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Improved plant cleanliness, productivity, and efficiency through the application of ozone-injected water in plant sanitation processes.

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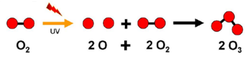
Abstract

Ozone, the tri-atomic form of oxygen (O_3), is a gas that is formed when diatomic oxygen (O_2) is exposed to high voltage electric fields or UV radiation. Ozone is an unstable molecule due to the weak bonds holding the third oxygen atom, making ozone a naturally powerful oxidizing and disinfecting agent. Ozone can be applied in commercial breweries in water purification and wastewater processing as well as a variety of sanitation processes including surface sanitization, clean-in-place (CIP) sanitation of tanks and piping, and bottle and cap rinsing during filling. Our analysis of these applications reveals significant potential for greater plant cleanliness and overall productivity and efficiency. Plant cleanliness is enhanced by the superior oxidizing and disinfecting capabilities of ozone-injected water. Our analysis of the implementation of a cold ozone CIP system in a large bottling plant demonstrated improved microbiological results, significant savings of chemicals and energy, and greater plant efficiency. After installation, ozone CIP was progressively adapted to nearly three-quarters of the typical CIP runs.

Introduction

What is ozone?

- Ozone (O_3) is tri-atomic oxygen formed when energy (electricity or UV) disrupts O_2 molecules.



- Delivers oxidizing power through the generation of hydroxyl free radicals in the decomposition of ozone.

$$O_3 + H_2O \rightarrow O_2 + HO\bullet + HO^-$$

- Most powerful commercially available oxidant

How does ozone kill microbes?

1. *Oxidation*: Breaks chemical bonds which disrupts cell walls. Precipitates suspended molecules.
2. *Disinfection*: Kills bacteria, viruses, molds, cysts, parasites. Effective against all common food borne pathogens.
3. *Decomposition*: Decomposes to oxygen.

Benefits of ozone-based sanitation:

- Powerful oxidant and disinfectant
- Effective against all common food borne pathogens
- Natural compound
- Few undesirable byproducts
- No issues of chemical taste contamination
- Broad application potential
- Regulatory acceptance

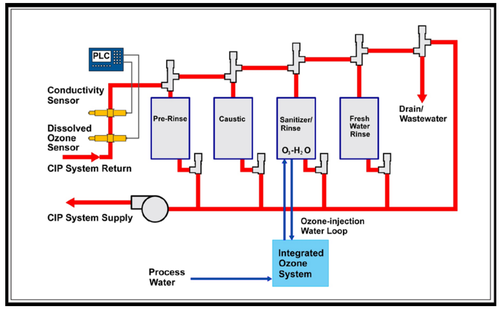
Brewery Applications

- Sanitation: Clean In place (CIP), Clean Out of Place (COP), surface sanitation
- Bottle and cap rinsing
- Water purification
- Wastewater treatment
- Hand sanitation
- General laboratory use

Systems and Equipment

Clean-in-place (CIP) is a method of cleaning the interior surfaces of pipes, vessels, and process equipment, without disassembly. The washing process consists of several cycles in which detergents, caustic, acid, and rinsing material is recycled through the process equipment via an automated system of tanks, valves, pumps, and heart exchangers managed by a programmable controller.

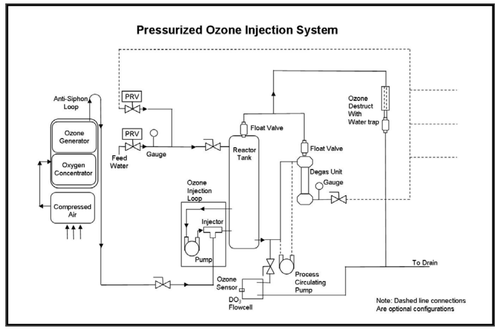
While conventional CIP significantly reduces the time and cost of sanitation compared to manual cleaning, elevated temperatures and chemical detergents are often required for complete effectiveness. As a result, significant amounts of energy and water are consumed in traditional CIP processes.



Ozone-injected water can improve the effectiveness of CIP because it is a very powerful oxidant that works well at reduced temperatures. Conventional high-temperature CIP processes require significant energy and time to ramp the entire system up to the target temperature and cool down at the end of the process. Ozone-injected water can replace chlorinated sanitizers, peracetic acid, and hot water rinse in traditional CIP protocols.

Four basic elements are required to form functional ozone systems:

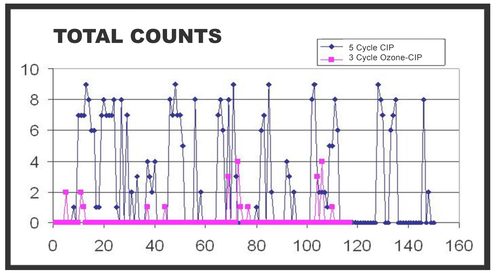
1. Oxygen/Feed Gas Preparation
2. Ozone Generation
3. Ozone Mass Transfer
4. Monitoring and Control



Results

Case Study System:
The results were obtained from pilot studies of an ozone-CIP system in a multi-product beverage processing/bottling plant.

Improved Cleanliness:
Microbiological Results: The total counts for three-cycle ozone CIP are superior to the results for five-cycle chemical CIP.



Improved Efficiency:
Water Savings:

- Ozone rinses and sanitizes simultaneously
- Fewer rinse steps reduce water usage by up to 40%

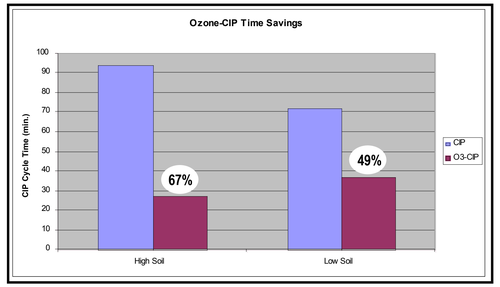
Chemical Savings:
Annual plant chemical savings: $290,000

Energy Savings:

- Annual plant energy savings: $72,000
- Hot water use successfully eliminated
- Less boiler infrastructure. Boiler systems require high maintenance
- Wastewater treatment load and costs also reduced

Time Savings:

- Time savings depends on soil level and protocol used
- Faster turn-around = higher productivity



Improved Productivity:

- Overall plant productivity increased by 4.1%.
- Allows 500,000 additional cases of product to be made annually.

Ozone is a Green Technology:

- Ozone can replace chlorine, hot water, and steam. Saves energy/reduces carbon footprint.
- More powerful in cold water. Reduces need for hot water and steam.
- Conserves water: Reduces rinsing (and chemical) requirements. Reclaims wastewater. Purifies and conditions low-quality source water.

Return on Investment:

- Plant realized annual savings of $425,000.
- Investment cost recovered in 12-18 months.

Design Considerations

Ozone Mass Transfer:
Must be simple and efficient: a venturi plus contacting tank works well.

Controls:
Interface with existing facility/CIP controls.

Facility Layout:
Ozonated water can be pumped directly into existing CIP skid tanks to replace traditional sanitizer.

Distance of Piping:

- Evaluate decay due to system design.
- Monitor ozone levels on return to skid to assure appropriate CT values.

Compatibility of Materials with Ozone:
Compatibility of materials directly exposed to ozone – e.g., pump seals, elastomers, valve seats, plastic components – should be verified.

Ozone Off-Gas Management:
The pressure drop across high energy impinging spray ball heads strips ozone gas out of solution and fill system with high concentration of ozone. This is a benefit for disinfection, but a safety concern. Tanks and lines should be air-purged through a high-capacity ozone destruct device.

Worker Safety:

- Ozone system must include ambient ozone monitoring system with safety interlock.
- Individual ozone monitoring systems for personnel should be considered.

Conclusions

- Existing chemical CIP systems can be easily retrofitted with integrated ozone systems to enhance efficacy and efficiency.
- Ozone-CIP improves plant cleanliness as evidenced by the microbiological results of the pilot study: total counts for three-cycle ozone CIP are superior to the results for five-cycle chemical CIP.
- Ozone-CIP yields significant savings of water, energy, and time. The beverage plant in our pilot study produced annual water savings of 40%, chemical savings of $290,000, energy savings of $72,000, and time savings of 49 to 67 percent.
- Ozone-CIP increases plant productivity by yielding greater profits while minimizing environmental impact. The pilot study revealed a productivity gain of 4%, allowing the bottling of 500,000 cases of additional product annually.
- Ozone-CIP destroys color and odor in the CIP system and leaves no residue to impact product flavor or color in subsequent batch.