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THEATRE DESIGN & TECHNOLOGY

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DIRTY WORK

Mulch, peat, sand, and soil-
when productions call for
the real thing

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DIRTY WORK

Using natural materials to evoke soil on stage

BY BRAD STEINMETZ

Crewmembers spread 300 cubic feet of peat onto the stage at the Palais Garnier for Pina Bausch's *The Rite of Spring*. For the full series of images and further discussion of the dirt stage used in the production, please visit https://www.operadeparis.fr/en/magazine/the-soil-of-the-rite-of-spring | Photo by Elena Bauer, courtesy l'Opéra national de Paris.

In 2014, the Park Avenue Armory in New York transformed into ancient Scotland for the Kenneth Branagh and Rob Ashford production of *Macbeth*. Key to this transformation was the muddy, rain-soaked battlefield that Christopher Oram designed as the central scenographic element. Creating a dirt effect on stage is a fairly common challenge in theatre; however, some productions call for more than just a paint treatment or a textured floor. After some trial and error with mulches and soils, the team for *Macbeth* found the optimal mixture was three parts finely ground pine bark to one part builder's sand (Brickman 2014).

In one of Pina Bausch's most famous works, *The Rite of Spring*, the entire stage, around 2,600 square feet, is covered in more than an inch of soil that dancers engage with throughout the piece (Gouhier 2017). With few exceptions, since its premiere in 1975, each production of *The Rite of Spring* around the world has required hundreds of pounds of peat with a specific texture and moisture level. In fact, the peat is often dispersed onto the stage during intermission by well-choreographed technicians for the audience to see. (View a time-lapse video of this intermission shift: https://youtu.be/lGXUl8F7xLE?t=60)

Although these types of productions are rare, many theatres have seen soil on their stages for imitative or aesthetic purposes. Some scripts, like *Native Gardens* by Karen Zacarías, ask for a domestic exterior with dirt in the yard. For others, like *Dirt* by Bryony Lavery, the material itself becomes almost a character in the world.

Any gathering of scene designers or technical directors is likely to produce stories, good and bad, of using dirt on stage.

However, no detailed guidance exists in our industry for selecting a natural material to evoke soil on stage. This is the surprising fact I learned when a recent production at The Ohio State University called for 420 square feet of our stage to be covered in soil. In 2020, Braden Graves, a student in The Ohio State University MFA program, produced a scene design to accompany a new script by our cohort of graduate acting students. Unfortunately, just as the planning and engineering had begun, the show was cancelled due to the pandemic. However, I salvaged the research question that remained and, with the help of my colleagues, faculty and staff from around our campus, and generous folks in the larger community, was able to address some of the knowledge gap around using dirt on stage.

Some Definitions

"Dirt" or "soil" means different things to different people. For example, a civil engineer understands dirt as a building material. By volume, about half of dirt consists of minerals of various sizes. Sand, silt, and clay represent the large, medium, and small sizes, and their relative percentages define the texture of soil. The other half of dirt is a fairly even mixture of air and water, with around 5 percent left over for organic matter. In agriculture, soil is defined by the amount and nature of its organic matter, its potential to hold water, its resistance to erosion, and numerous other variables that affect its fertility. Horticulture represents the primary consumers of mulch, which is normally chopped-up bits of various trees and plants. Silviculture, or tree farming, is where the materials for mulch often originate, although some are sourced from paper mills, land-clearing debris, and increasingly, from recycled pallet wood and other construction materials.

When selecting materials to use as dirt on the stage, we must consider another diverse group of constituents. For example, the technical director will likely work most closely with the material and will need information on costs, weight, and moisture content, and may need to consider acquiring tools most scene shops rarely use, such as wheelbarrows, rakes, and shovels. They will also need information about sourcing landscaping materials as well as a plan for striking the material, hopefully to somewhere other than a dumpster. Costume designers and technicians will want to know how the material affects fabric, how badly it stains, and how often a garment must be cleaned. Directors and scene designers may focus on how the material will look in the space and what ways a performer is able to interact with it.

For lighting designers, dirt can be a mixed blessing. As a floor treatment, dark soil does an excellent job absorbing light, giving designers greater control and greatly reducing bounce. If the soil enters the air, some designers may welcome the atmospheric effects on lighting beams; however, few will welcome the dust that may end up collecting in their instruments. In fact, this introduces an especially complicated aspect of using natural soils on stage: their effect on air quality. Airborne particulate matter (measured as PM) can cause a wide variety of health problems, a fact generally well known in theatre shops and studios accustomed to masking and dust collection. However, no industry standards exist for using dirt in a performance venue, so additional investigation is required.

Airborne particulate matter can include many types of materials, both organic matter (pollen, mold, bacteria, dander) and non-organic (dust, ash, smog, tobacco smoke). Some dangers lie in the type of material itself. For instance, crystalline silica, commonly found in sand, is known to cause silicosis, a chronic, progressive lung injury, although generally only after years of prolonged exposure. Nonetheless, this has led to a shift toward the use of silica-free sand on stages. (What is often described as "silica-free sand" is only free of inhalable silica dust. All sand contains silica, normally up to 80 percent but often higher in natural beach sands. Silica itself is inert and essentially harmless unless inhaled.)

Particulate matter can also come in many sizes and, where there is potential for inhalation exposure, bigger is generally better. Large, heavy particulates don't stay in the air as long, and the ones that do can be captured in the mouth or nasal cavities if inhaled. Particles that are 10 microns in diameter and smaller (PM_{10}) can sneak past those defenses and into the trachea and bronchial areas. Particles that are only 2.5 microns in diameter or smaller ($PM_{2.5}$) go even deeper into the lungs and become respirable. Because these smaller particles are the most dangerous, they are commonly the focus of health studies and regulations.

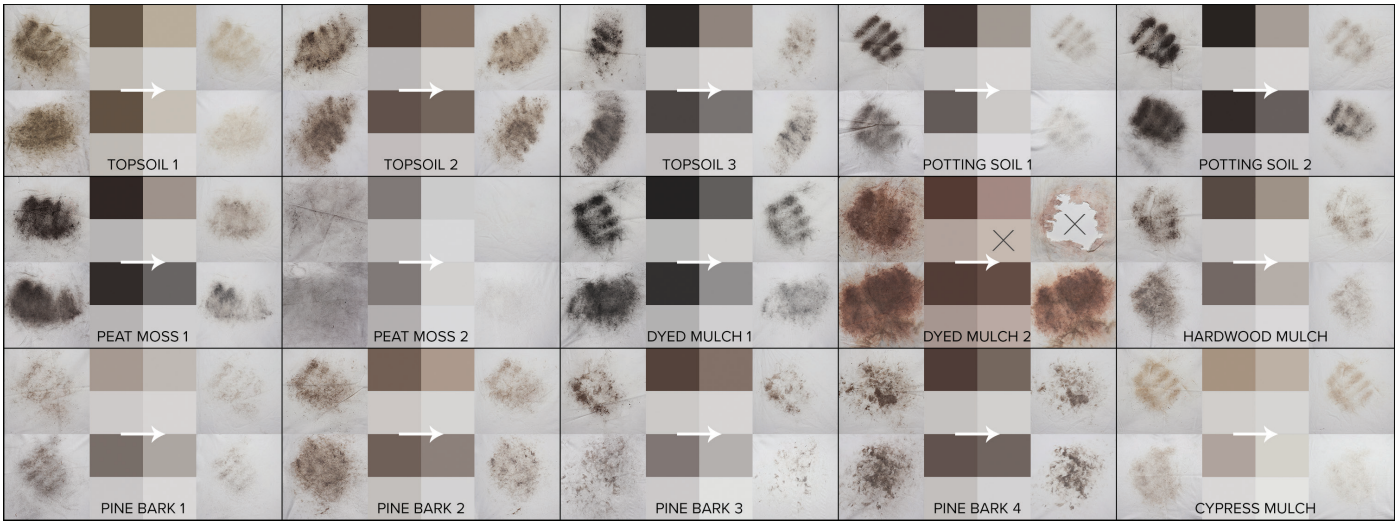
In the case of particulate matter, existing exposure regulations fail to adequately define an acceptable level in theatre applications. Most regulations focus on outdoor (ambient) air quality in an effort to address pollution. In the U.S., these are set by the Environment Protection Agency (EPA). Others focus on worker safety like those set by the Occupational Safety and Health Administration (OSHA), while some industry organizations offer their own recommendations for particulate levels (e.g., the American Conference of Governmental Industrial Hygienists or ACGIH). Even the World Health Organization (WHO) offers guidelines.

Looking only at the smaller $PM_{2.5}$ particles, as of 2021 the WHO now recommends a maximum level of 5 $\mu g/m^3$ for long-term exposure (averaged over one year) and a 15 $\mu g/m^3$ short-term limit (averaged over 24 hours). The national air quality standards set by the EPA are less stringent, with a long-term exposure level of 12 $\mu g/m^3$ for health and short-term limit of 35 $\mu g/m^3$ (see EPA 2014). Far more lenient is OSHA with an exposure limit of 5000 $\mu g/m^3$ in an 8-hour period, a figure that controversially has not been updated since 1971. (This OSHA exposure limit is for general particulate matter. Some specific particulate materials are regulated individually. For instance, OSHA's short-term limit for inhalable crystalline silica is 50 $\mu g/m^3$.) ACGIH recommends a threshold limit of 3,000 $\mu g/m^3$ not to be exceeded at any time (CDC 2021). To provide some context, the British Heart Foundation estimates that smoking a single cigarette in an otherwise pollution-free day is equivalent to a short-term $PM_{2.5}$ level of 28.8 $\mu g/m^3$ (AirQualityNews 2019).

Assessing Look and Performance

To examine the differences between commonly available landscaping materials, I selected a total of 15 types, including all major varieties of soil, peat, and mulch available at a leading garden center, Oakland Nurseries, as well as one type of

This study compares 15 natural landscaping materials available in central Ohio. | Image courtesy of Brad Steinmetz.



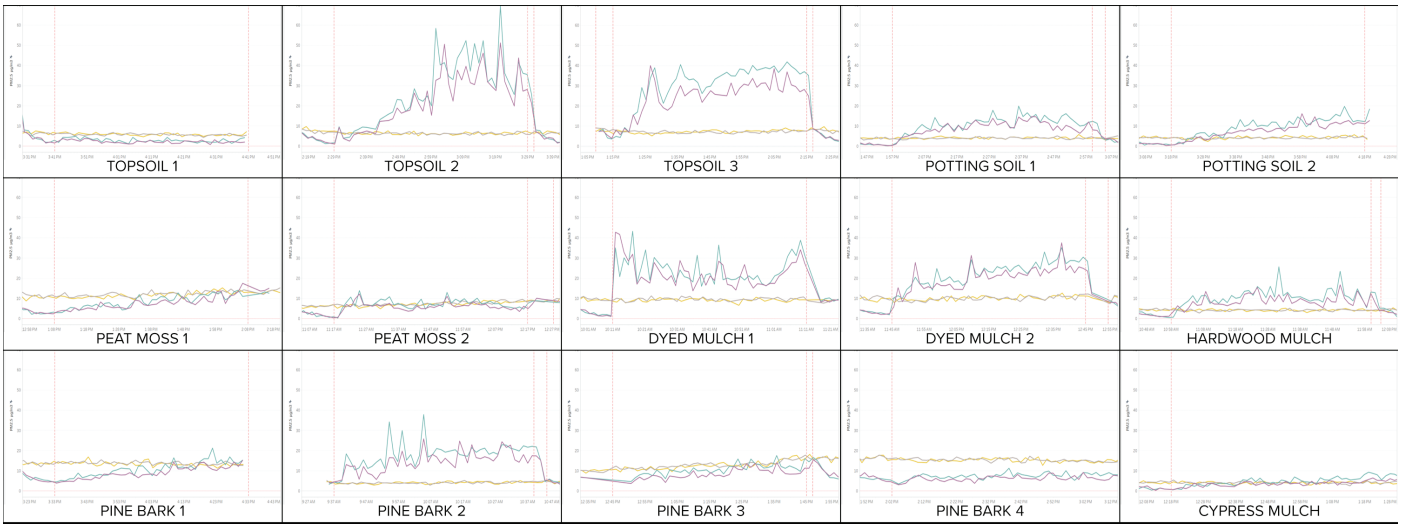
For each material, a natural and a synthetic fabric sample was stained by rubbing into the material for 30 seconds. Detailed photos were taken before and after laundering and measured for lightness. | Image courtesy of Brad Steinmetz.

topsoil available at a bulk soils company, Kurtz Brothers Mulch & Soils. Both companies generously donated their materials for the project.

The first analysis of materials supports designers and directors who need to know how a material looks and interacts with people. High-resolution digital images were taken of each material under controlled lighting. Not only do the images provide designers with a clear sense of the color and quality of each material, they have also been converted into seamless digital textures that can be used by designers in digital rendering and 3D modeling. These digital files are available to *TD&T* readers here https://go.osu.edu/dirt.

The texture and quality of each material affect how performers can interact with it. For instance, Topsoil 1 (from the bulk soils company) includes some harder chunks as large as 3 inches wide that could roll underfoot. However, these larger pieces could also be raked out or broken apart manually. The larger, oblong disks of pine bark (Pine Bark 3 and Pine Bark 4) are hard and smooth enough to slide around on themselves like coins; however, the smaller types are fairly easy to traverse. The potting soils and, to a lesser degree, the peats, compact underfoot and, in some cases, leave distinct footprints. Over time and use, they may compress more significantly, requiring reconditioning or perhaps additional material. Cypress mulch is made of long entangled strands, almost like coleslaw, and is difficult to lay out evenly; however, it is fairly easy to walk on and stays put nicely. If stage action involves digging, soils and peat work better than some of the mulches that have larger components.

In order to determine how darkly and how permanently a material might stain costumes, two types of test fabric were used—a natural, unbleached muslin and a synthetic white spandex. An eight-inch square of each test fabric was rubbed for 30 seconds into each landscaping material, fresh out of its bag. After spending a month sealed in individual plastic bags to set stains, each piece of test fabric was then photographed under controlled lighting conditions. The fabric was then laundered conventionally with detergent and hung to dry. Identical photos were



Materials were dried and tested for particulates 2.5 microns or smaller (PM2.5) in a testing chamber with MERV 13 filtration. Each material was agitated as the surrounding air was tested for one hour. | Images courtesy of Brad Steinmetz.

then taken of each piece of fabric and the digital images were compared before and after laundering to determine the overall reduction in lightness of the fabric. (Digital image analysis involved identifying the average color of the darkest one-third-inch square before and after laundering. Three individual lightness values of the color were averaged to create a total percent reduction in lightness.)

As logic would suggest, dyed mulches stain fabric more significantly and more permanently than most. Staining from Topsoil 1 washes out very well as does that of Peat Moss 2, which happens to have a lower moisture content out of the bag than Peat Moss 1, which did not fare as well. (Peat is a type of soil created when plant materials submerged in bogs break down over thousands of years. The most common type of peat is from the sphagnum moss plant, which is the source for Peat Moss 2. By contrast, Peat Moss 1 is composed of darker sedge peat. These differences may have also affected the results.) There is a moderate correlation between staining and moisture content where wetter materials tend to stain somewhat more. Contrary to expectations, neither the synthetic nor the natural fabrics consistently stained more significantly than the other type.

With respect to air quality, it would be impossible to produce side-by-side comparisons for all 15 materials in full production situations. Instead, this study compares the amount of airborne particulate matter for each material in a unique, controlled environment. A 100-cubic-foot test chamber was built that included an exhaust fan and an intake vent with a MERV 13 air filter, which removes more than 90 percent of particulate matter $PM_{2.5}$ or larger. The fan and filter were able to create an environment inside the chamber with significantly lower levels of particulate matter than the outside air, keeping the testing environment independent. The PM levels were measured every 80 seconds by PurpleAir PA-II-SD sensors, one outside the chamber and one inside, mounted one foot above the material.

Before testing, 40 cubic inches of each material was baked at 200 degrees for six hours in an effort to bring each to a similarly low moisture level. Each material was placed in a tray, along with three billiard balls to help agitate, and then secured to the platform of an orbital lab shaker located inside the test chamber. During each test, the chamber was closed, and the filtration system ran by itself for 15 minutes to clear the air, after which the lab shaker was turned on and ran one hour. $PM_{2.5}$ levels were tracked throughout the process and graphed over time.

Although Topsoil 1 produces the least airborne particulate matter, the other two topsoils produce the most, the highest being Topsoil 3 with an average level of 28.09 $\mu g/m^3$. This may be the result of the differences between bags of nursery topsoil, normally a custom mixture of materials like peat, sand, and soil amendments, and bulk topsoil, which is generally harvested from a greenfield site, sifted in various ways and sold by the truckload. Unfortunately, the specific origins and

Surrounded by 280 square feet of peat, Acacia Duncan performs in *HUM* by Sebastian Orr, directed by Eleni Papaleonardos and produced by Available Light Theatre. Scenery and lighting by Brad Steinmetz, costumes by Tatjana Longerot, sound by Dave Wallingford. | Photos courtesy of Brad Steinmetz.

ingredients of landscaping materials are rarely disclosed.

Both types of dyed mulch also register high levels of particulate matter. Interestingly, dyed mulch often contains recycled pallet or construction wood due to their greater ability to absorb dye. In this case, Dyed Mulch 1 is labeled as containing hardwood bark, while Dyed Mulch 2 includes no information on material sourcing. Surprisingly, both types of peat register very low levels of airborne particulates despite being comprised of relatively small, lightweight material.

Additional data was collected on price and weight per cubic foot, as well as on moisture levels out of the bag. For the latter, the 40 cubic inch trays of material were each weighed before and after baking to calculate moisture as a percent by weight. (See the chart on page 12 that compiles four main data points where lower numbers are generally preferable and labels match the average color of each material.)

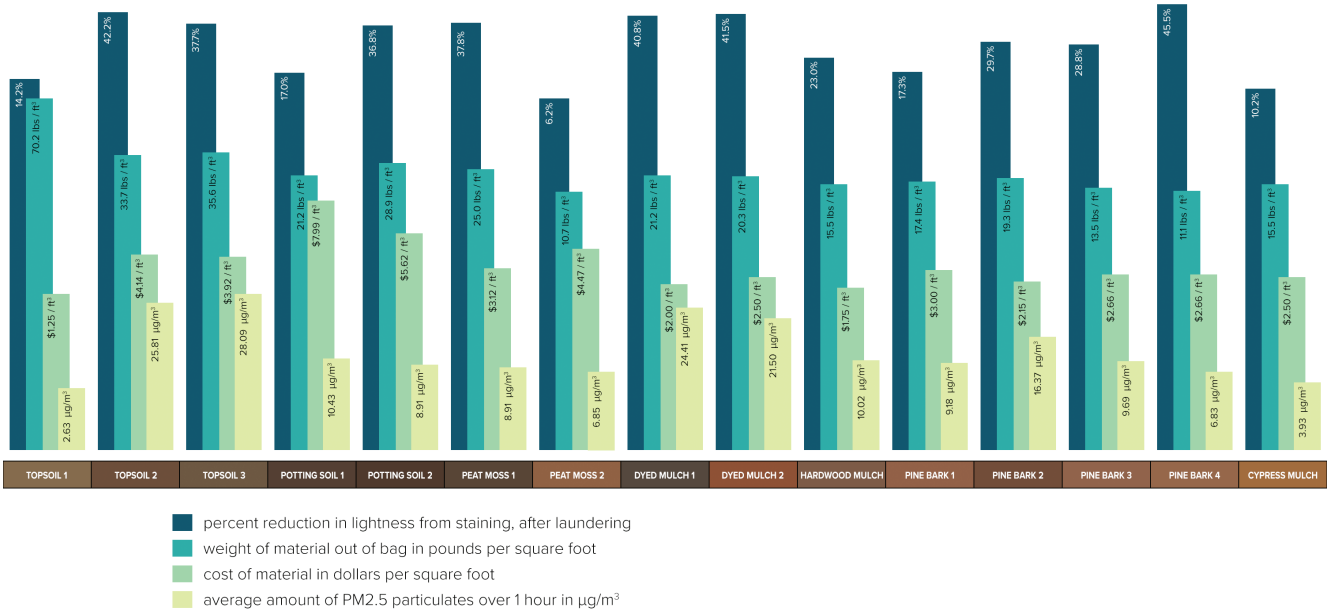
Comparing Options

To weigh the pros and cons of using natural landscaping materials vs. other possible solutions, this study examined three options, based on the cancelled Ohio State production, which called for 420 square feet of dirt and imagines a depth of .75 inches, when applicable.

The first option is based on Brigitte Bechtel's excellent faux dirt technique created for a production of *Native Gardens* by Karen Zacarías, set design by Carey Wong (Powers 2019). Among the benefits of this solution are that it can be created with conventional tools and materials, can be easily rolled up to travel, requires no real maintenance, and creates a stylized authenticity that looks great and remains consistent. Unfortunately, this option is not viable for a production that requires performers to interact with dirt in more tactile ways. Otherwise, the main downsides are its relatively high cost and the fact that all the materials, including paint, carpet and elastomeric, end up in a dumpster.

The second option enlists rubber mulch, a material normally created from recycled tires and available in a variety of colors and sizes. This solution is less costly than the detailed paint/texture treatment and quicker to create, though it would likely be slower to strike and travel. It may require additional tools to manage and load. Feedback from theatre practitioners who have used this material suggests it is easy to use and does not create airborne particles, but it does produce a subtle but distinct smell and leaves residue on hands as it is loaded or heavily worked. Although it may be possible for rubber mulch to find a new life after a production, many horticulturalists avoid using it because it leeches toxic substances as it degrades.

The third solution is an even mix of Topsoil 1 and Peat Moss 2, the cheapest of the three options and most authentic in terms of appearance and interaction. It is also the greenest solution and can avoid landfills altogether when it is donated or transferred to a municipal yard waste facility. One downside of these materials is management, which would likely require additional tools for loading and regular maintenance to restore desired



Brigitte Bechtel's Faux Dirt Technique
for *Fences*, from ROSCO "Spectrum" July, 2019

Materials:

indoor/outdoor carpet, 420 ft²	$ 415.18
Elastomeric , 5 gal	$ 64.25
Ground Walnut, 10 lbs	$ 12.60
Rosco Raw Umber, 1 gal	$ 48.49
Rosco Burnt Umber, 1 gal	$ 48.49
TOTAL	**$ 589.63**

Pros:
Rolls up and travels
No maintenance
Familiar materials, tools

Cons:
Cost
VOCs from paint and elastomeric
All materials end up in landfills

Rubber Mulch

Materials:

.8 mil Drop Cloth Plastic	$ 6.48
Brown Rubber Mulch, 26 ft³	$ 230.34
TOTAL	**$ 236.82**

Pros:
No maintenance

Cons:
Cost
Smell and VOCs from rubber
Materials have limited reuse, otherwise landfills

50% Topsoil, 50% Peat Moss

Materials:

.8 mil Drop Cloth Plastic	$ 6.48
Topsoil, 13 ft³	$ 51.45
Peat Moss, 13 ft³	$ 58.67
TOTAL	**$ 116.60**

Pros:
Cost
Natural apperance and use
Materials can be reused or transfered to yard waste

Cons:
Maintain moisture and position
Manage air quality

Three options are presented here for an area of 420 square feet and a depth of .75 inches. Additional research is needed to address full-scale production situations, fire retardancy, and ventilation systems. | Images courtesy of Brad Steinmetz.

positioning and moisture levels. The other main concerns would be dealing with the possibility of staining costumes and air quality.

Addressing Fire Safety

Fire safety is another important consideration. Although a side-by-side comparison of material ignition and flammability was beyond the scope of this study, research in other fields offers some guidance. In a study published in 2003 in the *Journal of Arboriculture*, 13 mulches were tested for ignition by cigarettes, matches, and a propane torch (Steward et. al. 2003). The most commonly ignited material was ground rubber. Although a dropped cigarette was not enough to cause ignition, with other exposure, ground rubber ignited consistently and was difficult to extinguish. Hardwood bark, cypress bark, and shredded pallets ignited relatively frequently. Pine bark of various sizes fared slightly better. Interestingly, cocoa shells proved to be among the most ignition-resistant mulches.

The University of Arizona Cooperative Extension published a 2007 report that tested eight natural mulches for ignition and flammability using methods similar to the Steward study from four years earlier. According to the report, "the organic mulches with the greatest amount of air space between the particles had the greatest ability to ignite and burn to the edge" of their test area (Rogstad, et. al. 2007). Shredded bark proved somewhat less fire prone than wood chips or pine nuggets.

Lastly, in a 2011 report, the University of Nevada Cooperative Extension studied eight materials and their relative combustion characteristics and found that shredded rubber again demonstrated the most hazardous fire behavior. Wood chips fared better than pine bark. All materials were ignited by a drop torch (Quarles and Smith 2011).

It is important to consider that each of these studies addresses fire risks in outdoor settings, including how easily a

material could catch fire and how readily it could perpetuate an existing fire. The indoor environments of theatre venues demand somewhat distinct considerations. For instance, accidental ignition may be a more crucial factor to consider for safety. Also, theatres can exert a higher level of control over air temperature and moisture levels. At the same time, hosting a public audience demands more rigorous fire prevention measures, as do local fire codes and regulations.

Future Considerations

Additional study is required to confidently answer some important questions. For instance, what level of airborne particulate matter can a performer or an audience member expect to experience when using a specific natural landscaping material? Had the Ohio State production not been canceled, the study could have tested in a true production environment, but only for one material. Also, it would have been difficult to apply this data to venues of different sizes using different HVAC systems. For instance, a displacement ventilation system might have benefits over a mixing system, and both would depend on the level of filtration used.

Nonetheless, it is interesting to note that, even with a particulate sensor placed one foot above very dry material being constantly agitated, all the average $PM_{2.5}$ levels over one hour were well below the 24-hour limit set by OSHA or the EPA. Nonetheless, no level of inhalable particulate matter is considered safe. In making decisions on acceptable levels of PM in theatres, it may be more valuable to consider the comfort of the actors and audience than to look to the higher limits seen in regulations for industry, as we do with atmospheric effects such as haze and fog.

This study was limited in scope to materials available locally, which reveals another variable to consider. The availability of landscaping materials varies widely by location and, although shipping might be an option for some, the weight and volume needed for most of these materials demand local sourcing. Even Pina Bausch's *The Rite of Spring* can't reasonably ship 300 cubic feet of peat moss when touring to other continents. Instead, technicians work with local soil companies to create their perfect mix of material. As a result of local limitations, many additional materials, including some commonly used in our industry, were not a part of this study. For instance, it would be valuable to have analogous data for crushed cork, ground walnut shells, and cocoa hulls.

Finally, more research is needed on fire safety and the use of natural landscaping materials in theatre productions. Although our industry is accustomed to identifying and mitigating fire risks, we generally look to walls and soft goods as flammability hazards and less often to the floor level or to floor treatments with these unique materials. It would be valuable to learn the effectiveness of theatrical fire retardant on these materials. Likewise, fire retardant from other industries made for exterior wood and mulch would be valuable to study in a theatrical setting.

Moisture is a crucial variable for many of the considerations in this study. During preliminary testing for airborne particulate matter, a clear correlation emerged between levels of PM and dryness of material. Of course, higher moisture content would also make materials less prone to accidental ignition and fire. Perhaps a future study could produce an optimal moisture level for landscaping materials that mitigates both of these hazards without greatly increasing the staining effect on costumes.

Author's Note: What began as a pandemic-induced curiosity grew into a substantial research project primarily due to the help of dozens of colleagues, friends, and strangers. My most significant finding is that curiosity shared with others is consistently met with kindness and generosity. All of the tools, materials, equipment, and spaces were donated, as was a good amount of labor. Advice and guidance was provided through conversations with professionals in our field, local business owners, new colleagues from around Ohio State's campus, and dear friends from my own department. Due to their generosity, this project was completed with a zero-dollar budget.

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techniques, and theatre-adjacent industries. He has created designs for more than two dozen world premiere productions and has collaborated with diverse artists such as director Marianne Weems, scenographer Jaroslav Malina, sculptor Malcolm Cochran and architect Tim Lai. Steinmetz is an active member of USITT, The Themed Entertainment Association (TEA) and The National Association for Museum Exhibition (NAME).

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