TECHNOFOSSILS of the ANTHROPOCENE

Media, Geology, and Plastics

Sy Taffel

Abstract **From the inception of modern, petrochemical-derived synthetic plastics to the contemporary situation in which over 300 million tons of plastic are produced each year, media assemblages and plastics constitute a range of intra-actions that contribute to our understanding of contemporary material politics. This article explores a number of issues surrounding entanglements of media and plastics, including the formation of vast oceanic plastic garbage patches, the treatment of highly toxic electronics waste, the usage of thermal papers that disrupt the human endocrine system, and the formation of technical fossils whose lack of biodegradability forms one strand of evidence within discourses of the Anthropocene. The material politics of plastics places into conversation temporal scales ranging from geological rhythms, which are measured in millions of years, to the hyperconsumption of 24/7 global capitalism, asking pertinent questions about how we conceptualize contemporary ethical and biopolitical issues surrounding humans and other living systems.**

Keywords **plastic, geology of media, media ecology, Anthropocene, ecocriticism**

Introduction

My fingers strike plastic keys connected to plastic switches mounted on a plastic keyboard. I gaze into a monitor whose stand and bezel are both made of plastic. Luminosity emanates from light-emitting diodes that are

Cultural Politics, Volume 12, Issue 3, © 2016 Duke University Press
DOI: 10.1215/17432197-3648906

encapsulated in plastic and whose light is diffused through several plastic sheets, evenly illuminating a screen that only houses LEDs along a single edge. The casing of the computer is partially composed of plastic, as are the interconnects and casings for each wire and the printed circuit boards used for the motherboard and graphics card. Although plastics are often utilized because they are lightweight materials, 15 to 25 percent of the total mass of consumer microelectronics including laptops, smartphones, and tablets is plastic (MCC 1996; Fisher and Kingsbury 2003; Hobi International 2013).

Despite the abundance of plastic within microelectronics devices, the role of plastics within media assemblages has been relatively neglected in materialist accounts of media technology, which have instead explored the roles performed by metals (Parikka 2015a, 2015b), minerals (Taffel 2015a) and scarce or exotic materials such as uranium (Cubitt 2015a), and rare earth elements (Cubitt 2015b). The focus on these substances is perhaps understandable, given that flows of electrons through digital infrastructures depend on the conductivity of copper, gold, and silicon, among other metallic substances, and that flows of light through rare earth and uranium-doped fiber optics carry binary data through the undersea network that forms the globalized physical connections of the Internet (Starosielski 2015). Indeed, Gilles Deleuze and Félix Guattari, whose geophilosophy permeates much of the discourse surrounding new materialism, argue that the machinic phylum—the flow of matter that synthesizes the domains of humans, nature, and technology into a single phylogenetic lineage—is best characterized by metallurgy: "Not everything is metal, but metal is everywhere. Metal is the conductor of all matter. The machinic phylum is metallurgical, or at least has a metallic head, as its itinerant probe-head or guidance device" (1987: 411).

By contrast, plastics frequently play relatively unglamorous roles within microelectronic assemblages. Plastics are commonly used because their poor electrical and thermal conductivity make them ideal insulators. Additionally, the manner by which plastics can be molded into a multiplicity of shapes while retaining strength and minimizing weight makes them well suited for cast parts, such as fans and casings. All of this gestures toward the plasticity from which these substances derive their title, the manner by which these malleable materials are able to be transformed. Counterintuitively, plasticity is also considered by Deleuze and Guattari to be a key quality of metallurgy, as metals are purified into ingots that are then forged, and then, later, resmelted and reformed, thus exemplifying the materiality of the machinic phylum that foregrounds flow and transformation through time and space.

Plastics, or more precisely petrochemical-derived synthetic plastics, are organic compounds constructed from chains of repeating macromolecules that are typically connected through strong covalent bonds. There are two types of synthetic plastics: thermoplastics, consisting of a chemical composition that does not transform when heated and so can be repeatedly remolded, and thermoset plastics, which undergo an irreversible chemical reaction that sets the plastic permanently. As a consequence, thermoplastics can be recycled relatively easily, since they are heated to break the long, repeating polymer chains, while thermoset plastics—which are used in microelectronics components such as circuit boards, where their higher levels of tensile strength and thermal resistance are desirable properties—have traditionally been destined for landfill.[1] Immediately we see that plastics are not a homogeneous category and that the specific material properties of particular plastics have implications in terms of both their suitability for usage within microelectronics and their ecological impacts.

Geology and plastic may appear to posit a contradiction. Geology, as the study of the earth and the rocks that compose it, explores a nonhuman world where time is measured in hundreds of millions of years, whereas petrochemical-derived plastics are materials produced by industrial chemistry and have existed for just over a century. What makes this encounter a productive one is the way in which a media geology of plastics reinserts anthropogenic industrial activity into the flows of matter and energy that make up the cosmos. It creates conversations between geological and industrial temporalities, foregrounding contemporaneous ecological crises and the material politics surrounding entanglements of media, plastics, and ecosystems. The key dynamic that emerges from juxtaposing these temporalities is the disjuncture in speeds between 24/7 consumer capitalism and geological durations; climate change and reductions in biodiversity arise from industrial rhythms that are out of alignment with those of the earth, conducting ecosystem engineering at a pace that outstrips many organisms' abilities to adapt. Following Gregory Bateson's (1972: 440) insight that "systems are always punishing of any species unwise enough to quarrel with its ecology," a media geology of plastic thus forms a critique of the unsustainable, and ultimately self-destructive, speeds of contemporary capitalism.

In foregrounding the political, ecological, and cultural affects associated with current applications of plastics, I apply the apertures of genealogy, ecology, and geology to consider ways that the past, present, and future of mediation is shaped by and shapes plastics. The plastic genealogies I trace connect the formation of Bakelite, the first synthetic plastic, to the industrial chemistry central to nineteenth-century photographic practices and nitrate films, demonstrating how media and plastics have entangled histories. The plastic ecologies I map include the treatment of the plastics content of electronic waste, the endocrine-disrupting chemicals found in thermal printing papers, and the circulation of plastics within oceanic gyres that is both an environment for new life and a hazard for many marine organisms. These cases raise numerous questions about health, pollution, and how we arrive at ethical judgments relating to the valuation of human and nonhuman lives. Finally, I consider plastic geologies in terms of the petroleum geology necessary for the production of plastics, the geopolitical and environmental ramifications of anthropogenic fossil-fuel usage, and how plastics form technofossils—novel geological entities that will compose part of the earth's stratigraphic record, constituting one strand of the evidence for the Anthropocene, a new geological age in which human-led actions affect global stratigraphic records. This analysis is designed to draw attention toward ways in which one of the materials most commonly associated with a throwaway consumer culture in fact produces environmental effects measured in millions of years, as opposed to the months that many microelectronic devices are actively used for. If we take questions around sustainability and resilience seriously, this juxtaposition indicates the urgent need for a dramatic reorientation of the material infrastructures and practices of consumption that underpin twenty-first-century digital cultures.

I argue that the development of modern plastics and audiovisual media cannot be understood in isolation from one another; they form a dyadic relationship in which each element perpetually transduces the other. As such, the relations between media and plastic are characterized by entangled intra-actions, whereby I follow Karen Barad's (2003: 822) understanding of matter as "substance in its intra-active becoming—not a thing, but a doing, a congealing of agency. Matter is a stabilizing and destabilizing process of iterative intra-activity." Departing from social constructivist and hylomorphic accounts in which plastics and media constitute inert matter that require humans to impose meaningful form onto them, I view both as dynamic intra-active becomings whose coevolutionary pathways transform material-discursive practices across technocultural milieus. The term *intra-active* is thus employed rather than the more commonly encountered *interactive* as a means of positing inseparability between mutually coconstituted entities. Entanglement and intra-action posit flows of becoming, in which entities do not exist in isolation from one another and can only be grasped as unfolding events, instead of as networks of interconnected but ontologically distinct and separable nodes.

From Bakelite to Blu-Ray

Although the focus of this article is on synthetic petrochemical-derived plastics, the development of these materials during the twentieth century followed the diverse historical employment of natural plastics such as shellac, resin, amber, ivory, and rubber. These substances were desirable for two primary reasons: their malleability ensured that they could take various shapes and forms, and they could function as hard varnishes or coatings for other materials. One serious drawback surrounding natural plastics was a lack of availability, particularly in the quantities desired by burgeoning levels of production associated with the industrial revolution during the nineteenth century in Western Europe and the United States. Consequently, there was a flurry of activity as the developing field of industrial chemistry sought to produce materials that could replicate and supplant natural plastics.

In the mid-nineteenth century, the development of nitrocellulose compounds appeared promising. While nitrocellulose was originally used as an explosive,[2] a key later use was as the first flexible photographic film base. Nitrate film with camphor as a plasticizer (a material used as an additive to enhance the malleability of a plastic) was used for both photographic and cinematic images from 1889 until the late 1940s, when it was superseded by less flammable cellulose acetate–based film stocks. While nitrocellulose was thus an important precursor to synthetic plastics and vital to the history of photographic and cinematic images, its volatility made it unsuitable for domestic usages. Consequently there were numerous attempts by nineteenth-century chemists to forge alternative substances ultimately leading to the production of Bakelite, the first synthetic plastic, which was patented by Leo Baekeland in 1907.

Prior to his pioneering work with plastics, Baekeland had been an academic chemist and amateur photographer, which in the late nineteenth century required a knowledge of photographic chemistry. In 1889, he received a scholarship to travel from Belgium to the United States; there he received a job offer to work as a chemist for E. and H. T. Anthony and

Company, which produced photographic plates and printing papers. Baekeland stayed for two years, in part working on the development of nitrocellulose film as a replacement for gelatin dry plates (Bijker 1997: 130). In 1893, Baekeland started his own company, which produced photographic papers, including, notably, the first photographic printing paper that could be exposed and developed under artificial light within a darkroom, which was refined and marketed as Velox. In 1899, Baekeland sold the company to George Eastman (of the Eastman Kodak Company) for $750,000 in a deal that included a clause stating that Baekeland would abstain from any subsequent involvement in the photographic industries. This money was partially invested in founding the laboratory and business venture that led to the invention and patenting of Bakelite. Thus we see how the inception of modern synthetic polymers is historically entangled with media technologies; the development of nitrocellulose plastics and synthetic polymers emerge from the same techno-cultural milieu, with developments in one area creating the environment out of which the possibility of the other eventuates. The similarities in the developmental processes of these substances is one way that the materiality of matter matters when it comes to comprehending the technological genealogy that encompasses plastics, photography, and cinema.

Once synthetic plastics had been developed, Bakelite and other plastics continued to be important to the development of media technologies. Bakelite was not only applied as an alternative to celluloid, shellac, and other natural plastics but was utilized in numerous other areas that leveraged its properties of being malleable, lightweight, and a poor conductor of electricity and heat. By the early twentieth century, plastics were being used in electrical lighting, telephony, wireless telegraphy, photography, and phonography. Indeed, looking back at the range of media devices and formats commonly employed throughout the last century, we find that plastics were crucial for numerous popular media technologies. While the earliest records were made of rubber and then shellac, the vinyl LP record introduced in 1948 by Columbia Records greatly increased both the storage time and fidelity of recordings and remains the standard format for records. Magnetic tape–based media frequently used plastics not only as a lightweight and durable casing but also, in the case of audio cassettes and VHS, as a polyester plastic film that served as the vehicle for the magnetic coating containing the data (Noble 2013). Optical formats, including CD, MiniDisc, DVD, and Blu-ray all employ lightweight polycarbonate plastic as the material from which the disks are made, and as we have seen, a substantial proportion of digital microelectronics devices are composed of plastic. Just as the evolution of synthetic polymers was dependent on the chemistry, experiences, and knowledge of producing nitrate films, the development of the last century's worth of media technologies is effectively unthinkable without plastics.

This dyadic relationship between media and plastics is perhaps unsurprising given the rapid increase in the production of plastics that occurred during the second half of the twentieth century and that has continued into the twenty-first. The versatility of plastics has allowed them to supplant less malleable materials such as wood, stone, and metal from a multiplicity of roles. While it was not until 1950 that global plastic production reached 0.5 million tons; today over 310 million tons of plastic are produced annually (Gourmelon

2015).[3] More plastic was produced in the first decade of the twenty-first century than in the entirety of the last (Thompson, Moore, et al. 2009), which has led to claims that contemporary technoculture is exemplified by plastics (Miller 2007; Thompson, Swan, et al. 2009). Carrying that idea further, if factory workers in the nineteenth and early twentieth centuries could be understood as cogs in the machine—solid metallic parts that served a single purpose—the contemporary information worker and precariat are perhaps better understood as plastic entities that are expected to remold themselves to occupy many niches throughout their working life. As a consequence, we find the concept of plasticity, especially when applied to human neurological structures and their epiphylogenetic entanglement with technologies, of central importance to grasping and affecting salient contemporary sociopolitical issues (Malabou 2008; Stiegler 2010).

Plastic Ecologies: The Plastisphere and Other Marine Life

Having outlined the entangled genealogies of media and plastics, I now move toward considering the ways that plastics are implicated in contemporary ecological issues surrounding pollution and toxicity. One of the most notorious affordances of synthetic plastics is that they are not biodegradable or will only degrade over prolonged durations, which means that the vast majority of plastics produced since the dawn of Bakelite are still present in contemporary ecosystems (Gregory and Andrady 2005; Andrady and Neal 2009). The accumulation of plastic occasionally forms the content of mainstream media pieces decrying the degradation of fragile natural systems by man-made pollutants. We see striking images of birds, turtles, fish, and other life-forms that mistake plastic debris for food, fill their stomachs until they no longer feel hunger, and then subsequently starve to death, leaving corpses filled with plastic. Plastics affect marine life ranging in size from plankton to whales; once ingested, it cannot be digested,[4] so plastic accumulates and is biomagnified up the food chain as larger organisms consume a multitude of smaller ones, all of which contain indigestible plastics. Current estimates suggest that 5.25 trillion plastic particles, with a combined weight of approximately 270,000 tons, are floating in the earth's oceans (Eriksen et al. 2014), much of which is pulled into oceanic gyres, circulatory currents that accumulate vast quantities of debris. Indeed, a recent report estimates that by 2050 the oceans will contain a greater weight of plastic than fish (Ellen Macarthur Foundation 2016: 29).

Such discourses, which emphasize plastic as pollutant—as the human (cultural) degradation of previously pure and pristine (natural) environments—are far removed from posthuman and new materialist approaches to entanglements of matter that elide binary oppositions of nature and culture. If thinking ecologically is to consider systems in terms of flows of energy and matter, then plastic ecologies are not just human cultural activity destroying otherwise homeostatic natural systems. As Jennifer Gabrys (2013: 209) pertinently asks: "How might a material politics of plastics that is less inclined toward a purifying discourse of environments and that is more invested in attending to the emergence of new material arrangements make possible a greater engagement with the new natures and practices?" Implementing such an investigation into plastic ecologies requires moving beyond a simplistic classification of plastics as evil industrial pollutants and instead focusing on the affects and affordances of particular plastics—on the way that their intra-actions across a range of material-discursive systems involve transforming the capacities of other bodies.

Such moves align my approach with the ethics proposed by Deleuze and Guattari, for whom escaping binary oppositions does not lead to the collapse of ethical distinctions or political responsibilities but instead asks us to consider the ways that agential capacities are transformed in multiple ways through material encounters: "There is no Good or Evil in Nature, but there are good and bad things for each existing mode. . . . The distinction between good things and bad provides the basis for a real ethical difference, which we must substitute for a false moral opposition" (Deleuze 1992a: 253–54). Good acts thus become ones that augment the affective capabilities of actors, whereas bad ones diminish them. The issue with oceanic plastic debris can thus be recast as one that subtracts from the capacities of a multitude of actors, those left unable to breathe or eat in order to sustain themselves because of ingesting bioaccumulative plastics or those whose reproductive, immune, and nervous systems are detrimentally affected by particular plasticizers. Plastics thus becomes problematic not because polymers or plasticizers are inherently bad or pollute otherwise pristine, natural environments but because particular intra-actions surrounding specific oceanic plastics diminish the agential capabilities of broad sections of aquatic life.

It must, however, be noted that not all biotic actors are negatively affected by oceanic plastics. Certain forms of bacteria have evolved to reside within marine plastics (Reisser et al. 2014), forming a microscopic ecosystem that has been referred to as the plastisphere: "a diverse microbial community of heterotrophs, autotrophs, predators, and symbionts" (Zettler, Mincer, and Amaral-Zettler 2013: 7137). These organisms, whose continued existence requires the presence of marine plastics, raises questions about how we assign value to different life-forms and further troubles straightforward proclamations that plastic is pollution. Following Jane Bennett's (2013: 246) comments surrounding the probable inescapability of a certain degree of species-level self-interest, we should acknowledge the anthropomorphism that decries the suffering of charismatic marine megafauna, such as turtles and whales, while ignoring the flourishing of aesthetically alien microbial life-forms who dwell within oceanic plastic gyres. Aesthetic distinctions are crucial here; it's easier to empathize with a penguin than with a microorganism that requires an electron microscope to become visible to human eyes. As Donna Haraway (2015: 159) reminds us, however, bacteria are the life-forms responsible for the most prominent transformations of the biosphere from the great oxygenation event 2.3 billion years ago onward. Microbes are present within the digestive tracts of all vertebrates and are necessary for digesting food; they provide traits that "we" have not been required to evolve "ourselves." The influence of bacteria within the human body is foregrounded by the astounding fact that microbial cells outnumber those that are exclusively "human" within "us" tenfold (Turnbaugh et al. 2007). And yet, as we see with reference to the plastisphere bacteria, other microbial life is often functionally invisible and deemed ethically unimportant.

The production of new environments for life that are hazardous to existing biotic systems, such as those found in oceanic gyres, troubles the biocentrism associated with deep ecology, which claims to focus on all life (Naess 1973; Devall and Sessions 1985). Here we find a situation whereby many life-forms are detrimentally affected, whereas other nascent forms thrive. What we witness is the dynamism of life adapting to new contexts, which inherently contradicts a conservationist ethic that seeks to preserve the past or present. From such perspectives, these new organisms are monstrous aberrations that reflect the damaged ecosystems they inhabit, but such outlooks merely underline normative anthropogenic assumptions about what constitutes a healthy environment (Holm 2012). What we see by examining oceanic plastic ecologies is that we do not make ethical judgments based on an objective understanding of what constitutes a pristine or polluted environment; we discriminate between differing forms of life using aesthetic preferences. This is, of course, deeply troubling for any normative ethics that either seeks to preserve all forms of life or seeks to craft an objectivist definition of pollution based on conservationist principles. As Mary Douglas's (1996: 40) seminal study surrounding rhetorics of pollution made clear, pollution is commonly defined as "matter out of place," and the way in which the "proper place" for matter is defined is a social construction, not an ontological fact. In the following section, I explore how plastic ecologies foreground the global externalization of harms from wealthy areas toward impoverished ones and problematize the notion of pollution as based on surpassing quantifiable toxicological thresholds and rigid boundaries, all of which raises further questions surrounding the material politics of pollution.

E-waste and Endocrine Disruption

There are numerous human health concerns regarding practices associated with media and plastics. These include those ensuing from the treatment of plastics within the rapidly growing global stream of e-waste, which, as of 2015, totaled in excess of 42 million tons (Baldé et al. 2015). There have been numerous articles explicating the toxicity, volume, and unequal global, social, and ecological impacts surrounding electronics waste (Gabrys 2011; Parikka 2011, 2013; Taffel 2013, 2015b). Most have focused on a handful of concerns: illegal flows of toxic material from the global rich to impoverished areas; the presence of heavy metals within e-waste; water supplies in close proximity to artisanal e-waste processing zones containing significant levels of lead, chromium, and other substances hazardous to humans and other biotic systems (Basel Action Network and Silicon Valley Toxics Coalition 2002); and the elevated levels of lead in the blood of children in affected areas (Guo et al. 2014).

When e-waste is manually recycled by artisanal workers, plastics are frequently treated as undesirable matter, in stark contrast to the valuable copper, gold, and other metallic components that are manually extracted and sold for reuse. Consequently, a significant proportion of the labor involved in manual e-waste recycling involves separating metals from plastics, and particular practices used to achieve this segmentation have adverse effects on the health of workers and local ecosystems. Printed circuit boards contain valuable components, including silicon microchips, gold-plated pins that connect microchips to the board, and powdered tantalum located inside capacitors. To retrieve these materials, workers typically use one of two methods: cooking the boards in fires or dissolving them acid. Cooking melts the tin solder that binds components to the board but also melts some of the board itself, which is a composite material composed of fiberglass (a thermoset plastic reinforced with glass fibers), a flame-resistant epoxy resin (another form of thermoset plastic), and a thin layer of copper foil into which the circuitry is etched. The primary problem with incineration arises from the presence of halogenated flame-retardants, which release brominated and chlorinated dioxins and furans when burned. These substances are classified as persistent environmental pollutants due to their long half-lives (seven to eleven years, once ingested), which means they tend to accumulate throughout the food chain, and they have been linked to cancers, impaired liver functioning, and various deficiencies of the immune, nervous, and endocrine systems (World Health Organization 2014). Similarly, when baths of nitric and hydrochloric acid are used to dissolve the circuit boards, allowing the valuable metal pins and other components to be retrieved, the waste liquid from the acids and dissolved polymers enters local rivers, soils, and water tables, where both the acidity of the mixture and some of the halogenated substances dissolved are hazardous to the health of humans and other living systems.

Some thermoplastics are, however, recovered during artisanal recycling. Although plastic casings, keyboard keys, and mouse buttons are less valuable substances than gold, silver, and copper, their resale provides a needed source of revenue for impoverished e-waste workers who often earn around US$1.50 a day (Roman and Puckett 2002). Plastic fragments are sorted by color and then melted to form recycled low-grade plastics, a process productively described as downcycling. The process results in lower-quality materials being produced and has been criticized by the sustainable design community for providing the appearance of moving toward a circular model of production even though downcycled materials can rarely be recycled again (McDonough and Braungart 2010). Since artisanal plastics recycling is generally conducted with no respiratory equipment, workers ingest the dioxins and furans released through the melting process (Basel Action Network and Silicon Valley Toxics Coalition 2002: 26). Thus, even where plastics are recycled, we find practices that involve the release of hazardous substances in poorly ventilated areas populated by workers who lack the education or capital to put in place measures to protect their health.

Considering e-waste provides further insights into plastic ecologies, indicating how practices surrounding artisanal recycling—a term that conventionally has connotations of sustainability and an ethic of environmental care—detrimentally affects workers and other inhabitants of these environments. Within the material assemblage of e-waste, plastics are often viewed as a type of detritus to be hazardously detached from more valuable materials; however, the specific polymers involved, and whether these are thermoset or thermoplastics, play an important role in determining what can be done with these materials. Similarly, the specific plasticizers and monomers used have differing affordances, with certain substances such as brominated and chlorinated flame-retardants, phthalates, and polyvinyl chloride posing health issues for biotic systems that are not posed by other plastics and plasticizers. Only by paying close attention to the specific arrangements and affordances of matter do we begin to grasp the material politics of plastics at play.

Another area of health concern that has garnered significant media attention is the use of plasticizers, such as phthalates, and of bisphenol A (BPA), a monomer used to manufacture transparent polycarbonate plastics and epoxy resins. The controversy surrounding these substances relates to their interactions with the human endocrine system, the network of hormone-secreting glands responsible for regulating metabolism, growth, development, reproduction, and mood. The endocrine system has been likened to a lock and key system (Liboiron 2013), in which specific hormones form keys that bind to specifically shaped receptor cells. The US Environmental Protection Agency has defined an endocrine disrupting chemical (EDC) as "an exogenous agent that interferes with the production, release, transport, metabolism, binding, action, or elimination of natural hormones in the body responsible for the maintenance of homeostasis and the regulation of developmental processes" (Kavlock et al. 1996: 716). While the polymer chains that make up plastics are unreactive with the endocrine system, plasticizers such as phthalates or, in the case of BPA, leftover molecules of the monomer precursor to polycarbonate plastics, can mimic hormones and bind, block, or otherwise interact with receptor cells, thus affecting the behavior of the endocrine system. As a result, BPA and phthalates have been linked to several forms of cancer (Soto and Sonnenschein 2010), as well as to disorders and pathologies of the reproductive, neurobehavioral, immune, and hormonal systems (Yang, Park, and Lee 2006).

Endocrine disrupting chemicals, such as BPA and phthalates, challenge one of the basic premises on which toxicological investigation has traditionally been founded: the Paracelsus principle. This principle, which states that "the dosage makes the poison," implies that there are safe levels of exposure to otherwise harmful substances. For most toxicological studies, a monotonic response curve applies, which may be linear or nonlinear, but in either case, the overall trajectory remains the same. By contrast, EDCs have been found to induce U-shaped or inverse U-shaped curves (Conolly and Lutz 2004). Numerous studies of BPA and phthalates suggest that adverse health effects may occur at low dosages but not at the higher ones used in traditional toxicological testing procedures (Vom Saal and Welshons 2006; Welshons, Nagel, and vom Saal 2006; Soto and Sonnenschein 2010; Meeker, Sathyanarayana, and Swan 2009). This has been hypothesized to occur because the endocrine system secretes small quantities of hormones, so similar volumes of EDCs provoke larger responses than dosages that flood the system (Vandenberg et al. 2012). While low-dosage hypotheses are still controversial within the epidemiological and toxicological sciences (Robertson and Farrelly 2015), they problematize straightforward notions of pollution or harm that are predicated on quantitative dosage boundaries. Indeed, the complex range of interactions surrounding the endocrine systems of living creatures and the multiple EDCs that are now thoroughly dispersed throughout the biosphere make it impossible to comprehend issues surrounding health and plasticizers by thinking about discrete entities; it instead requires approaches steeped in the entangled intra-actions of matter that affect systems in complex ways (Liboiron 2016).

Although BPA and phthalates are found in computers, CDs, and DVDs (Thompson 2013), concerns surrounding their impacts on human health have primarily been related to their use in packaging and vessels for food and drink, since there is evidence that EDCs can leach out of these materials and be ingested. In particular, there has been concern over the use of

BPA-based polycarbonate in baby bottles, with legislation preventing their sale now in place in numerous countries, including the European Union, Denmark, Canada, and Turkey. Another, and more surprising, source of BPA within humans comes from its use in the thermal papers commonly employed in cash registers and automated teller machines. Several studies have confirmed that quantifiable amounts of BPA are absorbed into the body from handling thermal paper (Liao and Kannan 2011; Ehrlich et al. 2014; Babu et al. 2015) and that the amount of measurable blood-borne BPA is dependent on the condition of the skin, with humid or greasy skin absorbing ten times more BPA than dry skin (Biedermann, Tschudin, and Grob 2010).

We generally think of our bodies as containing relatively rigid dermal boundaries; however, this notion is undermined by the absorption of BPA through contact with the skin. We are porous entities, and the degree of permeability is affected by contextual factors such as whether skin has recently come into contact with moisturizers, sunscreen, or sweat. We are reminded that our bodies are enmeshed within the flows of matter and energy of the machinic phylum, rather than forming the ontologically distinct Cartesian subjects traversing an exterior world of objects, which consciousness mistakenly posits. Plastic ecologies therefore require us to consider health impacts in ways that transcend the appearance of distinct objects interacting with one another and to ask questions about how we understand pollution and toxicological dosage within a context of intra-action and entanglement.

Plastic Geologies

The hydrocarbons that make up plastics are primarily derived from oil, coal, and natural gas. In each case, the fossilized remnants of organisms that lived eons ago are cracked and refined into monomers such as ethylene and propylene, which are then either processed into more complex monomers, such as styrene, vinyl chloride, and BPA, or combined to form polymers, such as polyethylene and polypropylene. Producing plastics involves the distillation and remolding of long-dead living matter, connecting plastic to Jussi Parikka's (2015b) revised deep time of the media, which foregrounds the geological processes necessary for contemporaneous technocultural production. Whereas Sigfried Zielinski's (2006) original deep time of the media sought to map circular patterns of technical invention that arose at various junctures throughout recorded human history, Parikka's reconceptualization moves toward understanding media within geological timeframes, processes that require millions of years rather than decades or centuries.

Situating technocultural systems within geological rhythms foregrounds the temporal disjuncture between the relative speeds of geological processes and industrial technoculture, the latter of which has transformed, in the space of just over two centuries, significant proportions of the earth's fossilized living matter into heat and plastic. The contemporary "life cycle" of plastics is one way of productively foregrounding this dromological imbalance; whereas fossil fuels take thousands of years to form, the industrial culture of plastics—the extraction, transportation, trading, fractional distillation, and transformation into monomers and then polymers, and then into products that are sold, used, and disposed of—takes place within a few months (Marriott and Minio-Paluello 2014). It is perhaps unsurprising given this context that a huge number of nonhuman biotic systems are failing to keep pace with the ecological changes being wrought by anthropogenic industrial activity. This focus on speed and relationality aligns my approach with Deleuzian ethology: "the study of the relations of speed and slowness, of the capacities for affecting and being affected that characterize each thing" (Deleuze 1992b: 627–28). Ecological crises are thus understood not as enacting (cultural) change to an otherwise static (natural) system but as increasing the pace of change within dynamic ecosystems beyond the adaptive potential of numerous biotic actors.

The combustion of fossil fuels is one of the main drivers of anthropogenic alterations to the global climate (IPCC 2013), and it is estimated that plastics are responsible for approximately 8 percent of global annual oil consumption (Andrady and Neal 2009; Thompson, Swan, et al. 2009), which is evenly split between the oil being transformed into plastic and that required to power the transformative process. Oil has also been a key strategic material implicated in global geopolitics since the end of the Second World War, with former British foreign secretary Selwyn Lloyd noting in 1956 that Middle Eastern oil was "a vital prize for any power interested in world influence or domination. We must at all costs maintain control of this oil" (quoted in Curtis 2003: 16). Actions during the late twentieth and early twenty-first centuries, including the overthrow of leaders such as Iran's Mohammed Mossadegh[5] and the two US-led Gulf Wars evidence the enduring strategic importance of Middle Eastern oil.

Around the turn of the century, there were heightened concerns that oil prices were rising, that oilfield discovery had begun to slow dramatically, and that global culture was heading toward a postpeak oil world where hydrocarbons would be significantly more expensive (Heinberg 2005; Bardi 2009; Bridge 2010). Given the global economic impact of the oil crisis of the 1970s, there were serious concerns that rising oil prices, which hit US$143 per barrel in 2008, would undermine enduring growth in the global economy. Over the past few years, however, fears about higher oil prices and supply shortages have receded significantly, and in 2016 prices dipped below US$30 a barrel. In the intervening period, a technological fix has "saved us" from peak oil. As the price of conventional (liquid) oil rose, and as mining and engineering technologies advanced, we passed the point where it became technically and economically viable to embark on the large-scale extraction of oil from unconventional sources, such as hydraulic fracturing (commonly known fracking) and tar sands. The presence of large deposits of these unconventional fossil fuels in the United States and Canada additionally granted these nations a degree of energy independence from the Middle East and other large fossil-fuel producers such as Russia and Venezuela that have fractious international relations with the United States and the European Union. In response, the Organization of the Petroleum Exporting Countries (OPEC) has allowed a global oversupply of oil, further depressing prices, largely because the additional infrastructural and energy costs associated with unconventional oil entails production costs of US$40–$110 per barrel (Randall 2014), so current prices render such ventures economically unviable.

Unconventional sources of oil come with serious ecological consequences, including the flammable water supplies polluted by hydraulic fracturing (dramatically captured in the documentary *Gasland* [2010]), the earthquakes that have been attributed to fracking (Ellsworth 2013), and the additional energy costs required for both the infrastructure and energy-intensive processes used to frack gas and convert tar sands into oil. While technology has seemingly solved the issue of peak oil, the solutions themselves fuel other ecological crises, such as anthropogenic climate change, since the extra energy required to produce unconventional oil entails significant additional greenhouse-gas emissions. The low price of fossil fuels also renders renewable energy sources economically uncompetitive, thus further contributing to the demand for those same combustible carbon-based fuels. Tellingly, at the United Nations's twenty-first session of the Conference of the Parties (COP21) held in Paris during December 2015, the agreed international text devolves voluntary emissions reductions to the future, with an understanding that from the mid-twenty-first century, the planet will be net carbon negative. With the technological fix for peak oil in mind, one can only wonder what ecological accidents will be associated with the geoengineering, carbon capture, sequestration, and other speculative technologies that may be employed to attempt this.

The sum impact of human societies on the earth has led to contemporary discourses of the Anthropocene, a novel geological epoch identified by quantifiable alterations to global stratigraphic records resulting from anthropogenic activities. Even though humans never act alone, or even as the homogenous mass suggested by discourses of the "Age of Man" (Kolbert 2011), the Anthropocene raises crucial questions about how human actions and intentions play important roles within contemporary ecological crises. Alongside the rising atmospheric concentrations of greenhouse gases, which have largely been attributed to the combustion of fossil fuels, and the consequent reduction in global biodiversity as species struggle to adapt to rapidly changing ecosystems, the abundance of plastics form one strand of geological evidence for the Anthropocene. The Anthropocene Working Group (Waters et al. 2016) cites the accumulation of plastics in both marine and terrestrial environments, allied with their resistance to processes of decay, as evidence that plastics exemplify the new geological category of technofossils (Zalasiewicz et al. 2014): technical objects whose material properties denote that they will become embedded within the planet's stratigraphic record.

Plastics may be transformed by a variety of geological processes, including being melted or compressed into forming new composite materials. Indeed, a geological study in Hawaii reported finding novel materials consisting of melted plastic that had become fused with beach sediments, igneous rock, and organic debris, which were named "plastiglomerates" (Corcoran, Moore, and Jazvac 2014). The formation of these new materials presents another aperture through which a geology of plastics asks us to contemplate mediation: the way that material activities are themselves inscribed into a form of archive, that of the geological record of the earth. Plastiglomerates and technofossils thus leave curious material traces whose geological appearance will be accompanied by a major reduction in global biodiversity, the sixth mass extinction event in the stratigraphic record. Thinking in geological terms about media and plastics therefore requires that we engage with the political and ethical dimensions of the deep time changes to global ecological systems.

Conclusion

Plastics are often neglected within materialist accounts of media, which have instead focused on metals and minerals, echoing practices whereby plastics make up the devalued, discarded digital detritus within electronics recycling. However, as we have seen, the lightweight, malleable forms of solidified oil employed within digital infrastructures have a range of political affects that are detrimental to numerous biotic systems. Within these entanglements, we have seen how matter comes to matter, how differences between thermoset and thermoplastics, or among specific monomers, polymers, and plasticizers, have a range of diverse affects and ways of impacting other bodies. Only through examining these affects in the context of how they alter capacities within assemblages do we comprehend the material politics of plastics: the ways that plastics can permit, afford, suggest, block, inhibit, bind, prevent, disrupt, poison, and otherwise impact a range of systems, including humans, fish, turtles, plankton, bacteria, rivers, oceans, and rocks. This article has explored the chemistry, ecology, and geology of plastics, a suite of approaches rarely encountered within the humanities and social sciences but one that is pivotal to comprehending the affordances of technological infrastructures and thus to understanding the material politics of communicative capitalism. Plastics thus exemplify why examining digital assemblages benefits from taking cultural studies' traditional commitment to interdisciplinary inquiry seriously; aspects of the material politics of contemporary technoculture—particularly those pertaining to ecological crises—cannot be adequately grasped without engaging with relevant scientific literature. This does not, however, suggest that scientific discourses contain adequate answers to the many complex ethical and political problematics arising from entanglements of matter; it is in these areas that the modes of critical inquiry associated with media and cultural studies should have significant input into contemporary debates.

Thinking about plastics brings the deep time relations of media technologies into sight: technologies are decentered from composing inert objects of consumer desire—with lifespans understood primarily within the annual developmental cycles of corporate upgrade cultures predicated on planned and perceived obsolescence—and instead reinserted into geological contexts where time is measured in durations entirely alien to humanity. This decentering process has a progressive politics that encourages us to think beyond the "always on" 24/7 speeds of consumer culture by juxtaposing this velocity with an assortment of slower rhythms that are failing to cope with the current pace of ecological change. Such a move encourages us to recognize that the machinic assemblages of communicative capitalism generate a "productivism that has lost all human finality" (Guattari 1995: 119), which threatens to dramatically alter not just the trajectories of individual species but the conditions for all life on earth for millions of years to come. While some species will thrive in these altered environments, the harms enacted to most organisms—as indicated by the term *mass extinction event*—denotes the urgent need for meaningful political action to address this situation.

We should, however, also be attentive to the political nihilism called forth by geological durations, where mass extinction events are not full stops but produce the conditions for the next wave of evolutionary activity. In these terms, two centuries of industrialized human culture are so brief that they fall within the range of uncertainty for many stratigraphic measurements; far less than a metaphorical blink of an eye, the Anthropocene is currently an imperceptibly short duration from the perspective of the planet. It may, as numerous prominent cultural commentators have argued, be easier to imagine the end of the world than the end of capitalism, but from a geological perspective, the latter will occur hundreds of millions of years before the former. While capitalism's collapse will likely be accompanied by a sixth mass extinction event recorded in the earth's strata, it will form the basis for the next great evolutionary blossoming. Even though ecologically oriented accounts foreground the obscenity of global ecological crises that emanate from the material-discursive practices of global capitalism, we do not similarly judge the actions of the cyanobacteria responsible for the oxygenation of earth's atmosphere 2.3 billion years ago, whose actions resulted in the extinction of the majority of the anaerobic organisms that had previously flourished. Mass extinction events seem distinctly less obscene when placed within a geological temporality where over 99 percent of the species that have existed upon the earth are already extinct (McKinney 1997: 110) and whereby previous great dyings compose the necessary preconditions for current forms of life.

Approaches that ask us to "think like a mountain" have merit insofar as they draw attention to ecological entanglement within webs of complex adaptive relations, but the durations involved in the geological processes that make mountains are so vast that they render human existence insignificant. Adopting such a perspective questions why we should care about the plight of drowning polar bears, refugees fleeing war-torn nations, or victims of famine, closely corresponding to statements from object-orientated ontologists that pain and suffering are merely correlationist conceits (Bogost 2012: 73). The lack of empathy present in such nihilistic perspectives is what distances geological temporalities from the embodied biological durations we collectively live through. Meaningful action in response to ecological crises undoubtedly requires an ethics and politics that make the reduction of suffering a central feature, but key questions remain as to how we value the suffering of different entities.

As the plastisphere reminds us, we do not and cannot judge the pain and suffering of all organisms equally. Actions motivated to assist certain ecological systems require discrimination against others; the notion of biotic horizontalism is a fantasy. While extinction conjures up the callous anthropic activities that slaughtered charismatic megafauna, such as the dodo, moa, and Atlas bear, or the genocidal activities directed toward Jews, Armenians, and Tutsis, a very different picture emerges when we consider the deliberate human-led eradication of smallpox. The key question is not if, but how, we arrive at collective decisions to attempt the rewilding, dispersion, protection, conservation, thinning, or removal of particular types of living and nonliving entities from specific ecosystems, while recognizing that the dynamism of ecological systems means that any certitude surrounding the deep-time impact of such actions is illusory. As we have seen, these decisions are often driven by a straightforward anthropocentricism, such as concerns over human health regarding EDCs and halogenated flame-retardants, or aesthetic and anthropomorphic resonances with creatures such as turtles and seabirds that die from ingesting plastic.

Thinking through entanglements of plastics, media, and culture is thus a way of foregrounding the issues present in a unilateral and ultimately self-defeating species narcissism that contends that only human suffering has value, in conservationist approaches that attempt to preserve dynamic ecosystems, in the politically unpalatable nihilism of geologically focused object-orientated approaches, and in the practical impossibilities of deep ecology's biocentricism. I have instead advocated the type of relational ethics proposed by Deleuze and Guattari, which foregrounds taking pragmatic decisions aimed at increasing the affective capacities of assemblages across the machinic phylum within embodied temporalities. Rather than a focus centered exclusively on the human, the environment, or life itself, this calls for what Deleuze and Guattari describe as the "logic of the AND": an ethics that encompasses multiple temporal, spatial, and relational registers in a transversal manner. With regard to media and plastics, the harms to humans and nonhumans endemic to current practices require urgent alterations to the pace of consumption and mode of production if we are to avert the dystopian futures predicted by contemporary climatological and biological sciences. This is not to state that plastics are inherently bad or polluting entities but that the modes of becoming they currently enact detrimentally affect the capacities of a multitude of human and nonhuman actors.

Throughout this article, I have argued that plastics have a range of affects that play pivotal roles in the past, present, and futures of media, while media and mediation are critical to grasping the development and production of synthetic polymers. Instead of occupying parallel histories connected at particular junctures, they emerge from an entangled technocultural milieu surrounding industrial chemistry in the nineteenth and early twentieth centuries; their subsequent histories form a dyadic relationship in which each term produces the other. Exploring these entanglements reveals that we carry with us microelectronics devices that are not only hewn from African tungsten, South American copper, and Chinese rare earth elements but that contain the refined remnants of prehistoric life. Not only do contemporary digital media physically connect us to geological time and globalized space, they also present the agglomeration of past life in the service of a present life that is actively remolding the potential for future life via their contribution to contemporary ecological crises. This foregrounds one way that this article has sought to contribute to the material politics of media: it attempts to "help the nonhuman elements contributing to capitalism to become more visible, grasped and understood" (Parikka 2015: 20). If we are to undertake meaningful collective action focused on altering the trajectory toward ecological catastrophe posited by the Anthropocene, we must move beyond the amnesia of a digital culture that tends to think in terms of virtuality and immateriality; we must, instead, engage critically with the specific affordances of material culture and with the vastness of the geological temporalities and globalized spatial scales currently being affected by a pathological technocultural assemblage.

Notes

1. Recent research, however, has discovered a method for recycling a specific thermoset polymer using strong acid to dissolve the polymers into component monomers (García et al. 2014).

2. Guncotton, an explosive, was the first proposed industrial application of nitrocellulose. In 1847, the main production plant of the new substance in Faversham, Kent, was destroyed by an explosion that resulted in the death of twenty-one workers and derived from the instability of guncotton at room temperature. It was only in the 1860s that a safe production process for guncotton was developed (Ponting 2011).
3. We should, however, note that while plastic is pivotal to microelectronics, this only makes up around 6 percent of the entire plastics industry, approximately 18 million tons per annum, whereas over 30 percent is used in packaging (including the packaging of microelectronics) (Plastics Europe 2015: 15).
4. Yoshida et al. (2016), however, have discovered a new species of bacteria that is able to digest polyethylene terephthalate, foregrounding the ability of bacteria to rapidly evolve traits to suit their ecology.
5. Mossadegh was a secular nationalist whose attempts to nationalize Iranian oil saw his removal by a US- and British-financed coup.

References

Andrady, Anthony L., and Mike A. Neal. 2009. "Applications and Societal Benefits of Plastics." *Philosophical Transactions of the Royal Society B: Biological Sciences* 364 (1526): 1977–84, doi: 10.1098/rstb.2008.0304.

Babu, Sainath, Sannihith N. Uppu, Brittany Martin, Ogad A. Agu, and Rao M. Uppu. 2015. "Unusually High Levels of Bisphenol A (BPA) in Thermal Paper Cash Register Receipts (CRs): Development and Application of a Robust LC-UV Method to Quantify BPA in CRs." *Toxicology Mechanisms and Methods* 25 (5): 410–16, doi: 10.3109/15376516.2015.1045661.

Baldé, C.P, F. Wang, R. Kuehr, and J. Huisman. 2015. *The Global E-waste Monitor 2014: Quantities, Flows, and Resources*. Bonn, Germany: United Nations University, IAS-SCYCLE.

Barad, Karen. 2003. "Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter." *Signs* 28 (3): 801–31.

Bardi, Ugo. 2009. "Peak Oil: The Four Stages of a New Idea." *Energy* 34 (3): 323–26.

Basel Action Network and Silicon Valley Toxics Coalition. 2002. *Exporting Harm: The High-Tech Trashing of Asia*, February 25, svtc.org/wp-content/uploads/technotrash.pdf.

Bateson, Gregory. 1972. *Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology*. Chicago: University of Chicago Press.

Bennett, Jane. 2013. "Earthling, Now and Forever?" In *Making the Geologic Now: Responses to Material Conditions of Contemporary Life*, edited by Elizabeth Ellsworth and Jamie Kruse, 243–46. New York: Punctum Books.

Biedermann, Sandra, Patrik Tschudin, and Koni Grob. 2010. "Transfer of Bisphenol A from Thermal Printer Paper to the Skin." *Analytical and Bioanalytical Chemistry* 398 (1): 571–76, doi: 10.1007/s00216-010-3936-9.

Bijker, Wiebe E. 1997. *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change*. Cambridge, MA: MIT Press.

Bogost, Ian. 2012. *Alien Phenomenology, or What It's Like to Be a Thing*. Minneapolis: University of Minnesota Press.

Bridge, Gavin. 2010. "Geographies of Peak Oil: The Other Carbon Problem." *Geoforum* 41 (4): 523–30.

Conolly, Rory B., and Werner K. Lutz. 2004. "Nonmonotonic Dose-Response Relationships: Mechanistic Basis, Kinetic Modeling, and Implications for Risk Assessment." *Toxicological Sciences* 77 (1): 151–57.

Corcoran, Patricia L, Charles J. Moore, and Kelly Jazvac. 2014. "An Anthropogenic Marker Horizon in the Future Rock Record." *GSA Today* 24 (6): 4–8.

Cubitt, Sean. 2015a. "Integral Waste." *Theory, Culture, and Society* 32 (4): 133–45, doi: 10.1177/0263276414537316.

Cubitt, Sean. 2015b. "Toxic Media: On the Ecological Impact of Cinema." In *Eco-Trauma Cinema*, edited by Anil Narine, 231–48. New York: Routledge.

Curtis, Mark. 2003. *Web of Deceit: Britain's Real Role in The World*. London: Random House.

Deleuze, Gilles. 1992a. *Expressionism in Philosophy: Spinoza*. New York: Zone Books.

Deleuze, Gilles. 1992b. "Ethology: Spinoza and Us." In *Zone 6: Incorporations*, edited by Jonathan Crary and Sandford Kwinter, 625–33. New York: Zone Books.

Deleuze, Gilles, and Félix Guattari. 1987. *A Thousand Plateaus: Capitalism and Schizophrenia*. Minneapolis: University of Minnesota Press.

Devall, Bill, and George Sessions. 1985. "Deep Ecology." In *Environmental Ethics: Readings in Theory and Application*, edited by Loius Pojman, Paul Pojman, and Katie McShane, 157–61. Boston: Wadsworth.

Douglas, Mary. 1966. *Purity and Danger: An Analysis of Concepts of Pollution and Taboo*. New York: Pantheon Books.

Ehrlich, Shelley, Antonia M. Calafat, Oliver Humblet, Thomas Smith, and Russ Hauser. 2014. "Handling of Thermal Receipts as a Source of Exposure to Bisphenol A." *JAMA* 311 (8): 859–60, doi: 10.1001/jama.2013.283735.

Ellen Macarthur Foundation. 2016. *The New Plastics Economy: Rethinking the Future of Plastics*. January 19, www.ellenmacarthurfoundation.org/publications/the-new-plastics-economy-rethinking-the-future-of-plastics.

Ellsworth, William L. 2013. "Injection-Induced Earthquakes." *Science* 341 (6142), doi: 10.1126/science.1225942.

Eriksen, Marcus, Laurent C. M. Lebreton, Henry S. Carson, Martin Thiel, Charles J. Moore, Jose C. Borerro, Francois Galgani, Peter G. Ryan, and Julia Reisser. 2014. "Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea." *PLoS One* 9 (12), doi: 10.1371/journal.pone.0111913.

Fisher, Michael M., and Tony Kingsbury. 2003. *An Industry Full of Potential: Ten Facts to Know about Plastics from Consumer Electronics—2003 Update*. Arlington, VA: American Plastics Council.

Gabrys, Jennifer. 2011. *Digital Rubbish: A Natural History of Electronics*. Ann Arbor: University of Michigan Press.

Gabrys, Jennifer. 2013. "Plastic and the Work of the Biodegradable." In *Accumulation: The Material Politics of Plastic*, edited by Jennifer Gabrys, Gay Hawkins, and Mike Michael, 208–27. Abingdon, UK: Routledge.

García, Jeannette M., Gavin O. Jones, Kumar Virwani, Bryan D. McCloskey, Dylan J. Boday, Gijs M. ter Huurne, Hans W. Horn, Daniel J. Coady, Abdulmalik M. Bintaleb, Abdullah M. S. Alabdulrahman, Fares Alsewailem, Hamid A. A. Almegren, and James L. Hedrick. 2014. "Recyclable, Strong Thermosets and Organogels via Paraformaldehyde Condensation with Diamines." *Science* 344 (6185): 732–35.

Gourmelon, Gaelle. 2015. "Global Plastic Production Rises, Recycling Lags." *Vital Signs Online*, January 28, Worldwatch Institute, www.worldwatch.org/global-plastic-production-rises-recycling-lags-0.

Gregory, Murray R., and Anthony L. Andrady. 2003. "Plastics in the Marine Environment." In *Plastics and the Environment*, edited by Anthony L. Andrady, 379–401. Hoboken, NJ: John Wiley and Sons.

Guattari, Félix. 1995. *Chaosmosis: An Ethico-Aesthetic Paradigm*. Bloomington: Indiana University Press.

Guo, Pi, Xijin Xu, Binliang Huang, Di Sun, Jian Zhang, Xiaojuan Chen, Qin Zhang, Xia Huo, and Yuantao Hao. 2014. "Blood Lead Levels and Associated Factors among Children in Guiyu of China: A Population-Based Study." *PLoS One* 9 (8), doi: 10.1371/journal.pone.0105470.

Haraway, Donna. 2015. "Anthropocene, Capitalocene, Plantationocene, Chthulucene: Making Kin." *Environmental Humanities* 6: 159–65.

Heinberg, Richard. 2005. *The Party's Over: Oil, War, and the Fate of Industrial Societies*. West Sussex, UK: Clairview Books.

Hobi International. 2013. *Product Analysis*. Green Electronics Council, greenelectronicscouncil.org/wp-content/uploads/2013/12/slateswkshp/GECTabletsWorkshopDec2013_Anatomy_Boswell.pdf.

Holm, Nicholas. 2012. "Consider the Squirrel: Freaks, Vermin, and Value in the Ruin(s) of Nature." *Cultural Critique* 80 (1): 56–95.

IPCC (Intergovernmental Panel on Climate Change). 2013. *Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Kavlock, Robert J., George P. Daston, Chris DeRosa, Penny Fenner-Crisp, L. Earl Gray, Steve Kaattari, George Lucier, Michael Luster, Michael J. Mac, and Carol Maczka. 1996. "Research Needs for the Risk Assessment of Health and Environmental Effects of Endocrine Disruptors: A Report of the US EPA-Sponsored Workshop." *Environmental Health Perspectives* 104 (Suppl. 4): 715–40.

Kolbert, Elizabeth. 2011. "Enter the Anthropocene—Age of Man." *National Geographic* 219 (3): 60.

Liao, Chunyang, and Kurunthachalam Kannan. 2011. "High Levels of Bisphenol A in Paper Currencies from Several Countries, and Implications for Dermal Exposure." *Environmental Science and Technology* 45 (16): 6761–68.

Liboiron, Max. 2013. "Plasticizers: A Twenty-First-Century Miasma." In *Accumulation: The Material Politics of Plastic*, edited by Jennifer Gabrys, Gay Hawkins, and Mike Michael, 134–49. Abingdon, UK: Routledge.

Liboiron, Max. 2016. "Redefining Pollution and Action: The Matter of Plastics." *Journal of Material Culture* 21 (1): 87–110, doi: 10.1177/1359183515622966.

Malabou, Catherine. 2008. *What Should We Do with Our Brain?* New York: Fordham University Press.

Marriott, James, and Mika Minio-Paluello. 2014. "The Political and Material Landscape of European Energy Distribution: Tracking the Oil Road." *Theory, Culture, and Society* 31 (5): 83–101.

MCC (Microelectronics and Computer Technology Corporation). 1996. *MCC Technical Report MCC-ECESM-001–96: Electronics Industry Environmental Roadmap*, www.cmu.edu/gdi/comprec/eier96roadmap.pdf.

McDonough, William, and Michael Braungart. 2010. *Cradle to Cradle: Remaking the Way We Make Things*. New York: Macmillan.

McKinney, Michael L. 1997. "How Do Rare Species Avoid Extinction? A Paleontological View." In *The Biology of Rarity*, edited by William E. Kunin and Kevin J. Gaston, 110–29. Frimley, UK: Springer.

Meeker, John D., Sheela Sathyanarayana, and Shanna H. Swan. 2009. "Phthalates and Other Additives in Plastics: Human Exposure and Associated Health Outcomes." *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 364 (1526): 2097–113.

Miller, Daniel. 2007. "Stone Age or Plastic Age?" *Archaeological Dialogues* 14 (1): 23–27.

Naess, Arne. 1973. "The Shallow and the Deep, Long-Range Ecology Movement: A Summary." *Inquiry* 16 (1–4): 95–100.

Noble, Jem. "VHS: A Posthumanist Aesthetics of Recording and Distribution." In *The Oxford Handbook of the Archaeology of the Contemporary World*, edited by Paul Graves-Brown, Rodney Harrison, and Angela Piccini, 728–42. Oxford: Oxford University Press.

Parikka, Jussi. 2011. *Medianatures: The Materiality of Information Technology and Electronic Waste*. London: Open Humanities Press.

Parikka, Jussi. 2013. "Media Zoology and Waste Management: Animal Energies and Medianatures." *NECSUS: European Journal of Media Studies* 2 (4): 527–44.

Parikka, Jussi. 2015a. "The Alchemic Digital, The Planetary Elemental." In "56th Venice Biennale," special issue, *E-flux Journal*, July 22, supercommunity.e-flux.com/texts/the-alchemic-digital-the-planetary-elemental/.

Parikka, Jussi. 2015b. *A Geology of Media*. Minneapolis: University of Minnesota Press.

Plastics Europe. 2015. *Plastics—The Facts 2014/2015: An Analysis of European Plastics Production, Demand, and Waste Data*. Association of Plastics Manufacturers, www.plasticseurope.org/Document/plastics-the-facts-2014.aspx.

Ponting, Clive. 2011. *Gunpowder: An Explosive History—From the Alchemists of China to the Battlefields of Europe*: New York: Random House.

Randall, Tom. 2014. "Break-Even Points for US Shale Oil." Bloomberg.com, October 17, www.bloomberg.com/news/2014-10-17/oil-is-cheap-but-not-so-cheap-that-americans-won-t-profit-from-it.html.

Reisser, Julia, Jeremy Shaw, Gustaaf Hallegraeff, Maira Proietti, David K. A. Barnes, Michele Thums, Chris Wilcox, Britta Denise Hardesty, and Charitha Pattiaratchi. 2014. "Millimeter-Sized Marine Plastics: A New Pelagic Habitat for Microorganisms and Invertebrates." *PLoS One* 9 (6), doi: 10.1371/journal.pone.0100289.

Robertson, T. J., and T. A. Farrelly. 2015. "Bisphenol A (BPA) Exposure in New Zealand: A Basis for Discussion." *Journal of the Royal Society of New Zealand* 45 (4): 184–96, doi: 10.1080/03036758.2015.1071271.

Roman, Lauren S., and Jim Puckett. 2002. "E-Scrap Exportation: Challenges and Considerations." IEEE International Symposium on Electronics and the Environment, IEEE Explore Digital Library, doi: 10.1109/ISEE.2002.10032343.

Soto, Ana M., and Carlos Sonnenschein. 2010. "Environmental Causes of Cancer: Endocrine Disruptors as Carcinogens." *Nature Reviews Endocrinology* 6 (7): 363–70.

Starosielski, Nicole. 2015. *The Undersea Network*. Durham, NC: Duke University Press.

Stiegler, Bernard. 2010. *For a New Critique of Political Economy*. Translated by Daniel Ross. Cambridge: Polity.

Taffel, Sy. 2013. "Scalar Entanglement in Digital Media Ecologies." *NECSUS: European Journal of Media Studies* 3 (1): 233–54.

Taffel, Sy. 2015a. "Towards an Ethical Electronics? Ecologies of Congolese Conflict Minerals." *Westminster Papers in Communication and Culture* 10 (1): 18–33, doi.org/10.16997/wpcc.210/.

Taffel, Sy. 2015b. "Archaeologies of Electronic Waste." *Journal of Contemporary Archaeology* 2 (1): 78–85.

Thompson, Richard. 2013. "Plastics, Environment, and Health." In *Accumulation: The Material Politics of Plastic*, edited by Jennifer Gabrys, Gay Hawkins, and Mike Michael. Abingdon, UK: Routledge.

Thompson, Richard C., Charles J. Moore, Frederick S. vom Saal, and Shanna H. Swan. 2009. "Plastics, the Environment, and Human Health: Current Consensus and Future Trends." *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 364 (1526): 2153–66.

Thompson, Richard C., Shanna H. Swan, Charles J. Moore, and Frederick S. vom Saal. 2009. "Our Plastic Age." *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 364 (1526): 1973–76.

Turnbaugh, Peter J., Ruth E. Ley, Micah Hamady, Claire Fraser-Liggett, Rob Knight, and Jeffrey I. Gordon. 2007. "The Human Microbiome Project: Exploring the Microbial Part of Ourselves in a Changing World." *Nature* 449 (7164): 804–10, doi: 10.1038/nature06244.

Vandenberg, Laura N., Theo Colborn, Tyrone B. Hayes, Jerrold J. Heindel, David R. Jacobs, Duk-Hee Lee, Toshi Shioda, Ana M. Soto, Frederick S. vom Saal, Wade V. Welshons, R. Thomas Zoeller, and John Peterson Myers. 2012. "Hormones and Endocrine-Disrupting Chemicals: Low-Dose Effects and Nonmonotonic Dose Responses." *Endocrine Reviews* 33 (3): 378–455, doi: 10.1210/er.2011-1050.

Vom Saal, Frederick S., and Wade V. Welshons. 2006. "Large Effects from Small Exposures. II. The Importance of Positive Controls in Low-Dose Research on Bisphenol A." *Environmental Research* 100 (1): 50–76.

Waters, Colin N., Jan Zalasiewicz, Colin Summerhayes, Anthony D. Barnosky, Clément Poirier, Agnieszka Gałuszka, Alejandro Cearreta, Matt Edgeworth, Erle C. Ellis, Michael Ellis, Catherine Jeandel, Reinhold Leinfelder, J. R. McNeill, Daniel deB. Richter, Will Steffen, James Syvitski, Davor Vidas, Michael Wagreich, Mark Williams, An Zhisheng, Jacques Grinevald, Eric Odada, Naomi Oreskes, and Alexander P. Wolfe. 2016. "The Anthropocene Is Functionally and Stratigraphically Distinct from the Holocene." *Science* 351 (6269), doi: 10.1126/science.aad2622.

Welshons, Wade V., Susan C. Nagel, and Frederick S. vom Saal. 2006. "Large Effects from Small Exposures. III. Endocrine Mechanisms Mediating Effects of Bisphenol A at Levels of Human Exposure." *Endocrinology* 147 (6): S56–S69.

World Health Organization. 2014. "Dioxins and Their Effect on Human Health." Fact Sheet No. 225, www.who.int/mediacentre/factsheets/fs225/en/.

Yang, Mihi, Mi Seon Park, and Ho Sun Lee. 2006. "Endocrine Disrupting Chemicals: Human Exposure and Health Risks." *Journal of Environmental Science and Health, Part C* 24 (2): 183–224, doi: 10.1080/10590500600936474.

Yoshida, Shosuke, Kazumi Hiraga, Toshihiko Takehana, Ikuo Taniguchi, Hironao Yamaji, Yasuhito Maeda, Kiyotsuna Toyohara, Kenji Miyamoto, Yoshiharu Kimura, and Kohei Oda. 2016. "A Bacterium That Degrades and Assimilates Poly(Ethylene Terephthalate)." *Science* 351 (6278): 1196–99.

Zalasiewicz, Jan, Mark Williams, Colin N. Waters, Anthony D. Barnosky, and Peter Haff. 2014. "The Technofossil Record of Humans." *Anthropocene Review* 1 (1): 34–43, doi: 10.1177/2053019613514953.

Zettler, Erik R., Tracy J. Mincer, and Linda A. Amaral-Zettler. 2013. "Life in the 'Plastisphere': Microbial Communities on Plastic Marine Debris." *Environmental Science and Technology* 47 (13): 7137–46, doi: 10.1021/es401288x.

Zielinski, Siegfried. 2006. *Deep Time of the Media: Toward an Archaeology of Hearing and Seeing by Technical Means*. Translated by Gloria Custance. Cambridge, MA: MIT Press.

Filmography

Gasland. DVD. Directed by Josh Fox. HBO Documentary Films, 2010.

Sy Taffel is a lecturer in media studies at Massey University, Aotearoa, New Zealand. In 2013 he completed a PhD in digital media ecologies at the University of Bristol. His research interests include political ecologies of digital media, digital media and political activism, the material impacts of media hardware, pervasive/locative media, and peer-to-peer production. He has published work in peer-reviewed journals, including *Convergence*, *Culture Machine*, and the *NECSUS: European Journal of Media Studies*. Sy has also worked as a filmmaker and photographer, and he has been involved with media activist projects including Indymedia, Climate Camp, and Hacktionlab.