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Family Martial Arts Center Kicks Out Harmful Disinfecting Chemicals While Defending Against COVID-19

"The Force of Nature units are amazing. We use it for everything and won't be using any other chemicals or cleaners."

Len Brassard, Owner, Family Martial Arts Center

Overview

In preparation for reopening their karate studio after being closed for four months in the beginning of the COVID-19 pandemic, the owners of Family Martial Arts Center (FMAC) of Leominster, Massachusetts, needed to identify a reliable source of cleaning and disinfecting products. They knew they needed to increase the frequency of cleaning and disinfecting required to keep their staff and students safe and wanted to ensure that the chemicals they used would not only be effective but would also not expose employees or students to asthmagens or neurodevelopmental hazards. Rather than continuing to buy pre-packaged products, FMAC purchased equipment that could generate safer cleaning and disinfecting solutions on demand, allowing them to maintain business efficiency, promote safety and stabilize access to cleaning products.

The studio facility is a 6,500 square foot open space that has various porous and non-porous surfaces throughout; the surface of the primary practice mat is non-porous, consisting of a vinyl film laminated to a non-woven backing. Before the pandemic, FMAC used packaged chemicals to clean and disinfect mats only at the end of each day.

The owners wanted to reopen with students onsite at the pre-pandemic capacity of five to six classes per day. However, to keep students and workers safe and healthy, FMAC now needed to clean after each class, which increased the frequency from once per day to five or six times per day. Continuing to use their previous cleaning and disinfecting chemicals took too long, which would either have limited the number of classes FMAC could offer in a day or dramatically extended their hours of operation in order to offer the same number of classes. This was not a viable business model for FMAC.

FMAC also had to contend with the difficulty of finding cleaning chemicals during the early months of the pandemic, when high consumer demand triggered a shortage of available chemicals. Finally, safety was also an important consideration; a majority of FMAC's students are under the age of 14, and the owners wished to avoid increasing students' and employees' exposure to chemicals associated with health risks.

An alternate on-demand, technology-based system would allow the employees to more quickly clean and disinfect the mats and other surface areas between each class. Based on performance

testing and using a small business grant from TURI, FMAC chose to purchase two types of technology for cleaning and disinfecting:

- Dry steam vapor units: Steam units are used to rapidly clean and disinfect the practice floor between classes.
- Electrochemical activation ("ECA") units: Electrolyzed water systems create a disinfecting solution in hand-held spray bottles for use on the high-touch areas not accessible by the large steam units, such as the front door, restroom and front-desk area.

Previous Method of Cleaning and Disinfecting

Prior to the pandemic, FMAC used a quaternary ammonium chloride-based product (commonly referred to as a "quat") to clean and disinfect surfaces, and bleach to disinfect areas contaminated by bodily fluids from sickness or injury. The quat product, KenClean Plus, is an EPA-registered disinfectant for non-porous surfaces. The solutions were applied to the exercise mats using a bucket and mop. For other surfaces, the bleach or quat was applied using spray and wipe methods.

This traditional method of cleaning and disinfecting was time-consuming, requiring a 10-minute contact time for the virus destruction (based on vendor-supplied instructions). The overall process of preparing the solutions, applying them to surfaces and maintaining proper contact time could take up to 40 minutes to complete. Prior to the pandemic, mats were cleaned and disinfected with quats only at the end of each day.

Alternative Disinfectants

The major focus of FMAC's reopening plan was to identify a safe, efficient and effective process to clean and disinfect the facility between each class. After consulting with TURI staff, FMAC selected the dry steam vapor system MondoVap®, from Advanced Vapor Technologies. This unit is designed to disinfect almost any surface, both porous and non-porous. The process uses only tap water and needs only seconds to eliminate microbes (bacteria and viruses) from a surface.

Electrochemical Activation (Electrolyzed water)

Electrochemical activation units use electricity to convert salt, water and vinegar into cleaning and disinfecting components. When an electrical current is applied to a salt and water solution, the molecules break apart to form hypochlorous acid (HOCl), a disinfectant, and a small amount of sodium hydroxide, which acts as a light duty cleaner. Some systems use vinegar to lower the pH of the solution to create the needed concentration of hypochlorous acid. This results in only trace amounts of sodium hydroxide and sodium hypochlorite (bleach), both of which would be greater in a higher pH solution.

Dry Steam Vapor

Most chemical disinfectants require surfaces to remain wet over extended periods of time (up to 10 minutes) and tend to leave a residue behind on the surface. For steam units, high temperature vapor effectively destroys many pathogens and has been shown effective on SARS-CoV-2 surrogate viruses. Steam also leaves no chemical residue behind.

In addition, steam vapor can penetrate vertical and horizontal surface pores where chemical disinfectants cannot. And unlike chemicals (especially bleach), steam vapor does not degrade surfaces over time and leaves no biofilm that tends to support/protect future microbial growth. The particular unit used at FMAC also has additional technology designed to increase the effectiveness and eliminate scale deposits.

FMAC was also looking to find a safer option for treatment of high-touch, high-risk areas where use of the steam unit may not be practical. The owners' research and conversations with TURI Laboratory staff led them to select a Force of Nature™ electrolyzed water system. This system uses activator capsules containing salt and vinegar to convert tap water to a disinfecting solution. Using its previous spray and wipe procedures, FMAC is now able to treat doorknobs, light switches, the restroom and the reception area without significantly retraining staff.

The following table shows the main environmental, health, and safety concerns associated with the previous cleaning and disinfecting solutions of bleach and the quat-based disinfectant (KenClean Plus), as well as the new steam and electrochemical activation units. For further comparison, an evaluation using TURI's Pollution Prevention Options Analysis (P2OASys) tool is provided in the Supplemental Information at the end of this document.

Health and Safety Comparison of Pre- and Post-Pandemic Cleaning and Disinfecting Chemicals

Timeframe	Product	Environmental Health and Safety Concerns
Pre-pandemic	Bleach (sodium hypochlorite)	Bleach can irritate 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.
	KenClean Plus (Active ingredients: didecyl dimethyl ammonium chloride and alkyl dimethyl benzyl ammonium chloride)	Quaternary ammonium chloride-based disinfectants can trigger asthma and other respiratory ailments, particularly worsening of existing asthma. Can be corrosive to eyes and skin; concentrated solutions may cause permanent damage. Disposal to surface or groundwater should be avoided due to aquatic toxicity concerns.
Post-pandemic	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. According to the manufacturer, the vapor expands rapidly but cools quickly, and the steam temperature 9 to 10 inches from the nozzle tip is less than 100°F – similar to the temperature of warm water.
	Force of Nature activator capsules (salt and vinegar)	There are no hazards associated with the activator capsules.
	Solution generated from Force of Nature system (water and hypochlorous acid)	Mildly irritating to the skin and respiratory system. Minimal generation of airborne chlorine, which can cause or exacerbate asthma.

Laboratory Performance Testing

After FMAC chose new technologies for its cleaning and disinfecting needs, TURI Laboratory staff tested the disinfection effectiveness of the steam and ECA units.

For virus testing purposes, the TURI Lab used an MS2 bacteriophage as a general viral surrogate for coronaviruses. Bacteriophages are considered good substitutions for viruses because they are safe to use, some of them are structurally similar to human/animal viruses, and they are relatively easy to produce. MS2 bacteriophage is a common and well-studied coronavirus surrogate, making it ideal for virucidal activity screening tests.

The TURI Lab established testing protocols to evaluate the effectiveness of the various chemicals at fixed contact times and concentrations. Because of FMAC's need for a short turnaround cleaning time, each alternative was tested for

one minute or less for this study. For the steam unit, staff were observed while piloting the unit and it was estimated that the contact time was approximately two seconds.

Tested Effectiveness of FMAC's Disinfectants on Surrogate Virus

Product	Active Ingredient	Concentration/ temperature	pH	Contact Time	% Reduction
Bleach	Hypochlorite	0.1% (1000 ppm)	10	1 min	99.9999
KenClean Plus[1]	Quaternary ammonium chlorides	4.2% active ingredients	7	1 min	99.74
Mondovap	Dry steam at Temperature	170 degrees F	7	2 sec[2]	99.76
Force of Nature	Hypochlorous acid	400 ppm	6	1 min	99.9999

[1] KenClean Plus label instructions specify a 10-minute contact time to achieve EPA required disinfection rates.
[2] Seven seconds is the vendor-recommended contact time for the MondoVap system. The two seconds was a close approximation of observed application time at FMAC.

As shown in the table above, the Lab found that the steam system achieved a 99.76% reduction of the MS2 in 2 seconds. To achieve a higher percent reduction, FMAC has instructed their staff to use a longer contact time. If a student or employee tests positive for COVID-19, the vendor-recommended disinfection contact time for SARS-CoV-2 will be used.

Field Testing

Following performance testing in the Lab, the MondoVap and Force of Nature technologies were tested at FMAC to determine the workflow requirements and efficiencies.

FMAC's past cleaning practices required 25 to 40 minutes for cleaning and drying of the practice mat area. Switching to the steam vapor unit reduced the time required to only 10 minutes. With the addition of a second steam unit, the staff further reduced cleaning times to just under 5 minutes. This more streamlined cleaning cycle ensures that FMAC is able to maintain short transition times between classes without sacrificing the safety of its students and teachers. FMAC staff have commented on the significantly faster drying time, the ease of setting up the new equipment, and how the studio feels and smells cleaner compared to pre-pandemic times.

Cost Information

Prior to the COVID-19 pandemic, FMAC did not routinely disinfect surfaces other than the floor mats, which were treated with the quaternary ammonium product at the end of each day. In addition, a few gallon bottles of bleach were used during the year for floor disinfection if it was contaminated with blood or other bodily fluids. Historically, the cost of disinfecting chemicals was approximately $325/year.

Switching to the steam cleaning method has allowed FMAC to continue to offer five to six classes per day during the same hours of operation. They were able to avoid economic impacts associated with loss of income from reducing the number of classes offered or increased costs for paying staff to work longer hours.

Cost of FMAC's Cleaning and Disinfecting

Product	Annual Cost Using New Methods	One-Time Capital Cost
MondoVap	Minimal cost of water and electricity	$3,500/unit – purchased 2
Force of Nature	$240 for capsules (2-3 capsules per week for a solution that lasts 2-3 days, operating 6 days a week)	$50/unit – purchased 2
Totals:	$240	$7,100

FMAC received a TURI small business grant in the amount of $10,000, which covered the capital costs of the new equipment and a supply of Force of Nature tablets to last approximately two years. The new equipment and cleaning process has allowed FMAC to stay open on a pre-pandemic schedule without increasing staff time.

Summary

FMAC's owners felt that they would not be able to hold in-person classes as they had in the past if they kept using their traditional processes of cleaning and disinfecting. The mop and bucket method took too long and left behind chemical residue. Having learned about hazards associated with exposure to residue chemicals, the owners would have then felt obligated to require mat shoes and restrict the students from touching the mat surfaces.

If the new steam and electrochemical activation units had not been identified and purchased for use, FMAC would have had to quadruple its use of the quat product and it would still not have been able to offer the same number of classes as before the pandemic. The longer application and drying times of the old system would have increased time needed for cleaning and disinfecting and would have required more employee hours to operate. FMAC's choice to buy more than one steam unit for between-class disinfection has allowed the facility to maintain their pre-pandemic schedule and still effectively clean the studio.

Based on the lab and field testing of the MondoVap steam unit and the Force of Nature ECA technology, FMAC moved forward with its reopening plan, confident that the process changes would provide a safer studio in terms of both COVID-19 and chemical exposure.

Since the COVID-19 virus can be airborne, FMAC also purchased air filtration units (Avari 600 Electrostatic Air Purifier units) that are designed for large spaces, can capture small particles, and operate at low noise levels. These units were not funded or tested by TURI, but the owners of FMAC decided that a filtration system was an essential part of FMAC's reopening plan.

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 and quats. The table below shows the results of the P2OASys evaluation in eight categories. 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, quats and each of the alternatives are summarized below.

Category	Bleach	KenClean Plus (Quat)	MondoVap (Dry Steam)	Force of Nature (HOCl)
Acute Human Effects	VH	VH	L	M
Chronic Human Effects	H	VH	L	M
Ecological Hazards	VH	VH	L	L
Environmental Fate & Transport	VH	H	L	M
Atmospheric Hazard	L	M	L	L
Physical Properties	VH	M	L	M
Process Factors	VH	H	VH	M
Life Cycle Factors	VH	VH	L	M

L = Low M = Medium H = High VH = Very High

Bleach

The higher concerns are for the undiluted product. The P2OASys analysis is based on a 5% bleach solution (the typical concentration of household bleach). It should be noted that a 5% bleach solution had been diluted to generate a 1000 ppm free available chlorine solution for use at FMAC.

Bleach received a rating of VH for acute human effects—it causes severe skin burns and irritation and eye damage and can cause respiratory irritation. 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. Bleach received a VH for ecological effects as it is considered to be very toxic to aquatic life with long-lasting effects. 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. Bleach is caustic and corrosive, with a strong odor, which contributed to the rating of VH in the physical properties category. The process factor that contributed to the rating of VH was the high exposure potential that could result in the health hazards

TURI developed the Pollution Prevention Options Analysis System (P2OASys) tool to help companies determine whether the toxics use reduction (TUR) options they are considering improve upon their existing process when looking at environmental, health and safety endpoints. By using P2OASys, unforeseen negative environmental, worker or public health impacts may be identified prior to adopting the proposed changes. Potential hazards posed by current and alternative processes identified during the TUR planning process are compared using data endpoints for eight main categories that encompass chemical, physical, psychosocial and environmental hazards. Using both quantitative data and qualitative input, the tool can rate each category based on endpoints that correlate with values, key phrases, Globally Harmonized System of Classification and Labeling of Chemicals (GHS), and other government agencies' designations.

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.

KenClean Plus

This ready-to-use product has an active concentration of 4.2% quaternary ammonium chlorides (didecyl dimethyl ammonium chloride and alkyl dimethyl benzyl ammonium chloride). The analysis is based on information provided in the safety data sheet and several available online EHS databases. The main hazards identified are for inhalation, dermal and eye exposure. This product resulted in very high ratings for acute exposure, including causing severe skin burns and eye damage. For long-term human exposure, concerns include respiratory and skin sensitization and possible endocrine disruption. The active ingredients also showed both acute and chronic concerns for aquatic toxicity. The life cycle concerns are for upstream manufacturing and downstream disposal.

MondoVap

The MondoVap system received a rating of 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. The manufacturer indicates that at 9 to 10 inches from the nozzle tip the temperature is less than 100˚F. 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

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 levels of concern result because there is no concentrated chlorine source being used to generate the hypochlorous acid solution. The Force of Nature unit requires the purchase of pre-packaged activator capsules to generate the solution for cleaning and disinfecting. Use of hypochlorous acid solutions results in lower airborne chlorine exposures than the use of bleach and therefore lower concerns for asthma.

The Toxics Use Reduction Institute (TURI) at UMass Lowell *provides the resources and tools to help Massachusetts companies and communities make the Commonwealth a safer place to live and work. TURI awards grants to businesses, community organizations, and researchers to discover new opportunities to reduce the use of toxic chemicals and to demonstrate technologies to peers. For more information, visit http://www.turi.org or contact info@turi.org, 978-934-3275.*