



COVID-19 and children's health in the United States: Consideration of physical and social environments during the pandemic

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ABSTRACT

Public health measures necessary to counteract the coronavirus disease 2019 (COVID-19) pandemic have resulted in dramatic changes in the physical and social environments within which children grow and develop. As our understanding of the pathways for viral exposure and associated health outcomes in children evolves, it is critical to consider how changes in the social, cultural, economic, and physical environments resulting from the pandemic could affect the development of children. This review article considers the environments and settings that create the backdrop for children's health in the United States during the COVID-19 pandemic, including current threats to child development that stem from: A) change in exposures to environmental contaminants such as heavy metals, pesticides, disinfectants, air pollution and the built environment; B) changes in food environments resulting from adverse economic repercussion of the pandemic and limited reach of existing safety nets; C) limited access to children's educational and developmental resources; D) changes in the social environments at the individual and household levels, and their interplay with family stressors and mental health; E) social injustice and racism. The environmental changes due to COVID-19 are overlaid onto existing environmental and social disparities. This results in disproportionate effects among children in low-income settings and among populations experiencing the effects of structural racism. This article draws attention to many environments that should be considered in current and future policy responses to protect children's health amid pandemics.

1. Introduction

Compared to adults, children have experienced lower rates of morbidity and mortality from coronavirus disease 2019 (COVID-19), despite having had similar trends in incidence and percent positive test results for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (Leidman 2021). Yet, the harm to children associated with the COVID-19 pandemic can occur in multiple, often hidden, ways and focusing exclusively on the health effects of the infection misses the

broader impact of the pandemic on children's lives. Although children are resilient, the pandemic is affecting multiple facets of their everyday lives and may result in a lasting impact on their health and development.

Public health measures necessary to counteract the COVID-19 pandemic, coupled with economic effects from a strained labor market, have resulted in dramatic changes to the physical and social environments within which children grow and develop. Children inhabit "total environments"—physical (e.g., built, natural, chemical) social, cultural, economic—which contribute to their growth and development

Abbreviations: COVID-19, Coronavirus Disease 2019; SARS-CoV-2, Severe acute respiratory syndrome coronavirus-2.

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(Hibbert and Tulve 2019; Ruiz et al., 2016). As our understanding of the pathways for viral exposure (American Academy of Pediatrics; Morawska and Cao 2020) and associated health outcomes (Morawska and Milton 2020; Nakra et al., 2020) in children evolves, it is also critical to consider pandemic-related changes in these broader environments that could affect children's development now and in the future. It is believed that stay-at-home and social distancing measures are altering children's physical and social environments and exposure risks, particularly affecting children already made vulnerable by preexisting socio-economic (Lancker and Parolin 2020; Sharma et al., 2020b), health (Fortuna et al., 2020), and environmental disparities and injustices (Woolf et al., 2020).

Although children have the lowest morbidity and mortality resulting from COVID-19, they experienced the earliest and most stringent social and physical restrictions resulting from the pandemic. In the spring of 2020, nearly 55 million children in the United States (U.S.) were impacted by school closures (Map: Coronavirus and School Closures - Education Week 2020). As of January 22, 2021, 75% of school districts in the US offered either full online or hybrid (online and in-person) learning (MCH Strategic Data 2021), extending the period of physical and social distancing, and potentially isolation, for children and their families. A new resurgence in COVID-19 cases in January 2021 is resulting in expansion of virtual learning in schools (MCH Strategic Data 2021). It is perhaps not surprising that the pandemic has been called a "social crisis in the making" for today's children (Van Lancker and Parolin 2020).

This article considers how the COVID-19 pandemic is affecting the environments and settings in which U.S. children grow up, and how this public health crisis magnifies the preexisting environmental, health, social and economic inequities. We provide a brief discussion of the current threats to child development stemming from environmental contaminants, reduced access to green and blue spaces, changes to social environments including altered social interactions and family dynamics, reduced economic and other safety nets protecting children, and major social (in)justice issues that the pandemic has exposed. Our objective is to draw attention to noxious environments surrounding children that should be mitigated, or at minimum considered, in current and future policy responses to pandemics, or other public health emergencies. We offer a holistic focus for consideration of broader health realities and exposures that have changed or have been exacerbated as a result of necessary measures to counter the pandemic. We acknowledge the importance of following COVID-19 public health recommendations, and do not intend to de-emphasize the severity of the virus.

2. Environmental exposures during COVID-19

Of all the facets of children's lives affected by COVID-19, the physical environment, and particularly exposures to environmental contaminants, have received minimal attention thus far. While stay-at-home orders work to control the spread of COVID-19 infection, these orders likely translate to higher exposures to indoor pollutants that could exacerbate pre-existing conditions for many children. Below, we include select examples of changes in children's environmental exposures that could be directly or indirectly related to the pandemic.

Allergens and indoor air pollutants. Stay-at-home orders have increased the amount of time people spend inside homes (Rice et al., 2020). Exposures to allergens and common indoor air pollutants, including particulate matter (PM), secondhand smoke, nitrogen dioxide, and mold can exacerbate asthma morbidity and increase the risk of acute respiratory infections (Matsui et al., 2016). Exposures to air pollutants are of particular concern for children because they can inhale more contaminants than adults given that they breathe more air per body weight (American Academy of Pediatrics Council on Environmental Health 2019a; Kliegman and St Geme 2019). In the U.S., asthma affects approximately 10% of children (>600,000) with a prevalence as high as 25% in some communities of color and low-income populations (Matsui

et al., 2016). The use of gas stoves without proper ventilation is associated with asthma symptoms (Duramad et al., 2006), and household use of wood stoves as a primary heat source (a practice occurring in about 15% of New England households in 2015) was associated with adverse respiratory health outcomes in children (Rokoff et al., 2017). Other indoor pollutants of concern that may exacerbate prevalent respiratory conditions include indoor mold, which can trigger allergic reactions and asthma symptoms (Karvonen et al., 2015; Tischer et al., 2011). Airborne mold particles can trigger eye, skin, nose, throat and lung irritation in individuals with or without pre-existing allergies (Medicine 2004). Additionally, early life exposure to mold is reported to play a critical role in childhood asthma development and exacerbates other respiratory conditions (Kanchongkittiphon Watcharoot et al., 2015).

Outdoor air. One benefit of following stay-at-home orders was a notable decrease in vehicular traffic, which contributed to a decrease in air pollutants such as black carbon, nitrogen dioxide, and PM in some cities (Sharma et al., 2020a; Tobías et al., 2020). Decreases in particle pollution are associated with fewer episodes of chronic cough, bronchitis, common cold, and conjunctivitis symptoms among children (American Lung Association; Bayer-Oglesby et al., 2005). Nevertheless, reduced pollution levels due to the global response to the pandemic appear uneven both across the U.S. (Chen et al., 2020) and among countries around the world (Schiermeier 2020), and have been short-lived worldwide (Le Quéré et al., 2020). Proposed responses to the current economic downturn that relax environmental regulations or actively promote fossil fuel use to make up for losses in production (Gardiner 2020; The Institute for Policy Integrity, New York University School of Law 2020), are not only likely to erase, but exacerbate pollution and environmental damage into the future.

Air quality appears to be associated with COVID-19 infections and pathophysiologically, PM exposure could facilitate COVID-19 infection by increasing angiotensin-converting enzyme in the lung (Tung et al., 2021). Data from Italy suggest that through May 2020, those cities that had over 100 days per year exceeding limits for PM₁₀ or ozone had higher numbers of COVID-19 infections and deaths, even after controlling for population density (Coccia 2021). Preliminary analyses of U.S. data up to June 2020 described associations of long-term average PM_{2.5} concentrations between 2000 and 2016 and county-level COVID mortality rates (Wu et al., 2020). In late January and February 2020 in China, higher air pollution was associated with higher number of new confirmed cases, counteracting the effects of higher temperature on suppressing viral transmission (Zhang et al., 2020b). Air pollution could also create conditions that support transmission of the virus in cities with little wind and low average temperature (Coccia 2021).

Earth and climate. Planetary health approaches view the earth's changing climate as an imminent threat to human health (Almada et al., 2017). Across the U.S., 2020 was one of the hottest years on record, with heat waves noted in several areas of the country (Brown 2021). This resulted in greater demand for cooling and electricity which led to strained power grids and blackouts (e.g. in California) (CBS Los Angeles Staff 2020), and placed many at risk for heat-related illness. At the other extreme, snowfall and unusually cold winter temperatures in southern U.S. states like Texas, have also damaged power grids and affected the water supply (Mai, H.J. 2021; Romo, Vanessa 2021). Wildfires raging in western U.S. states during the summer resulted in poor air quality locally, and smoke clouds that carried carbon dioxide, black and brown carbon, PM and ozone precursors to most of North America by mid-September 2020 (Andrew 2020; US EPA 2019). Other extreme weather events related to climate change include hurricanes, which had elevated activity on the Atlantic coast in the summer of 2020 (Di Liberto 2020). COVID-19 complicated emergency responses to these events, including evacuations and aid delivery (Siegler, Kirk and Stewart, Ian 2020). Severe weather events may also limit people's ability to comply with guidelines to reduce the spread of the virus, like accessing testing or vaccination centers, avoiding crowds while seeking air-conditioned

spaces in heatwaves and warm spaces in winter storms, or hand washing during periods of limited clean water supply. Infrastructural resilience in the face of climate disaster remains centrally important (Chang 2010), especially during a pandemic. Plans to strengthen infrastructure (Ready 2020) are more important than ever to ensure that necessary resources remain accessible in the face of climate-stress-induced hazards and disasters during the pandemic. Changes in children's physical environments, stemming from disruptions in utilities, services and infrastructure, or loss of housing, could also exacerbate the social and economic inequities already exposed by the pandemic (Benfer et al., 2021). For example, as families attempted to warm their homes and cook by any means possible during winter power outages in Texas, there was a rise in carbon monoxide poisoning due to improper indoor use of outdoor devices such as grills, portable generators, and other heating sources (Treisman, Rachel 2021).

Lead. Lead impacts developing organ systems, including the heart, kidney (ATSDR 2020), and the immune system (Dietert and Piepenbrink 2006) and is a potent neurotoxicant linked to slowed growth and development, including learning, behavior, hearing, and speech problems in children (ATSDR 2020) which can persist into adulthood (Reuben et al., 2019). Lead exposure is widespread and there are numerous sources of household lead exposure, including water, lead-contaminated household dust and outdoor soil from old chipping paint, and the legacy of leaded gasoline (Braun et al., 2018; Gaitens et al., 2009; Mielke et al., 1997; Oulhote et al., 2013). Lead exposure serves as an example of the social inequities of the pandemic's impact. Children living in lower-income neighborhoods may be disproportionately exposed to many indoor pollutants, including lead (American Academy of Pediatrics Council on Environmental Health 2019b; Lynch and Meier 2020; Mielke et al., 2019; White et al., 2016).

In the U.S., all children are supposed to be screened for lead exposure; yet, the volume of lead tests for 1-2 year-olds has fallen since the start of the pandemic (Zeltner 2020), and it is unclear how other lead prevention activities (home inspections and remediation) will be impacted. New Orleans provides a case study of the overlapping social and lead exposure disparities, highlighting how myriad factors that put children in harm's way can be compounded during the pandemic. In Louisiana, by early April 2020, 70% of the COVID-19 fatalities were among Black people, who make up 32% of the state's population (Ferdinand 2020; McCarthy 2020). Similarly, a study of environmental lead sources and children's lead exposure concurrently noted that Black people were twice as likely as White people to inhabit environments with high amounts of lead in their soil (Campanella and Mielke 2008).

Pesticides. While children shelter-in-place, they may experience higher exposure to pesticides used and stored in their homes. Exposure to pesticides, particularly during critical developmental stages, could increase children's risk of both short- and long-term health effects (Dórea 2021; Muñoz-Quezada et al., 2013). With children spending more time indoors, there may be a greater likelihood of access and accidental poisoning by pesticides not stored or used safely in the home (Namulanda 2016). Exposures to current-use pesticides, like organophosphates or pyrethroids, have been associated with asthma symptoms, decreased lung function (Raanan et al., 2015, 2016), lower cognitive performance, greater attention problems (Viel et al. 2015, 2017), and autism traits in children (Sagiv et al., 2018), as well as increased depressive symptoms in adolescents (Suarez-Lopez et al. 2019, 2020). Pesticide exposure may disproportionately affect those children already made vulnerable by living in poorly-maintained homes, who may have greater pesticide exposure because of housing conditions and pest infestations (López-Gálvez et al., 2019; Quirós-Alcalá et al., 2011). Children living in agricultural communities may experience elevated exposures to both COVID-19 infection and to pesticides resulting from take-home exposure of farmworker parents (Lewnard et al., 2021), who are considered essential workers and therefore not sheltering-in-place, and because of pesticide use on farms near or within their community (Bradman et al., 2009; Suarez-Lopez et al., 2012; Suárez-López et al.,

2020).

Disinfectants, personal care products, and other chemical exposures. In the first quarter of 2020, there was a marked increase in the number of reported exposures to cleaners and disinfectants via ingestion or inhalation, with children younger than 5 years of age representing 36–47% of all cases (Chang 2020). By December 2020, almost 25,000 hand sanitizer exposure cases among children 12 years of age and younger were managed by poison controls centers in the U.S. (American Association of Poison Control Centers 2021). Many hand sanitizers are scented and are available in appealing, brightly colored bottles, which could contribute to ingestion by young children. The alcohol content in hand sanitizers can range from 40% to 95% (American Association of Poison Control Centers 2021) and ingestion can result in adverse health effects, particularly among small children (FDA 2020; Mahmood et al., 2020). Other compounds found in many cleaning products include quaternary ammonium compounds, which are raising concerns of negative health effects (Melin et al. 2014, 2016). Additionally, frequent use of household cleaning products in early life has been associated with an increased risk for childhood wheeze and asthma (Parks et al., 2020).

Ingestion of other potentially dangerous substances or products, including medications, vitamin supplements, and personal care products by young children spending more time at home is also a concern. The proper use, storage, and care for these products is a necessary area of attention for individual households. As children spend more time indoors, the potential for exposure to other common indoor toxicants such as brominated flame retardants present in upholstery sold prior to 2015, formaldehyde from pressed hard-wood products, phthalates from vinyl flooring, volatile organic compounds, radon, and others also grows (Malliaris and Kalantzi 2017; Vardoulakis et al., 2020). Finally, there are concerns that early childhood exposure to per and polyfluoroalkyl substances (PFAS), which are persistent pollutants almost ubiquitous in the U.S. population (U.S. Department of Health and Human Services 2019), may decrease the immunological protective response duration of some vaccines (Grandjean et al., 2017). These exposures are of particular concern in the 2337 locations across the U.S. where PFAS-contaminated drinking water has been reported (EWG 2021). Currently, it is unknown whether these chemicals may result in lower efficacy of SARS-CoV-2 vaccines.

Built, green, and blue spaces. The built environment has played an important role in SARS-CoV-2 infection in the U.S., with more densely populated households experiencing higher infection rates. For example, higher proportions of multi-family homes within census tracts were associated with higher hospitalization rates among infected individuals (Cromer et al., 2020). In the state of Rhode Island, neighborhood financial, housing, and transportation insecurity were each related to higher risk of COVID-19 infection (Rozenfeld et al., 2020). Across U.S. metropolitan areas, residing in densely populated zip codes served as a mediator in the association of Black race and Hispanic ethnicity with the likelihood of SARS-CoV-2 infection (Vahidy et al., 2020).

Furthermore, restrictions on outdoor recreation and social gatherings have been necessary to slow the viral transmission, but have reduced the frequency of outdoor activities and access to green and blue spaces for many people (Rice et al., 2020). These reductions were substantially greater among people living in urban areas with high population density, compared to those in rural areas or small towns (Rice et al., 2020). Children living in apartment buildings have even more restricted outdoor time due to lack of access to a backyard. The Centers for Disease Control and Prevention (CDC) point to physical and mental health benefits of physical activity for children's health during the COVID-19 pandemic (CDC, 2020b). It appears, however, that time spent in areas linked with outdoor recreation (e.g. parks or beaches) was reduced by 30% across 15 countries during the first months of the pandemic (Guan et al., 2020). Specific data for U.S. children do not appear to be available, but according to a survey of Canadian children conducted prior to July 2020, less than 5% of children were meeting age-appropriate movement behavior guidelines during the pandemic

(Moore et al., 2020), while also spending more time on screens and social media (Lannoy 2020). A simulation study in the U.S. estimated increases up to 2.4% in childhood obesity through March 2021 from COVID-19-related reduction in physical activity and school closures (An 2020). A small study at a tertiary New York City referral center compared exercise performance in youth 3–6 months post shutdown to a matched pre-pandemic cohort, and documented differences in functional capacity and anaerobic threshold among children (Dayton et al., 2021). These studies suggest that impacts to children's exercise, movement, and access to safe outdoor play will likely be important areas of focus for future research.

3. Food environments

The economic repercussions of the pandemic have been grave. The unemployment rate jumped from ~4% throughout 2019 to 14.7% in April 2020 (17–18% among Black and Hispanic individuals) (Bureau of Labor Statistics, U.S. Department of Labor 2020), followed by decreases to 7.9% by September (Bureau of Labor Statistics, U.S. Department of Labor 2020). Unemployment and low income are the major predictors of food insecurity in the U.S. An estimated 14% of families with children were already experiencing some level of food insecurity (either uncertain or limited access to food to ensure a healthy and active lifestyle) before the pandemic (Kinsey et al., 2020). The share of households with children who are food insecure jumped from ~3% overall (~5% Hispanic, ~7.5% Black) in 2018 to ~16% (25% Hispanic, 30% Black) in early June 2020 (Bauer 2020). The proportion of children living in food-insecure households could increase by 1.6%–9.3% points (12.4–18.0 million children) due to the pandemic, depending on the actual increases in the rates of unemployment and poverty (The Impact of Coronavirus on Food Insecurity | Feeding America 2020). Some of the safety net programs meant to help poor families, such as the Supplemental Nutrition Assistance Program (SNAP, which serves approximately 40 million people each year), have increased the level of benefits the families receive or have allowed online food purchases. Food insecurity also remains high among farmworker families (Mora et al., 2020), many of whom are undocumented immigrants, due to underutilization of safety net programs (Page et al., 2020), and food banks being overwhelmed by high demand (White 2020). Furthermore, states and local communities have been inconsistent in how safety net programs are implemented (Kinsey et al., 2020). U.S. children from socially and economically disadvantaged groups and those utilizing nutritional assistance programs already tend to have lower diet quality (Gu and Tucker 2017; Thomson et al., 2019). Reductions in the quality of foods may be among the first accommodations families make to growing food insecurity, which could in turn be related to exposure to environmental chemicals. For instance, packaged foods, which are often less expensive than fresh foods, may contain many food contact chemicals that could be taken up by humans (Muncke et al., 2020).

School meals and snacks provide up to two-thirds of children's nutritional needs (Dunn et al., 2020), but at least initially, a dearth of policies and programs to provide food aid when schools closed meant that this vital resource became unavailable. As school administrators attempted to decipher how to provide meals to the tens of millions of children who rely on them, local and national policy struggled to keep up with increased demand (Sugar 2020). School closures, even if short, have contributed to economic stresses, particularly in low-income or single-parent families, that include loss of income or additional expenses related to childcare (Tsai et al., 2017; Zheteyeva et al., 2017). Thus, school closures are likely to contribute to food insecurity (Van Lancker and Parolin 2020), both directly and indirectly. Food insecurity and hunger are associated with myriad health, educational, emotional, and behavioral problems in children (Seligman and Berkowitz 2019; Shankar et al., 2017).

4. Educational and developmental resources

School and childcare closures have changed family dynamics and children's daily routines, thus impacting children's social environments. Experiences during formative years underpin children's social relationships, school success, and future professional lives (Knudsen et al., 2006). While all families, even those with plentiful resources, have increased educational and caregiving responsibilities, disadvantaged families are experiencing distinctly negative impacts (Clark et al., 2020; Fortuna et al., 2020). The COVID-19 pandemic is widening existing social inequalities (Bambra et al., 2020), and the abrupt closure of schools in spring 2020 disproportionately affected some children and families more than others, both in terms of educational and broader social impacts (Esposito and Principi 2020).

Different age groups experience the pandemic in different ways. Physical distancing reduces opportunities for young children to play with their peers, engage in typical rough-and-tumble learning, or develop empathy. For young children, social distancing may delay or disrupt the development of socio-emotional skills and attentional and behavioral control (CDC 2020a; Loades et al., 2020; Ye 2020). Some older students may prefer remote learning that allows them to set their own pace and gives them the flexibility to focus on topics and activities they enjoy, and remaining at home may be a welcome respite for the roughly 20% of 6–12 graders who experience bullying in school (DeVoe et al., 2019). However, social isolation could interfere with peer relationships, mentorship and counseling at schools, sports, arts, and other learning opportunities beyond those offered through the physically distanced classroom (Klemko 2020).

Some adolescents may be expected to support the family financially during the pandemic, or provide childcare to younger siblings, rather than spending time on schoolwork, especially in households where parents are essential workers (Yoshikawa et al., 2020). Although the United Nations Educational, Scientific and Cultural Organization (UNESCO) and other organizations have called for uninterrupted learning during the pandemic (UNESCO 2020a), essential workers, single parents, and households already living in stressful conditions have little time to devote to helping their children with online learning (Bayrakdar and Guveli 2020; Yoshikawa et al., 2020). Other barriers for distance learning include limited or no access to home internet, which affected 6% of children ages 3 to 18 in the U.S. in 2018 (9% for Hispanic, 10% Black, and 20% American Indian/Alaska Native children) (IES-NCES 2020b). This digital divide is further compounded for children whose parents have low literacy, mental health problems, and/or important physical disabilities, as well as by interruptions to electric utilities in areas that face poverty and/or climate stress. Students with access to their own computer, high-speed internet, and in families with additional resources are better positioned to transition rapidly to digital learning. Programs that distribute laptop computers to students have been successfully implemented in many parts of the country to address these gaps, as have "Low-tech" distance learning, such as radio and television programming or paper packets, albeit with lower student engagement and monitoring compared to online education (UNESCO 2020b).

In the U.S., over 7 million children (14% of all public school students) receive special education services (IES-NCES 2020a). The benefits of these services are maximized by in-person contact between the specialist and the student or among students. Many digital learning platforms are not compatible with assistive technologies for children with some disabilities (Baron et al., 2020; Federal data summary School Years 2015-16 through 2017-18, 2020). Children who have difficulty engaging in learning, such as those with neurocognitive or learning delays and autism spectrum disorder, may be among the most affected by online learning. Homeschooling of children with special needs may be difficult for parents who lack the needed skills. Speech and occupational therapy, education support, assistive technology, and other services for disabled children are often available only at school. Moreover,

it may not be feasible to adhere both to distancing guidelines and the criteria outlined by each student's individualized education program (American Academy of Pediatrics 2020).

5. Social environments and mental health

COVID-19 is indirectly impacting the mental health of children, particularly those at risk for serious physical and mental health harm (Silliman Cohen and Bosk 2020). Many U.S. children live in multiple homes, in precarious situations, or are unsheltered. According to the National Center for Homeless Education, 1.5 million homeless children were enrolled in public schools or educational agencies in 2017 (Federal data summary School Years 2015-16 through 2017-18, 2020); for them, loss of access to school (including free or reduced meals) can represent a major stressor. School closures also limit the ability of the educational system to identify cases of neglect, abuse, and human trafficking, or to provide assistance or referrals for further assistance. For example, between March and April 2020, there was a reduction in the number of reports of child maltreatment in Florida, plausibly due to decreased contact with mandated reporters in schools (Baron et al., 2020). Reports from other settings suggested an increase in abusive head trauma among children between March and April of 2020 in comparison to the previous 3 years (Sidpra et al., 2020). For these reasons and more, child advocacy leaders have called for coordinated action by the international community to protect children from violence during the pandemic (WHO 2020).

Studies in China have found COVID-19-related home confinement to be associated with deteriorated levels of attention and higher anger frequency among 6-to-17-year-old children diagnosed with attention deficit hyperactivity disorder (Zhang et al., 2020a), while others describe symptoms of inattention, irritability, worry (Jiao et al., 2020), depression, and anxiety (Xie et al., 2020) among children more generally. In cases in which parents continue to work during the pandemic and leave children to self-care, the consequence may be more behavioral problems, including anxiety and withdrawal, risk-taking behaviors, and unintentional injuries (Esposito and Principi 2020). Children of essential workers, many of whom are low-wage earners, may be particularly affected by this.

Beyond worries about the pandemic, children's mental health or academic performance could be adversely impacted by family finances, parental unemployment, and parental adverse mental health, although maternal, family, or community resiliency factors may counteract some of these effects (Cairns et al., 2020; Murry and Brody 1999). Serious psychological distress among adults is associated in a dose-dependent manner with the number of financial stressors (food insecurity, financial worries, healthcare insecurity, etc.) (Tsuchiya et al., 2020). Notably, single-parent, female-headed households may be particularly affected. Children spending more time at home may also witness more family conflicts (Mora et al., 2020). On the other hand, parents of children with disabilities or developmental disorders already experience higher stress, depression, or somatic symptoms (Boyd 2002; Mailick Seltzer et al., 2001), and these are likely to be compounded by limited access to school or healthcare resources.

Approximately 40,000 minors, including several hundred under 12 years of age, are held in youth detention facilities across the U.S. (Statistical Briefing Book, 2020). Beyond the potential for COVID-19 transmission within such enclosed facilities, these children face sharp decreases in visits from family and advocates during the pandemic. This builds on stressors such as fears about their health and that of family members, unanticipated parental separation, disrupted social dynamics and school activities, or bullying, all of which can result in profound and long-lasting developmental impacts (Singh et al., 2020). To control infections in U.S. family detention centers, a June 2020 ruling by a federal judge mandated the release of migrant children from three such centers (Alvarez 2020). In the case of juvenile detention centers, the Department of Justice has cautioned that "releasing high-risk, high-need youth into

stressful environments without proper services in place increases pressure on the family structure and raises the likelihood of reoffending" (Harp 2020).

6. Social injustice and racism

The pandemic has amplified social injustices, economic structures, and structural racism in the U.S. For instance, concerns over safety have been reflected in the lower level of support expressed by Black and Hispanic parents for reopening schools in the fall of 2020 (Gilbert 2020). Specifically, all parents were equally concerned about the quality of their children's education, but in a survey conducted in July 2020, more Black parents (92.6%) than White (84.1%) parents were very or somewhat concerned with their children contracting COVID-19 in school. Furthermore, 52% of "essential" workers are low-income, 41% are people of color, and 17% immigrants (Rho et al., 2020). People of color make up most essential workers in food and agriculture (50%) and in industrial, commercial, residential facilities and services (53%), whereas 70% of essential workers do not have a college degree and 10% did not complete high school (Economic Policy Institute 2020; McNicholas and Poydock 2020).

Marginalized groups, including Native Americans, also are more likely to have pre-existing conditions and reside in places that limit their ability to observe physical distancing guidelines (Evans 2020). They and their families are at increased risk for SARS-CoV-2 infection (Dorning and Skerritt 2020; Eskenazi et al., 2020). Furthermore, migrant workers, many of whom are undocumented, are most vulnerable to coercion and denial of workers' rights. By January 2021 in the U.S., Hispanic, Black, Pacific Islanders, and Indigenous Americans all had COVID-19-related death rates that were twice or more than those of Whites and Asians (APM Research Lab Staff 2021). Meanwhile, people of Asian descent are experiencing prejudice and xenophobia related to the framing of the origins of the pandemic (Dhanani and Franz 2021). Even before the pandemic, Black children were three times more likely than White children to lose a mother by the time they were 10 years old (Umberson et al., 2017), an important disparity that affects children's physical and mental health (Turecki and Meaney 2016; Umberson et al., 2017). Some marginalized communities have less access to healthcare, while also feeling disrespected, treated unfairly or receiving lower quality care; this predisposes them to poorer outcomes due to comorbid conditions (Tai et al., 2020).

Beyond seeing their communities disproportionately affected by COVID-19, children of color have recently borne witness to the deaths of numerous people of color during interactions with the police, to street protests in which their community members or loved ones have taken part, and to negative public rhetoric and even backlash. These examples bring attention to structural societal and economic injustices that underlie COVID-19-related disparities. Children who experienced direct or vicarious (indirect) discriminatory or racist environments had poorer mental and physical health, with lifelong consequences (Heard-Garris et al., 2018; Trent et al., 2019; Williams et al., 2019). Altered immune function, inflammation or stress responses are potential biological consequences of discrimination which could also contribute to the comorbidities that increase the risk of serious COVID-19 infections (Ajilore and Thames 2020).

7. Discussion & considerations for Children's health stakeholders

Public health efforts to counteract the spread of SARS-CoV-2 and to reduce its related morbidity and mortality have been essential, and we strongly encourage continued adherence to public health recommendations. It is, nevertheless, valuable to acknowledge how the continuing pandemic and the counteracting public health and economic responses have altered children's environments. Children have experienced many intersecting changes in their physical and social environments, resulting

in increased potential for exposure to stressors and mixtures of contaminants. In many ways, the pandemic has provided a window into the social, economic, and structural systems already creating environmental health risks for children and highlights the importance of appropriate resource allocation to address disparities. The principles of social justice and ethics in public health not only require that public health interventions be effective and proportionally tailored against a threat, but that they produce the fewest possible secondary adverse effects, and allocate both the burdens and benefits equitably across society (Berkman 2008).

As environmental exposures intersect and interact with stressful or toxic social and economic environments, the impacts on children's health can be amplified and experienced for long periods of time and perhaps across generations. We call on policy makers to recognize that as loci or sources of adversity, children's environments are an important determinant of health that should be addressed during and after the pandemic. We recommend the inclusion of environmental health professionals in the design and implementation of public health responses to emergencies. Likewise, we urge environmental health researchers, practitioners, and advocates to seek out opportunities to discuss children's environmental health during public health emergencies. The creation or strengthening of research-practice partnerships (Coburn et al., 2013) or similar coalitions that include environmental health scientists could shorten the pipeline between research and policy.

It is also imperative that environmental health scientists, advocates and practitioners understand and expose disparities and injustices in environmental exposures among children. In responding to pandemics or other emergency situations, it is paramount to recognize which children are made vulnerable by structural racism and other inequalities, and how resources can expediently be made available to them. Tools that help visualize the interplay of social and environmental constructs (Egendorf et al., 2021) with COVID-19 (and other conditions), such as those released by the Center for Environmental Health Disparities in Los Angeles (Center for Environmental Health Disparities Research), could help inform community members, researchers, and policy makers. Working across disciplines to understand how children's exposures to environmental contaminants and mixtures change during public health emergencies and how these exposures fit within the broader context of children's environments would help us better plan for similar events in the future.

The National Institutes of Health and other agencies have made available funding streams to promote research on the health consequences of COVID-19. We recommend that observational research in this area include: 1) documentation of how children's physical and social environments have changed across the pandemic, 2) investigation of the short and long-term developmental consequences of those environmental changes, particularly at the intersection of climate-related emergencies, 3) investigation of the effects of physical and social environments on SARS-CoV-2 infection and COVID-19 morbidity among children, 4) examination of the role of environmental chemical exposures on vaccine efficacy. Paradigms, including anthropology of environmental health (Singer 2016), syndemics (Singer 2017) and structural/historical violence (Peña 2011), that connect multidimensional socio-environmental exposures and outcomes can help with framing and moving forward research and programmatic agendas. On the implementation side, funding is needed to scale up interventions we already know work to reduce learning gaps or mental health problems in at-risk children. A deeper understanding of all the environments that have changed during the pandemic, their intersections, and their compounded effects on children should inform the targeting and delivery of the intervention programs.

Author's statement

Drs. Suarez-Lopez, Cairns, Sripada, Quiros-Alcala, Mielke, Eskenazi, Etzel and Kordas conceptualized the manuscript, were involved in drafting and critically reviewing the manuscript for important intellectual content, and revised the manuscript as needed. All authors approved the

final manuscript as submitted and agree to be accountable for all aspects of the work.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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