Cognitive Vitality Reports® are reports written by neuroscientists at the Alzheimer's Drug Discovery Foundation (ADDF). These scientific reports include analysis of drugs, drugs-in-development, drug targets, supplements, nutraceuticals, food/drink, non-pharmacologic interventions, and risk factors. Neuroscientists evaluate the potential benefit (or harm) for brain health, as well as for age-related health concerns that can affect brain health (e.g., cardiovascular diseases, cancers, diabetes/metabolic syndrome). In addition, these reports include evaluation of safety data, from clinical trials if available, and from preclinical models.

Textile Toxins

Evidence Summary

Chemicals in clothing, such as azo dyes, PFAS for water resistance, and PBDEs for flame retardants, have carcinogenic properties, and may induce immunological reactions in chemically sensitive individuals.

Brain health risk: Chemicals in clothing may negatively impact cognition in chemically sensitive individuals stemming from neurogenic inflammation and oxidative stress.

Aging and related health risk: Chemicals used in textile manufacturing can trigger immunogenic reactions and oxidative stress that may lead to functional disorders in sensitive individuals. Some chemicals are also considered carcinogenic.

Safety: Risks are highest in those exposed to new, unwashed garments, such as those working in the textile/fashion industry. Washing clothing and wearing neutral colored natural fiber garments can reduce exposure to textile toxins.

What is it?

Textiles are treated with numerous chemicals in order to achieve characteristics desired by consumers. Many of these chemicals have been found to be harmful to human health, though the potential safety risks for the vast majority of these chemicals have not been characterized. Chemical classes that have been most strongly associated with adverse health risks include per- and polyfluoroalkyl substances (PFAS), which are used to confer water resistance, polybrominated diphenyl ethers (PBDEs), which are used as flame retardants, and disperse azobenzene dyes, which are used as colorants [1; 2; 3].

Brain health risk: Chemicals in clothing may negatively impact cognition in chemically sensitive individuals stemming from neurogenic inflammation and oxidative stress.

Types of evidence:

- 1 observational study regarding cognitive symptoms in multiple chemical sensitivity (MCS)
- 1 observational study on the association between MCS and dementia
- 4 neuroimaging studies of odorant-related cognitive processing in MCS
- Numerous laboratory studies

Human research to suggest negative impacts to dementia incidence or worsened cognitive function:

Textiles are treated with a wide variety of chemicals in order to obtain desired properties such as color, softness, water resistance, etc. Many of these chemicals have an established potential for neurotoxicity, including formaldehyde, per- and polyfluoroalkyl substances (PFAS), and polybrominated diphenyl ethers (PBDEs), while the potential neurotoxic profile of the vast majority of chemicals used in clothing manufacturing has not been determined. Additionally, trace elements and heavy metals are used in the manufacturing process, such as dyeing [4]. The levels of different metals or other potentially toxic elements can vary depending on the type of fabric and the color, though, in general, higher levels are found in synthetic fabrics, particularly polyester [4]. As a result, the true risk profile of different types of garments remains unclear. Individuals involved in the textile or fashion industry have much higher exposure to these chemicals relative to the consumer, as the risks generally follow dose-dependent exposure. However, clothing and other textiles are being treated with increasing numbers of chemicals, which adds additional complexity in terms of the way that these chemicals interact with one another.

While the levels of individual chemicals in clothing may be below limits of established toxicity, there may be synergistic interactions which increase the potential toxicity when present in combination. Exposure to these chemicals in textiles, even at levels below the supposed levels of toxicity, can lead to the development of multiple chemical sensitivity (MCS) in susceptible individuals [5]. Neurological symptoms, including headaches, dizziness, fatigue, irritability, cognitive deficits, anxiety, and difficulty concentrating are a common feature of MCS [6]. In a case-control study including 70 cases of MCS and 140 controls, cognitive alterations were one of the most common symptoms associated with MCS, and the only symptom class that was significantly elevated in participants under the age of 40 (odds ratio [OR]: 31.25, 95% CI 13.79 to 70.80) [7]. Based on data from the 2015-16 Canadian Community Health Survey, which included 745,700 participants over the age of 40, the incidence of Alzheimer's disease and other dementias was higher in individuals with MCS (1.6%) relative to the general population (0.9%) (p=0.046) [8].

Human research to suggest harm to patients with dementia:

It has not yet been established whether exposure to textile toxins exacerbates disease progression in dementia patients, or whether dementia patients have heightened sensitivity to the potentially harmful effects of textile toxins.

Mechanisms of action for neurotoxicity identified from laboratory and clinical research:

Neuroimaging studies have indicated differences in neural processing in individuals with MCS [5]. In general, individuals with MCS do not appear to be more sensitive to the detection of odorants, however, they will subjectively rate odorants as more intense and unpleasant [9; 10]. This may stem from differences in the activation of limbic brain regions, such as the amygdala, hippocampus, and putamen [11]. This is suggestive of hyperactivity leading to limbic sensitization. One study found that there was a distinctive activation of the prefrontal cortex in participants with MCS relative to healthy controls upon repeated exposure to odorants leading to inadequate odor processing [12]. The linkage between the limbic driven emotional responses with the prefrontal cortex may negatively impact stimuli processing. A separate study similarly found altered cerebral blood flow in the prefrontal area, which may be related to alterations to cognitive and memory processing systems stemming from prior exposure events [10]. Similarly, another study found that participants with MCS showed impairments on smell-related cognitive tests, such as odor identification and forced choice tests, but have normal odor detection capacity [9]. Together these studies suggest that cognitive processing is altered in individuals with MCS,

as excessive activity in the limbic regions may impair cognitive performance by increasing cognitive load in response to chemical stimuli.

There are several hypotheses regarding the mechanisms underlying altered brain activity and central sensitization. These include neurogenic inflammation, excessive oxidative stress, and TRP receptor sensitization. TRPV1 and TRPA1 are chemosensitive receptors, and their upregulation can lower the threshold for cellular responses toward chemical stimuli. These receptors have been shown to be upregulated in individuals with chemical sensitivities as well as in those with neurodegeneration.

APOE4 interactions: Not established.

Aging and related health risk: Chemicals used in textile manufacturing can trigger immunogenic reactions and oxidative stress that may lead to functional disorders in sensitive individuals. Some chemicals are also considered carcinogenic.

Types of evidence:

- 1 review of epidemiological studies for PFAS and cancer
- 3 studies on dyes and immunological reactions
- 3 gene association studies for multiple chemical sensitivity
- 3 reviews on multiple chemical sensitivity
- Numerous laboratory studies

Cancer: POTENTIAL RISK

Many textile chemicals have been found to have carcinogenic properties, including dyes, flame retardants, formaldehyde, and PFAS. Various studies have found evidence to suggest that individuals working in the textile industry are at increased risk for some types of cancer [13]. While evidence of the carcinogenicity of these textile chemicals has been demonstrated in animal models, causal associations in human cancer cases have been more difficult to establish. The epidemiological evidence is strongest for PFAS, which has been classified as a possible carcinogen by the International Agency for Research on Cancer and Environmental Protection Agency (EPA) [1]. A review of epidemiological evidence including 16 cohort studies, 10 case-control studies, one cross-sectional study, and one ecological study found that while there were no consistent associations across studies between cancer and PFAS, there was evidence to support risks for testicular cancer and kidney cancer with elevated perfluorooctanoic acid

(PFOA) exposure [14]. Additionally, high exposure occupational cohort studies provide evidence for a potential increased risk for prostate cancer.

Immunogenic reactions: POTENTIAL RISK
Many textile chemicals, particularly dyes, have been established as allergens. The most common reactions occur on the skin, such as contact dermatitis, and in the lungs, such as asthma. Dye dermatitis occurs as a result of an immune reaction to industrial dyes. Some classes of dyes, such as disperse and reactive, appear to be the most immunogenic. Patch tests are typically used to test the immunogenicity of various dyes. Textile dye mix, which is a composition of some of the most immunoreactive dyes, is commonly used to test for textile dye allergies [15]. Textile dye mix is composed of one anthraquinone type dye (Disperse Blue 35), and seven azo type dyes (Disperse Orange 1, Disperse Orange 3, Disperse Red 1, Disperse Red 17, Disperse Yellow 3, Disperse Blue 106, and Disperse Blue 124). One study found that the dyes in the mix that most often trigger a positive patch test were Disperse Orange 3 and Disperse Blue 106 [15]. Another study found that Disperse Blue 106 was a very potent sensitizer, with an EC3 of 0.015%, and concluded that Disperse Blue 106 should not be used in textiles with consumer use [16]. EC3 is a measure of skin sensitization potency, with values less than 0.1% considered extreme sensitizers based on local lymph node assays. Since patch tests typically use concentrations of 1%, they pose the risk of inducing sensitization to extreme sensitizer dyes [16]. In cultured human keratinocytes, Disperse Red 1 was found to have immunotoxic properties, by inducing the production of the cytokine IL-12 [17].
Some reactive dyes have been associated with dermal reactions and respiratory symptoms [18]. Based on the presence of serum immunoglobulin E (IgE) antibodies to reactive dyes, it is thought that these symptoms are IgE-mediated, and that airborne dye molecules may act as haptens, or small molecules that elicit immune reactions when combined with carrier proteins, to induce respiratory reactions [18]. These effects are most common in individuals working in the textile industry [18]. Exposure to these dyes was found to be a major cause of occupational asthma in Korea [18]. Reactive Black GR dye was the reactive dye that was most commonly associated with asthma [18]. In cultured human keratinocytes, the reactive dyes Reactive Green 19 and Reactive Blue 2 were found to enhance the production of reactive oxygen species (ROS) and promote the upregulation of metalloproteases MMP-2 and MMP-9 [17].

Multiple chemical sensitivity: POTENTIAL RISK
Multiple chemical sensitivity (MCS), which is also called idiopathic environmental intolerance, is a multisystem disorder that manifests in response to exposure to various chemicals or environmental

contaminants [5]. Individuals with MCS are sensitive to these environmental contaminants at levels that are below the established levels of toxicity for the general population. MCS is not recognized by the World Health Organization, and is considered a controversial diagnosis due to the lack of objective pathophysiological processes [6]. Many consider MCS to be a disorder of psychosomatic origin due to the high rates of anxiety and other psychiatric symptoms in this population, however, there is increasing evidence to support a role for neurogenic inflammation, and the impacts to the CNS may manifest as psychiatric symptoms [5]. It is characterized by six major criteria: (1) it is a chronic condition; (2) there are reproducible symptoms; (3) multiple organ systems are affected; (4) the responses occur under conditions of low-level exposure; (5) symptoms stem from multiple unrelated chemical triggers, and (6) the symptoms improve or resolve when the trigger is removed [19]. The major symptom classes include neurocognitive, physical, gastrointestinal, dermatological, respiratory, anxiety-depressive, hyperosmia (sensitivity to smells), and asthenia (fatigue) [6].

Risk factors: The prevalence varies widely across studies ranging from 3% to 26%, depending on the population [20]. Susceptibility to MCS is multifaceted, involving numerous gene-environment interactions. Occupational exposure to chemicals is a major risk factor. Female sex is also a risk factor, as women make up around 80% of MCS cases [21]. Oxidative stress and inflammation appear to be major contributors to the development and expression of MCS. In the Danish population based DanFunD study (n=9,656), individuals with MCS and functional somatic disorders had higher rates of insulin resistance and impaired glucose metabolism, relative to the general population, which may be related to elevated levels of oxidative stress in these individuals [22]. Due to the complexity of gene-environment interactions, there are no clear causally implicated genes, though variants in several genes involved in xenobiotic metabolism phase I and II, antioxidant defense, lipid metabolism and one-carbon pathway have been identified in gene association studies [23]. Variants resulting in reduced capacity for detoxification and coping with oxidative stress have been associated with increased risk for MCS. These include the SOD2 Val16Ala polymorphism (rs4880), in which the Ala/Ala (OR: 4.30, 95% CI 1.23 to 15.03) and Ala/Val (OR: 4.53, 95% CI 1.52 to 13.51) genotypes were more prevalent in individuals with MCS, relative to controls [24]. The adenosine receptor 2A (ADORA2A) is present on nearly all immune cells, and low levels are associated with higher rates of inflammation [23]. The ADORA2A rs2298383 TT variant was found to be more prevalent in individuals with MCS (OR: 2.86, CI 95% 1.99 to 4.12). mRNA levels of ADORA2A were lower in those with the TT genotype, while levels of the pro-inflammatory cytokine IFN-gamma, and the cytokine IL-4, which is involved in mast cell activation, were found to be elevated [23]. Mast cell activation has been implicated in MCS based on overlap with mast cell activation syndrome in terms of chemical triggers [25]. The extremely fast activation of mast cells may account for

the rapid onset of symptoms following exposure to triggering chemicals in individuals with MCS. Paraoxonase-1 (PON1) encodes a glycoprotein that counteracts atherosclerosis by protecting low-density lipoprotein (LDL) against oxidative modification and promoting the antioxidant activity of high-density lipoprotein (HDL) [26]. It also plays a role in the biodegradation of many organophosphates, including pesticides and nerve gases. Individuals with the PON1 rs662 (PON1 A575G) and PON1 rs705379 (PON1 C-108T) genotypes have a reduced capacity to cope with oxidative stress, and have been found to be more prone to neurological symptoms, as well as depression and anxiety symptoms in the context of MCS and other chemical exposure-related disorders, such as Gulf War syndrome [26].

Biomarkers: Due to the variability in triggers and symptoms across individuals with MCS, there are efforts to develop more reliable biomarkers. Aside from differences in neural processing to odorants based on imaging measures [5], there are studies suggesting differences in serum profiles as well as the profile of exhaled volatiles in the breath. Stemming from the association between lower tolerance to oxidative stress with MCS, markers of oxidative stress and antioxidant capacity, such as ROS, malondialdehyde (MDA), 4-hydroxynonenal (4-HNE), superoxide dismutase (SOD), glutathione, and total antioxidant capacity have been proposed as relevant biomarkers [27]. Immune biomarkers have also been proposed, due to the role of immune hyperactivity in allergic responses, however, there has been considerable variability across studies in terms of cytokines and autoantibodies, suggesting MCS is not associated with a distinct immune profile [27]. For example, one study found that hypersensitivity to an odorant (n-butanol) in terms of psychological symptoms, was not associated with altered upper airway cytokine levels and inflammation [28]. A study found that volatile organic compounds in exhaled breath could be used to differentiate individuals with MCS from controls, and that those with MCS had a profile that was similar to what is seen in individuals exposed to polluted air and experiencing hypoxia [29]. Excessive free radicals/oxidative stressors are hypothesized to drive a cycle stimulating tissue hypoxia and compensatory hyperventilation.

Treatments: There are currently no clinically validated treatments for MCS. Low dose immunotherapy is an alternative treatment to traditional allergy shots that covers a broader range of irritants, and is thought to reset the immune system to promote tolerance to the allergens [30]. An *ex vivo* study in 47 patients with food and chemical sensitivities found that low-dose immunotherapy reduced lymphocytic intracellular calcium ion concentrations, leading to a normalization of immune cell signaling in response to test allergens [30]. Pilot trials testing mindfulness-based cognitive therapy have found minor benefits on illness perceptions, but have failed to show significant benefits in terms of reducing symptoms of

anxiety and depression or improving quality of life measures [31]. A case study in a woman with right parietal lobe epilepsy noted that starting treatment with the anti-epileptic drug levetiracetam (250 mg/day) eliminated her MCS symptoms, suggesting that glutamatergic overactivation may have played a role in the manifestation of her MCS symptoms [32]. Sensitization of the NMDA glutamate receptor is hypothesized to play a role in MCS, as excessive oxidative species can lead to NMDAR activation and foster a cycle of excessive glutamate release and toxicity [29].

Safety: Risks are highest in those exposed to new, unwashed garments, such as those working in the textile/fashion industry. Washing clothing and wearing neutral colored natural fiber garments can reduce exposure to textile toxins.

Types of evidence:

- 2 meta-analyses on PFAS
- 1 review on PFAS and human health
- 2 reviews on PBDEs and human health
- 2 studies on the prevalence of azo dyes
- Numerous laboratory studies

While the safety profile for the vast majority of chemicals used in clothing and other textiles has not been established, there are some chemicals which have been associated with increased risks for toxicity in various organ systems. According to the Swedish Chemical Agency, approximately 10% of the 2,400 textile-related chemicals have shown potential hazards to human health, while 5% are considered hazards for the environment (KEMI 2014).

Textile dyes: There are multiple classes of textile dyes, including acid, basic, direct, disperse, mordant, reactive, sulfur, azoic, and vat dyes [17].
Disperse azobenzene dyes are synthetic dyes used to color synthetic fabrics such as polyester, nylon, and acrylic [33]. They are the most commonly used dyes today, encompassing approximately 70% of the dyes used as industrial colorants. Due to their low molecular weight and lipophilic nature, disperse dyes are able to penetrate the skin, and consequently are the most allergenic. Some disperse azo dyes have been shown to be mutagenic and genotoxic, stemming from their ability to release carcinogenic aromatic amines (arylamines) via reductive cleavage. The majority of disperse azo dyes used in the textile industry are currently unregulated. A study investigating the presence of these dyes in the

Swedish textile market detected 62 azo disperse dyes, with Disperse Red 167:1 as the most common, occurring in 67% of garments [34]. Arylamines were detected at high levels in many of the garments, exceeding 1 mg/g, with halogenated dinitroanilines detected at 3 mg/g, which is 100 times higher than the upper limit set by the EU. Notably, the majority of the azo disperse dyes detected in the garments were distinct from those contained in the textile mix included in the European baseline patch test series (Disperse Orange 1 and 3, Disperse Red 1 and 17, Disperse Yellow 3, Disperse Blue 106 and 124) as established allergens. This suggests that many of the unregulated disperse azo dyes may also have immunotoxic properties. The increasing use of potentially toxic azo dyes may have health implications, as a study has found that these dyes are common components of household dust. Based on the dyes found in dust from a sample of 124 households, black-colored textiles may be an important source of azobenzene disperse dyes found in household dust [33]. The azo dyes were frequently found in conjunction with other textile-related chemicals, such as flame retardants. To date, biomarkers of exposure to azobenzene disperse dyes have not been established.

Reactive dyes are the most permanent dyes, and offer the best color fastness, as they react with fibers to form a covalent bond [35]. These fiber reactive dyes are primarily used on cellulosic fabrics, such as cotton, hemp, linen, viscose, rayon, and bamboo. Reactive dyes have also been associated with dermal reactions and are a major source of occupational allergic respiratory reactions, such as asthma [18].

PFAS, often referred to as 'forever chemicals' have gained a lot of attention in recent years due to their pervasiveness in the environment and in our bodies. The half-lives of some of the most common PFAS are around two to four years, with long chain PFAS exhibiting longer half-lives than short chain PFAS [36]. The bioaccumulation of PFAS is a major driver of their potential to induce toxicity. PFOA and perfluorooctane sulfonic acid (PFOS) have been phased out of production due to guidance from the FDA in 2016 (FDA). However, there are thousands of PFAS, and hundreds of PFAS currently in use have little or no toxicology data. In many cases, products that had previously used PFOA and PFOS have switched to using other PFAS [1]. As a result, many products that claim not to contain PFOA or PFOS could still pose health risks. Approximately half the states in the U.S. have enacted some type of restrictions regarding the use of PFAS in consumer products [37]. However, the majority of these regulations are aimed at food packaging, and only two states, NY and CA, currently have restrictions for PFAS levels in clothing. PFAS are widely used in clothing to confer water/stain resistance, such as products containing Gore-Tex technology. PFAS have been associated with metabolic and liver toxicity, which may be related to the disruption of PPAR signaling [1]. A meta-analysis including 24 epidemiological studies found that exposure to PFOA, PFOS, and perfluorononanoic acid (PFNA) were associated with elevated levels of the liver enzyme alanine aminotransferase (ALT) [38]. In mice, PFOS exposure promotes hepatic steatosis,

and was found to prevent the metabolic benefits of calorie restriction and metformin [39]. Exposure to PFAS has been associated with impaired immune function, including reduced efficacy of vaccines [1]. A meta-analysis including 14 studies with approximately 4,830 participants assessed the impacts of PFAS (PFOA and PFOS) on antibody levels following vaccination with tetanus (n = 7), diphtheria (n=6), measles (n=4), rubella (n=3), Haemophilus influenzae type b (n=2), influenza A H1N1 (n=2), hepatitis A (n=1), hepatitis B (n=1), influenza A H2N3 (n=1), influenza B (n=1), and mumps (n=1) [40]. There were inverse associations between PFAS levels and serum antibody levels, in which higher PFAS levels were associated with a less productive antibody response. The strongest associations were between PFOA with diphtheria, tetanus, and rubella, PFOS with rubella, as well as perfluorohexane sulfonate (PFHxS) with rubella. PFAS have been associated with endocrine disrupting effects, including lower testosterone levels and sperm count in men, as well as hypothyroidism. PFAS have been associated with cardiovascular effects in some studies, particularly arterial thrombosis, however, the effects have been mixed across studies [1]. PFAS have also been identified as possible carcinogens.
Biomarkers: PFAS can be measured in the serum.According to a report by the National Academy of Sciences, serum levels over 20 ng/mL are cause for concern, and levels between 2-20 ng/mL may be associated with adverse health effects in sensitive populations [41]. In 2022, the EPA proposed health advisory values for PFAS, and levels over these values may negatively impact health outcomes. The health advisory values are 0.004 ppt (parts per trillion) for PFOA, 0.02 ppt for PFOS, 10 ppt for Gex chemicals, and 2,000 ppt for perfluorobutane sulfonate (PFBS) (EPA Public Webinar) .

Brominated flame retardants such as polybrominated diphenyl ethers (PBDEs) have been associated with a variety of adverse health effects [2]. Since PBDEs are not chemically bonded to the fibers, they are readily released into the environment, including into the bloodstream of an individual wearing a PBDE-containing garment [2]. Due to their lipophilic nature, they readily bind organic matter, and have long half-lives of approximately 28 years. They can enter soil and water, leading to the contamination of our food and waterways, which are the major sources by which PBDEs enter the body [2; 42]. PBDEs can also be shed into household dust and be ingested as airborne particles [2]. Brominated flame retardants can damage mitochondrial DNA and interfere with mitochondrial function, leading to metabolic dysfunction [42]. They are considered obesogens due to their effects on genes involved in glucose and lipid metabolism, and have been shown to promote non-alcoholic fatty liver disease (NAFLD) in animal models. In rats, PBDEs are associated with oxidative damage stemming from insufficient levels of NAD+ and antioxidants, leading to hyperglycemia [2]. Preclinical studies suggest they are pro-atherogenic, since brominated flame retardants are able to traverse the vascular walls, and promote foam cell formation due to their effects on cholesterol production and inflammatory cytokine secretion [42].

Oxidative stress damage induced by PBDEs has been found to cause toxicity to the liver, kidneys, thyroid, brain, gut, and immune system in preclinical models [2]. PBDEs can be measured in human biofluids, including serum, and have been tracked in the U.S. population as part of the National Health and Nutrition Examination Survey (NHANES) study. PBDEs are defined by their number and position of their bromine atoms, and are referred to as congeners. PBDE congeners with detection frequencies over 60% in all demographic groups included BDE28 (90%), BDE47 (100%), BDE99 (99%), BDE100 (100%), BDE153 (100%), and BB153 (77%) [43].

Sources and dosing:

Synthetic clothing and performance fabrics: Synthetic fabrics, such as polyester, nylon, acrylic, and elastane (spandex), generally contain higher loads of textile toxins, relative to natural fiber fabrics, particularly with respect to dye allergens, such disperse azo dyes, which are the predominate dyes used to color synthetic fabrics. Chemical loads are also high in semi-synthetic cellulose-derived fibers, such as acetate and rayon (viscose). Brightly colored synthetic and semi-synthetic clothing, particularly oranges and reds, are most likely to contain highly allergenic azo dyes, such as those included in the textile dye mix used in patch testing. Additionally, chemical treatment, often involving members of the PFAS family, is used in the formation of performance fabrics, such as those indicated by the labels for stain resistance, wrinkle resistant, static resistant, permanent press, stain-proof, and moth repellent. PFAS are also present in a variety of other personal care products, such as menstrual products and dental floss [44; 45]. Fire retardant fabrics typically contain PBDEs.
Alternative: Organic neutral colored natural fiber clothing, such as cotton, merino wool, cashmere, linen, and silk, tend to have a lower chemical load because fewer chemicals are needed for processing the fibers into clothing, and the dyes preferentially used for these fabrics tend to be less toxic and carry lower levels of heavy metal contaminants. Neutral colored undyed or minimally dyed clothing further reduces the risk for exposure to potentially irritating dyes. It is important to seek out organic fibers for plant fiber-based fabrics, because pesticide and herbicide residue can become imbedded in the fibers, which are not readily removed during manufacturing or through routine washing.

Testing for textile toxins:
Textile manufacturers can send out their garments for testing for a wide range of chemicals and heavy metals, but aside from products designed for use in children, this type of testing is largely voluntary. Due to the large number of chemicals used in textile manufacturing whose safety profiles have not been characterized, it is not possible to test a garment for all possible chemical irritants, however, purchasing

garments that have labels indicating that they have gone through testing for chemicals with established toxicity can greatly reduce the risk that a garment will expose an individual to dangerous levels of known toxins.

OEKO-TEX® STANDARD 100 Label ensures that every part of the garment/product has been tested and was found not to contain harmful substances including a comprehensive list of both regulated and non-regulated substances that goes beyond national and international standards. The validity of the certificate can be checked on their website based on the certificate numbers (Label Check). They have a Buying Guide which can be used to find products containing their certified label. Their Made in Green label additionally ensures that the products were manufactured according to environmental friendly and socially sustainable conditions.

Toxic-Free FUTURE: Their Retailer Report Card ranks companies based on their use of toxic chemicals.

AFIRM group: The Apparel and Footwear International RSL Management (AFIRM) group is a group of retailers who agree not to use chemicals from the Restricted Substances List (RSL) in their products based on potential harms to the worker, consumer, and/or environment, and complies with all international standards. Their mission is to reduce the impact of harmful substances in the apparel and footwear supply chain.

bluesign® is the gold standard for sustainable textiles. Items carrying a bluesign PRODUCT or APPROVED label have been manufactured to strict safety and environmental requirements.

ZDHC Roadmap to Zero leads the fashion industry to eliminate harmful chemicals from its global supply chain. ZDHC is an organization comprising over 320 signatories from across the industry including Brands, Suppliers, Solution Providers and Chemical Suppliers. Members adhere to a restricted substance list and wastewater testing.

Once a garment has been purchased, there are some additional tests that an individual can perform to look for the presence of specific toxins.

PFAS: A simple test for PFAS on clothing is the water droplet test (Ecology Center). Since PFAS allow fabrics to repel water, if a drop of water beads up and rolls off without leaving residue, there is a strong likelihood that the garment contains PFAS. Whereas, if the water soaks into the fabric, it likely does not

contain PFAS. Due to the naturally water repellent properties of wool, this test does not work well for wool.

Lead: Some lead test kits can be used to detect the presence of metallurgic lead dust in clothing.

Strategies to remove toxins from clothing:

Newly manufactured clothing contains the highest levels of toxins, which is why individuals that work in garment manufacturing or in the fashion industry are at highest risk for toxin exposure. New garments should be washed prior to wearing them. It is claimed that up to 60% of formaldehyde can be removed by washing. The use of white vinegar, borax, or baking soda may ensure better formaldehyde removal. Air hanging clothing to off-gas for at least 12 hours may also be beneficial. Dry cleaning should be avoided, as the process adds to the chemical load of clothing. Hand washing is best, but eco-friendly dry cleaning, such as wet cleaning and liquid carbon dioxide cleaning, which do not use toxic chemicals, are good alternatives. Although the overall chemical load decreases with repeated washing, the exposure to some volatile PFAS can actually increase with repeated washing and wearing [46]. Some specially formulated brands of laundry detergent can remove heavy metal contaminants from clothing.

Research underway:

There are efforts underway to develop safer dyes, as well as to develop methods to safely extract chemicals from textile manufacturing wastewater. The BioColour Project is working to develop biobased dyes and pigments.

Search terms:

Pubmed, Google: Textile toxins, PFAS, PBDEs, Textile dyes

- Alzheimer's disease, neurodegeneration, dementia, cogntion, multiple chemical sensitivity, cancer, allergens, biomarkers, metabolism, toxicity, safety

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