

## The Autism Biosolids Conundrum\*

**\*Despite overwhelming evidence that certain heavy metals, toxic organic chemicals and infectious agents play an important role in triggering autism and other environmental health problems, the U.S. Environmental Protection Agency supports land application of largely unmonitored concentrations of these contaminants in biosolids.**

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### ABSTRACT

Before Congress passed the Clean Water Act of 1972, municipalities throughout the United States discharged hazardous municipal and industrial wastes directly into rivers and other waterways. Every chemical and biological agent linked to neurodevelopmental disorders, including those linked to “autism spectrum disorders” (ASDs), spilled into coastal waters and settled on the bottoms of the oceans. The solution to pollution was dilution. To comply with the Clean Water Act of 1972, President Carter created wastewater treatment plants throughout the United States to extract heavy metals and toxic organic chemicals from water and concentrate them in sewage sludges that were dumped offshore and buried in landfills. In 1988, Congress banned ocean dumping of sewage sludges because of their potential for causing vaccine-derived polio epidemics. Suddenly, high concentrations of every heavy metal, toxic organic chemical and vaccine-derived viruses linked to autism, including rubella and cytomegalovirus, had no place to go but land. The solution to pollution shifted from diluting pollutants in water to concentrating them on land at hundreds of thousands to millions of times higher concentrations, including on commercial farms that produce our nation’s food supplies. Now, all of the most dangerous pollutants regulated by EPA no longer require biomagnification up the food chain to harm public health. Promoted by EPA and the USDA as safe and environmentally beneficial, land application practices quickly spread worldwide. Here, the author relies largely, albeit not exclusively, on EPA’s own research to address the implications. As a whole, it indicates that the global shift that EPA’s 503 Sludge Rule created in the accumulation of pollutants from ocean sediments to populated land surfaces is causally related to sharp increases in the incidence of neurodevelopmental disorders worldwide. Autism in its severe infantile form is more or less at the center of this entire class of disorders that appears to have become epidemic beginning in late 1988. EPA dismissed controversial claims linking MMR vaccination to autism, but never addressed the role that widespread land application of sewage sludges (a.k.a. biosolids), which contain highly virulent strains of vaccine-derived measles, rubella and other viruses, may play in autism. Notwithstanding this glaring omission, the global shift that EPA policies on biosolids created in human exposures to complex mixtures of measles, rubella and other viruses derived from live vaccines, combined with high concentrations of potentially every

heavy metal and chemical pollutant linked to autism, could explain sharp increases in the incidences of autism and other ASDs that began in 1988.

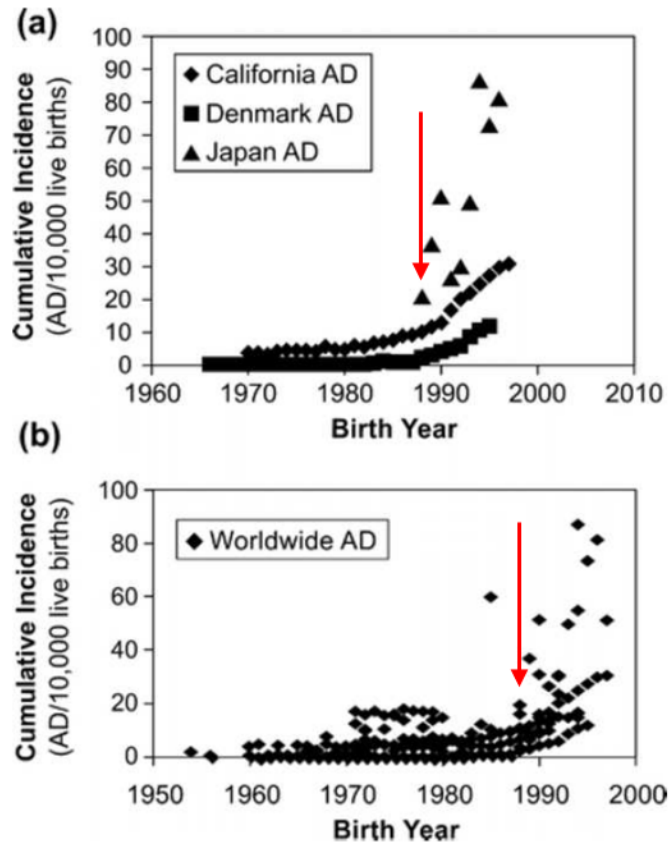
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## Introduction

Following mainstream trends in the previous decade for differentiating ASDs, McDonald and Paul (2010) described the Kanner-type of “infantile” autism as “a severe neurodevelopmental disorder typically identified in early childhood” (p. 2112). Based on multiple studies (California Department of Developmental Services, 2003; Lauritsen, Pedersen, & Mortensen, 2004; Honda et al., 2005), they discovered evidence of a sharp increase in the “cumulative incidence” of this disorder “about 1988-1989” (note the red arrow in parts (a) and (b) of **Figure 1**). Based on cohort birth years for children born in the 1950s through the 1990s, they determined that the mean cumulative incidence of autism per 10,000 live births worldwide rose from 6.0 to 24.2.

The time frame for a potential environmental changepoint reported by McDonald and Paul (2010) was later closely approximated by Nevison (2014; Nevison et al., 2018). Collectively, the onset of these increases coincided with Congress banning ocean dumping of sewage sludges containing high concentrations of every pollutant suspected of triggering severe autism, ASDs in general, and neurodevelopmental disorders on a grand scale. Although Congress passed Clean Water and Clear Air Acts, it passed no comparable legislation to ensure the safety of the soil in which we grow our crops, feed our livestock, and from which dust particles enter the air, rivers, and oceans.

Once Congress banned ocean dumping, sewage sludges had nowhere to go but to the land on which we live. Inevitably, much of the contamination present in sewage sludges loaded into the soil via land application must end up in our drinking water and food. Here, I argue that a preponderance of



**Figure 1.** Marking an environmental changepoint at about 1988 for AD incidence: (a) data from California, Denmark, and Japan; and (b) worldwide. Reprinted by permission from McDonald and Paul (2010), “Timing of increased autistic disorder cumulative incidence,” in *Environmental Science & Technology*, 44, p. 2113. All rights reserved.

concordant evidence suggests the possibility that land application of sewage sludges, also commonly referred to as “biosolids”, may have been, and still remain, a driving force behind the apparent rising incidence of ASDs and other neurodevelopmental disorders.

Various studies have documented respiratory illnesses associated with exposures to sewage sludge particulates carried by winds blowing across fields covered with dried sewage sludges (Dorn, Reddy, Lamphere, Gaeuman, & Lanese, 1985; Lewis & Gattie, 2002; Lewis, Gattie, Novak, Sanchez, & Pumphrey, 2002; Khuder et al., 2007; Wing, Lowman, Keil, & Marshall, 2014; Jaremków, Noga, & Pawlas, 2018). These results are not surprising considering the levels of chemical irritants, immunosuppressants and respiratory pathogens present in sewage sludges. They underscore the connection between air pollutants and the prevalence of neurodevelopmental disorders including severe ASDs, as well as infectious diseases, and cancers as reported by others (Windham, Zhang, Gunier, Croen, & Grether, 2006; Kalkbrenner et al., 2010; Becerra, Wilhelm, Olsen, Cockburn, & Ritz, 2013; Fordyce et al., 2018; Grova, Schroeder, Olivier, & Turner, 2019; Pelch Katherine E., Bolden Ashley L., & Kwiatkowski Carol F., 2019).

Researchers investigating selective serotonin reuptake inhibitor fluoxetine, for example, discovered that as little as 1 part-per-billion (ppb) adversely affected the central nervous system in fathead minnows, and increasing the concentration tenfold also adversely affected the gut microbiome (Weinberger & Klaper, 2014; Mole & Brooks, 2019). The authors identified wastewater treatment plants as the primary source of this drinking water contaminant. According to a survey conducted by the EPA (United States Environmental Protection Agency, 2009), fluoxetine concentrations in sewage sludges range from 12.4 to 3,130 µg/kg (ppb). Currently, EPA places no limits on the concentrations of any hazardous organic chemical wastes in sewage sludges applied to land; and it only regulates a few indicator pathogens, *e.g.* salmonella and *E. coli* (see Flemming, Simhon, & Odumeru, 2017).

Although sewage sludges typically contain highly complex mixtures of infectious agents and hazardous chemical wastes, the incidences of cancer (American Cancer Society, 2019), birth defects (CDC 1991) and Alzheimer’s Disease (Rocca et al. 2011) do not indicate that shifting pollutants from ocean sediments to land surfaces in 1988 had any immediate effect on environmentally-triggered diseases and disorders worldwide. This is not surprising given that immediate health effects associated with land application of sewage sludges, *e.g.*, infections of the skin, respiratory tract and gastrointestinal tract, are largely confined to populations living within 1 km of land application sites (Lewis *et al.* 2002). They involve high exposure levels to mixtures of irritant chemicals and live vaccine-derived viruses that immediately elicit coughing and burning eyes.

Immediate, worldwide increases in the incidence of ASDs, especially of the more severe variety denoted technically as AD, beginning in 1988 likely involved exposures to much lower concentrations spread via the upper atmosphere. Similar sharp increases occurred in obsessive compulsive disorder during the 1980s (Stoll, Tohen, & Baldessarini, 1992). Linking low concentrations of neurotoxic dust particles raining down from the upper atmosphere to autism suggests that certain areas of the brain, and the developing brain in particular (Goldman & Miller, 2012), are vulnerable to the effects of even extremely low concentrations of highly complex mixtures of hazardous chemical and biological wastes.

## From sea to soil: The politics of sewage sludge

Heavy metals, polychlorinated biphenyls, perfluoroalkyl substances, organochlorine pesticides, endocrine disruptors and other pollutants associated with neurodevelopmental disorders are lipophilic, environmentally persistent, magnified up the food-chain, and associated with increased risks for adverse developmental, reproductive, and neurological effects in humans and animals. EPA classifies such chemicals as priority pollutants. Priority pollutants found in rivers, lakes and streams drain into coastal areas and mix with global ocean currents. Eventually, they concentrate in organic matter in ocean sediments, far removed from direct contact with humans.

In 1972, Congress passed the Clean Water Act to further lower pollution levels in rivers, lakes and other surface waters. President Carter, in turn, created the largest public works program since the Great Depression by having wastewater treatment plants (WTPs) constructed in every municipality within the United States and its territories. WTPs extract traces of fat-soluble pollutants from water by allowing them to concentrate in sewage sludges, which are mainly comprised of human feces, much like they naturally concentrate in the organic matter that settles out and mixes with ocean sediments. As fat solubility rises, however, so does neurotoxicity (European Parliament 2001). Moreover, concentrations of neurotoxic pollutants in sewage sludges are typically hundreds of thousands to millions of times higher in sewage sludges than they could ever exist if they were dissolved in water (United States Environmental Protection Agency, 2009). Consequently, widespread exposures to sewage sludges may lead to sharp increases in neurological disorders, including ASDs.

Unfortunately, there are inherent difficulties in differentiating the diagnosis and treatment of the heterogeneous neurodevelopmental disorders under the large umbrella of ASDs and peripheral disorders. McPartland (2017), for example, concluded that “social cognition is impacted in multiple disorders, including autism but also schizophrenia and anxiety, and biomarkers germane to treatment selection or outcome measurement may be common across disorders with overlapping clinical symptomatology” (p. 2). In any case, the author of this paper has addressed the apparent increasing pervasiveness, and the severity of the growing epidemics of neurodevelopmental disorders in the context of a global shift in the transport and fate of pollutants linked to autism, which began in the late 1980s.

When the United States and other nations began constructing wastewater treatment plants in the 1970s, most sewage sludges were destined for landfills or were dumped offshore. The turning point for increases in the diagnosis of ASDs, which began in late 1988, precisely marks the time at which the transport and fate of all priority pollutants linked to ASDs began to shift from ocean sediments to land surfaces in populated areas.<sup>6</sup> Until then, ocean dumping prevented highly concentrated priority pollutants in sewage sludges from coming into direct contact with human populations as a whole. Even sewage treatment plant workers are exposed primarily by handling the wet material

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<sup>6</sup> Efforts to definitively distinguish various diagnoses, for example ASDs in general from IDs, and the more severe AD as being clearly distinct from Asperger syndrome, have become widely recognized as problematic (Casanova, Sharp, Chakraborty, Sumi, & Casanova, 2016; McPartland, 2017; Richard, Hodges, & Carlson, 2019; Thurm, Farmer, Salzman, Lord, & Bishop, 2019). Since 2013 when *DSM-5* was published, therefore, many researchers have defaulted to the general descriptor, ASDs, more or less lumping the various sub-categories together.



while wearing protective gear. By contrast, pregnant women and newborn children living within several kilometers of land application sites continually ingest and inhale sewage sludge dusts accumulating in their living and work spaces.

Roy, Tang, and Edwards (2019) found that concentrations of lead and other priority pollutants in sewage sludges mirror their levels in drinking water and blood samples taken from exposed populations. These results are important, albeit not unexpected, since land application of sewage sludges directly contribute to drinking water pollution via water runoff, groundwater contamination and windborne particulates settling out in surface waters. Most importantly, their results underscore the irony of spending billions of dollars to remove traces of pollutants from water only to amplify their concentrations on land where they contaminate air, drinking water supplies and agricultural products.

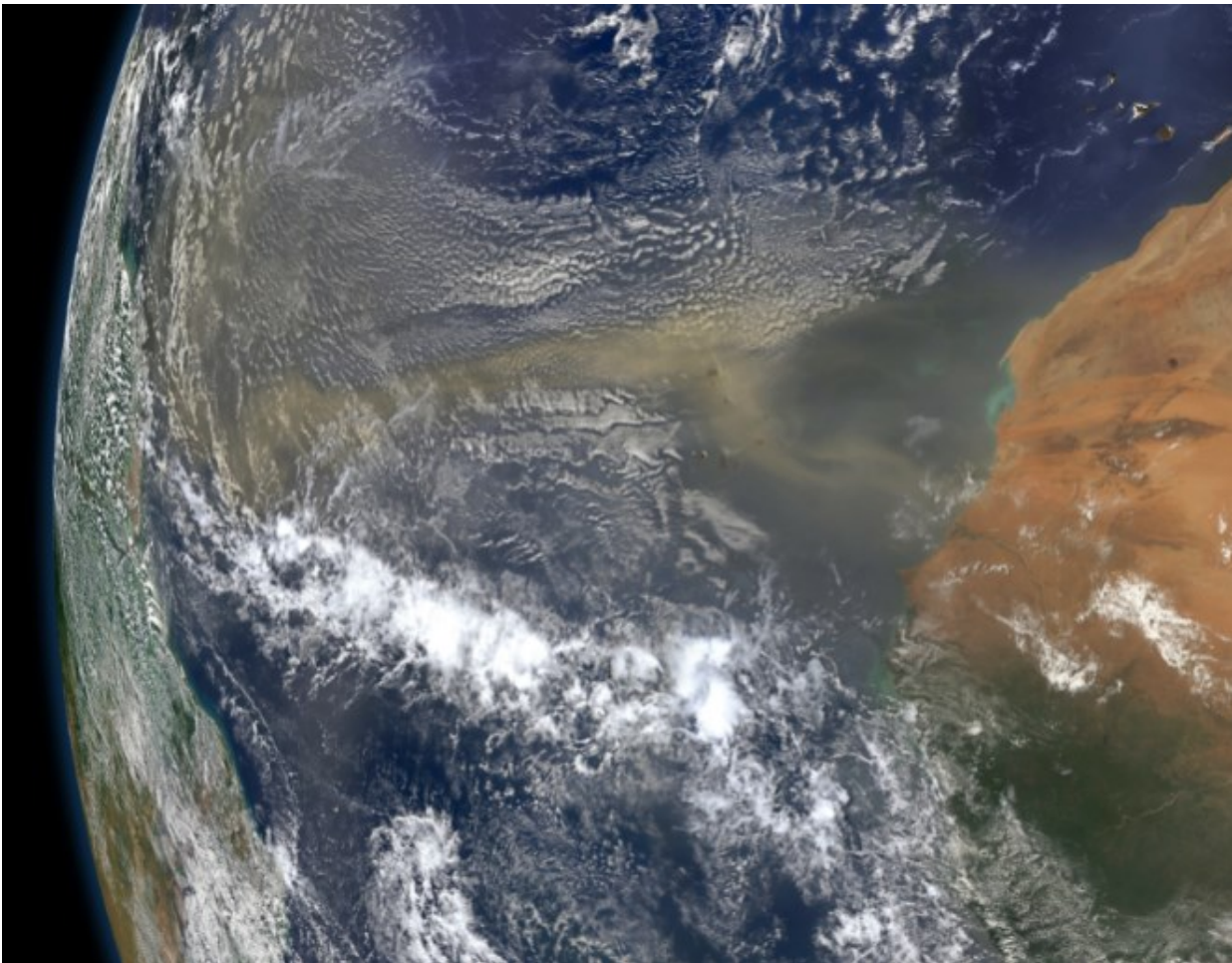


Figure 2. A view from one of NASA's satellites shows how dust from one continent, carrying the surface pollutants with it, is transported by wind to rain down on another.

Viewed from NASA's Earth-observation satellites (see [Figure 2](#)), the global impact of shifting priority pollutants in sewage sludges from seafloor sediments to land surfaces is clearly visible. Dusts generated by one continent traversing oceans and raining down upon other continents renders comparisons of the incidence of neurodevelopmental disorders over time from one country to another difficult to monitor, at best. Even Switzerland, for example, though benefiting from banning

land application of sewage sludges (Federal Department of the Environment, Transport, Energy and Communications, Switzerland, 2003), is nonetheless vulnerable to sewage sludge dusts picked up and transported across Europe in the upper atmosphere that enter Switzerland from all directions. Prevailing winds moving westward over the country collide with other air masses headed in the opposite direction along the North Atlantic Drift, as well as downward from the Arctic and northward from the Mediterranean.

## Managing the “science”

In a 5-year study conducted at the University of Florida, the incorporation of dried sewage sludges at 10 to 20 percent of swine rations depressed their weight gains and increased kidney cadmium levels (Edds & Davidson, 1981). Cadmium levels increased by 17 and 24 ppm for swine receiving rations containing sewage compared with 4 ppm in controls. Levels of cadmium, and lead as well, increased in the liver and kidneys of weanling pigs. Reproductive performance was increasingly suppressed in second generation sows. When liver and kidney tissues were dried, ground, and incorporated into mouse diets, metals were translocated through the cattle and swine tissues, and resulted in increased levels of cadmium, nickel, chromium, and lead in liver and kidney tissues of mice.

Results of the University of Florida study demonstrated that complex mixtures of high concentrations of heavy metals and toxic organic chemicals in sewage sludges can enter the human diet when applied to farmland. Studies by Shelton et al. (2014; also see Gangemi et al., 2016; Gialloreti et al., 2019) have documented increased incidences of neurodevelopmental disorders, ASDs in particular, among residents living near agricultural areas where pesticides are used. Such studies, however, fail to address whether agricultural use of sewage sludges containing high concentrations of potentially every other pollutant linked to ASDs and neurodevelopmental disorders are playing a role. Studies focused on specific chemicals, or groups of chemicals, would be more insightful if, for instance, the incidence of ASDs prior to 1988 were known and could be reliably compared with incidence in the mid-1990s and beyond, even now, long after land application of sewage sludges had become widespread.

Working hand-in-hand with the wastewater industry, EPA’s Office of Water (OW) proposed the “503 Sludge Rule” or the “503 Rule” (United States Environmental Protection Agency, 1993). It deregulated all pollutants in sewage sludges except ten heavy metals, plus nitrogen and phosphorus, and began promoting application of biosolids to land as an “organic” fertilizer. The only treatment required for land application of sewage sludges is adding lime, or subjecting them to low levels of heat to reduce indicator pathogens, typically, only *E. coli* and *Salmonella*, though almost two dozen fecal coliforms, enteric viruses, and parasites are supposedly monitored (Kamler & Soria, 2012, p. 134). Absent any untainted body of science to support the safety of land application of such sewage sludges, scientists at EPA’s Office of Research and Development (ORD) opposed the practice. Based on a paucity of data demonstrating adverse health effects, and while ignoring widespread suppression of research documenting adverse health effects within EPA and the USDA, researchers funded by federal agencies and the wastewater industry have promoted land application of biosolids as safe and environmentally beneficial (see Batley, Kirby, & McLaughlin, 2013; Broderick & Evans, 2017).

The prevalence, however, of high concentrations of EPA-listed priority pollutants in sewage sludges, which are known to cause severe neurological and developmental disorders, combined with the ongoing world-wide increase in neurodevelopmental disorders, including ASDs, is prima facie evidence to the contrary (Gangemi et al., 2016; Hicks, Wang, Fry, Doraiswamy, & Wohlford, 2017; Bölte, Girdler, & Marschik, 2019; Grova et al., 2019). These, plus countless similar studies linking parts-per-billion levels of exposures to increases in the incidence of chronic neurodevelopmental diseases and disorders is sufficient to refute claims about the safety of biosolids, which continue to be issued by federal agencies, the wastewater industry, and the institutions they fund.

All 12 field laboratories of the EPA-Office of Research and Development (EPA-ORD) unanimously rejected the 503 Sludge Rule when the EPA-Office of Water (EPA-OW) first proposed it in 1992. To counter widespread opposition from EPA research scientists, EPA-OW worked with the Water Environment Federation (WEF), which represented the wastewater industry, to establish a National Biosolids Public Acceptance Campaign (United States Environmental Protection Agency, 1992-1999). Its goal was to discredit reports of adverse health effects, and render land application of sewage sludges non-controversial by the year 2000. In short, the US EPA was engaging in a propaganda campaign at taxpayers' expense and to their detriment, rather than doing unbiased scientific research to protect them from harm.

Field studies conducted by the author and his colleagues at 10 land application sites across the U.S. and Canada indicated that soil particles dispersed from treated fields were causing serious adverse health effects (Lewis *et al.* 2002). Residents' medical records and soil tests at a small (10-ha) land application site in New Hampshire, for example, indicated that eye irritation, skin rashes, difficulty breathing, vomiting, and flu-like symptoms correlated with exposures to dusts blowing from the site. Cumulative exposures to sewage sludge dusts decreased linearly with distance, and produced one or more of these symptoms among all 28 residents occupying eight houses located  $\leq 130$  m from the field. In similar studies, Ghosh found that dusts blowing from fields treated with biosolids contained high levels of *S. aureus* (Ghosh, 2005).

The authors reported one fatality at the New Hampshire site involving a young college student visiting his parents over the Thanksgiving Holidays. While sleeping under bedsheets collecting visible amounts of sewage sludge dusts entering through his bedroom window, he experienced severe respiratory distress and succumbed before emergency care could arrive. Based on DNA analyses, the authors determined that *Brevundimonas diminuta*, which is known to cause sudden respiratory failure among hospital patients using contaminated masks, was proliferating in biosolids applied in the neighborhood at the time of his death. Symptoms of chemical irritation and respiratory infections, including staphylococcal pneumonia, frequently recurred among residents living near the site for at least one year after sewage sludge applications ceased.

## **Vaccine sources for rubella and cytomegalovirus**

Rubella, which causes Congenital Rubella Syndrome (CRS), is considered a vaccine-preventable cause of autism (Berger, Navar-Boggan, & Omer, 2011; Lambert, Strebel, Orenstein, Icenogle, & Poland, 2015; A. Ornoy, Weinstein-Fudim, & Ergaz, 2015; Hutton, 2016; Asher Ornoy, Weinstein-Fudim, & Ergaz, 2016). Its exposure route is respiratory; and, it has been a reportable disease since 1966 (Lambert et al., 2015). Because complex mixtures of priority pollutants in sewage sludges

increase the risks of contracting respiratory infections (Lewis et al., 2002), sewage sludge dusts carrying live, vaccine-derived rubella virus may lead to neurodevelopmental disorders that will often be diagnosed as autism. In the presence of highly complex mixtures of priority pollutants, even sub-clinical rubella infections may trigger CRS, an ASD diagnosis, or both. If true, then under-reporting of rubella makes correlating statistics on the incidence of rubella, CRS and ASDs difficult at best. Still, annual rubella occurrences may yield insight into some of the risks that land application of sewage sludges poses.

During the last rubella epidemic in the United States, 448,796 cases were reported in 1964 (Centers for Disease Control and Prevention, 1991). When Congress banned ocean dumping of sewage sludge in 1988, annual rubella cases had dropped to 221, their lowest since 1966 (Centers for Disease Control and Prevention, 1991). In 1993, EPA deregulated almost all pollutants in sewage sludges, and yet rubella cases recorded from 1994-1997 remained low, averaging 183 cases per year (Centers for Disease Control and Prevention, 1997). Had the epidemic not abated, land-applied sewage sludges may have been even more prone to trigger increases in ASDs.

Another contaminant associated with both sludges and with neurodevelopmental disorders is the cytomegalovirus which has been suspected as a potential causal factor in ASDs along with rubella (Ornoy et al., 2015; Sakamoto, Moriuchi, Matsuzaki, Motoyama, & Moriuchi, 2015; Zhang & Fang, 2019). As in the case of the polyomaviruses and simian 40, cytomegalovirus has been associated with metastatic breast cancer (Richardson et al., 2015; Valle Oseguera & Spencer, 2017; Herbein, 2018; Yang et al., 2019). Additionally, the cytomegalovirus, and the polyomavirus simian 40, also known as the “vacuolating virus”, is known to have been transmitted to the human population through the Sabin and Salk polio vaccines (Hilleman, 1998; Sierra-Honigmann & Krause, 2002; Sakamoto et al., 2015; Shen, Xu, Chen, Tang, & Huang, 2018; Zhang & Fang, 2019). These viruses were also cultivated in simians (Sierra-Honigmann & Krause, 2002; Richardson et al., 2015).

## **When the mouse squeals**

Research on adverse effects of land application of sewage sludges was effectively blocked by Henry L. Longest, II, who was the architect of EPA’s land application policies. Soon after the author reported adverse health effects linked to biosolids, Longest was appointed Acting Assistant Administrator of EPA-ORD. This move virtually guaranteed that EPA research scientists would not be allowed to publish any results that could undermine the 503 Biosolids Rule (Snyder, 2005). To this end, Longest withdrew the author’s research funding for publishing a commentary in *Nature* (Lewis et al., 1999), which raised public concerns over land application of sewage sludges. Longest also attempted to remove the author’s laboratory director for approving a research article that the author published in *Nature* (Lewis et al., 1999), which sparked public concerns over land application of sewage sludges. The results of field and laboratory studies revealed that organic nutrients in sewage sludges alter biodegradation pathways. These findings rendered EPA’s risk assessments unreliable for about a third of the organic pollutants it regulates. Fortunately, the laboratory director’s removal was blocked by EPA Administrator Carol Browner.

After holding hearings into retaliations against the author by senior executive service officials at EPA who were responsible for developing EPA’s sewage sludge policies, Congress passed The Notification and Federal Employee Antidiscrimination and Retaliation Act (United States Equal



Employment Opportunity Commission, 2002). It specifically refers to EPA's retaliations as a basis for the Act: "[An] Occupational Safety and Health Administration investigation found that the Environmental Protection Agency had retaliated against a senior scientist for disagreeing with that agency on a matter of science and for helping Congress to carry out its oversight responsibilities...." Lobbyists for the Senior Executive Service, however, persuaded Congress to exclude senior-level managers from being subject to any penalties under the *No Fear Act* (G J Shaw, 2002). Armed with impunity, Longest unilaterally executed the author's retirement from federal service. This, despite EPA having signed a settlement agreeing to permit the author to continue his research for another four years as required by the Intergovernmental Personnel Act. By terminating the author, Longest signaled other EPA scientists who might be inclined to question the sewage sludge policies he had developed. The *No Fear Act*, therefore, did not actually alleviate any real fears that EPA scientists had or might have in the future that could prevent them from publicly expressing concerns about land application of sewage sludges. On the contrary, the No Fear Act protected those in power rather than vulnerable researchers, whom this Act actually gave even more cause to be fearful.

This law, it seems, draws attention to an analogous phenomenon scientists refer to as "the ecology of fear." Brown, Landré, and Gurung (1999) found that a single mouse being captured by a hawk in plain view of other mice clears the whole field: "Merely the threat of predation may be sufficient; [but] death by predation must occur to make this threat credible." In 2008, a survey of 1,600 scientists at EPA-ORD found that over half had experienced political interference within the previous five years; 22% witnessed selective or incomplete use of data to justify an EPA regulation; and 17% were directed to inappropriately exclude or alter technical information. Many respondents feared retaliation if they failed to comply (Union of Concerned Scientists, 2008). As President Eisenhower had warned decades before the survey was conducted, "The prospect of domination of the nation's scholars by Federal employment, project allocations, and the power of money is ever present and is gravely to be regarded (Eisenhower, 1961)." The heart of the problem was summed up by a respondent to the UCS (2008) survey of research scientists at the US EPA: "science is used only if it furthers pre-existing policy; otherwise it is ignored, marginalized or suppressed" (p. 2).

## **Toxic soup capacity**

Landrigan and colleagues suggested that research on environmental causes of neurodevelopmental disorders, including "autism, attention deficit/hyperactivity disorder (ADHD), mental retardation, dyslexia, and other biologically based disorders of brain development" should focus on specific pollutants and chemical groups that are consistently implicated by multiple studies (Landrigan et al., 2012). This includes lead, methylmercury, polychlorinated biphenyls, organophosphate pesticides, organochlorine pesticides, endocrine disruptors, automotive exhaust, polycyclic aromatic hydrocarbons, brominated flame retardants, and perfluorinated compounds. If, however, shifting the global accumulation of priority pollutants and infectious agents from ocean sediments to populated land surfaces is the primary driving force, research should approach the problem from the side of the persons injured. We should focus particularly on the developing brain and its vulnerability to complex mixtures of chemical and biological agents. We know, for instance, that ASDs are linked to such causal agents. Experimental designs and regulatory approaches should resemble those used to investigate the effects of tobacco smoke, and should focus on preventing avoidable exposures.

The increases in neurodevelopmental disorders, along with ASDs and other environmentally triggered diseases that can be definitively associated with land application of sewage sludges are largely irreversible. Highly complex mixtures of trace levels of heavy metals including copper, zinc, mercury, chromium and cadmium, cause common biodegradation pathways to shut down (Said & Lewis, 1991). Trace levels of chromium, which EPA deregulated in sewage sludges in 1994, inhibited biodegradation the most when mixed with traces of other heavy metals. In practice, this effect was apparently manifested later on in the form of “dead patches” on hayfields fertilized with sewage sludges where hundreds of head of cattle died when grazing on hay contaminated with complex mixtures of thallium, other heavy metals and toxic organic chemicals (Tollefson, 2008; Solano et al., 2009; Caritá, Mazzeo, & Marin-Morales, 2019).

Follow up studies since Tollefson’s critical article appeared in *Nature* 2008, showed that contaminants in sewage sludge are not only biologically harmful to living plants and animals, and not only are they exceedingly difficult to biodegrade through normal microbial action, but the combined effects of multiple contaminants are genotoxic and mutagenic (Solano et al., 2009; Mazzeo, Fernandes, & Marin-Morales, 2016; Caritá et al., 2019). Meantime, any number of claims, based on failed “searches” designed in such a way as to find no evidence that sewage sludge is, for instance, mutagenic or carcinogenic (P. R. P. da Silva, Barbisan, Dagli, & Saldiva, 2012), are all absurdly false. Failed searches prove nothing whatsoever. By contrast, however, just one search revealing genotoxicity and cytotoxicity (for example, V. H. P. da Silva et al., 2014), is sufficient to show that the opposite is true, and the review by Caritá et al. (2019) shows that there are many such studies revealing the absurdity of using highly contaminated sludges in producing consumable products for humans. The relevant findings show that inevitable harm must come from using sewage sludges in producing consumable foodstuffs and livestock feeds — much of which would likely only be detected generations downstream after it is too late to do anything to prevent it.

In the decades since our 1991 study was published, there have been many theoretical and experimental efforts to enhance the biodegradation of sewage sludge contaminants (see, for instance, Nascimento, Silveira, Bidone, & Sabadini-Santos, 2019 and their references). Some adverse health and environmental effects of targeted contaminants have been ameliorated, though not entirely reversed, under highly controlled conditions (Briceño, Fuentes, Saez, Diez, & Benimeli, 2018; Aparicio, Raimondo, Gil, Benimeli, & Polti, 2018; Aparicio et al., 2019; Baoune, Aparicio, Pucci, Ould El Hadj-Khelil, & Polti, 2019; Baoune et al., 2019; Zalko et al., 2006; de Moura et al., 2016; Mazzeo et al., 2016; Chen et al., 2019; Gu et al., 2019; Handan et al., 2019; Salama, Arab, Hassan, Al robaian, & Maghrabi, 2019). Authors of these studies generally caution, however, that applying their findings to “field scale” decontamination efforts is not warranted. It is unlikely that cost-effective means for completely decontaminating large tracts of land treated with biosolids will be available in the near future, if ever.

Decades after biosolids were applied to one of the dairy farms that the author investigated, large areas of vegetation, including invasive weeds, turned to charcoal whenever they sprouted in certain areas treated with sewage sludges (Heilprin, Vineys, & Associated Press Writers, 2008). The long-term inability of soil to support vegetative growth may have resulted from the exceeding complexity of toxic and mutagenic chemicals in sewage sludges overcoming the plants’ genetic capacity to withstand their harmful effects. It is reasonable to assume that, as the complexity of mixtures of

toxic and mutagenic chemicals in the environment rises, the diversity of plants and animals capable of surviving any given exposure level will decrease. Adverse effects, as we noted in 1991 (Said & Lewis, 1991), can occur due to synergistic interactions at increasingly lower concentrations as the number and diversity of chemical agents in complex mixtures continue to increase. That result was clearly implied in our laboratory experiments in 1991, and has since been demonstrated with many species (Hawkins, Morgan, & Davies, 2009; Komjarova & Blust, 2009; Vellinger et al., 2012; Green & Walmsley, 2013; Luís, Ferreira, Fonte, Oliveira, & Guilhermino, 2015; Gao, Feng, Wang, & Zhu, 2017; Wen et al., 2018; Rahmani, Asadi, Fatehizadeh, Rahmani, & Zare, 2019).

At some point, increases in the complexity of mixtures of priority pollutants exceeds the “toxic soup capacity” of most, if not all, living organisms. As the author first proposed at a meeting of the Royal Society of London (Lewis, 2015), the mounting adverse effects of increasingly complex mixtures of priority pollutants will eventually outpace the rates at which adaptational processes can enable populations, even the whole of life on Earth, to adapt. The most egregious aspect of the legacy of land application of sewage sludges is that adverse effects on public health and the environment could have been avoided had EPA’s 503 Sludge Rule required gasification or other thermal processes capable of reducing toxic organic chemicals to simple carbonates, phosphates, sulfates and other building blocks of life, and tying up traces of heavy metals in activated carbon, prior to land application (Kamler & Soria, 2012).

Indigenous populations entering the Americas at the end of the last Ice Age fertilized nutrient-depleted soils in Brazil’s Amazonian basin with mixtures of charcoal, bone, and manure. This practice, which continued for thousands of years, created organically rich soils that continue to regenerate themselves without any further human support. To this day, the once-barren Amazonian basin supports a diversity of life that is unmatched anywhere else on Earth. As a result of EPA’s 503 Sludge Rule, modern civilization has chosen to render much of the earth’s soils incapable of supporting healthy, complex forms of life in the long run.

Nevertheless, it is theoretically possible to heat wastewater containing sewage to a super-critical temperature (above 374° Centigrade) using “bolt on end-of-pipe systems” which can cause the wastewater to be completely gasified while concentrations of pollutants are in their most diluted forms. Almost a full decade ago, Kamler and Soria detailed many aspects of the process. They proposed ways to engineer systems to achieve safe and economically feasible disposal of the “14.6 trillion gallons of municipal wastewater” being transported to about 17 thousand processing plants in the US each year. Because of the costs involved with gasification and other means of pyrolysis, current engineering technologies will require creative advances before economically viable systems can be put in place throughout the world. Plainly, EPA’s current approach to the disposal of hazardous municipal and industrial wastes under the 503 Sludge Rule is unsustainable.

## **Discussion**

Multiple studies have demonstrated that live vaccine-derived viruses survive wastewater treatment processes and soil application (Tierney, Sullivan, & Larkin, 1977; Soares, Pepper, & Gerba, 1992; Schlindwein, Rigotto, Simões, & Barardi, 2010; González et al., 2019). Currently, live vaccines approved by the CDC include measles, mumps, and rubella in the MMR combined vaccine, plus rotavirus, smallpox, chickenpox, and yellow fever. It is important, therefore, to recognize that

concentrated complex mixtures of heavy metals and toxic organic chemicals are not the only concern with land application of treated sewage sludges a.k.a. biosolids. Indeed, the United States barred twelve New Jersey sea coast communities from dumping sewage sludges into the Atlantic because of their potential to cause vaccine-derived polio epidemics as sewage sludges wash up along shorelines (USA v. Asbury Park, 1972). Although EPA dismissed any link between vaccines and autism (McDonald and Paul, 2010), it never addressed the role that land application of vaccine-laden sewage sludges, and any resulting vaccine-derived epidemics of measles, rubella and other viruses, may play in autism.

Except for gasification and methods that employ extreme heat capable of completely incinerating organic matter (Kamler & Soria, 2012), technologies used for treating sewage sludges fail to achieve high-level disinfection (Gattie & Lewis, 2004; Ruiz-Hernando et al., 2014; Li et al., 2019). Therefore, all municipal sewage sludges likely contain high concentrations of virulent strains of vaccine-derived viruses. Despite a clear potential for exacerbating and perpetuating outbreaks, the CDC, EPA and other federal agencies are paying no attention to the role land application of sewage sludges is likely playing in outbreaks of vaccine-derived viruses. This includes in Pakistan and other areas of the world where vaccine-derived outbreaks of poliovirus (Centers for Disease Control and Prevention, 2019) are currently on the rise according to data monitoring by the World Health Organization (World Health Organization, 2019).

The purpose of this paper, in part, is to elucidate an environmentally-based changepoint, or at least a general time frame, for seemingly dramatic increases in the incidence of neurodevelopmental disorders, especially those known as “autism spectrum disorders” (ASDs). In their Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (*DSM-5*; 2013), the American Psychiatric Association differentiates various ASDs within this group, which McPartland (2017) recognized as being extremely heterogeneous. “Autism disorder” (AD), which is one of several categories that the Association recognized, is similar to the early-onset ASD first diagnosed by Kanner (1943). *DSM-5* differentiates AD from “intellectual disability” (ID), a different class of conditions that is also highly heterogeneous and may be comorbid with AD, or some other ill-defined category of ASD or other similar conditions. *DSM-5* was also aimed at separating AD from the milder form of “high-functioning autism”, indistinguishable according to much of the literature from “Asperger syndrome” — a disorder introduced into the psychiatric literature by Hans Asperger (1944). R. A. Ritvo, E. R. Ritvo, Guthrie, and M. J. Ritvo (2008); also R. A. Ritvo, E. R. Ritvo, Guthrie, Yuwiler, M. J. Ritvo, & Weisbender, 2008) used a scale that was entirely effective so far as distinguishing persons diagnosed with either high-functioning autism or Asperger syndrome from typical adults, but failed to distinguish high-functioning autism from Asperger syndrome, which is commonly characterized as being less severe, and is diagnosed at a later age; *i.e.*, its onset reportedly occurs later than more severe forms of ASD.

McDonald and Paul (2010) joined Rutter (2005, p. 2) in questioning whether the apparent increase in the incidences of autism beginning as early as late 1988 represents “a true rise in incidence (of autism) due to some environmental risk factor”, or is an artifact. Stating that “it remains quite obscure as to what that [risk] factor might be”, Rutter seemed inclined to think it might be real (see also Wazana, Bresnahan, & Kline, 2007; Rutter, 2009). Based on the examination of multiple databases (Christensen, 2016; Nevison, Blaxill, & Zahorodny, 2018) others have more recently



concluded that “the number of reported ASD cases has dramatically increased in recent years, reaching an alarming level of 1 in 68 children in the USA. This reported outcome represents a 25-fold increase between 1970 and 2012” (Bennabi *et al.*, 2019, p. 2).

Despite the fact that “contributions of several genetic and environmental factors are now well accepted”, Bennabi and colleagues assert that “the etiopathogenesis of ASD remains largely unknown” (p. 2). The author of this paper argues that conflicting federal policies and decades of political suppression have obscured how that apparent increases in autism may largely reflect major changes in the global transport and fate of high concentrations of *all* environmental contaminants linked to autism, which began to be applied to farms, forests and other public and private lands beginning in the late 1980s and early 90s. Further examination of this linkage using more powerful data-mining capabilities (Chaste & Leboyer, 2012; Modabbernia, Velthorst, & Reichenberg, 2017; Gialloreti *et al.*, 2019) is urgently needed worldwide. Pharmaceuticals, including rubella, polio and other live-virus vaccines found in sewage sludges, are of particular concern. Hence, editors and reviewers concurred on the appropriateness of this paper for inclusion in this journal.

Some researchers and theoreticians still remain convinced that “changing criteria of diagnosis”, more “public awareness”, and even “mistaken diagnoses” are the main sources of apparent increases in the number of valid diagnoses of neurodevelopmental disorders. Based on the information presented here, however, it should be evident that the epidemic of ASDs and neurodevelopmental disorders in general is real, and that sewage sludge policies developed by Senior Executive Service employees at the U.S. EPA and USDA are likely major contributors, if not the main causal factors, behind rising incidences of neurodevelopmental disorders occurring around the world. Contrary to my position, some researchers continue to hold to the expressed view of Rutter (2005), Wazana, Bresnahan, and Kline (2007), who have argued persistently that the world-wide rise in the number of neurodevelopmental disorders is owed to something other than an actual material, real “secular”, increase. Researchers subscribing to that view include, for example, McPartland, Reichow, and Volkmar (2012), Graf, Miller, Epstein, and Rapin (2017), Fombonne (2018), and Fombonne, Myers, Chavez, Hill, and Zuckerman (2019). All of these seem to be reading from the same script, still arguing that we must dismiss any “real” increases in the incidence of ASDs, in particular, not to mention all the heterogeneous comorbid conditions that go with that class. Yet, the overwhelming body of science continues to associate elevated incidence of ASDs, and neurodevelopmental disorders in general, with exposure to a wide range of environmental pollutants known to cause adverse developmental and neurological injuries (Fordyce, Leonhard, & Chang, 2018; Huang *et al.*, 2019; Landrigan, Lambertini, & Birnbaum, 2012; Liang, Yin, & Faiola, 2019). Furthermore, it is evident that these increases will continue unabated along with a host of environmentally triggered diseases and disorders caused as priority pollutants accumulate on land surfaces and are transported far and wide by wind, water runoff, and groundwater movement.

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## Competing interests

Key portions of this commentary were prepared for the Fall 2019 Hannah Arendt Center for Politics and Humanities Symposium at Bard College, entitled The Microbiome, Farming, and Medicine held at Annandale-on-Hudson, NY. The Center plans to archive the author's historical documents regarding his research and writings on the subject of this commentary, and make them publicly available. The author receives royalties for Science for Sale (Skyhorse Publishing, NY), which addresses land application of sewage sludges. A second book dealing with the subject is also in the works.

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