The Rise of Composting at UVA—Challenges and Opportunities

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

Madeleine Alwine
Spring 2020

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor
Rider W. Foley, Department of Engineering and Society

Introduction

Pollution from plastic waste is a major problem affecting the Earth's ecosystems with 14 million tons of plastic entering the ocean every year (Condor Ferries, 2021). This plastic can be ingested or otherwise physically harm marine life, leading to energy depletion, stunted growth, and damaged fertility (Ritchie & Roser, 2018). Plastics have also been shown to be a vehicle for toxic contaminants such as polychlorinated biphenyls (PCBs), which can pose a threat to human health when bioaccumulated up the food chain (Ritchie & Roser, 2018). About 300 million tons of plastic is produced each year worldwide, half of which is single-use plastic (Lindwall, 2020). Single-use plastic (SUP) is intended to be used once and then disposed. Common types include bottles, wrappers, straws, bags, and cutlery. In recent years, the United States has developed a heavy reliance on single-use plastics, consuming 96kg of plastic packaging per capita per year (Chen et al., 2021). Additionally, the burdens created by excessive waste production and the management of waste are not equally distributed among the population (Mohai & Saha, 2015).

To combat this, Governor Ralph Northam of Virginia has ordered that all state agencies immediately discontinue purchase and distribution of single-use plastics as well as completely phase out their use by 2025 (Exec. Order No. 97, 2021). As a public institution of higher education in the Commonwealth, the University of Virginia (UVA) must adapt its waste management strategy to comply with this executive order. UVA is at a crossroads with composting. The recent ban on SUPs across the Commonwealth pushes the University to quickly adapt the status quo waste management system to allow for more compostable materials in the waste stream. The UVA Sustainability 2020-2030 Plan is another driving factor, with goals to reduce landfilled waste to 30% of the University's 2010 tonnage, while simultaneously striving to make university operations carbon neutral and eventually fossil fuel free (University of

Virginia, 2020). This project seeks to analyze the effect of the recent single-use plastic ban on UVA's waste management, with respect to various sustainability metrics.

Effect of SUP Ban on UVA's Waste Management

The 2021-2022 "Un-fantastic Plastics" capstone project team consists of seven members committed to addressing these challenges on behalf of the University of Virginia Office of Sustainability and Facilities Management by April 2022. The team's main objective is to analyze the solid waste management (SWM) of the University against the backdrop of relevant priorities, evaluate possible structural changes to the system, and identify and compare the performance of the current SWM to those alternatives. The team will plan the methodology of the analysis and identify any assumptions by creating a model which reflects the following parameters: landfilled mass in tonnage, composted mass in tonnage, global warming potential (GWP) in kg Carbon Dioxide-equivalent (CO2-eq), energy in MJ, and cost in U.S. dollars (USD). These parameters were chosen to reflect the goals of the UVA Sustainability Plan, and show tradeoffs between the various priorities.

In order to plan the methodology of analysis, the team must consider the relationships and tradeoffs between the model parameters. A major challenge faced by the project team is the inconsistent data records of SWM at the University. In light of the insufficiency of data, the team will use ranges of historical and projected data, as well as values sourced from scholarly investigation, to evaluate the target parameters. The target parameters will be evaluated annually for 2018 to represent the status quo and for the 2021 academic year to represent post-ban. The model will be created using Microsoft Excel software and Google Sheets collaborative network technology through Google Drive. The model will be optimized in Spring 2022 for presentation of viable, alternative waste stream options to UVA Facilities Management.

The results of the team's analysis will help inform decisions made by UVA Facilities Management about future SWM practices and will reveal the most environmentally responsible path for the university to take in light of the SUP ban. The lack of preexisting data and analysis of SWM at the university shows that this topic has not been explored in depth previously. The abrupt change in UVA's waste management strategy due to the executive order necessitates this kind of comprehensive analysis, and can set a precedent for continual optimization of the university's waste management. The analysis could also potentially uncover the environmental risks associated with composting, which is generally considered to be a "green" form of SWM. It is important to analyze both the environmental and social implications of composting in practice as this form of waste management grows.

Additionally, it is important for UVA to consider the externalities that arise due to the presence of improper materials in the composted waste. Due to imperfect sorting practices, contamination is an inevitable challenge for composting programs. A study done on composting facilities in Spain found that composted waste contained an average of 10.7% improper materials (Rodriguez et al., 2020). When improper materials such as plastics, metals, and glass are put through the composting process, a variety of environmental issues result, undermining the environmental benefits of composting. One major challenge specifically comes from implementing large scale composting in an existing system where packaging is often made of a mixture of compostable and non-compostable materials. Plastic coated paper products are a prevalent example of this type of mixed-material packaging. These products are often still collected by composting programs, or mistakenly composted by individuals who are not educated on proper composting practices. The issue of contamination makes composting difficult to implement on a large scale, which presents a challenge as UVA seeks to increase composting in light of the SUP ban.

Improper Waste Management and Negative Consequences

While the technical work focuses on the role of composting in UVA's waste management strategy, the STS topic will explore the hazards that result from improper waste sorting practices in composting facilities. Composting is intended to be a more sustainable way of managing organic waste. Ideally, the process recycles organic matter into useful fertilizer. However, when integrated into the existing system with imperfect sorting, abundant plastic waste, and inequitable distribution of waste management facilities, unintended consequences occur that have negative impacts on both the environment and human welfare. I will be using Michael Harrison's Interactive Sociotechnical Analysis (ISTA) framework to analyze the unintended consequences of implementing new technology. Harrison argues that unintended consequences are often not due to technical flaws, but rather due to sociotechnical interactions between the new technology and the existing social system. This framework is centered on the importance of examining technology-in-use, rather than the uses intended by the designers (Harrison et al., 2007). Harrison uses the framework to analyze the unintended consequences of healthcare information technology, but it can also be applied to SWM.

A major contamination challenge occurs when composting is implemented in a social system where mixed material packaging, such as plastic-coated paper, is abundant. A study of plastic-coated paper products determined that the plastic coatings did not biodegrade, the coatings inhibited the biodegradation of the paper, and that microplastics were shed from all plastic-coated samples (Brinton et al., 2011). In this case, the presence of improper materials not only prevents the successful decomposition of the compostable material, but also creates an environmental hazard. Plastic debris is often consumed by a variety of species and has been shown to bioaccumulate up the food web. Additionally, microplastics can migrate from the gut to the circular and lymphatic systems, transporting contaminants with them (Brinton et al., 2011).

The presence of plastics in the composted waste stream also creates toxic heavy metals pollution. A study of heavy metal production at a food waste treatment plant in China concluded that the leachate produced during food waste composting contains highly hazardous amounts of cadmium (Cd), likely from plastics mixed with food waste (Chu et al., 2019). Similarly, the presence of improper materials in the waste stream is also linked to the presence of heavy metals in the compost product itself (Rodriguez et al., 2020). Heavy metals pollution threatens ecosystems by causing loss of soil nutrients, and therefore adversely affecting plant life and crops (Jiang et al. 2020). Heavy metals also have a variety of negative human health impacts. Cadmium specifically is a highly persistent and toxic endocrine disrupting chemical that is linked to development of prostate and breast cancer (Pan et al., 2009). Instead of creating a usable fertilizer as intended, when plastic contamination is present, the compost product poses risks to environmental and human health.

In addition to improper sorting practices and excessive plastic waste generation, the existing social system in the U.S. also has a history of longstanding systemic racism. When a growing technology such as composting is integrated into a system where the burdens of waste management are unequally distributed, unintended social consequences occur. As composting grows as a solid waste management method, the environmental justice implications of this practice must be considered. The environmental justice movement seeks for everyone to enjoy equal protection from environmental hazards and have equal involvement in the development and implementation of environmental policies (EPA, 2021). Historically, the hazards caused by excessive consumption and waste generation disproportionately impact low-income communities of color. Over half of all people in the US who live within 3 kilometers of a hazardous waste landfill are people of color (Mohai & Saha, 2015). Additionally, black Americans are three times more likely to die from exposure to pollutants than white Americans (Di et al., 2017). Because of the hazards enumerated in this paper, when siting composting facilities, decision-makers must consider geographic equity. This type of equity refers to the location of communities and their proximity to environmental hazards and locally unwanted land uses (Bullard, 2001).

However, there are many actors within the existing social system that hold the "not in my backyard" (NIMBY) mentality when it comes to SWM facilities. There are many political and economic challenges associated with NIMBY which pose an obstacle to the equitable siting of composting facilities. Michael Gerrard in his essay "The Victims of NIMBY" (1994) seeks to identify the parties hurt by the NIMBY mentality. Gerrard argues that in the future, NIMBY battles by the affluent could cause waste management facilities to be moved to minority neighborhoods. For this reason, he states that "minority communities should be given the technical and legal resources they need to participate in the siting decisions" (Gerrard, 1994). This is particularly relevant to composting, which has a large potential to grow in the future. Similarly, researchers in Taiwan created a decision-making model for composting facility site selection. Their model results identified resistance from residents as the most influential obstacle in location selection and determined that decision-makers give strong preference to areas with lower NIMBY resistance (Liu et al., 2018). When composting is integrated into a social system with high NIMBY resistance, the burdens of waste management are pushed onto vulnerable populations.

Research Question and Methods

What is the degree of compost contamination at the University of Virginia, and what strategies could be used to limit contamination? With increasing concern for the severity of climate change and pollution, the world is moving toward alternative waste management techniques. Through this transition, composting has become an increasingly prevalent form of waste management. Moving forward, it is important to consider not only the environmental impacts of the technology itself, such as greenhouse gas emissions and energy use, but also the issue of contamination which is largely impacted by human waste disposal behavior. In order to answer this question, data from waste audits of compost bins around UVA grounds was obtained from the UVA Office of Sustainability (OFS). The waste audits analyzed the contents of the waste stream by sorting the waste into categories and weighing it (Busch Systems, 2019).

Two different waste audits were used as data sources, one performed on compost bins located outside of Observatory Hill (Ohill) and Newcomb dining halls and the other performed on bins outside of McIntire Amphitheater, which is very central to grounds and the site of several food trucks (Aramark, 2022). The first of the two waste audits was performed from September to December 2021 at Ohill and Newcomb dining halls by the student Zero Waste Ambassadors through UVA OFS. Students recorded how much compost was in the bin, how long it took to sort, as well as the contaminants that were present. The second of the two waste audits was performed during January and February of 2022 at McIntire Amphitheater by volunteers through UVA OFS. Both composted and landfilled waste were sorted as part of the audit. Volunteers recorded the temperature for the day, compost weight and volume, quantities of contaminants, trash weight and volume, and the weight and volume of compostable materials in the trash. From these two data sources, I identified the most common contaminants, and analyzed the impact of environmental factors on the nature and degree of contamination. This method sheds light on the amount of contamination that enters UVA's compost bins, as well as what the contamination consists of. Once this was determined, I reviewed prior literature on techniques to minimize waste contamination and analyzed them for applicability to UVA's waste management system. The results of this research can be used to make recommendations to UVA Facilities Management and help to alleviate the hazards resulting from compost contamination at UVA and in the surrounding Charlottesville community.

Results

Compost collected on grounds at UVA contains significant amounts of contamination and will require an intervention in order to improve waste sorting before expanding composting across the university. The contamination is dominated by mixed material and plastic items. The most common contaminants across the two audits were receipts, non-compostable cups, and plastic cutlery, which are all easily mistaken for compostable items by an untrained individual. This emphasizes the need for more comprehensive education and training on proper waste sorting before composting can be expanded across grounds. There were also differences in contaminants across the two audits, emphasizing the importance of setting in creating a contamination reduction strategy. Additionally, the trash bins contained 51% compostable materials by weight, which is a significant opportunity for UVA to divert waste from landfills and work towards its sustainability goals (University of Virginia, 2020). Based on the results from the waste audits, three potential solutions to the contamination issue were identified including increased education and training, site-specific signage, and hand-sorting.

Audit 1: Ohill and Newcomb Dining Hall

At the Ohill and Newcomb Dining Hall locations, the vast majority (over 60%) of all contamination was comprised of receipts and non-compostable cups. A full breakdown of contaminant frequency is shown is Figure 1 below. The frequency of receipts and non-compostable cups in the contamination shows the importance of being educated on proper composting practices. To an untrained individual, these items would seem compostable, but the actually contain non-compostable plastic (Everyday Recycler, 2021).

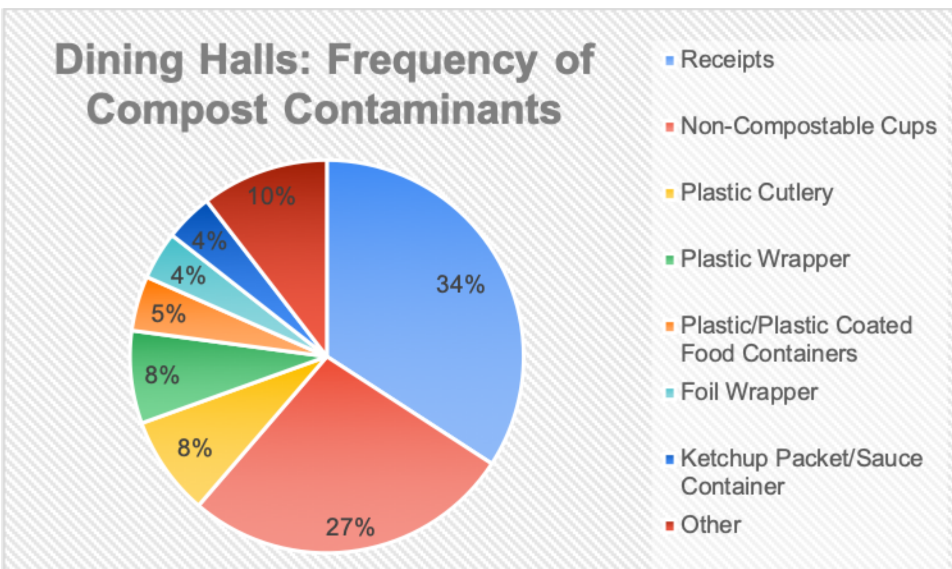

Figure 1. Breakdown of Compost Contaminants in Dining Halls

Next the contaminants were grouped by material to assess what the contamination is commonly made of. 70% of the contamination was mixed material, with much of that being plastic-coated paper products such as non-compostable cups and plastic-coated food containers (BASF SE, 2022). A full breakdown is shown in Figure 2 below.

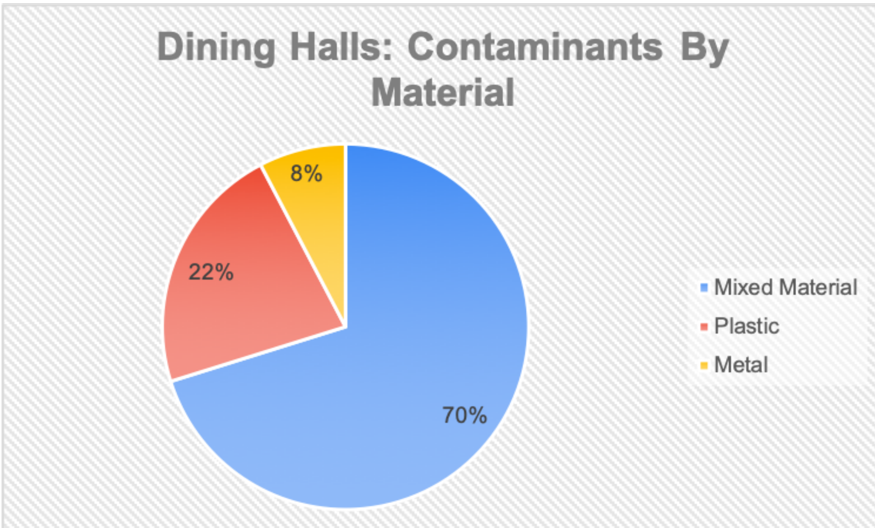

Figure 2. Contaminant Breakdown by Material in Dining Halls

The waste audit revealed that dining hall contaminants were dominated by mixed material—especially plastic and paper—contaminants, with the main two being receipts and non-compostable cups. This is consistent with the ISTA framework, as it demonstrates the consequence, severe contamination, of introducing composting in a social system where there is abundant mixed-material packaging, and users are not properly trained on proper sorting and disposal. A study of waste collection performance and sorting behavior found that "strong motivation for waste disposal and/or greater attention to finding trash bins might contribute to waste separation encouragement" (Leeabai et al., 2021). In order to solve the issue of contamination, it is important for UVA to educate students and faculty and foster a motivation for composting and sustainable waste management.

Participants also recorded the time needed to sort through the bins. The most commonly reported time interval was 10-15 minutes, while the average time range was approximately 13-19 minutes. This information is important when considering hand sorting as a possible solution to the contamination issue. UVA employees currently hand sort recyclable materials by type before sending them to the proper facilities (Sustainability UVA, 2019). The relatively short sorting time required for composting makes it so compostables could be integrated into the existing hand sorting system without much additional manpower, making this a viable solution to the contamination issue. However, Sonny Beale, UVA Recycling Programs Superintendent, pointed out some drawbacks of the hand-sorting solution. He argues that although this has been proven successful at reducing contamination, it misses the opportunity to educate users on proper disposal and sorting. He also points out that “it is a dirty job that most wouldn’t want to participate in doing for a number of reasons” (Beale & Alwine, 2022).

Audit 2: McIntire Amphitheater

At the Amphitheater bin location, the most common contaminant was plastic cutlery, followed by receipts and non-compostable cups. Again, the contaminants were also classified by material. The most common material at this location was plastic, due to the large amount of plastic cutlery. Figures 3 and 4 show a full breakdown of the contaminants and materials.

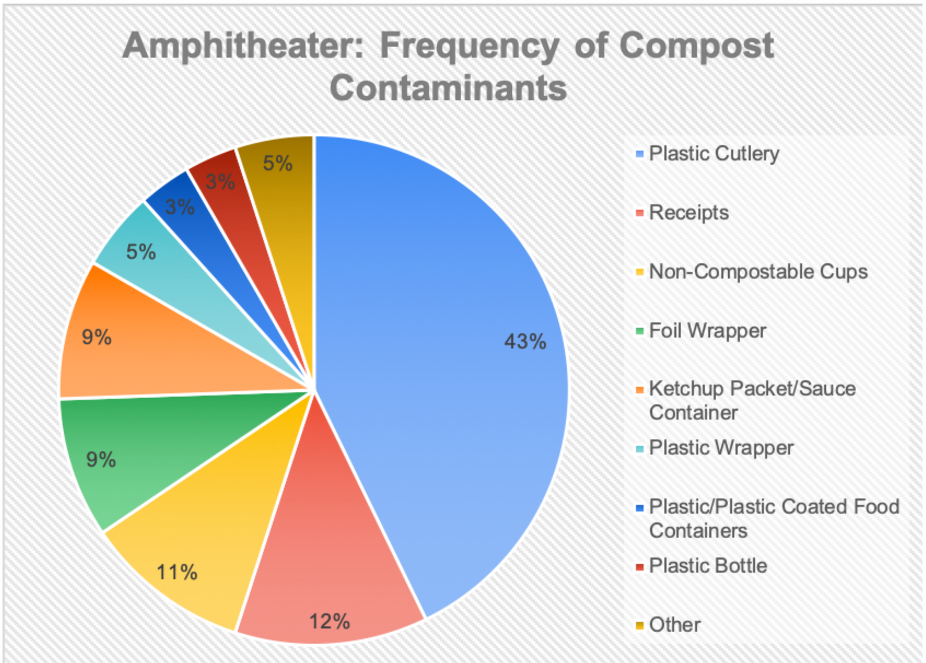

Figure 3. Breakdown of Compost Contaminants in the Amphitheater

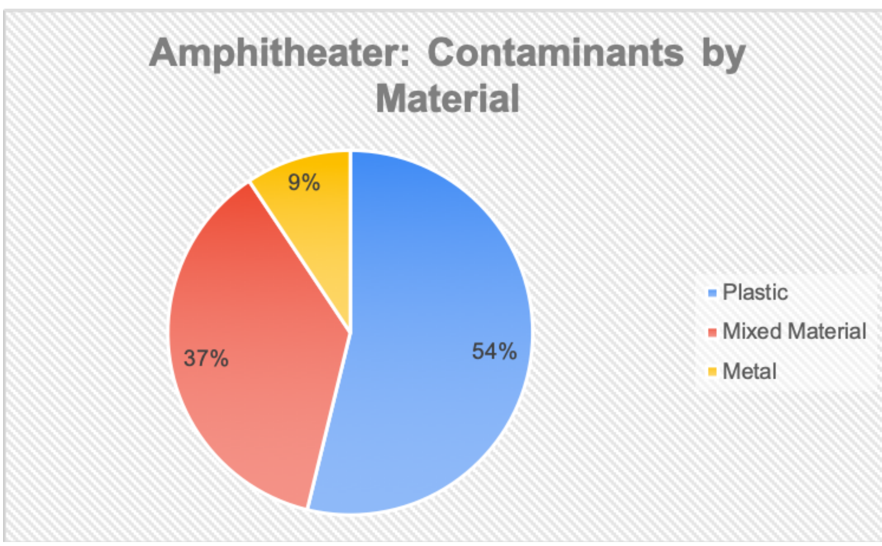

Figure 4. Contaminant Breakdown by Material in the Amphitheater

These results differ from the dining halls, which were dominated by mixed-material packaging, with the highest counts of receipts and non-compostable cups. This difference in contaminants between the dining halls and the amphitheater shows the importance of setting on the nature of compost contamination. This is also consistent with the ISTA framework, as it shows the importance of understanding the system in which the technology is being implemented. The proximity of food trucks that carry non-compostable cutlery to the amphitheater had a significant impact on the compost contamination. The sociotechnical interactions between the implementation of composting and the prevalence of non-compostable materials used by the surrounding facilities must be considered when creating a contamination reduction strategy. This suggests that setting-specific instructions may be helpful for limiting contamination. For example, signs at the amphitheater could reinforce that the cutlery is *not* compostable, and the same for non-compostable cups at the dining halls. This suggestion is supported by a study of composting in university settings which found that having signage of permitted *and* prohibited items decreases levels of contamination when compared to the baseline (Szczucinski et al., 2019).

There is also a relationship between the number of contaminants reported and the weight of compost in the bin. This positive correlation is shown in Figure 5 below. This suggests that when the bins are more heavily used, contamination increases. This presents a challenge for UVA to balance the desire to increase the amount of compost collected, while still avoiding contamination.

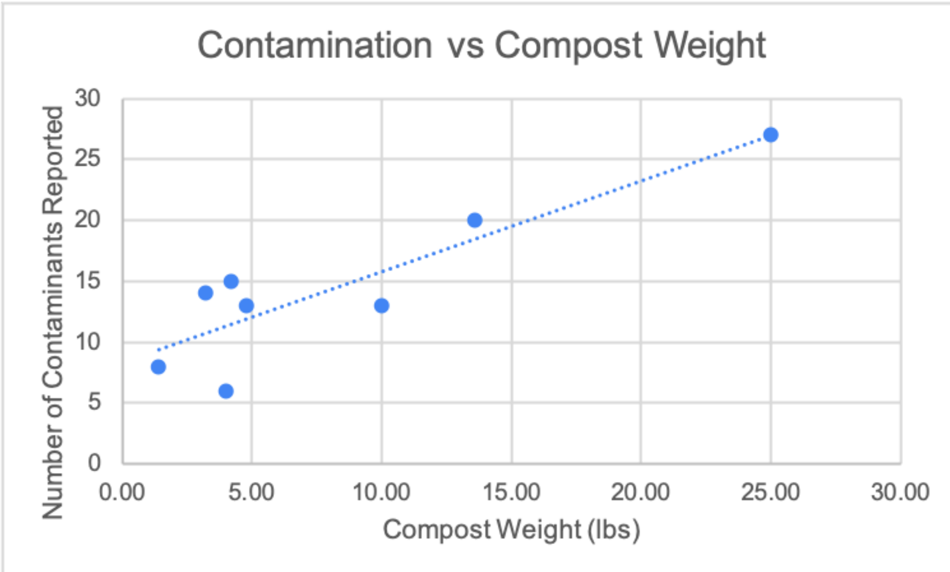

Figure 5. Contamination vs. Compost Weight

Finally, I analyzed the amount compostable materials in the landfilled waste. On average, the trash contained 51% compostable materials by weight, with a minimum of 37% and a maximum of 69%. This could be due to people often putting heavier food waste in the landfill bin and putting lighter materials such as clamshell containers and cups that are explicitly labeled as “compostable” in the compost bin. This presents a major opportunity for UVA to increase composted waste and divert from landfills. This would help UVA achieve its goal of reducing landfilled waste to 30% of the 2010 tonnage (University of Virginia, 2020). However, the data also suggests that with more usage of the bins, there will likely be more contamination. Black Bear composting, the composting company employed by UVA, will only accept up to 1% contamination in the compost they manage (Black Bear Composting, 2021). This emphasizes the need for an intervention of some sort before expanding composting across grounds. The results of my research suggest that increased education and training, site-specific signage, and hand-sorting are all viable solutions that could help UVA reduce contamination and be able to expand composting initiatives in order to achieve their sustainability goals.

Discussion

Michael Harrison's Interactive Sociotechnical Analysis framework explores the unintended consequences of technology in use and can help us to understand the results of my research (Harrison et al., 2007). Introducing composting at UVA changes the existing social system as students and faculty adapt to this new waste disposal option. However, the surrounding environment and infrastructure impacts the use of compost bins and determines the effectiveness of this SWM strategy. The university does not provide comprehensive training on proper composting for students and faculty, so when the compost bins are surrounded by dining establishments that provide non-compostable materials, significant amounts of contamination result. Because of this issue, the unintended consequences necessitate changes in the social system, such as the Zero Waste Ambassadors program, to remove the contamination before sending the compost to Black Bear Composting. As UVA looks to expand composting across grounds, more permanent reform of the compost collection and processing system is necessary.

A major limitation of this research is the inconsistency in the collection and recording of data. In both audits many different people were sorting the waste and collecting the data. Because of this, there were inconsistencies in how the data was recorded. For example, in some cases exact counts of specific contaminants were recorded (ex: "3 receipts"), but in other cases the results were more qualitative (ex: "a few receipts"). When tracking contaminants, I translated these entries into numerical values, but it is possible that I may have over- or under-counted for certain contaminants. Another major limitation is that the two audits used slightly different methodologies and collected different data, so it was difficult to compare the two.

In the future, I would reach out to UVA Sustainability in advance in order to have sufficient time to plan a more comprehensive analysis. I would like to plan a consistent methodology that could be applied in waste audits in several locations around grounds. Data collected would include exact counts and descriptions of contaminants, as well as the weights and volumes of total composted waste, compost contamination, total landfilled waste, and compostable materials in the trash. This way, I could determine the percent compost contamination and the percent of landfilled waste that is compostable by weight and volume. Conducting various audits with consistent methodology would help to reveal how the nature and amount of contamination varies across grounds and over time.

As I continue my engineering practice, I will build upon this research when working to incorporate sustainability into my career. After graduation, I will begin work as a civil engineer in a rotational program in the public sector, specifically in public works and environmental services. One of my rotations focuses on solid waste management. The SWM challenges faced by UVA are likely very similar to those faced by a county government. This project has provided me with valuable background knowledge on SWM that I will carry with me as I begin my career. My other rotations include stormwater management and wastewater management. Although these are not related to solid waste, both areas have potential to implement sustainable technologies. I will apply the knowledge and skills that I learned through my research to avoid unintended consequences of sustainable technologies by developing an understanding of the social system in which they operate.

Conclusion

Excessive production of plastic waste is a threat to ecological and human health and is a major SWM challenge. This issue has led to an increased focus on composting as a sustainable alternative. In Virginia, this took the form of an executive order issued by Governor Northam banning single-use plastics in government facilities. As a public university, UVA must adapt its waste management strategy to comply with this executive order by increasing the amount of compostable materials in the waste stream. The results of my analysis suggest that the compost collected on grounds at UVA contains significant amounts of contamination and will require an intervention to improve waste sorting in order to successfully expand composting across the university. To continue this research, the next step is to test the interventions suggested in this research paper, including increased education and training, site-specific signage, and hand-sorting. By conducting waste audits before and after implementing one of these strategies, the effectiveness of each intervention can be determined. Reducing compost contamination is essential due to the severe hazards created by improper sorting and the presence of improper materials in the compost waste stream. The results of this research can be used to make recommendations to UVA Facilities Management in order to mitigate the university's environmental impact and reduce the hazards resulting from compost contamination at UVA and in the surrounding community.

References

Aramark. (2022). *Street eats*. UVA Dine. Retrieved March 2, 2022, from https://virginia.campusdish.com/LocationsAndMenus/StreetEats

BASF SE. (2022). *The Paper Coffee Cup recycling puzzle*. The anatomy of a cup | Where business meets science. Retrieved February 21, 2022, from https://insights.basf.com/home/article/read/anatomy-of-a-cup#:~:text=Most%20paper%20cups%20are%20made%20with%20a%20thin%20layer%20of,the%20cup%20from%20getting%20soggy

Beale, S., & Alwine, M. (2022). Email exchange with Sonny Beale. other.

Black Bear Composting. (2021). *Our process - optimizing for nature*. Black Bear Composting: Our Process: Charlottesville, Harrisonburg, Staunton and Waynesboro. Retrieved February 26, 2022, from https://www.blackbearcomposting.com/composting-process.php

Brinton, W., Dietz, C., Bouyounan, A., & Matsch, D. (2011, April). The Environmental Hazards Inherent in the Composting of Plastic-Coated Paper Products. Mt. Vernon, ME; Wood End Laboratories, Inc., Ecocycle, Inc. .

Bullard, R. D. (2001). Environmental justice in the 21st Century: Race still matters. *Phylon (1960-)*, *49*(3/4), 151–171. https://doi.org/10.2307/3132626

Busch Systems. (2019, May 10). What is a waste audit?: RC. Busch Systems Resource Center. Retrieved March 1, 2022, from https://www.buschsystems.com/resource-center/page/what-is-a-waste-audit

Chen, Y., Awasthi, A. K., Wei, F., Tan, Q., & Li, J. (2021). Single-use plastics: Production, usage, disposal, and adverse impacts. *Science of The Total Environment*, *752*. https://doi.org/10.1016/j.scitotenv.2020.141772

Chu, Z., Fan, X., Wang, W., & Huang, W.-chiao. (2019). Quantitative evaluation of heavy metals' pollution hazards and estimation of heavy metals' environmental costs in leachate during food waste composting. *Waste Management*, *84*, 119–128. https://doi.org/10.1016/j.wasman.2018.11.031

Condor Ferries. (2021). *100+ plastic in the Ocean Statistics & Facts (2020-2021)*. Plastic in the Ocean Statistics. Retrieved October 23, 2021, from https://www.condorferries.co.uk/plastic-in-the-ocean-statistics.

Di, Q., Wang, Y., Zanobetti, A., & Wang, Y. (2017). Air pollution and mortality in the Medicare population. *New England Journal of Medicine, 377*(15), 1497-1499. doi:10.1056/nejmc1709849

Environmental Protection Agency. (2021). *Environmental Justice*. EPA. Retrieved October 30, 2021, from https://www.epa.gov/environmentaljustice.

Environmental Protection Agency. (2021). *Plastics: Material-Specific Data*. EPA. Retrieved October 22, 2021, from https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data.

Everyday Recycler. (2021, September 20). *Recycling Bin or trash can? are receipts recyclable?* Everyday Recycler. Retrieved February 21, 2022, from https://everydayrecycler.com/are-receipts-recyclable/

Exec. Order No. 97, Commonwealth of B=Virginia Office of the Governor (March 23, 2021).

Gerrard, M. B. (1994). The victims of nimby. Fordham Urban Law Journal, 21(3), 495-522.

Harrison, M., Koppel, R., & Bar-Lev, S.,(2007). Unintended Consequences of Information Technologies in Health Care—An Interactive Sociotechnical Analysis, Journal of the American Medical Informatics Association, 14(5), 542-549.

IPCC. (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change *Cambridge University Press*. In Press.

Jiang, H.-H., Cai, L.-M., Wen, H.-H., Hu, G.-C., Chen, L.-G., & Luo, J. (2020). An integrated approach to quantifying ecological and human health risks from different sources of soil heavy metals. *Science of The Total Environment*, *701*. https://doi.org/10.1016/j.scitotenv.2019.134466

Leeabai, N., Areeprasert, C., Khaobang, C., Viriyapanitchakij, N., Bussa, B., Dilinazi, D., & Takahashi, F. (2021). The effects of color preference and noticeability of trash bins on waste collection performance and waste-sorting behaviors. *Waste Management*, *121*, 153–163. https://doi.org/10.1016/j.wasman.2020.12.010

Lindwall, C. (2020, January 9). *Single-use plastics 101*. NRDC. Retrieved October 22, 2021, from https://www.nrdc.org/stories/single-use-plastics-101.

Liu, K.-M., Lin, S.-H., Hsieh, J.-C., & Tzeng, G.-H. (2018). Improving the food waste composting facilities site selection for sustainable development using a hybrid modified MADM model. *Waste Management*, *75*, 44–59. https://doi.org/10.1016/j.wasman.2018.02.017

Mohai, P., & Saha, R. (2015). Which came first, people or pollution? assessing the disparate siting and post-siting demographic change hypotheses of environmental injustice. *Environmental Research Letters, 10*(11), 115008. doi:10.1088/1748-9326/10/11/115008

Pan, J., Plant, J. A., Voulvoulis, N., Oates, C. J., & Ihlenfeld, C. (2009). Cadmium levels in Europe: Implications for human health. *Environmental Geochemistry and Health*, *32*(1), 1–12. https://doi.org/10.1007/s10653-009-9273-2

Reinthaler, F. F., Marth, E., Eibel, U., Enayat, U., Feenstra, O., Friedl, H., Köck, M., Pichler-Semmelrock, F. P., Pridnig, G., & Schlacher, R. (1997). The assessment of airborne microorganisms in large-scale composting facilities and their immediate surroundings. *Aerobiologia*, *13*(3), 167–175. https://doi.org/10.1007/bf02694504

Ritchie, H., & Roser, M. (2018). Plastic Pollution. *Our World in Data*. Retrieved October 22, 2021, from https://ourworldindata.org/plastic-pollution#citation.

Rodrigues, L. C., Puig-Ventosa, I., López, M., Martínez, F. X., Ruiz, A. G., & Bertrán, T. G. (2020). The impact of improper materials in Biowaste on the quality of compost. *Journal of Cleaner Production*, *251*, 119601. https://doi.org/10.1016/j.jclepro.2019.119601

Sustainability UVA. (2019). *Where Does UVA's Waste Go?* Charlottesville, VA.

Szczucinski, D., Gelino, B. W., Cintron, C. J., Becirevic, A., & Reed, D. D. (2019). Increasing appropriate composting in high-traffic university settings. *Behavior Analysis in Practice*, *13*(1), 22–28. https://doi.org/10.1007/s40617-019-00358-1

Tsai, C.-J., Chen, M.-L., Ye, A.-D., Chou, M.-S., Shen, S.-H., & Mao, I.-F. (2008). The relationship of odor concentration and the critical components emitted from food waste composting plants. *Atmospheric Environment*, *42*(35), 8246–8251. https://doi.org/10.1016/j.atmosenv.2008.07.055

University of Virginia. (2020). (rep.). *University of Virginia Sustainability 2020-2030 Plan* (pp. 1–20). Charlottesville, Virginia.

Walker, T. R., & McKay, D. C. (2021). Comment on "Five misperceptions surrounding the environmental impacts of single-use plastic." *Environmental Science & Technology*, *55*(2), 1339–1340. https://doi.org/10.1021/acs.est.0c07842

Winner, L. (1980). Do Artifacts Have Politics? Daedalus, 109(1), 121-136. doi:184.171.106.7