OZONE BASED WASTEWATER TREATMENT SOLUTIONS

Kyle Greene [1], Mike Zelen [2], Harold Kinasewich [3], Chris Kinasewich [4], Todd Webb [5]

[1] Seair Diffusion Systems, Edmonton, Alberta, Canada, Kyle@seair.ca
[2] Seair Diffusion Systems, Edmonton, Alberta, Canada, mzelen@shaw.ca
[3] Seair Diffusion Systems, Edmonton, Alberta, Canada, harold@seair.ca
[4] Seair Diffusion Systems, Edmonton, Alberta, Canada, chris@seair.ca
[5] Seair Diffusion Systems, Edmonton, Alberta, Canada, todd@seair.ca

Abstract

Ozone has been used in wastewater treatment for decades as a form of tertiary sterilization. As a tertiary treatment process it is generally thought to be too expensive to produce, and very wasteful. Ozone is a strong oxidant and will react with unsaturated hydrocarbons very effectively. Ozone, combined with Seair`s patented diffusion technology can do much more.

Ozone combined with microbubble diffusion allows for extremely high mass transfer of the gas to wastewater. This means creating a supersaturate solution of ozone with little to no off gassing in a very stable state. Supersaturate ozone solutions allow reactions with unsaturated hydrocarbons to happen faster, but also push reactions that typically would not happen in less concentrated solutions. BOD, COD, TSS and bacteria are now easily eliminated very efficiently and economically, as a result there is no primary or secondary sludge formation

The key to Seair's systems is the ability to efficiently diffuse ozone and oxygen gas into the wastewater stream. Seair's diffusion system produces 5 micron sized bubbles through the Seair's patented diffusion chamber. The micro-bubbles dramatically increase the available surface area for reaction and result in an extremely stable super-saturate solution. Gas remains in solution for extended periods of time, which facilitates maximum treatment results and minimal off gassing.

Seair utilizes a patented process where ozone is used in primary, secondary and tertiary treatment processes representing a best practice wastewater solution. This technology has been proven in the harshest environment, Northern Canada, and has expanded to small communities, remote industrial mining and exploration sites which face considerable challenges to implement environmentally and economically viable wastewater treatment solutions. Seair`s patented wastewater treatment system will meet or exceed any government regulation for discharge.

Key differentiating features of the proprietary Seair system, and the adaptability of the Seair diffusion system to wastewater treatment applications will be discussed in this presentation.

Keywords: Ozone, Ozonation, Advanced Oxidation, Wastewater Treatment, Sludge-Free

Introduction

Optimal wastewater treatment is a challenge facing many municipalities and organizations throughout the world. However, there are some economically viable options for environmentally conscious businesses and governments.

The use of ozone coupled with biological treatment can be a very cost-effective and efficient wastewater treatment solution (Marco et al, 1997). Ozone has a very strong oxidation potential (Beltrán, 2004) which makes it ideal in wastewater treatment applications. When combined with conventional biological treatment methods, a cost effective and proficient wastewater treatment system is achievable. The focus of this study is the evaluation of the effectiveness of an advanced diffusion system's ability to use ozone and oxygen in the treatment of wastewater.

This report involves a detailed examination of the Seair 12m Portable Wastewater Treatment Plant (PWW40). The patented ozone-oxygen-ozone based wastewater treatment system is available in a packaged portable unit. The system utilizes advanced diffusion systems to achieve efficient mass transfer of gas to fluid. In order to quantify the PWW40's ability to treat remote industrial camp sewage, a field study was conducted on April 23-27, 2007 at the Seair Septic Inc. facility in Spruce Grove, Alberta, Canada.

Materials and Methodology

PWW40 System Overview

The PWW40 municipal treatment system is housed in a 12 m sea container and is designed to treat:

Table 1: Seair PWW40 Wastewater Treatment Plant Design Parameters (Marsh, 2007)

Design Parameters	Units	Amount
Average Daily Flow	m^3/d	22.5
Influent BOD_5	mg/L	400
Influent TSS	mg/L	400
Influent Oil and Grease	mg/L	100

Effluent from this process is designed to meet and exceed Alberta standards for surface discharge (AB Env, 2006), with no sludge formation. The treatment systems were originally engineered for treatment of remote industrial camp waste and have been expanded to municipal wastewater treatment. (Marsh, 2007)

The treatment process utilizes a patented diffusion technology that produces a 5μm bubble, allowing for extremely high mass transfer efficiency. The resulting supersaturated solution attains a stable condition where the gases remain in solution for extended periods of time, or until they are consumed by chemical reactions.

Picture 1: Seair Portable Wastewater Treatment Plant

The following is a summary of the multiple stages of the PWW40 treatment process:

Table 2: General Plant Tank Volumes and Associated Detention Time. (Marsh, 2007)

Stage	Treatment Process	Tank Volume Approximate (Litres)	Avg Detention Time (h)
Holding	Influent Equalization	7,000	4.2
Pretreatment	Advanced Ozone Oxidation	2,600	3.1
Aeration	Aerobic Biological Digestion	7,000	8.4
Polishing	Advanced Ozone Oxidation	2,600	3.1

In the first process the raw sewage is treated by maceration with a grinder pump, which increases the surface area for ozone reactions. The larger organic material is partially oxidized and primary sludge is removed. The second process is an aeration phase where condensed oxygen is diffused to promote biological growth. The broken down material from the primary treatment process and the oxygen allow for accelerated biological growth, increasing biological treatment efficiency. Lastly, the mixed liquor from the second process is transferred to the ozone polishing stage, oxidizing the remaining organic material, removing all colour, and disinfecting final effluent. (Marsh, 2007)

Picture 2: Inside of PWW40 Treatment Plant

Waste Water Treatment Plant (WWTP) Technical Processes

Domestic wastewater treatment systems generally consist of a combination of physical, chemical, and/or biological processes that are designed and operated to achieve certain contaminant removal efficiencies and/or a certain effluent quality. The PWW40 incorporates the following physical, biological and chemical treatment processes:

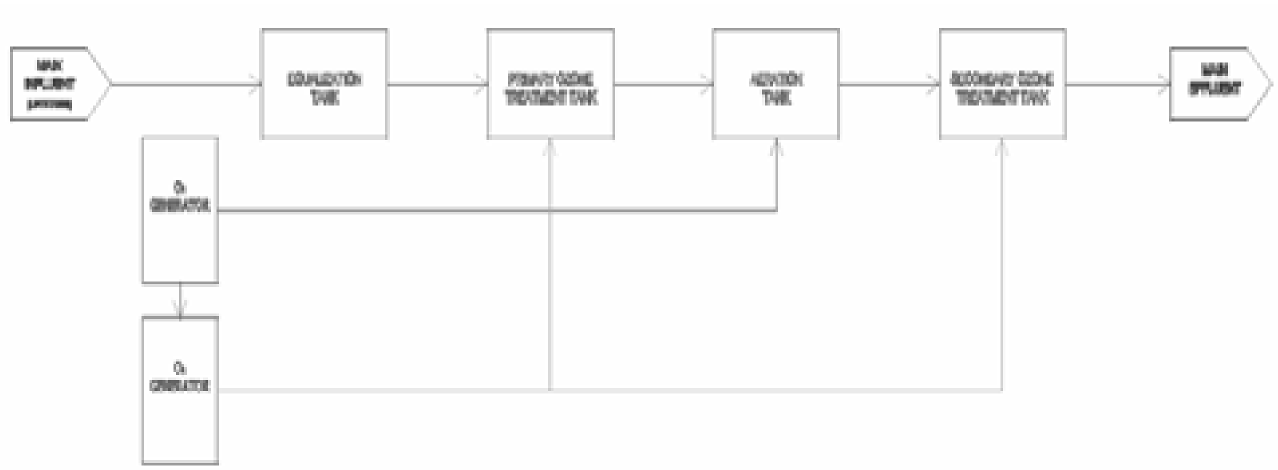
i. *Influent Holding/Equalization Tank;*

ii. *Primary Advanced Oxidation;*

iii. *Aeration; and*

iv. *Secondary Advanced oxidation* (Marsh, 2007)

Figure 1: Process Flow of PWW40 Wastewater Treatment Plant (Marsh, 2007)



The following sections provide a description of each of these processes.

i. Holding/Equalization Tank

The first process unit in the WWTP is a holding/equalization tank. The function of the unit is to provide sufficient retention of raw wastewater influent to allow the operation of the subsequent process units in a batch mode. Raw wastewater is pumped to the holding/equalization tank from an external lift station. The tank functions solely as a storage/equalization tank. Fluid in this tank is not mixed or aerated and therefore is in an anoxic state. No treatment processes occur inside the equalization tank; it is necessary due to the diurnal nature of industrial camps (Marsh, 2007).

ii. Primary Ozone Treatment Tank (Pre-treatment)

The next process unit is the primary advanced oxidation system using ozone. The primary purpose of this treatment process unit is to chemically oxidize the easily oxidized biochemical oxygen demand (BOD) and oil and grease (O/G). Within the first treatment step a grinder pump grinds the sewage to increase the surface area for ozone treatment (Marsh, 2007).

The primary ozone treatment tank operates as a batch reactor. The fluid in the tank is continuously circulated through a patented SA75 Seair ozone diffusion system at a hydraulic rate of 140L/min. Ozone is generated on-site using oxygen-enriched air, which is delivered by an AS12 oxygen generator. The ozone generator is supplied by Guardian Manufacturing Inc. and is capable of producing up to 8% (32g/hr) ozone by weight in the gas stream when using pure oxygen. Dissolved ozone levels in this tank are maintained at about 2mg/L (Marsh, 2007).

Treated water from the ozone treatment tank is transferred to an aeration tank when the high level float in the equalization tank is triggered. Once treated water has been transferred to the aeration tank, raw water stored in the equalization tank is transferred to the primary ozone treatment tank (Marsh, 2007).

iii. Aeration Tank

The aeration tank in the WWTP provides some aerobic biological treatment of the ozone-pretreated wastewater. Microbes utilize the organic matter in the wastewater as a food/energy source, producing additional biomass, carbon dioxide and water. The process does not include biomass collection and recycling. Biomass accumulation occurs as a result of only a portion (i.e. 37%) of the tank's contents being removed each cycle, and therefore a certain level of suspended growth biological treatment develops (Marsh, 2007).

The aeration tank is operated as a batch reactor. The wastewater in this tank is continuously circulated through a patented SA75 Seair diffusion system at a hydraulic rate of 100L/min. The Seair diffusion system is supplied with oxygen-enriched air by an AS12 oxygen generator, which results in elevated dissolved oxygen (DO) levels in the tank (Marsh, 2007).

During the testing, the aeration tank was monitored for dissolved oxygen (DO) and temperature. The tank was monitored at two time points: 45 hours and 90 hours into normal operation. At 45 hours, the temperature of the aeration tank was 24.3°C with a DO of 28.75 mg/L. At 90 hours, the temperature of the aeration tank was 25.4°C with a DO of 32.83 mg/L. These high DO levels are considered to be the result from the use of diffused concentrated oxygen in the system (Marsh, 2007).

The contents of the tank are transferred to an ozone-polishing tank as part of the series of transfers triggered by the wastewater level in the holding/equalization tank (Marsh, 2007).

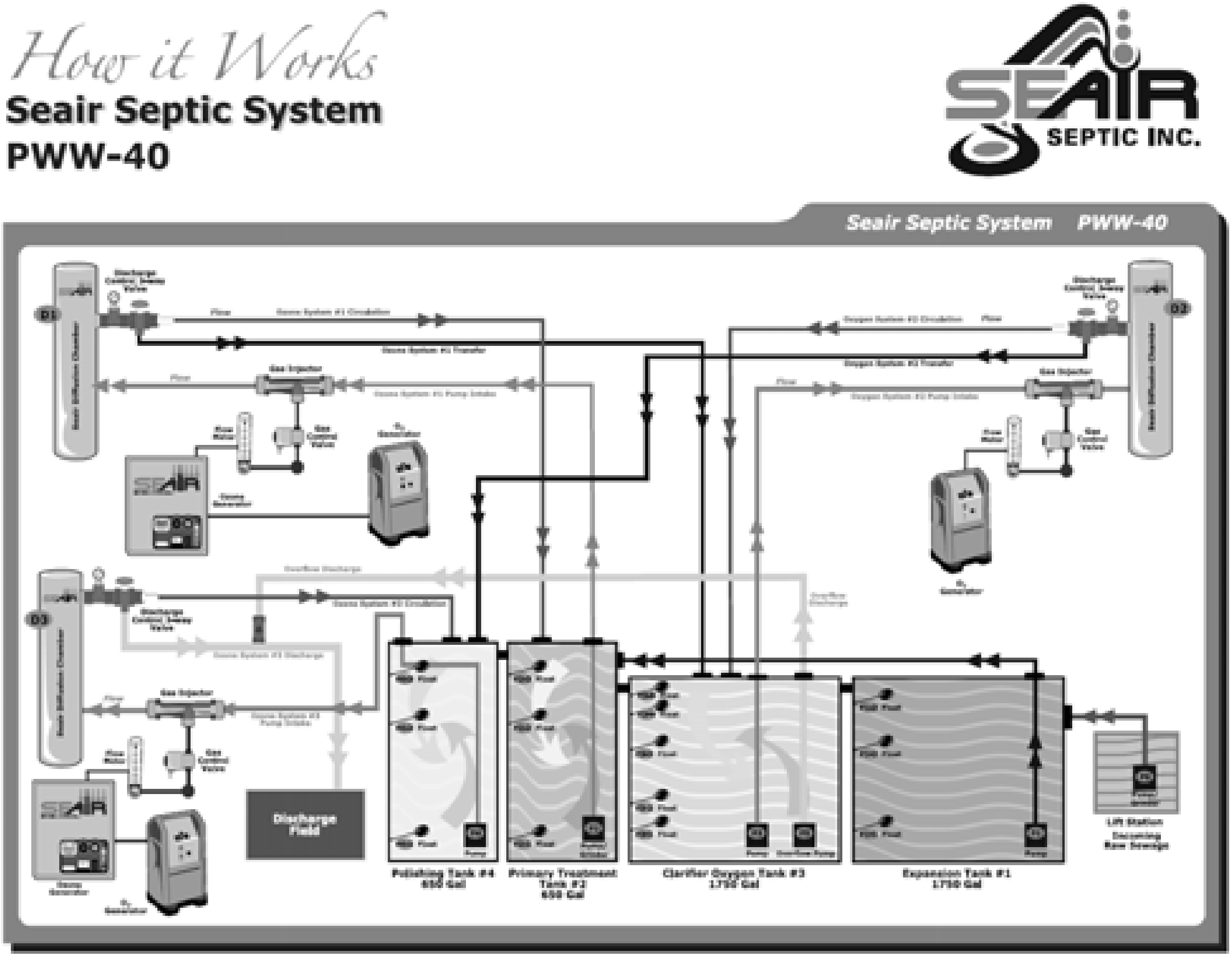
iv. Secondary Ozone Treatment (Ozone-Polishing) Tank

The primary purpose of the ozone-polishing process unit is the further reduction of biochemical oxygen demand (BOD) and total suspended solids (TSS) through ozone advanced oxidation (Marsh, 2007).

The ozone-polishing tank is the final tank in the WWTP prior to effluent discharge or use, and is operated as a batch reactor. The fluid in the tank is continuously circulated through a patented SA75 Seair diffusion system at a hydraulic rate of 100L/min. Ozone is generated using oxygen-enriched air, which is supplied through an AS12 oxygen generator. The ozone generator is capable of producing up to 8% ozone when using pure oxygen. Dissolved ozone levels in the tank are maintained at about 5 mg/L (Marsh, 2007).

When the high level float triggers in the equalization tank, the ozone-polishing tank releases its contents into the environment via surface discharge. After discharging, the ozone-polishing tank is refilled from fluid in the aeration tank (Marsh, 2007).

Figure 2: General Schematic of PWW40 Treatment System.



Plant Hydraulics

The entire WWTP discharge and transfer is controlled through the high level float in the equalization tank. When the high level float triggers, the ozone-polishing tank discharges and is refilled from the fluid in the aeration tank. The primary ozone treatment tank then discharges to the aeration tank and the equalization/holding tank discharges to the primary ozone treatment tank. The overall average design hydraulic retention time in the WWTP is 18.6 hours and in the three treatment process units is 14.6 hours. (Marsh, 2007)

Specifications

Table 3: Ozone and Oxygen Generator Specifications (Airsep, 2004), (Guardian Manufacturing Inc.), (Marsh, 2007)

AS-12 Oxygen Generator		
Oxygen Output	0.32	Nm^3/hr (@ 0-62 kPa)
Oxygen Purity	≥ 90%	

Guardian Ozone Generator		
Ozone Output	32	g/hr
Ozone Concentration	8%	

Note: Nm^3 = (Normal cubic meters) gas measured at 1 atm 0°C

Power requirements

The total treatment system has low power consumption, for the full oxidation process. The power consumption and associated costs are categorized by each component:

Table 4: Power Consumption and Associated costs (@ $0.07/kWh)

	Current (A)	Voltage (V)	Power (W)	kWh/22.5m3	cost/22.5m3 ($)	cost/m3 ($)
Ozone cell	14.6	230	3358	80.59	5.64	0.25
Grinder Pump	13.5	230	3105	74.52	5.22	0.23
Transfer Pumps	2.7	230	621	14.90	1.04	0.05
Oxygen Condenser	1.8	230	414	9.94	0.70	0.03
Total	32.6		7498	179.95	12.60	0.56

Results

The Seair PWW40 was monitored and sampled over the course of normal operations at the Seair Septic Inc. facility in Spruce Grove, Alberta, Canada from Monday, April 23 until Friday, April 27, 2007. The influent used in the trials was composed of raw wastewater from operating plants used in work camps. The raw sewage was drawn from wet sleeping units as well as a kitchen and common area, providing a typical sewage loading influent.

The influent and effluent were analysed through an array of tests, the results of which are shown in Table 5.

Note: WWTPs typically have a process stabilization period during which the effluent quality improves with time until steady state operation is reached. It was determined that after start-up, the systems require approximately 90 hours (approximately five complete cycles) to stabilize and achieve optimal performance. The treated effluent values shown in Table 4 are the averaged laboratory results from effluent samples taken on the fifth full cycle of operation of the WWTPs. The laboratory data are considered to represent normal performance (Marsh, 2007)

Table 5: Influent and Effluent Results from Testing April 23-April 27, 2007(Marsh, 2007)

Parameter	Units	Raw Wastewater (n=4)	After Treatment 40-Foot WWTP (n=4)	% Reduction
BOD_5	mg/L	184.3	13.5	> 90%
COD	mg O_2/L	495.5	82.3	
Phenol	mg/L	4.7	0.0	> 99.9%
Oil and Grease	mg/L	27.8	5.5	> 80 %
Ammonium - N	mg/L	48.1	79.5	
Kjeldahl Nitrogen	mg/L	103.0	104.3	
Organic Nitrogen	mg/L	54.9	24.9	
Phosphorous	mg/L	8.2	5.1	
Organic Carbon	mg/L	129.0	41.7	
TSS	mg/L	66.0	10.8	> 80%
Fecal Coliforms	CFU/100 mL	4075000	3	> 99.9%
Total Coliforms	CFU/100 mL	8250000	11	> 99.9%

Discussion

The discharge from the PWW40 wastewater treatment plant exceeded the regulations set forth by Alberta Housing and Municipal affairs for surface discharge for wastewater treatment plants with flow of under 22.5m^3 (AB Env, 2006). The sewage that entered the system was not filtered or screened raw sewage from a remote camp in Northern Alberta. When the cycles were finished there was no residual primary or secondary sludge. The only residual material left in the system was inert material such as sand and silt.

In addition, the PWW40 wastewater treatment plant achieved removal of: >90% BOD_5, >99.9% Phenol, total coliforms and fecal coliforms, and >80% TSS and oil & grease (see Table 4) (Marsh, 2007).

Picture 3: Visual Samples Taken, 0h, 4h,16h

The cost associate with the operation and maintenance of the equipment is minimal due to the limited moving parts. There are 3 pumps for transfer and cycling and 3 oxygen generators which are standard maintenance items. The plasma block ozone generator is a sealed system and utilized radio waves, as opposed to electric arcs for the production of ozone, extending the life of the total system. The patented diffusion tower does not have any moving parts and has been shown not to plug after three years of raw sewage treatment. Daily operating costs are primarily due to the electrical consumption of the system. The treatment plant uses 180 kWh of energy for the treatment of 22.5m^3 of raw sewage, totalling a cost of \$0.56/m^3 treated (@ \$0.07/kWh).

It is worthwhile to mention that the wastewater treatment system has no odour associated with it. The ozone and oxygen treatment processes oxidize the hydrogen sulphide and volatile organic material which is associated with raw influent, eliminating influent odour. Furthermore, the ozone and oxygen processes do not become anaerobic, eliminating the new odour forming compounds.

The absence of sludge and the significant decrease in BOD and COD suggest that the organic material was totally oxidized and removed as carbon dioxide gas. (Scheminski et al., 2000). This removal eliminates the need for sludge to be trucked into municipalities for treatment and stabilization, a substantial cost savings for the customer. Due to the lack of sludge removal, smell associated with sludge suction onto transport trucks is eliminated as well.

Conclusion

The study supports a conclusion that that diffused ozone can be an environmentally sound and cost-effective means of wastewater treatment at any location. A multi-stage batch process, coupled with high efficiency ozone generators and diffusion systems that optimize gas mass transfer and wastewater interaction can be automated in secure self-contained units. Furthermore, the limited number of moving parts minimizes wear and tear, which in turn reduces ongoing maintenance costs and labour requirements. All raw sewage is completely oxidized such that there is no residual sludge requiring disposal. The only system output is clean water suitable for surface discharge or reuse in industrial processes.

The prescribed process includes initial processing that eliminates odour causing compounds and oxidizes oils and greases that would otherwise lead to downstream equipment fouling. The process is extremely scalable with higher throughputs achievable simply by increasing the size of processing equipment and tankage.

References

Airsep, (2004). *AS-12 PSA Oxygen Generator Instruction Manual.* Airsep Corporation. Buffalo, NY

Alberta Environment, (2006). *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems*. January 2006.

Beltrán, Fernando (2004). *Ozone Reaction Kinetics for Water and Wastewater Systems*. CRC Press LLC. Boca Raton, Florida.

Guardian Manufacturing Inc. website, Retrieved August 1, 2008 from*:* *http://www.guardianmfg.com/gmi_017.htm*

Marco, A. Espulgas, S. Saum, G. (1997). *How and Why Combine Chemical and Biological Processes for Wastewater Treatment.* Water Science and Technology. Vol. 34, No. 4 (pp 321-327)

Marsh, B. Spink, D (2007). *Technical Specifications: Seair 40-foot Wastewater Treatment Plant*. Revision 4

Metcaif & Eddy. (2003). *Wastewater Engineering: Treatment and Reuse*. McGraw-Hill. New York, NY**.**

Scheminski, A. Krull, R. Hempel, D.C. (2000).*Oxidative treatment of digested sewage sludge with ozone.* Water Science and Technology*.* Vol. 42, No. 9 (pp 151–158)

Acknowledgements

The authors would like to acknowledge Guy Scott, Seair Diffusion Systems' Australian representative and distributor. Guy Scott has been with Seair Diffusion Systems for the past six years and has been pivotal in getting Seair established in Australia.