CLEANING LABORATORY EVALUATION SUMMARY

SCL #:	2020
DateRun:	08/31/2020
Experimenters:	Alicia McCarthy
ClientType:	Food Manufacturer
ProjectNumber:	Project #1
Substrates:	Plastic
PartType:	Part
Contaminants:	Dirt
Cleaning Methods:	Low Pressure Spray
Analytical Methods:	Organism count
Purpose:	
Experimental Procedure:	

Overview

Fat Moon Mushrooms grows mushrooms in a renovated mill building in Chelmsford, Massachusetts, for distribution to restaurants, farm stands, and small grocery stores in the Northeast region of the state. Fat Moon produces 200 to 500 pounds of mushrooms weekly, including shiitake, oyster, lion's mane, and chestnut.

Growing mushrooms indoors requires a moist environment and an acceptable growth medium, such as straw, sawdust, or coffee grounds. Fat Moon currently purchases pre-inoculated growing blocks from a vendor and then cultivates them in one of their two grow rooms.

Due to the nature of the product and the growing process, unwanted mold and bacteria contaminate the plastic sheeting hanging on the walls of the grow room. The plastic sheeting is hung to keep the wallboard underneath from getting contaminated and moist; the plastic sheeting is easier to clean and sanitize than the porous wallboard.

Because the mold and bacteria on the walls was potentially becoming airborne and migrating to the grow blocks, Fat Moon was sanitizing the plastic sheeting with a diluted bleach mixture. However, bleach is an eye, mouth, lung and skin irritant and can also cause and/or trigger asthma.

Concerned about the potential negative health impacts of bleach, Fat Moon discussed finding a safer alternative with the Toxics Use Reduction Institute (TURI) at UMass Lowell. The TURI cleaning lab tested the performance of safer methods to potentially replace bleach at Fat Moon. Ultimately, the owner of Fat Moon chose to switch to a product generated from a salt mixture dissolved in water and electrochemically activated to create a hypochlorous acid solution. The solution worked for the business's needs, is considered safer than bleach, and is a cost-effective alternative.

Alternative Sanitizers

To determine what safer alternative could be effective, the TURI lab tested two off-the-shelf sanitizers and two appliances that generate sanitizers. The lab then assessed the performance of each of the four sanitizers in comparison to bleach.

The two appliances tested were a MondoVap® Steam cleaner and a Force of Nature™ electrochemical activation (ECA) system. Each appliance generates a sanitizer which is then applied to the surface.

- The MondoVap 2400 Institutional System creates and applies high temperature saturated steam vapor for sanitizing surfaces.
- The Force of Nature system converts salt, water and vinegar into electrolyzed water, changing the chemical composition of the solution into hypochlorous acid for sanitizing and sodium hydroxide for cleaning

The two ready-made sanitizers tested were white vinegar and hypochlorous acid generated from NaDCC (sodium dichloroisocyanurate) tablets mixed with water.

- White vinegar contains acetic acid, which is a sanitizing agent.
- NaDCC tablets are effervescent tablets which produce a chlorine solution, consisting of hypochlorous acid and chlorinated isocyanurates, which provide a "reservoir" of additional hypochlorous acid when added to water. BruTab 6S® is a brand name of one type of NaDCC tablet.

CLEANING LABORATORY EVALUATION SUMMARY

Environmental, Health, and Safety Analysis of Alternatives

Below is a table highlighting the greatest environmental health and safety concerns associated with each technology or product.

EHS Comparison of Sanitizing Options	
Product	Environmental Health and Safety Concerns
Bleach	Bleach can be irritating to a person's skin and eyes. Regular use can cause and/or trigger asthma and other respiratory ailments. Special precautions must be taken when disposing of bleach.
MondoVap system (water – steam)	The use of a pressurized system to generate steam at a high temperature (exceeding 220˚F) creates a risk of burns. The vapor expands rapidly and cools quickly. According to the manufacturer, 9-10 inches from the nozzle tip the temperature is less than 100˚F.[1]
Force of Nature:	
Activator capsules	There are no hazards associated with the activator capsules.
Solution generated from Force of Nature (hypochlorous acid)	Mildly irritating to the skin and respiratory system.
Pre-diluted vinegar at 5% acidity	Can be harmful to a person's skin and eyes at high concentrations. The strong odor can be a nuisance to workers.
NaDCC Tablet:	
Solid NaDCC tablet	Concentrated NaDCC tablets or residual dust is hazardous if swallowed or inhaled. The tablets should only be handled while wearing gloves. Special considerations must be taken during disposal, as toxic gases can be created when mixed with an acid. NaDCC tablets also have disposal concerns as they may be harmful to aquatic life and are oxidizing solids.[2] Mixing oxidizers with acids often amplifies the oxidizer's reactivity and can create toxic gases.
Solution generated from NaDCC tablet mixed with water (hypochlorous acid and chlorinated isocyanurates)	This hypochlorous acid and chlorinated isocyanurates solution is very irritating to the eyes and mildly irritating to the skin and respiratory system The chlorinated isocyanurates have low acute oral and dermal toxicity but are very irritating to the eyes, and EPA has placed them in Toxicity Category I

	(indicating the highest level of acute toxicity) for this effect. They are very mild skin irritants and are not considered to be skin sensitizers.[3]

The TURI lab used the P2OASys tool (Pollution Prevention Options Analysis System) to evaluate the potential environmental, worker and public health impacts of the proposed alternatives as compared to those associated with bleach. The P2OASys results suggest that bleach is the most hazardous sanitizer, with a "very high" overall hazard rating, followed by NaDCC tablets and vinegar with a "high" rating, and the Force of Nature system with a "medium" rating. The MondoVAP system received a hazard rating of "low," which makes it the safest option. See the Supplemental Information at the end of this document for more information on P2OASys and the assessment of alternatives.

In terms of chlorine exposure, it is worth noting that high airborne chlorine levels can be an asthma trigger. Using hypochlorous acid solutions, such as those generated by the Force of Nature system, results in lower airborne chlorine levels than using bleach. In addition, the Force of Nature system does not require a highly concentrated source of chlorine--like the NaDCC tablets--to generate an appropriate cleaning solution.



Testing Grid

Results:

Performance Testing

The TURI lab tested the performance of the four alternative sanitizers against the performance of bleach using 1' x 1' samples of plastic that had been hung on the walls in the Fat Moon grow rooms for about a week, until they were visually contaminated (the sheeting was cloudy). They were then removed from the grow rooms and taken to a work area just outside the grow rooms, where the first steps of the performance testing were conducted. The squares were visually observed to establish a baseline of contamination. The following procedures were then administered for each dirty plastic square and then for each section sanitized by the alternatives:

1. A cotton-tipped swab was swiped across the plastic square.
2. The swab was then placed in a sterile neutralizing broth (used to halt activity of any remaining sanitizer).
3. The broth was then taken back to the TURI lab.
4. In the lab, the broth was used to inoculate a sterile petri dish.
5. The dish was then incubated for two days to allow microorganisms to grow.
6. Colonies were then counted on the dish.
7. Squares were sanitized and steps 1 through 6 above were repeated.
8. The percentage of contamination removed was determined by comparing the pre- and post-sanitizing colonies.

The table below shows the testing results.

Performance of Bleach and Alternatives		
Sanitizer	Solution used / ppm free available chlorine (FAC)	Performance: % Reduction of microorganisms
Bleach (household bleach 5% solution)	2 to 5 ml bleach diluted in 1000 ml water (100-200 ppm)	100%
NaDCC tablets	2 tablets in 2000 ml water (2000 ppm)	97.6%
MondoVap 2400	Steam temperature exceeding 220˚F	97.0%

	at generation, but less than 100˚F 9 to 10 inches from the nozzle	
Force of Nature	1 capsule in 0.75 liter water (220 ppm)	73.1%
Vinegar	5% acidity	66.0%

The costs of the alternatives below are based on vendor information obtained in 2019.

Cost of Bleach and Alternatives		
Appliance/ Sanitizer	Notes	Cost for products as commercially available
Bleach	Household bleach ~5% solution	approx. $3/gallon
NaDCC tablets	Two 3.5 gram tablets mixed with 1 quart of water generates a 2153 ppm chlorine solution	approx. $0.65/ tablet
MondoVap 2400		approx. $3,900 capital cost, and cost of water and electricity
Force of Nature	Replace solution every two weeks; 1 capsule makes 12 oz	approx. $90 capital cost, then cost of salts, water, and electricity – approx. $0.80/capsule
Vinegar	Used at 5% dilution	approx. $2/gallon

The MondoVap 2400 steam cleaning machine proved to be very effective, but the $3,900 cost may be prohibitive for a small business like Fat Moon. However, lower-cost steam cleaning machines on the market (ranging from about $40 to $500 depending on the size, sophistication, and attachments) may be more feasible. Because the lab did not test other steam cleaning equipment in this application, TURI cannot verify their effectiveness here; however, the TURI lab has tested other steam cleaning equipment for other applications and can be contacted for those results.

Both Force of Nature and vinegar were significantly less effective than the bleach benchmark. However, with additional scrubbing, their effectiveness could likely be improved. NaDCC emerged as the best combination of safety, performance and cost.

Supplemental Information: Environmental, Health, and Safety Analysis of Alternatives

The TURI lab used the P2OASys tool (Pollution Prevention Options Analysis System) to evaluate the potential environmental, worker and public health impacts of the proposed alternatives as compared to those associated with bleach. The table below shows the results of the P2OASys evaluation in eight categories. Lower "scores" are more desirable. The data boxes colored red below indicate at least one significant hazard in that category. The data used to assess each alternative can be found in the P2OASys database, accessible at p2oasys.turi.org. The most significant environmental, health, and safety concerns (rated as "very high" or "VH") for bleach and each of the alternatives are summarized below.

EHS Evaluation of Bleach and Alternatives					
Category	Bleach (Clorox Regular)	MondoVap System (Water – Steam)	Force of Nature	NaDCC (BruTab 6S, 2,153 ppm)	Vinegar 5%
Acute Human Effects	VH	L	M	VH	H
Chronic Human Effects	H	L	M	M	M
Ecological Hazards	VH	L	L	VH	M
	VH	L	M	H	L

CLEANING LABORATORY EVALUATION SUMMARY

Environmental Fate & Transport					
Atmospheric Hazard	L	L	L	L	L
Physical Properties	VH	L	M	M	VH
Process Factors	VH	VH	H	M	M
Life Cycle Factors	VH	L	M	H	H

In this process, 5% bleach was diluted to generate a low ppm FAC solution. The higher concerns (and higher scores) are based on the undiluted product. Bleach received a rating of VH for acute human effects due to it being especially irritating to the skin, eyes, and respiratory system.3 Also, it is considered an asthmagen and sensitizer, so using this product as a spray application on a regular basis puts workers at an increased risk of asthma and other respiratory illnesses.4 Bleach received a VH for ecological effects as it is considered to be very toxic to aquatic life with long lasting effects.4 The rating of VH for environmental fate and transport was due to bleach slowly breaking down in the environment and the possibility of hazardous degradation products forming in the process.5 Bleach is caustic and corrosive, with a strong odor, which contributed to the rating of VH in the physical properties category.4 The process factor that contributed to the rating of VH was the high exposure potential that could result in the health hazards described. Upstream effects that contributed to a VH rating in life cycle factors relate to the use of hazardous materials that create concerns for air, water or land and require careful handling during disposal. Finally, bleach must be reported to local and state emergency response committees in the event of a spill/emergency.

The MondoVap system received a rating on VH for the process factors category because using steam requires a high temperature (325˚F in boiler; exceeding 220˚F at nozzle tip) and pressure system (operating at 60 psi) which creates a risk of burns. However, the risk of the high-temperature steam actually reaching a worker is low, since the vapor expands rapidly and cools quickly, so at 9 to 10 inches from the nozzle tip the temperature is less than 100˚F.1 Also, the water and energy use weighed heavily in the process factors category. Otherwise, the main chemical ingredient used in this system, water, has very little negative impact on human or environmental health, as indicated by the low ratings shown in the table.

Force of Nature, which relies on common household ingredients (salt, water and vinegar), did not receive a rating of VH in any category. The lower level of concern (and lower scores) result because there is no concentrated chlorine source being used to generate a low ppm FAC solution. The Force of Nature unit requires the purchase of pre- packaged activator capsules to generate the solution for cleaning and sanitizing. Use of hypochlorous acid solutions result in lower airborne chlorine exposures than the use of bleach and therefore lower concerns for asthma.

Although NaDCC tablets and Force of Nature generate the same hypochlorous acid solution, NaDCC tablets are more hazardous because the use of the concentrated NaDCC tablet and the chlorinated isocyanurates. The NaDCC found in BruTabs received a rating of VH in acute human effects because if the tablet is swallowed or comes in contact with skin, or if tablet dust residue is inhaled, it can be dangerous for workers' health and safety, and proper personal protective equipment is required.6 Chlorinated isocyanurates are very irritating to the eyes and considered mild skin irritants.3 The NaDCC received a rating of VH for ecological effects because it is hazardous for the environment and may be toxic to aquatic life.2 NaDCC tablets have disposal concerns as they are oxidizing solids.2 Mixing oxidizers with acids often amplifies the oxidizers reactivity and can create toxic gases. Use of hypochlorous acid solutions results in lower airborne chlorine exposures than the use of bleach and therefore reduces concerns for asthma.

Vinegar received a rating of VH for physical properties because it is a corrosive liquid (pH of 2.6). In addition, vinegar has a strong odor that can be a nuisance to workers exposed to it.

Summary:

Substrates:	Plastic				
Contaminants:	Dirt				
Company Name:	**Product Name:**	**Conc.:**	**Efficiency:**	**Effective:**	**Observations:**
Lab Chem	Sodium Hypochlorite (2-3% w/v)	0.02	100.00	☑	% Reduction of microorganisms
Brulin Corporation	Brulin BruTab 6S	2000 ppm	97.60	☑	% Reduction of microorganisms
Advanced Vapor Technologies LLC	MondoVap 2400	100	97.00	☑	% Reduction of microorganisms
Healthier Cleaning Innovations	Force of Nature	400 ppm	73.10	☑	% Reduction of microorganisms
Acros Organic	Acetic Acid	6	66.00	☐	

					% Reduction of microorganisms

Conclusion:

Implementation

Taking into account the hazard comparison provided using the P2OASys analysis, the results of performance testing, and the relative cost information, the owner of Fat Moon chose to try both the Force of Nature ECA technology and the NaDCC tablets in her process. Because of the potential worker health and safety hazards associated with the use of the NaDCC tablets, and the need to mix tablets with water using personal protective equipment (gloves and protective eyewear), the owner decided not to pursue the use of the NaDCC tablets as a standard practice. The Force of Nature hypochlorous acid generator worked well since the contamination was visibly removed, but because it requires the purchase of pre-packaged activator capsules to generate the solution for cleaning and sanitizing, the owner at Fat Moon looked at a similar product. She identified a product by EcoloxTech which uses the same technology, but users can add their own salt and vinegar to generate the sanitizing solution.

After testing its performance in her grow rooms, the owner continues to use the Ecolox unit and is happy with the results. This system generates a full liter of hypochlorous acid solution at a time, which speeds her process; the salt and vinegar are easy to source; and there is minimal risk for her employees during handling. Ultimately, the owner would prefer a larger system that generates more of the solution at a time.

1 User Guide for MondoVap 2400 (2010), Advanced Vapor Technologies: http://www.naslibrary.com/guides/bm/books/MondoVap.pdf Accessed: April 2, 2020.

2 Sodium dichloroisocyanurate (NaDCC) Safety Data Sheet, Version 6.1, Sigma-Aldrich Inc: St. Louis, MO, February 20, 2020: https://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=US&language=en&productNumber=218928

3 Clorox Bleach-Regular Safety Data Sheet, Reference No. 1534511, The Clorox Company: Oakland, CA, March 6, 2020. https://www.thecloroxcompany.com/wp-content/uploads/2020/03/Clorox-Disinfecting-Bleach_EN2.pdf Accessed: April 2, 2020.

4 Association of Occupational and Environmental Clinics (AOEC). Sodium hypochlorite (bleach). AOEC Exposure code 322.10. Available at: http://www.aoecdata.org/ExpCodeLookup.aspx. Accessed: April 2, 2020.

5 EPI Suite (2020). US EPA Estimation Programs Interface (EPI) Suite™ for Microsoft® Windows, v 4.11. United States Environmental Protection Agency, Washington, DC, USA.

6 BruTab 6S Safety Data Sheet, Version 9.0, Brulin & Company Incorporated: Indianapolis, IN, June 13, 2019: http://bhcinc.com/download/brutab-6s-161021-sdsenglish/?wpdmdl=14597&ind=1585080217050 Accessed: April 2, 2020.