Circularity Across Cities Big and Small: Working to Manage Plastics and Biodegradable Organic Materials

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Abstract

Developed by the Circularity Informatics Lab at the University of Georgia, the Circularity Assessment Protocol (CAP) is a standardized assessment protocol to inform decision-makers by collecting community-level data. Grounded in systems thinking, the CAP uses a hub-and-spoke model to holistically characterize how consumer materials come into a community, are consumed, managed or leaked into the environment. The model is comprised of seven spokes: 1) input, 2) community, 3) material and product design, 4) use, 5) collection, 6) end of cycle, and 7) leakage. At the center, the system is driven by policy, economics and governance with key influencers including non-governmental organizations, industry, and government. The CAP has been conducted in 56 cities in 16 countries globally. For this work, the CAP was conducted in six US cities to examine the material flows of plastic packaging for fast-moving consumer goods (FMCG) and biodegradable organic materials. (e.g., food waste). The cities' characteristics varied by population size and setting including Minneapolis, MN; Atlanta, GA; Athens, GA; Vicksburg, MS; Cape Girardeau, MO; and Blytheville, AR. In each city, data was collected on FMCGs in stores and restaurant to-go packaging. Product packaging, organic material management, and recycling methods (including quantities, where available) were documented. Quantitative data was collected for products, packaging, use, and leakage. Stratified random sampling generates comparable results between the cities for leakage with density of litter ranging from 0.55 items/m^2 to 1.2 items/m^2. Current systems for industrial composting were documented in Minneapolis and Athens, with estimates in other cities of how much organic waste could be diverted if composting occurred. This work also included a social media analysis conducted across the United States to illustrate knowledge and sentiment to composting and compostable materials. Interest in biodegradable and compostable materials, concern over plastics, and other related materials seems to be growing on social media. While individuals participate in these interrelated conversations, nonprofits, companies, and some professionals in this space seem to be leading the discourse. Cities had various actions after conducting CAP. Two of the mayors from cities that hosted CAPs have become leaders in communicating about circularity, plastic pollution, and their city's perspective at national meetings and discussing Extended Producer Responsibility (EPR). One city was reinstituting recycling with a private contractor. The CAP open data platform allows for conversations among the cities and the public, sharing of data, and tools to implement a systems change from the ground up.

Introduction and Motivation

Concerns over plastic use and management are highly relevant with global agreements led by the UN under discussion. Cities bear the burden of waste management that comes with the often-expanding use of plastic connected to both local and global climate and justice issues (Ford et al., 2022; Jambeck & Walker-Franklin, 2023; UNEP, 2021). Cities see the issue first-hand by trying to manage a dynamic waste stream and plastic trash littering their environment, impacting livelihoods, tourism, fishing, and human health (Beaumont et al., 2019; Landrigan et al., 2023; Leggett et al., 2018; Thompson et al., 2009). While the Circular Economy has been presented as an approach to reducing plastic pollution, with actual management of materials taking place at the city level, it begs the question of how does the circular economy translate to the management of materials in a community? The Circularity Assessment Protocol (CAP) was conceived and developed from 2018 – 2020 to bring information to city decision-makers and involve local community members as Local Implementation Partners (LIPs). The goal of the CAP is to *translate a context-sensitive "circular economy" to the community level to provide a snapshot of data to support decision-making (Jambeck et al., 2024).* CAPs highlight practices or products contributing to circularity, as well as identify opportunities to optimize circularity in a community. Communities then make their own choices as

it works for them in their context and situation to amplify what is already working or make changes to improve circularity (Jambeck et al., 2024). Even with companies making commitments to make packaging compostable or recyclable by future dates, infrastructure is still needed to manage the materials, with a special focus on composting infrastructure for managing compostable and/or biodegradable (home compostable) products and materials. This work looked at both plastic packaging for fast-moving consumer goods (FMCG) and biodegradable organic materials in six different cities using the Circularity Assessment Protocol (CAP).

Review of Related Work

Cities and local governments are commonly where waste management knowledge and practices are held (Banerjee & Sarkhel, 2020; Benito et al., 2021); however, cities are not often suggested as starting places for circular economy principles since piecemeal, unconnected solutions are insufficient to create a more circular system (Kirchherr et al., 2018; Palafox-Alcantar et al., 2020; Williams, 2019). However, when cities come together as a group, they have synergy from common messages, sharing ideas and ideals, and yet recognizing their own context. One such group is the Mississippi River Cities and Towns Initiative, where a group of 104 mayors have committed to reducing plastic pollution in the Mississippi River (https://www.mrcti.org/mississippi-river-plastic-pollution-initiative). Since the burden of waste management inherently falls at the community level, so strategies to address it should come from local knowledge and context, which is the goal of the CAP which can be illustrated by its use in Metro Manila and in a cohort of six cities in the Urban Ocean Program (Maddalene et al., 2023; Jambeck et al., 2024). While global policy may be established and corporations may make commitments and changes, communities can drive change with collaboration and local action.

Technology Approach

Grounded in systems thinking, the CAP uses a hub-and-spoke model to holistically characterize how consumer materials come into a community, are consumed, managed or leaked into the environment. The model is comprised of seven spokes: 1) input, 2) community, 3) material and product design, 4) use, 5) collection, 6) end of cycle, and 7) leakage. At the center, the system is driven by policy, economics and governance with key influencers including non-governmental organizations, industry, and government (Figure 1).

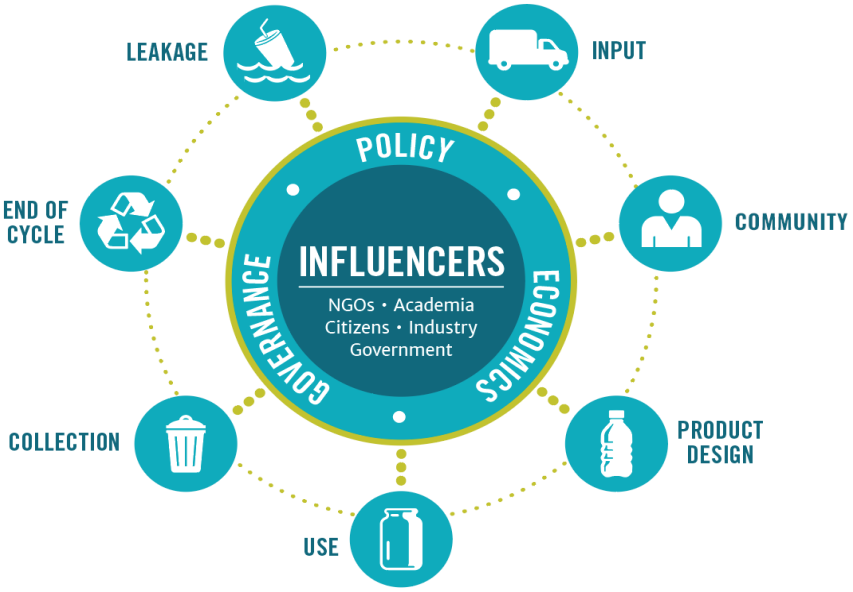

Figure 1. Hub and spoke model of the Circularity Assessment Protocol (CAP) conducted and compared across six US Cities.

By conducting fieldwork and data collection, the CAP answers the following questions for each spoke. Detailed methods for data collection (quantitative and qualitative) are included in Jambeck et al., 2024 and Maddalene et al., 2023.

- Input - What products are sold in the community and where do they originate?
- Community - What conversations are happening and what are the stakeholders' attitudes and perceptions?
- Product Design - What materials, formats, and innovations are found in products, particularly packaging?
- Use - What are the community trends around use and reuse of product types?
- Collection - How much and what types of waste are generated? How much is collected and what infrastructure exists?
- End-of-Cycle - How is waste disposed? What is the fate of waste once it is properly discarded? How is it treated?
- Leakage - What waste ends up in the environment? How and why is it getting there?

The CAP has been conducted in 56 cities in 16 countries globally. For this work, the CAP was conducted in six US cities to examine the material flows of plastic packaging for fast-moving consumer goods (FMCG) and biodegradable organic materials. (e.g., food waste). The cities' characteristics varied by population size and setting including: Minneapolis, MN; Atlanta, GA; Athens, GA; Vicksburg, MS; Cape Girardeau, MO; and Blytheville, AR (Table 1). The only city with an increasing population is Athens. Blytheville and Vicksburg report decreasing population and Atlanta, Minneapolis, and Cape Girardeau, all have stable populations. In each city, data was collected on FMCGs in stores and restaurant to-go packaging. Product packaging, organic material management, and recycling methods (including quantities, where available) were documented. Quantitative data was collected for products, packaging, use, and leakage. Qualitative data was collected for the community spoke.

Table 1. Cities where CAP was conducted for this project

State	**City**	**Population (trend)**	**Fieldwork/Interview/Engagement Dates**
Georgia	Atlanta	499,127 (stable)	June 2022
Minnesota	Minneapolis	425,096 (stable)	July 2022
Georgia	Athens	128,561 (increasing)	August 2022
Missouri	Cape Girardeau	40,377 (stable)	September 2022 (MRCTI Meeting), October 2022, March 2023 (MRCTI Meeting)
Mississippi	Vicksburg	20,391 (decreasing)	July 2022, September 2022 (MRCTI Meeting), March 2023 (MRCTI Meeting)
Arkansas	Blytheville	12,706 (decreasing)	March 2023, March 2023 (MRCTI Meeting), September 2023 (MRCTI Meeting)

Input

Beverages, chips, and candy as fast-moving consumer goods (FMCG) are all documented for input, including top and popular brands, manufacturing location (when available), and parent company location. Two cities, Atlanta and Minneapolis, had parent and manufacturing locations in their city for at least one FMCG (beverages in Atlanta and chips and beverages in Minneapolis). 20% of manufacturing and 30% of parent companies for beverages are local to Atlanta because it is home to the headquarters of Coca-Cola. In all other cities (Athens, Cape Girardeau, Vicksburg, and Blytheville), manufacturing and parent companies are further away, but the majority are still domestic and several are in surrounding states. Candy is the most frequently imported FMCG across all the cities. The large percentage of domestic parent companies and manufacturers for FMCG facilitates engaging companies about Extended Producer Responsibility (EPR) including waste management, product design, alternative materials, and alternative product delivery systems. The larger cities especially, could lead community initiatives toward working with top local brands and producers that operate locations proximate to the city. Minnesota passed an EPR policy in May 2024, the Packaging Waste and Cost Reduction Act, which will implement EPR in a phased approach over time. The product and packaging data contained in these CAPs could be helpful in designing and implementing such a policy.

Community

Stakeholders in each city were interviewed, often as a group in the smaller cities, to provide information and their perspectives on circular materials management in their city. A deeper dive was conducted in Atlanta in collaboration with additional funding from NSF Convergence Accelerator (CA) (grant 2236080). In Atlanta, stakeholders mentioned how education, infrastructure, and economic issues all played into peoples' abilities to participate in circular activities. These themes also related to interviewees' suggestions of creating better signage, more transparent information, and increased infrastructure (particularly in the realm of composting). Keeping environmental justice at the forefront of any effort is pivotal. For example, through field observations, the team noticed that low-income areas of Atlanta are the most exposed to plastics and expanded polystyrene products in both the stores and restaurants through takeout containers and disposable tableware. Minneapolis has a very engaged community around circularity, solid waste, and plastic pollution reduction. There are a multitude of resources available to businesses and community members alike. The city is engaged with its residents on this topic and proactive in working with the community. Minneapolis is also the only city in the group with a curbside composting program. Key issues mentioned in Blytheville included the recycling center being closed, as well as weather complicating waste management efforts. It was clear that the ethos of cooperation among government officials in Blytheville enables resilience when navigating existing barriers and challenges. In Athens, a core group of engaged residents recycling is counterbalanced by relatively widespread confusion about recycling practices. This confusion is exacerbated by sometimes conflicting information sources and unclear product labeling, contributing to high contamination rates in collected recyclables. Socioeconomic disparities in sustainable waste practices were observed, with higher participation rates among upper-middle-class residents. Post-COVID issues, including labor shortages and supply chain disruptions, have compounded existing challenges such as budget constraints and public reluctance to fund waste management services (across all cities). Despite these obstacles, the waste management system demonstrates adaptability, with ongoing efforts to improve community engagement and education. In Vicksburg, more research is needed in the area of community interactions with plastic consumption and waste management and resources are limited. The small size of Vicksburg means that local advancement of large-scale waste management schemes may be challenging, but smaller-scale waste management schemes or working in combination with other cities may help. The Cape Girardeau community works together to collect and manage solid waste, including plastic waste. At present, successful collection of plastic waste relies heavily on behaviors at the household and individual level. As such, efforts toward education and incentivization strategies can help encourage behavior that helps waste infrastructure run smoothly.

From July 1st, 2021, to August 31st, 2021, the Social Media Engagement and Evaluation (SEE Suite) group at the University of Georgia's Grady College of Journalism and Mass Communication conducted a Compostable Plastics & Bioplastics Social Media Analysis using Brandwatch to aid in our understanding of consumer access and awareness of compostable and biodegradable plastics. A total of 33,325 mentions of related terms from across the USA (Figure 2) on X were examined to address three questions:

- Are people aware of and purchasing biodegradable plastic alternatives?
- Do people have access to compostable/biodegradable plastics in their community?
- What types of composting systems would people like to see in their communities?

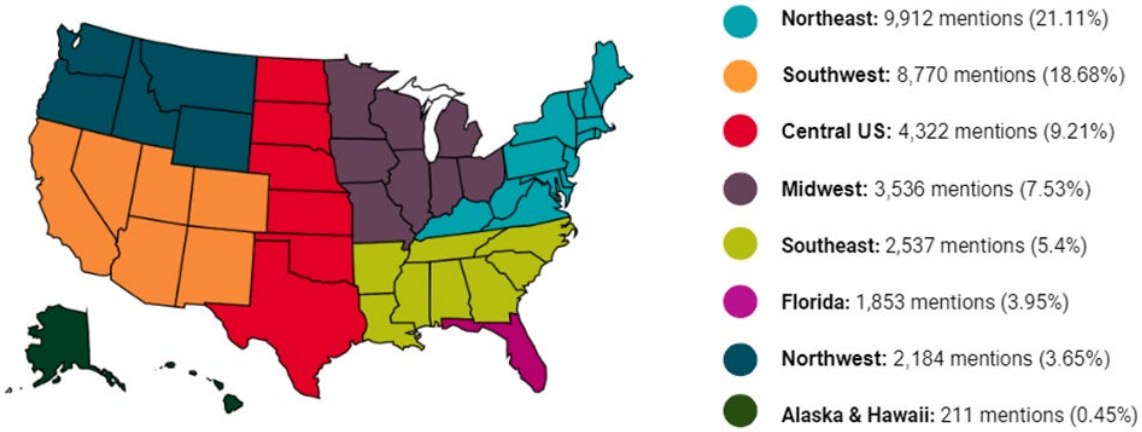

Figure 2. Geographic Analysis by Region

Conversations related to the awareness of and purchasing of biodegradable plastic alternatives that were analyzed varied by region. 3.7% of the conversations related to biodegradable plastics were from the Southeast, while 7.5% of these conversations were from the Midwest. In contrast, 31% of biodegradable plastic conversations came from the Northeast and the Southwest, which indicates the regional awareness of plastic alternatives is higher in these areas than in the Southeast and Midwest. Tweets based on terms such as buy, own, purchase, use etc. captured 13.36% of the dataset, yet these conversations mostly discussed purchasing straws made from bioplastics, biodegradable/compostable straws, and reusable bags. Overall, purchasing patterns were difficult to gauge based on these conversations.

About half of those concerned with industrial composting came mostly from individuals with related professional experience, while the other half originated from nonprofits and professional/trade organizations such as Closed Loop Partners, Industrial Packaging, Nature Works, and the Plastics Industry Association. Most of these conversations revolved around the heat differences between home composting and industrial composting. Other conversations consisted of consumers purchasing biodegradable plastics with the intention of home composting, only to realize that the purchased items had to be sent to industrial composting, while other Tweets were from companies highlighting biodegradable plastics that can be home composted.

Home composting conversations tended to be broader, and had roughly equal representation from individuals, nonprofits, and companies. 25% of these conversations yielded no insights relating to how to live a more sustainable life or what activities to do to celebrate Earth Day. In contrast, insightful conversations tended to revolve around what items should and should not be added to home compost. A significant number of conversations were about how biodegradable plastics and stickers should not go into one's home compost. Overlapping conversations between Tweets about industrial composting and Tweets about home composting tended to share that industrial facilities are much hotter and that biodegradable plastic products must be sent to an industrial facility. Again, Tweets from companies highlighted products that can be home composted.

About half of the conversations on "greenwashing" within the compostable/biodegradable plastics space came from individual users, while the other half came from media outlets, companies, nonprofits, and trade/professional organizations. Most of these Tweets focused on how biodegradable/compostable plastics/bioplastics are greenwashing, yet they rarely are explicit about sharing why. Conversations also focused on buzzwords that are typically used to convince consumers that a product is more environmentally friendly, such as "plant-based," "biodegradable," "all natural," and "compostable." Although less common, conversations about how to avoid greenwashing typically bring up product labeling and certification, such as the USDA Certified Biobased label. Interestingly, there were a few instances where specific brands were called out for explicit greenwashing.

Aside from the major themes related to industrial composting, home composting, and greenwashing, additional themes that emerged were the following: Packaging & Products: related to the materials used in packaging, as well as consumer products (21.31% of all mentions), The Environment: mentioned ecological systems from which bioplastics primarily benefit, such as oceans and plants (20.19% of all mentions), Circular Economy: primarily mentioned topics of recycling, composting, and reusing plastics (14.11% of all mentions), Purchasing Compostable/Biodegradable Plastics: related to the purchasing of biodegradable plastics instead of other plastic that is more environmentally harmful (13.36% of all mentions), Research, Innovation, & Design: focused mainly on research related to bioplastics and the market, as well as new forms of compostable and biodegradable technology (11.1% of all mentions).

Product Design and Use

The majority of FMCG across all the cities are packaged in multilayer film (36-57%), followed by PET (27-43%), and then smaller percentages (12% or less, most less than 10%) for HDPE, PP, and paperboard. Atlanta and Minneapolis are the only two cities with compostable packaging in FMCG. Innovative and alternative packaging in FMCG is not available in the smaller cities. To-go items at restaurants were also documented including utensils, straws, cups and to-go food containers. Again, Minneapolis and Atlanta had the most variety and most alternatives to plastic in this case. Compostable materials were offered for utensils, cups and to-go food containers in Minneapolis, straws and food containers in Atlanta, cups and straws in Athens, and straws in Cape Girardeau. Compostable products are available for purchase in stores; however, they are all more expensive, except for non-coated paper plates (Table 2).

Table 2. Cost of compostable alternatives when compared to traditional plastics

Compostable Product	Material Label	Unit Cost v. Traditional Plastic
Cups	Paper	1.9x
Cups	Paper	4.7x
Plates	Paper	0.8x
Plates	Paper (made from sugarcane)	5.2x
Plates	Paper (made from plants)	5.1x
Plates	Paper (made from plants)	2.3x
Plates	Sugarcane pulp	1.1x
Utensils	PLA	2.1x
Utensils	Made from plants	2.5x
Bowls	Paper (made from sugarcane)	2.4x
Bowls	Sugarcane pulp	1.2x

Collection and End of Cycle

All cities had single-family home curbside collection in the city jurisdiction. Outside of the incorporated Athens-Clarke County (e.g., the parts of Athens that are in other counties), the city does not offer curbside collection and private haulers need to be hired or community members have to haul their own waste to a county transfer station or landfill. Recycling is not offered by adjacent Jackson County where one small part of Athens is located. Athens had recently started a pilot program of drop-off stations for compost which has become permanent. Athens also provides curbside recycling and drop-off centers for recycling throughout the city. Minneapolis is the only city to offer curbside composting and recycling. Atlanta and Cape Girardeau offer curbside recycling. Private haulers and companies can be hired in Atlanta for composting. Vicksburg and Blytheville cities are unable to offer curbside recycling through the city. However, since CAP has been conducted, Vicksburg is now serviced by a private company called Recyclops. Further dialogue with Vicksburg would be needed to determine if the government and community members are satisfied with this private company.

Leakage

A spatially stratified random sampling method generated survey areas for conducting transects, which were selected within nine 1-square kilometer areas and were distributed across three groups of population count (upper, middle, lower) across the cities. These population counts were based on the Oak Ridge National Laboratory's LandScan global ambient population data for 2021 (Sims et al. 2022). Litter items were recorded using the open-source Debris Tracker mobile application ('app') (Jambeck and Johnsen, 2015). Litter was examined based on abundance, proportion of material and product types, and product densities across all transects and aggregated across the three population groupings. Average litter densities ranged from 0.55 to 1.2 items/m^2 across all the cities. The characterization of the categories of litter are shown in Figure 3. The largest percentage was plastic fragments in half the cities, Cape Girardeau, Blytheville and Vicksburg (tied for largest in Atlanta with food plastic) which ranged from 16 to 32%. The largest percentage in Minneapolis and Athens was tobacco products and across the cities ranges from 11 to 29%. Food plastic was a large category as well, ranging from 13% (Minneapolis) to 24% in Athens. Aluminum cans and plastic bottles were highest by relative proportion in Blytheville where there are not enough resources to offer curbside recycling. Bottles and cans are relatively lowest in Minneapolis. Foam fragments were relatively highest in Cape Girardeau. Foam fragments often come from larger pieces of expanded polystyrene breaking apart which can cause a large number of fragments in an area. Likewise, the relatively high quantity of glass fragments in Atlanta is from broken bottles. Cigarette butts were relatively highest in Minneapolis and Athens.

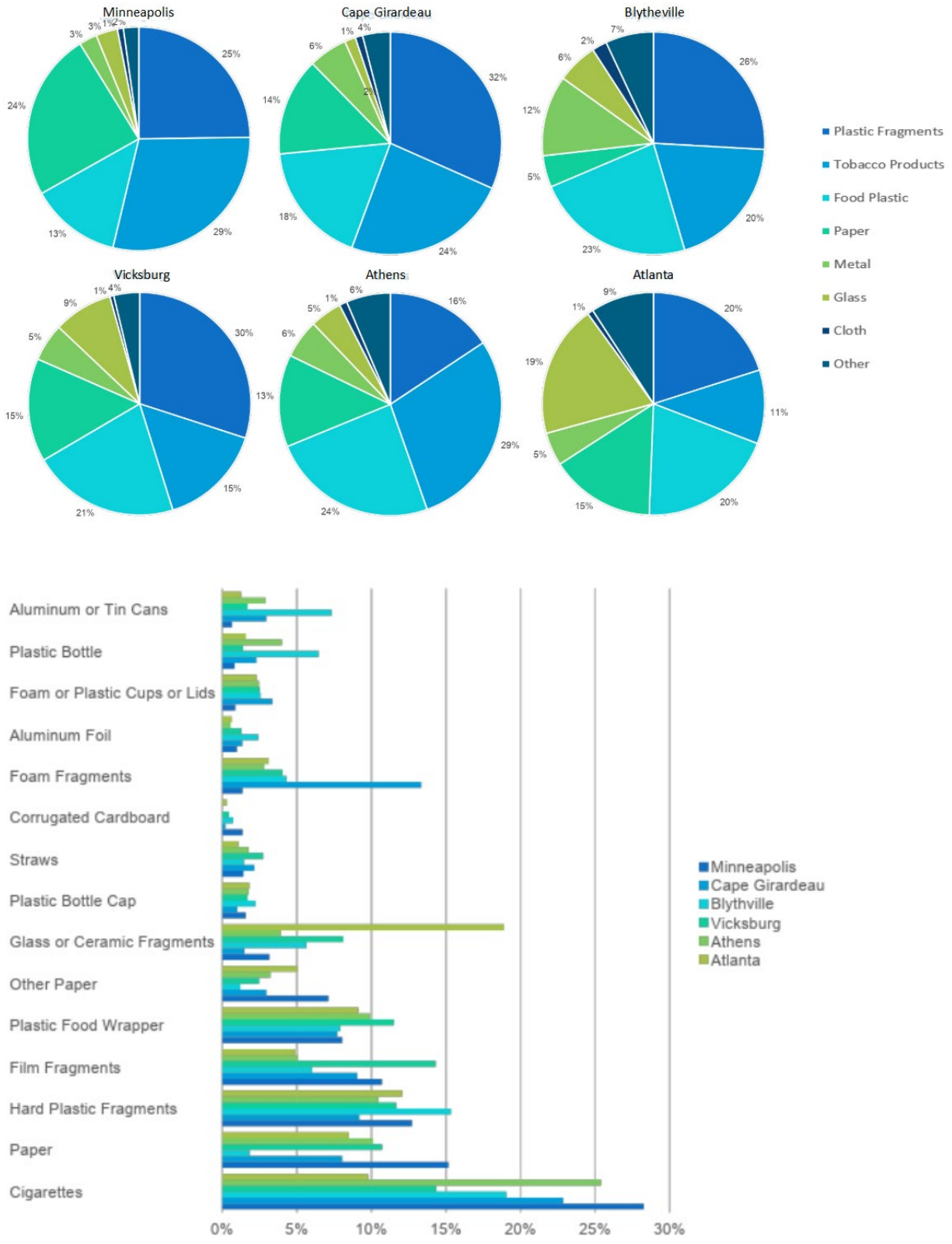

Figure 3. Categories and items found in the litter across the six cities

Discussion

For each city that did not already have composting (curbside or drop-off), a composting development model was used to create an estimate of organics diversion, greenhouse gas (GHG) reduction, and estimated costs of the program (Table 3). While Atlanta did have some private companies for composting, an estimate was made on impacts if curbside composting was available, however lack of data limited the inclusion of a cost estimate.

Table 3. Curbside Composting with 70% Participation Model Estimates

City	# of households	Quantities (tons)	GHG Reduction (MTCO2E)	# of gas cars driven annually	Cost/ Household/mo.
Cape Girardeau	9,000	750- 1,499	298 - 595	71 - 142	$18.08
Blytheville	7,111	1,742 - 3,483	692 - 1,384	165 - 329	$15.29
Vicksburg	10,841	3,351 - 6,702	1,331 - 2,662	317 - 634	$14.38
Atlanta	253,355	21,898 - 43,795	8,698 - 17,396	2,070 – 4,140	No calc

One challenge of engaging the communities in this project is that all of these cities, no matter their size, do not have enough resources to put forward much time or effort to engage on circularity or waste management. Minneapolis had the most comprehensive circularity, and spent time mentoring Athens through a compost pilot, but typically other community needs (e.g., roads/sidewalks/infrastructure, water, wastewater, safety, etc.) need to be prioritized over thinking or working on circularity. This is starkly evident in the smaller cities where solid waste programs are often limited to primarily collection and disposal. However, the cities of Atlanta, Blytheville, Vicksburg, and Athens remain engaged in actively working on circularity with UGA or other project partners. The city of Minneapolis remains a leader in circularity. Two of the mayors from cities that hosted CAPs have become leaders in communicating about circularity, plastic pollution, and their city's perspective at national meetings and discussing Extended Producer Responsibility (EPR). Mayor Logan from Blytheville, AR has become a leader in communicating about circularity, plastic pollution and her city's perspective. Mayor Logan traveled and presented her city's perspective which the CAP conducted in her city informed at the following meetings: The WWF Plastics Policy Summit (March 2023) and The Cities of American meeting (April 2023). Blytheville is actively working with a private company to bring back recycling of cans and bottles in their city. In addition, Cape Girardeau's mayor, Mayor Kinder, presented at the Mississippi River City and Towns Initiative (MRCTI) Lobby Day Reception in Washington, DC, March 7, 2024. She presented on extended producer responsibility (EPR) which is one of the opportunities outlined in the CAP report for Cape Girardeau.

Conclusion & Recommendations

The overall goal of optimizing circularity is to prevent pollution from the production of plastics through use and management. Opportunities were identified across all the cities in each CAP compiled for this work. Common opportunities are:

- Collaborate with local manufacturers and brands to promote innovation in sustainable packaging and design and/or Extended Producer Responsibility (EPR), emphasizing product design, alternative materials, and sustainable delivery systems. (Input)
- Address inequities in alternatives, waste management infrastructure, and resources. (Community)
- Facilitate communication between cities to share best practices. (Community)
- Engage consistently with the community. (Community)
- If alternative and compostable packaging is to be promoted, industrial composting infrastructure is needed and education of consumers is critical. (Product Design)
- Provide grants and/or incentives for innovative product design and waste reduction strategies through reuse. (Product Design and Use)
- Expand the availability of alternative delivery systems and reusable systems by partnering with local businesses to reduce packaging waste or create reuse systems (e.g., reusable container programs for restaurants). (Use)
- Highlight and support local businesses' efforts to innovate and reduce our reliance on plastic and single-use materials (Use and Product Design).
- Expand industrial compost collection when possible. (Collection)

- Map and address gaps in curbside and drop-off access, ensuring equitable coverage across cities. (Collection)
- Use public-private partnerships or private companies to expand composting and recycling in smaller cities.
- Expand composting infrastructure to handle growing volumes of biodegradable materials and educate consumers on proper management practices. (End-of-Cycle)
- Focus on waste diversion strategies, combining recycling, composting, and upstream waste reduction, including using local policies to do so. (Input, End-of-Cycle and Leakage)
- Use the USEPA Escaped Trash Risk Map or collect and analyze leakage to identify opportunities for targeted interventions. (Leakage)
- Use cleanup and drop-off events for proactive management of hard-to-recycle items. (Leakage)

Cross-cutting themes include: collaboration with stakeholders (e.g., government, community members, companies) are crucial to advancing circularity goals, equitable resource and infrastructure distribution are critical, and while not often a priority or possible with given resources, data collection can identify gaps and refine strategies for targeting and obtaining resources like applying for grants. The Circularity Informatics Lab at the University of Georgia is working with partners to expand CAP resources through the NSF-funded project SpheriCity, where CAP data on plastics (and eventually the built environment) will be available online through data portals and dashboards. The SpheriCity open data platform allows for conversations among the cities and the public, sharing of data, and tools to implement a systems change from the ground up.

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