WINWERKS & POWELL ELECTROCOAGULATION

"30 Years of EFFECTIVE, RELIABLE, SAFE Wastewater Applications"

Powell Water Microalgae System (PWMAS) Lagoon Optimization Description- Primary, Secondary and Tertiary Raw Sewage Treatment

Patent Number: US 10,358,361 B2
Issued to: Scott Wade Powell
Powell Water Systems, Inc. PWMAS

The PWMAS provides lagoon aeration via microalgae (biological oxygen generators) that greatly improves wastewater treatment compared to both non-aerated lagoons and aerated discharging lagoons and can be done at a much lower lifetime cost compared with surface aerators. A robust and diverse community of microalgae is used for aeration of a wastewater lagoon. Unlike the cyanobacteria that forms a surface mat on lagoons and lakes, the microalgae utilized by the PWMAS, disperses evenly within the lagoon, thus providing 100% available oxygen for microbes to remove the incoming waste product --also known as biochemical oxygen demand (BOD5). Every structure and supporting equipment included in the PWMAS is used to maximize the growth of the microalgae and microbes; therefore, maximizing overall wastewater treatment. The PWMAS includes a systems control facility for the production and distribution of site-specific microalgae and microbes. The following is a description of the major components of the PWMAS.

Systems Control Facility

A microalgae growth center is built near the primary lagoon to house the site-specific microalgae and microbe growth incubators. The system control center provides a protected environment with spectrum-specific light designed for season-specific and site-specific microalgae growth. Optimally, the growth tanks will receive light for approximately 22 hours per day, either by sunlight or targeted light spectra.

The growth tanks receive water from the local municipal water supply. This water is filtered to remove any particulate matter and residual chlorine that may be harmful to the system equipment and/or microalgae.

In addition to the lighting, microalgae are supplied with nutrient-specific microalgae food for optimal growth. Immersion heaters are installed to maintain the optimal temperature for microalgae growth. The microalgae/microbe-laden waters from the growth tanks is continually gravity-fed to a common collection tank and then distributed to the primary lagoon.

A site-specific mixing system and multiple weighted pipelines evenly distribute the microalgae/microbes throughout the lagoon.

The continual introduction of microalgae from the system control facility ensure that a high concentration of oxygen is kept in the lagoons.

The mixing system can be powered by solar panels connected to a set of batteries.

Electrocoagulation (EC)

System Redundancy

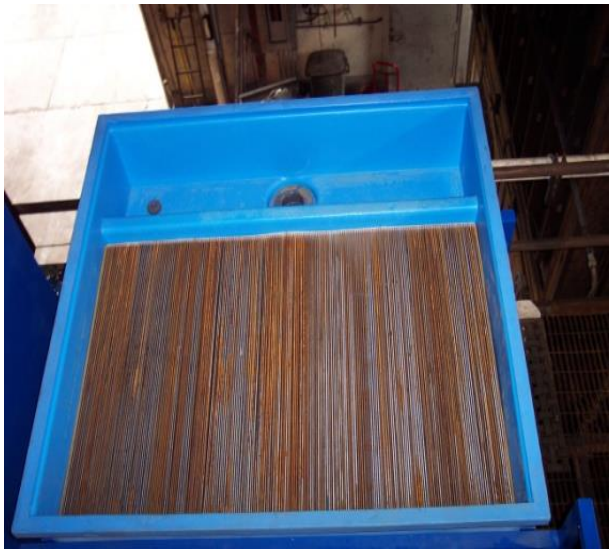
During times of upset conditions in lagoon systems such as ice, illegal dumping of pesticides, fats, oils, and grease (FOG), electrocoagulation is used to ensure towns and industrial lagoons are kept in compliance during these upset times. Electrocoagulation (EC) is also added as the final disinfection step in the PWMAS process, eliminating chemical/UV or other disinfection processes. Electrocoagulation is effective in removing 99+% or a 4-log removal of fecal coliform as well as a high removal rate of pharmaceuticals, personal care products, and viruses.

Microalgae incubator greenhouse

Microalgae aerobic pond

Electrocoagulation on Mezzanine,

217 blade EC tank



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What is Powell Water Systems Electrocoagulation

• electro-- apply an electrical charge to water
• coagulation-- process of changing the particle surface charge, allowing suspended matter to form larger particles
• advanced and economical water treatment technology.
• removes suspended solids to sub-micron levels
• breaks emulsions such as fats, oil and grease
• oxidizes and eradicates heavy metals from water without the use of filters or the addition of separation chemicals
• direct current is applied to the first and last blade.

- the liquid then becomes a conductor, allowing the current to pass freely throughout the chamber.
- results in a flood of electrons into the water, neutralizing charged particles, causing them to precipitate out of solution.
- the metal blades react to the current by releasing charged metal ions that act like chemical coagulants.

The Powell Water Systems will have the ability to produce economical and sustainable wastewater treatment anywhere in the world.

Kurt Tetzlaff WinWerks IPD
858 342 2659

Scott Powell, Powell Water Systems, Inc.
303-241-2489

System Control/Microalgae R & D, Judd Sundine, 720-363-0548

System Operator, Jeff Couch, 970-231-9937

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August 7, 2010

Dear Mr. Hamilton,

The purpose of this letter is to inform you of the results we have recently obtained from our tests of the Powell Water Systems Electrocoagulation unit for removal of biological pathogens and indicators from sewage.

We performed a trial using a single sample of raw sewage obtained from a municipal wastewater treatment facility in southwest Florida. Samples were tested to determine the abundance of two types of bacteria and four types of viruses before and after treatment with the electrocoagulation unit. The electrocoagulation process resulted in significant decreases in the concentration of all microorganisms tested, and in several cases reduced the concentration of the pathogens to below the detection limits of our assays. Electrocoagulation led to an approximately 4 log reduction in the concentrations of both fecal coliforms and Enterococci (approximately 99.999% decrease). Concentrations of phages (viruses that infect bacteria) infectious for *Eschericia coli* and *Bacillus subtilis* decreased from several thousand plaque forming units (pfu) per milliliter to less than one pfu per milliliter. In addition, concentrations of human polyomaviruses were reduced from approximately 10,000 copies per milliliter to below assay detection limits, demonstrating that electrocoagulation removed human pathogenic viruses.

In addition, we determined the efficiency of electrocoagulation for removing *Pepper mild mottle virus* (PMMoV), which is a plant pathogen that has recently been found at extremely high concentrations in human sewage. PMMoV was found in the raw sewage at approximately 60,000 copies per milliliter and electrocoagulation reduced the PMMoV concentrations to below detection limits. This is extremely encouraging since we typically see PMMoV concentrations in excess of 10,000 copies per milliliter in final effluent from most commercial treatment plants.

My laboratory has spent several years studying the types of viruses and bacteria present in raw sewage and treated wastewater, with the goals of identifying pathogens that present a risk to public health as well as effective indicators that can be used for water quality testing. In our preliminary experiment, the Powell Electrocoagulation unit reduced all the tested biological agents (including both bacteria and viruses) with greater efficacy than current wastewater treatment practices.

Thank you for facilitating this trial, and I hope that we can continue to work together in the future to further evaluate this very promising treatment process.

Sincerely,

Dr. Mya Breitbart

Reduction of nutrients, microbes, and personal care products in domestic wastewater by a benchtop electrocoagulation unit

E. M. Symonds[1], M. M. Cook[1], S. M. McQuaig[2], R. M. Ulrich[1], R. O. Schenck[1], J. O. Lukasik[3], E. S. Van Vleet[1] & M. Breitbart[1]

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To preserve environmental and human health, improved treatment processes are needed to reduce nutrients, microbes, and emerging chemical contaminants from domestic wastewater prior to discharge into the environment. Electrocoagulation (EC) treatment is increasingly used to treat industrial wastewater; however, this technology has not yet been thoroughly assessed for its potential to reduce concentrations of nutrients, a variety of microbial surrogates, and personal care products found in domestic wastewater. This investigation's objective was to determine the efficiency of a benchtop EC unit with aluminum sacrificial electrodes to reduce concentrations of the aforementioned biological and chemical pollutants from raw and tertiary-treated domestic wastewater. EC treatment resulted in significant reductions ($p < 0.05$, $\alpha = 0.05$) in phosphate, all microbial surrogates, and several personal care products from raw and tertiary-treated domestic wastewater. When wastewater was augmented with microbial surrogates representing bacterial, viral, and protozoan pathogens to measure the extent of reduction, EC treatment resulted in up to 7-$\log_{10}$ reduction of microbial surrogates. Future pilot and full-scale investigations are needed to optimize EC treatment for the following: reducing nitrogen species, personal care products, and energy consumption; elucidating the mechanisms behind microbial reductions; and performing life cycle analyses to determine the appropriateness of implementation.

Summary of Contaminant Removal Efficacy

Powell Water Systems, Inc.
Summary of Contaminant Removal Efficacy
Utilizing Electrocoagulation Technology

Biologicals

Contaminant	Before	After	% Removal
Bacteria	110,000,000 cfu	2,700 cfu	99+
Coliform	318,000,000 cfu	ND (<1) cfu	99+
E. coli	>2,419.2 mpn	ND (<0.01) mpn	99+
Enterococcus	83 mpn	ND (<10) mpn	82
Total Coliform	>2,419.2 mpn	ND (<0.1) mpn	99+
Cyanotoxin	67.7 ug/l	2.2 ug/l	97

Dyes

Contaminant	Before (NTU)	After (NTU)	% Removal
Ref. 006-691	125.1	12.1	90
Ref. 006-692	129.4	2.2	98
Ref. 006-854	68.30	0.68	99+
Ref. 006-851	2,340	4.5	99+

Hydrocarbons

Contaminant	Before (mg/l)	After (mg/l)	% Removal
Benzene	90.1	0.3590	99+
Ethyl Benzene	428	0.372	99+
MP-Xylene	41.6	0.057	99+
MTBE	21.58	0.0462	99+
O-Xylene	191	0.416	99+
PCB	0.0007	ND (<0.0001)	85
Petroleum Hydrocarbons	72.5	ND (<0.2)	99+
Toluene	28,480	0.227	99+

Nutrients

Contaminant	Before (mg/l)	After (mg/l)	% Removal
Ammonia	49	19.4	60
Nitrate	11.7	2.6	77
Nitrite	21	12	42
Nitrogen TKN	1,118.88	59.08	94
Phosphate	28	ND (0.2)	99+
Potassium	200	110	45
Sulfate	104	68	34

Pesticides

Contaminant	Before (mg/l)	After (mg/l)	% Removal
Aldrin	0.063	ND (0.001)	98
Chlorpyriphos	5.87	ND (0.03)	99+
Cypermethrin	1.3	0.07	94
DDT	0.261	0.002	99+
Diazinon	34	0.21	99+
Lindane	0.143	ND (0.001)	99+
Propetamphos	80.87	0.36	99+

Metals / Minerals

Contaminant	Before (mg/l)	After (mg/l)	% Removal
Aluminum	224	ND (0.7)	99+
Arsenic	0.076	ND (<0.002)	97
Barium	0.014	ND (<0.001)	93
Boron	4.86	1.41	70
Cadmium	0.125	ND (<0.004)	96
Calcium	1,321	21.4	98
Chromium	139.	ND (<0.1)	99+
Cobalt	0.1238	0.0214	82
Copper	0.7984	ND (<0.0020)	99+
Cyanide (free)	723	ND (<0.02)	99+
Fluoride	1.1	0.415	62
Gold	5.72	1.38	75
Iron	68.34	0.19	99+
Lead	0.59	0.0032	99+
Magnesium	13.15	0.04	99+
Manganese	1.061	0.018	98
Mercury	0.72	ND (<0.003)	98
Molybdenum	0.35	0.029	91
Nickel	183	0.07	99+
Platinum	4.4	0.68	84
Selenium	68	38	44
Silicon	21.07	ND (0.10)	99+
Silver	0.0081	0.0006	92
Tin	0.213	ND (<0.020)	90
Vanadium	0.262	ND (<0.002)	99+
Zinc	221	0.140	99+

Synthetic Organic Compounds/Organics

Contaminant	Before	After (mg/l)	% Removal
BOD_5	1,050 mg/l	14 mg/l	98
NTU	35.38 mg/l	0.32 mg/l	99+
TSS	1,560 mg/l	8 mg/l	99+
PFOS	140 ng/l	3.1 ng/l	98
PFOA	44 ng/l	5.0 ng/l	89

Radioisotopes

Contaminant	Before	After	% Removal
Americium-241	71.99 pCi/l	0.57 pCi/l	99+
Plutonium-239	29.85 pCi/l	0.29 pCi/l	99+
Radium	1093 pCi/l	0.10 pCi/l	99+
Uranium	0.13 mg/l	0.0002 mg/l	99+

Abbreviations:

mg/l = milligrams per liter or parts per million
pCi/l = picocuries per liter
cfu = colony forming unit
mpn = most probable number
ND = not detectable at the reporting limit
NTU = nephelometric turbidity units

WINWERKS & POWELL ELECTROCOAGULATION

"30 Years of EFFECTIVE, RELIABLE, SAFE Waste Water Applications"

Electrocoagulating wastewater, after Powell's patented Aerobic Microalgae Lagoon primary treatment, kills pathogens and viruses to meet EPA surface discharge requirements. Electrocoagulation ("electrocuting dirty water clean") provides a very safe, economical and environmentally qualified water treatment for meeting discharge standards and compliance requirements. Recover water, capital and operating costs by eliminating discharge fees and fines, harvesting water resources for beneficial reuse, and reducing water replacement costs. Design Build + Operate & P3 Delivery

Contaminants Removed	Percentage of Removal
Radioactive Substances	**99%+**
BOD	**90%+**
TSS (Clay, coal, silt, silica, etc.)	**99%+**
Fats, Oils, Grease	**93-99%+**
Water From Sludge	**50-80%+**
Heavy Metals	**95-99%+**
Phosphates	**93%+**
Total Coliform	**99.99%+**

1.5 GPM to 60 M+ GPD

System Capabilities for Pretreated Microalgae Wastewater
Destroys & removes bacteria, viruses, and cysts
Removes complex organics, endocrine disruptors (EDCs),
Other characteristics if present
Removes heavy metals to pass TCLP and MCL
Dewaters MFT, TFT and FFT 99% dewatered, structurally sound
Breaks oil emulsions in water
Removes fats, oil, and grease
Processes multiple contaminants, simultaneously
Flexible to meet changing effluent
Designed to meet discharge standards
Reduces energy consumption/ damage to RO membranes

Facts & Benefits

- Turnkey delivery, single point of responsibility
- Over 200 site installs; consistent and reliable results
- Proven; University & Case Studies, White Papers
- Low operating and maintenance costs
- Low power requirements & minimal operator attention
- No chemical additions
- Handles a wide variation in the waste streams
- Sustainability; reduce sludge, energy and landfill use
- Treats multiple contaminants & pretreats for salts and RO
- Water reuse- resulting in zero discharge

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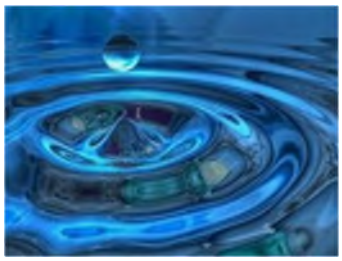
WINWERKS & POWELL ELECTROCOAGULATION

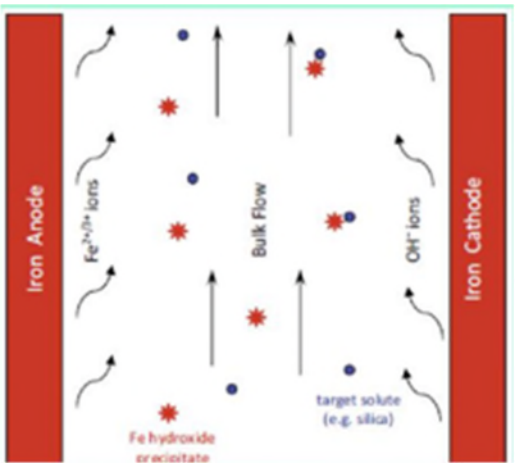
The Technology Process Narrative Used with Microalgae Pretreatment

www.winwerksipd.com/electrocoagulation-facts

Electrocoagulation (EC) has been in existence for decades with the first patent issued in 1906. However, it has been only during the past 30 years that the process has been fully commercialized as a result of technological advancements by Powell Water Systems to overcome the deficiencies of previous units. Used with microalgae pretreatment of municipal, slaughterhouse and food processing wastewaters, it meets EPA surface water discharge standards. Patent granted on July 23, 2019, #US 10,358,361 B2.



Electrocoagulation] uses direct current to cause sacrificial electrode ions to remove undesirable contaminants either by chemical reaction and precipitation or by causing colloidal materials to coalesce and then removed by electrolytic flotation. Powell's patented and proven electrochemical system copes with a variety of wastewaters. These waters can originate from municipal wastewater, slaughterhouse, food processing, brewery or tannery process water, coal utility plants, paper pulp mill waste, metal plating, or steel mill effluent . Phosphates, chromate, boron, arsenic, lead and mercury laden effluents are removed as well as silicas, magnesium, and calcium to soften water. These wastewaters will be reduced to clear, clean, odorless and reusable water. In most cases, especially domestic sewage, the treated water effluent will be better than the raw water from which it had originated."[1]



In the Electrocoagulation process, the electrical current is introduced into water via parallel plates constructed of various metals that are selected to optimize the removal process. The two most common plate materials are iron and aluminum. In accordance with Faraday's Law, metal ions will be split off or sacrificed into the liquid medium. 'these metal ions tend to form metal oxides that electromechanically attract to the contaminants that have been destabilized.

The unit also contains an air purge system to fluidize precipitates, polarity reversing to extend blade life and prevent contaminants from coating the blades, and an automated clean-in–place system. The acid solution used in the automated cleaning cycle is recycled and, when exhausted, it is routed through the EC system for final disposal. Frequency, every 4-6 hours, 20-minute cycle or less.

No chemicals are needed for the treatment process. Solids are removed by filters or clarifiers with water available for reuse or discharge.

Scalable to handle small and large flows of multi-million gallons per day
Mobile Systems

(1) Eckenfelder, W.W. and Cecil, L.K. "Applications of New Concepts of Physical-Chemical Wastewater Treatment." Vanderbilt University; Nashville, TN: Pergamon Press, Inc.

Powell Water Systems Installations
WinWerks IPD Contact Development Services

EC Efficacy: Metals, Ions, Solids, Hardness, Bacteria, Radioisotopes, and Turbidity

Contaminant	Before (mg/l)	After (mg/l)	Removal Rate %
Aldrin (pesticide)	0.063	ND (0.001)	**98**
Aluminium	224	ND (0.7)	**99+**
Ammonia	49	19.4	**60**
Arsenic	0.076	ND (<0.002)	**97**
Barium	0.014	ND (<0.001)	**93**
Benzene	90.1	0.36	**99+**
BOD5	1,050	14	**98**
Boron	4.86	1.41	**70**
Cadmium	0.125	ND (<0.004)	**96**
Calcium	1,321	21.4	**98**
Chlorpyriphos	5.87	ND (0.03)	**99+**
Chromium	139	ND (<0.1)	**99+**
Cobalt	0.1238	0.0214	**82**
Copper	0.7984	ND (<0.0020)	**99+**
Cyanide (free)	723	ND (<0.02)	**99+**
Cypermethrin	1.3	0.07	**94**
DDT	0.261	0.002	**99+**
Diazinon	34	0.21	**99+**
Ethyl Benzene	428	0.372	**99+**
Fluoride	1.1	0.415	**62**
Gold	5.72	1.38	**75**
Iron	68.34	0.19	**99+**
Lead	0.59	0.0032	**99+**
Lindane	0.143	ND (0.001)	**99+**
Magnesium	13.15	0.04	**99+**
Manganese	1.061	0.018	**98**
Mercury	0.72	ND (<0.003)	**98**
Molybdenum	0.35	0.029	**91**
MP-Xylene	41.6	0.057	**99+**
MTBE	21.58	0.0462	**99+**
Nickel	183	0.07	**99+**
Nitrate	11.7	2.6	**77**
Nitrite	21	12	**42**
Nitrogen TKN	1,118	59	**94**
NTU	35.38	0.32	**99**
O-Xylene	191	0.416	**99+**
PCB	0.0007	ND (<0.0001)	**85**
Petro Hydrocarbons	72.5	ND (<0.2)	**99+**

Contaminant	Before (mg/l)	After (mg/l)	Removal Rate %
Phosphate	28	ND (0.2)	**99+**
Platinum	4.4	0.68	**84**
Potassium	200	110	**45**
Propetamphos	80.87	0.36	**99+**
Selenium	68	38	**44**
Silicon	21.07	ND (0.10)	**99+**
Sulfate	104	68	**34**
Silver	0.0081	0.0006	**92**
Tin	0.213	ND (<0.020)	**90**
Toluene	28,480	0.227	**99+**
TSS	1,560	8	**99+**
Vanadium	0.262	ND (<0.002)	**99+**
Zinc	221	0.140	**99+**

Bacteria	Before (cfu)	After (cfu)	Removal Rate %
Bacteria	110,000,000 cfu	2,700 cfu	**99+**
Coliform	318,000,000 cfu	ND (<1) cfu	**99+**
E. coli	>2,419.2 mpn	ND (<0.01) mpn	**99+**
Enterococcus	83 mpn	ND (<10.) mpn	**82**
Total Coliform	>2,419.2 mpn	ND (<0.1) mpn	**99+**

Radioisotopes	Before (pCi/L)	After (pCi/L)	Removal Rate %
Americium-241	71.99 pCi/L	0.57 pCi/L	**99+**
Plutonium-239	29.85 pCi/L	0.29 pCi/L	**99+**
Radium	1093.pCi/L	0.10 pCi/L	**99+**
	Before mg/L	**After mg/L**	
Uranium	0.13 mg/L	0.0002 mg/L	**99+**

Dyes	Before (NTU)	After (NTU)	Removal Rate %
Ref. 006-691	125.1	12.1	**90**
Ref. 006-692	129.4	2.2	**98**
Ref. 006-854	68.30	0.68	**99+**
Ref. 006-851	2,340	4.5	**99+**

Notes: ND = Not Detected at the Reporting Limit mg/l = milligram per liter or part per million pCi/L = picocuries per liter

Powell Water Systems Installations
WinWerks IPD Contact Development Services

Alcan–Canada • Alcan International Limited–Canada • Alfa Appliance Service–Colorado • Anadarko Petroleum–Wyoming • Apex Processing Systems–Australia • Aquamanzi–California • Associated Plating–California • AWES–Colorado • BacTee Systems–North Dakota • Barreto Manufacturing–Oregon • BASX Systems–Colorado • Beckley Water Company–West Virginia • Beijing Wall Investment–China • Ben Gerker Company–Missouri • Boeing–Arizona • Brian Collins–United Kingdom • Burlington Engineering–California • Carige Water Technology–Puerto Rico • Chautauqua Hardware–New York • Chevron Energy Technology Company–California • Christ Water USA–Intel–Washington • CleanWaters LTD–Korea • Colorado Energy Management–New Mexico • Compañía Chilena de Tabacos S.A.–Chile • Conoco Phillips–Oklahoma • Consolidated Meats Group–Australia • Dong Lim Industrial–Korea • Doosan Industrial Development–Korea • E.A.R.T.H / I.M.S.E (Division) - Kingdom of Saudi Arabia • Ethan Allen Coachworks–Vermont • EC System (Thailand) Co–Bangkok • EC&P–Korea • Eco Dewell International–Arizona • EcoGeo International–South Korea • El Paso Electric Company–Texas • Electro Chemical Finishing–Michigan • Emerald Performance Materials–Wyoming • Environmental Solutions & Products–Indiana • ES3–Utah • Fontaniva Bonifico –Italy • Flagship Ecosystems Pte Ltd–Singapore • George A. Bull, Jr–Illinois • Gerber Pumps International–Florida • Golden Star Technology–California • Golder Associates Inc – Colorado • Hyannis Car Wash–Massachusetts • I G B Vetsch AG–Switzerland • Ilen Seafoods–Ireland • Indland Empire Oilseeds–Washington • Integralsa SA–Mexico • Intel–Oregon • International Dehydrated Foods–Missouri • J C Engineering Consultant–Taiwan • Joe's Plating–California • Joyner's Die Casting & Plating–Minnesota • Kent Troup–New York • KVF–Quad–Illinois • Lawrence Livermore National Labs–California • LIG–Korea • Metal Preparations Co–New York • Natural Environmental Systems–Missouri • Natural Systems–California • NEAT Environmental Inc–Canada • New Century Water–California • New China Limited–Texas • Newalta Corporation–Canada • Office of Naval Research–Virginia • Peagasus Environmental Group–Washington • Piedras Negras–Mexico • Production Plating–Washington • Quantum Ionics–Florida • RAK Gas Commission–UAE • REW Nukem–South Carolina • Rhapsody Environmental–California • Rich–Aqua Environmental–Taiwan • Sam–Chang Foundry–Korea • Sammis Oil and Gas–Canada • Samsung SDI Cheonan–Korea • Samsung SDI Pusan–Korea • San Antonio Trade Group–Texas • Santa Clara Waste Water–California • Separation Process Technologies–Japan • Shihlin Electric & Engineering Corp–Taiwan • Southern California Water Company– California • Spence Electro Plating–California • SUMCO Oregon Corp–Oregon • Sumco USA Cincinnati Division– Ohio • Sustainable Industrial Development–Pakistan • Tecprosol International C. A. • Ted Bozarth–Texas • Terra–Magic–Oregon • The Art Alliance–Florida • Tom Beckwith International–California • Troop Environmental Alternatives–New York • TSS Filtration Services–Texas • Tyson Fresh Meats–South Dakota • U S Army Research–Pennsylvania • UCO–California • Ultra Wheel Company–California • United States Navy–California • Universal Systems–Oregon • Uxmal–Mexico • Vermont Organics Reclamation–Vermont • Wastech International–New Hampshire • Wastewater Treatment Associates–Colorado • Water & Power Technologies Inc–Utah • Water Solutions–Oregon • Water Systems Integrators–Colorado • Western Finance & Lease–North Dakota • William Long Sales–Michigan • WMC Corp–Ontario • World Water Works–New York

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