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Cindy Isenhour

Michael Haedicke

Brieanne Berry

Jean MacRae

Travis Blackmer

*See next page for additional authors*

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**Authors**

Cindy Isenhour, Michael Haedicke, Brienne Berry, Jean MacRae, Travis Blackmer, and Skyler Horton

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# Toxicants, entanglement, and mitigation in New England's emerging circular economy for food waste

Cindy Isenhour<sup>1</sup> · Michael Haedicke<sup>2</sup> · Brienne Berry<sup>3</sup> · Jean MacRae<sup>4</sup> · Travis Blackmer<sup>5</sup> · Skyler Horton<sup>6</sup>

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## Abstract

Drawing on research with food waste recycling facilities in New England, this paper explores a fundamental tension between the eco-modernist logics of the circular economy and the reality of contemporary waste streams. Composting and digestion are promoted as key solutions to food waste, due to their ability to return nutrients to agricultural soils. However, our work suggests that food waste processors increasingly find themselves responsible for policing boundaries between distinct “material” and “biological” systems as imagined by the architects of the circular economy—boundaries penetrable by toxicants. This responsibility creates significant problems for processors due to the regulatory, educational, and structural barriers documented in this research. This paper contributes to scholarship which suggests the need to rethink the modernist logics of the circular economy and to recognize the realities of entangled material and biological systems. More specifically, we argue that if circularity is the goal, policy needs to recognize the barriers food waste processors face and concentrate circularity efforts further upstream to ensure fair, just, and safe circular food systems.

**Keywords** Food · Agriculture · Waste · Circular economy · Toxicants · Composting/digestion · Eco-modernism

## Introduction: “toxic trespass”

“Dear Mother, ...I feel completely violated” read a letter submitted to Mother Earth News. The writer lamented,

*I picked up a double load of compost from a local farmer. I diligently spread it into my new garden beds and around my young fruit trees and blackberries... Come spring, however, almost everything I had planted in my garden beds exhibited bizarre*

*growth — if it grew at all. I was completely perplexed ... Googling terms such as ... 'distorted growth' and 'leaf curl' finally led me to discover that my supposedly organic amendment had been contaminated by a persistent herbicide known as aminopyralid. This stuff is an ecological WMD,... I feel completely violated. My ground was poisoned, about \$1,000 worth of perennials and veggies were ruined, and I still have a pile of toxic manure sitting in my yard* (Goodman 2013:1).

✉ Cindy Isenhour  
cynthia.isenhour@maine.edu

- <sup>1</sup> Department of Anthropology, Climate Change Institute, University of Maine, Orono, ME, USA
- <sup>2</sup> Department of Sociology, University of Maine, Orono, ME, USA
- <sup>3</sup> Department of Anthropology, University of Maine, Orono, ME, USA
- <sup>4</sup> School of Civil and Environmental Engineering, University of Maine, Orono, ME, USA
- <sup>5</sup> School of Economics, University of Maine, Orono, ME, USA
- <sup>6</sup> Human Dimensions of Climate Change, University of Maine, Orono, ME, USA

Toxicants can leave us feeling violated when they seep into unexpected and unanticipated places. These sentiments suggest that a border has been crossed, a boundary traversed, and an injustice experienced. Scholars have described these transgressions as a form of “toxic trespass” (Grandia 2019) that invades and occupies, that appropriates our worlds (Serres 2010). Suggestions of borders and distinct realms upon which toxicants intrude are echoed in contemporary conceptualizations of the circular economy, which envision resource loops in separate biological and material systems. In this case, the “technical” system which produces synthetic, man-made toxicants like aminopyralid are separate from the “biological” systems that transform discarded food into beneficial soil

amendments. From this perspective, any contamination is clearly an intrusion, a form of trespass.

However, the toxicants that make their way into our food systems present a direct challenge to modernist conceptualizations of the circular economy. The humanities and social sciences have helped to usher in this challenge, drawing our attention to helplessly entangled, co-produced relations, and encounters between materials and living beings. These interventions have made clear the relational nature of biological and material interactions, in direct challenge to depictions of stable and non-porous boundaries. Indeed, the modernist distinctions human societies have constructed—between different groups of humans, human and non-humans, between life and non-living matter, culture and nature, and between the technical and the biological (Haraway 2016; Povinelli 2016)—are increasingly questioned.

In what follows, we draw on research with composting and digestion facilities licensed to receive food waste throughout New England. These facilities are participating in efforts to prevent food waste from going to landfills, mitigate climate change, improve economic efficiencies, and facilitate the movement towards more circular, less wasteful, regional food systems. To do so safely, food waste processors must also ensure that their biological processes are protected from toxic trespass. We explore processor perceptions of contamination, their attempts to mitigate risk, and the barriers they face as they undertake the seemingly impossible task of fortifying ontological boundaries between technical and biological systems that do not exist in biology or chemistry. Our work builds on Blanchette's project to understand the "politics of labor with complex anthropogenic materials" (2019:80) in facilities where nutrients from food and other organic waste streams are recovered for the purpose of nutrient cycling—but where it is extremely difficult for workers to prevent, detect, or mitigate the intrusion of unseen toxicants.

The data we present document the educational, regulatory, and structural barriers that processors face. Our work also reveals a growing sense of injustice among processors as they confront potential economic and legal liability for the toxicants that enter their systems—often by means beyond their control or ability to mitigate. Together, the research implies a need to rethink the dualism of modernist circular economy logics, to recognize the constraints processors face, and to concentrate circularity efforts upstream in order to move toward safe resource loops and more just transitions to circular food systems.

## Background: food waste reduction through more circular food systems

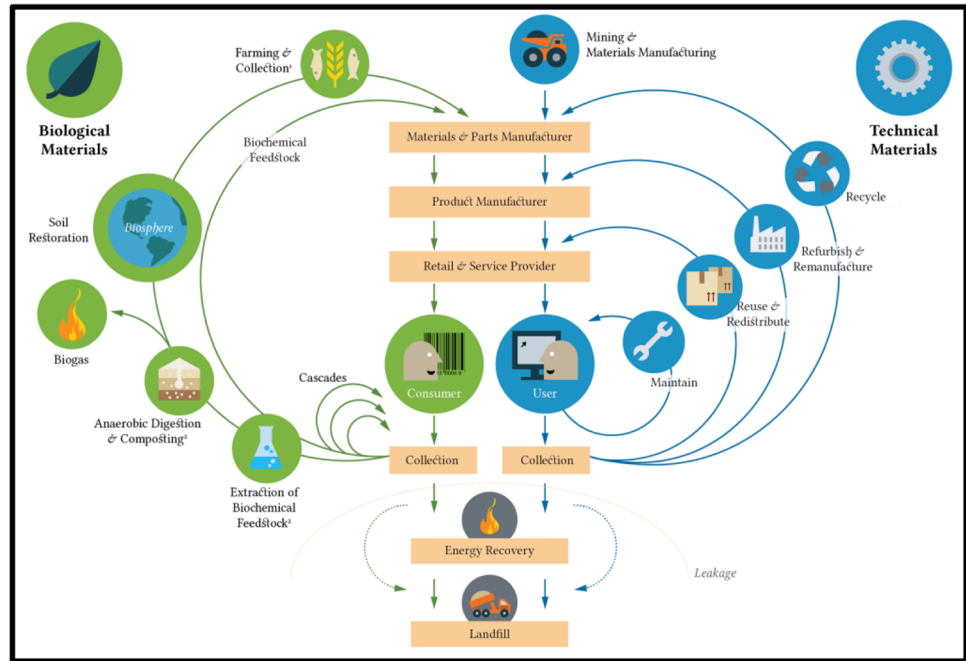
Increasingly, the American public has become aware of and concerned about the issue of food waste (Desilver 2019). Approximately one-third of all the food produced

for human consumption each year is lost or wasted (Buzby et al. 2014; FAO 2011). These losses have significant implications in a world where far too many people are hungry and malnourished. They also represent an enormous waste of resources: money, petroleum, water, human labor, and intellectual investment. In the USA, for example, we collectively spend \$218 billion a year on food that is never eaten, totaling 1.3% of GDP (ReFED 2016). These losses also have consequential environmental impacts, both direct and indirect—from the emissions associated with the gas used to grow and transport food, the wasted irrigation water, and the methane released by discarded food in landfills, to the water contamination generated as decomposing foods mix with toxic pharmaceuticals, plasticizers, and pesticide residues in landfills and then sometimes seep into water systems (Schwarzbauer et al. 2002).

The New England region has been relatively progressive in their efforts to address food waste (Donahue et al. 2014), making significant investments in regional agricultural development and nutrient cycling processes. Over the past decade, several states in the region have passed bans on the landfilling of food scraps. Vermont's Universal Recycling Law requires all waste generators, even households, to recycle discarded foods. Connecticut, Rhode Island, and Massachusetts implemented landfill bans for food waste produced by commercial generators. With the requirement to recycle food waste, there has been a rapid expansion in composting and anaerobic digestion capacity and processing throughout the region. As of 2019, there were more than 150 facilities licensed to process food waste in Northern New England alone. These facilities represent a wide array of business models, both public and private. Some facilities are located on private farms, receive food waste from paying clients, and sell soil amendments. Other on-farm processors accept food waste for free to process and apply on their own land. Some organizations pay for high-quality food waste to produce premium and certified organic fertilizers for sale nationally. Large municipality-led efforts also take food waste from households, some to produce energy and digestate, while others produce compost that is available free to residents.

Both digestion and composting are common methods for stabilizing food wastes without attracting pests or producing odor. Both recover nutrients and organic matter that enrich the soil and are seen as a vital component of more circular, and sustainable, food systems. Important to note, however, is that while composting and digestion processes are effective for controlling pathogens, many heavy metals and synthetic chemicals can move through these processes and end up in the soil amendments they produce (O'Connor et al. 2021). Unfortunately, potential toxicants can enter organics processing through multiple pathways

**Fig. 1** Ellen MacArthur Foundation “butterfly” diagram of the circular economy. Reproduced with the permission of the Ellen MacArthur Foundation. Copyright Ellen MacArthur Foundation 2019, [www.ellenmacarthurfoundation.org](http://www.ellenmacarthurfoundation.org)



(e.g. horse manure, food packaging, or other inputs like straw) and are impossible to detect without extensive and often prohibitively expensive testing. Testing for persistent herbicides, for example, routinely cost \$150–200 per sample (Coker 2014).

Given the recent attention to the problem of food waste, nutrient cycling through compost and digestion is envisioned as an integral part of a future characterized by circular, rather than linear production-consumption-disposal systems. Certainly, addressing food waste is an important challenge and composters and digesters have an important role to play as we move toward more circular and less wasteful economies. The Ellen MacArthur Foundation (EMF), a leader in Circular Economy research and policy, has developed and popularized the “butterfly” depiction of the circular economy (see Fig. 1) which includes a road map for more circular food systems (EMF 2020). Their concept for the circular economy features two “wings,” separate resource loops for technical and biological materials. The left “wing” depicts the recovery process for valuable biological resources embodied in food waste (and other biological materials) as they are processed and then fed back into productive agricultural systems. In this diagram, food scraps and waste are collected from grocers, restaurants, and households then moved clockwise, to “anaerobic digestion & composting” where residual value can be extracted and utilized for “soil restoration.” By helping to operationalize this road map, digesters and composters are seen as key contributors to waste reduction, economic savings, and healthier soils.

## Literature review: imaginary boundaries and entanglement in the circular economy

The EMF butterfly diagram imagines biological resource loops that are wholly separate from the technical systems that produce materials like synthetic chemicals, such as pesticides, flame retardants, and non-stick coatings. These technical materials are toxicants (Liboiron 2017), quite distinct from the naturally produced toxins found in fungi, snakes, or spiders. They are synthetic and man-made. However, in this depiction of a circular economy, they are bounded from the left and circulate within the confines of “technical” loops. The possibility of trespass is not acknowledged in the ideal circular economy.

Gregson et al. (2015) and Reno (2011) have both observed that the concept of the circular economy, as used among both academics and practitioners, “tends to be uncritical, descriptive and deeply normative” (Gregson et al. 2015:219). Part of the efficiency-based, technological optimism of eco-modernity, circular economy is celebrated as a triple-win concept which allows for simultaneous environmental protection, efficiency gain, and economic growth. And yet, as Liboiron (2018) and others have argued, when these systems are materially entangled and the onto-epistemological boundaries we have built are not strong enough to contain chemistry, the toxicity of much of the waste stream presents a “serious problem for concepts like circular economy, which assumes that all wasted materials can be brought back into economic and consumption cycles” (Liboiron 2018:1).

This uncritical embrace of the circular economy model speaks to a larger issue: the often-unacknowledged influence

of modernist thinking in contemporary discourses of environmental sustainability, including those related to the circular economy. Modernism, in this context, refers to more than simply a naïve faith in the power of new technologies to cut cleanly through complex environmental problems (Wapner 2010). As Latour and others have contended, modernist thought distinguishes itself through the creation of impermeable ontological boundaries between the natural world and the human world (Latour 1993; Bennett 2010). It is this modernist logic that is used to promote the circular economy as a means to decouple economic growth (a human institution) from ecological harm (nature) through innovation and alternative technologies. The United Nations Environment Program writes, “Improving the rate of resource productivity (doing more with less) faster than the economic growth rate is the notion behind decoupling” (2011:vx). This shift, the eco-modernist Breakthrough Institute argues, will require a “radical decoupling of humans from nature” (2015:23). Because it assumes that nature and society are separate, this eco-modernist thinking is myopic when it comes to recognizing the entanglement of biological and technical materials in the creation of contemporary environmental problems, such as the contamination of food waste. Sometimes toxicants are entangled with food as far back as the farm, when pesticides were applied and remain, in trace amounts, on food products later discarded. In other cases, toxicants make their way in through food packages that contain, for example, PFAS designed to prevent sticking or the penetration of grease. As in many environmental discourses like that associated with the circular economy, an ecomodernist logic further deepens concepts of a nature-culture divide, by insisting that natural limits can be overcome by maintaining boundaries and through technological progress. As eco-modernists Shellenberger and Nordhaus have notoriously written “The solution to the unintended consequences of modernity is, and always has been, more modernity” (2012:1).

This failure, or refusal, to recognize entanglement is not only built on a nature culture divide, but it also frames all problems and solutions as matters of applying human innovation to nature. It refuses to acknowledge that some problems have their roots in human political-economic systems that enable environmental benefits and burdens to be distributed in highly unequal and unjust ways. In the context of circular food systems, this failure to recognize the politics of entanglement has created a system which holds composters and digesters responsible for securing the line between biological and technical processes while the companies that produced trespassing chemicals accrue the benefits and, all too often, evade responsibility. In just the past few years, stories of toxic trespass have multiplied—of crops ruined, of milk cows contaminated, and of loads of contaminated compost sent to the landfill (Crunten 2020; Hannon 2021). Stories about PFAS and persistent herbicides suggest that

one of the fundamental goals of the circular economy—to design waste and pollution out of the system (De Decker 2018; Haas et al. 2015)—has gone unfulfilled. Instead, the majority of efforts to implement the circular economy in food systems are confined to the end of the lifecycle in the waste processing phase (CGRI 2020), long after the toxicants that might accumulate in our food systems have been engineered, sold, produced profits, and introduced into both biological and technical systems. The laborers who power food waste processing systems, it seems, are increasingly on the front lines, trying to defend biological processes from toxic intrusion.

Anthropological and sociological research has revealed that our experiences and understandings about toxic entanglements are shaped by our historical experiences and situational positions. Communities that have suffered multiple exposures at the hands of industrial polluters and have had their concerns dismissed by regulatory agencies—like the Hyde Park residents described by Melissa Checker (2005), the residents of *Colonia Periférico* of whom Elizabeth Roberts writes (2017), or of the First Nations people living in Canada’s Chemical Valley described by Sara Weibe (2016)—understand toxics and potential risks through a memory and embodiment of environmental injustices, ill health, and contestations with colonial scientific and regulatory regimes. These communities try to create and maintain boundaries as part of what Roberts calls a “crucial survival response within the continued violent capitalist interpenetration of all the earth’s biota” (2017:594). Communities such as these have been in the vanguard of political agitation for environmental justice, building on the legacy of civil rights activism to call for the spaces where people live, work, and play to be protected from toxic incursions (Di Chiro 1996; Mohai et al 2009; Taylor 2000). Through numerous local struggles, participants in this movement have crafted a politically resonant frame, or characterization of these toxic assaults, that asserts that “the rights of toxic contamination victims have been usurped by more powerful social actors, and that ‘justice’ resides in the return of these rights” (Capek 1993: 8). At a minimum, these rights are understood in both distributive and procedural terms, that is, in terms of the elimination of arrangements that disproportionately and unjustly subject disenfranchised communities to environmental risks and in terms of the creation of democratic mechanisms to allow for full community participation in decisions that affect the welfare of residents (Shrader-Frechette 2005).

But what happens when toxic entanglements ensnare those who have traditionally been racially, ethnically, or financially privileged to have lived without a memory of toxic injustice and who are, rather, involved in highly celebrated sustainability efforts? In certain ways, the food waste processors in our study occupy a position that is not unlike



those of residents of communities facing toxic contamination: they are forced to deal with toxicants produced by industry for private gain, and they face significant health and financial risks as a result of this situation. But these processors also possess numerous social advantages which, historically, have discouraged people of privilege from linking personal troubles to a larger critique of unjust social arrangements (Kozlowski and Perkins 2015) or to think reflexively about modernist ontologies that create false separations. If these food waste processors are exposed to chemicals that endanger their health or their businesses are forced to bear legal and economic liability for contamination they did not introduce—do they come to understand the transition toward the circular economy in a different way? Or do their privileged positions in society or their professional occupations prevent them from calling out these problems? These are not idle questions. As critics have pointed out, proponents of the circular economy have largely avoided discussions about how to ensure just transitions to a circular economy, preferring a technocratic approach that emphasizes the apolitical and abstract environmental benefits of circular arrangements (Kirchherr et al 2017; Murray et al. 2017). The ability of circularity to exercise a truly transformative force in economic arrangements, however, may well hinge on the ability of participants to understand themselves in solidarity with others who struggle against toxic contamination and to embrace critiques of unequal power and accountability in profit-oriented industrial agricultural systems.

### Researching the emergent risks of more circular food systems: methods

Our research sets out to understand how food waste processors perceive contamination risks and to explore the mitigation measures they have put in place to prevent toxicants from making their way into the compost or digestate. We were also interested in the extent to which processors understood contamination events as a failure of their own processes or as unjust systemic issues. The project builds upon a 6-year transdisciplinary research effort by the Materials Management Research Group at the University of Maine. Composed of engineers, economists, anthropologists, sociologists, health scientists, and a wide variety of community partners, this transdisciplinary group has worked on a variety of projects related to waste throughout New England, including food sharing efforts in schools, waste policy, and the potential risks of PFAS in food packaging (Isenhour et al. 2016; Berry and Acheson 2017; Thakali and MacRae 2021). In the process of conducting this work, the team has hosted a number of stakeholder engagement efforts, including six workshops that drew together composters, digesters, landfill operators, state regulators, town

managers, and haulers. This early work with stakeholders, the overwhelming majority of whom are middle class and white, suggested that the clear majority are hopeful that the expansion of food waste recycling will support the waste management and food waste hierarchies—simultaneously delivering economic, environmental, and social benefits (Isenhour and Blackmer 2018).

Given the widely shared view among stakeholders that this transition was a positive movement toward sustainability (provided it made financial sense and reduced costs), we sought to understand what potential, unanticipated risks might compromise this new system—as a means for helping our partners with research-informed risk planning and mitigation. In this paper, we focus on a subset of that work, specifically on a survey of facilities licensed to receive food waste in VT, ME, and MA as well as a series of follow-up interviews. The survey (sample = 114, response rate 29% or 33 responses) focused on processors' perceptions of and experiences with contamination and containment. The survey was sent in both paper format and via email using Qualtrics survey software, for participant convenience. Surveys included a range of question formats including short answer, multiple choice, rankings, and Likert scales. The survey also included open-ended prompts which allowed representatives of the participating processing facilities to respond in sentences or short paragraphs. In total, we received 33 responses, fairly evenly distributed across the three states and from a range of facilities. We could not detect any clear sampling bias in the survey responses. Our participants included composters and anaerobic digesters operating with a range of business models. Some are private and carefully curate the food waste they purchase so that they can sell high-end, organically certified products to the general public. Others are large private processors that are paid to accept food waste from throughout the region, including packaged wastes from grocers that can be depackaged, ground, and fed into digesters where microbes produce methane and digestate sold to farms as soil conditioners. Other facilities are publicly supported and accept food waste that has been co-mingled with other waste products. Still, other facilities are public/private partnerships that have invested in the collection of household food waste and produce compost used for municipal purposes or given freely to community members. These various models and others, based on size and the quality of inputs, largely determine the quality of outputs and their chance of contamination. All the facilities we surveyed receive food waste by the truckload and invest considerable effort to visually inspect, screen, and pre-process (grind/pulp) each load before introducing it into their systems.

Our analysis of the qualitative survey results raised additional questions for our team. While facility representatives mentioned concerns about potential contaminants like herbicide residues and PFAS far less frequently than common contaminants like trash and glass, some open-ended responses suggested a deep concern with these unseen toxicants. This discrepancy prompted us to revise our application for research with human subjects and recruit participants for short follow-up interviews. We extended the invitation to all the processors who took the survey ( $n = 33$ ). Five facilities agreed including a range of facility types from a small-scale municipal composter to a high-end national distributor of organic compost. The volunteer pool, while small, did roughly mirror the composition of the larger sample of survey participants in terms of facility type and business model. Proportionally, we had more interview volunteers from Maine, perhaps due to our affiliation with the University of Maine. We also note that because our research was introduced to all participants as a study about contamination and mitigation, facilities concerned about risks that are difficult to mitigate may have been more likely to respond. That said, of the five facilities that agreed to interviews, only two had included comments about unseen contaminants on their surveys.

The semi-structured interviews were designed to further explore processor decisions about how to prevent and mitigate contamination risks. We also asked participants to help us understand why aggregated survey results indicated that unseen toxicants were mentioned less frequently than more common concerns like fruit stickers, straws, and glass in the survey—despite our observation that many wrote comments specifically about rare but extremely consequential contaminants. While our interview sample was small ( $n = 5$ ), we found that when combined with qualitative survey responses, we were able to reach thematic saturation by the third interview—meaning that the fourth and fifth interview produced no new thematic codes that were not already represented by the qualitative survey responses or the first three interviews (Guest et al. 2020). It is also worth noting that these interviews, and our discussion of them in the pages to come, are not meant to represent the food waste processing industry as a whole. There is too much diversity to attempt to do so even with a much larger sample. Instead, we sought to understand specific and contextualized experiences with contamination, in a variety of food waste recycling models that are intended to help circularize our food systems. This design was executed in an attempt to understand various processor experiences with contamination, prevention, and mitigation.

While outside of the scope of this paper, our team also completed biological and chemical analyses of food waste destined for composting and digestion facilities throughout New England (MacRae 2020). Testing allowed us to

compliment processor perceptions of toxic entanglement with information about unknown encounters with contaminants that intruded, unnoticed. That work revealed that while nearly all samples (85%) contained some physical contamination, which is always of great concern to food recyclers, many of the food waste samples we collected ( $n = 72$ ) also contained PFAS (56%) or antibiotic resistance genes (ARGs) (> 95%). Both ARGs and PFAS have significant human health impacts and can accumulate in the soil and food systems. Testing was thus an essential part of our work as we sought to understand both our interlocutor's attempts to create boundaries between biological and technological cycles as well as their successes and failures.

## Research results: on trash and toxic traces

Despite the anger of the “Dear Mother” writer with whom we started this paper, the potential for crop losses, long-term soil contamination, or liability—our survey of composting and digestion facilities licensed to receive food waste in Vermont, Massachusetts, and Maine revealed that, of all the potential contaminants found in food waste (herbicide residues, produce stickers, pathogens, glass fragments, plasticizers, PFAS, cutlery), only about 20% of the processors who responded linked the most significant risk to their systems to unseen contaminants. The overwhelming majority of respondents were more concerned about visible plastics, glass, and films—all of which are able to be screened or picked out, but, if missed, present a significant challenge to their brand given that gardeners and farmers can also see these contaminants in the soil amendments they buy from composters and digesters.

Processors who ranked unseen contaminants as the most significant risk were in the clear minority. However, an open-ended question about contaminants of greatest concern told a slightly different story. Some wrote about toxic chemicals because of “their potential to be difficult to detect” and their ability to “prevent beneficial reuse.” A third respondent wrote, “you cannot see them, we do not test for them and they likely present the highest liability issue, however remote that might be” (Processor Survey 2018).

Follow-up interviews were conducted, in part, to explore these concerns. During our conversations with food waste processors, we increasingly came to understand the difficult positions they occupied—tasked with running a financially viable enterprise and with preventing toxic trespass, regardless of where the toxicants were introduced or their ability to contain them. We also learned how prohibitively expensive it is to test even a small sample of input materials for common contaminants. Despite processors' positive intentions and contributions to creating more sustainable food systems—and the fact that they bear very little



responsibility for introducing contaminants—they can be held legally, financially, and morally liable. In the pages to come, we outline three key barriers processors face as they try to mitigate contamination risks. All three barriers help to illustrate the disjuncture between the modernist logics of the circular economy and the realities of food waste processing in New England’s increasingly circular food systems. First, there was a generalized lack of awareness of many risks presented by potential toxicants. Second, we found that emerging markets for food waste recycling and derivatives were also characterized by weak, unclear, and inconsistent regulations. Finally, we note significant structural limitations and injustices inherent in a system that is far from circular, but places the onus for circularity on actors at the end of the lifecycle.

### **“I don’t know what I don’t know”: on the difficulty of anticipating toxic trespass**

Mark,<sup>1</sup> a facility operator who has been in the compost industry for decades but has only recently been licensed to accept food waste, failed to register surprise when we mentioned our survey had turned up relatively low levels of concern for unseen toxicants. He said,

*I think that we have so little information, knowledge even brought to our attention, that there could be ... things we really don't even understand or think about or know about it.... I don't even know what problems I'm supposed to be aware of. I don't know what I don't know. And so, I think it's really a lack of understanding that there could even be issues there. I think education is kind of critical. I mean we're at the compost school and none of that was brought up.* (Interview 11/12/19).

The scientific literature, while far from complete, offers warnings about the potential for food waste recycling to contaminate food supplies with other substances introduced during food processing, packaging, waste collection, or in the recycling process—including heavy metals, microplastics, pathogens, and toxicants (Thakali and MacRae 2021). One study, for example, found that micro plastics typically make up, on average, about 5% of compost produced from municipal solid waste (Brinton 2005). Often associated with the packaging of foods—particularly as large quantities of food waste are being fed through depackaging machines or recovered from mixed waste at “dirty” materials recovery facilities (dirty MRFs)—these microplastics are resistant to

degradation which means they accumulate in the environment, affecting biota, biodiversity, and ecosystem processes (Ng et al. 2018). One research participant, partially aware of the problem told us:

*So,...there is a certain type of plastic, I haven't nailed it down. It's either number 5 or like number 3 or something - that tends to fragment in the compost piles and gets to be these really small flecks of plastic,.... I don't know if it's micro leaching but it largely comes out changed. Like gloves, you know like kitchen gloves, ...like the blue latex gloves? They go through the whole process just fine. They come out just like they went in - umm except like hard and smooshed....but if this stuff is micro leaching something, that would be a problem and I don't know about that.* (Interview 8/8/18).

Microplastics have been found in alarming concentrations in earthworm burrows and are associated with stunted growth and mortality in the species, leading to increased soil density (Huerta Lwanga et al. 2016). High levels of microplastic contamination are also associated with decreased functional diversity. Perhaps worse, as plastics break apart, many of them leach the chemical additives used in their manufacture. Yet many studies have yet to capture the full impact of these chemical additives that “act as endocrine disruptors in addition to those which bioaccumulate, where long-term exposure at low doses may alter cell functions or cause DNA damage” (Ng et al. 2018:1385).

If, as Wynne (1987) Liboiron (2018) and MacBride (2011) have suggested, waste is made in part through our efforts to identify, categorize, and measure it, then how can waste processors account for the toxic elements of waste they are responsible for processing if they are impossible to sense without prolonged exposures or cost prohibitive measurement? These challenges certainly speak to the perils of a modernist logic that imagines separate biological and material systems and thus fails to require toxicant producers to clearly define these forms of waste or the possibility and consequences of entanglement.

### **“There’s no regulation for it, so no one gives a hoot”: on testing and regulation**

A related theme that emerged in both qualitative survey responses and interviews was linked to uncertainties about testing and regulation. Most facilities test their compost or digestate when it is finished—to check for pH, nutrient content, moisture content, maturity, and stability. But as one research participant wrote in the survey, in reference to these unseen chemical contaminants, “There’s no regulations for it, so no one gives a hoot.” Unless facilities have

<sup>1</sup> Please note we use pseudonyms for all research participants.

subscribed to a voluntary quality certification program, they rarely test for contaminants like heavy metals, pathogens, or organic halides. While some research participants like Mark clearly don't "know what they don't know" others talked about the sheer difficulty associated with figuring it out. One participant, Dale, clearly frustrated by the idea of ever being able to fully know what is coming in, or his ability to keep contaminants out said, "I don't even know how to test that, like how do you homogenize and macerate a truck load of food scraps... it's not just a cost thing, it's like—is it even possible?" For Dale, the idea that he should be held responsible for contaminants that he cannot detect seemed both frustrating, and unfair.

Rather than studying the possibility of entanglement and synergistic effects, the US regulatory system for chemicals has been characterized by a market-friendly approach which favors access to markets over the precautionary principle that might more fully investigate the potential risks and realities of toxic entanglement (GAO 2017). Testing for contamination in the USA is a voluntary, slow, and extremely expensive process that many facilities say they simply cannot afford in an increasingly competitive market. Unless all processors are required to bear such expenses, those that do put themselves at a competitive disadvantage. There is no one test for all herbicides, so a concerned facility would need to ask the lab to run each one, with each test costing hundreds of dollars (Coker 2014). Margaret, the sales and quality assurance manager for a large, high-end commercial compost facility said:

*the best way I have found to protect us, other than controlling your raw materials —where I can go and chase somebody down —is to do a bioassay or grow outs...so if something is contaminated you immediately see a tray, 'well holy crap...what is wrong with this soil?'... then you can do additional testing to figure out exactly what it is. (Interview 8/10/18).*

Margaret works for one of the few facilities that invests in regular grow outs, but academic research suggests even that may not be adequate (Thakali and MacRae 2021). Some toxicants may be present, but at levels too low for acute toxicity to plants in grow out tests. But toxicants can still build up in food webs over time and often go undetected until their concentrations pose a threat to ecological and human health. For example, PFAS was on farms for years before it showed up in water and milk (Rigby et al. 2015) and more recently in foraging wildlife (Hoey 2021).

In situations of significant uncertainty and with serious problems of "undone science" (Frickel et al. 2010), one of the best protections facility managers have for maintaining boundaries and protecting from contaminants is the formation and maintenance of strong social relationships with the

generators of the process inputs: food scraps, manure, cattle bedding, food processing residuals, shellfish. Several managers talked about the importance of having good relationships with organic waste generators and their haulers. They talked about having regular contact so that all parties understand the process, as well as what can be accepted—to formulate relations of mutual respect. Erik, a compost facility representative claims that in order to prevent contamination, "the biggest thing comes back to constantly talking to your generators. I mean that's like the most critical component." Margaret, echoing this sentiment, said that her facility's owner had been working with the same waste generators for over 20 years, "he's like, I drive by the farm a few times a week, I know what is going on." In several cases, processors told us that they have terminated relationships with waste generators or haulers who delivered loads with unacceptable levels of contamination. These strategies, as useful as they are, are likely simply no longer tenable as food waste recycling expands into residential and additional institutional spaces. It would be impossible for processors to form relationships with the individual households that are rapidly signing up for curbside food scrap collection subscriptions or participating in a growing number of municipality-led composting programs. Nearly 30 years ago Gillet warned, "The more MSW composting is accepted as a waste disposal option (in contrast to the somewhat more limited production of a useful soil amendment), the more serious becomes the issue of whether total risk has been broadened excessively" (1992:158).

While many facilities have developed means to police the boundaries of their biological processes, many also expressed frustration that uncertain and unclear regulatory frames and testing requirements were creating an uneven playing field. A representative from a community compost organization in Rhode Island was recently quoted by the press, arguing that having a single standard for PFAS in packaging would be helpful for processors. He said, "Without clear guidelines there is confusion about proper disposal of materials, producing business risks for the composting sector and impacts on environmental health" (Hannon 2021:1).

While some facilities are investing heavily in grow outs, generator visits, training, and testing, others were effectively gaining a competitive advantage by reducing or eliminating these costs. Without consumers who are aware of the differences or testing and regulatory frames that require all processors to be so careful, a few processors felt that the safety of the entire system was being undermined by the pressure to remain economically competitive. That said, it is also important to note that many of the same processors are wary of additional regulation. They want greater certainty and a fair and level playing field. One participant argued that if more regulation is necessary, it should be directed at the

producers of the toxic chemicals rather than food waste recyclers. As society moves toward more circular economic forms, it is certainly important to think about how to ensure these transitions are just for all the actors involved.

### **“No way in hell it belongs in any of our products’’: structural constraints on modernist ideology**

This brings us to a third barrier mentioned by processors in the survey and in interviews. While composting and digestion facilities can manage things like their bacterial assemblages and process temperatures to control pathogens, when the “technical” trespasses into their biological systems, there is often very little they can do. Batches of compost and digestate contaminated with toxicants must be discarded into landfills and processing equipment cleaned, often at significant cost. A few facility representatives expressed frustration, pointing to a fundamental tension between their responsibility for controlling unseen contamination and the fact that they have very little responsibility for the trespassing toxicants and few means to adequately control them.

The perspectives of these concerned food waste recyclers point to a much larger problem about the prevalence of toxic chemicals making their way into our food systems, during food production, processing, packaging, disposal, or through other inputs in the recycling process (MacRae et al. 2020). In increasingly circular food systems, some processors worry about their place—and potential liability—in these systems that come with the risk of circulating bioaccumulative toxicants.

All 33 the food waste recycling facilities that partnered with us for this research reported investing in training programs for their waste generators, hauling companies, and their own employees in an attempt to fortify the boundaries between biological feedstocks and contaminants from the “technical system.” And yet, despite these investments in relationships, in labor, in training, and in testing, many facilities are frustrated by the uncertainty and by the burden. We heard story after story about new feedstocks of considerable residual value that later turned out to be a source of significant contamination. Short paper fiber from paper mills seemed like a good idea to compost, said one research participant, “and there’s no [regulatory] limit, so you can just fly right through...but those heavy metals, they’re going to stay right there... and there is no way in hell it belongs in any of our products.” Another facility used lobster shells in their product, which also seemed like a great idea until they learned that some of the lobsters from a particular region had been contaminated by an industrial spill of mercury. More recently several respondents mentioned their wariness of biodegradable

composting bags and service-ware, much of which is found to contain grease and water-resistant coatings of PFAS (Choi et al. 2019). One remarked,

I know the state of Vermont, ... filed a lawsuit against several of these companies that...label this stuff biodegradable and it’s, you know, the bio part behind that is really pretty suspect. A petroleum-based product can still degrade, you know, it’s still a biological action but it’s not anything you want in your soil.

The US approach to approving and regulating new chemicals takes a market-friendly and weak regulatory approach. In contrast to the EU’s REACH program which requires chemical manufacturers to demonstrate safety prior to approval, the US’s Toxic Substances Control Act (TSCA) does not require chemical manufacturers to provide data on human health and environmental effects, unless the EPA specifically intervenes (GAO 2007). The burden for proving that these chemicals are not safe (in certain applications, due to synergistic effects or when concentrated in environments over time) thus falls to those that are affected by them, like composters facing lawsuits or violated gardeners. Increasingly, it seems that the US food waste recycling industry is pushing back on what they see as an unjust system given that they can be financially, morally, and legally responsible for contamination associated with a lax chemical regulatory regime (Crunden 2020; USCC 2020).

Maine recently passed a ban on the sale of products with the intentional inclusion of PFAS (Hogue 2021), a move that was advocated for by national trade groups as well as local representatives of organics recycling systems. A dairy farmer in Maine—whose milk was contaminated by PFAS due to the application of biosolids—testified in front of the Environment and Natural Resources committee. He said,

***Just like the PFAS that ruined me, the new PFAS chemicals are long lived. If we continue to use them in products such as food packaging now, we may well be finding them in our soil and water decades from now. And remember that the chemical industry folks also said the chemicals that destroyed my farm were safe for use*** (Maine State Legislature 2019).

Amplifying these calls, the US Compost Council has written that, “It is imperative that the compost industry advocate for phaseout of all PFAS chemicals, which we are doing by supporting all bills in state and national legislatures that would do that” (USCC 2021). Similarly, the North East Biosolids and Residuals Association has argued about PFAS, “We do know phasing this out will result in

reduced exposure, ... At this point, it's the only cost-effective method" (Crunden 2020:1).

These efforts underline the importance of broadening circular economy initiatives beyond their current focus on redirecting waste streams towards economically and ecologically beneficial uses. There also needs to be intentional thought about just and safe transitions to more circular economic forms. Facility managers wrestle not only with regulation that requires food waste recycling, but also with a regulatory system that fails to prevent upstream contamination of biological wastes. They receive the food waste we produce and try to extract value from it to help circularize the system but are also at risk of contaminating ecosystems. This, as many participants pointed out, is not a comfortable position to be in and many food waste processing facilities are therefore starting to advocate for tighter regulations on chemical manufacture and use.

### **Conclusion: on entanglement, upstream solutions, and just transitions to circular economy**

Our conversations with food waste processors suggest the need to rethink the dualisms of circular economic logics and to invest in discussions about just transitions toward more circular, less wasteful systems. These conversations point to several barriers that processors face including a lack of information, cost-prohibitive and difficult testing technologies, and a weak regulatory environment—all of which present significant challenges for facilities and their employees as they try to police the imaginary boundaries between the biological and the technical. Our findings imply the need to concentrate future efforts for circularity further upstream, where producers have the power to make important decisions about the chemicals and materials they use in their products. These same conversations also suggest the need to more closely regulate toxicants with the potential to accumulate in increasingly circular food systems. This might be done by trying to understand the entangled relations of these substances and how they interact within clearly inseparable biological and material realms. Finally, our work suggests the need to think about the circular economy as more than a technical and economic fix. Instead, we need to think, with intention, about issues of justice and the distribution of environmental benefits and burdens as we transition toward more circular systems of production, consumption, and disposal.

To further cement these arguments, let us return to the story of herbicide contamination from Mother Earth News—which was not an isolated incident. In fact, this small-scale example of toxic trespass has been replicated all over the country, and often on much larger scales. Just a few years

ago, a major commercial composting organization in New England had to settle a large claim because an herbicide made its way into their system. The toxicants were eventually traced back to herbicide residues on grain, produced in the grain belt. Later, those grains were used to manufacture horse feed in the Midwest. That feed (with traces of a persistent herbicide) was fed to horses in New England where it passed through equine digestive systems and was concentrated in manure. From there, the manure was mixed with food waste and other inputs to produce compost. That compost was sold to local farmers and gardeners who incorporated it into their soil. The result was that many farmers and gardeners felt violated—their soil had been poisoned and their crops ruined.

The composting operation involved in this example had absolutely no idea that the manure they were incorporating into their systems would be tainted by herbicides. But, the effects of herbicides are immediate, plants die, and the composting company was considered liable. Chemicals like PFAS and many other organics do not show up as obvious acute toxicity, but they build up in our food, and in us over time, introducing additional risk and uncertainty into the whole system. This kind of contamination can take years to recognize, and it may take decades and significant investments for affected sites to recover.

While the food waste processing facility featured in this example believed they were contributing to sustainability efforts—something beneficial for the health of our food systems, they became unknowingly complicit in toxic trespass. They were only one player in a complex system and yet, they were held legally and financially liable for the toxic intrusion. The complexity of this example reminds us that compost and digestion operators are entangled in toxic webs. We can view their place in those webs as victims, as perpetrators, as sustainability pioneers bringing about a new circular economy by policing the boundaries of technical and biological systems, or as enablers and disseminators of toxic trespass. Many of them increasingly understand themselves as active agents pushing against an unjust system. These divergent roles, however, “challenge any easy recognition of a *we* who has a right to live uncontaminated, of a toxin separate from and threatening this *we*, and of a neutral position from which to adjudicate this separation” (Langwick 2018:421). And yet it does seem clear that, despite the uncertainties, some food waste processors are pushing back against what they argue is an unjust system, one in which powerful actors are able to profit while those with little responsibility bear the burden.

It also seems quite clear, based on our research, that the ideals of the circular economy are far from realized, particularly given that the responsibility for operationalizing the concept has, for the most part, been passed on to facility employees and managers like Mark who “don't know what



they don't know" but try, often in vain, to maintain boundaries between technical and biological systems as envisioned by the proponents of the Circular Economy. These logics are favored and supported by many of the perpetrators of toxic intrusion who have also invested heavily in the concept of the Circular Economy. When the chemical industries refuse to publicly recognize or take responsibility for the possibility of entanglement, Mark and his colleagues work to maintain these artificial boundaries, to order systems in the interest of sustainability. But this false order enables the reproduction of toxic systems and the uneven relations that shape, as Liboiron writes, "what forms of life are supported to persist, thrive, and alter, and what forms of life are destroyed, injured, and constrained." In this case, garden vegetables are far from the only potential victims.

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**Data availability** Transcripts and raw survey data available upon request at [cynthia.isenhour@maine.edu](mailto:cynthia.isenhour@maine.edu).

**Code availability** NA.

## Declarations

**Ethics approval** The research reported on in this paper received human subjects review board certification (University of Maine 06\_17\_18).

**Conflict of interest** The authors declare no competing interests.

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## References

- Bennett J (2010) *Vibrant matter: the political ecology of things*. Duke University Press
- Berry B, Acheson A (2017) Sharing isn't easy: food waste and food redistribution in maine K–12 schools. *Maine Policy Review* 26(1):47–58. <https://digitalcommons.library.umaine.edu/mpr/vol26/iss1/7>
- Blanchette A (2019) Living Waste and the Labor of Toxic Health on American Factory Farms. *Med Anthropol Q* 33(1):80–100. <https://doi.org/10.1111/maq.12491>
- Breakthrough Institute (2015) An ecomodernist manifesto. [www.Ecomodernism.org](http://www.Ecomodernism.org)
- Brinton WF Jr (2005) Characterization of man-made foreign matter and its presence in multiple size fractions from mixed waste composting. *Compost Sci Util* 13(4):274–280. <https://doi.org/10.1080/1065657X.2005.10702251>
- Buzby JC, Farah-Wells H, Hyman J (2014) "The estimated amount, value, and calories of postharvest food losses at the retail and consumer levels in the United States." EIB-121. U.S. Department of Agriculture, Economic Research Service
- Capek S (1993) The "environmental justice" frame: a conceptual discussion and application. *Soc Probl* 40:5–24
- CGRI (2020) Circularity Gap Report. <https://www.circularity-gap.world/2020>
- Checker M (2005) Polluted promises: environmental racism and the search for justice in a southern town. New York University Press
- Choi YJ, Lazcano RK, Yousefi P, Trim H, Lee LS (2019) Perfluoroalkyl acid characterization in U.S. municipal organic solid waste composts. *Environ Sci Technol Lett* 6(6):372–377
- Coker C (2014) Testing for persistent herbicides in feedstocks and compost. *BioCycle*, January 2014
- Crunden EA (2020) 'We can never get to zero': organics recyclers face hard choices in responding to PFAS contamination. *Waste Dive*, 19 October. <https://www.wastedive.com/news/pfas-chemicals-organics-recycling-compost-biosolids/587044/>
- De Decker K (2018) How circular is the circular economy? *Low Tech Magazine*, 3 November. <https://www.lowtechmagazine.com/2018/11/how-circular-is-the-circular-economy.html>
- Desilver D (2019) Americans say they're changing behaviors to help the environment. Pew Research Center. Accessed 20 December, 2020. <https://www.pewresearch.org/fact-tank/2019/12/19/americans-say-theyre-changing-behaviors-to-help-the-environment-but-is-it-making-a-difference/>
- Di Chiro G (1996) Nature as community: the convergence of environment and social justice. In: Cronon W (ed) *Uncommon Ground: Rethinking the Human Place in Nature*. W.W. Norton, pp 298–320
- Donahue B, Burke J, Anderson M, Beal A, Kelly T, Lapping M, Ramer H, Libby R, Berlin L (2014) *A New England food vision: healthy food for all, sustainable farming and fishing, thriving communities*. Food Solutions New England, University of New Hampshire, Durham
- Ellen MacArthur Foundation (2020) Circular economy system diagram. <https://www.ellenmacarthurfoundation.org/circular-economy/concept/infographic>
- FAO (2011) Global food losses and food waste - extent, causes and prevention. Food and Agriculture Organization of the United Nations, Rome
- Frickel S, Gibbon S, Howard J, Kempner J, Ottinger G, Hess DJ (2010) Undone science: charting social movement and civil society challenges to research agenda setting. *Sci Technol Human Values* 35:444–473
- Gillet J (1992) Issues in risk assessment of compost from municipal solid waste: occupational health and safety, public health, and environmental concerns. *Biomass and Bioenergy* 3(3–4):145–162
- Goodman D (2013) Dear MOTHER: February/March 2013. *Mother Earth News*, Feb/March. <https://www.motherearthnews.com/homesteading-and-livestock/dear-mother-february-march-2013-zm0z13fzmzhr>

- Grandia L (2019) Toxic tropics: purity and danger in everywhere in everyday life. *J Ecol Anthropol* 21(1): 1–10. <https://scholarcommons.usf.edu/jea/>
- Gregson N, Crang M, Fuller S, Holmes H (2015) Interrogating the circular economy: the moral economy of resource recovery in the EU. *Econ Soc* 44(2):218–243
- Guest R, Namey E, Chen M (2020) A simple method to assess and report thematic saturation in qualitative research. *PLoS ONE* 15(5):e0232076. <https://doi.org/10.1371/journal.pone.0232076>
- Haas W, Krausmann F, Wiedenhofer D, Heinz M (2015) How circular is the global economy?: an assessment of material flows, waste production, and recycling in the European Union and the World in 2005. *J Ind Ecol* 19(5):765–777. <https://doi.org/10.1111/jiec.12244>
- Hannon B (2021) Bills to regulate ‘forever chemicals’ strongly supported in Senate Committee Testimony. *EcoRI News*. Accessed July 2021 at: <https://www.ecori.org/government/2021/5/7/bills-to-regulate-forever-chemicals-strongly-supported-in-senate-testimony>
- Haraway DJ (2016) *Staying with the trouble: making kin in the chthulucene* (Illustrated edition). Duke University Press Books
- Hoey D (2021) Maine issues ‘do not eat’ advisory for deer harvested near PFAS-contaminated fields in fairfield area. *Portland Press Herald*, November 24, 2021. <https://www.pressherald.com/2021/11/23/maine-issues-do-not-eat-order-for-deer-harvested-near-pfas-contaminated-fields/>
- Hogue C (2021) World’s first ban on products with PFAS adopted in Maine. *Chemical and Engineering News*. July 19, 2021. <https://cen.acs.org/environment/persistent-pollutants/Worlds-first-ban-products-PFAS/99/web/2021/07>
- Huerta Lwanga E, Gertsen H, Gooren H, Peters P, Salánki T, van der Ploeg M, Besseling E, Koelmans AA, Geissen V (2016) Microplastics in the terrestrial ecosystem: implications for *Lumbricus terrestris* (Oligochaeta, Lumbricidae). *Environ Sci Technol* 50(5):2685–2691. <https://doi.org/10.1021/acs.est.5b05478>
- Isenhour C, Blackmer T, Wagner T, Silka L, Peckenhams J, Hart D, MacRae J (2016) Moving up the waste hierarchy in maine: learning from “best practice” state-level policy for waste reduction and recovery. *Maine Policy Review* 25(1):15–29. <https://digitalcommons.library.umaine.edu/mpr/vol25/iss1/6>
- Isenhour C, Blackmer T (2018) Waste is not the maine way: LD1534 stakeholder working group final report. University of Maine Senator George J. Mitchell Center for Sustainability Solutions. <https://umaine.edu/mitchellcenter/wpcontent/uploads/sites/293/2018/01/FINAL-FULL-REPORT.pdf>
- Kirchherr J, Reike D, Hekkert M (2017) Conceptualizing the circular economy: an analysis of 114 definitions. *Resour Conserv Recycl* 127:221–232
- Kozlowski M, Perkins H (2015) Environmental justice in Appalachia Ohio? An expanded consideration of privilege and the role it plays in defending the contaminated status quo in a white, working-class community. *Local Environ* 21(10):1288–1304
- Langwick SA (2018) A politics of habitability: plants, healing, and sovereignty in a toxic world. *Cult Anthropol* 33(3): 415–443. <https://doi.org/10.14506/ca33.3.06>
- Latour B (1993) *We have never been modern*. Harvard University Press
- Liboiron M (2017) Toxins or toxicants: why the difference matters. *Discard Studies*. <https://discardstudies.com/2017/09/11/toxins-or-toxicants-why-the-difference-matters/>
- Liboiron M (2018) The what and the why of discard studies. *Discard Studies*. <https://discardstudies.com/2018/09/01/the-what-and-the-why-of-discard-studies/>
- MacBride S (2011) *Recycling reconsidered: the present failure and future promise of environmental action in the United States*. The MIT Press
- MacRae J, Nayak B, Isenhour C, Blackmer T, Silka L (2020) The emergent risks of food waste recovery: characterizing the contaminants in msw organics from different sources. Final Report to the Environmental Research and Education Foundation. [https://erefndn.org/wp-content/uploads/2021/01/Final-Report\\_EREFRisk-Food-Waste\\_2020.pdf](https://erefndn.org/wp-content/uploads/2021/01/Final-Report_EREFRisk-Food-Waste_2020.pdf)
- Maine State Legislature (2019) Testimony to the Joint Standing Committee on Environment and Natural Resources; LD 1433, “An Act To Protect the Environment and Public Health by Further Reducing Toxic Chemicals in Packaging”. April 17, 2019
- Mohai P, Pellow D, Roberts JT (2009) Environmental justice. *Annu Rev Environ Resour* 34:405–430
- Murray A, Skene K, Haynes K (2017) The circular economy: an interdisciplinary of the concept and application in the global economy. *J Bus Ethics* 140(3):369–380
- Ng E-L, Huerta Lwanga E, Eldridge SM, Johnston P, Hu H-W, Geissen V, Chen D (2018) An overview of microplastic and nanoplastic pollution in agroecosystems. *Sci Total Environ* 627:1377–1388. <https://doi.org/10.1016/j.scitotenv.2018.01.341>
- O’Connor J, Hong SA, Bradney L, Dutta S, Xiong X, Tsang D, Ramadass K, Vinu A, Kirkham MB, Bolan N (2021) A review on the valorisation of food waste as a nutrient source and soil amendment. *Environ Pollut* 272:115985
- Povinelli EA (2016) *Geontologies: a requiem to late liberalism* (Illustrated edition). Duke University Press Books
- Refed (2016) “A Roadmap to Reduce U.S. Food Waste by 20 Percent.” Refed
- Reno J (2011) Managing the experience of evidence: England’s experimental waste technologies and their immodest witnesses. *Sci Technol Human Values* 36(6):842–863. <https://doi.org/10.1177/0162243910376158>
- Rigby H, Dowding A, Fernandez A, Humphries D, Petch R, Reynolds C, Rose M, Smith S (2015) Organic contaminant content and physico-chemical characteristics of waste material recycled in agriculture. *Agriculture* 5(4):1289–1328
- Robert EFS (2017) What gets inside: violent entanglements and toxic boundaries in Mexico City. *Cult Anthropol* 32(4): 592–619. <https://doi.org/10.14506/ca32.4.07>
- Shellenberger M, Nordhaus T (2012) *Evolve: the case for modernization as the road to salvation*. The Breakthrough Institute. <https://thebreakthrough.org/journal/issue-2/evolve>
- Schwarzbauer J, Heim S, Brinker S, Littke R (2002) Occurrence and alteration of organic contaminants in seepage and leakage water from a waste deposit landfill. *Water Res* 36(9):2275–2287
- Serres M (2010) *Malfeasance: appropriation through pollution?* Stanford University Press
- Shrader-Frechette K (2005) *Environmental justice: creating equality, reclaiming democracy*. Oxford University Press
- Taylor D (2000) The rise of the environmental justice paradigm: injustice framing and the social construction of environmental discourses. *Am Behav Sci* 43:508–580
- Thakali A, MacRae JD (2021) A review of chemical and microbial contamination in food: What are the threats to a circular food system? *Environ Res* 194:110635. <https://doi.org/10.1016/j.envres.2020.110635>
- United Nations Environment Program (2011) *Decoupling: natural resource use and environmental impacts from economic growth*. UNEP/Earthprint
- United States Compost Council (2020) USCC position: persistent herbicides. United States Compost Council. <https://cdn.ymaws.com/www.compostingcouncil.org/resource/resmgr/images/advocacy/USCC-Position-PH.pdf>
- United States Compost Council (2021). *Federal and State Regulations Affecting PFAS in Compost*. <https://www.compostingcouncil.org/page/FederalandStateRegulationsAffectingPFASinCompost>



- United States Government Accountability Office (2007) Chemical regulation: comparison of U.S. and recently enacted European Union approaches to protect against the risks of toxic chemicals. GAO-07–825: Published: Aug 17, 2007
- United States Government Accountability Office (2017) Comparison of U.S. and recently enacted European Union approaches to protect against the risks of toxic chemicals. Report GAO-07-825.
- Wapner P (2010) Living through the end of nature: the future of American environmentalism. MIT Press
- Wiebe SM (2016) Everyday exposure: indigenous mobilization and environmental justice in Canada's Chemical Valley. UBC Press. <https://www.ubcpres.ca/everyday-exposure>
- Wynne B (1987) Risk management and hazardous waste: implementation and the dialectics of credibility. Springer