

The Toxicities of Laundry Products in the Home: A Review and Commentary on Environmental Oncology

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Received Date: July 04 2022

Accepted Date: July 05 2022

Published Date: August 04 2022

Abstract

This review of the aggregated data to date finds the overwhelming weight of the evidence supports the contention that many laundry products, via contained ingredients and byproducts such as phthalates, plasticizers, bisphenols, polybrominated diphenyl ethers (PBDEs), polycyclic aromatic hydrocarbons (PAHs), phenols, per- and polyfluoroalkyl substances (PFAS) known as “forever chemicals”, and the contaminant 1,4-dioxane, add significant elevated risk to humans in the reproductive/fertility; respiratory/pulmonary (asthma, cardiopulmonary disease); neurological/cognitive (ADHD, autism); metabolic (diabetes, obesity); and oncogenic (cancer) domains of human health. We focus discussion on the toxicity of these laundry products, the subject of much research and regulatory scrutiny, in order to provide a new understanding of the current state-of-the-art in environmental oncology as it concerns these toxins. We also provide a summary of existing and emerging legislation to regulate and thereby limit the potential multifaceted harms of these products. Concerns have been sufficiently serious and well evidenced that most of these toxic chemicals have been banned in the EU and dozens of nations, with pending prohibitions in over a dozen states in the U.S., and with major retailers now pledging for their elimination from cosmetics, personal care and household products in the near future. But as both a corrective, and a motivation, we also document some of the regulatory resistance and inertia that regrettably impedes more aggressive action.

Overview of the Dangers: Our review of the aggregated

data to date finds the weight of the evidence demonstrating that among household, personal care, and cosmetic products, fragranced laundry products and dryer sheets in particular, add significant risk to humans in various domains, especially (1) reproductive/fertility, stemming largely from endocrine disrupting chemical (EDC) components like phthalates, bisphenols, and parabens that can dysregulate estrogen pathways, and can also serve as “pubertal influencers”, advancing to younger years the age of puberty; (2) respiratory/pulmonary, in particular asthma and cardiopulmonary diseases; (3) neurological/cognitive, in terms of components that can exert neurotoxic activity, with adverse impact on ADHD and autism, among others; (4) metabolic disease, especially diabetes and obesity, with components said to be obesogenic; (5) and oncologic, via increased risk of endocrine-related cancers, especially breast, prostate, and colorectal cancers, as well other malignancies.

Numerous extensive investigations and aggregated scientific safety and toxicity studies have concluded that common products used in the laundry process contain complex mixtures of endocrine-disrupting compounds (EDCs) and asthma-related compounds [Dodson 2012]. Endocrine disrupting compounds (EDCs) are agents that can alter hormonal signaling and the expected normal functioning of the endocrine system in both humans and animals via mimicking estrogen, and have potential effects on developing reproductive and nervous systems, metabolism, and cancer development and outcome, and can also be associated with adverse developmental effects and in humans [Colborn 1993] [Parlett 2013] [Jurewicz 2011] [Chen 2014] [Ventrice 2014] [Lee 2022]. The most common EDCs are dioxins, polychlorinated biphenyls (PCBs), bisphenol A (BPA), perfluoroalkyl and polyfluoroalkyl substances (PFAS), and parabens. These are found in detergents including plasticizers, commonly phthalates, used in these laundry detergents to increase the separation of particles to prevent clumping and improve a material's plasticity or fluidity, and in plastics, children's toys, foods, cosmetics, and some pharmaceuticals [NIEHS].

The implications in the oncology setting alone are extensive. Consider that systematic review and meta-analysis has concluded that exposure to these EDCs is strongly linked to dysregulated inflammatory responses, via their association with circulating levels of inflammatory markers like C-reactive protein (CRP) and interleukin (IL)-6, among others [Liu 2022] [Danforth 2021]. In turn, research from University of Pennsylvania researchers from their nested case-control study

that drew cases and controls from the WABC-II (Wellness After Breast Cancer-II Cohort) prospective cohort study provides plausible evidence that levels of serum inflammatory protein CRP is independently associated with an increased breast cancer relapse risk in hormone-positive / HER2-negative (HR+/HER2-) breast cancer in the adjuvant setting [McAndrew 2021], and there is further systematic review and meta-analytic evidence that high serum CRP in metastatic breast cancer patients is an indicator of poor prognosis [Mikkelsen 2022], these associations are being validated across multiple malignancy types. At the genome level, we have the findings of the WHI dbGaP (Women's Health Initiative Database for Genotypes and Phenotypes) Study, a genome-wide association study (GWAS) [Jung 2021a] and the first study characterizing genetic determinants of inflammatory cytokines, especially CRP and IL-6, and the genomic associations of these inflammatory markers with breast cancer development, and the same researchers documented the potential causal relationship between genetically elevated CRP concentrations and postmenopausal invasive breast cancer, under influence of particular lifestyle factors and breast cancer subtypes, using a Mendelian randomization approach [Jung 2021b]. There are similar findings for the association between IL-6 and CRP in other malignancies like colorectal cancer (CRC) [Ose 2022] [An 2022] [Hidayat 2021], and the oncogenic effect of EDCs extends to endometriosis [Wieczorek 2022], and prostate cancer [Bleak 2021] [Corti 2022] [Lacouture 2022], among still other malignancy types [Michels 2021].

Phthalates, also being endocrine disruptors, are used in fragrances, home and personal care products, and laundry products, and because they are semi-volatile, they are found in indoor air and dust, with exposure to humans via inhalation, ingestion, and skin absorption. In addition, note that phthalates – like DEP (diethyl phthalate) – are often added to fragrance to make the scent linger, so are extremely common in all scented products including dryer sheets and softeners. These phthalates (Phth), known endocrine-disruptors, may play a role in breast carcinogenesis. Low-molecular-weight phthalates (LMWPhth) are commonly found in personal care products while high MWPhth (HMWPhth) are used primarily as plasticizers. The weight of the scientific evidence finds that phthalates are associated with asthma and wheezing in children [Bornehag 2010] [Kumar 1995] [Parks 2020], among other harms (see below), as are other common laundry agents. The specific epidemiology of one of these, asthma-related QACs (quaternary ammonium compounds, aka “quats”) has been documented extensively by the Mount Sinai Selikoff Centers for Occupational Health (SSCOH) in collaboration with the Bellevue/NYU Occupational & Environmental Medicine Clinic (BNOEMC) [SSCOH/BNOEMC 2016].

This has led to numerous calls by environmental scientists for the total prohibition of such agents from all consumer products. Consider Project TENDR (Targeting Environmental

Neuro-Development Risks) [<http://projecttendr.com/>], led by Dr. Russ Hauser, Professor of Reproductive Physiology and Professor of Environmental and Occupational Epidemiology at Harvard T.H. Chan School of Public Health, which recently issued, along with experts in toxic chemicals and neurodevelopment, a National Call to Action (“Why phthalates should be restricted or banned from consumer products” [Hauser 2021]), supported by the National Institute of Environmental Health Sciences (NIEHS) National Toxicology Program (NTP); the Center for Environmental Research and Children's Health (CERCH); the American Academy of Pediatrics Environmental Health Council; the Environmental Defense Fund (EDF); the Collaborative on Health and the Environment (CHE); the National Medical Association Commission on Environmental Health; the Science and Environmental Health Network (SEHN); the Natural Resources Defense Council (NRDC); and the Children's Environmental Health Network (CEHN), among dozens of others across the nation. (See our summary of legislation below). Collectively, on the neurological front alone, there is overwhelming scientific evidence linking these toxic environmental chemicals to neurodevelopmental disorders that can impair brain development and increase risks for learning, attention, and behavioral disorders in childhood, including autism spectrum disorder (ASD), attention deficits, hyperactivity, intellectual disability and learning disorders [Engel 2021] with bisphenols similarly associated with cognitive deficits and attention-deficit disorder in children following prenatal exposure [Kahn 2020].

Hazards in the Laundry: The labeling terms “natural,” “non-toxic,” and “green” are unregulated and require no standardized ingredient information. Indeed, a recent study [Steinemann 2011] found that the volatile organic compound (VOC) composition of “green”-labeled fragranced products was not significantly different from that of other fragranced products with regard to number of hazardous chemicals as defined under U.S. federal laws [Potera 2011]. Testing by the Environmental Working Group (EWG) has also revealed that 75% of the fragrances contain phthalates, linked to diabetes, obesity and hormone (endocrine) disruption which affects both development and fertility, and the Mt. Sinai Children's Environmental Health Center (CEHC) has linked early prenatal exposure to synthetic fragrance that includes endocrine disruptors (as with dryer sheets), both to ADHD and autism [Landrigan 2012] [Mount Sinai 2012] [Bagasra 2013]. Recognizing that household dust is a vast repository of consumer product chemicals and pollutants, researchers at UC Davis conducted a large study of these potentially hazardous agents in California house dust [Shin 2020], including semi-volatile organic compounds (SVOCs) for which household dust is a reservoir, finding that in the 119 newly detected compounds, 13 had endocrine-disrupting potential, while another 7 had neurotoxic potential. These included phthalates; plasticizers; phenols and bisphenols; PBDEs (polybrominated diphenyl ethers); OP-FRs (organophosphate flame retar-

dants); PAHs (polycyclic aromatic hydrocarbons); and PFAS. One large analysis investigated 1135 chemicals in cleaning products and 886 in laundry products with potential reproductive and estrogen-receptor mediated (ER-mediated) toxicities using the European Union CLP (Classification, Labeling and Packaging) classification and the EPA's ToxCast database, identifying 53 with potential reproductive toxicity and 310 with potential ER-mediated toxicity [Lee 2021], suggesting extensive potential EDC exposure from laundry detergents and household cleaners. Given the high level of hazards stemming from toxins and contaminants in laundry products, the environmental education group, the Hitchcock Center, has called them "wearable air pollution" [Dover 2012], supporting seminal studies on dryer air vent emissions [Goodman 2019] [Steinmann 2013]. In addition, scented laundry product emissions emanating from dryer vents during the normal process of clothes washing, in the home and in commercial locations, are categorized as an "exposure context" for adverse consequences on human health [Steinmann 2021], and motivate fragrance-free policies in indoor environments, workplaces, schools, health care facilities, and public buildings [Steinmann 2019a], justified in part by the fact that on an average 32.2% of the general population the United States, Australia, the United Kingdom, and Sweden report adverse health effects when exposed to fragranced products, higher in asthmatic (57.8%) and in autism spectrum disorders/ASD (75.8%), populations [Steinmann 2019b].

PFAS in the Laundry - and in Us - Forever

This latter group of chemicals, the PFAS (per- and polyfluoroalkyl substances) represents a class of thousands of chemicals used in cosmetics, laundry products, household cleaning products, cookware and food packaging, carpeting, outdoor attire, firefighting foams and in almost innumerable industrial processes, before being discharged into our waterways and which are linked to cancer promotion, hormone disruption, immune suppression, and adverse reproductive functioning. Because of the fact that they are highly resistant to breaking down in the environment and so may be with us forever, they are commonly called "forever chemicals", and can be found in the blood, breast milk, and a newborn baby's umbilical cord blood [Perfluorochemicals CDC 2017]. And contrary to constant reassurance by the chemical industry that current use of PFAS does not build up in humans, recent evidence decisively shows the opposite. In a recent study [Zheng 2021] these toxic PFAS chemicals were found in 100% of breast milk samples in mothers tested in the United States, exposing nursing infants to significant harms, including the later development of immune dysfunction, dyslipidemia, pregnancy-induced hypertension, damage to the liver, elevated risk of thyroid disease, reduced fertility, and various cancers [Rappazo 2017] [Sunderland 2019]. And it is demonstrated that current-use short-chain PFAS have been increasing worldwide, doubling about every 4 years [Zheng 2021]. Finally, there's mounting evidence that PFAS exposure may exert immunotoxic activity, compromising the effective antibody immune response,

especially critical in vulnerable populations, including infants and children, requiring COVID-19 vaccination [Quinete 2021] [Catelan 2021] [Grandjean 2017]. At this time, both extensive research efforts, and regulatory activity in PFAS identification, toxicity, pervasiveness, remediation and mitigation are ongoing and accelerating across the globe, and there is now widespread recognition of PFAS being a critical health hazard facing the modern world [Panieri 2022] [Newell 2022] [Antoniou 2022] [Brennan 2021] [Bell 2021]; see below for more.

The Fragrance-Free Myth

Note that although many of these products may be labeled as 'fragrance-free' they may still contain fragrance compounds if those are used not for scent per se, but rather as preservatives or fixatives. In a seminal study of effective volatile organic compound (VOC)-reduction strategies [Goodman 2019], researchers conducted a comprehensive investigation of emissions from dryer vents during use of fragranced versus fragrance-free laundry products, showing that the simple strategy of changing from fragranced to fragrance-free products can be an effective approach to reducing ambient air pollution and potential health risks. Thus, in households using fragranced laundry detergents, the highest concentration of d-limonene (a common fragrance agent found in laundry products like dryer sheets and detergents) from a dryer vent was 118 µg/m³, compared to just 0.26 µg/m³ in households using only fragrance-free laundry products, and after households using fragranced detergent switched to using fragrance-free detergent, the concentrations of d-limonene in dryer vent emissions were reduced by up to 99.7%. D-limonene is associated with multiple adverse effects, including breathing difficulties manifested in wheezing or coughing [NICNAS 2002], and can react with ozone to generate hazardous air pollutants which include formaldehyde, acetaldehyde, and ultrafine particles, known respiratory irritants and carcinogens [Nazaroff 2004]. As one extensive review noted, "these fragrance compounds are wolves in sheep's clothing", referring to constituents of phthalates, parabens, and essential oils, among others, found in household cleaning/fragrant agents including laundry detergents, given their long-term health perils secondary to their ability to dysregulate hormonal signaling systems [Patel 2017]. In addition, laundry detergents, laundry drying sheets, fabric softeners are evidenced to contain and constitute artificial fragrances that are both "optional and hazardous commodities" [Patel 2021]. Moreover, researchers investigating the specific hazard of neurotoxicity of these fragrance products have found that of a vast array of commercial products, these laundry product toxins contained the highest number and concentration of endocrine disruptors (and of asthma-triggering compounds) [Pinkas 2017]. In the U.S. 12.5% of adults reported adverse health effects (asthma attacks, migraine headaches) from the fragrance of laundry products emitting from a dryer vent, with 28.9% of adults with diagnosed asthma or an asthma-like condition reporting adverse health effects from these dryer-vent fragrances [Steinmann 2018; 2018c]. It has been

noted that the pathologies triggered by endocrine disrupting compounds (EDCs) include neuropathies like depression and autism; malignant disease like breast cancer and prostate cancer; endocrinopathies like gynecomastia; organ damage like hepatotoxicity, among many others [Patel 2017]. On a positive note, as we noted above it has been demonstrated that switching from fragranced to fragrance-free laundry products allows dryer vent emissions of a leading contaminant and environmental pollutant, limonene, to be reduced up to 99.7% [Goodman 2021].

The Cancer Connection: In addition, there are “secondary hazard” effects: limonene and other volatile aromatic terpenes (pine, citrus oils, essential oils) react with ozone present in the surrounding air to generate secondary pollutants that include formaldehyde (probable human carcinogen), acetaldehyde (probable human carcinogen), acetone (respiratory / pulmonary irritant), and ultra-fine particles known as PM0.1, particles classified by the International Agency for Research on Cancer (IARC) and the US National Toxicology Program (NTP) as Group 1 human carcinogens, associated with lung cancer and as well as cardiopulmonary disease) [ACS]. Another class of agents commonly used in dryer sheets is nonylphenol ethoxylates (or NPEs), a mix of petrochemical cleaning agents also used in many laundry detergents as surfactants, lowering the surface tension of water to allow for a deeper cleaning and penetration. And it is known that certain agents like dichlorobenzene can not only induce short-term irritation of the skin, throat and eyes, but have chronic, long-term effects on the liver, skin, and central nervous system (CNS), which has led the United States Environmental Protection Agency (EPA) to warn of it being suspected to cause human cancer, therefore classifying it as a possible human carcinogen [EPA 1999.]. But despite being completely banned in Canada and the EU, these agents are still found in laundry products in the U.S.

The connection of these agents to breast cancer has been particularly well researched and documented. Most alarmingly, new human clinical evidence from the Multiethnic Cohort Study of 798 women presented June (2020) shows that phthalate exposure – and also parabens [BCPP Parabens] and other EDCs – is associated with increased risk of invasive breast cancer [Wu 2020], and may be higher risk still in subgroups of women with greater genetic susceptibility such as women with BRCA-mutations, as shown in a systematic review of 56 studies [Zeinomar 2020], cross-validating other critical studies [Terry 2019] [Ahern 2019]. A widely used class of phthalates, known as high molecular weight phthalates (HMWPhth) are used primarily as plasticizers found in a broad swatch of products from personal care to laundry products including dryer sheets, but in the notoriously underregulated U.S. markets, producers are not required by the FDA to list all ingredients in a product, only so-called “active ingredients”, and numerous individual chemicals in cosmetics like phthalates in fragrances are not required to be labeled,

and so represent a hidden danger to the consumer [BCPP Phthalates]. This is in contrast to the EU where full-disclosure is required, and endocrine disruptors like phthalates and parabens have already been prohibited since 2005.

We also have several epidemiological studies linking endocrine disrupting compound (EDC) exposure with breast cancer risk, and still more importantly, with poor prognosis, which include the case-control study finding increased risk of breast cancer in North Mexico states among women exposed to diethyl phthalate [Lopez-Carrillo 2010], in agreement with the reviews from The Silent Spring Institute [Rodgers 2018], and the “Coimbra” Review [Encarnação 2019]. This wide spectrum and penetration of adverse effects of endocrine disrupting compound (EDC) was acknowledged by The Endocrine Society as early as 2009 in their Scientific Statement on EDCs addressing the concerns to public health based on evidence of the effects of EDCs on male [Radke 2018] and female reproduction, breast development, prostate and breast cancer, neuroendocrinology, thyroid, metabolism and obesity, and cardiovascular endocrinology [Diamanti-Kandarakis 2009], and multiple studies document that the well-known hallmarks of cancer can develop at concentrations within the range of those measured in human breast tissues [Darbre 2021]. In addition, EDCs can function as pubertal influencers, accelerating the processing of maturation of secondary sexual characteristics [Lucaccioni 2020], with recent studies accumulating evidence of exposure to EDCs during puberty predisposing to breast cancer later in life, and affecting a woman’s reproductive potential and ovarian reserve, and may influence outcome in assisted reproductive technology (ART), while elevating risk of the development of breast cancer at any age [Karwacka 2019] [Yilmaz 2020] [Giulivo 2017] [Morgan 2017], with certain EDCs in the paraben class of environmental phenols associated with 30–50% higher odds of breast cancer development and inversely associated with all-cause mortality [Parada 2019]. Indeed, using data from the National Health and Nutrition Examination Survey (NHANES) prospectively linked to National Center for Health Statistics (NCHS) mortality data, women in the United States were found to be at greater mortality risk in association with exposure to certain (ethyl, methyl, butyl), and total, parabens [Hendryx 2022].

In this connection, Breast Cancer Prevention Partners (BCPP) released a landmark report in 2018 — Right to Know: Exposing Toxic Fragrance Chemicals in Beauty, Personal Care and Cleaning Products [BCPP Right to Know]. The report exposes the presence of harmful fragrance chemicals linked to cancer, hormone disruption, reproductive harm, and respiratory toxicity, not appearing on the label, especially unregulated toxic fragrance chemicals, all tested by BCPP using state-of-the-art laboratory testing via two-dimensional gas chromatography (GCxGC) Time-of-Flight (TOF) analysis. Fragrance chemicals made up three-quarters of the toxic chemicals in the beauty, personal care and cleaning /

household products tested, with one in four of the total 338 fragrance chemicals detected linked to serious chronic health effects, as documented in their Red List of Chemicals of Concern as part of their Campaign for Safe Cosmetics [BCPP Red List]. The list included 102 chemicals found in personal care products that pose serious chronic health concerns including cancer, hormone disruption, and reproductive and developmental harm, and also now includes chemicals used in cleaning products and in fragrance (including dryer sheet), cross-confirmed by authoritative scientific bodies.

Intersecting with their oncological impact, a recent review of the evidence has found an “obesogenic” impact from EDCs including bisphenols, phthalates, biphenyls, and parabens, all common in laundry products including dryer sheets and laundry softeners, in that early life exposure to EDCs may impose an increased risk of obesity in later life [Yang 2018] [Mallhi 2011] and the effect of such exposure has further been found to correlate with increased body weight and/or body mass index during all life stages [Legeay 2017] [Liu 2019] [Liu 2017], among many other hazards including neurotoxicity, reproductive toxicity, cytotoxicity, genotoxicity, and carcinogenicity associated with the notorious bisphenol A (BPA) [Xing 2022].

Legislation, Regulation and Voluntary Restrictions

Based on the robust aggregated evidence of multiple harms, including the fact that in California, 1.6 tons of volatile organic compounds or VOCs are emitted daily from fragranced cosmetics and personal care products alone [BCPP Legislation 2020], vastly more if we add cleaning and laundry products, California now bans 24 endocrine disrupting compounds including phthalates and parabens linked to breast cancer, as of the signing into law by Gov. Gavin Newsom of the landmark Toxic-Free Cosmetics Act (TFCA), Assembly Bill 2762, as of September 30th 2020, joining the European Union and dozens of nations - including Australia, Canada, Japan, Mexico and the UK - in protecting against these widespread but hidden toxic compounds [California TFCA 2020]. SB312 also closes an abused federal labeling loophole allowing companies to claim trade secret protection for chemicals used to impart fragrance or flavor. The banned chemicals included long chain PFAS chemicals, endocrine disruptors linked to cancer and immune system suppression; the phthalates dibutyl phthalate and diethylhexyl phthalate; the parabens isobutylparaben and isopropylparaben; among others.

Besides California that has already legislated its ban through the passage in law of the Toxic-Free Cosmetics Act (TFCA), many states are moving towards bans of toxic personal care and cleaning products with other joining in near future. In addition, a move to national regulations is already underway, with several proposals currently pending in Congress, one being H.R. 5279 Amendment, the Cosmetic Safety Enhancement Act (CSEA) of 2020. Note that all phthalates are classified as dangerous substances by the European

Union’s REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) regulation. In addition, there is increasing corporate voluntary initiatives. Many environmentally conscious firms have taken the initiative to ban or progressively reduce towards ultimate elimination many of these toxic chemicals, as tracked and documented by the group Mind the Store, a program of Toxic-Free Future, which issues a Grade Report for the top retailers in their annual report, Who’s Minding the Store? — A Report Card on Retailer Actions to Eliminate Toxic Chemicals [Mind the Store 2021].

Breakthrough: New Recognition of the Toxicity of PFAS “Forever Chemicals”

Based on a comprehensive analysis of the US EPA ECHO database that provides an interface to federal and state data for over 1,500,000 regulated facilities, coupled with state-specific case studies [Andrews 2021], there are known to be over 42,000 sources of per- and polyfluoroalkyl substances (PFAS) used in thousands of industrial and consumer products and processes, including household and laundry and personal care products and cosmetics, cookware, food and food packaging, carpets, clothing, and outdoor gear, that have extremely high environmental persistence, breaking down very slowly over time and lingering for decades both in people’s bodies and in the environment, and hence known as “forever chemicals”, with risks building up over a lifetime of exposure in humans. The EPA, after consistently – and against the evidence – downplaying the extensively documented hazards of PFAS, and claiming that the levels of exposure that the EPA judged safe in humans were in fact thousands of times higher than true safe thresholds established beyond reasonable doubt by the best of scientific evidence and consensus, has on June 15, 2022 now admitted that PFAS represent “an urgent public health and environmental issue facing communities across the United States” and that safe levels of exposure to PFAS, the levels at which harms might not occur, should be thousands of times lower than the limits it first proposed back in 2016, and has issued nonbinding health advisories that set health risk thresholds for two PFAS, PFOA and PFOS, to near zero, replacing 2016 guidelines that had set them to 70 parts per trillion (ppt) [EPA 2022]. This is a remarkable move namely the EPA cutting the safe level of the PFAS chemical PFOA by more than 17,000 times the previous agency-declared tolerable limit, now down to just four parts per quadrillion, and in essence declaring that any detectable amounts of PFOA and PFOS are unsafe to consume. The critical path to this change of regulatory sentiment occurred with the EPA’s announcement on November 16, 2021 of a new PFAS Strategic Roadmap, the supporting scientific research of which was to fall under the auspices of the agency’s Science Advisory Board (EPA SAB) based on best evidence to date, with the EPA further adding that one of the most common PFAS, perfluorooctanoic acid (PFOA), is strongly evidenced as a carcinogen [EPA 2021] (As an aside for moviegoers, PFOA figured centrally in the popular film “Dark Waters” (2019)

directed by Todd Haynes).

But we need to go further, to not solely concentrate on drinking water sources and reservoirs and lakes, which are the “ends of the pipeline”, but tackle the sources that include the everyday “up-drain” consumer products that people use which are weaving their way down residential and commercial drains; as Emily Remmel, Director of Regulatory Affairs of the National Association of Clean Water Agencies (NACWA) representing wastewater authorities, has put it, “*washing your clothes, washing your face, washing your dishes*” are the significant upstream sources to contamination of drinking water facilities [Bagenstose 2022].

Regulatory Resistance and Failure of Duty of Care: Although these long-overdue recognitions are welcome, this adds to the many instances of what we call regulatory resistance and inertia to scientific evidence and consensus, given that this is in fact the first time the EPA relied on scientific data about the impact on human health of PFAS, but readily available to researchers, forcing the EPA to wholly reverse its position on safe levels of human exposure. As a result, the agency has changed its position on safe levels of exposure. Still, emerging new evidence suggests that evidence of potential human risks of many chemicals (neurological effects, birth defects, and cancer) were removed or minimized by EPA staff [Steiner 2022].

Another singular instance of such resistance concerns the New York City (NYC) Hillview Reservoir, a 90-acre water storage reservoir located in southeastern Yonkers, New York, and the last stop before treated water for human consumption by city residents enters the New York City (NYC) water distribution system. Although chemical disinfection and ultraviolet treatment can occur upstream of the Hillview Reservoir, the reservoir itself is not covered, allowing for pathogens from birds, animals and other contaminating sources to enter the water stored there. But despite regulatory requirements active against the City of New York and the NYC Department of Environmental Protection (DEP), to wit a New York State (NYS) Administrative Order in 1999, a federal regulation under the Safe Drinking Water Act (SDWA) under EPA compliance monitoring in 2005, and an EPA Administrative Order in 2010, among others, all of which required the cover and all of which were entered into and with specific agreed performance dates, the City of New York and the NYC Department of Environmental Protection (DEP) failed to meet any of the dates for the construction of the mandated cover, whose cost in 1999 was estimated to be modest. On March 18, 2019 U.S. Attorneys for the Eastern District of New York (EDNY) filed a Safe Drinking Water Act (SDWA) complaint against the City of New York and the NYC Department of Environmental Protection (DEP), seeking to require the City to cover the Hillview Reservoir, and the Eastern District of New York (EDNY) also lodged on that same date a proposed Judicial Consent Decree and Judgment with the Court that would

require the City to implement the cover and needed upgrades at the reservoir over the next thirty years, at an estimated cost of over \$2 billion, with a target date of not later than 2049. This is fifty years after the City of New York and the NYC Department of Environmental Protection (DEP) first agreed to its construction. The City of New York and its agent the NYC Department of Environmental Protection (DEP) will also pay a \$1 million penalty to the United States, a \$50,000 penalty to New York State, and implement a \$200,000 Water Quality Benefit Project [EDNY 2019]. This failure of due diligence further impacts on PFAS contamination, as it is known that avian eggs and tissues and droppings are, as the National Audubon Society has noted, “chock-full of widely used PFAS” [Audubon 2019], and hence add to PFAS recontamination of unprotected – like the uncovered Hillview facility – reservoirs, compromising human health.

Legislative Action at Local State Level: A landmark advance is New York former Governor Cuomo’s signing into law a bill (NYS Bill No. 4389B/A 6295A) [NYS Senate Bill S4389B] that bans more than trace amounts of the toxin and carcinogen 1,4-dioxane, a known contaminant and carcinogen (classified as a Group B2, probable human carcinogen, by the Environmental Protection Agency (EPA) that readily penetrates the skin and can be released to the air and breathed in, and migrates to New York’s water systems and water bodies as well as workplaces, and in a broad spectrum of products we use. 1,4-dioxane is widespread in laundry products, especially detergents, but also in cosmetic products and personal care products, and in 97% of hair relaxers, 57% of baby soaps and children’s bubble bath and body washes and so ubiquitous that in an assessment by the Environmental Working Group (EWG), it was found that 22 percent of all products for any use whatsoever may be contaminated with 1,4-dioxane [EWG Report 2007]. Note 1,4-dioxane has three principle routes: by skin penetration, by consumption of polluted water, and more rarely, by inhalation (mainly among industrial workers in close contact with it). The NYS ban officially begins to take effect January 1, 2023, with increasingly stringent requirements over a two-year period, and with California and many other states to shortly follow suit. Efforts to bring forward the start date by a year are currently ongoing. It is important to appreciate that 1,4-dioxane is a byproduct of the combination of other ingredients reacting together to form it under the process known as ethoxylation, not itself an ingredient, so it will not be found on any product label. Common ingredients that lead to 1,4-dioxane formation are from sodium laureth sulfate and other laureths; chemicals in the polyethylene glycol (PEG) class; and chemicals compounds with “xynol”, “cetareth”, “oleth” “laureate”, and “myrrh” as part of their designations.

Legislative Action at the Multi-state Level - the AG Consortium: On March 22, 2021 New York Attorney General Letitia James, leading a coalition of 15 attorneys general (NY, HI, IL, MA, ME, MD, MN, NY, OR, PA, RI, VT, VA, WA, DC, and City of New York) served legal action [NY Attorney General

2021] in support the Biden Administration's remedy against the numerous deficiencies of the EPA's risk evaluation of the highly-toxic chemical 1,4-dioxane (hereafter "dioxane"), a risk evaluation that was one of numerous "midnight" blatantly anti-environmental actions taken by the former administration in its closing days. The EPA's risk evaluation has minimized or dismissed dioxane's well evidenced dangers to workers, low-income community's residents, communities of color, and the general public, with the manifest intent to restrict the EPA from implementing regulatory measures to eliminate the substantial health risks posed by dioxane.

The action of this "AG Coalition" as we call it, seeks to support the Biden Administration's current and projected efforts to correct the many deficiencies in the EPA's dioxane risk evaluation. And given that the procedures used for chemical risk evaluations under the Toxic Substances Control Act (TSCA) have been identified as potentially contrary to President Biden's Executive Order on Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis, Executive Order No. 13990 [Executive Order Whitehouse 2021], they are therefore subject to revision, rescission, or suspension. The AG Coalition charges that the EPA under the former administration ignored both science and the law in an effort to block necessary action to address the numerous serious health and environmental dangers via a fatally-flawed risk evaluation.

The chemical is also formed as a byproduct from the breakdown of other chemicals in a variety of consumer products, including laundry and other detergents, household cleaners, and personal care products, and is released into the air, water, and soil at places where it is produced or used. The New York Public Interest Research Group (NYPIRG) has reported that at least 12 million New Yorkers drink water with some level of significant concern of 1,4-dioxane contamination, and in addition their data analysis has found that 176 water systems that impact 16 million New Yorkers contain one or more emerging contaminants, with every region in New York State affected, including Long Island's groundwater, which is the sole source of drinking water for almost 3 million state residents [NYPIRG 2019].

Because of its potential for substantial harm to public health and the environment, the EPA selected 1,4-dioxane as one of the initial 10 chemical substances subject to its initial risk evaluations, required under the TSCA amendments of 2016. That law requires the EPA to perform comprehensive evaluations of the risks associated with the "full range of exposures" people have to the chemical. The coalition argues that the EPA's 1,4-dioxane risk evaluation excludes many potential pathways and exposures. Despite the fact that 1,4-dioxane has many significant exposure pathways that expose people to the toxic chemical, including drinking contaminated water, breathing contaminated air, exposure through contaminated soil, and including exposure from

laundry products (a residue of it can be left over in clothes after washing cycles), the EPA's risk evaluation under the former administration found no "unreasonable risk" to the general public from 1,4-dioxane's numerous uses. But the EPA risk evaluation is fatally confounded by the fact that the exposure to the general public the EPA examined was limited, unrealistically, to solely recreational swimming, with no examination of exposure pathways like drinking contaminated water, and using household and laundry cleaning agents that can significantly harm people's health. The EPA is also charged by the AG Coalition with failing to assess 1,4-dioxane's exposure risks to vulnerable populations such as infants, children, pregnant women, workers, and the elderly whose risk may be substantially higher than the general public, and the EPA used the unsupported assumption that workers will use consistently, properly and effectively, personal protective equipment which is assumed, without evidence, to protect against 1,4-dioxane exposure, and by doing so the EPA underestimated the chemical's risks to workers, and succumbed to the urgings of industry trade groups intent on blocking related state-level policies [NY Attorney General 2021].

Conclusions

It is clear, as we have marshaled the evidence above, that laundry products, in such widespread use in the home, impose extensive reproductive/fertility, respiratory/pulmonary, neurological and neurocognitive, metabolic, and oncological risks to human health, both by direct exposure, and by their ultimate contamination of water distribution systems, and that these hazards are now being recognized as requiring urgent regulatory and legislative actions to curtail their use. Some of these efforts we have documented in our paper are highly commendable and are buttressed and extended by voluntary restrictions from major retailers, to their credit. But despite this, there remain as we have shown large pockets of regulatory resistance and inertia, and not infrequent politicization, we believe that must be overcome, by:

1. more comprehensive public education of the dangers,
2. more timely and mandatory legislative actions for their prohibition and mitigation of these contaminants within the many domains of their use, and
3. by more coordinated research aimed at building global scientific consensus on their maximal thresholds of safe human exposure, to replace the current patchwork quilt of unaligned and heavily siloed research endeavors.

Competing interests

Author has declared that no competing interests exist.

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