The Public Health Threat of Pollutant Exposure

Krista Bennett ND MSAOM,
Paula Mader ND MSAOM,
Lyn Patrick ND

Integrative Health Policy Consortium:
Committee on Environment and Health

Americans are experiencing a multi-dimensional health crisis that involves chronic disease and environmental exposure to toxic metals, chemicals and crippling economic stress. This situation is compounded by diminishing access to health services, an adequate number of well-educated health care providers and support for implementing cost-effective solutions. Day after day, the blood, organs and cells of American bodies are being exposed to toxic chemicals through our water, air and foods. They consistently deliver a silent supply of toxicant metals, chemicals and air pollution that disrupt and impair the vital systems that nourish health. The sources of these toxins are known and verifiable. This paper summarizes the impacts of four categories of toxicants and presents a policy path that can dissipate the crisis facing all Americans.

No one is insulated from the impacts of daily toxin exposure that generates a wide range of chronic illnesses such as cancer, obesity, diabetes, autoimmune, hormonal, neurological and behavioral diseases on which Americans spend more than 90% of their healthcare dollars. The economic costs for the American people have been accelerating for decades and the impact of the single category of hormone disrupting chemicals recently exceeded an annual cost of 340 billion dollars.

Healthcare policy options are needed that address:

- standards for medical care that include assessing levels of toxicant exposure
- education of the public and healthcare professionals
- innovation of effective medicines, technologies and delivery of care.

Responses that mitigate this American health crisis require a change of social, consumer, economic and political perspectives. Most Americans are willing to take responsibility for sustaining good health when they become aware of the threats that are avoidable and treatable. Our government and private institutions have vested interests in facilitating this outcome. This White Paper offers specific recommendations for the four daily toxicant exposures we identify here that are found in the blood and urine of most Americans: lead, arsenic, perfluorinates (the "forever chemicals"), and bisphenols.

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The Public Health Threat of Pollutant Exposure

Americans are experiencing a health crisis never before seen in our history. Those affected are not just aging Americans but young adults and children. Federal data shows that in 2019, more than half of young adults between the ages of 18-34 (nearly 54%) now deal with at least one chronic health issue. The most prevalent conditions are obesity (25.5%), depression (21.3%), and elevated blood pressure (10.7%). Almost one in every four (22%) young Americans has been diagnosed with two or more chronic conditions. Even among those without a disability or those who identified as students, the levels of chronic disease were remarkably high (46-48%). (Watson et al., 2022)

The health status of children in the U.S. is no better. Citing the National Survey of Children's Health, the Center for Disease Control (CDC) states that more than 40% of school-aged children and adolescents have at least one chronic illness. (National Survey of Children's Health [NSCH], 2021).

The CDC defines chronic illness as "conditions that last 1 year or more and require ongoing medical attention or limit activities of daily living or both." In children, this list includes asthma, obesity, epilepsy, food allergies, diabetes, and others, as well as behavioral problems. Currently, the incidence of "behavioral problems" in U.S. children is rising precipitously, far faster than evidence for better diagnosis. (National Survey of Children's Health [NSCH], 2021). In 1999, the percentage of U.S. children whose parents reported their child had received a diagnosis of ADHD was 5.5%. By 2019, that figure had risen to just under 10%. (Olfson et al., 2023)

Most importantly for this White Paper, evidence is growing regarding the causal factors for health conditions. One of the most evident factors is everyday exposure to environmental chemicals. (Ghassabian et al., 2021; Melough et al., 2022)

This relationship between daily chemical exposure and disease is serious enough that in 2015, The Endocrine Society, the largest global professional member organization of endocrinologists and researchers, published a second Scientific Statement on environmental endocrine-disrupting chemicals (EDCs). This document identified over 1,300 research studies citing evidence surrounding the connection between common exposure to pesticides and ADHD, bisphenol A (BPA) and diabetes as well as kidney and bladder cancers, and arsenic (a common drinking water contaminant) with cardiovascular disease, cancer, and obesity. (Gore et al., 2015) (Diamanti-Kandarakis et al., 2009). Ninety percent of the United States' annual healthcare cost expenditures, measured at 4.1 trillion, are for individuals with the aforementioned diseases, along with other chronic diseases and mental health conditions. Although poor diet, lack of physical activity, and socioeconomic pressures are known to contribute to obesity, depression, cardiovascular disease, and diabetes; there is overwhelming evidence that environmental chemical exposures can directly lead to these conditions. (Buttorff et al., 2017) The financial burden imposed by endocrine-disrupting chemicals has been estimated to have attributable disease costs of $340 billion per year in the USA which is 2.3% of GDP. (Duh-Leong C 2023)

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230 toxic chemicals found in a representative sample of the U.S. population for the last 30 years. The "National Report on Human Exposure to Environmental Chemicals" documents blood and urine levels of pollutants in over 90% of the U.S. population.These low-level chronic exposures have been found to be causal for morbidity and mortality from cardiovascular disease, diabetes, cancer, obesity, and autoimmune disease

" Obesity, type 2 diabetes, depression, hypertension, cardiovascular disease, and many cancers are known to be caused by toxic metal and chemical exposures that Americans experience daily in air, water, and food. "

Obesity, type 2 diabetes, depression, hypertension, cardiovascular disease, and many cancers are known to be caused by toxic metal and chemical exposures that Americans experience daily in air, water, and food. (Lamas et al 2016) A major challenge to changing this untenable situation is that the large majority of healthcare providers are ill-equipped to identify the myriad of toxicants their patients are exposed to. Measuring these toxicants is difficult or impossible due to a lack of training in non-occupational environmental exposures; this knowledge and skill are missing from their medical education. Documentation and guidance for correcting this knowledge gap are major points of this White Paper and will be discussed.

Despite the Congressional overhaul of the Toxic Substances Control Act or TSCA in 2016, little to nothing has changed in the past seven years. There are more than 82,000 chemicals used commercially in the United States, of which over 2,500 are considered high-volume production chemicals, meaning that they are produced or imported into the U.S. in quantities of at least 1 million pounds (or 500 tons) per year. (HPV Chemical Hazard Characterizations, 2014)

Less than 200 of these chemicals have been adequately tested to ensure their safety in people. Studies have documented that industrial chemicals and toxic metals accumulate in human tissue through air, water, and dietary exposure routes. Demonstrable levels of these toxicants can be found in newborns, children, and non-occupationally exposed adults.

The CDC has been accumulating a database of over 230 toxic chemicals found in a representative sample of the U.S. population for the last 30 years. The "National Report on Human Exposure to Environmental Chemicals" documents blood and urine levels of pollutants in over 90% of the U.S. population (National Report on Human Exposure to Environmental Chemicals[NRHEEC], 2023). These low-level chronic exposures have been found to be causal for morbidity and mortality from cardiovascular disease, diabetes, cancer, obesity, and autoimmune disease.

The need to address these exposures has never been more pressing; recent epidemiologic evidence points to environmental toxicant exposure as a cause of compromised immunity for bacterial, viral, and fungal infections. (Paustenbach, 2000; Winans et al., 2011)

And given the costs associated with the SARS-CoV-2 pandemic, the effect of toxicant chemical exposure may create an even greater burden as exposure to airborne toxicants can exacerbate the risk for infection and illness due to COVID-19. A recent analysis by Harvard

T H Chan School of Public Health indicated that there is strong evidence that wildfires, as well as the buildings they engulf, have amplified the effect of airborne PM2.5 (smoke particles less than 2.5 microns in diameter) on COVID-19 cases and deaths. PM2.5 are small molecules produced by combustion, either in smoke from fires or air pollution, that contain toxic metals, including lead and arsenic, as well as pesticides, solvents, and microplastics like BPA.

The Harvard researchers estimated that a 1 ug/m^3 increase in average long-term PM 2.5 exposure was associated with an 11% increase in COVID-19 death rates in the United States. To better imagine the significance of this, PM 2.5 can vary from double digits to triple digits (PM 2.5 readings ranged from 35 to over 500 ug/m^3 in Northern California during 2020).

This means that a change in the air quality in San Francisco air from a PM2.5 count of 35, which is normal on a clear day before the wildfires of 2020, would contrast with a PM2.5 count of 465 at the height of the fires. This would result in a 5115% increase or a 51 times higher COVID-19 death rate (Zho et. al, 2021; Wu, Nethery, et al., 2020).

To meet the challenge of intervening with the growing impact of environmental toxins on peoples' health, medical students and all primary healthcare providers need to become skilled at understanding our population's environmental chemical exposures, how to test for them, and most importantly: how to address them. Only then will we have a fighting chance to alter the dangerous trajectory we are on and regain the health of our nation's people.

Introduction

In order to clearly identify both the problem and the solution, we are focusing on four specific toxicant exposures in this paper:

- Arsenic
- Lead
- Bisphenols (BPA, BPS, BPF)
- Perfluorinated Substances (PFAS)

There is sufficient research showing these toxicants significantly impact the American population and are directly responsible for many of the diseases addressed above. BPA (as well as other bisphenols), PFAS, and arsenic are all considered carcinogenic, endocrine-disrupting chemicals. The body of this paper will provide details on both the extent of exposure and their impact on disease.

The Inability of the Healthcare System to Address Toxicant Exposures

Unfortunately, there is a very large knowledge gap in the healthcare system for knowing how to identify and address these toxic exposures. As early as 1995, governmental agencies identified this specific issue with strong advice to correct the glaring problem. **To this day, there has been no effective change in medical school curricula or post-graduate training to alter our education system and make substantial changes in diagnosis and management.**

According to the Institute of Medicine in their report Environmental Medicine: Integrating a Missing Element into Medical Education:

"For many years, physicians and other health care providers have been largely uninvolved in environmental issues related to human health. Certainly, their undergraduate and graduate medical education did little to encourage or prepare them for such involvement. Indeed, the paucity of their training in this area has been well documented."

The report goes on to say: "The above examples are typical of the complex questions and situations associated with environmental factors increasingly encountered by physicians, who, in the course of their clinical training, may have had little preparation for dealing with them. Unaware of this potential shortcoming and faced with growing concerns about the potential health effects of environmental damage and contamination, people seek help from their physicians because, in general, they trust them and value their advice."

"In order to respond appropriately, physicians need to be clinically competent in environmental medicine and dissuaded from the all too common practice of reflexively offering blanket reassurance to patients who feel they have been exposed to, or harmed by an environmental toxicant." (Institute of Medicine, 1995) Other studies published in the medical literature echo these strong requests to upgrade medical training. (Zachek et al., 2015; Massaquoi & Edwards, 2015,Bijlsma & Cohen, 2016; Massaquoi & Edwards, 2015)

Goals for this White Paper

1. Underscore the critical and immediate need to upgrade medical education.

2. To include the assessment of environmental toxicant exposure

3. To address whole-person healthcare in order to support toxicant avoidance education and lead to a reduction of the body burden of these disease-causing pollutants.

> "Unfortunately, there is a very large knowledge gap in the healthcare system for knowing how to identify and address these toxic exposures."

This is of immediate concern, and urgent action to legislate and fund these efforts is necessary.

Arsenic

Arsenic is a naturally occurring metalloid found widely in the environment. There are both inorganic and organic sources of arsenic, inorganic arsenic being the generally more toxic form. Organic arsenic, the less toxic form, can be found in high concentrations in clams, oysters, mussels, crabs, lobsters, and other crustaceans. Lower concentrations can be found in rice, mushrooms, poultry, and other seafood products. For many people, organic arsenic is excreted primarily through urine within 2-14 days of ingestion. A small percentage of arsenic is eliminated through sweat, feces, hair, and nails (Crinnion, Pizzorno 2018 p.120-21; ATSDR, 2015).

Inorganic arsenic is the generally more toxic form and is found in drinking and ground water, rice, smoking tobacco, soils, sediments, and woods preserved with arsenic compounds (playgrounds). Drinking water is the greatest source of inorganic arsenic, with concentrations of toxic exposure varying depending on arsenic in that region. Rice is the greatest dietary source of inorganic arsenic and may contain both inorganic and organic types. Toxic load in rice depends on the quality of groundwater that was used for growing the rice, the water in which the rice is washed, and the water used for cooking (ATSDR 2010; CDC 2017; Crinnion, Pizzorno 2018 p.120-21).

Inorganic and organic arsenic forms are still being used in pesticide products, despite claims that inorganic arsenic production and commercial use in pesticides in the US has been put to a halt. Arsenic, alongside other heavy metals, was present in almost every sample tested for a study measuring glyphosate-based herbicides and pesticides (Defarge et al., 2017). A common source of inorganic arsenic today is copper chromated arsenate (CCA) treated wood, a wood preservative used to weatherproof wood and prevent decay. CCA-treated wood is found in playgrounds, industrial areas, decks, recreational facilities, and residential construction. Manufacturers removed arsenic from the process of wood preservation in 2003 due to rising health concerns. Arsenic has been found to leach to the surface of the wood and into the soil beneath the structures, where it may expose children and adults through skin contact. (Hemond, 2004; Khan et al., 2006; Kim, 2006; ATSDR 2007)

Although an agreement prevents the use of CCA treated wood in residential areas, soil from preexisting structures remains contaminated with arsenic, and the high cost of replacement for other nontoxic materials serves as a limitation. This is a concerning issue for children, who with frequent hand-to-mouth activity, carry the risk for arsenic contamination when playing on CCA treated playgrounds. Additionally, children are less efficient at metabolizing arsenic to its less toxic form (Kim, 2006).

The United States drinking water standard for arsenic is 10 ug/L, or ten parts per billion (ppb), lowered from 50ug/L in 2001. In 1993, The WHO recommended a maximum exposure of 10 ppb of arsenic in drinking water, though several countries remain at 50 ppb, and other countries have no evidence of arsenic regulation. There is debate around what the most appropriate arsenic regulatory level should be, and some agencies are recommending a Public Health Goal of 4 ppt. (Office of Environmental Health Hazard Assessment [OEHHA], 2023). This regulatory level reflects science showing harm from arsenic in drinking water for vulnerable populations.

Inorganic arsenic is the generally more toxic form and is found in:

- DRINKING & GROUND WATER
- DIET (RICE)
- SMOKING TOBACCO
- SOILS
- SEDIMENTS
- WOOD / PLAYGROUNDS

Arsenic: Impact On Disease

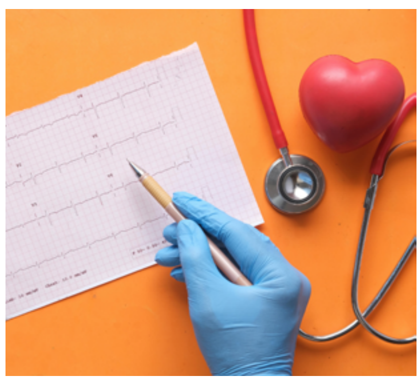
Diabetes

The harmful effects of low to moderate levels of arsenic have been well researched and exemplified in the Strong Heart Study with a population-based prospective cohort of up to 20-year follow-ups in American Indian communities. **It was found that low to moderate levels of arsenic (less than 10 ppb) in drinking water are associated with increased all-cause mortality and cardiovascular mortality.** Low to moderate levels of exposure were correlated with increased cancer mortality, and a correlation was found at these exposure levels between poor arsenic metabolism and the increased risk for diabetes. Other studies have found evidence of a correlation between diabetes and exposure to arsenic; however, data from the Strong Heart Study proves that even low levels of arsenic are a significant burden for disease. The study calls into question the actual safety of current federal regulatory levels of arsenic in drinking water (Kuo et al., 2022).

A study in 2019 measuring the burden of disease of arsenic in drinking water in the U.S. supplied by wells estimated that annually, 500 premature deaths due to ischemic heart disease and 1,000 cancer cases, half of which were fatal, were the result of arsenic contamination. In terms of economic cost this adds up to **$10.9 billion annually,** without taking into account the cost of other arsenic-influencing conditions, such as diabetes and other cardiovascular diseases such as stroke. (Greco et al., 2019).

Cardiovascular Disease

As discussed above, low to moderate levels of inorganic arsenic are a significant etiologic factor contributing to cardiovascular disease. In the Strong Heart Study, fatal and non-fatal cardiovascular events were associated with what is considered low levels of urinary arsenic.These findings are suggestive of no apparent threshold for arsenic exposure related to cardiovascular disease meaning that even low levels of arsenic exposure in food or drinking water can cause health effects (Moon et al., 2013). Just like lead, no level of arsenic may be safe in the human body.



Cancer

With the current regulation for arsenic levels in drinking water at 10 µg/L, it's estimated that there will be one excess cancer death per 400 people (Frisbie & Mitchell, 2022). whereas the former guideline of 50µg/L had estimated one cancer death per 81 people. Drinking water with arsenic levels lower than the EPA standard still increases the risk of disease over several years of exposure, as does acute, high-level exposure to arsenic (Minnesota Department of Health, 2022). Prolonged arsenic exposure is linked to an increase in bladder and lung cancers, among other cancers of the skin, kidney, nasal passages, liver, and prostate. It's important to recognize that both acute and chronic exposure to inorganic arsenic subjects people to varying types of cardiovascular, metabolic, and neurodevelopmental diseases (Crinnion, Pizzorno 2018), (United States Environmental Protection Agency [EPA], 2022).

Call to Action

Arsenic

The correlation between arsenic exposure and disease must be acknowledged by legislators, medical professionals, teachers, and students in order to implement adequate testing and regulatory standards.

High levels of arsenic are strongly associated with cancer incidence and mortality, and low-level exposure to arsenic has been linked to increased incidence of cardiovascular disease and diabetes, stressing the importance of a new, low threshold to exposure.

> “Lowering the exposure limit in drinking water from 10µg/L to <0.004µg/L would lower the lifetime cancer risk to just one excess cancer death per 1 million people, as opposed to 1 cancer death per 400 people at 10ug/L”
>
> (Frisbie & Mitchell, 2022).

In 2000, the EPA proposed a decrease from 50 ppb to 5 ppb, and evaluated cost/benefit at just 3 ppb, however; there was “insufficient evidence” at the time that the benefit of lowering the standard would be worth the cost (United States Environmental Protection Agency [EPA], 2022; Tiemann, 2007).

Lead

Lead is the most abundant toxic metal in the Earth's crust. Prior to the Industrial Revolution, environmental lead exposure to human populations was relatively low. Large-scale mining mobilized and distributed this non-essential element into the environment. Compared to other non-essential elements, lead contamination is among the highest. The greatest increase in environmental lead was at the beginning of the 20th century due to the use of lead in gasoline, following the boom of the automobile industry. (Tong et al., 2000).

Much of our exposure now comes from numerous sources in our environment – lead-based paint in old homes, drinking water, ceramics, pipes, batteries, and imported dishware. (United States Environmental Protection Agency [USEPA], 2023).

Human skeletal remains prove that the burden lead creates in our bodies is far greater in today's population than that of our pre-industrial ancestors. The pre-industrial or natural blood level in these humans is reported to be around 0.016 mg/dl, which is 50-200 times lower than the lowest reported value of people today living in remote regions of the northern or southern hemisphere (Tong et al., 2000).

At high levels of human exposure, there is damage to nearly every organ and organ system, with the central nervous system, kidneys, and blood being affected the most and often resulting in death. At low levels, biochemical processes are drastically affected, including impairment of neurobehavioral, cardiovascular, renal, and reproductive function (Tong et al., 2000; Lanphear et al., 2018).

Today, US public health officials and health care practitioners have collectively agreed that lead exposure during childhood can have serious and harmful effects. The CDC introduced a blood lead reference value to identify the 3% of children who have the highest blood lead levels (97.5th percentile). This value is established at 3.5 µg/dL for children and 3.5 µg/dL for adults (Childhood Lead Poisoning Prevention, 2022). Chronic exposure to lead, even at low levels, can result in adverse health effects; therefore, clinicians are advised to monitor patients with elevated blood lead levels (BLLs) until they fall below 3.5 µg/dL.

As it stands, the CDC and National Institute for Occupational Safety and Health (NIOSH) have a variety of regulations and recommendations for adult lead exposure in the workplace; yet, these regulations and recommendations have not yet been adapted or integrated as guidelines for the general public. Adult lead exposure in the workplace is measured by taking a blood sample, which indicates if the person was exposed to lead. There is disagreement between the Council of State and Territorial Epidemiologists' (CSTE) blood lead reference value of 3.5 µg/dL or below for adults and state or federal occupational health and safety guidelines, which vary between 3.5 and 30µg/dL. (National Institute for Occupational Safety and Health [NIOSH], 2023)

Much of our exposure now comes from numerous sources in our environment:

- OLD HOMES (LEAD-BASED PAINT)
- DRINKING WATER
- CERAMICS
- PIPES
- BATTERIES
- IMPORTED DISHWARE

"Chronic exposure to lead, even at low levels, can result in adverse health effects; therefore, clinicians are advised to monitor patients with elevated blood lead levels (BLLs) until they fall below 3.5 µg/dL."

Lead: Impact On Disease

In 2016, the total cost of cardiovascular disease in the US was

$318 billion

If 13-20% of cardiovascular disease in the US is due to lead exposure, then establishing nationwide guidelines to screen for and treat the public would mean saving the US government

$41-63 billion each year.

Cardiovascular Disease

Low-level lead exposure is an important risk factor in blood lead concentration-related mortality in the US. A longitudinal study in adults found that concentrations of blood lead lower than 5 μg/dL were associated with all-cause mortality, cardiovascular disease mortality, and ischemic heart disease mortality. In the United States, around 2-3 million cardiovascular deaths occur annually, and about 400,000 of these are due to low-level lead exposure, estimated at 13-20% of total deaths. (Lanphear et al., 2018).

This research, a result of following a subset of the CDC NHANES research population for 19 years, illustrated the shocking statistic that lead exposure is responsible for 29% of all fatal heart attacks and 37% of all stroke-related deaths. This data is so compelling that a previous report of this cohort published in 2009 was accompanied by an editorial in the journal of the American Heart Association calling blood lead levels "more predictive of heart disease than blood cholesterol levels." (Menke A., et al. 2006)

Since that editorial was published in 2006, no change has taken place in federal guidance for testing blood lead levels in American adults who are at risk for or currently diagnosed with heart disease.

Hypertension and coronary artery stenosis are linked to lead exposure (Miao et al., 2020). A study looking at lead and coronary artery disease found that blood lead levels measured at less than 5μg/dL were positively associated with the prevalence of moderate-to-severe coronary artery stenosis (Kim et al., 2021). At this same blood lead level (less than 5μg/dL), there is substantial evidence to infer a causal relationship between lead exposure and hypertension (Navas-Acien et al., 2007). With this data, it is clear that current occupational safety standards for blood lead levels must be lowered, and a criterion must be established to screen for elevated lead exposure in adults.

In 2016, the total cost of cardiovascular disease in the US (including high blood pressure, congestive heart failure, coronary heart disease, stroke, atrial fibrillation, and other diseases) was $318 billion, with high blood pressure costing $68 billion and coronary heart disease costing $89 billion. (American Heart Association [AHA], 2017). If 13-20% of cardiovascular disease in the US is due to lead exposure, then establishing nationwide guidelines to screen for and treat the public would mean saving the US government $41-63 billion each year.

> “In the United States, around 2-3 million cardiovascular deaths occur annually, and about 400,000 of these are due to low-level lead exposure, estimated at 13-20% of total deaths.”

Cognition

The CDC has made the decision to lower the blood lead threshold to the new cutoff of 3.5µg/dL (based on the 97.5th percentile of blood lead levels in American children ages 1 to 5 years old), and there is sufficient evidence that blood lead levels 3.5 µg/dL are associated with broad-based and specific indices of reduced cognitive function, increased attention-related behavior diagnoses, and increased antisocial problem behaviors (National Toxicology Program [NTP], 2012).

In 2015, it was estimated that over 170 million people (>53% of the US population) had BLLs above 5 µg/dL at some point in their lives leading to a loss of IQ points and culminating in a significant loss of cognitive function for the nation (McFarland et al., 2022). One main issue with these current regulations and recommendations is that adults in the workforce with a BLL greater than 3.5 µg/dL may be experiencing harm.

There is no safe detectable level of lead identified in children; therefore, there needs to be more aggressive programs that are aimed at reducing childhood lead exposure (Boyle et al., 2021). One study found that blood lead levels of ≥2 µg/dL, in children ages 6-24 months resulted in lost grade school intelligence quotient (IQ) points once they were between 5-10 years old (Boyle et al., 2021).

While children with a blood lead level <1µg/dL were assumed to have an unaffected IQ score, those with blood lead levels between 1-10µg/dL were found to have a 7- point reduction in IQ (Muennig, 2009). With blood lead levels <3 µg/dL there is a significant increase in ADHD symptoms, one of the most common neurodevelopmental diseases. The overall cost of ADHD on the US medical system in 2019 was $321 million (He et al., 2019).

The link between blood lead levels and decreased IQ scores has a significant impact on high school graduation rates and the likelihood of future earnings. Lead exposure is directly linked to behavioral problems. Data shows an increase in crime rates secondary to lower IQ scores and behavioral problems. (Muennig, 2009) By reducing blood lead levels to <1µg/dL in children from birth to 6 years old, the US may be able to reduce crime rates and increase on-time high school graduation rates. "The net societal benefits arising from these improvements in high school graduation rates and reductions in crime would amount to $50 000 (SD, $14 000) per child annually at a discount rate of 3%. This would result in overall savings of approximately $1.2 trillion (SD, $341 billion) and produce an additional 4.8 million quality adjusted life years (SD, 2 million QALYs) for US society as a whole (Muennig, 2009)." The estimated economic burden of lead exposure of children in the U.S. is between $50 billion and $84 billion annually due to reduced productivity and costs related to health care, education, and incarceration. (Health Impact Project. Pew Charitable Trusts 2017) The cost to achieve a blood lead level <1µg/dL is minimal when compared to the economic burden lead exposure has on the US economy.

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Call to Action

Lead

The inadequate regulatory guidelines for lead exposure in adults are a significant public health and economic concern. We know that blood lead, even at low levels (<3.5 µg/dL), does pose a serious health risk, even though it is often overlooked. Not only are the current recommended and regulatory guidelines ignoring health risks for low levels of lead, but they are also completely dismissing an entire population that is potentially being severely affected by lead exposure.

All federal regulatory bodies in the U.S. have agreed that there is no safe level of lead exposure

(World Health Organization, 2023).

In 2016, the average blood lead level in adults was 0.92 µg/dL, which means we are all being exposed to lead to some degree.

(https://www.cdc.gov/niosh/topics/ables/ReferenceBloodLevelsforAdults.html)

Bisphenols (BPA, BPS, BPF)

Bisphenol A is a ubiquitous endocrine disruptor found in 93% of Americans according to the data from the 2003-2004 National Health and Nutrition Examination Survey (NHANES III) conducted by the CDC. Once studies demonstrated the toxicity of BPA, the industry's response was to create new Bisphenols (BPS, BPF, BASF), which are just as toxic and have the same carcinogenic potential as BPA.

Endocrine-disrupting chemicals (EDCs) can mimic, block, or interfere with hormones in the body and can also affect the immune and nervous systems. EDCs have been associated with a broad range of health issues and affect the body at very low doses, in much the same way that hormones work (at micromolecular levels), and often with non-monotonic dose effects, meaning more is not more harmful, and lower doses of bisphenols can sometimes have a more damaging effect.

Bisphenols (BPA, BPS, BPF, BASF, and many more) are found in plastic food and beverage containers, the lining of canned food and canned beverages, thermal receipts, drinking water, personal care products, and polluted air. BPA is added to plastic to make it harder, i.e., polycarbonate plastics contain BPA. BPA is a known endocrine-disrupting chemical linked in epidemiologic studies with risk for type 2 diabetes, obesity, cancer, and cardiovascular disease. (Abraham A et al. 2020)

Most recently, in January of 2022, BPA was assessed by the European Food Safety Authority (EFSA) as an immune toxicant at exposure levels significantly lower than previously established safety intakes. The latest risk assessment by the European Food Safety Authority (EFSA) recommended a reduction in the safe levels of BPA by a factor of 20,000 (the tolerable daily intake was updated to 0.2 ng/kg body weight per day from 4,000 ng/kg body weight per day) The average exposure level in the U.S. is approximately 50 mcg/kg/day – thousands of times higher than EFSA's proposed safety standard (EFSA Panel on Food Contact Materials, Enzymes and Processing Aids (CEP) et al. 2023; Lambre, 2022; Lakind & Naiman, 2008). On December 19. 2024, the European Commission adopted a ban on the use of Bisphenol A (BPA) in food contact materials, due to its potentially harmful health impact. (European Commission. (n.d.).)

On Jan 27, 2021, a group of concerned scientists, including Former Director of the National Institute of Environmental Health Sciences (NIEHS)- Linda Burnbaum Ph.D., petitioned the FDA's Office of Food Additive Safety to remove BPA as an approved food additive as a result of the EFSA action. (Neltner et al., 2021).

Microplastics, tiny plastic particles that result from both commercial product development and the breakdown of larger plastics, are an emerging problem for us. Research has already shown that in marine life microplastics demonstrate the ability to alter behavior, gastrointestinal health, feeding, mating, and reproduction.

In terms of human health, microplastics have now been found in:

- Liver (Horvatits et al., 2022)
- Intestines (Ibrahim et al., 2020)
- Spleen (Kannan & Vimalkumar, 2021)
- Brain (Kannan & Vimalkumar, 2021)
- Blood (Leslie et al., 2022)
- Testis (Zhao et al., 2023)
- Placentas (Ragusa et al., 2021)
- Carotid plaque (Marfella et al., 2024)
- Lung (Amato-Lourenço et al., 2021)
- Penis (Codrington et al., 2024)

The quest to study human health effects and their effect on healthcare costs have begun. In 2018 alone, the hormone-disrupting effects of plastics in the nation's food and water led to a quarter of a trillion dollars in additional health care costs, according to findings recently published in the Journal of the Endocrine Society.

The New England Journal of Medicine recently published an article that examined microplastics in plaque. The presence of microplastics in carotid plaque was shown to increase the risk of cardiovascular events by 450% as compared to people whose plaque did not have any. Considering microplastics as a risk factor for the number 1 killer in America is certainly food for thought.

Additionally, plastics and microplastics are manufactured using thousands of different chemicals and these chemicals, as well as the pollutants and toxic metals that they adsorb, also desorb into your body, providing additional routes of entry for toxicants.

Bisphenols are found in:

PLASTIC FOOD AND BEVERAGE CONTAINERS

THE LINING OF CANNED FOOD AND BEVERAGES

THERMAL RECEIPTS

DRINKING WATER

PERSONAL CARE PRODUCTS

POLLUTED AIR

Bisphenols: Impact On Disease

Metabolic Disease and Diabetes

BPA and other bisphenol compounds (BPF, BPS, and other compounds) are considered to be both obesogens and diabetogens. Analyses have determined that activity, caloric intake, and genetics are insufficient to explain the magnitude and speed of the increase in the incidence of obesity; indicating pollutants are likely the reason for the worsening of the obesity epidemic. NHANES data compared BMI between US adults in 1988 and 2006, and found a 2.3 kg/m2 increase in adult BMI in 2006 compared with 1988 even with the same amount of caloric intake (macronutrient specific) and energy spent. Current evidence indicates that gene variants can only explain about 2.7% of the individual variation in BMI (Egusquiza & Blumberg, 2020).

Over 600 peer-reviewed studies published since 2005 in scientific journals have examined the relationship between BPA (and its analogs) and obesity or diabetes. One recent meta-analysis concluded that for every 1 ng/mL increase in urinary BPA the risk for obesity was increased by 11% (Wu, Li, et al., 2020).

For the first time in the United States since the Great Depression, a projected decrease in human life expectancy is predicted due to the rising incidences of obesity and diabetes. In the EU alone, prenatal exposure to BPA was estimated to have a 20% to 69% probability of causing 42,400 cases of childhood obesity, with associated lifetime costs of €1.54 billion ($1.65 billion dollars) (Legler et. al, 2015). An estimate of cost associated with endocrine disrupting chemical exposure in the U.S. puts the societal burden $340 billion per year. (Trasande L, et al. 2023) The twin epidemics of obesity and diabetes have co-occurred with the increase in production of environmental toxicants, in particular, the endocrine disruptors. Traditional risk factors alone cannot account for the dramatic rise in both diabetes and obesity. The increase in endocrine disruptors is therefore contributory to the rising health epidemics (Legler et. al, 2015).

BPA in animal models has produced hyperinsulinemia and insulin resistance, both associated with pancreatic B-cell disruption. BPA is also an estrogen agonist and has been shown to impair glucose homeostasis, resulting in pancreatic beta-cell dysfunction, inflammation, oxidative stress, and insulin resistance. BPA binding to estrogen receptors at the physiologic range or below has the ability to disrupt the islets of Langerhans, which is responsible for glucose metabolism (Hwang et al., 2018). BPA binding to pancreatic beta-cells leads to insulin resistance. In the meta-analysis described in this paragraph, BPA was found to be positively associated with Type-2 diabetes risk (Alonso-Magdalena et. al, 2010).

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Bisphenols: Impact On Disease

As Bisphenol A, the legacy bisphenol, became identified with its health harms and was consequently restricted in the marketplace, the BPA substitutes BPS, BPF, BPAF have been utilized as replacements. However, their chemical profile and health effects have been shown to be very similar. In a recent prospective study, the French D.E.S.I.R.study (Rancière et al., 2019), the top 75% of BPA urine levels were associated with a near doubling of diabetes, while any urinary BPS found was associated with a near tripling of incident diabetes. (Rancière et. al, 2019).

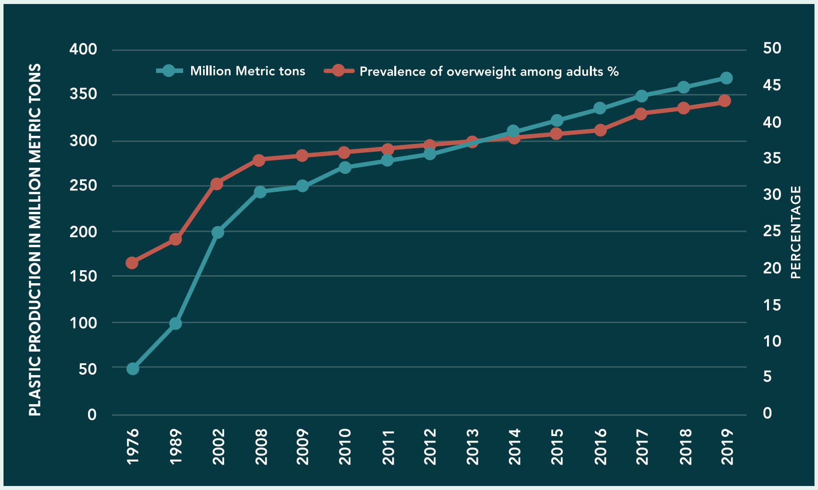
The authors of a recent paper addressing the urgent situation of endocrine-disrupting and metabolism-altering chemicals conclude: "It is now incumbent on clinicians and public health agencies to incorporate [this knowledge] into comprehensive strategies to address the metabolic disease pandemic..... what is needed is a narrative change that shifts the focus from management to prevention." [Sargis RM, Heindel JJ, Padmanabhan V. et al. 2019 see above]

Thousands of studies on Bisphenol A have described the following health effects:

- Behavior and learning disorders
- Developmental disorders
- Obesity
- Type 2 Diabetes
- Cardiovascular disease
- Reproductive disorders
- Breast, ovary, uterus, and prostate cancer
- Thyroid disruption
- Asthma
- Altered liver function
- Impaired learning and memory
- Altered sperm count and quality
- Risk of miscarriage
- All-cause mortality

(Vom Saal and Vandenberg, 2021)

Correlation of plastic production to obesity



Global annual plastic production and prevalence of overweight over the past 4 decades (Source: Plastics- The Facts 2020, page 16; WHO: http://apps.who.int/gho/data/view.mian.GLOBAL2461A?lang=e; Obesity data from CDC: https://www.cdc.gov/nchs/products/databriefs/db360.htm).

Call to Action

Bisphenols

In the U.S., a coalition of scientists, physicians, and environmental groups are calling on the FDA to institute a regulatory re-evaluation of the safe total daily intake (TDI) of BPA. Based on EFSA's new suggestion, the average US citizen's BPA exposure is 5,000 times the new limit. There is an urgent unmet need to re-evaluate BPA in this context and exert regulatory pressure to drastically reduce or eliminate exposure to this ubiquitous toxicant especially among pregnant women and infants to prevent any negative effects on children's neurodevelopment.

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Perfluorinated Substances (PFAS)

PFAS, otherwise known as perfluorinated or polyfluoroalkyl substances, are also termed "the forever chemicals" due to their very long half-lives in the human body. There are over 9,000 different PFAS, but 31 common compounds have been identified and are tested for in humans (U.S. Environmental Protection Agency, 2021). These synthetic chemicals have been widely used for many decades in consumer products such as disposable food packaging, household products, cookware, personal care items, outdoor gear, carpet, and industrial applications (Sunderland et al, 2019).

Despite regulatory efforts to phase out certain legacy or long chain PFAS, such as PFOS and PFOA, their persistence in the environment, along with short-chain PFAS, continue to pollute air and water sources. These short-chain PFAS alternatives are proposed to decrease risk for environmental persistence; however, many of these chemicals continue to be unregulated and untested with respect to health risks, particularly regarding reproductive effects (Rickard, Rizvi, & Fenton, 2022).

As of March 24th, 2025, the Environmental Working Group has identified 2719 sites in the US that have identified PFAS in drinking water. This data is taken directly from the Environmental Protection Agency's UCMR-5 data identifying 143 million people in communities throughout the U.S. that have drinking water which has tested positive for PFAS. (Environmental Working Group, 2025)

Data from 2020 shows that over 200 million people in the U.S. likely receive drinking water with a PFOA and PFOS concentration at or above 1 ng/L (Andrews & Naidenko, 2020). While drinking water sources of perflourinates in the US have been identified in multiple cities and towns, the other major exposure source of PFAS appears to be fish. A study found elevated concentrations of serum PFAS among high-frequency fish consumers in the U.S. National Health and Nutrition Exam Survey between 2007 and 2014. The European Food Safety Authority (EFSA) recently estimated that fish and other seafood account for up to 86% of dietary PFAS exposure in adults (Sunderland et al, 2019).

Currently, perfluorinates are ubiquitous in the U.S. population: in the NHANES study of U.S. adolescents and adults in 2003-2004, four perfluorinates (PFOS, PFOA, PFHxS, and PFNA) were detected in greater than 98% of all 2,094 participants. Although levels for three of the perfluorinate compounds had dropped due to a phasing out of their production (32% lower for PFOS, 25% lower for PFOA, 10% lower for PFHxS), levels of the fourth chemical, PFNA, had doubled since the NHANES 1999–2000 report ($p < 0.001$) (Calafat et. al, 2007).

PFAS are considered endocrine-disrupting chemicals (EDCs), which are particular types of exogenous chemicals, either synthetic or natural, that mimic endogenous hormones. These EDCs often interfere with normal endocrine signals. In recent years, EDCs have been found to be associated with chronic diseases, raising considerable public health concerns (Yan et al., 2022).
PFAS are not readily eliminated from the body through feces, urine, or sweat and have long half-lives, between 1.5 and 8.5 years (Rosato et al., 2023). It takes approximately five years for a toxicant to be completely eliminated from the body. Still, it can take longer, and there are no estimates for how long it will take the current PFAS body burden to be eliminated. The only potential evidence for decreasing the body burden of PFAS may entail phlebotomy or use of the prescription medication cholestyramine (Genius et al., 2014).

PFAS are found in:

- DRINKING WATER
- FISH
- FRYING PANS (TEFLON)
- RAIN JACKETS (GORTEX)
- TAKE-AWAY CARTONS (CARDBOARD)

Perfluorinated Substances (PFAS)

According to the CDC, PFAS levels in the blood appear to be 16 times higher in the U.S. than Italy and India, and 30 times higher than in Peru. Blood levels in the U.S. are also about two to three times higher than in Japan, Brazil, Belgium, Poland, Columbia, Malaysia, and Korea (Calafat et al., 2006a, 2006b, 2007; Kannan et al., 2004). Manufactured chemicals like PFOA, PFOS, and the other 9,000 members of the PFAS family are not being tested for in the general population, even though they have been in production since the 1940s. They are termed "forever chemicals" because they do not appear to biodegrade in the environment, and their half-lives in humans are on the order of years. The CDC NHANES study has been testing blood levels of 12 PFAS since 1999 and states that they have found PFAS in nearly everyone tested (Centers for Disease Control and Prevention [CDC], 2022).

Undoubtedly, each of us has been exposed to PFAS, with differing levels circulating in our bodies. How it affects our health varies from person to person. However, scientific research from recent years has been able to conclude that PFAS exposure increases the risk for certain diseases. A recent report from the National Academies of Sciences, Engineering, and Medicine (NAS) (1995) has identified these health risks: decreased antibody response, dyslipidemia (abnormally high cholesterol), decreased infant and fetal growth, and increased risk of kidney cancer.

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Perfluorinated Substances: Impact On Disease

Metabolic Disease and Diabetes

A prospective study explored the relationship between prenatal PFA exposure (including PFOA, PFOS, PFNA, and PFHxS) and obesity in children born to women living downstream from a fluoropolymer (PFAS) manufacturing plant. The results found that those children born to the top 66% of mothers with blood PFOA levels had greater body fat at eight years old compared with children in the lowest 30% of blood PFOA levels. Additionally, the results found an association between higher prenatal serum PFOA concentration and a more rapid increase in body mass index (BMI) between 2-8 years old (Braun et al., 2016).

One meta-analysis found that PFOA concentration was significantly associated with a higher risk of gestational diabetes mellitus (GDM), one of the most common pregnancy complications. According to the latest estimates of the International Diabetes Federation (IDF) in 2019, the global prevalence of GDM was 14%, equivalent to approximately 20 million births annually (Wang et. al, 2022).

Multiple studies have found that higher serum PFAS levels, particularly PFOA and PFOS, are consistently associated with abnormal lipid profiles, including increased total and LDL cholesterol. Although the effect size varies across studies, data from the C8 Health Project revealed that children in the highest PFAS exposure group had total cholesterol levels elevated by 4.6 to 8.5 mg/dL compared to those with lowest exposure. Similarly, data from NHANES 2003–2004 revealed that adults with the highest PFAS levels had 9.8 to 13.4 mg/dL higher total cholesterol than those in the lowest exposure group (Sunderland et al, 2019).

Other Health Conditions

Exposure to PFAS has been correlated with many different health conditions: kidney and testicular cancer, low birth weight, thyroid disease, decreased sperm quality, cancer, asthma, ulcerative colitis, arthritis, cardiovascular disease, reproductive damage, and immunotoxicity. Areas with high levels of perfluorinates in drinking water have shown, in all genders, an increased incidence of diabetes, cerebrovascular diseases, myocardial infarction, and Alzheimer's disease, and in females, an increased prevalence of kidney cancer, breast cancer, and Parkinson's disease (Bonato et al, 2020).

Reproductive Toxicity

Over the past few decades, global data has shown a persistent decline in female pregnancy rates, an alarming trend influenced by various factors including sociocultural shifts and increasing environmental exposures. One of the most concerning environmental factors affecting reproduction is the impact of PFAs.

New research has demonstrated the ability of PFAS to impair female reproductive health by directly affecting reproductive tissues and disrupting endocrine-regulated systems, including the breast, thyroid, and hypothalamic-pituitary-gonadal axis. These endocrine disruptors have the potential to impair endogenous hormone metabolism such as production of estrogen, progesterone, and testosterone (Rickard et al., 2022).

A longitudinal population-based study conducted in Singapore observed that women attempting to conceive for a one-year follow-up had a lower likelihood of achieving clinical pregnancy and live birth with higher exposure to PFAS, both as individual compounds and in combination. The analysis indicated that each quartile rise in PFDA, PFOS, PFOA, and PFHpA corresponded to a 5–10% average decrease in fecundability. Moreover, when PFAS were considered as a combined mixture, researchers observed an astounding 30–40% average reduction in the likelihood of clinical pregnancy and live birth per quartile increase. These findings align with previous evidence from animal models suggesting PFAS may disrupt female reproductive function. (Cohen et al., 2023)

PFAS exposure:

- Increased risk of breast cancer
- elevated liver enzymes
- increased risk of pregnancy-induced hypertension
- increased risk of testicular cancer
- thyroid disease
- ulcerative colitis in adults
- decreased antibody response
- dyslipidemia (abnormally high cholesterol),
- decreased infant and fetal growth
- increased risk of kidney cancer

(National Academy of Sciences 2022)

Call to Action

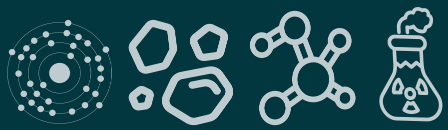
Perfluorinated Substances

A 2022 NAS Report recommends that all healthcare providers test patient's blood PFAS levels if they have been exposed or live in areas where drinking water levels of PFAS are elevated (see map: https://www.ewg.org/interactive-maps/pfas_contamination/) and associated with an increased risk of adverse effects. The patients should be seen and get regular screenings and lab test monitoring for many health impacts that may be related to PFAS exposure: increased risk of breast cancer, elevated liver enzymes, increased risk of pregnancy-induced hypertension, and increased risk of testicular cancer, thyroid disease, and ulcerative colitis in adults (National Academy of Sciences 2022).

The 2022 NAS Report recommends providers test for serum levels of PFAS in patients who may have exposure to PFAS occupationally or who live near possible sources of drinking water contamination. Although this guidance document was published in 2022, no avenues have opened through the CDC or other federal or state agencies to follow this guidance and make testing available through insurance reimbursement or other avenues.

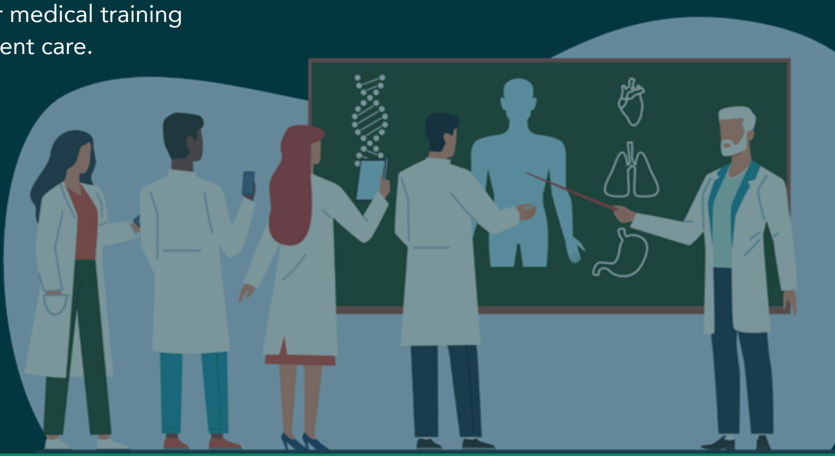
We are at a crossroads in healthcare, where policies must be established to address these concerns. Now, nearly 90 years later, we are starting to observe the detrimental effects these chemicals, and other environmental toxicants have on the health of this country.

The Need For Training Primary Healthcare Providers



The need to address environmental toxicant exposures in patient's environments and understand their role in health and disease has never been greater. Both post-graduate and undergraduate training are needed to address appropriate biomonitoring for all of the toxicants listed here (as well as other endocrine disruptors and harmful chemicals) in our population. Training is also needed for appropriate interventions in both avoidance of these toxicants and treatment for their damaging effects.

As the Institute of Medicine concluded in the report mentioned earlier in this White Paper (Institute of Medicine. 1995) , we need competency-based learning objectives for medical training in environmental toxicant exposure-related patient care. The curriculum they outline involves relevant assessment, testing, and training for direct patient care. The recommendations of the IOM Report need to be implemented through mandatory curricula in medical training programs as well as mandatory post-graduate Continuing Medical Education requirements.



As the current landscape of medical training becomes ever more reliant on pharmaceutical solutions for a world where toxicant exposure is ubiquitous, directly addressing the problem at its source will result in **significant cost savings and a healthier, more productive population.**

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