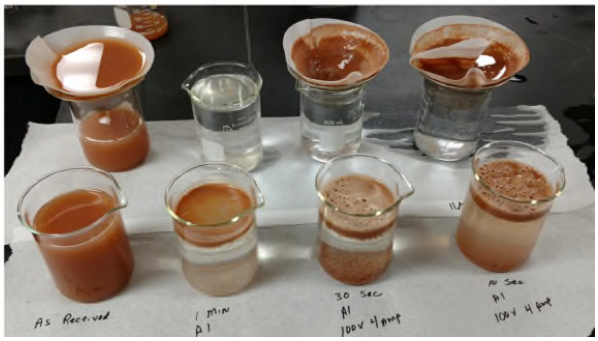
CASE STUDY- OPTIMALLY REMOVE COLLOIDAL CLAYS FROM STORM WATER

On-site Electrocoagulation cleans 1400 NTU water to below 50 NTU/ costs less than trucking

Target: WinWerks - Powell Turnkey Electrocoagulation Systems clean and reclaim 40,000,000 gallons of storm water, TSS of 1400 NTU to below 50 NTU.

Coal Mine Surface Run Off Water
Colloidal Clay Separation from Water
062017



Rationale: Owner is actively involved with CCR and US coal ash pits that are in need of various forms of remediation. WinWerks' turnkey approach using Powell Electrocoagulation systems, engineering and intellectual property, with WinWerks Design Builder installs provides a treatment process that works better than traditional chemical or sedimentation options, typically faster & cheaper. EC produces clean reclaimed water from various wastewater or storm water sources, converts toxic metals in sludge to harmless oxides for safe storage in conventional landfills. Couple this with agreements for turnkey system leasing or priced at cost / 1000 treated gallons, our solutions provide Owner with an easy way to treat various contaminated waters and save money.

Coal Mine Storm water treatment. After testing an Owner supplied sample, WinWerks Powell established an electrocoagulation treatment time of 10 seconds to reduce the 1400 NTU water sample to less than 1 NTU, using an 11-micron filter. Owner confirmed the clay density through the water column to establish the optimal treatment leading to water discharge and harvested clay fines. Concept designs settled the final system discharge limits, and site scope, budget, & schedule developed.

EC System Concept Scope:300 GPM EC, clarifiers and geo tubes, miscellaneous pumps, pipes, meters
WinWerks proposed a turnkey system: design / build with EC operations supervision + complete system O & M

Work Based upon the following market view:

- WinWerks Powell electrocoagulation & turnkey delivery indicate saving 35% +/- over conventional storm water remediation strategies.

Financial: Budgetary Cost to Treat 40 M Gallons of Storm Water

General Scope	Scenario 1	Scenario 2
General System EC size, in a container + Clarifiers / geotubes @ 10 second contact time Includes EC System Equipment, personnel + O & M; By Owner, Electric Power, take water and solids, post treatment, pump water to WW surge tank Operation Days Start Operations (1- or 2-weeks setup) Complete Cost of treatment 40,000,000 Gallons Cost/ Gallon	300 GPM 24 hr./ day 7 days/ week with 20 hrs. production **111** **Sept. 15, 2017** **Dec. 27, 2017** **$1,800,000** **$0.045**	1500 GPM 24 hr./ day 7 days/ week with 20 hrs. production **23** **Dec. 1, 2017** **Dec. 23, 2017** **$2,200,000** **$0.055**

WinWerks final system can operate with for lower cost, higher productivity and safety. Powell Water has tested the Project Site storm water with colloidal clays and can deploy in two weeks. concept designs for colloidal clay removal, subject to on site verifications and coordination with Owner.

WINWERKS
INNOVATIVE PROJECT DELIVERY
(858) T 350-1358 F 350-1359
3741 Overpark Road, San Diego, California 92130
winwerksipd.com

TEST REPORT: Project Site Storm Water EC Treatment
June 20, 2017

Executive Summary Owner requires treatment and disposal of 40-million gallons of stored storm water and additional 600-1200 GPM storm water flows, all mixed with colloidal clay. Water is currently stored in a Project Site CCP structural fill site reservoir.

A June *20,* 2017 Powell Water demonstrated that its 1 liter/minute Electrocoagulation machine separated colloidal clay from storm water and showed the following:

The NTU of raw storm water is 1400; exceeding the North Carolina MCL of an NTU of 50.

10-seconds of EC treatment reduced the NTU from 1400 to 1 after the EC effluent passed through an 11-micron filter.

Conclusion: EC is capable of separating colloidal clay from water.

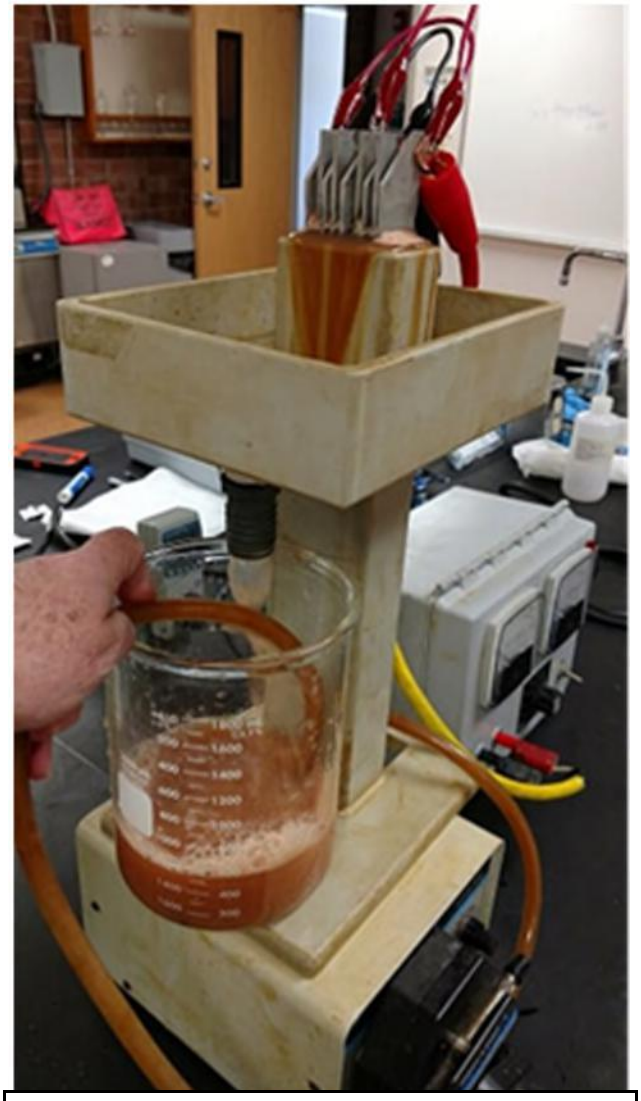


Fig 1. Storm water with colloidal clay EC influent

Figure 1 shows raw water with NTU-1400 as influent to a 1 liter/min EC system.

Note the opaque orange raw water influent contaminated with clay.
10-sec of EC treatment reduced clay contamination in EC-treated and filtered water to an NTU of 1.

EC-treated NTU=1 would meet EPA requirements for drinking water turbidity and close to the desired drinking water level of 0.3 NTU. This could possibly allow EC-treated. water to replace potable water purchases at the Project Site.

Figure 2 shows filtered storm water plus 3 samples of EC-treated storm water from the Project Site

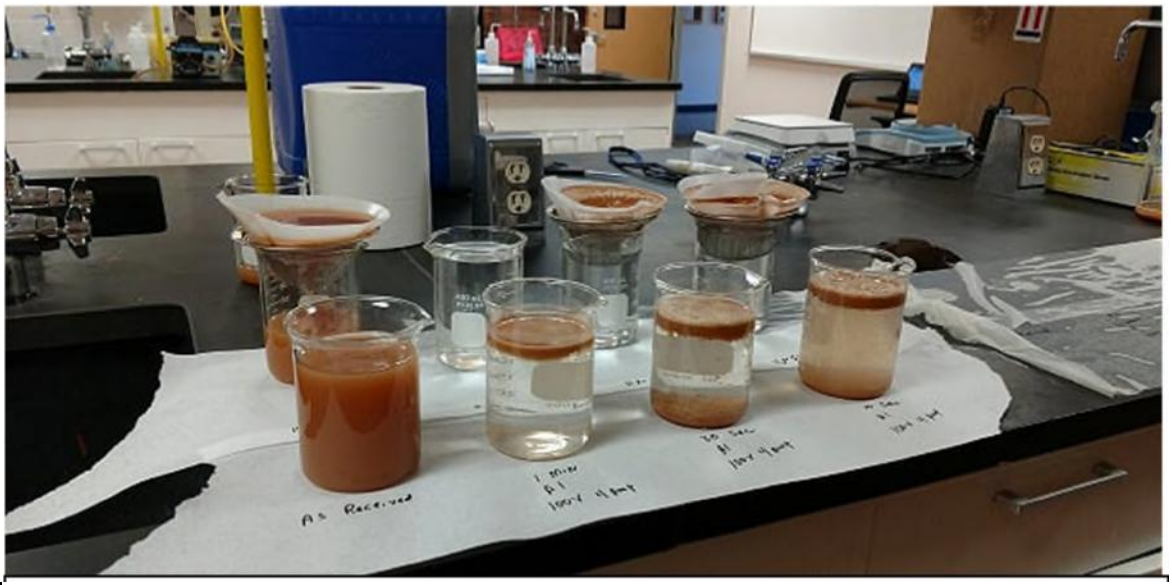


Fig 2. Left - Decanted EC-treated Storm Water; Middle - Non-filtered EC-treated Storm Water; Right - 11-micron filtered, EC-treated Storm Water (NTU = 1)

On the left is storm water passed through an 11-micron filter having an NTU of 1300, 93% of that of raw water.

Second from the left is 60-second EC-treated storm water that has not been filtered (front) and filtered water in the rear that has an NTU of 1.

3rd from the left is 30-second EC-treated storm water with unfiltered water in the front and filtered water at the rear that has an NTU of 1.

On the right is 10-second EC-treated storm water that has been filtered with an 11-micron filter and has an NTU of 1.

This storm water sample, polluted with colloidal clay, should include one of the following two filtration methods for minimizing solids and meeting turbidity standards: Use a geotechnical dewatering tube or a clarifier.

Options:

1. Within 2 weeks ship a 50 GPM (69,000 GPD) EC machine to Project Site.
2. Or within 6 Weeks ship an upgraded 50 GPM EC system to process 414,000 GPD
3. Or within 16 weeks ship larger EC system to process the storm water and leachate.

Powell Water Systems Inc.
19331 East Tufts Circle
Centennial, Colorado 80015 USA
Telephone +1 303 627 0320
Telefax +1 303 627 0116
http://www.powellwater.com
powellwater@powellwater.com

Coal Mine Surface Run Off Water
Colloidal Clay Separation from Water

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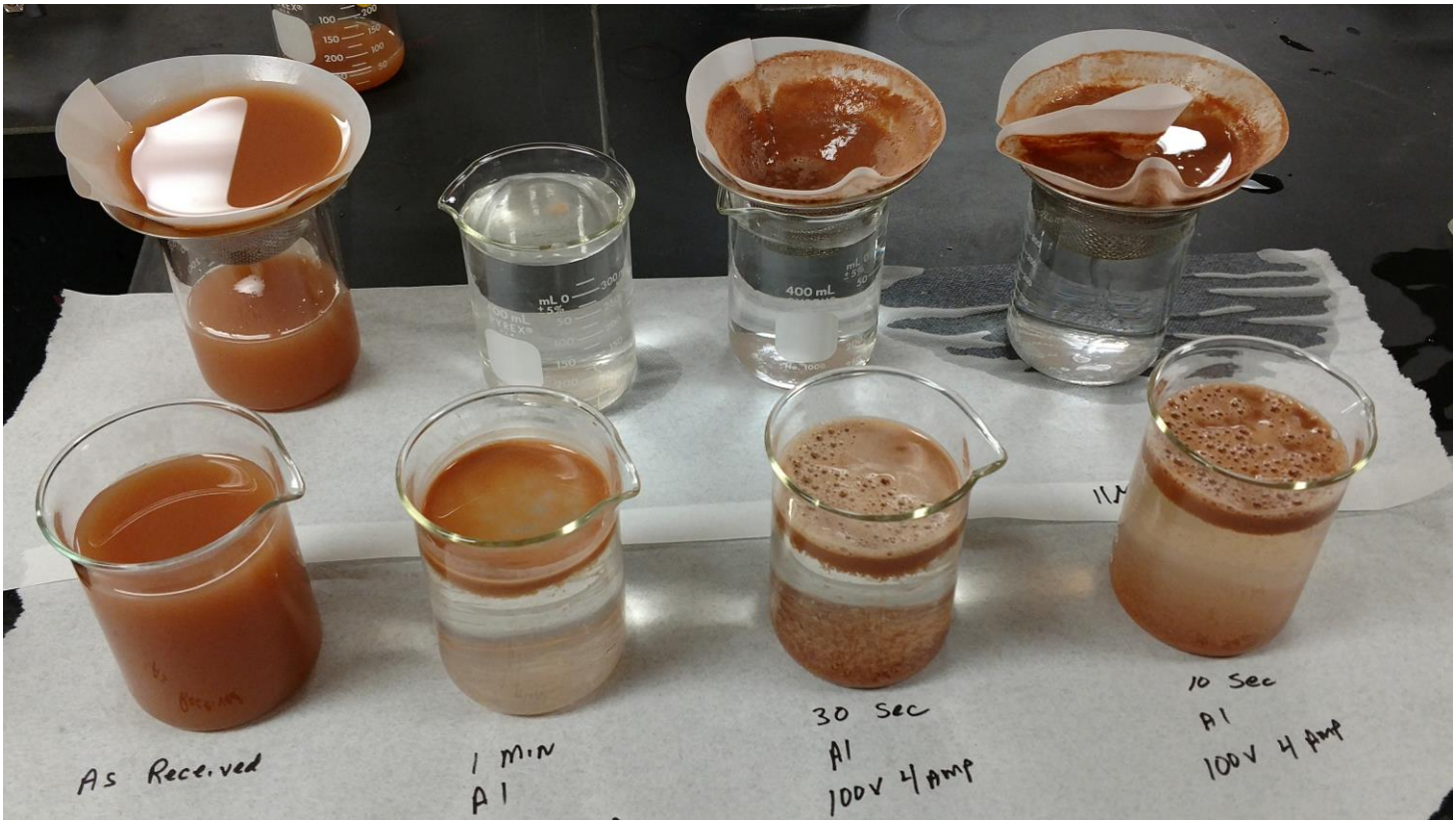

Clay that passes Through the filter And plugs the filter	Powell EC 1 min residence time filters clear	Powell EC 0.5 min residence time filters clear	Powell EC 0.16 min residence time filters clear
0 kWh of Electricity used per 1,000 gallons treated	6.3 kWh of Electricity used per 1,000 gallons treated	3.15 kWh of Electricity used per 1,000 gallons treated	1 kWh of Electricity used per 1,000 gallons treated

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19331 East Tufts Circle
Centennial, Colorado 80015 USA
Telephone +1 303 627 0320
Telefax +1 303 627 0116
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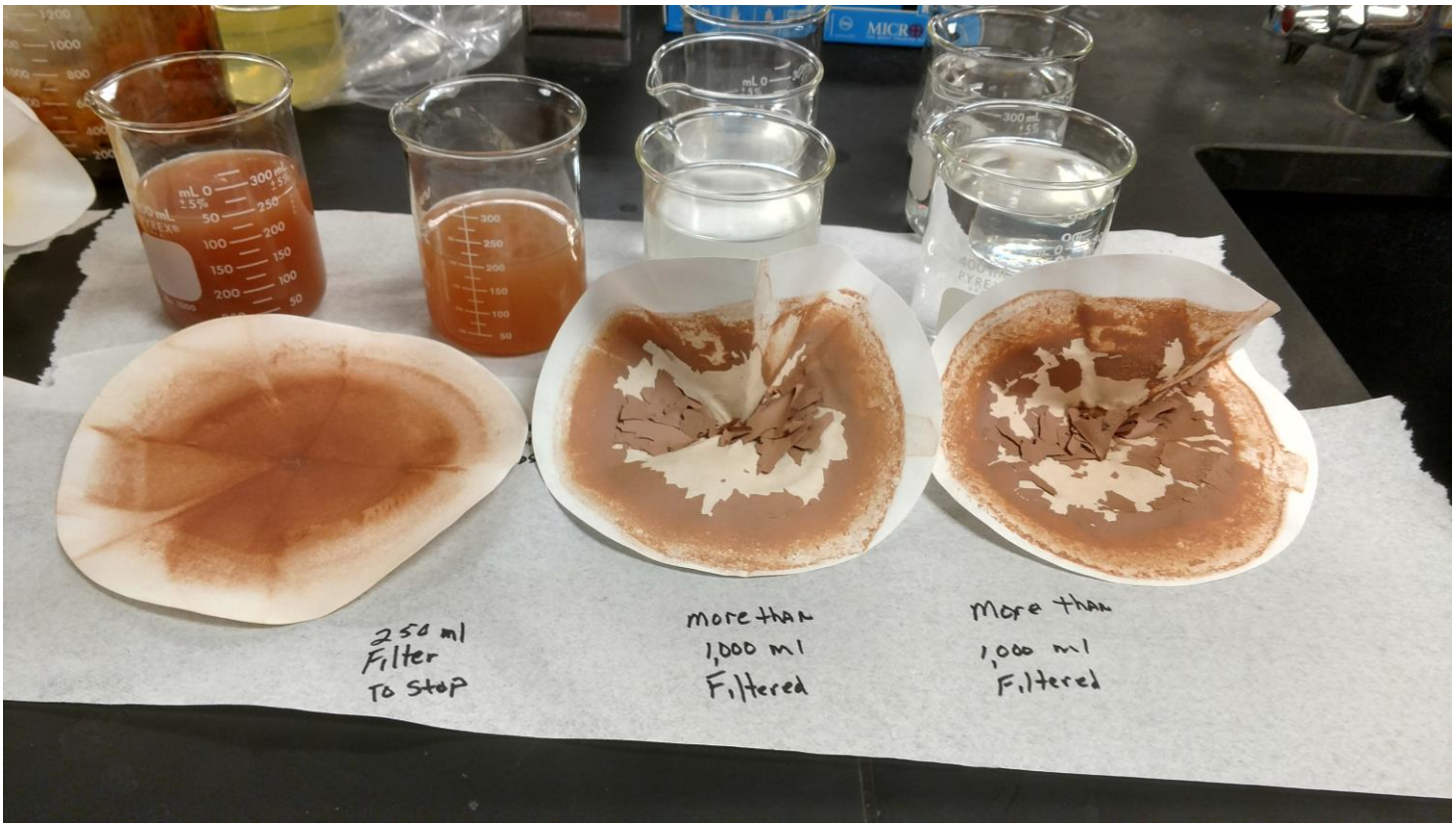
Coal Mine Surface Run Off Water
Powell Electrocoagulated Solids



Plugged clay filter from the as Received water after 250 ml Passing through the 11-micron Whatman #1 filter paper

The Powell electrocoagulated water passes clear water through the 11-micron Whatman #1 filter paper. The solids volume for 1,000 ml is shown above after 11 days. The solids are in an oxide form, and dry sufficiently to crack, and flack off the filter paper.

United States Environmental Protection Agency stated “When compared with alum treatment, electrocoagulation provided approximately 83% less sludge volume and a 76% improvement in filtration rate” (United States Environmental Protection Agency EPA/540/S-93/504 September 1993 SITE Superfund Innovative Technology Evaluation)

Exhibit A

Electrocoagulation Design and Operation Design Concept

For Colloidal Clay Removal

EC - Clarifier - Geotube System Description: The proposed 300 or 1500 GPM EC – Clarifier– Geotube Remediation system marries proven technologies in a novel way. EC is used commercially with atmospheric clarifiers and filters. The ability of clarifiers to remove large volumes of solids is coupled with a filter bag that is designed to remove sufficient solids to maintain an NTU of < 50 in the treated system effluent. The atmospheric clarifiers remove 90% of solids prior to effluent entering the geo tubes that remove an additional 6 to 8% of solids.

Total solids (TSS + TDS) are expected to range from 0.5% (3,960 lb./day) to 2.0% (15,206 lb. day) of colloidal clay with the clarifier removing ~ 97% of the clay and the geo-tube removing ~ 2.6% of the clay. Owner to confirm any variance in the water column assumption as we finalize design. The EC can handle up to 5% solids which will be addressed with more clarifier/ tube capacity.

The geo-tube reduces clarifier permeate turbidity from 87 NTU to less than 50 NTU. The geo-tube can also replace the use of a clarifier if the clarifier is taken offline for maintenance. In this situation the geo-tube would retain 97% of the solids rather than only 2.6% of the colloidal clay solids.

Project Description:
Powell Water can upgrade an in stock 50 GPM EC System (60-sec treatment time) to a 300 GPM capability (10-sec treatment time). This machine can be on site within 7 weeks of contract funding. Treating the 40-million gallons of water takes 111 days after site startup and completes treatment 165 days from contract award.

The alternative 1500 GPM EC system will be built from scratch and commissioned 10 weeks later than the smaller system. Complete treatment of 40 million gallons occurs over 23 days of operation, after startup.

Of interest, the smaller 300 GPM system treats 63% (25,200,000 gallons) of storm water from the mine pit before the larger 1,500 GPM system comes online in December 2017.

The colloidal clay solids produced by EC treatment are hydrophobic and are expected to improve performance of the Owner drying bed that currently has a capacity of 200 to 250 GPM.

WinWerks EC scope:
EC machine of choice, in a 20’ or 40’ x 8’ x 8’ container, WinWerks Design Builder supplied onsite supervision, labor and O & M for the EC system, surge tank, 2-10 clarifiers & 20- 60 geo tubes depending upon EC size, pumps and pipes for system integration.

Owner provides an adequate sized gravel pad depending upon EC equipment selected adjacent to the drying beds, the 460V 3 phase power to a POC within 20 feet of EC equipment, access to site equipment/ operators; for example taking the filled geotubes for disposal, pumping influent to WW surge tank, taking away solids, and pumping sludge to the drying bed and permeate to MPDS stream, and water testing.

WINWERKS & POWELL ELECTROCOAGULATION

TURNKEY DELIVERY for CLEAN COAL WASTEWATER ADVANTAGE

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

Electrocoagulation (electrocuting wastewater streams) is a proprietary, economical and environmentally qualified water treatment for meeting coal discharge standards and compliance requirements. Recover capital and operating costs by eliminating discharge fees and fines, harvesting sustainable resources for beneficial reuse, avoiding landfills and significantly reducing water replacement costs. WinWerks provides Design Build & P3 Delivery

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

50-600 GPM EC

System Capabilities for Coal & CCP Treatment

Removes dissolved heavy metals and pass TCLP
Removes suspended and colloidal solids
Breaks oil emulsions in water Removes fats, oil, and grease Removes complex organics Destroys & removes bacteria, viruses, and cysts Processes multiple contaminants, simultaneously 1.5 GPM to 600 GPM and larger systems to fit flows
Designed to meet discharge standards

Wastewaters can be treated for as low as
1-4kWh per 1,000 gallons & 1 man-hour/ day

Facts & Benefits for Coal and CCP Treatments

- Turnkey delivery, single point of responsibility
- Over 125 contracts; 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 wide variations in the CCP waste streams
- Sustainability; reduce sludge, energy and landfill use
- Treats multiple contaminants, simultaneously
- Removes RO membrane destroying silica's & lowers O& M
- Water reuse- resulting in zero liquid discharge (ZLD)

3 GPM EC System

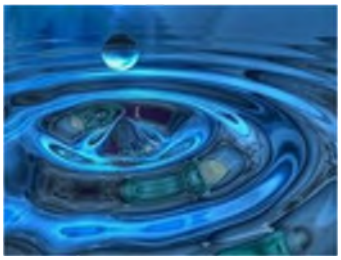
WINWERKS & POWELL ELECTROCOAGULATION

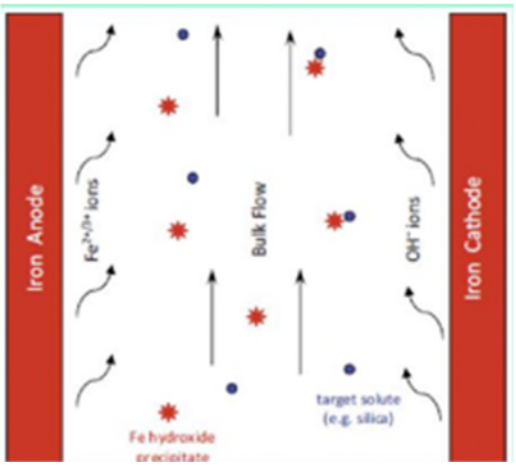
The Technology Process Narrative

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 to overcome the deficiencies of previous units.

Electrocoagulation] utilizes 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 coal utility plants, paper pulp mill waste, metal plating, tanneries, canning factories, steel mill effluent, slaughterhouses, or PWWTP. Chromate, boron, arsenic, lead and mercury laden effluents, as well as domestic sewage are treated. 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 required for the treatment process. Solids are removed by filters or clarifiers with water available for reuse or discharge.

(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

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Developer, Turnkey	**Technology and Product Engineering**
WinWerks IPD	Powell Water Systems Inc
3741 Overpark Rd.	19331 East Tufts Circle
San Diego, CA	Centennial, Colorado
92130 USA	80015-5820 USA
Telephone 858-350-1358	Telephone 303 627 0320
Fax 858-350-1359	Fax 303 627 0116
Cell 858-342-2659	Cell 303 241 2489
ktetzlaff@winwerksipd.com	Skype: powellwater
www.winwerksipd.com	www.powellwater.com