable	<sup>c</sup>
Meets	Polo shirt	100% organic cotton	Soft hand, shrink resistant	Vietnam	Women	Not detectable	<sup>c</sup>
Meets	Polo shirt	95% pima cotton, 5% spandex	None identified	Vietnam	Women	Not detectable	<sup>c</sup>
Meets	Socks	76% cotton, 21% nylon, 3% lycra	None identified	Pakistan	Women	Not detectable	<sup>c</sup>
Meets	Socks	77% cotton, 18% polyester, 3% natural latex rubber, 1% spandex	None identified	USA	Women	Not detectable	<sup>c</sup>
Meets	Sweatpants	85% cotton, 15% polyester	None identified	Cambodia	Women	Not detectable	<sup>c</sup>
Meets	Sweatpants	90% cotton, 10% spandex	None identified	Bangladesh	Women	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	Assembled in Guatemala	Women	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	China	Women	Not detectable	Not detectable
Meets	T-shirt	100% cotton	Pre-shrunk	Honduras	Women	Not detectable	<sup>c</sup>
Meets	T-shirt	100% cotton	None identified	Thailand	Women	Not detectable	<sup>c</sup>

**Appendix V: Results of Formaldehyde Tests  
for a Sample of Clothing and Bed Linens Sold  
in the United States**

Comparison to most stringent regulatory standards for formaldehyde <sup>a</sup>	Item type	Fiber content identified on label	Fabric performance characteristic identified on label or packaging	Country identified on label	Target customer	Formaldehyde level in parts per million <sup>b</sup>	
						Japanese test	AATCC test
Meets	Underwear	92% cotton, 8% spandex	None identified	China	Women	Not detectable	<sup>c</sup>
Meets	Underwear	95% cotton, 5% spandex	None identified	Bangladesh	Women	Not detectable	<sup>c</sup>

Source: GAO analysis of information provided on items' labels or packaging and test data from an accredited commercial laboratory.

<sup>a</sup>As compared with the most stringent regulatory standards for formaldehyde identified by the American Apparel and Footwear Association, *Restricted Substance List*, Release 6, 2010.

<sup>b</sup>Formaldehyde levels listed as "not detectable" are below 20 parts per million for the Japanese test and 10 parts per million for the AATCC test.

<sup>c</sup>This item was tested only by the Japanese test.

<sup>d</sup>Infants/toddlers refers to children younger than 3 years of age.

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# Appendix VI: GAO Contact and Staff Acknowledgments

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## GAO Contact

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## Staff Acknowledgments

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