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The Plastics Crisis: A Neuropsychiatric Problem Hidden in Plain Sight

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The impact of plastics on health is an area of increasing concern. Plastics specifically affect brain health and development, which is why psychiatry must pay attention to the growing plastics crisis.

Neuropsychiatric Effects

Negative health effects emerge at all stages of the plastics life cycle (production, use, and disposal). At the production stage, plastics account for 3.7% of global carbon emissions and contribute directly to climate change.[1] In the United States, plastics companies collectively release carbon emissions equivalent to 116 coal plants each year.[2] The negative mental health impacts of climate change have been well documented in *Psychiatric Times*.[3] The production plants for plastics also emit toxic air pollutants; air pollution is known to worsen neurocognitive and behavioral outcomes in children and to contribute to cognitive decline and dementias such as those associated with Parkinson disease and Alzheimer disease.[4,5] These factories often abut disadvantaged communities, exacerbating health inequities.

What Are Plastics?

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Most plastics are fossil fuel–derived hydrocarbon polymers that are compounded with chemical additives that imbue desired physical properties (eg, durability, color, oil or water repellency). Industrial applications of plastics include packaging and single-use plastics (accounting for 31% of all plastics), buildings/construction (17%), transportation (14%), textiles (10%), and consumer/institutional products including medical products (10%).[1]

Two properties of plastics are critical to understanding their impacts on health. First, plastics products contain chemical additives that are loosely embedded in the hydrocarbon polymer matrix. Examples of chemical additives include formaldehyde, phthalates, bisphenol A, polyvinyl chlorides, and per- and polyfluoroalkyl substances such as perfluorooctanoic acid and perfluorooctane sulfonate. In a study from 2021, researchers estimated that more than 10,000 chemical substances can be added to plastics, of which 24% have data indicating medium or high concern for human hazard —carcinogens, endocrine disruptors, or organ toxins—and 39% lack any data on possible health effects.[2] A more recent comprehensive report funded by the Norwegian Research Council identified more than 16,000 possible chemical additives; at least 25% are of concern for effects on health, and only 6% are subject to regulation.[3] Accordingly, any discussion of plastics needs to consider the impacts not only from the hydrocarbon polymers but also from the chemical additives.

Second, once produced, plastics persist in the environment and do not biodegrade. Over time, they break down into smaller and smaller pieces of hydrocarbon polymer with embedded chemicals. Fragments smaller than 5 mm are called microplastics and pieces smaller than 1 µm are called nanoplastics.[4] These tiny pieces readily disperse in the air, water, and soil and are ubiquitous in the environment, found everywhere from the top of Mount Everest to the deepest oceanic trench.[5] Moreover, their quantity is hardly insignificant: one study estimates that the ocean floor contains 14 million tons of microplastics.[5] Importantly, micro- and nanoplastics are small enough to be bioactive at the cellular level.

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Another component of the plastic production process is the land or marine transport of small pieces of virgin (ie, newly created) plastic polymers called pellets or nurdles to other factories that create the final plastics product. The spillage of plastics pellets and nurdles is a major source of environmental contamination, contributing to plastics eventually making their way into our bodies.[6] Additionally, transporting the chemicals required to produce plastic polymers can cause environmental health disasters, as occurred with the derailment of the train carrying vinyl chloride (used to make the polymer polyvinyl chloride) in East Palestine, Ohio, in 2023.[7]

At the use stage, plastics enter the human body primarily through inhalation or ingestion.[8] Fragments smaller than 5 mm are called microplastics and pieces smaller than 1 µm are called nanoplastics.[4] With normal use, synthetic textiles (clothing, curtains, carpets) and plastic flooring materials release microplastics into the air and are a major source of inhaled microparticles in indoor environments, especially those with poor ventilation.[9,10] Sources of microplastics in the outdoor air originate from elements such as tire erosion, brake dust, paint, microfilaments from clothing, and general air pollution.[10] In terms of entry of plastics into food and water, aquatic-derived consumables such as seafood and salt contain micro- and nanoplastic particles because of extensive plastics pollution in oceans and water; animal proteins also have been found to contain microplastics. A 1-L plastic water bottle has 240,000 detectable micro- and nanoplastic particles in the water, and microwaving food in plastic containers or using plastic teabags can release billions of nanoplastic particles.[11-15] Oceans and groundwater can be contaminated by plastics at the manufacturing and disposal stages, but plastics also enter the water system at the use stage from personal care products containing microbeads and the washing of synthetic textiles such as polyester or microfiber. Once inhaled or ingested, micro- and nanoplastics can enter the circulation in multiple ways and accumulate in body tissue, including the placenta, amniotic fluid, testes, liver, kidneys, spleen, joints, heart, and brain.[8,16]

Research into the direct effects of plastics on brain health is still relatively nascent.[17] However, the neurodevelopmental and neurocognitive effects are particularly concerning. It is helpful to consider separately the effects of micro- and nanoplastic particles and the effects of chemical additives. Direct toxicity from micro- and nanoplastics depends on polymer type, shape, size, and charge.[8,18] Animal models clearly document the transit of microplastics into the brain, with resultant morphologic changes and eventual cell death in microglia, inflammatory changes, and dramatic changes in neurotransmitter expression.16 Results of preclinical studies in mice show that nanoplastics bind to α-synuclein and promote fibril formation in dopaminergic neurons (**Figure 1**), and that drinking microplastics-contaminated water induced dementialike behavioral and brain changes.[19-21] Toxicological studies have linked the buildup of nanoplastics in the brains of carp to morphological and behavioral changes, and zebra fish larvae's motor activity is affected by these neurotoxins.[19,22] In 20220, Prüst et al reviewed the neurotoxicity of micro- and nanoplastics in a variety of species and found that they induced oxidative stress, neuroinflammation, and subsequent changes in motility and behavior.[23] No studies have yet been done on their effect on human brain tissue.

In addition to direct neuronal toxicity, micro- and nanoplastics affect other organ systems that can impact brain health. First, microplastics have been documented in human placentas, raising the question of their impact on fetal brain development,

Figure 1. *Reproduction of Figure 9B from Liu et al*[21]

given the link between placental health and future risk of neuropsychiatric conditions.[24,25] Second, microplastics accumulate in the heart and blood vessels. New research is emerging on how microplastics affect cardiovascular health, which in turn affects brain health. A recent prospective study in *The New England Journal of Medicine* assessed outcomes in patients who underwent carotid endarterectomy for asymptomatic disease.[26] Plastic polymers were detected in the removed plaques of 58% of patients, and these patients had a dramatically higher composite risk of myocardial infarction, stroke, or all-cause death over a 34-week follow-up period (HR, 4.53; $P < .001$). Third, the interaction between gut and mental health is of increasing focus in psychiatry, and ingestion of microplastics has substantial effects on gut function and the human microbiome.[27] Microplastics in the gut cause disruptions in endothelial tight junctions, accumulate in gut endothelial cells, change the composition of the microbiome, and cause bacteria to produce biofilms.[16] These changes in permeability and dysbiosis lead to elevation of inflammatory cytokines and markers of oxidative stress, damage to the gut reflected in cracked villi and small vessel proliferation, and many other changes.[16]

A separate but related body of research has investigated the effects of chemical additives in plastics. For example, bisphenol-A (BPA), which can be found in food and beverage containers and baby bottles, among many other sources, has been implicated in neurodevelopmental, mood/anxiety, and neurocognitive disorders.[28-30] Results of initial research that followed a small cohort of children starting at gestation suggest that prenatal BPA exposure is associated with anxiety and depression in boys.[31] Based on their extensive expertise in environmental health research, Grandjean and Landrigan hypothesized that BPA and other plastics chemical additives are neurotoxic and that their increased presence accounts for the increasing prevalence of autism, attention-deficit hyperactivity disorder, and cognitive impairments in children.[32] BPA can also disrupt the blood-brain barrier, making it a potential environmental risk factor for Alzheimer disease.[30] New research has recently been funded to investigate BPA and blood-brain barrier disruption in patients with Alzheimer disease.[19]

In the disposal stage, most plastics end up littered or in landfills. Physical erosion and UV radiation degrade the macroplastics into micro- and nanoplastics, which ultimately leach into the environment, where they become sources for human ingestion and inhalation. A small percentage of plastics end up incinerated with other trash. Incineration produces more air pollution, which impacts brain health as described earlier, and can leave up to 100,000 pieces of microplastics in the residual ash per metric ton of waste, making it a potential source of environmental microplastics pollution.[33]

A Growing Problem

Unfortunately, the environmental and health burdens of plastics will only increase due to the sheer scale of plastic use. Annual global plastics use has grown from 72 million tons in 1980 to 445 million tons in 2020 and is projected to double by 2040 and triple by 2060 under current policies and regulations (**Figure 2**).[1] Single-use plastics will account for a significant part of that increase, underscoring the importance of advocating for its reduction and supporting rigorous and effective regulation across the globe. Recycling is not a panacea: Between 1950-2015, humanity has produced 8.3 billion metric tons of plastics in total, of which 30% is still in use, 9% is incinerated, and 60% has accumulated as litter or landfill; overall, only 9% has been recycled.[34] Increasing recycling rates would not solve the problem because many plastics, especially single-use plastics, cannot be recycled. Plastics are necessary for certain aspects of modern life, most notably in health care; however, many plastics are unnecessary and can be replaced with eco-friendly alternatives that are reusable or made from truly recyclable materials.

Looking Forward

__Figure 2.__ Global Plastics Use in Million Tons

Some jurisdictions have made progress toward eliminating plastics waste. Several US states have started addressing plastics pollution with bag bans, food container restrictions, and extended producer responsibility programs. At the federal level, the Break Free From Plastics Pollution Act was introduced in Congress in 2020 and 2023, though it was not passed in either year.[35] Internationally, the United Nations is negotiating a binding Global Plastics Treaty.[36] However, the fossil fuel and plastics companies, as well as their lobbying group, the American Chemistry Council, have pushed back forcefully.[37] The petrochemical industry needs plastics as an alternative source of revenue, given the push for clean energy, and is actively hampering legislative progress.[38]

So what can psychiatrists do to address this problem and advocate for brain health? As individuals, we can contact our representatives at the local, state, federal, and international levels; advocate for the reduction of plastics in our workplaces[39,40]; and commit to reducing unnecessary plastics in at least 1 aspect of our personal lives. The Plastic Free July website, a key initiative of the Plastic Free Foundation, has many suggestions, including reducing single-use plastics for food and drinks and avoiding fast fashion and synthetic textiles such as polyester.[41]

As a field, psychiatrists need to assess how our health care systems and professional organizations are using plastics and contributing to plastics waste. The goal is not to eliminate *all* plastics but to eliminate unnecessary plastics. We can also encourage research funding in this area to obtain more definitive findings about the neuropsychiatric impacts of plastics. However, we ought not wait for the outcome of these research studies to begin taking immediate action. There are countless examples of public health mistakes that could have been prevented if early warning signs were heeded.[42,43] The preliminary evidence warrants urgent intervention in the plastics crisis. Let's act to safeguard brain health before it is too late, especially for future generations.

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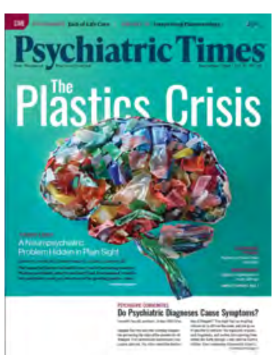

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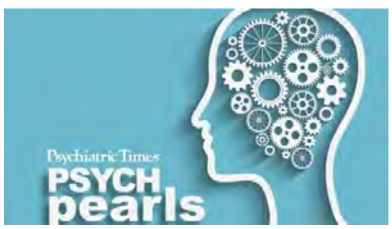

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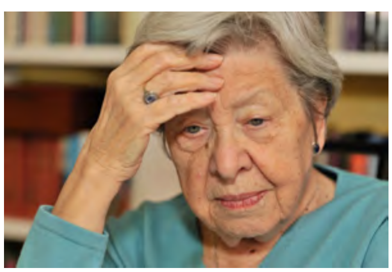

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