CLEANING LABORATORY EVALUATION SUMMARY

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ClientType:	Brewery
ProjectNumber:	Project #1
Substrates:	Stainless Steel
PartType:	Part
Contaminants:	Food
Cleaning Methods:	Immersion/Soak
Analytical Methods:	
Purpose:	To assess various chemicals for cleaning and sanitization of brewing equipment

Experimental Procedure:

I. Introduction

Background

Breweries need to both clean and sanitize their vats between batches. Chemicals are used to remove the residue left behind in each step of the brewing process as well as sanitize in preparation for the next batch, leading to potential human exposure to, and environmental release of, harmful chemicals.

Many traditional cleaners and sanitizers may potentially incur more risk to the worker than necessary, which ultimately hurts return on investment in an industry where many small producers have a narrow profit margin. Most of the chemicals used require tremendous amounts of heat and are often applied without a secondary rinse for convenience. Much of the equipment can be sensitive to acidic chemicals, or chlorine-based cleaners, so additional consideration of compatibility must be made based on the particular equipment used in each setup. Because breweries are regulated under the Food Safety Modernization Act, and are classified as Food Plants, certain requirements for Food Safety Plans may apply. These requirements are mainly related to food safety but could require a facility to prepare a sanitation schedule thereby bringing consideration to what chemicals are used for sanitation and leaving space for alternatives.

The laboratory at the Toxics Use Reduction Institute at UMass Lowell (TURI) completed an evaluation of common cleaning and sanitizing chemicals and potential alternatives. Cleaners and sanitizers were tested based on their ability to remove soils accrued in the primary brewing and fermentation processes, as well as to ensure sanitization of the tanks between uses.

About This Report

This document has been prepared to:
1) Provide background information about the use of traditional cleaners and sanitizers in the brewing process
2) Provide technical, financial, environmental, health and safety, and basic regulatory information on alternatives to the traditional cleaners and sanitizers
3) Assist breweries in the process of identifying which alternative(s) offer the best fit for their facility

Information about traditional cleaners and sanitizers is provided in Section II of this report, and the alternatives in Section III, with a comparison of the alternatives in Section IV.

About the Alternatives

The alternatives to the traditional cleaners and sanitizers that are assessed in this report were chosen based on current trends in the cleaning and sanitizing process within the food and beverage sector, and on efforts underway in Massachusetts and across the country to find economically viable and environmentally preferred methods for cleaning and sanitizing brewing vats.

The four cleaning alternatives assessed are:

- LFE Enzymatic cleaner
- Electro-Chemical Activation (ECA) cleaner generated by Force of Nature equipment
- Surface Cleanse 930
- Micro A07

The six sanitizing alternatives assessed are:

- Peracetic acid (PAA)
- ECA sanitizer generated by Force of Nature equipment
- Lactic acid
- Caprylic acid
- Sodium dichloroisocyanurate (NaDCC) tablets
- Ozone

The performance testing was performed in a matrix fashion – pairing each cleaner with each of the sanitizers for each test run. The full testing methodology can be found in Section IV of this report. Below is a brief overview of each of the cleaning and sanitizing alternatives. More detailed information can

be found in Section III of this report. The alternatives were chosen for evaluation to provide a product from four different categories of cleaners using different active or main ingredients. TURI does not endorse any specific product; trade names are used only to make the comparison clearer.

Cleaning Alternatives
LFE Enzymatic Cleaner
LFE Enzymatic cleaner is a commercially available product. The primary ingredients are propylene glycol and alcohols.
Electro-Chemical Activation (ECA)
ECA cleaner is generated via a technology that modifies water by adding a salt and running it through an electrochemical cell. The result is an electrolyzed water which is able to inactivate germs and viruses. The cleaning solution generated is a weak sodium hydroxide solution.
Surface Cleanse 930
Surface Cleanse 930 is a commercially available product, labeled as a concentrated neutral cleaner. The primary ingredient is a polymer with an ether component.
Micro AO7
Micro AO7 is a commercially available product. The primary ingredient is citric acid.

Sanitizing Alternatives
Peracetic acid
Peracetic acid is a sanitizer mainly composed of acetic acid and hydrogen peroxide.
Electro-Chemical Activation (ECA)
ECA sanitizer is generated via the same process as the ECA cleaner, a technology that modifies water by adding a salt and running it through an electrochemical cell. The sanitizing solution generated is a hypochlorous acid and sodium hypochlorite mixture.
Lactic acid
Lactic acid is a natural antibacterial agent often used for de-scaling and an ingredient in disinfecting and sanitizing products.
Caprylic acid
Caprylic acid is a natural agent produced by the distillation of coconut or palm kernel oils.
Sodium dichloroisocyanurate (NaDCC)
NaDCC is a form of chlorine used for disinfection and sanitization purposes, available commercially in tablet form. A hypochlorous acid is generated by dissolving the tablets in water to achieve a desired concentration.
Ozone
Aqueous ozone is a water-based sanitizer. The ozone gas is produced at the point of use in an ozone generator where oxygen is split into atoms and reunited with O2 molecules to form ozone (O3).

Assessing the Alternatives
There are numerous criteria to be considered when assessing the alternatives to traditional cleaning and sanitizing chemicals in the brewing process. This report evaluates the four alternative cleaners and six sanitizers and the ensuing combinations based on the following factors:

- Environmental and human health considerations. Many traditional cleaning and sanitizing agents are bad for the environment and can be dangerous to use, but are the alternatives safer? Key criteria for environmental and human health for brewery cleaning and sanitizing operations are provided. To evaluate the EHS considerations for the baseline chemicals and alternatives considered, the TURI Pollution Prevention Options Analysis System (P2OASys) tool was used. P2OASys is a hazard assessment tool that uses both quantitative and qualitative data to identify potential hazards posed by current and alternative processes. P2OASys houses 150 endpoints for eight main categories that encompass chemical, physical, psychological and environmental hazards. There are several subcategories that are used to rate each main category based on endpoints that correlate with values, key phrases, Global Harmonizing System (GHS) classifications, and other government agencies' designations. Final scores range from 2 to 10, with the lower score being more desirable. The P2OASys analysis results presented in this report reflect data input by the TURI lab staff using their professional judgment. More details can be found in Appendix A of this report.
- Performance considerations. For cleaning, lab staff determined how much of the contaminants were removed using gravimetric analysis. For sanitizing, lab staff determined if any microorganisms remained after sanitizing by measuring actively growing microorganisms through detection of adenosine triphosphate (ATP).
- Financial considerations. These considerations include capital investment (the cost of any new equipment needed to generate cleaning or sanitizing solutions) as well as the cost of commercially available cleaning or sanitizing solutions.
- Regulatory and safety considerations. Basic information is presented on what regulatory issues a brewer should consider when choosing a cleaner or sanitizer. Safety considerations are included in the P2OASys physical characteristics category.

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Brewing vats

Results:

II. Description of Traditional Cleaning and Sanitizing Processes
This section of the report provides baseline information on the most prevalent types of cleaners and sanitizers in the brewing industry today, based on conversations with brewers in Massachusetts and chemical vendors. The specific products chosen are meant to represent categories of cleaners that contain different types of active ingredients. The information presented here is used as a baseline in this alternatives assessment to compare the four alternatives to traditional cleaners and six alternatives to traditional sanitizers in the following two sections of the report.

Technical Information
Chemistries
Cleaning: Current chemistries used in the cleaning process include products like Powdered Brewers Wash (PBW), Veracity Caustic Cleaner (Veracity), or Liquid Metal Safe (LMS). All three of these baseline cleaners were tested as part of this alternatives assessment.

Table 1: Key Ingredients of Baseline Cleaners

Cleaner	Key Ingredients
PBW	Sodium Tripolyphosphate (15-40%) Sodium Metasilicate (15-40%) Sodium Percarbonate (10-30%) Poly(itaconic acid, sodium salt) (7-13%)
Veracity	Sodium Hydroxide (10-30% Propylene Glycol (3-7%) Sodium Gluconate (1-5%)
LMS	Sodium Silicate (10-30%) Sodium Hydroxide (3-7%) Tetrasodium EDTA (1-5%)

Sanitizing: Current chemistries used in the sanitization process include products such as Star San; this product was used as the baseline for the sanitizers tested for this report.

Table 2: Key Ingredients of Baseline Sanitizer

Sanitizer	Key Ingredients
Star San	Phosphoric Acid (50%) Dodecylbenzene Sulfonic Acid (15%) Isopropyl Alcohol (10%)

Equipment and Processes
The current cleaning and sanitizing process at most breweries is a clean-in-place (CIP) process. This means that the chemicals are pumped into the vat and recirculated through a spray ball for a certain amount of time, ensuring that the chemicals reach all surface areas inside the vat. The chemicals are then gravity-drained through the bottom of the vat and discharged to a drain.

Performance
The current cleaning and sanitizing process is fairly standard across the industry. Though chemistries may differ in trade name and processes may vary somewhat due to size and throughput, essentially the brewing vats are cleaned and sanitized in a similar fashion from brewery to brewery. Small facilities tend to learn from other larger facilities how to clean and sanitize, therefore simply passing along what works.

Waste Management
Waste from the cleaning and sanitizing process is discharged to the drains in the breweries. Small facilities discharge to their local publicly owned treatment works (POTW) while larger facilities may have their own wastewater pre-treatment system on site. It is important for the breweries to work with their local POTWs to make sure they are in compliance with discharge requirements; however, these requirements usually tie to biological rather than chemical discharges from the brewing process.

Financial Information
The costs of the traditional cleaning and sanitizing process are the costs of the chemistry. Below are some typical costs for the cleaners and sanitizers TURI used as baselines.

Table 3: Costs for Baseline Cleaners/Sanitizers

Product	Cost/Unit

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Cleaners	
PBW	$7 per lb. with dilution of 1-2 oz. per gallon of water
Veracity	Distributed by Alpha Chemical – contact for costs
LMS	Distributed by Alpha Chemical – contact for costs
Sanitizer	
Star San	$23 for 32 oz. with dilution of 1 oz. per 5 gallons of water

Environmental, Health and Safety Information
While the traditional cleaners and sanitizers work well for their intended purposes, their toxicological footprint is also significant. The environmental, health, and safety profiles are presented below. The data in the tables comes from the TURI P2OASys tool, which provides a comparison analysis between the various traditional cleaners used as a baseline in this analysis. The data inputted to the P2OASys tool to generate a score for each cleaner is based on a set of databases (as detailed in Appendix A) and professional judgment of the TURI lab staff. The raw data that was used to roll up into the ratings presented here is found in Supplement 1 of this report as well as in P2OASys. The ratings are meant to provide a basis for comparison between products. The products earning a rating of "very high" concern are explained below each of the tables.

Table 4: Summary of Health Effects Associated with Baseline Cleaners

P2OASys Category	Powder Keg	Veracity Caustic Cleaner	Liquid Metal Safe
Acute Human Effects	VH	VH	VH
Chronic Human Effects	H	VH	H
Ecological Hazards	M	H	L
Environmental Fate & Transport	M	VH	M
Atmospheric Hazard	L	L	L
Physical Properties	H	VH	VH
Process Factors	M	H	H
Life Cycle Factors	L	H	H
Product Rating	*M*	*H*	*M*

Explanation of "very high" product ratings:

- Powder Keg received a rating of VH for acute human health effects due to its inhalation and oral toxicity. This cleaner can be harmful if it is ingested and may cause breathing difficulties. In addition, exposure may result in irritating effects to the skin and eyes.[1]
- Veracity Caustic Cleaner received a rating of VH for acute human health effects as it is harmful if ingested or inhaled. Due to its caustic nature exposure may result in respiratory irritation and irreversible skin burns and eye damage. Workers who are exposed to this cleaner for long periods of time may develop respiratory sensitivity, allergy, or asthma symptoms. Veracity received a VH rating in chronic human effects due to this risk of irreversible damage to organs through prolonged or repeated exposure. Veracity's bioaccumulation potential weighed heavily in the environmental fate and transport category and resulted in an overall rating of VH. Lastly, Veracity's highly caustic and corrosive characteristic played a major role in the rating of VH for physical properties.[ii]

[1] Powder Keg, Safety Data Sheet (2014), Alpha Chemical Services, Inc.

[ii] Veracity Caustic Cleaner, Safety Data Sheet (2020), International Products Corporation.

- Liquid Metal Safe received a VH rating for acute human effects due to the risk of irreversible skin burns and eye damage from short-term exposure. Liquid Metal Safe is a strong acid and mildly corrosive which contributed to a higher rating of VH for physical properties.[i]

Table 5: *Summary of Health Effects Associated with Baseline Cleaners*

P2OASys Category	Star San
Acute Human Effects	VH
Chronic Human Effects	H
Ecological Hazards	H
Environmental Fate & Transport	H

Atmospheric Hazard	M
Physical Properties	VH
Process Factors	H
Life Cycle Factors	H
Product Rating	*H*

Explanation of "very high" product rating:

- Star San received a rating of VH for acute human health effects as it is harmful if inhaled, swallowed, or comes in contact with skin. Also, exposure may result in irritating effects to the eyes, skin, and respiratory system. Hazards of concern that led to a rating of VH in physical properties include high corrosivity and acidity. Star San is also considered a combustible liquid.[ii]

[i] Liquid Metal Safe, Safety Data Sheet (2018), Alpha Chemical Service, Inc.

[ii] Star San, Safety Data Sheet (2015), Five Star Chemicals & Supply, Inc.

Regulatory Information

Traditional cleaners and sanitizers have high or low pHs by their nature – making them strong acids or bases and more hazardous than more neutral products. Breweries typically discharge to their local POTW or in-house pre-treatment plants. Breweries should check with their local POTW to determine their discharge limits, if any, that relate to their chemical discharges. Workers handling the chemicals should follow all OSHA handling requirements as noted on the product Safety Data Sheets (SDS). All other guidelines on the SDS should be reviewed and adhered to as well.

III. Description of Alternatives for Cleaning and Sanitizing at Breweries

Introduction

In 2016, TURI began exploring alternative chemistries for cleaning and sanitizing at Merrimack Ales in Lowell, Massachusetts. The brewery was just opening and was interested in learning about safer alternatives. ECA technology was tested for both cleaning and sanitizing, and NaDCC tablets were tested for the sanitizing step. After that work concluded in 2018, TURI decided to perform lab testing on a larger suite of alternatives for both cleaning and sanitizing to generate consistent lab data that could be shared with breweries across Massachusetts and the rest of the country.

This section provides detailed descriptions of four alternatives for cleaning and six alternatives for sanitizing at breweries. These alternatives are listed as either a category or specific product. If a specific product is listed it is only meant to represent a larger category that use a typical active ingredient. TURI does not endorse any specific product or process over another.

Cleaning:

- LFE Enzymatic cleaner
- Electro-Chemical Activation (ECA) cleaner generated by Force of Nature equipment
- Surface Cleanse 930
- Micro A07

Sanitizing:

- Peracetic acid (PAA)
- ECA sanitizer generated by Force of Nature equipment
- Lactic acid
- Caprylic acid
- Sodium dichloroisocyanurate (NaDCC) tablets
- Ozone

Like the description of traditional cleaners and sanitizers in Section II, each alternative is described in terms of technical, financial, environmental, health and safety, and regulatory factors. The reader can find the Safety Data Sheets in Supplement 2 to this report for additional information on the solvent ingredients.

Cleaners

LFE Enzymatic Cleaner

LFE Enzymatic Cleaner is a CIP cleaner for cleaning fruit juice and other food contact surfaces. Enzymatic-microbial cleaners contain blends of naturally occurring and nonpathogenic microbes that inhibit a

bioremediation process. The cleaning chemistry cleans the desired area and the microbes breakdown the grease, oils, and any other contaminants that were removed from the soiled surface. The cleaning chemistry can

vary between enzymatic cleaners; the cleaner evaluated in this assessment contains propylene glycol and alcohols as the active ingredients.

Electro-Chemical Activation

Electro-chemical activation is a technology which generates a cleaning solution by running water through an electrochemical cell. With the proper voltage, the water is electrolyzed or "activated," which is then capable of killing germs and viruses. ECA allows for the user to generate two cleaning solutions on-site. The first is a detergent called catholyte, which is a weak sodium hydroxide solution of approximately 400 ppm and with a pH of greater than 11.4. The second is a sanitizer or anolyte, which is a hypochlorous acid and sodium hypochlorite mixture with a pH of 6.8 and a free available chlorine concentration of about 190 ppm. Switching to the ECA cleaning process would require the purchase of new equipment. ECA equipment comes in a variety of sizes – from home units that generate only liters at a time to wall- or skid-mounted units installed at a facility that can generate many gallons at a time. The unit tested for this analysis is called Force of Nature and is the size of a home unit.

Surface Cleanse 930

Surface Cleanse 930 is considered a neutral aqueous cleaner. The mixture of nonionic surfactants allows for Surface Cleanse to be used on various substrates and delicate materials without the risk of surface damage. It can be used in hard and soft water and for many different cleaning processes including CIP, immersion, ultrasonic, and more. Surface Cleanse could be used as a ready-made cleaning product.

Micro A07

Micro A07 is an acidic aqueous cleaner consisting of a blend of anionic surfactants and chelating citric acid. Micro A07 is suitable for most hard surfaces and can be used to clean a variety of contaminants. It can be used for various cleaning processes, including CIP. This cleaner is non-corrosive and does not contain solvents, phosphates, silicates, or phenols. Micro A07 could be readily implemented into existing processes and would not require the user to purchase new cleaning equipment.

Sanitizers

Peracetic acid (PAA)

Peracetic acid is an organic peroxide mixture of acetic acid and hydrogen peroxide in a stabilized solution. The hydrogen peroxide assists in stabilizing the PAA and adds oxidation capacity to the entire solution. PAA is a very effective biocide and is capable of eliminating a broad range of microorganisms, including yeast, spores, coliforms, and food spoilage organisms. It can also operate at a range of temperatures varying from 40˚F to 104˚F and can be used in numerous applications. The United States Environmental Protection Agency has approved PAA for circulation cleaning and industrial sanitizing of equipment such as fillers, tanks, evaporators, aseptic equipment, and pipelines, and for sanitizing previously cleaned food contact surfaces of equipment. PAA is readily degradable, but has a strong, pungent odor.

ECA sanitizer generated by Force of Nature equipment

As noted above, ECA technology generates a second stream, which is a hypochlorous acid and sodium hypochlorite mixture. Therefore, ECA equipment could be used to generate a cleaner, a sanitizer, or both.

Lactic acid

Lactic acid is an organic acid that can be used in a variety of applications and on various surfaces as an antimicrobial solution. At the highest level of purification, lactic acid is a colorless and odorless liquid. Lactic acid would not require the purchase of new equipment and could be used with the existing CIP process.

Caprylic acid

Caprylic acid, also called octanoic acid is an organic saturated fatty acid and antimicrobial pesticide used in the commercial food and beverage industry as a food contact surface sanitizer. Caprylic acid can be used in CIP processes and would not require any new equipment.

Sodium dichloroisocyanurate (NaDCC) tablets

NaDCC is a form of chlorine used for disinfection and sanitization. Effervescent tablets are commercially available in different NaDCC concentrations, to allow for the user to generate different strengths of cleaners or sanitizers at a time depending on the desired application. When the NaDCC tablet is added to water, it produces hypochlorous acid and chlorine isocyanurates, which provide a "reservoir" of additional hypochlorous acid. The hypochlorous acid reacts through oxidization with microorganisms and ultimately kills them. NaDCC tablets can be used in CIP processes and would not require any new equipment. NaDCC tablets are also very stable and have a long shelf life.

Ozone

Ozone has been approved as an antimicrobial food additive by the FDA, USDA, USDA Organic, FISI, OSHA, and EPA. Aqueous ozone has many sanitizing capabilities and is able to break down molds, mildews, and bacterial biofilms, and reduce the levels of oils, fats, and greases from food-contact and non-contact surfaces. Ozone gas is produced using a device called an ozone generator. Using electricity and oxygen-enriched feed gas, the ozone generator has the ability to split oxygen molecules into two oxygen atoms. Ozone can then be produced after the oxygen atoms unite with other oxygen molecules. Ozone can be used as a gas or dissolved in water for targeted operations such as surface sanitation. Using ozone would require some equipment or facility modifications, since the aqueous product is typically hard-piped into existing sanitation lines for a centralized system.

IV. Comparison of Baseline Cleaners and Sanitizers to Alternatives

This section compares traditional cleaners and sanitizers to the four alternative cleaners and six alternative sanitizers in four categories of criteria:

- Environmental and human health impacts
- Technical performance
- Financial factors
- Regulatory and safety considerations

Tables listing the alternatives and assessment criteria are provided to facilitate comparisons. This information is also summarized in Section I of this report.

Environmental and Human Health Comparison

A primary concern for brewery workers is exposure to the cleaning and sanitizing chemicals, which happens during materials management. Hazards can include inhalation, skin burns, and eye irritation.

Below is the table of P2OASys results for the four cleaning alternatives and six sanitizer alternatives tested. The ratings in the table are generated from the TURI lab P2OASys tool as described in Appendix A and using professional judgment. The ratings provide a relative comparison between products. Any ratings of “very high” (VH) are explained in the text following the table.

Table 6: *EHS Evaluation of Cleaning Alternatives*

P2OASys Category	LFE Enzymatic Cleaner	ECA cleaner	Surface Cleanse 930	Micro A07
Acute Human Effects	M	M	M	H
Chronic Human Effects	H	M	L	M
Ecological Hazards	H	L	L	L
Environmental Fate & Transport	M	M	M	M
Atmospheric Hazard	L	L	L	M
Physical Properties	H	M	M	H
Process Factors	M	H	M	M
Life Cycle Factors	M	M	L	L
Product Rating	*M*	*M*	*L*	*M*

None of the four cleaning alternatives earned a rating of VH in the P2OASys evaluation.

Table 7: *EHS Evaluation of Sanitizing Alternatives*

P2OASys Category	PAA Sanitizer (Spartan FP)	ECA Sanitizer	Lactic acid (88%)	Caprylic Acid (99%)	NaDCC Tablets	Ozone
Acute Human Effects	VH	M	VH	VH	VH	VH
Chronic Human Effects	VH	M	L	M	M	M
Ecological Hazards	M	L	L	M	VH	H
Environmental Fate & Transport	H	M	M	M	H	M
Atmospheric Hazard	L	L	L	L	L	H
Physical Properties	VH	M	H	VH	M	VH
Process Factors	VH	H	M	H	M	H
Life Cycle Factors	VH	M	L	H	H	H
Product Rating	*H*	*M*	*M*	*M*	*H*	*H*

Explanation of "very high" product ratings:

- The **PAA** product received the least desirable P2OASys evaluation, with five categories rating VH. PAA received a VH for acute human health effects due to it being harmful if inhaled or swallowed. Also, PAA is corrosive and exposure can result in skin burns, respiratory irritation and possible irreversible eye damage. The American Conference of Governmental Industrial Hygienists has established a short term exposure limit (STEL) of 1.24 mg/m^3 (0.4 ppm) to protect workers against irritation of eyes, skin, and the upper respiratory tract, which also contributed to the high rating in acute human effects.[i] PAA received a VH rating for chronic human health effects because it is considered a respiratory sensitizer and asthmagen as noted by the Association of Occupational and Environmental Clinics (AOEC). [ii] PAA is a flammable liquid, highly acidic, and corrosive which lead to it receiving a rating of VH for physical properties.[iii] PAA received a rating of VH in process factors because of the hazards associated with working with this cleaner and the potential risks to workers' health and safety. Life cycle factors was also rated VH because the process requires the use of hazardous materials that creates concern for water, air, land and it must be carefully disposed of.
- The **ECA** sanitizer, which relies on common household ingredients (salt, water and vinegar), did not receive a rating of VH in a single category. The ECA sanitizer requires the purchase of pre-packaged salts (including salt and vinegar) to generate the solution for cleaning and sanitizing. While airborne chlorine from the hypochlorous acid at 220 ppm FAC (free available chlorine) is associated with asthma, the exposure is expected to be much lower than for the higher FAC NaDCC solutions.
- **Lactic acid** received a VH rating for the acute human health effects category due to the risk of irritating effects to skin and eyes if exposed.[iv]

Caprylic acid received a VH for acute human health effects because it may cause breathing difficulties if inhaled and may be harmful when in contact with skin. Also, it is harmful if ingested and exposure may

[i] ACGIH® (American Conference of Governmental Industrial Hygienists) (2016). Annual TLVs® (Threshold Limit 4 Values) and BEIs® (Biological Exposure Indices) booklet. Cincinnati, OH: ACGIH® Signature Publications.

[ii] Association of Occupational and Environmental Clinics (AOEC). Peracetic acid. AOEC Exposure code 050.42. Available at: http://www.aoecdata.org/ExpCodeLookup.aspx. Accessed: June 1, 2020.

[iii] PAA Sanitizer, Safety Data Sheet (2019), Spartan Chemical Company, Inc.

[iv] Lactic acid, Safety Data Sheet (2020), Sigma-Aldrich Inc.

- result in irritating effects to the skin and eyes. Caprylic acid is acidic and has a pungent or irritating odor, which contributed to a rating of VH for physical properties.[i]

Although **NaDCC tablets** and the ECA technology generate the same hypochlorous acid solution, NaDCC tablets are more hazardous because of the use of the concentrated NaDCC tablet and chlorinated isocyanurates. The concentration of free available chlorine is much higher for the solution generated from NaDCC tablets, at approximately 1076 ppm. The NaDCC received a rating of VH in acute human effects

because if the tablet is swallowed or comes in contact with skin, or dust residue is inhaled, it can be dangerous for workers' health and safety, and proper personal protective equipment is required. Chlorinated isocyanurates are very irritating to the eyes and considered mild skin irritants.[ii] The NaDCC received a rating of VH for ecological effects because it is hazardous for the environment and may be toxic to aquatic life. NaDCC tablets have disposal concerns as they are oxidizing solids.[iii] Mixing oxidizers with acids often amplifies the oxidizers' reactivity and can create toxic gases

[i] Caprylic acid, Safety Data Sheet (2020), Sigma-Aldrich Inc.

[ii] US EPA 1992. Chlorinated Isocyanurates, Registered Eligibility Document (RED) Facts, EPA-738-F-92-010, Office of Prevention, Pesticides and Toxic Substances (7508W): https://archive.epa.gov/pesticides/reregistration/web/pdf/0569fact.pdf

[iii] Sodium dichloroisocyanurate (NaDCC), Safety Data Sheet (2020), Sigma-Aldrich Inc.

- Ozone received a rating of VH in acute human effects because it may cause breathing difficulties and may be harmful if swallowed. Also, exposure may result in irritating effects to the skin and eyes. Ozone has a very low permissible exposure limit (PEL) of 0.1 ppm which largely contributed to the overall rating of VH for acute human effects.12 Physical properties that led to an overall rating of VH for ozone were pH, reactivity, and its pungent or irritating odor.

Technical Performance Comparison

In order to evaluate the efficacy of the cleaners and sanitizers, performance testing was conducted at the TURI laboratory. The key technical parameter for cleaning is to ensure that all beer residue is removed. This is especially important because a sanitizer will perform the best when the surface is free of residue or buildup. The key technical parameter for sanitizing is to ensure the surface is free of biological residue.

Laboratory Performance Testing

To simulate real-world cleaning, for the testing substrate, the TURI lab used 2"x4" stainless steel coupons of the same type (304 and 316 stainless steel) that many beer vats are made of. A beer sludge originating from a porter-style brew was provided by a brewer. The sludge was received from the trub of the brew, which came at the end of the brew kettle process. The trub is the leftover sludge at the bottom of the brew kettle after boiled product has been transferred to the fermenter. This leftover sludge and sediment mixture was used to represent hard-to-remove soils in the brewing process.

Gravimetric analysis was used to determine the cleanliness of coupons. Coupons were weighed and then soiled with the beer sludge. Using a swab, the beer mixture was applied to one side of the coupons and then baked in an oven at 140˚F for one hour to simulate the buildup of beer inside the vat. After the coupons were allowed to cool, they were weighed again to obtain the weight of the contaminant. The first step in the cleaning process was to pre-rinse all the coupons. For each cleaner, 21 coupons were used, and separated into groups of three. To pre-rinse, the coupons were fully immersed in a beaker of room-temperature tap water with a stir bar for 15 minutes. Coupons were then cleaned in sets of three, fully immersed in a beaker with a stir bar, using the recommended parameters for each cleaner listed below.

Table 8: *Testing Parameters for Cleaners*

Product	Temp ˚F	Time (Min.)	Dilution
Baseline Cleaners			
Powder Keg	125	30	2 oz. per gallon (14.75 mL per 950 mL of water)
Veracity Caustic Cleaner	125	30	2 oz. per gallon (14.75 mL per 950 mL of water)
Liquid Metal Safe	125	30	2 oz. per gallon (14.75 mL per 950 mL of water)
Alternative Cleaners			
LFE Enzymatic	125	30	2 oz. per gallon (14.75 mL per 950 mL of water)
ECA (Cleaning Level)	68	30	1 capsule for 12 oz.
Surface Cleanse 930	110	30	1-2% dilution
Micro A07	150	30	1-2% dilution

To test the efficacy of the sanitizers, adenosine triphosphate (ATP) monitoring was conducted using a handheld ATP meter. The ATP test rapidly measures actively growing microorganisms. Immediately after

cleaning, one coupon per set was swabbed for ATP analysis. After drying for 24 hours, the coupons were weighed for a final clean weight. Each set of three was then sanitized with a different sanitizer using the recommended parameters listed below.

Table 9: *Testing Parameters for Sanitizers*

Product	Temp ˚F	Time (Min.)	Dilution
Baseline Sanitizer			
Star San	68	2	1 oz. per 5 gallons
Alternative Sanitizers			
Peracetic Acid	68	1	1 oz. per 5 gallons
ECA (Sanitizing Level)	68	10	Sanitizing level - 1 capsule
Lactic Acid	68	2	1 oz. per 5 gallons
Caprylic Acid	68	2	1 oz. per 5 gallons
NaDCC tablets (Sanitizing Level)	68	10	1 tablet per gallon
Ozone	68	10	1.5 – 2 PPM of ozonated water

Immediately after sanitizing, one coupon per set was swabbed for ATP analysis again.

Table 10: *Gravimetric Results for Cleaners*

Cleaner	Overall Average % Soil Removal After Cleaner
Baseline Cleaners	
Powder Keg	92.22
Veracity Caustic Cleaner	96.87
Liquid Metal Safe	97.77
Alternative Cleaners	
LFE Enzymatic	79.77
ECA (Cleaning Level)	92.67
Surface Cleanse 930	98.15
Micro A07	97.20

Gravimetrically, Surface Cleanse 930 performed the best at removing sludge from stainless steel coupons, with a 98% removal. LFE Enzymatic cleaner was the least effective, with a 79% removal. LFE Enzymatic also required a rinse step after cleaning, as it left a residue on the coupons. After rinsing with 130˚F tap water for fifteen minutes, the residue was removed. The average percentage was taken after the rinse step.

ATP Analysis Results

ATP threshold guidelines for general food processors recommend pass/fail limits be determined by the facility, but default levels are 0-10 RLU (relative light units) for a pass reading, 11-30 for a caution reading, and greater than 31 as a fail reading.

Table 11: *Results of ATP Analysis*

	Baseline Sanitizer		Alternative Sanitizers											
	Star San		Peracetic Acid		ECA (Sanitizing Level)		Lactic Acid		Caprylic Acid		NaDCC (Sanitizing Level)		Ozone	
	ATP C*	ATP S*	ATP C	ATP S	ATP C	ATP S	ATP C	ATP S	ATP C	ATP S	ATP C	ATP S	ATP C	ATP S
Baseline Cleaners														

Powder Keg	0	0	0	0	0	0	0	0	0	1	5	0	0	3
Veracity	0	1	0	2	0	0	0	10	1	0	0	5	0	0
Liquid Metal Safe	1	2	1	2	0	0	1	3	1	0	0	2	0	1
Alternative Cleaners														
LFE Enzymatic	1	2	0	0	0	0	1	3	1	0	0	2	0	1
ECA (Cleaning Level)	0	0	0	0	1	2	0	0	0	0	0	1	0	0
Surface Cleanse 930	2	3	0	0	0	0	0	0	0	0	0	0	0	0
Micro A07	0	1	0	1	0	0	0	0	0	0	0	1	3	1
* ATP C: ATP reading after cleaning. ATP S: ATP reading after sanitizing.														

All of the sanitizers were effective, with ATP readings of 10 or less. Lactic acid had the highest but still a passing ATP reading of 10. ECA produced the most effective ATP readings with almost all zeros, except for when it was used together as both a cleaner and sanitizer.

Financial Comparison

It is important that not only the new cleaning product or system clean well, but also that it is affordable. Costs for switching to an alternative cleaning product or technology can vary greatly depending on facility needs. The tables below shows a cost comparison of the baseline cleaners and sanitizers to alternatives. These costs displayed are vendor-supplied, and prices may vary.

Cleaners

Sample costs of chemistries and raw materials for cleaners are listed in the table below.

Table 12: *Summary of Cost for Cleaners*

Product	Quantity	Cost
Baseline Cleaners		
Powder Keg	50-55 gallon drum	$850 - $1,050
Veracity Caustic Cleaner	50-55 gallon drum	$575 - $650
Liquid Metal Safe	50-55 gallon drum	$450 - $550
Alternative Cleaners		
LFE Enzymatic	50-55 gallon drum	$2,100 - $2,735
ECA (Cleaning Level)	Large unit (>6 L/min) to generate varying rates of solution Small unit (4-6 L/min) to generate varying rates of solution	$6,000 - $10,000 $500 - $3,000
Surface Cleanse 930	200 kg net wt. plastic drum	$2,190
Micro A07	225 kg net wt. plastic drum	$1,606

The capital cost of switching to a new cleaning system such as the ECA device can range from several hundreds of dollars to several thousand depending on the size and amount needed. However, brewers may find that after the up-front costs are covered, they will be saving money on cleaning products, since now they have to purchase only the salt or premixed activator capsules depending on device requirements.

Sanitizers

Sample costs of chemistries and raw materials for sanitizers are listed in the table below.

Table 13: *Summary of Cost for Sanitizers*

Product	Quantity	Cost
Baseline Sanitizer		
Star San (.16%)	55-gallon drum	$1,883
Alternative Sanitizers		
Peracetic Acid (.16%)	55-gallon drum of 15% solution – to be diluted	$1,400
ECA (Sanitizing Level)	Large unit (>6 L/min) to generate varying rates of solution Small unit (4-6 L/min) to generate varying rates of solution	$6,000 - $10,000 $500 - $3,000
ECA Activator Capsules (if required; some units use only table salt and vinegar)	50	$40
Lactic Acid (.16%)	Contact vendors for sizing	Contact vendors for pricing
Caprylic Acid (.16%)	Contact vendors for sizing	Contact vendors for pricing
NaDCC tablets (Sanitizing Level)	Tub of 256 tablets	$150
Ozone	Units producing from 1 to 100 gpm at 2ppm	$8,000 - $48,000

The capital cost of switching to a new sanitizing system such as an ozone generator can range from several hundreds of dollars to several thousand depending on the size and amount needed. Typically the ozone generator is hard-piped into the existing sanitization lines, but there are also mobile units available. After the initial upfront cost, there are many opportunities for savings, as ozone is produced on-site, eliminating the need to buy, store, handle, or dispose of chemicals.

Regulatory and Safety Considerations

Many of the alternatives to traditional cleaners and sanitizers have material handling and discharge considerations. Breweries typically discharge to their local POTW or in-house pre-treatment plants. Breweries should check with their local POTW to determine their discharge limits, if any, that relate to their chemical discharges. Workers handling the chemicals should follow all OSHA handling requirements as noted on the product SDSs. All other guidelines on the SDSs should be reviewed and adhered to as well.

Summary:

Substrates:	Stainless Steel				
Contaminants:	Food				
Company Name:	**Product Name:**	**Conc.:**	**Efficiency:**	**Effective:**	**Observations:**
No Specific Vendor	Electrolyzed Water		92.67	☑	
International Products Corporation	Surface Cleanse Concentrated Neutral 930		98.15	☑	
International Products Corporation	Micro A07		97.20	☑	

Conclusion:

V. Summary

The alternatives assessed in this report represent technically and economically feasible alternatives to traditional cleaners and sanitizers used in the beer brewing process. The ability of individual facilities to

justify the financial impact of switching to one of the alternatives varies. From a performance perspective, the skill of the facility employees is an important factor to consider when evaluating which alternative satisfies individual facility needs. From a regulatory perspective, the regulations governing the alternatives are no stricter than regulations for traditional cleaners and sanitizers.

The primary differences between the various alternatives are associated with the environmental and human health and safety characteristics of the alternative systems. The most serious health effects associated with cleaning and sanitizing products for brewers are respiratory effects leading to increased risk of asthma, and acute toxicity concerns from handling corrosive concentrates, which can cause permanent eye damage and severe skin burns. The alternative cleaning products discussed in this report would reduce workers' risks to these hazards, since they offer significantly better environmental health and safety profiles in comparison to baseline cleaners. The alternative cleaners have neutral pHs and very minor hazards associated with them. All cleaners except LFE Enzymatic Cleaner performed equally effectively as baseline cleaners. LFE Enzymatic still performed well with almost 80% removal, but required an extra post-rinse step that other cleaners did not.

All of the alternative sanitizers were effective, with ATP readings of 10 RLU or less. The ECA device produced the most effective ATP readings with almost all zeros, and had the most desirable environmental health and safety profile among all the alternative sanitizers assessed. PAA sanitizers are not recommended as safer alternatives and should be used with caution, as they are listed as substances that cause respiratory sensitization leading to asthma, and they pose similar acute toxicity hazards due to their corrosive properties. Surface Cleanse 930 had the greatest overall percent removal compared to baseline and alternative cleaners. When cleaned with Surface Cleanse 930 first, every sanitizer except Star San produced ATP readings of 0.

Capital investment may be another major decision factor for a facility. Small operations like those of local craft brewers and microbreweries may not be able to feasibly invest in a new piece of cleaning or sanitizing equipment.

The following tables summarize the comparison of the alternatives, based on environmental, human health and safety endpoints, technical performance, and financial implications. The key environmental and human health categories shown on this table are considered the most relevant for the cleaning and sanitizing applications at breweries.

Breweries seeking safer alternatives to their existing cleaning and sanitizing chemistry should consider the key environmental and human health criteria initially, and then apply the performance and financial criteria to their individual facilities to determine the best alternative for their facility.

Table 14: *Summary Comparison of Cleaning Baseline and Alternatives*

Key Assessment Criteria		Baseline Cleaners			Alternative Cleaners			
		Powder Keg	**Veracity Caustic Cleaner**	**Liquid Metal Safe**	**LFE Enzymatic**	**Electro-Chemical Activation**	**Surface Cleanse 930**	**Micro A07**
Environmental Human Health	P2OASys rating (L,M,H,VH)	M	H	M	M	M	L	M
Physical Safety	P2OASys primary concern–category with rating of VH	Acute human health effects	Acute & chronic human health effects; environmental fate and transport; physical properties	Acute human health effects & physical properties	No categories rated as VH	No categories rated as VH	No categories rated as VH	No categorie rated as VH
Technical Performance	TURI Lab performance results - % soil removal	92.22	96.87	97.77	79.77	92.67	98.15	97.20
Financial	Capital equipment costs	n/a	n/a	n/a	n/a	Large (> 6L/ min) unit to generate varying rates of solution $6,000-10,000 Small unit (4-6 L/min) to generate varying rates of solution $500-$3,000	n/a	n/a
	Chemical costs	50-55 gal drum	50-55 gal drum	50-55 gal drum	50-55 gal drum		200 kg net wt.	225 kg net wt.

		$850-1,050	$575-650	$450-550	$2,100-$2,735	Cost of salt, water and electricity	plastic drum $2,190	plastic drum $1,606

Table 15: *Summary Comparison of Sanitizing Baseline and Alternatives*

Key Assessment Criteria		Baseline Sanitizer	Alternative Sanitizers					
		Star San	Peracetic Acid	ECA	Lactic Acid	Caprylic Acid	NaDCC Tablets	Ozone
Environmental Human Health Physical Safety	P2OASys rating (L,M,H,VH)	H	H	M	M	M	H	H
	P2OASys primary concern – category with rating of VH	Acute human health effects; physical properties	Acute human health effects; chronic human health effects physical properties; process factors; life cycle	No categories rated as VH	Acute human health effects	Acute human health effects; physical properties	Acute human health effects; ecological effects	Acute human health effects; physical properties
		0 - 3	0 - 2	0 - 2	0 - 10	0 - 1	0 - 5	0 - 3

CLEANING LABORATORY EVALUATION SUMMARY

Technical Performance	TURI Lab performance results – range of ATP readings for all cleaners paired with each sanitizer							
Financial	Capital equipment costs	n/a	n/a	Large unit (>6 L/min) to generate varying rates of solution $6,000-10,000 Small unit (4-6 L/min) to generate varying rates of solution $500-$3,000	n/a	n/a	n/a	Units producing from 1 to 100 gpm at 2ppm $8,000-$48,000
	Chemical costs	55 gal drum $1,883	55-gallon drum of 15% solution $1,400	Cost of salt, water and electricity	Contact vendor for pricing	Contact vendor for pricing	Tub of 256 Tablets $150	Cost of electricity

CLEANING LABORATORY EVALUATION SUMMARY

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References

[1] Powder Keg, Safety Data Sheet (2014), Alpha Chemical Services, Inc.

[1] Veracity Caustic Cleaner, Safety Data Sheet (2020), International Products Corporation.

[1] Liquid Metal Safe, Safety Data Sheet (2018), Alpha Chemical Service, Inc.

[1] Star San, Safety Data Sheet (2015), Five Star Chemicals & Supply, Inc.

[1] ACGIH® (American Conference of Governmental Industrial Hygienists) (2016). Annual TLVs® (Threshold Limit 4 Values) and BEIs® (Biological Exposure Indices) booklet. Cincinnati, OH: ACGIH® Signature Publications.

[1] Association of Occupational and Environmental Clinics (AOEC). Peracetic acid. AOEC Exposure code 050.42. Available at: http://www.aoecdata.org/ExpCodeLookup.aspx. Accessed: June 1, 2020.

[1] PAA Sanitizer, Safety Data Sheet (2019), Spartan Chemical Company, Inc.

[1] Lactic acid, Safety Data Sheet (2020), Sigma-Aldrich Inc.

[1] Caprylic acid, Safety Data Sheet (2020), Sigma-Aldrich Inc.

[1] US EPA 1992. Chlorinated Isocyanurates, Registered Eligibility Document (RED) Facts, EPA-738-F-92-010, Office of Prevention, Pesticides and Toxic Substances (7508W): https://archive.epa.gov/pesticides/reregistration/web/pdf/0569fact.pdf

[1] Sodium dichloroisocyanurate (NaDCC), Safety Data Sheet (2020), Sigma-Aldrich Inc.