Ozone Implementation and Lessons Learned at the Pure Water Monterey Advanced Groundwater Replenishment Facility

John Kenny

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ABSTRACT

Ozone Implementation and Lessons Learned at the Pure Water Monterey, 1 mgd, Advanced Groundwater Replenishment Facility. This would be a story of piloting, full-scale performance, design dose and decay kinetics, and particularly the impact ozone has on TOC in RO permeate. This would also discuss the challenges meeting 0.25 mg/L TOC for the first 3 months as required by CA DDW. This project was key to informing the design of the PureWater Soquel AWPF Project.

PureWater Soquel WPC Background

Denise Funk and Jann Yamauchi

Brown and Caldwell

Abstract

Pure Water Soquel Chanticleer AWPF Background. This potable reuse project is critical to sustain the community's drinking water supply by replenishing the groundwater aquifer. Secondary effluent from the Santa Cruz Wastewater Treatment Facility (WWTF) will be pumped 5 miles to the new Chanticleer AWPF to undergo ozonation followed by MF/RO/UV-AOP prior to injection into the groundwater basin. Ozone is critical to the success of the treatment process due to the high nitrite and TOC levels of this secondary effluent. Nitrite is not completely removed through RO and the process is not fully understood by RO membrane suppliers. Therefore, end of life nitrite rejection can be quite low (less than 90 percent) thereby seriously impacting the UV-peroxide AOP performance. To solve this problem, ozonation will remove nitrite along with oxidizing organics to improve microfiltration flux. Discussion topics will include managing water quality risk, project budget, schedule, and making decisions without pilot testing. This is very much a first-of-its-kind project that implements ozone to manage water quality risk, enhance performance, and make the project viable. Ozone was found to be the most feasible approach based on treatment objectives, cost, footprint and site-specific conditions.

Tuesday, August 16, 2022

Session 1 (1-3) Ozone for Water Reuse in California

Discussion of the Design Criteria of the PureWater Soquel WPC

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Abstract

Discussion of the Design Criteria of the PureWater Soquel WPC. Nick and Denise would discuss a challenge and then have a dialog about the pro's/con's from the perspective of the owner's engineer and the design build contractor. It is a story of working together to arrive at the treatment process of Ozone:MF:RO:UV-peroxide. The presentation will discuss how ozone was eventually added to the process and nitrifying filters and pipeline oxygenation eliminated, why ozone can be dosed to manage nitrite, enhance microfiltration flux, not exceed RO permeate TOC limits and provide risk management for UV-peroxide AOP performance.

Evaluating Southern Nevada's Ozone System to Meet New Cryptosporidium-Based Targets

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ABSTRACT

The 600-mgd Alfred Merritt Smith Water Treatment Facility (WTF) and 300-mgd River Mountain WTF, owned and operated by the Southern Nevada Water Authority (SNWA), provide treated water from Lake Meade to the Las Vegas metropolitan area. Both plants use an ozone-direct filtration treatment process and have been in service for more than twenty years. The ozone process was originally designed to meet a disinfection target of 2-log Cryptosporidium inactivation based on a water industry research study (prior to USEPA regulations) and currently operates with a disinfection target of 0.5-log Crypto inactivation to meet CT requirements under the USEPA Long-Term 2 Enhanced Surface Water Treatment Rule. Ozone system upgrades at both SNWA plants are being planned to meet a design target of 1.5-log Crypto inactivation to prepare for a potential reclassification into Bin 2 of the LT2ESWTR that may result from climate-driven water quality changes in Lake Meade. The CT values for Crypto inactivation are calculated using the extended log integration method. This method provides a more accurate assessment of the ozone residual provide in each ozone contactor, optimizes the ozone dose to meet disinfection goals and reduces bromate formation rates relative to the more conservative Ceffluent method.

This paper will present the results of an ozone system capacity analysis for both plants to meet new Crypto-based disinfection goals through the development of ozone production design envelopes using the extended log integration method. The design envelopes provide a conservative estimate of oxygen feed gas and ozone production requirements over the entire range of plant flows and water quality conditions. The results of this analysis were used to select the optimal capacity and number of ozone generators required to meet both design and operational targets for the oxygen feed gas and ozone generation systems at both plants.

Lessons Learned: 20+ Years of Operational Experience and Next Steps in Casper, Wyoming

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Abstract

The Central Wyoming Regional Water System Joint Powers Board has operated a water treatment plant treating surface water and groundwater under the direct influence of surface water (GWUDI) for the past 23 years using ozone. Ozone is used for the 27 MGD conventional surface water treatment train to provide >0.5-log Giardia and >2.0-log virus inactivation/destruction. Up to 25 MGD of GWUDI, which is treated separately from surface water, is dosed with ozone to provide 4X2-log Giardia inactivation (i.e., enough ozone and contact time to achieve 4-log inactivation twice). Surface water and groundwater ozone disinfection comes from four (three duty + one standby) LOX-feed generators, each rated for 400-lb/day production.

In the decades since the facilities started in 1999, the utility has learned a lot of lessons in ozone system operations. The purpose of this presentation is to share this information with other ozone operators and designers to improve current and future operations at other facilities. One of the lessons is that as the system aged, operations staff turned off the nitrogen feed system without any changes in performance. In addition, the multiple side stream feed pumps were installed as fixed speed units; each discharged 3 MGD regardless of overall plant flow to the distribution system. Installing variable frequency drives will save considerable energy and cost. Finally, staff have developed maintenance strategies to keep the aging units running since replacement parts are no longer available.

The aging equipment, and difficulty in keeping the units running, has led the Board to identify replacement generators. This presentation also provides an overview on how the new ozone generators are being selected, with an emphasis on staff applying their decades of lessons learned in evaluating replacement equipment.

Better with Age: Ozone's History and Path Forward at the Mannheim Water Treatment Plant

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Abstract

Ozone has been an integral treatment process at the Region of Waterloo's Mannheim Water Treatment Plant since commissioning in 1992. Originally operated in a pre-ozonation mode to provide taste and odour control, ozone has evolved over the past 30 years. Notable changes include ozone addition post-coagulation (1993), a period where ozone was utilized for disinfection (1993-2001), transition of the ozone dosing target back to taste and odour control alongside UV implementation (2004), and a transition from air-fed ozone generation to a liquid oxygen system (2004/05).

Beginning in 2018, a review of the ozone system was conducted to identify potential risks to the long-term operation of this essential system. This study recommended actions and alternatives to allow for continued operation of the ozone system as well as provided the Region with a schedule and capital plan for the suggested activities.

This presentation will focus on upgrades which have recently been completed or are currently underway. These include transitioning from fine-bubble diffusers to side stream ozone injection, replacement of ozone generator power supply units, completion of generator maintenance and mechanical refurbishment, calcium thiosulphate quenching system upgrades, an ozone sample station assessment to facilitate online decay coefficient calculations and an ozone destruct system review. The driver for each activity will be discussed.

The implementation of side stream injection has resulted in improved ozone transfer efficiency, reducing chlorine costs due to lower chlorine demand and improved residual stability. Improvements to the calcium thiosulphate system have reduced the frequency of ambient ozone gas alarms. On-line calculation of ozone decay will allow for disinfection credits to be calculated in real-time using the integrated disinfection design framework (IDDF) to quantify the disinfection provided. Mechanical refurbishment and maintenance of the generators, in conjunction with PSU replacement is anticipated to delay generator replacement by more than 10 years.

Degradation of Micropollutants in WWTP Effluent by Ozonation, Comparison of Three Ozonation Systems

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Abstract

The communal wastewater treatment plant (WWTP) of Wervershoof (NL) is emitting its effluent into the surface water of the Yssel Lake. The Yssel lake is the main source for the drinking water of North-Holland, produced by PWN Water Supply Company North-Holland (PWN). The water in the Yssel Lake currently contains traces of micro pollutants, including traces of pharmaceuticals. The micro pollutants in the WWTP effluent can contribute to the concentrations found in the Yssel Lake. The Dutch water authority Hoogheemraadschap Hollands Noorderkwartier (HHNK) is responsible for the treatment plant of Wervershoof. PWN, PWNT and HHNK are working closely together on the topic of removal of micro pollutants, applying the knowledge on drinking water production to wastewater treatment, to protect the quality of the drinking water source and to contribute to a healthy environment for humans and animals.

On WWTP Wervershoof a full scale ozonation installation of 700 m3/hr was built, treating the effluent of the WWTP before emitting the water to the surface water system. The installation contains three different ozonation systems: two conventional systems (diffusers and venturi) and an innovative system (roturi). Treating the same wastewater with three different systems will yield a lot of information. Interesting topics will be: the micro pollutant removal rates, energy consumption and transformation by product formation, such as bromate formation. In two years a recommendation for an ozone dosing system for future installations will be obtained. In addition to the experience of the applied technologies, the installation will be used to study the possibilities for reuse of this treated water in the future.

Ozone Based Advanced Oxidation and Coagulation: Essential Tools for Pharmaceutical Control and Ceramic Membrane Flux Enhancement in WWTP Effluent Reuse

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Abstract

In the province of North-Holland (The Netherlands), WWTP Wervershoof of water authority HHNK is discharging its effluent containing a wide range of micropollutants (i.e. pharmaceuticals, antibiotic resistant genes, viruses) in the Ijssel Lake a few kilometres away from PWN water supply company's water inlet for drinking and industrial water. Because of source protection and the ambition for high quality reuse applications of treated WWTP effluent, HHNK, PWN and PWNT invested heavily in a multibarrier approach with ozonation, coagulation and ceramic membrane filtration (CMF). The focus in this study is pharmaceutical control and CMF flux enhancement.

By ozonation of wwtp effluent applying an ozone dose of 0.75/1 g/g O3/DOC, most target pharmaceuticals were degraded > 80%, satisfying the requirements for pharmaceutical control set by the Dutch government. An ozone dosage of 1.9/1 g/g O3/DOC resulted in a degradation of >99%.

At this high O3 dose significant amounts of bromate are produced. Ozone based advanced oxidation (O3/H2O2) experiments have shown a non-selective pharmaceutical degradation without bromate formation can be achieved. For a selected ozone regime a ratio of 0.25/1 g/g H2O2/O3 is able to reduce the bromate formation from 18 to <1 µg/l.

Applying an ozone dose of 1.9/1 g/g O3/DOC resulted in a sustainable flux increase from 100 Lmh without pretreatment to 227 Lmh with ozone pretreatment. However a significant amount of bromate was formed caused by the ozone residual of 0.6 mg/L.

Therefore CMF pretreatment with ozonation (1.9/1 g/g O3/DOC) and coagulation (10 mg/L Fe3+) was investigated. Avoiding an ozone residual on the membrane a sustainable flux of 250 Lmh could be achieved. So ozone based AOP and coagulation pretreatment is ideally suited for pharmaceutical control and CMF flux enhancement.

This research effort has provided starting conditions for a full scale O3-coagulation-CMF reuse demonstration plant.

Evaluation of Ozone and Biofiltration as Barriers for Pathogen Removal in Water Reuse and Wastewater Treatment

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Abstract

Ensuring and microbial safety of finished water remains the greatest acute health concern in water reuse applications. The lack of regulations surrounding pathogen removal in water reuse has in some cases led to the extension of drinking water treatment regulations to these applications. This presents a challenge in some cases, for example, the use of a CT value to quantify ozone inactivation of viruses has been shown to be conservative and difficult to manage in high bromide waters. Therefore, new frameworks must be created and validated in order to ensure sufficient pathogen removal is achieved in water reuse. This is particularly important in carbon-based advanced treatment, where the validation of these treatment processes is very limited when compared with membrane-based treatment.

This study will evaluate the removal and inactivation of pathogens and indicator microorganisms through a carbon-based indirect potable reuse train. The Sustainable Water Initiative for Tomorrow (SWIFT) is the indirect potable reuse effort of the Hampton Roads Sanitation District (HRSD). SWIFT is a carbon-based treatment train including flocculation/sedimentation, ozonation, biofiltration, granular activated carbon, UV disinfection, and managed aquifer recharge. Currently, the pathogen removal credits for conventional filtration and ozonation are achieved according to traditional methods described in the LT2ESWTR. This presentation will show preliminary pilot-scale and 1-MGD scale data that has been collected documenting the removal of pathogens and indicators by each treatment process. Various treatment scenarios have been evaluated including various chemical doses, ozone doses, and disinfection byproduct control methods. Low ozone exposure conditions while using ozone in combination with hydrogen peroxide has been evaluated extensively as this will be implemented at the first full-scale SWIFT facility. This presentation will also demonstrate the ability for ozone/BAF treatment to meet wastewater treatment disinfection goals. This study will highlight the shortcomings and challenges associated with pathogen monitoring in these applications.

Right Sizing Your Ozone System for a Multi-Barrier Approach to Taste and Odor Control

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Abstract

The San Francisco Public Utilities Commission (SFPUC) initiated a program to implement ozone to control algal-based tastes and odors, enhance primary disinfection, and reduce disinfection byproducts (DBPs) at the Sunol Valley Water Treatment Plant. The project is complicated by multiple surface water supplies, seasonal variations in key source water constituents (e.g., bromide, natural organic matter, turbidity, pH, and alkalinity), operating flows ranging from 20 to 160 mgd, and the need to start and stop water production at the plant on relatively short notice throughout the calendar year.

In 2020-21, SFPUC and the design team conducted a bench-scale study to evaluate a multi-barrier approach featuring ozonation followed by powdered activated carbon (PAC) and conventional treatment. Special investigations were included to evaluate advanced oxidation (i.e., ozone and hydrogen peroxide) and bromate control techniques (i.e., pH suppression and chloramination before ozone addition), refine the ozone dose requirements, and assess formation of the nine halogenated acetic acids (HAA9) evaluated under the Unregulated Contaminants Monitoring Rule No. 4 (UCMR4).

Results of the bench-scale testing program were used to refine the proposed treatment process, reduce the maximum ozone dose by approximately 40 percent compared to preliminary recommendations, and establish design and operating criteria for the new ozone system that will improve the plant's robustness over a wide range of flows and variations in water quality, will be less costly to construct, and easier and more efficient to operate. Test procedures, results, and the impacts of the facilities design and estimated costs will be summarized in the presentation.

BTS: Ozone System Start-Up (Toledo/Collins Park WTP)

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Abstract

Collins Park Water Treatment Plant in Toledo, OH decided to utilize oxidation through ozone to treat microcystin caused by seasonal harmful algal blooms. Black & Veatch was selected to design and then commission the Ozone System installed by Xylem-Wedeco.

Though system start-up and commissioning was scheduled for the summer of 2021, the planning and preparation for a successful start-up and handover began well before that. This presentation will describe the steps taken by the various parties involved in the project to achieve an efficient commissioning and handover and the lessons learned in the process.

The topics to be covered are: early identification of key participants and understanding their roles, analyzing the order of events to provide smooth transitions in commissioning activities, setting achievable and realistic expectations, and involving end-users (the operators) in discussions early and often.

State-of-the-Art Ozone Pilot Plant Design and Application

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Abstract

In 2017, SNWA decided to move forward with the replacement of a 20-year old pilot plant. Several improvements to pilot plant were incorporated into the new design including dual train operation, additional influent water supply flexibility, data acquisition software (SCADA), remote access to equipment, UPS system, etc. This presentation will detail the planning, design, construction, operation, and servicing of the new pilot plant equipment with focus on the ozonation system. The discussion will start with location considerations and SNWA's redesign and use of a utilidor between two ozone contactors to house the pilot plant. In the pilot, the raw water is first characterized with several online water quality analyzers on the raw water module. The raw water can also be amended or pretreated via chemical dosing. Prior to entering the dual train ozone skid, the water is temperature-controlled with water heaters. The SNWA ozone skid is designed so that ozone gas can be delivered via sidestream injection or fine bubble diffusion in each train. Sampling, monitoring, operation, and data processing (e.g., CT equations) features of the ozone skid will be reviewed. Ozone pilot results will be presented to demonstrate beneficial applications of the pilot including a direct comparison of dissolution methods, a comparison of bromate formation/control data generated by a previous generation pilot versus the state-of-the-art pilot, and a comparison of pilot, bench, and full-scale data. Following the ozone skid in the treatment train is a dual train coagulation/flocculation skid and a four-column filtration skid, simulating the full-scale direct filtration plant. SNWA's pilot plants have been invaluable in addressing challenges and will continue to be vital in planning full-scale operations and infrastructure for the coming decades.

Contaminants Formation in Small Capacity Ozone Generators: Influence of the Moisture

Roger Franco Baldissera, Leticia de Aguiar Martins, Fabio Rahmeier, Vicente Canalli, Marcal Pires

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Abstract

The generation of undesirable contaminants, mainly nitrogen oxides and nitric acid, has been reported in the production of ozone by the corona discharge, using air as feed gas. The influence of operational and environmental conditions demonstrated a wide concentration range and diversity of the contaminants generated. However, the study of the presence of nitrous acid as well as the influence of moisture on the generation and behavior of both HNO3 and HNO2, has received less attention. The objective of this study is to evaluate the influence of moisture on the generation of the nitric and nitrous acids in the O3 production in small capacity ozone generators. Two ozone generators (15 mg O3/h) were used, in constant and intermittent production modes, with zero air or oxygen (99.9%) at a flow rate of 2 L/min and with different relative humidity (0%, 20%, 50%, and 90%). The ozone-containing airflow has passed through three traps containing ultrapure deionized water. The concentration of ozone generated was determined on a reference analyzer (ThermoScientific, IQ49) and nitrite and nitrate concentrations in water was analyzed by ion chromatography (Dionex, DX500). The results suggest that the formation of nitric acid is significantly and inversely proportional to relative humidity, whereas the formation of nitrous acid presents an inverse behavior. The molar ratios between HNO2/O3 and HNO3/O3 ranged from 0 to 0.49 and 0.16 to 0.98, respectively, indicating significant formation of the contaminants under the conditions studied. In addition, the pH of the deionized water ranged from 5.5 to 3.5, corroborating with a probable formation/dissolution of acidic compounds. As expected, the use of O2 as feed gas inhibits the formation of contaminants. Different results were observed for the second ozone generator, with higher HNO2 concentration compared to HNO3, suggesting variability between tested O3 generator models. Complementary tests, to detail the influence of moisture and other operating conditions on the generation of contaminants, are in progress.

Implementation of a System for Performance Evaluation and Calibration of Low-Cost Ozone Sensors

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Abstract

The use of low-cost portable sensors for the analysis of ozone in ambient air has increased in recent years due to their simplicity of use, which allows for greater spatial coverage of the dispersion of this pollutant. However, currently there is still no approved standard for validation and verification of these low-cost sensors. Therefore, in order to monitor ozone concentrations in indoor and outdoor ambient air with reliability, a system capable of generating stable atmospheres at different concentration levels was developed, using EPA-certified reference analyzers, to evaluate performance parameters and perform the calibration of the Scentroid - DR1000L and Soarability - Sniffer 4D V2 monitors (which contain low-cost sensors for O3). Six performance-related parameters were evaluated: linear correlation coefficient, accuracy, precision, response time, bias, interference from other contaminants, and long-term drift. The tests performed indicated significant differences between the data obtained by the DR1000L monitor compared to the sensor of the reference analyzer, compromising the accuracy of the measurements. After recalibration of the O3 sensor in the DR1000L monitor, this variation was corrected, presenting relevant data of linear correlation coefficient (R=0.99884), precision (>98.10%), accuracy (>94.42%), response time (81.135s) and bias (≤ 0.013 ppm). Long-term drift testing indicated the necessity of recalibration every 30 days. Preliminary tests for the O3 sensor of the Sniffer 4D, V2 monitor also indicated significant differences on the linear correlation coefficient and the need for periodic recalibration. Complementary tests are being done to fully validate the equipment. The evaluated low-cost O3 sensors are considered suitable for monitoring this pollutant in ambient air as long as their performance parameters are known, and they are routinely calibrated.

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Poster Session

Optimization of the ETAP Processes Involved in the Control of THMs

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Abstract

It is becoming more and more common in Europe and the USA, the simultaneous use of Ozone in two points of the treatment sequence of a conventional ETAP: Pre-Ozonation and Intermediate Ozonation. Replacing Chlorine as an oxidizing agent in head processes, due to its known reaction with different fractions of dissolved organic matter (DOM) present in the water, giving rise to the generation of disinfection by-products (DBPs). Trihalomethanes (THMs) are one of the main constituents of these DBPs (40-50 %); being classified in group 2B by the IARC.

In this work, the efficiency of elimination of the components of the DOM characterization vector (DOC, UV254, SUVA254, THMs) achieved by the different configurations of operation under study in an experimental Pilot Plant is evaluated; using Chlorine (Pre-Chlorination) or Ozone (Pre-Ozonation and Intermediate Ozonation). The objective is to select the most effective configuration(s) that optimizes the water purification treatment line from the Zadorra reservoir (Bizkaia, Basque Country, Spain). Focusing on the elimination of the precursor fractions of organic matter and on the minimization of the formation of THMs in the Final disinfection (exit from the plant).

It is important to highlight the greater efficiency of elimination of the aromatic composition (≈ 80% UV254 absorbance) provided by the use of Ozone (≈ 1.5 mg O3/L) up to the GAC filter. In addition, the configuration with Ozone presents the lowest values in terms of the potential for the formation of THMs throughout the entire treatment line (≈ 12 µg/L) and at the plant outlet after 12 hours in the tank (≈ 14.5 µg/L). Justified by the lower values of UV254 absorbance (0.004 cm-1 ± 59.44 %) in contact with Chlorine in the Final Disinfection.

Effects of Interaction Between In-Package Dielectric Barrier Discharge and High CO2 Anaerobic Atmosphere on Quality of Raw Poultry Meat

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Abstract

Several lines of findings show that cold plasma apparatuses generate ozone and effectively inactivate microbes when CO2 is used as a working gas. Dielectric barrier discharge (DBD) is one of common techniques for generating cold plasma and also widely used for ozone production. The objective of the present study was to investigate the effect of interaction between in-package DBD treatment (IPDBD) and high CO2 anaerobic package on quality of raw chicken breast meat. Raw meat samples non-inoculated and inoculated with Campylobacter jejuni and Salmonella Typhimurium were packaged in 0, 30, 70, or 100% CO2 (with make-up gas N2) and treated with IPDBD at 70 kV for 3 min. Ozone formation, microbial counts, pH, and color were measured. The IPDBD resulted in formation in ozone in 100% CO2 packages ($P < 0.05$). There were no interaction effects on psychrophile growth, Campylobacter and Salmonella populations, and changes in meat lightness, redness, and yellowness ($P > 0.05$). However, the interaction affected meat pH. The IPDBD treatment resulted reduced psychrophile growth, Campylobacter population and redness but increased lightness and yellowness ($P < 0.05$) of raw chicken breast meat surfaces.

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Poster Session

Ozone Analyzer Replacement Program at SNWA Drinking Water Treatment Facilities

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Abstract

Ozone is used as the primary disinfectant, prior to filtration (a.k.a.; pre-ozonation), at SNWA's two drinking water treatment facilities (WTFs). At each WTF, on-line dissolved ozone (DO3) monitoring is essential for operations control and optimization, as well as calculating and reporting CT for log-disinfection credit. On-line (DO3) monitoring is applied in 3 different cells within each ozone contactor and at the combined ozone effluent. The DO3 analyzers at each WTF were over 15 years old, approaching the end of their expected lifetimes, and needed replacement. An interdisciplinary committee was formed with the objectives to compare various on-line analyzers qualitatively and quantitatively. The process and trial results that the committee used to select replacement analyzers will be discussed.

Based on their design, analysis method (probe vs. sparge-UV), presence of a local display, previous customer service quality, and the cost range, four out of thirteen DO3 analyzers were selected for a trial. These analyzers were installed on test boards, monitored, and maintained at both WTFs by operations staff for over a year. External utility surveys were also performed, and important lessons learned were recorded. After the trial, the analyzers were quantitatively and qualitatively evaluated and ranked by the committee for each of nine categories: ruggedness, installation, data storage/controller, accuracy, responsiveness, calibration/verification, maintenance, customer service, and cost. The specific findings for each category and the ranking table allowed the committee to systematically evaluate the options and select one analyzer model to replace all 50 DO3 sensors across the two WTFs. This program was also used to select and replace various other obsolete and aging on-line analyzers (e.g., O3 feed gas/ambient, turbidimeters, particle counters, chlorine) at WTFs and in the distribution system.

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Poster Session

Development of an Untargeted Method for Screening the Removal of Semivolatile Contaminants in Wastewater During Ozonation

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Abstract

The removal of microcontaminants is wastewater by ozonation is fundamental to improve the quality of the produced effluent in order to ensure environmental and health protection. Chromatographic techniques coupled to high resolution mass spectrometry (HRMS) have been used for evaluating the removal of a wide range of organic contaminants using an untargeted approach. Most of studies focus on polar contaminants that are detectable by liquid chromatography coupled to HRMS techniques, but untargeted screening methods for removal assessment of semivolatile contaminants have been few investigated. In this study, a method for screening the removal of semivolatile contaminants by gas chromatography coupled to Orbitrap mass spectrometry (GC-Orbitrap-MS) was developed and applied to ozone treated wastewater. A workflow for untargeted analysis using the TraceFinder software was developed in order to optimize the detection and identification parameters for processing the acquired HRMS data. The proposed methodology was validated using target analysis and then it was applied to the screening of contaminants in ozone treated wastewater samples, demonstrating the analytical feasibility of this method for monitoring the removal of a wide range of contaminants, allowing optimizing ozone doses to ensure the efficiency of wastewater treatment plants.

Indirect Potable Reuse Regulatory Compliance with Ozone and Biological Activated Carbon

Fred Gerringer[1], Aaron Cook[2], Tim Suydam[1], Bryan Melara[1], Andy Salveson[2], Brynne Weeks[2]

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Abstract

Fallbrook Public Utility District (FPUD) and US Marine Corps Base Camp Pendleton (MCBCP) have spent the past several years implementing a conjunctive use project (CUP) that will supply FPUD with groundwater pumped from MCBCP. However, the frequency and quantity of water that CUP will supply FPUD depends upon annual rainfall, resulting in significant periods of time when this infrastructure will not be used.

To maximize the use of the CUP infrastructure, MCBCP and FPUD are considering the implantation of an indirect potable reuse (IPR) project using recycled water from MCBCP's Southern Regional Tertiary Treatment Plant (SRTTP). This facility produces disinfected tertiary effluent for non-potable use. Complying with California's IPR regulations, particularly the wastewater total organic carbon (TOC) limit of 0.5 mg/L, requires additional treatment beyond what is currently provided. A treatment train of ozone, biological activated carbon (BAC), membrane filtration (MF), granular activated carbon (GAC) and ultraviolet (UV) disinfection was selected to avoid the challenges and water loss associated with the disposal of reverse osmosis concentrate.

Pilot testing of all unit processes, except UV disinfection, is being conducted to demonstrate regulatory compliance and to help develop design criteria of a full-scale project. This testing is evaluating the following issues:

- Options for quenching the free chlorine residual entering the pilot plant
- Ozone disinfection byproduct formation
- Ozone/BAC removal of TOC
- BAC filter operations and performance
- The maximum MF flux achievable after ozone/BAC
- Per- and polyfluoroakyl substances removal by GAC

The pilot study will be completed in July 2022, and the test data will be presented at the IOA-PAG Conference. These results will feed into the feasibility report that will define the regulatory approach, design criteria, and estimated implementation costs of the project.

Evaluation of Ozone-Based Pretreatments on the Breakthrough of Perfluorinated Acids during Granular Activated Carbon Treatment of Municipal Wastewater

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Abstract

Per- and polyfluoroalkyl substances (PFASs) represent a large group of recalcitrant anthropogenic compounds that pose a substantial risk to the wastewater sector with respect to treatment, reuse, and environmental discharge. Municipal wastewater treatment plants (WWTPs) serve as one of the main vectors for PFASs contamination into the aquatic environment as they receive PFASs from residential, commercial, and industrial sources. During the O3-BAF-GAC treatment train, the drastic changes of DOM characteristics (e.g., aromaticity, molecular weight, double bond equivalents) through O3 and BAF may have a substantial influence on PFAS removal in subsequent GAC treatment. This talk aims to evaluate the effect of O3-BAF on PFAS removal efficiency during subsequent GAC treatment.

Wednesday, August 17, 2022

Session 5 (5-3) Biofiltration Applications

Benefits and Challenges of Adding Ozonation and Converting to Biological filtration at a California Drinking Water Plant

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In Summer 2020, the Zone 7 Water Agency (District) commissioned a new raw water ozonation system at the 40-MGD Del Valle Water Treatment Plant. Concurrently, the District also began modifying treatment practices to convert the newly upgraded granular media filters from conventional operation (with a free chlorine residual) to biologic filtration.

After approximately 18 months of operation, the District and designer collected and compared before and after data on chemical usage, settled water quality, filtered water quality and production, solids production, and customer complaints related to taste and odor and/or other aesthetic characteristics.

The presentation presents an overview of the process and facilities improvements, benefits realized, problems encountered, and lessons learned. Topics include:

- Coagulation and organics removal
- Carbon dioxide for stabilization of raw water pH and optimization of ozone doses
- Filtered water turbidity
- Filter run lengths, headlosses, and backwashing requirements
- Mitigating manganese challenges with seasonal water quality changes
- Monitoring and controlling biologic filtration
- Taste and odor
- DBPs (bromate, trihalomethanes, and haloacetic acids)
- Residuals production, handling and dewatering

Developing an Ozone-biofiltration Design Standard for Ohio Public Water Systems

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Abstract

Ozone and paired ozone-biofiltration for drinking water treatment can be used to effectively address health-relevant issues that many public water systems (PWSs) face, including disinfection byproducts (DBPs) and organic contaminants such as microcystin. While ozone has been implemented for decades in North America PWSs, it is considered an "emerging technology" in the State of Ohio and commonly requires costly pilot-scale demonstration during Ohio EPA's Plan Approval process due to the lack of extensive design criteria in the Ten State Standards (TSS). In order to lower demonstration requirements for Plan Approval and therefore lower the required cost and time for the design and implementation of ozone, the Ohio Water Resources Center (Ohio WRC) at The Ohio State University has partnered with Ohio EPA and other stakeholders to develop a design standard for ozone/BAF. The Ohio EPA plans to adopt the standard as a supplement to the TSS.

Central to the development of the design standard has been the input of design professionals and public utility representatives from across the U.S. Two advisory committees for the project were established to provide international expertise and local Ohio context.

Deliverables of the standard include design guidelines for various water quality goals, with the aim to allow future ozone/BAF design using ozone bench-scale demonstration for small to medium sized PWSs targeting organic contaminants. The standard will also include a filter TOC reduction model from ozone-BAF as a function of common water quality parameters to support future design for DBP precursors. The model has been created with extensive data analysis from a collection of pilot and full-scale ozone-BAF studies from facilities across North America. With the collaboration of Ohio WRC, Ohio EPA, design professionals, and public utilities, the ozone-biofiltration design standard will enable impactful improvements to finished drinking water quality in Ohio and potentially beyond.

Draft DPR Regulations in the Golden State: What Ozone/BAC Brings to the Table

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In March of 2021, the California Division of Drinking Water (DDW) released draft DPR regulations (which were subsequently revised in August 2021). Among several differences from the groundwater and surface water augmentation regulations (released in 2014 and 2018, respectively), one major addition to the draft DPR regulations is the requirement of ozone with biological activated carbon (ozone/BAC). The main driver for inclusion of these technologies into the draft DPR regulation is to bolster chemical control in the absence of significant environmental buffers. Two major components of chemical control are: 1) attenuation of chemical peaks, and 2) removal of contaminants of emerging concern (CECs) that are not fully removed by reverse osmosis (RO) or ultraviolet oxidation processes (UV/AOP). Recent work completed for Water Reuse Foundation (WRF) Project 4832, included analysis of water quality data from 16 participating facilities with pilot-, demo-, or full-scale ozone/BAC installations treating wastewater effluents around the globe. These data, coupled with an extensive literature review, showcased the efficacy of ozone/BAC at removing several CEC groups including disinfection byproducts (and total organic carbon for disinfection byproduct formation potential), pharmaceuticals and personal care products, pesticides, and other industrial chemicals. In past work done under Water Environment & Research Foundation (WERF) Project 14-12, attenuation of peaks of acetone, formaldehyde, NDMA, and 1,4-dioxane was demonstrated through spiking studies at the City of San Diego's 1 mgd Pure Water Demonstration Facility (PWDF). The recent WRF Project 4991 evaluated potential chemical peaks in DPR trains and recommended ozone/BAC as an effective barrier. Additional work at the PWDF showed improved water quality of the RO concentrate stream, which should minimize impacts of waste discharge to water bodies. Ozone/BAC offers robustness to potable reuse projects on several fronts and is a vital addition for public health protection as the industry moves forward with DPR.

Bromate and Chemical Control Strategies for O3/BAC in Potable Reuse

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Abstract

As an increasing number of water reuse projects currently evaluate the feasibility of implementing an ozonation process, the formation of bromate presents a practical barrier as municipalities seek to meet organic oxidation and disinfection goals. The WRF 5035 project included an analysis of bromate formation and chemical control strategies received from five participating water reuse facilities. Bromate formation data from one facility showed that fine bubble diffusion formed lower concentrations of bromate compared to side stream addition. Bromate data was analyzed to determine correlations with water quality parameters. Bromate formation correlated with an increase in O3:TOC ratio, allowing a good fit (R2=0.93) using power function of O3:TOC ratio and bromate formation (as molar ratio of bromide converted to bromate). This empirical model indicates that bromate formation is not dependent on initial bromide formation at bromide concentrations <1 mg/L, that are typically present in reclaimed waters. Presence of monochloramine and hydrogen peroxide reduced bromate formation as concentrations of these chemical was increased. The use of monochloramine was found to be more effective than hydrogen peroxide for bromate control in every given case on a concentration basis. Increasing monochloramine concentrations were found to exponentially reduce bromate formation to varying degrees depending on O3:TOC ratio. This research provides an empirical model including predictive equations that can be used as a design tool to estimate the bromate formation and the expected control provided by the monochloramine at a desired O3:TOC ratio and initial bromide concentration. The empirical model estimates were found to be in good agreement with experimental data (R2=0.94), while within a set of boundary conditions of key water quality parameters.

Digital Twin Implementation for Real-Time Prediction of Bromate Formation and Micropollutants Removal at the WWTP Wervershoof (NL)

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Abstract

Water scarcity is a global timely and pressing concern. However, many of its causes can be predicted, avoided, or mitigated if targeted actions are taken. Modelling can be used to refine the design and operation of ozonation facilities aiming at the indirect reuse of wastewater treatment plant (WWTP) effluent. When reuse is considered, the presence of trace organic contaminants (TrOCs) is nowadays to be included in the assessment. The Wervershoof WWTP, operated by water authority Hoogheemraadschap Hollands Noorderkwartier (HHNK), discharges into the IJssel Lake, a main drinking water source of the region of North-Holland. HHNK, PWN Water Supply Company North-Holland (PWN) and PWNT are working on an advanced treatment project, combining the knowledge in drinking water production and wastewater treatment with today's power of digital twins for advanced testing and monitoring, to further treat the effluent of the WWTP.

In this work a 700 m3/h ozonation facility is modelled to remove TrOCs and allow the testing of three different ozone dosing systems. Computation Fluid Dynamics (CFD) and the AMOZONE ozonation kinetic model are applied to understand the hydraulic behavior of design details and understand their effect on the reaction kinetics involved in ozonation, from the reaction with organics, to the removal of micropollutants (MPs), the formation of bromate. The CFD results are used to design the online digital twin, to merge a detailed description of hydraulics with the potential of a fast model able to simulate real-time the behavior of the installation.

Here we present results of the specific goals of the digital twin: 1) predict in real-time TrOCs removal, bromate formation and other key variables, 2) assess the impact of upstream WWTP dynamics on ozonation, 3) run in-parallel virtual piloting test and 4) maximise process efficiency and performance.

Enhancing Advanced Oxidation and Bromate Control Through Multi-Point Ozone Dissolution with Hydrogen Peroxide

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Abstract

Ozone-biofiltration (O3-BAF) based potable reuse schemes without reverse osmosis have recently gained attention for reuse in inland locations. However, uncontrolled bromate formation through ozonation may limit implementation when bromide is present. Testing was conducted on secondary and tertiary effluents from four treatment plants which will be upgraded with O3-BAF based advanced treatment for indirect potable reuse as part of HRSD's SWIFT Program. In this study a novel multi-point ozone dissolution method was tested with hydrogen peroxide (H¬2O2) addition for bromate control. In this configuration the ozone dose was split between up to eight diffusers, increasing the effective peroxide to ozone ratio at each diffuser and minimizing the ozone residual available for bromate formation. In a pilot test with three diffusers, bromate formation was decreased by as much as 90% when compared to a traditional single-point dissolution method with peroxide addition. This allowed higher ozone doses to be applied for 1,4-dioxane removal while requiring as much as 85% less H2O2 when compared to a single diffuser.

The optimal number of diffusers increased with increasing ozone dose and bromide concentration. At a fixed ozone dose of 9.1 mg/L and 6.4 mg/L H2O2 (1:1 mg O3: mg TOC, 1:1 mol H2O2: mol O3), dosing between three diffusers allowed bromate to be kept below the MCL at up to 0.8 mg/L bromide, whereas six and eight diffusers were effective at up to approximately 1.5 and 1.75 mg/L Br-, respectively. Testing for the final plant is ongoing, with bromide concentrations often higher than 2.0 mg/L and relatively low TOC and alkalinity, it is likely that pH suppression and/or enhanced coagulation may be required to control bromate formation. The results of these tests as well as the implications on downstream biofiltration will be presented.

Using O3: TOC Ratio to Address CECs and Bromate through O3/BAF Process

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Abstract

Treatment trains based on ozone and biologically active filtration (ozone/BAF) are becoming a proven alternative to RO-based treatment trains for potable reuse applications due to their ability to produce high-quality purified effluents with lower capital and operational costs. Work completed as part of WRF 4832 addressed unresolved questions related to the ozone/BAF process by reviewing performance of different surrogates and indicators for the prediction of the removal of contaminants of emerging concern (CEC). The O3:TOC ratio is a ratio of the ozone dose (mg/L) to the TOC concentration in the influent of the ozone system (mg/L). The ratio can be an effective way to account for varying ozone demand due to changes in TOC and indirectly ensure that an adequate ozone dose was applied for a target level of CEC removal. A review of relevant literature indicated that ozone-reactive CECs are efficiently eliminated even at a low O3:TOC ratios, but this ratio is insufficient to substantially remove compounds that are more resistant to oxidation by ozone. This project recommended an O3:TOC ratio of at least 0.5 to increase removals of these CECs. Bromate is an important DBP to consider when determining the proper O3:TOC ratio. Analysis of data collected from participating organizations in WRF 5035, which is evaluating bromate control measures, indicated that a ratio between 0.5 and 0.6 will generally result in bromate formation that keeps the effluent concentration close to the MCL of 10 µg/L. There is variance in bromate formation potential between wastewater matrices, so the ozone influent water quality needs to be considered on an individual basis. If bromate formation is controlled by using chloramines or hydrogen peroxide, then a higher TOC ratio can be used for additional CEC removal. This presentation will also provide an overview of CEC removal by BAF.

Impact of Varying Sidestream Ozone Contact Times on Bromate Formation and Disinfection

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Abstract

Recent decades have seen an increase in utilities employing ozonation, more specifically via sidestream injection (SSI), for reasons such as lower capital and operational costs and improved ozone transfer efficiency among other operational benefits. Pilot and full-scale investigations led by researchers at the Southern Nevada Water Authority revealed decreased bromate formation and increased CT during SSI as compared to the fine bubble diffusion of ozone (O3) in drinking water. The impact of the same strategy in wastewater matrices and, therefore, in the context of potable reuse is not known. Since bromate formation is a function of both O3 dose and exposure, we hypothesized that lowering the SSI-O3 contact time will lower the bromate formation while also achieving the same disinfection CT, which is only accounted for downstream from the point of blending with the mainstream. Pilot-scale evaluations were conducted on a tertiary filtered wastewater effluent at varying SSI-O3 contact times of 1.9s, 5s, 10s and 30s, each at O3 doses corresponding to 0.5, 0.75 and 1 mg-O3/mg-total organic carbon (TOC). Bromate levels within the SS increased with increase in O3 transferred dose and SSI-O3 contact time for similar transferred ozone doses. Similar dose impacts were observed with bromate concentrations in the mainstream, however with minimal impact from SSI-O3 contact for similar transferred ozone doses suggesting that bromate continued to form within the mainstream in the presence of sufficient O3 residuals. Disinfection CT profiles calculated using residual O3 measurements showed a decreasing pattern with increasing SSI-O3 contact for similar transferred ozone doses. Microbial disinfection efficacy was further assessed using surrogate parameters such as cellular adenosine triphosphate (ATP), flow cytometry, total coliform and E-Coli.

Underwater Peroxone AOP: Design and Implementation of 1,800 ppd Sidestream Ozone Injection at the 64 MGD R.B. Simms Water Treatment Plant

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Abstract

Spartanburg Water in South Carolina is facing growing raw water challenges such as iron, manganese, and algal blooms that cause significant taste and odor events at their 64 mgd R.B. Simms Water Treatment Plant. To address these challenges, a peroxone advanced oxidation process (AOP) was designed and is currently under construction at the plant. The peroxone system is designed to apply an ozone dose up to 6 mg/L with or without 3 mg/L hydrogen peroxide for AOP. The total ozone capacity is 1,800 pounds per day (ppd), provided by two 900 ppd LOX-fed generators. The most distinguishing feature of this design is the ozone introduction system: ozone is applied at the raw water intake structure with a pipeline flash reactor that is underwater and utilizes a 54-inch pipeline reactor for contact time upstream of the conventional water treatment. This presentation will detail the major design challenges and decisions that have culminated in a truly unique ozone system. While the plant's intake feeds a gravity pipeline, a pumped sidestream was designed to convey and apply ozone to the raw water. This sidestream system includes sloped well submersible pumps and three parallel sidestream injection skids to provide up to 4,800 gallons per minute of sidestream flow. The generators and injection skids are housed in a new designated ozone treatment building with SCADA-integrated and automated controls. This project showcase demonstrates how space constraints, complex hydraulics, and advanced process needs can all be satisfied with creative engineering and construction.

Impact of Contactor Hydraulics on the Ozonation Process

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Abstract

Ozone contactors have two apparently contradictory functions – firstly to dissolve the ozone in water as rapidly as possible, i.e., provide near instantaneous mixing and mass transfer and secondly to provide the necessary contact time for complete oxidation and disinfection. In theory, this seems to require both a continuously stirred tank reactor and a plug flow reactor, when the design parameters for these are opposite.

With ozone being expensive to generate, high volumetric efficiency is a key driving factor when designing ozone dissolution and contacting systems. Dispersion has a more pronounced negative impact on 3-log removal than on 2-log removal system design. To reduce unavoidable short-circuiting and dispersion in rectangular tanks, engineers depend on tracer studies when available and assign baffling factors as a margin of safety to achieve the required disinfection Ct. Improving contactor hydraulics by adding baffles, while helpful, can drive up capital costs significantly.

This paper reviews ozone contactor design methods and the effect of ozone dissolution method on contactor hydraulics. Operating data from recent ozone contactor installations are utilized to test the applicability and limitations posed by broad engineering assumptions on design mixing and mass transfer efficiency, specific energy, materials and required physical footprint per unit of ozone transferred. Potential issues of scale-up are investigated.

Effective ozonation costs including plant pumping costs are compared for various ozone contactor configurations. One of the key benefits of homogenous mixing is tighter ozone dose control, which in turn can offer material savings from lower LOX use, and improvement of automated dosing systems. Ozone generation technology is getting more energy efficient by the day, serving as a reminder that design of ozone dissolution systems needs to continually improve to keep up with advances in ozone generation technology.

Key words: Ozone; Contactor; Hydraulics: Side-stream Venturi Injection; Multi-phase; Computational Fluid Dynamics; CFD; Residual; Coefficient of Variation; COV; Sampling;

Impact of Experimental Method on Batch Ozonation Testing by CFD and Kinetic Modeling

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Abstract

Batch ozonation experiments have been used for decades as a method to evaluate the ozone demand of a given water matrix, on the suitability of ozone technology for micropollutants (MPs) removal, and even on its potential BrO3 production. However, no standardized technique is currently available. Ozonation tests performed by different laboratories on the same water matrix show that the output of such experiments can be strongly biased by the way it is executed, especially when BrO3 formation is a concern. The time and speed of injection, as well as the location where O3 solution is supplied can drastically change the results. Even the O3 stock solution concentration itself can influence the BrO3 formation.

In this work, by coupling experimental tests and the use of the AMOZONE ozonation kinetic model integrated with computational fluid dynamics (CFD), important insights on the performance of Batch Ozonation tests are reported. The simulations in 3D and in microsecond time scale revealed the complex net of reactions involved in a batch experiment and how its execution can be better standardized to have more consistent results regarding the removal of MPs and the BrO3 formation and ensure data reproducibility.

Experiments were focused on testing the effect of ozone dose, stock solution concentration, and time of injection on MPs removal and BrO3 formation. The AMOZONE kinetic ozonation model was applied in CFD environment to replicate the experimental results and understand where the main improvements in the methodology were possible.

The joint effort between lab experiments and CFD simulations coupled with the AMOZONE kinetic ozonation model will contribute to set standards for the execution of batch ozonation tests and gain confidence in the applicability of ozone technology.

Combined use of Ozone, GAC, and UF in Multi-Barrier Schemes for Emerging Contaminants Removal

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Abstract

The removal of 13 contaminants of emerging concern (albendazole, carbamazepine, propanolol, saccharin, ibuprofen, hydrochlorothiazide, sucralose, acetaminophen, albendazole, acesulfame, diclofenac, sulfamethoxazole and caffeine) from pure water and secondary effluents samples by ozonation treatment coupled with granular activated carbon (GAC) filters and an additional ultra-filtration membrane unit (UF) were investigated. The configuration assessed was O3+GAC+O3+UF. Briefly, a 1 L volume of the water sample was fortified with 100 µg L−1 of each target compound for each assay. The concentrations of the contaminants were determined by a validated analytical method using on-line solid-phase extraction ultra-high performance liquid chromatography-tandem mass spectrometry (SPU-UHPLC-MS/MS). An experimental design was used to investigate the influence of the O3 concentration on the integrated system. The selected contaminants were removed in very different proportions during the steps of each process. Ozonation and GAC alone eliminated most of the investigated contaminants. In contrast, no significant removal of the compounds was reached by UF alone. On the other hand, the combined system, O3+GAC+O3+UF was efficient eliminating the contaminants, reaching about 100% of removal (below the detection limit of the method), as well as added security to the system.

Wastewater Reuse for Agriculture – Smart Control Concepts

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Abstract

Germany set up a Government funded program to develop flexible and sustainable concepts for agriculture water reuse in 2019. One of the approved projects (FlexTreat) is looking into the development and demonstration of processes to fulfill the requirements in innovative water management concepts in agriculture.

One part “Digital Green Tech” investigates in advanced monitoring and control concepts of the treatment train “Ozonation + Biological Filtration + UV” including the development of a digital twin of the real plant and the use of neural networks. Artificial Intelligence will be used to generate so called “Virtual Sensors” for information which can´t be measured on-line directly.

The project will run over 3 years Feb 2021 till Jan 2024. The installation of the real pilot treatment train was accomplished in Sep 2021. Till summer 2022 the project will deliver the first results of operation and digital twin.

Spraying of Ozonated Water: Mass Transfer Characterization of the Droplets Formation Region

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Abstract

For their controversial effects on the health and the environment, the use of pesticides in agriculture must be reduce to face increasing regulatory and societal pressures. The ozone molecule has been identified as a good candidate to substitute those chemicals partially or fully, especially thank to its biocide properties and its low persistence in the environment. A wide range of microorganisms related to the agrifood industry has been inhibited by ozonated water, giving hope for the development of crops treatments with OW. But the process of spraying has been showed to induce strong mass transfer phenomenon between the sprayed liquid and the air. This ozone desorption dramatically reduces the effect of ozonated water since low residual ozone doses are then applied to the plant.

First, the present work proposes a global characterization of the mass transfer occurring in a spray. The method relies on the collection and the titration of the sprayed liquid along the spray. The ozone desorption rates are compared with dioxygen absorption rates, and their similarities showed that ozone loss during spraying is only due to mass transfer phenomenon (and not to self-decomposition). Moreover, for both solutes, most of the mass transfer (≈70%) occurred in the atomizing liquid film that form the droplets at the direct exit of the nozzle. General correlations allowed to predict the desorption occurring in the already formed droplets, but not during their formation in the liquid film.

Then, an original method based on light absorption through a dioxygen sensitive dye (resazurin) has been developed to locally assess the mass transfer in this atomizing liquid film. Measurements confirmed that the transfer occurring in the small region is quite strong and allowed correlations to be made to realize a simple model for this liquid film region.

From the complementarity of both the global and local approaches, the mass transfer of ozone can be fully predicted, from the direct exit of the nozzle (2-3cm) to the cloud of droplets (80cm-1m) produced by a spray. This understanding allows to prepare adequate ozone doses for plants treatments and would allow propositions of technical solutions to create anti-desorption devices for the spraying of OW.

Gas/Solid Synthesis of Ozonized Cyclodextrins and their Application for Extending the Conservation Period of Tomatoes

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Abstract

Cyclodextrins (CDs) are biocompatible cyclic polysaccharides composed with a variable number of d-glucose units. Such supramolecular entities are generally used because of their ability to form host-guest complexes in solution with many species. In this study, ozonized 2-hydroxypropyl-β-cyclodextrin (HP-β-CD) has been synthetized by an original gas/solid process: solid CDs are directly put in contact with gaseous ozone (O3) in a gas/solid reactor. The materials obtained by this technique showed interesting oxidative properties, which could be used in practical biological applications such as disinfection, crop protection and fruit preservation. First, the influence of the salient synthesis process parameters on the properties of the ozonized CD were analyzed using a design of experiment (DOE) methodology. A set of 27 experiments have been performed following a three-level Box-Behnken design to build a model able to correlate the effect of the process parameters (gas volume flow rate, reaction time, synthesis temperature and O3 concentration in the feed gas) to ten chosen response factors linked to the material properties (oxidative power, concentration of the identified by-products, etc…). Then, a blend of ozonized CDs resulting from this DOE was used in fruit preservation experiments to test if the presence of such materials close to fruits could increase their conservation period. Concerning the results obtained, the multi-response design was successfully validated with random tests, and optimized to find the optimal set of process parameters maximizing the oxidative power of the ozonized materials. In addition, we have demonstrated that, in a closed container at 20°C, the presence of ozonized CDs located close to cherry tomatoes drastically extend their preservation period compared to the case where the fruits are conserved with pure HP-β-CD or without any CDs inside the box. Consequently, we believe that ozonized CDs may have a great potential for biological applications, in particular in food industry.

Industrial Process Water Treatment Employing Ozone-Based Advanced Oxidation

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Abstract

Industrial process waters often contain toxic and non-biodegradable contaminants that challenge conventional methods of water treatment such as physical-chemical and biological to meet discharge criteria. As a result, accumulation of toxic chemicals e.g. carcinogens, endocrine disruptors in ground and surface waters pose a serious threat to the living being and the environment. Degradation/destruction of toxic and/or recalcitrant chemicals employing advanced oxidation processes (AOPs) such as ozone-based oxidation, Fenton oxidation, and electrochemical oxidation are well cited in the literature. Among different AOPs, ozone-based advanced oxidation has wide acceptance due to its versatility of using UV and/or H2O2 along with ozone that provides a higher oxidation capability and ease of application to water and wastewater treatment. Furthermore, ozone based AOP generates no sludge compared to other AOPs e.g. Fenton and electrochemical oxidation.

Experienced water professionals are challenged to predict applicability of ozone to the industrial process waters due to their complex matrix and unknown chemicals. A well-designed lab-scale treatability study with proper controls perform a key role in designing a full-scale application by providing information such as ozone dose, pH, contact time, and necessity of UV/H2O2/catalyst to remove selected pollutants. In the case studies that will be discussed in this paper, a 25 L lab-scale reactor equipped with an ozone generator was used, with capability of dosing ozone at high concentration (e.g. > 10% ozone by weight) and dosing UV and/or H2O2 along with ozone at controlled pH and temperature. Additionally, the lab-scale AOP apparatus was equipped with on-line ozone analyzers to monitor and control feed-gas, off-gas, and aqueous ozone concentrations. Hence, information collected by this state-of-the-art lab-scale AOP unit were directly applicable to full-scale design/installations.

Tests results from studies on the process water from micro-electronics, chemical manufacturing, pharmaceutical, petrochemical, automobile, and textile industries were compiled to evaluate efficacy and applicability of the ozone-based advanced oxidation. In general ozone based AOP was found to be effective in removing organic carbon measured as COD and TOC. It also oxidized nitrogenous compounds that were difficult to remove employing physical-chemical and/or biological treatment. This paper focuses on sharing experiences obtained from lab-scale treatability studies and full-scale applications of ozone-based oxidation for industrial process water treatment.

Evaluating Full-Scale Performance of Alternative Ozone Dissolution Systems for Hydrogen Sulfide Oxidation

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Abstract

Oxidation with ozone is a reliable and efficient method for odor control and removal of hydrogen sulfide The Orlando Utilities Commission (OUC) owns and operates seven groundwater plants serving the Orlando metropolitan area. Starting in the late 1990s, the OUC WTPs were upgraded with ozone treatment using fine bubble diffusers (FBD) for gas dissolution followed by over-and-under contacting basins for removal of hydrogen sulfide from well water. Several of the OUC plants were studied to quantify gas/liquid mixing and mass transfer efficiency of the existing FBD dissolution systems and reported difficulties in obtaining stable residuals for ozone dose control, due to poor mixing. In the last two decades, ozonation with sidestream injection (SSI) has been increasingly adopted as an alternative to traditional FBD systems to provide increased process flexibility and control, wider turndown capabilities and potentially eliminating the need for confined space entry into the contactors for inspection and replacement of diffusers. Since 2010, OUC has upgraded several ozone plants, converting from FBD to SSI ozone dissolution systems.

This paper compares design, operations and treatment performance efficiency of the two ozone dissolution systems. Real-time data from three OUC plants with capacities ranging from 20 to 40 mgd, were analyzed to compare mass transfer efficiency, ozone residual stability, and impacts on control schemes for H2S oxidation. Results show that complete hydrogen sulfide oxidation was achieved following conversion to the SSI system, with improved operations and tighter ozone dose control, resulting in lower oxygen and ozone production requirements.

Leveraging Collaborative Project Delivery to Optimize Ozone Design for the City of Enid

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Abstract

Construction on the City of Enid's new surface water treatment plant (WTP), with an initial capacity of 10.5 MGD of potable water production, is under-way. The new WTP was designed by Garver under an innovative alternative project delivery model that saw Garney selected as the construction manager at-risk (CMAR) for each phase of the water supply project. The alternative delivery process was critical in meeting the City's schedule for delivery of the new water and reducing overall project costs. One facility that significantly improved in both the required time of construction, operational flexibility, and cost was the City's new Ozone Generation and Feed Facility at the WTP. Originally conceived as a raw water oxidation solution with conventional over-under-baffled contactors, the City's ozone solution became a multipurpose Advanced Oxidation Process during the collaborative design process. With Garney as the CMAR, cost-savings were found in alternative ozone contactor designs (i.e., utilizing stainless-steel piping for ozone contact, and static mixers for ozone solution injection and mixing) that reduced the cost of the new Facility, and allowed the City to construct 2 application points for ozone instead of 1. Now under construction, the City's Ozone Facility will provide modular, flexible, ozone-advanced oxidation for taste-and-odor and aesthetic improvements in raw source water to the plant, and settled water from high-rate clarifiers. This presentation will address both the challenges and benefits of collaborative project delivery for ozone design for surface water treatment.

Ozone Quenching Efficiency with Varying Reagents and Conditions

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Abstract

Chemical reducing agents are applied to quench residual ozone in the last contactors or effluent chambers at full-scale drinking and waste water treatment facilities. Ozone quenching agents are also used during sample collection to halt ozone reactions during full- to bench-scale studies. Understanding the efficiency and rate at which quenching occurs is essential for optimization and in ensuring operational/safety goals are met. The majority of treatment facilities use either calcium thiosulfate (aka. CTS), sodium bisulfite, or hydrogen peroxide to quench ozone. Other reducing agents that could be used to quench ozone include sodium thiosulfate, sodium sulfite, sodium metabisulfite, potassium metabisulfite, and ascorbic acid. The practical benefits and limitations of each quenching agent will be discussed. The kinetics of ozone quenching with each of these reagents was evaluated in Colorado River water at ambient temperature in batch experiments. The rate of quenching was evaluated, as well as a comparison of the theoretical ozone-to-quenching agent mass ratios and the measured ratios. Some agents including CTS and sodium thiosulfate required substantially more quenching agent than what is indicated by stoichiometry. Some reagents required less quenching agent than the theoretical mass ratio, indicating that secondary reactions occur. Anecdotally, some reagents (e.g., peroxide, bisulfite) have been described as requiring more time to quench ozone than other reagents (e.g. CTS); but experimental results demonstrated that with ideal mixing conditions, quenching occurred at similar rates for all reagents evaluated. The effect of mixing conditions, water temperature, pH, and applied concentration ratios on quenching efficiency were also evaluated for each reagent.

Ozonation and Advanced Oxidation Treatment of Amine-Based Carbon Capture Process Wastewaters

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Abstract

As the today's economy still relies on the fossil fuel-based energy sources, including coal, petroleum, and natural gas, for another several decades, the further development and broader implementations of carbon capture, utilization, and storage (CCUS) technologies are needed to reduce global carbon dioxide emissions. The amine-based carbon capture (ACC) process using ethanolamine as a sorbent is one of the proven technologies for carbon dioxide capture and has been used in full-scale at several locations throughout the world. This process generates three liquid waste streams namely wash water, desorber condensate, and reclaimer wastewater, all of which reportedly contain high concentrations of used ethanolamine and its degradation products, such as small organic acids (e.g., formic acid, acetic acid, and oxalic acid), nitrosamines [e.g., N-nitrosodiethanolamine and N-nitrosodimethylamine (NDMA)], and other thermal and oxidative degradation products. Due to the toxicity and potential environmental impacts of the wastewaters, development of cost-effective wastewater treatment methods is necessary for a wider application of the ACC process in the existing and upcoming CCUS projects. To date, various researchers have attempted to treat the ACC process wastewaters using oxidation, UV photolysis, granular activated carbon, biodegradation, and bioconversion. Among them, ozonation and ozone or UV-based advanced oxidation process appear to be promising because ozone is known for its reactivity towards amines, including ethanolamine, while UV photolysis is known to be effective in nitrosamine degradation, including NDMA. In this presentation, we will review the status of existing CCUS projects in the United States, as well as the principle of the ACC process wastewater generation and characteristics. We explore the potential uses of ozone, alone or in combination with UV photolysis, for the treatment of the ACC process wastewaters. A bench-scale ozone treatment experiment with simulated/real ACC process wastewater is currently underway at Texas State University, and its preliminary results will be presented.

Ozone for Safe and Effective Disinfection of Surfaces

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Abstract

Ozone is a strong oxidant used successfully for disinfection of viruses, bacteria, bacteria and parasites in water treatment for decades. Current studies indicated that ozone can be utilized for disinfection of viruses in both air and different kinds of surfaces, increasing its potential for use in the fight against SARS-CoV-2 transmission.

The primary transmission route for SARS-CoV-2 is likely direct exposure to droplets produced by individuals infected with the virus, with increasing evidence of aerosol transmission. Potential gaseous ozone applications include, but not limited to; decontamination of air and surfaces in classrooms, hospital rooms, long term care facilities, workplaces, ambulances, or any indoor environment which that may be exposed to contamination by individual that might be carriers to viruses such as SARS-CoV-2 virus.

Some of the benefits of ozone, when compared with other disinfectants, include ease of onsite generation and decomposition to oxygen and not leaving any trace of chemicals that can cause harm to individuals use the area after the disinfection application.

Routine disinfection practices have evolved during the ongoing pandemic, and several sectors have required enhanced disinfection of contact surfaces. SARS-CoV-2 has shown to persist on surfaces up to 72 hours, whereas other coronaviruses have persisted up to 9 days on surfaces.

The application involves a portable ozone generator with an inbuilt ozone destruction cycle to remove ozone after use, and can be controlled remotely with a wireless connection from smartphone or tablet so that the operators do not need to be physically present (space must be unoccupied) at any point during the treatment cycle.

An integrated safety sensor ensures that the ozone destruct cycle is not concluded until the treated area is within Health and Safety limits. The unit can apply the disinfection procedure depending on expected contamination level and size of the space to be disinfected.

CerroZone: The World First FDA 510(k) Certified Air Purification System that Harnesses the Natural Power of Ozone

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Abstract

CerroZone manufacturers the world's first FDA 510(k) certified air purification system that harnesses the natural power of ozone. Our patent pending technology eliminates harmful airborne pathogens including Covid-19. Independent certified 3rd party lab testing has shown CerroZone can achieve 99%+ pathogen elimination in 1.2 seconds and 4 LoG reduction, 99.99%, in under 15 seconds. Our technology is scalable and we are currently engineering an in-ceiling unit, as well as industrial units for both poultry and marijuana farming.

We all know the power of ozone, the difference is our technology allows for humans and animals to be present, 24/7, without health risks.

In addition to testing on LIVE Covid we are currently testing on LIVE Delta variant with the same level of excellent results expected. We have also recorded gram-positive bacteria (Staph) -> 3.61 LOG Reduction (99.975% Reduction) & gram-negative bacteria (Pseudomonas) -> 2.91 Log Reduction (99.881% Reduction), both in a single pass (approx. 1.2 seconds). (Bacteria with thick peptidoglycan are called gram positive. If the peptidoglycan layer is thin, it's classified as gram negative). Here is the distinction between Staph and MRSA: https://www.staph-infection-resources.com/info/info-staph-vs-mrsa/ "MRSA and Staph are the same species of bacteria."

What is unique about our technology is we use the power of ozone only internally. The level of ozone we exhaust from our device is averaging 0.001ppm or 80% lower than the required Intertek Certication mark of 0.005ppm for 'Zero Ozone'. (For reference inside our 'kill box' we are creating a level of ozone at approximately 15ppm).

Given the results we are reviewing the merit of having Intertek design a new standard much lower than the current 'Zero Ozone' to further differentiate ourselves from other air purifiers.

MicroForce: Intertwining Ozonation and Biological Oxidation for a Sustainable, Compact and Economicla Removal of Micropollutants from WWTP Effluent

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Abstract

MicroForce combines ozonation and biological oxidation to remove organic micropollutants from WWTP effluent in a sustainable and economical way. The MicroForce process consists of two successive O3/Bio reactors connected in series, in which each O3/Bio reactor uses a specific, low ozone dose. This converts non-biodegradable molecules into smaller, biodegradable components that are simultaneously mineralized in a sustainable, biological manner using biofilm-on-carrier technology. By means of a feasibility study, this innovative technology was evaluated on various criteria, i.e. the removal efficiency of 11 indicator substances, the carbon footprint, TCO and the applicability on WWTPs in the Netherlands. This feasibility study showed that MicroForce scores excellent on carbon footprint and TCO. The carbon footprint is 59 g CO2 per m3 wastewater treated, which means a reduction of about 55% compared to stand-alone ozonation with post sand filtration. The main saving in carbon footprint is due to the lower ozone dose required for indicator substance removal, which in turn allows for lower energy and raw material consumption. The TCO of MicroForce is estimated to be 0,06 € per m3 wastewater treated, which is also a reduction of about 60% compared to stand-alone ozonation. Considering the removal efficiency of MicroForce for the 11 indicator substances of the Dutch Ministry of Infrastructure and the Environment, it can be concluded that 85-95% removal is achieved for at least 7 of 11 indicator substances with a dose of 0,3 g O3/g DOC. Due to the lower ozone dose required in this technology, combined with an innovative ozone dissolution method, the formation of bromate is mitigated. Finally, this study also showed that the modular, plug and play concept of MicroForce allows a high applicability at hotspot WWTPs in the Netherlands. The compact construction is made possible by short residence times in the biological system and via intelligent ozone dosing.

From Virtual Piloting to Digital Twin, Full Control from Ozone Feasibility Assessment to Operation

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Abstract

Drinking water treatment and (indirect) potable water reuse (IPR) is nowadays a topic of major attention due to the rising (and interconnected) concerns about water scarcity and micropollutants (MPs) such as pharmaceuticals and pesticides. In this perspective, there is no distinction between secondary effluent treatment and drinking water production apart from regulatory differences, both applications need more and more advanced control capabilities of ozone installations. In this perspective digitalization of the water sector helps reducing the uncertainty with a spectrum of digital tools, such advanced monitoring and modelling tools. The kinetic model AMOZONE mechanistically describe the reactions of ozone with different water matrices, and has nowadays a wide spectrum of full-scale applications ranging from secondary effluent treatment to drinking water production, including the use of UV reactors, and multiple advanced oxidation process. In this work we present the four main pillars of any ozone installation, i.e. i) technology selection, ii) conceptual design, iii) detail design and construction, iv) process operation and monitoring, and how AMOZONE is being applied in each of these steps. The main outcomes can be summarized in the most recent advancement in the understanding of the bromate limitation potential for a specific water matrix, how ozone can be used to limit energy use in UV reactors, the potential savings achievable at the design phase, and the optimization of design for disinfection.