State-of-the-art Electrochemical Technologies for Industrial Water Treatment in the Kingdom of Saudi Arabia

Presented by:

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President & C.E.O.

enpar Technologies Inc. | Miahona مياهنا

Company Profiles

ENPAR is a Canadian Company formed in 1997 that is associated with the University of Guelph. ENPAR is a "Technology Company" applying its patented and proprietary "Electrochemical Technologies" to the treatment of waste water, desalination water and drinking water contaminated by metals or nutrients, i.e., nitrate/ammonia associated with the mining, metal processing, chemical, agricultural, municipal and waste management sectors.

MIAHONA provides management and concession services for urban utilities including water supply, waste water collection and treatment facilities; EPCO/BOO/BOT basis for water and waste water treatment plants. As leading holding company, Miahona also offers urban utility engineering consultation in water and wastewater disciplines in Saudi Arabia and MENA region.

Water Issues

- Ammonia
- Arsenic
- Fluoride
- Hardness
- Metal ions
- Nitrate
- Radionuclides
- TDS (Salinity)

Current Technologies

Contaminant	Technology
Nitrate	Biological, Ion Exchange
Ammonia	Biological
Arsenic	Absorbents
Fluoride	Membrane Systems
Salinity	Membrane Systems
Hardness	Ion Exchange
Radionuclides	Chemical Precipitation

Capacitive Deionization

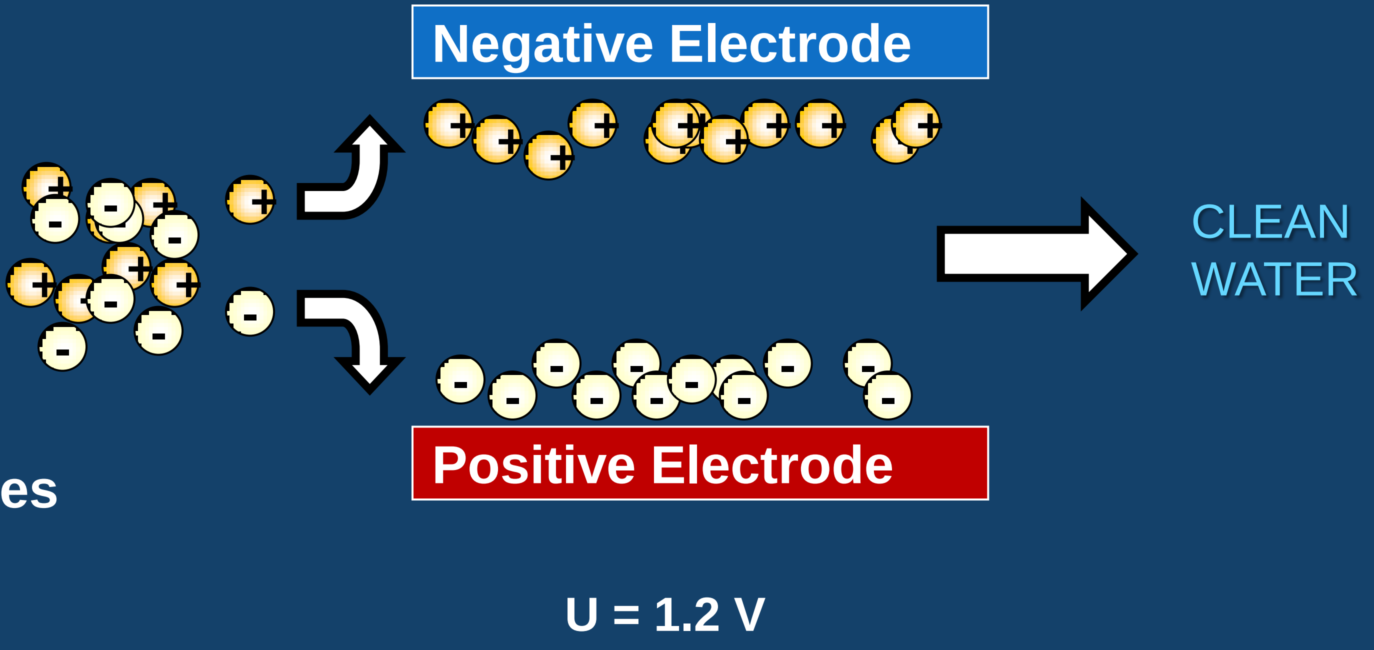
- Electrostatic removal of Total Dissolved Solids
- High ion removal efficiency
- High water recovery

ENPAR's ESD System treats all dissolved ions including arsenic, fluoride, hardness, metals and nitrate while maintaining *HIGH WATER RECOVERIES*.

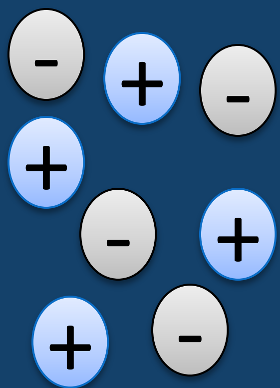
ESD purifies water through Capacitive Deionization (CDI) using proprietary carbon electrodes.

ESD System

Ammonia
Arsenic
Fluoride
Metal ions
Nitrate
Radionuclides



Operation - Purification



Contaminants

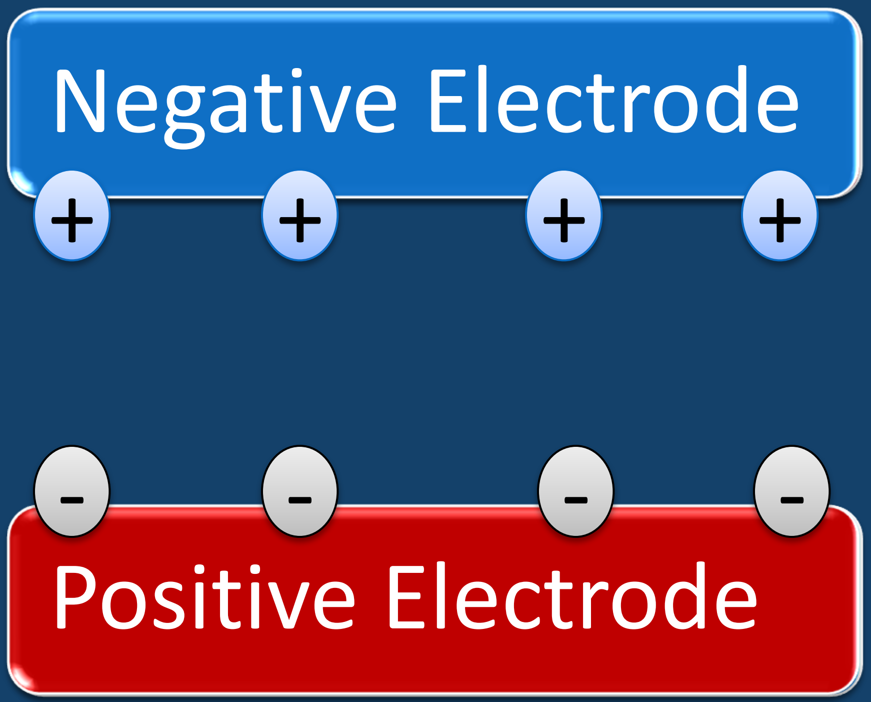
Negative Electrode

Positive Electrode

- U = 1.2 Volt

Operation - Regeneration

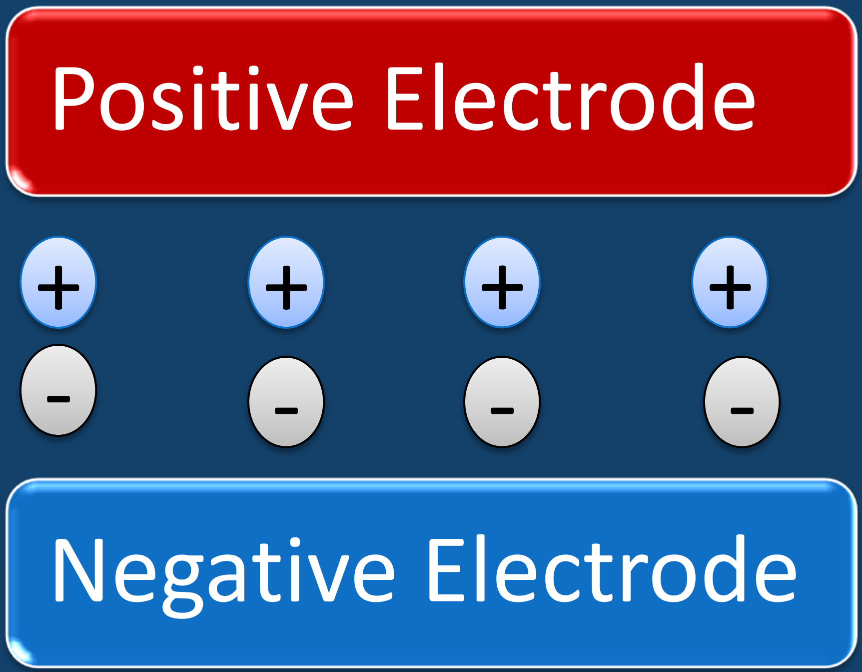
- **The polarity is reversed.**
- **Ions move away from the electrodes.**



- U = 1.2 V

Operation - Purge

- **During the purge the ions are removed as a small volume of concentrate.**



- U = 1.2 V

Main Advantages of ESD System

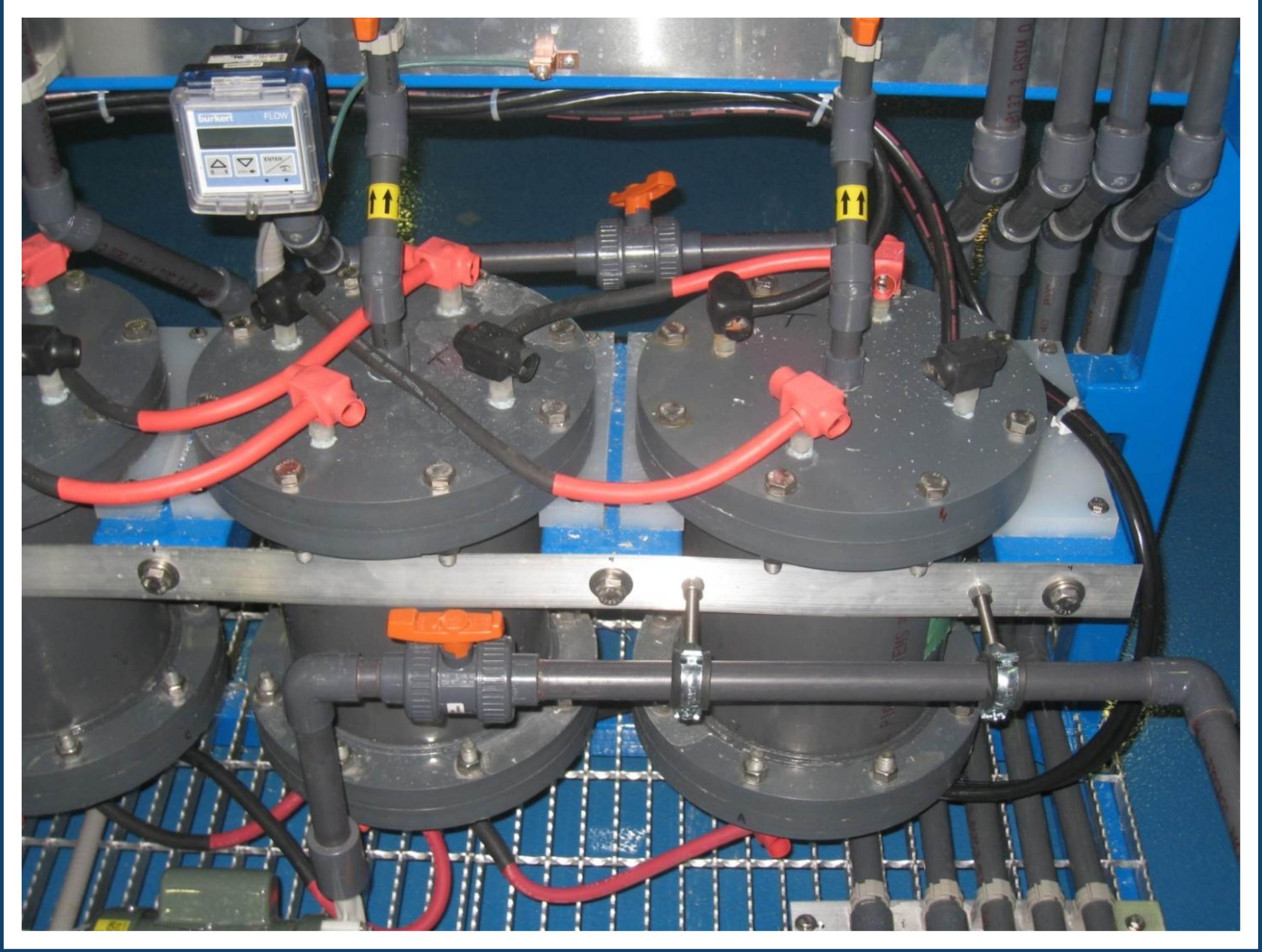
- High water recoveries
- High ion removal efficiencies
- Long cycle life of capacitor materials
- No continual addition of chemicals for drinking water and brackish water applications
- Designed to target either all ions or monovalent ions (nitrate, fluoride, chloride, perchlorate, cyanide)
- Low maintenance and ease of operation
- Adjustable output water quality and recovery

ESD vs Membrane (RO)

(Comparison is for drinking water quality)

ESD	Membrane (RO)
>95% water recovery (WR)	WR 70 -75% 1st stage WR 85% 2nd stage
\$0.06 per m^3	\$0.08 – 0.16 per m^3
No Water Softening	Water Softening
Low maintenance	High maintenance
Total ion removal/ mono-valent ions	Total ion removal

Heart of the ESD System – CDI Cell



4-Cell ESD 9k

Republic of Korea

Mobile Unit –South Africa/Australia

10-Cell ESD 24K

Application 1 - Recycling / Reuse

Case 1 - PUB Singapore

- Pilot testing: 2008 – 2011
  - RO reject: 2.0 - 2.7 mS/cm
  - Water recovery: 90 %
  - Ion Removal: 80 – 90 %
- Demonstration plant
  - 150 m^3 / day
- Full scale: 5000 m^3 / day

2-Cell ESD 5K

Application 1 - Recycling / Reuse

Case 2 - RO Reject Project 2010

- RO reject
- Conductivity: 13.5 mS / cm
- Treated water: 0.9 mS / cm
- Water recovery: 66.42%

- Brackish groundwater
- Conductivity: 3.21 mS / cm
- Ion Removal: 74%
- Water recovery : >91%

Application 1 – Recycling / Recycling

Case 2 continued - RO Concentrate

		Stage 1	Stage 2	Stage 3
Inlet	mS/cm	13.48	10.11	6.33
Concentrate	mS/cm	35.30	29.90	15.40
Treated	mS/cm	10.11	6.33	0.927
TDS Removal (%)		25.00	37.39	85.36 (93.12[1])
Water Recovery (%)		86.99	85.39	68.48 (66.42[2])

[1]Overall removal of TDS over three stages of water treatment

[2]Overall water recovery when recycling Stage 3 waste stream into Stage 1 inlet for processing

Application 2 – Stand Alone System

Case 1 - Ground Water Nitrate Treatment

- Groundwater (Guelph Ontario)
  - Nitrate-N of 34 mg/L
  - TDS of 790 mg/L
- All ion design – treated water
  - < 10 mg nitrate-N /L
  - 70 % removal of TDS
  - Water recoveries - 95%
- Mono-valent design – selective removal of monovalent ions
  - 69% removal of nitrate
  - 35% removal of overall TDS
  - Lower power requirements

Application 2 – Stand Alone System

Case 1 - Mono-valent Design – Nitrate in Groundwater

Parameter (unit)	Input	Treated Water	Waste Stream
pH	8.15	7.93	7.85
Conductivity (µS/cm)	1,300	870	6,800
TDS (mg/L)	787	512	4110
Ca (mg/L)	69	68	170
Mg (mg/L)	17	17	31
Na (mg/L)	127	59	770
K (mg/L)	56	23	510
NO_3^--N (mg/L)	31	9.6	270
Cl- (mg/L)	130	72	940
SO_4^{2-} (mg/L)	130	120	270
Water Recovery		92%	

Application 2 – Stand Alone System

Case 2 - Ground Water Arsenic Treatment

Huautla, Mexico - Collaboration with Government of Mexico

- ground water arsenic of 0.210 mg/L
- spiked ground water of 0.820 mg/L
- TDS of 339 mg/L

Results:

- < 0.005 mg As/L for both raw and spiked groundwater
- 99.4% removal efficiency
- water recovery - 97 %
- CDI cells - 0.80 kWh/m^3
- total power consumption - 1.37 kWh/m^3

Summary

- ESD is a proven reliable, high efficiency and low maintenance treatment system
- Applicable to the treatment of drinking water, wastewater and industrial process water
- High removal efficiencies with high water recoveries and minimal waste volumes
- Enhances efficiency of existing conventional RO systems
- Effective approach for drinking water issues, i.e., nitrate and arsenic

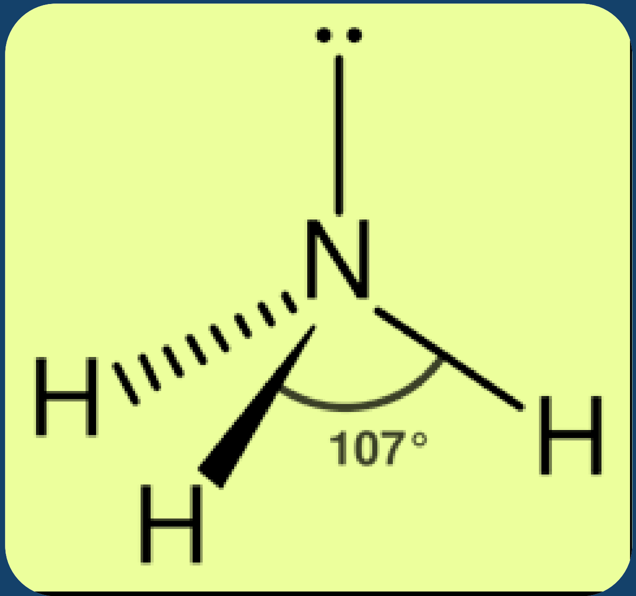
AmmEL-LC and AmmEL-HC

Patented AmmEL Processes for the Treatment of Ammonia in Municipal and Industrial Wastewater

Ammonia Converted to Environmentally–Friendly Nitrogen Gas

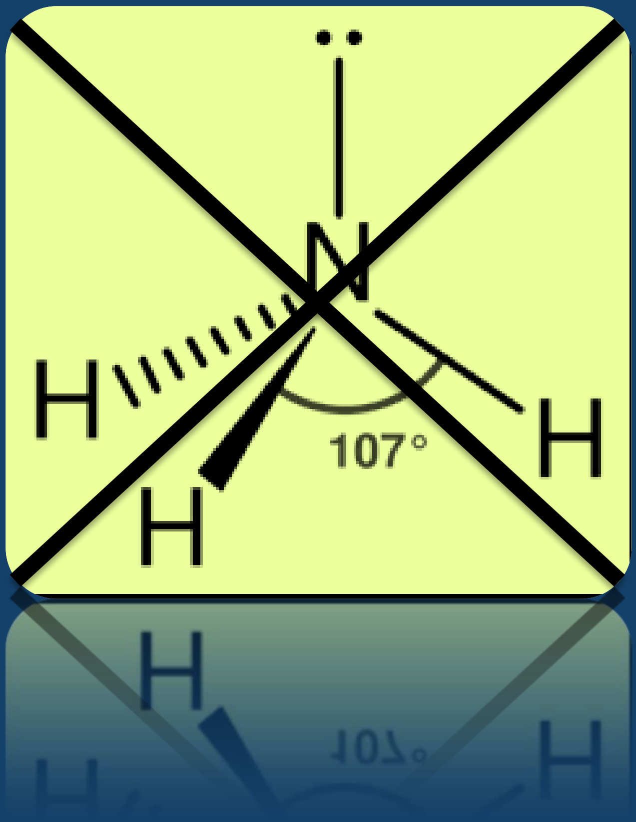
Introduction

- Ammonia listed as a toxic substance by Environment Canada
- One approach in the mining industry has been to lower the pH of the effluent to render it less toxic by shifting the NH_3/NH_4^+ equilibrium
- While this approach has assisted in meeting acute lethality discharge requirements, the total ammonia-N released into the environment is not reduced
- Current technology for treating ammonia relies heavily on biological activity (e.g. nitrification) to convert ammonia to nitrate

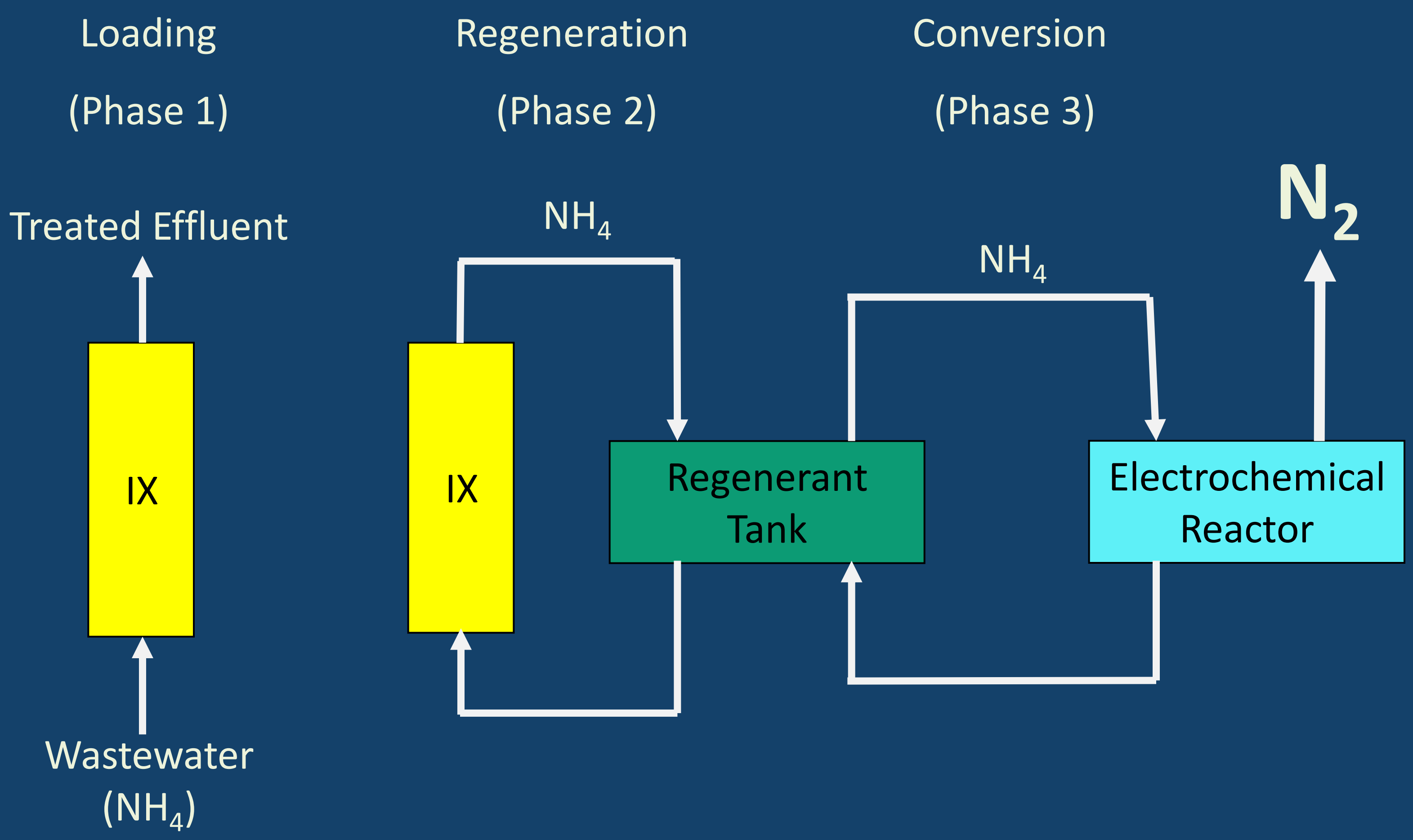


Introduction

- Total nitrogen removal requires additional biological processes to remove nitrate from wastewater prior to discharge
- Biological treatment systems are adversely affected by cold temperatures and changes in effluent composition
- A novel and patented ion-exchange/electrochemical treatment technology (the AmmEL system) has been developed by Enpar Technologies, Inc. which is not adversely affected by low temperature



The AmmEL-LC Process



The AmmEL Advantage

- Eliminates nitrogen loading by converting ammonia directly into innocuous N_2
- Does not produce nitrate and the GHG nitrous oxide associated with biological treatment
- Not affected by high calcium conditions
- Intermittent operation - no start-up delays
- Can be fully automated - low maintenance

System Applications

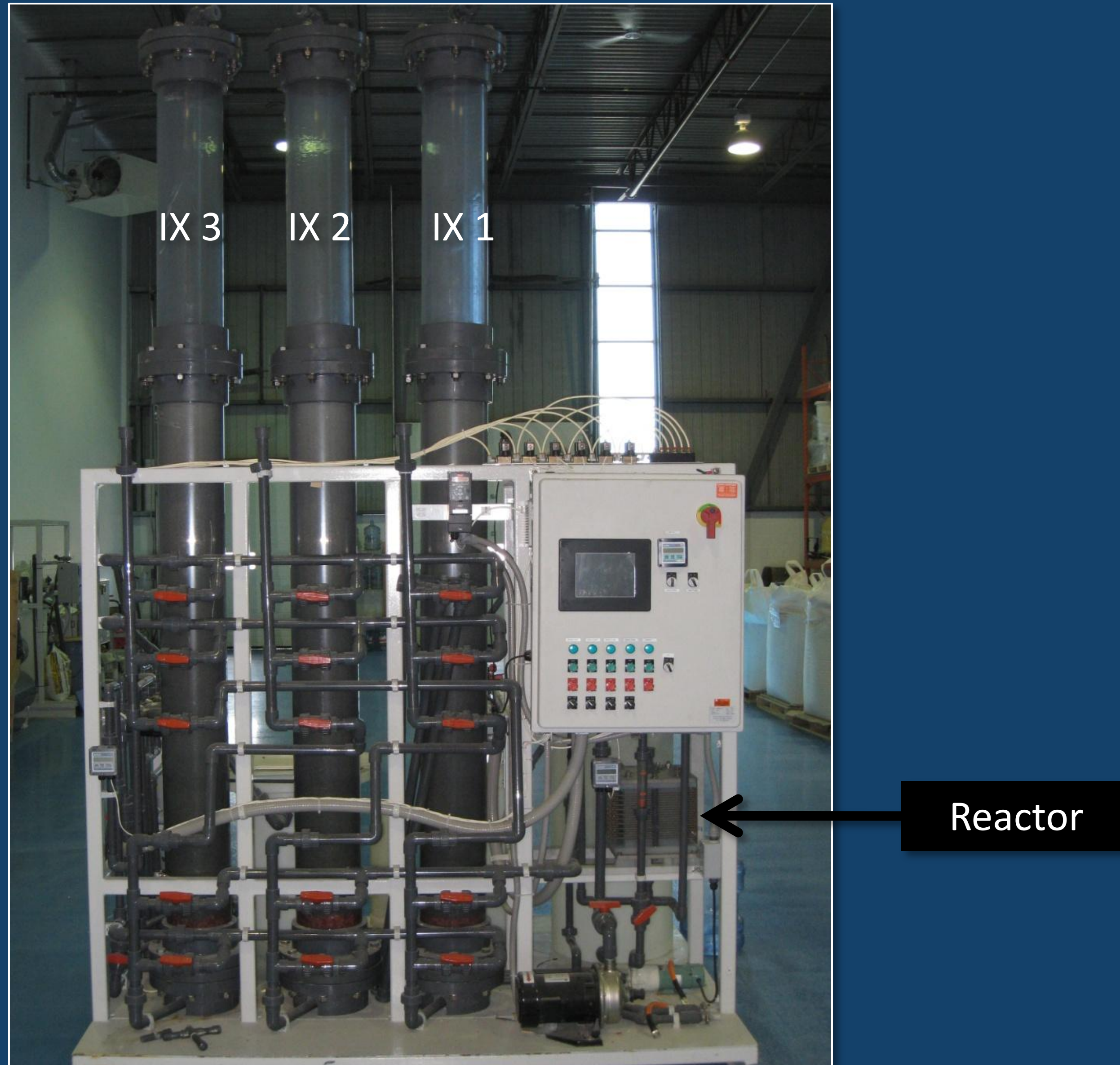
- Mining effluent or process streams containing ammonia derived from the use of ammonia based blasting powder and/or the oxidation of cyanide
- Tertiary treatment for municipal waste water treatment plants (MWTP) and lagoon systems
- Process streams related to steel, fertilizer and chemical industries

Pilot Study

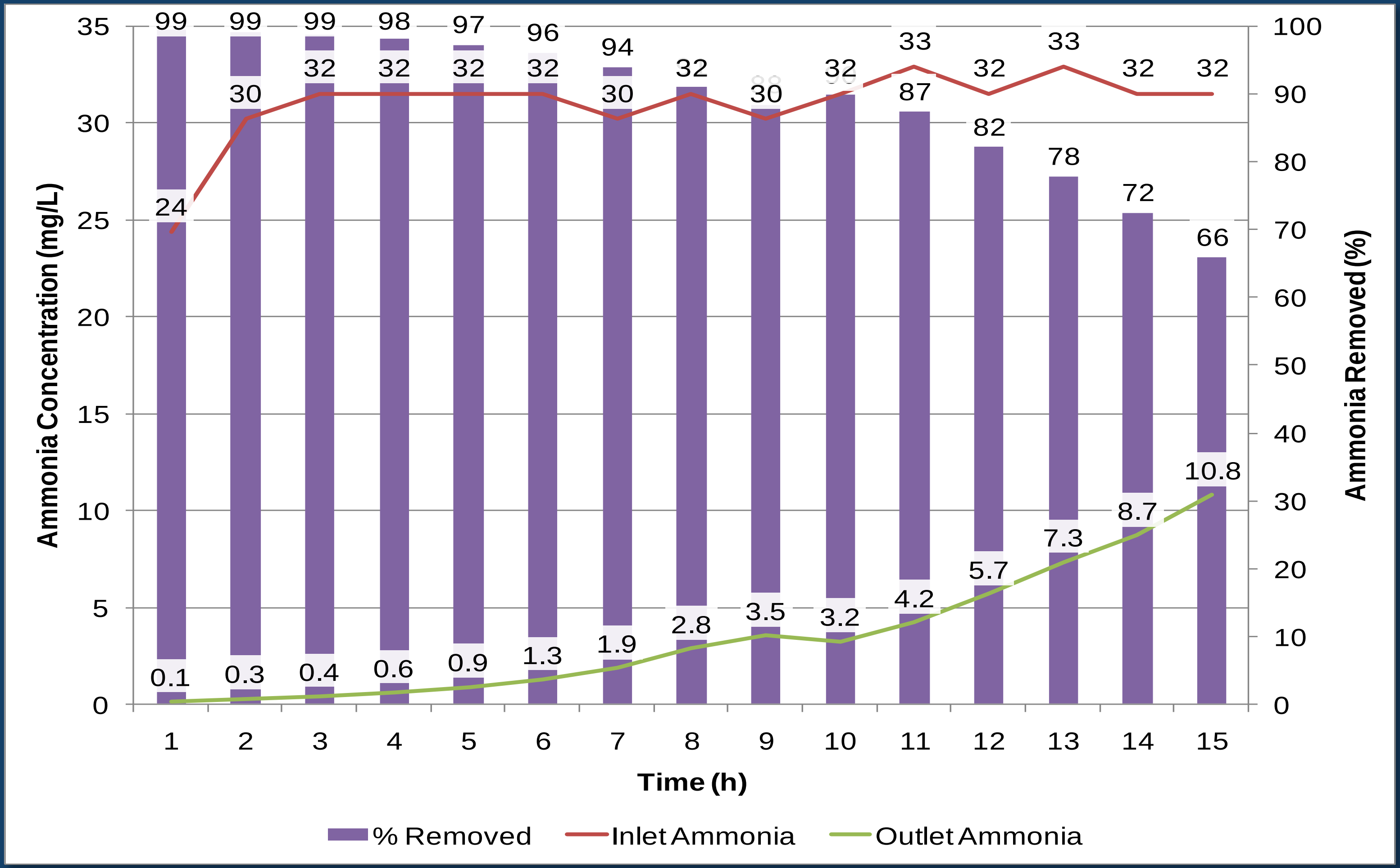
The *AmmEL-LC* System

AmmEL-LC Pilot Unit Specifications

- 3-20 cm x 3.05m fluidized bed IX columns, BV = 59.3L in a lead/lag arragement
- 1.5 kW electrochemical reactor
- Main operating conditions:
  – Wastewater flow rate: 18-20 L/min
  – Recharge brine flow rate: 8-10 L/min
  – Brine NaCl concentration: 3-4%
  – Cell current: 150 A


IX 3
IX 2
IX 1
Reactor

Typical Series Column Results



Ammonia Loading, Columns C1 & C3

Series Column Results

	C_2 & C_1	C_1 & C_3	C_3 & C_2
Flow Rate (L/min)	18.2	18.1	18.3
Total Run Time (h)	16	15	13
Water Temperature (°C)	5.9	6.0	5.9
Inlet pH	7.79	7.84	7.82
Outlet pH	7.86	7.86	7.91
Average Inlet NH_3 (mg/L)	23.0	31.0	35.3
Average Outlet NH_3 (mg/L)	4.0	3.4	4.5

Full-Scale Installation

- The system is designed to treat 400 m^3 of mine waste per day containing an average of 30 mg of ammonia-nitrogen/L
- Emission levels are 10 mg NH_3-N/L
- Three zeolite filled 30 cm (i.d.) x 6 m ion exchange columns
- Electrochemical reactor → 18 m^2 of anode surface area; 16V, 2000A DC rectifier
- Chlorine gas scrubber to comply with Ontario MOE chlorine emission levels

Ion Exchange Columns

Electrochemical Reactor

AmmEL vs Biological

AmmEL

- **Ammonia is converted to nitrogen gas**
- **No GHG, Nitrate**
- **Complete solution**
- **Small footprint**
- **$1.6 M (1MLPD)**

Biological

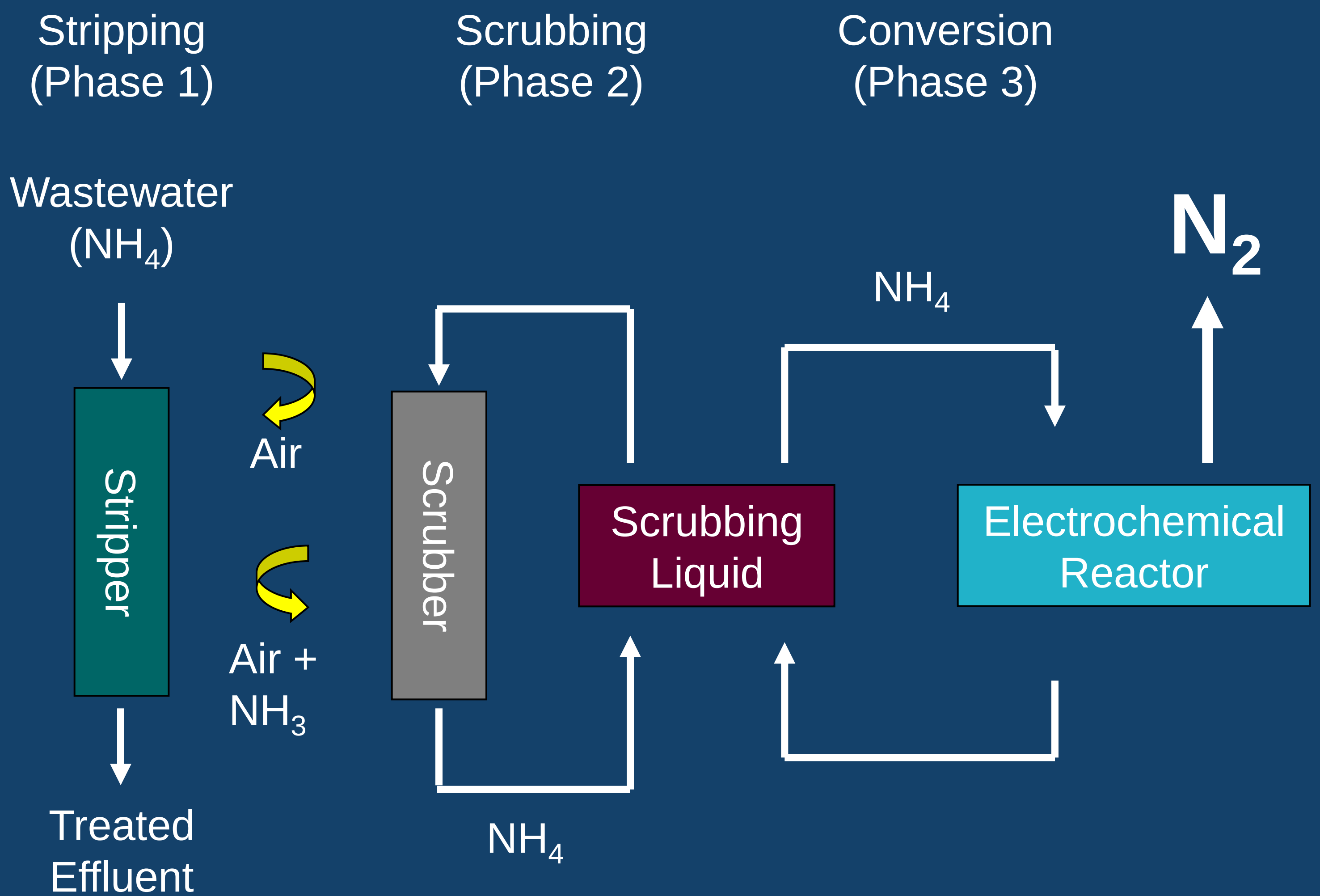
- **Ammonia is converted to nitrate (carcinogen)**
- **Creates GHG**
- **Partial solution**
- **Large footprint**
- **$1.7 – $2.5 M (1MLPD)**

The AmmEL-HC System

(SS Version)

Electrochemical / Strip & Scrub Method for the Treatment of Water Containing Higher Ammonia Concentrations

The AmmEL-HC System



The AmmEL-HC System

(City of Edmonton Pilot Unit)

Thank You