TECHNICAL MANUAL

Electro Contaminant Removal (ECR)

Science, Systems and Applications

FLAGSHIP
DHAKA

ECR Capabilities

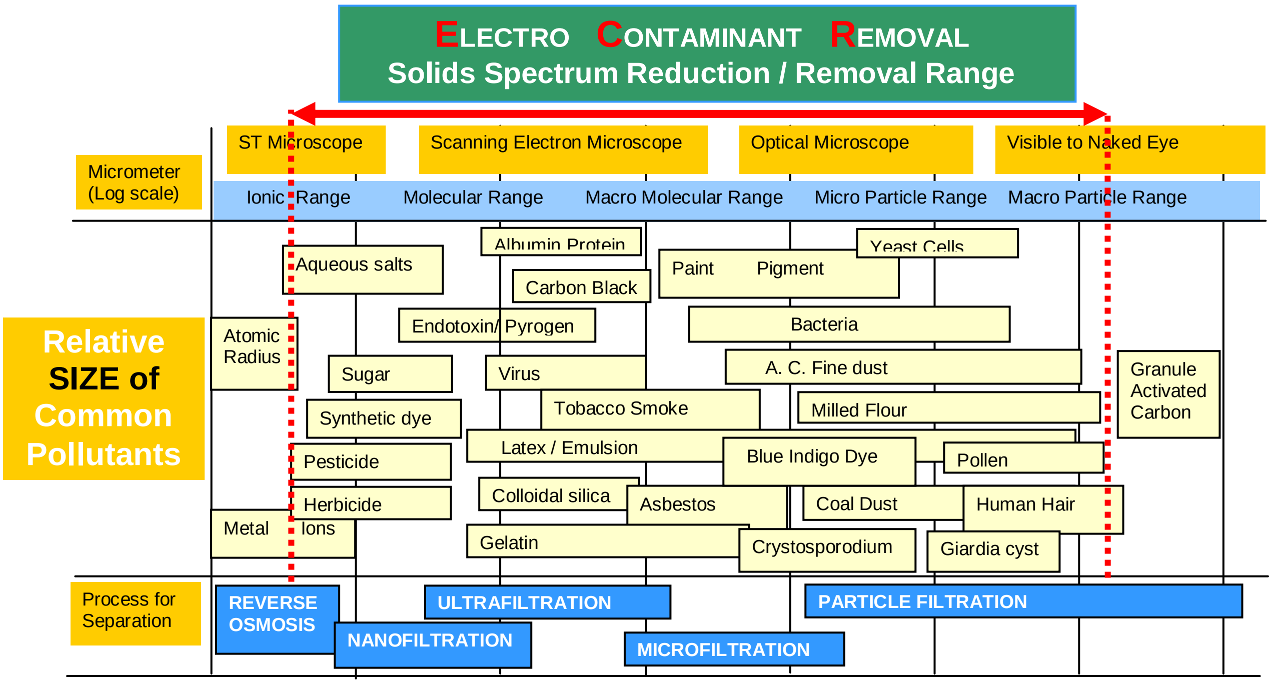
- Removes heavy metals as oxides
- Removes suspended and colloidal solids
- Breaks oil emulsions in water & Removes FOG
- Destroys & removes bacteria, viruses, and cysts
- Processes multiple contaminants at various levels

ECR Benefits

- Low capital & operating costs
- Low power & maintenance requirements
- Handles wide variations in the waste stream
- NO chemical additions = Sludge minimization
- Treats multiple contaminants for Water reuse

Rationale Due to the development of various industry sectors such as textile, oil & gas exploration, electroplating, tannery, industries in general; a large amount of wastewater is generated during the production. Wastewaters contain high concentration of pollutants, toxins, COD, BOD, salts, metals, color, etc. Many treatment processes have been developed for wastewater such as biological, evaporation, integrated aeration and ozonation, chemical processes, etc. However, all these treatment schemes, individually, are impractical or unviable. Considering the majority of wastewater purification operations; <u>the electro-chemical procedure has been proven and found to be a reliable process because of its low sludge generation, low start-up and operating costs, no chemical additions into the treated water and high treatment efficiencies.</u> One more process has been developed to the commercial stage and is being used on several industrial wastewaters in S.E. Asia. <u>The ECR process is known as Electro Contaminant Removal (ECR)</u> <u>or more commonly known as electrocoagulation, electro-deposition, electro-flotation, electro-oxidation, etc.</u>

ECR Science *is based on valid & proven principles involving responses of water pollutants/ contaminants to electric fields and electrically induced oxidation and reduction reactions.*



<u>Contractor – Office of U.S. NAVAL RESEARCH</u> *Mickley & Assoc., Boulder Colorado*

December 2004

"Pretreatment Capabilities and Benefits of ECR"

"The results do clearly indicate the most beneficial application of ECR in terms of providing pretreatment is to membrane systems. <u>The use of ECR in front of a multi-membrane systems of UF/RO or MF/RO has promise to improve performance of the membrane system and to broaden its application to include feed water having high suspended solids levels".</u>

Coagulation and Electro-coagulation Chemical coagulation has been used for decades to destabilize suspensions and to effect precipitation of soluble metal species, as well as other inorganic species from aqueous streams, thereby permitting their removal through sedimentation or filtration. Alum, lime, and/or polymers have been the chemical coagulants used. These additions, however, tend to generate large volumes of sludge with high bound water content that can be slow to filter and difficult to dewater. These treatment chemicals also tend to increase the total dissolved solids content of the effluent, making it unacceptable for reuse within industrial applications.

The Flagship ECR System offers an alternative to the use of metal salts or polymers and poly-electrolyte addition for breaking stable emulsions and suspensions. The system removes metals, colloidal solids and particles, and soluble inorganic pollutants from aqueous media by introducing highly charged polymeric metal hydroxide species. These species neutralize the electrostatic charges on suspended solids to facilitate agglomeration and resultant separation from the aqueous phase. The ECR offers an additional step by taking advantage of the technology's inherent electro-flotation mechanism; wherein hydrogen gas is released at the cathode surface. Electro-floatation simply floats pollutants to the surface of the water wherein it is mixed with hydrogen and oxygen generated from water electrolysis. Each Unit employs diffused air to expedite the floatation process thus allowing water solids to pass between individual electrodes and remain afloat longer; thus allowing the bulk/ majority solids to be removed from the surface instead of waiting for the precipitation process to occur. By removing the bulk surface solids, smaller and less complicated conventional clarification devises can be employed.

The pH, pollutant type and concentration, the bubble size and position, floc stability and agglomerate size all influence the operation of the ECR unit. The overall mechanism is a combination of mechanisms functioning synergistically. The dominant mechanism may vary throughout the dynamic process as the reaction progresses. The dominant mechanism will almost certainly shift with changes in operating parameters and pollutant types.

Highly charged cations destabilize any colloidal particles by the formation of polyvalent polyhydroxide complexes. These complexes have high adsorption properties, forming aggregates with pollutants. Evolution of hydrogen gas aids in mixing and hence flocculation. Once the floc is generated, the electrolytic gas creates a flotation effect removing the pollutants to the floc - foam layer at the liquid surface. There are a variety of ways in which species can interact in solution:

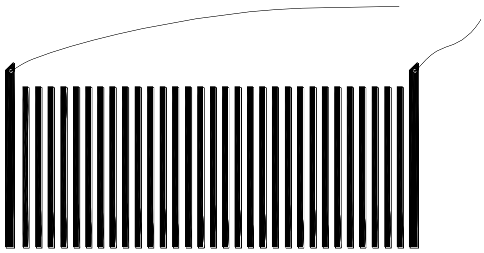
1. Migration to an oppositely charged electrode (electrophoresis) and aggregation due to charge neutralization.
2. The cation or hydroxyl ion (OH-) forms a precipitate with the pollutant.
3. The metallic cation interacts with OH- to form a hydroxide, which has high adsorption properties thus bonding to the pollutant (bridge coagulation).
4. The hydroxides form larger lattice-like structures and sweeps through the water (sweep coagulation).
5. Oxidation of pollutants to less toxic species.
6. Removal by electroflotation and adhesion to bubbles.

Journal of Hazardous Materials *Gebze Institute. Turkey* ***March 2003***

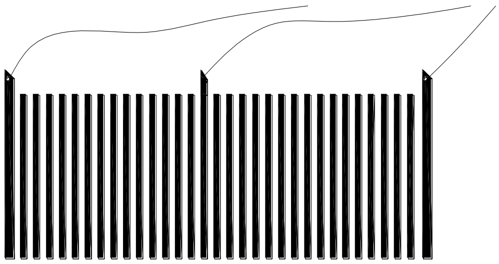
"Treatment of TEXTILE Wastewaters by ECR using Iron & Aluminum electrodes" *Department of Environmental Engineering.*

"The electro generated flocs separate rapidly and remove color and turb-idity form dyeing waste waters. The process has been found to be very efficient in COD removal and de-coloration with low-energy consumption".

DESCRIPTION of the ECR System In its simplest form, an ECR reactor is made up of electrolytic cells with one anode and one cathode. When connected to an external power source, the anode material will electrochemically corrode due to oxidation, while the cathode become passive. But, this arrangement is not suitable for wastewater treatment, because for a workable rate of metal dissolution, the use of electrodes with large surface area is required. This has been achieved by using cells with electrodes either in parallel or in double configurations. ECR cell arrangements are either parallel or doubled as shown below.



Parallel Cell
For Conductive Waste Waters



Double Cell
For Non- Conductive Waste Waters

ECR essentially consists of pairs of conductive metal plates placed between two parallel electrodes and a dc power source. The conductive metal plates are commonly known as "sacrificial electrodes" or common mild steel. The sacrificial anode lowers the dissolution potential of the anode and minimizes the passivity of the cathode.

The parallel arrangement of plates is electrically similar to a single cell with many electrodes and interconnections. In double cell arrangement, a higher potential difference is required for a given current to flow because the cells connected in series have higher resistance. The same current would, however, flow through all the electrodes. On the other hand, in Parallel cell arrangement the electric current is divided between all the electrodes in relation to the resistance of the individual cells.

ECR bipolar electrodes with parallel cells are preferred because less electricity is required. In this instance the sacrificial electrodes are placed between the two parallel electrodes without a middle electrical connection.

This cell arrangement provides a simple set-up, which facilitates easy maintenance during use. When an electric current is passed through the two electrodes, the neutral sides of the conductive plates will be transformed to charged sides, which have opposite charge compared to the parallel side beside it.

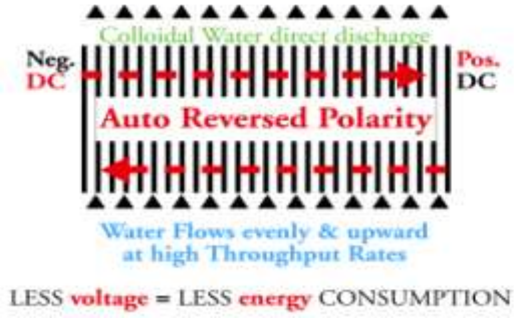
Thus, during ECR, the positive side undergoes anode reactions, while on the negative side, cathode reaction is encountered. The released ions neutralize the charges of the particles and thereby initiate coagulation. In addition, as water containing colloidal particulates, oils, or other contaminants move through the applied electric field, there may be ionization, electrolysis, hydrolysis, and free-radical formation which may alter the physical and chemical properties of water and contaminants. As a result, the reactive and excited state causes contaminants to be released from water and destroyed or made less soluble.

Colorado Hazardous Waste Management Society *MTS Journal. Vol. 27, No. 1 67* ***1989***

"ECR Treatment of Ship Bilgewater for the U.S. Coast Guard in Alaska""The results show that electrocoagulation treatment is effective in destabilizing oil emulsions. Removal efficiencies (extractable oil) exceeded 99% resulting in non-detectable values of less than 0.2mg/L TPH values in the effluent. The process was also effective in removing heavy metals with removal efficiencies ranging from 71 to 99%".

Tech SYSTEM OVERVIEW The common element of ECR passes electricity through water. The physical chamber to induce the electricity in the water varies greatly. The chambers vary in flow rate & electrical input configuration, etc. The basic principal is to cause electrons (amps) to flow through the liquid. The reaction takes place on the surface interface between liquid and blades.

Electro Chemical Reaction Chamber



ECR is the distinct economical and environmental choice for meeting water treatment standards and compliance requirements. ECR recovers capital and operating costs by eliminating the need for chemicals, discharge fees and fines, harvesting water resources, and significantly reducing water replacement costs.

Cost of sacrificial metal used within the chamber The conductive material in the ECR unit will dissolve and provide a coagulation nucleus from the blades like Fe++ and Al ++. Because the conductive material dissolves and must be replaced periodically, the form of that material has direct operating cost considerations. The ECR uses common metal bar stock in standard widths available directly from the steel mill.

Surface area configuration ECR treatment occurs at the surface interface between the liquid and the conductive material. Flat plates allow distances to be set that are far enough apart to lessen the clogging caused by large particles in the water, and close enough together to lessen the amount of voltage required to move the electricity through the liquid. The ECR chamber is designed with 3.5mm cells.

Directional flow ECR in general causes air to be liberated from the water. Air bubbles float to the top of any liquid. The bubbles can attach to the surface of the conductive material which blocks the metal liquid interface. The lack of conductivity within the chamber will prevent electrons from passing through the liquid which stops the treatment process. The ECR chamber directs water flow in the same direction as air bubbles float. The system eliminates pressure and resistance because the water flows in the same direction as the air bubbles thus ECR blades do not need to withstand pressure. The ECR units use standard 3-3.6mm thick sheet stock. Because the ECR blades are not specialty cut with lasers or precision machined, the cost is only the price of the steel.

Electrical connections Electricity enters the chamber in anode and cathode pairs. The voltage between the anode and cathode pairs must be set by transforming the grid power to the voltage desired between the pairs. The cost of transformers and the cost of electrical conductors to handle the amperage between the anode and cathode pairs greatly limit the flow rate of traditional outdated chambers. The ECR reaction chamber and its bipolar design allows direct line voltage to be converted from AC to DC and this saves the weight and space of electrical transformers. This also allows for the energy efficiency of operating the power at less than 3 volts per gap between blades, which saves on electrical consumption and it eliminates the need to connect an electrical conductor to each plate, which saves on the labor and blade construction cost. Electrical cost savings depends upon the voltage difference applied between the conductive materials. Power is purchased in watts. A watt is a volt times an amp.

Flow rate within the chamber Units operate at atmospheric pressure. Because the conductive material has no pressure requirement, the chamber can be built to meet any flow rate. However, operational constraints such as the weight and size of steel plates play an important role in determining chamber size. Unit designs are built in 5-15, 10-30, 30-60, 60-120, 120-180M3 per hour configurations for one man operations. Actual flow rates can increase or decrease based on specific conductivity factors of a given wastewater stream. Multiples chambers are configured with high quality electrical requirements for specific waters and power delivery per flow rates.

Scientific Conclusions The fact that ECR technology is now successfully applied to contaminated water around the world is testament to its existing application to the RMG Sector in BD. The ECR Water System has clearly preformed some of the more complex requirements needed to remove a wide range of wastewater pollutants.: See references found at www.flagshipdhaka.com :

The below results are provided by customers and/or have been reported by an Analytical Laboratory!

INDUSTRIAL INFLUENT into a Water Treatment Works Plant

SINGAPORE – DHAKA / 2005 - 2017

X = Not Tested	JT-RAW	JT-ECR No Amps	JT-ECR A1	JT-ECR A2	JT-ECR A3	JT-ECR B1	JT-ECR B2	JT-ECR B3		
ECR Settings		.25 A x 35V	1.0 A x 70V	2.5 A x 110V	5.0 A X 175V	1.0 A x 70V	2.5 A x 110V	5.0 A x 175V		
Power Consumption / M3		0.036 KWH	0.30 KWH	1.146 KWH	3.646 KWH	0.167 KWH	0.637 KWH	2.025 KWH	REGIONAL RESULTS	
Parameter Name	***RAW Results***	***ECR Results***	***ECR Results***	***ECR Results***	***ECR Results***	***ECR Results***	***ECR Results***	***ECR Results***	***Units***	***Method Reference***
BOD	638	388	359	338	321	389	325	338	mg/L	APHA 5210B
COD	1150	875	867	865	844	881	822	812	mg/L	USEPA 410.4
Copper	5.38	0.33	0.138	x	x	x	x	0.045	mg/L	USEPA 6010B
Lead	0.063	<0.013	<0.013	x	x	x	x	<0.013	mg/L	USEPA 6010B
Nickel	1.03	0.66	0.521	x	x	x	x	0.314	mg/L	USEPA 6010B
Oil & Grease	16.8	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	mg/L	USEPA 413.2
pH	6.5	6.7	8.8	8.7	9.0	7.7	8.2	8.2	Units	USEPA 9040B
TSS	228	19.3	14.0	9.3	<2.5	28.7	6.0	14.0	mg/L	APHA 2540 D
Turbidity	129	22.7	0.6	0.4	0.3	1.0	0.7	0.8	NTU	USEPA 180.1
Zinc	0.553	<0.004	<0.004	x	x	x	x	<0.004	mg/L	USEPA 6010B

SUPERNATANT – Compressed Garbage Leachate

SINGAPORE – 2006/ 2007

Parameter In Mg/L	***RAW Leachate***	***ECR Result***	***Max. Limit***	***Method Reference***
pH Value	3.8	5.3	6-9	APHA 4500H-98
COD	68,000	25,000	600	APHA 5220-05
TSS	3,440	380	400	APHA 2540D-05
TD Solids	32,800	19,000	3,000	APHA 2540C-05
Fats , O&G	2,560	380	60	APHA 5520-05

SEWAGE - Domestic Influent

Chenai INDIA - 2005

Parameter In PPM	***RAW Water***	***ECR Result***	
TD Solids	3,500	140	75 Volt 5.0 Amp
COD	550	32	
BOD	500	13	
O&G	75	Nil	
TSS	75	8	
E.COLI		Absent	
FECALCOLIFORM		Absent	
STREPTOCOCCOCI		Negative	

FOOD (Soy Sauce) Mfr.

Johor, MALAYSIA – 2005

Parameter In Mg/L	***RAW Water***	***ECR Result***	***Max. Limit***
TD Salts	748	790	--
TSS	5,041	2.2	100
COD	21,668	909	100
BOD	6,373	327	50
pH	4.4	6.2	5.5-9.0
Fats O&G	38	Nil	10.0

FOOD (Soft Drink) Mfr.

Bandung, INDONESIA - 2006

COD > Bio	356	331	100
TSS > Bio	51	12	200
COD < Bio	10,540	279	100
TSS < Bio	9,402	23	200

FOOD (Chili & Tomato) Mfr.

Jawa Rawat, INDONESIA -2006

COD < Bio	6,300	2,700	Alum. Elec-trodes
pH < Bio	3.7	6.0	
Color	Red	Clear	

TEXTILE Industry

INDIA, BANGLADESH – 2005-2007

Operations	*Parameter In Mg/L*	*RAW Result*	*ECR Result*	*Method Reference*
Dye Bath & Finish Mixed Washwaters	TD Salts	2,930	3,100	APHA 2540
	TSS	57	4	APHA 2540
	COD	413	164	APHA 5220
	BOD	148	78	APHA 5210
	Color	>250	30	HAZEN Unit
	pH	9.7	10.8	APHA 4500
Yarn Weaving Water Jet	COD	871	98	APHA 5220
	BOD	309	34	APHA 5210
	O&G	142	.02	APHA 5520
	Color	150	10	APHA 2120
	pH	5.8	8.6	APHA 4500
DYE Bath & Finish Mixed Washwaters	TD Salts	323	321	APHA 2540
	TSS	267	171	APHA 2540
	COD	842	355	APHA 5220
	BOD	249	112	APHA 5210
	Color	>250	60	LOVI Meter
	pH	10.3	10.9	APHA 4500
Dyeing Printing Post Bio..	COD	713	270	3A X 75V
	COD	4,923	980	6A X 200V
	COD	98	16	2.5A X 250V
TEXTILE RIVER Feed Water	TD Salts	494	625	APHA 2540
	TSS	20	4	APHA 2540
	COD	27	14	APHA 5220
	BOD	9	5	APHA 5210
	Color	50	20	HAZEN Unit
	pH	3.8	4.1	APHA 4500
	Hardness	30	34	APHA 2340

Central Effluent Treatment Plant – SIPCOT – Erode, India

Effluent Dye Bath	COD	728	272	Site Lab
	COD	3,060	1,440	Site Lab

EXPLORATION Drill Waters

(SCR) Melibur, INDONESIA- 2005

Parameter In Mg/L	*RAW Water*	*ECR Result*	*Max. Limit*
COD	615	60	100
Phenol	.98	.27	0.5
Ammonia	4.83	2.44	1.0
O&G	270	.41	10.0
pH	7.5	8.7	6-9
Iron	0.31	Nil	5.0
Manganese	0.086	0.009	2.0

EXPLORATION Drill Waters

(SCR) Jambi, INDONESIA 2006 - 2008

COD	375	38	Close Reflux
BOD	215	15	Azide Mod.
TSS	2,950	98	Dried at 105
O&G	577	Nil	Soxhlet Extr.
Turbidity	1,332	18	Nephelometric
H2S	0.24	0.02	Iodometric
Ammonia	38	4	Titrimetric
Lead	0.73	0.002	AAS
pH	8.0	8.2	Elecrometric
Color	14,000	500	HAZEN Unit

PRODUCED Waters

(SCR) Duri, INDONESIA - 2008

COD	610	58	100
BOD	375	15	50
Phenol	0.63	0.19	0.5
O&G	156	Nil	10.0
pH	7.5	8.7	6-9
Arsenic	180	Nil	0.1
Iron	0.52	Nil	5.0
Manganese	0.086	0.009	2.0

TANNERY (Raw Hide) Operation

Erode, INDIA - 2005

Parameter In Mg/L	*RAW Water*	*ECR Result*
Collection Tank Effluent		
COD	7,560	2,943
BOD	3,442	1,012
Reverse Osmosis Feed Water		
COD	102	96
BOD	27	17
Chromium Recovery by ECR		
Iron Cells	10 Amps	3,603 Total Cr.
Alum. Cells	10 Amps	2,370 Total Cr.

TANNERY (Shoe) Operation

East Java, INDONEISA - 2006

Parameter In ppm	*RAW Water*	*ECR Result*
COD < Bio	4,500	1,200

Heavy Metals	Average % Removed or Recovered	Other Contaminants		Average% Removed
Aluminum	99.0	Aldrin	PESTICIDES	98.0
Arsenic	96.0	Chloreiviphos		99.0
Barium	98.0	Cypermethrin		94.0
Calcium	98.0	DDT		99.0
Cadmium	98.0	Diazinon		99.0
Chromium	99.0	Lindane		99.0
Cobalt	62.0	Proptamphos		99.0
Copper	99.0	Boron		70.0
Iron	99.0	Cyanide		99.0
Lead	97.0	E. Benzene		99.0
Magnesium	98.0	MP-Zylene		98.0
Manganese	83.0	O-Zylene		98.0
Mercury	66.0	Toluene		99.0
Molybdenum	80.0	Fluoride		60.0
Nickel	99.0	Nitrate		40.0
Vanadium	95.0	Nitrogen TKN		93.0
Zinc	99.0	PCB-Arochlor		82.0
Platinum	83.0	Hydrocarbons		98.0
Selenium	42.0	Phosphate		98.0
Silver	91.0	Potasium		45.0
Tin	89.0	Silicon		99.0

TEXTILE Industry	**Dhaka, BANGLADESH**			**April 2007**
Parameters	***Raw Water***	***ECR Result***	***Bangladesh Discharge Limits***	***Method Reference***
M. Ind. Factory				
TDS	2,840	2,865	2100	Mg/L
pH	8.62	9.54	6-9	
TSS	60	8	150	Mg/L
Turbidity	670	88		FTU
COD	310	125	200	Mg/L
U. Group Factory				
TDS	1,420	1,415	2100	Mg/L
pH	8.31	8.41	6-9	
TSS	27	4	150	Mg/L
Turbidity	43	25		FTU
COD	190	28	200	Mg/L
S. Textile Factory				
TDS	750	760	2100	Mg/L
pH	10.53	9.85	6-9	
TSS	83	18	150	Mg/L
Turbidity	461	29		FTU
COD	490	318	200	Mg/L
M. Group Factory				
TDS	2,765	2,135	2100	Mg/L
pH	8.91	9.05	6-9	
TSS	105	27	150	Mg/L
Turbidity	172	74		FTU
COD	404	80	200	Mg/L
S. Denim Washing				
TDS	164	139	2100	Mg/L
pH	6.58	6.68	6-9	
TSS	417	31	150	Mg/L
Turbidity	310	36		FTU
COD	808	190	200	Mg/L
PAPER RECYCLING – PACKAGING Factory				
TDS	926	754	2100	Mg/L
pH	6.61	7.55	6-9	
TSS	1,143	7	150	Mg/L
Turbidity	636	29		FTU
COD	1,112	350	200	Mg/L

OTHER APPLICATIONS

Lagoon and Pit Cleanup

ECR performs reclamation of ground water contaminated with heavy metals, high molecular weight hydrocarbons and halogenated hydrocarbons.

Process & Rinse Waters

ECR treats process & rinse waters from electroplating, computer board & chip manufactures, paint rinse water, steel production, mining industry, automotive, airline and equipment repair & washing.

Cooling Waters

ECR is used to pre-treat water entering towers as well as blow down water to remove algae, suspended solids, calcium, and magnesium buildup.

Water Pretreatment

ECR has proven effective in removing bacteria, silica and TSS prior to subsequent polishing with reverse osmosis, ultra & nano-filtration.

Food & Beverage

Meat, Poultry, Fish, - Total plant effluents. The ECR can harvest additional protein & fat while removing FOG and COD.

Emulsified Oils in Water

ECR removes metals, oils, & dirt, from the exploration waters inherent with oil gathering and processing facilities .

ADVANTAGES of ECR

- ECR gives good, clear, colorless & sometimes odorless water.
- ECR sludge is easy to de-water & is a low sludge producing System.
- ECR systems have no moving parts, thus requiring less maintenance.
- ECR effluent has less TD Solids contributing to lower water recovery costs.
- ECR removes the smallest colloidal particles & facilitates faster coagulation

DIS-ADVANTAGES of ECR

- Electricity may be too expensive in many parts of the world
- ECR **will NOT** remove Salts & Mono-valent Ions