



Evaluation and Selection of Technologies for the Removal of RDX from an Industrial Wastewater Stream

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What is RDX?

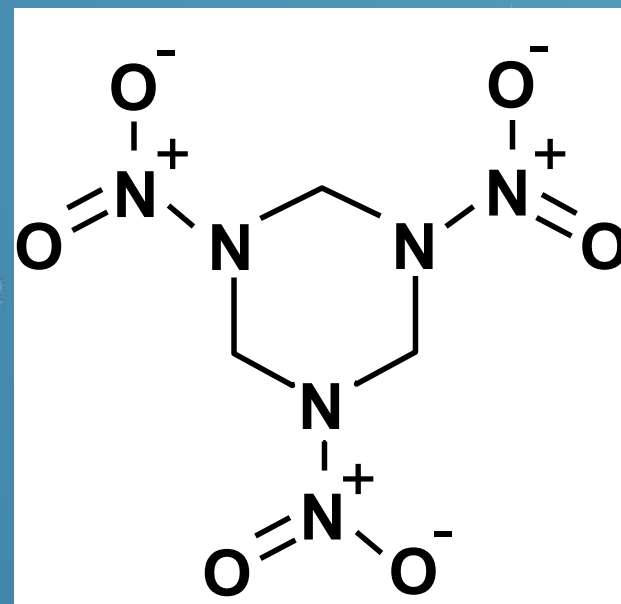
- Nitramine explosive
- Listed wastes under subpart D of RCRA

Environmentally Relevant

- Army Ammunition Plants
- Demilitarization sites

Solubility at 20°C ~ 40 mg/L

Density at 20°C 1.82 g/mL



hexahydro-1,3,5-trinitro-1,3,5 triazine

Royal Demolition eXplosive
Research Department Explosive
cyclonite or hexogen



RDX in Water

- **RDX production results in saturated or supersaturated RDX process wastewater (excess of 40 mg/L)**
- **EPA Lifetime health advisory limit for RDX in drinking water is 2 µg/L**



Problem

Large volumes of water with RDX exit production area

HSAAP has a large industrial wastewater treatment plant

but

RDX is difficult to treat with aerobic biological processes

Objective

Find technologies that can reduce concentration of RDX before entering the waste treatment system

Government/Industry Team

PM

Joint Services
(Funding and Management)



BAE SYSTEMS



Goal: Assess a broad scope of technologies and approaches to mitigating RDX wastewater at HSAAP



Processes that destroy RDX

Non Destructive

- Granular Activated Carbon
- Reverse Osmosis

Destructive

- Anaerobic biological processes
 - Anaerobic fluidized bed
- Zero-Valiant Iron (ZVI)
 - Filter or mixed in batch slurry
- Bi-metallic Particles - mixed in batch slurry
- Ultraviolet Oxidation
- Alkaline Hydrolysis
- Electrochemical - direct electrolytic



Treatment Issues in Production Facilities

Safety

Iron & glass sensitize RDX crystals

All electrical systems must be explosion proof

Process

High RDX concentrations in some process water

Large volumes of water used (Safety)



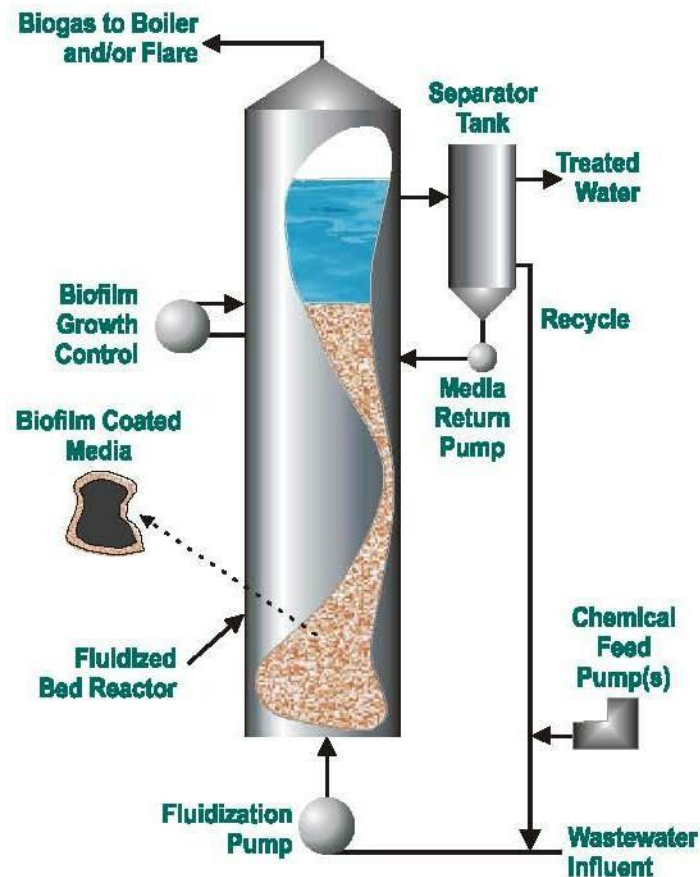
Granular Activated Carbon (GAC)

- **GAC** - good adsorbent medium
 - High surface area to volume ratio
 - 1 gram = 1,000 m² (surface area)
 - accumulates large number of contaminant molecules
-
- **GAC Regeneration**
 - Thermal
 - Solvent
 - Removed as Hazardous Waste
 - DOT Class 1 explosive hazard > 10% by mass
 - Expensive – cost increase > 2X in last 5 years



Anaerobic Fluidized Bed

- Installed McAlester AAP treats “pink water” from load & pack operations (TNT/RDX/HMX)
- Replaces GAC sorption



cost of treatment

Reverse Osmosis (RO)

Benefits

Low operating and maintainance cost

PLC automated operations

Reduces RDX contaminant mass loading to IWWP

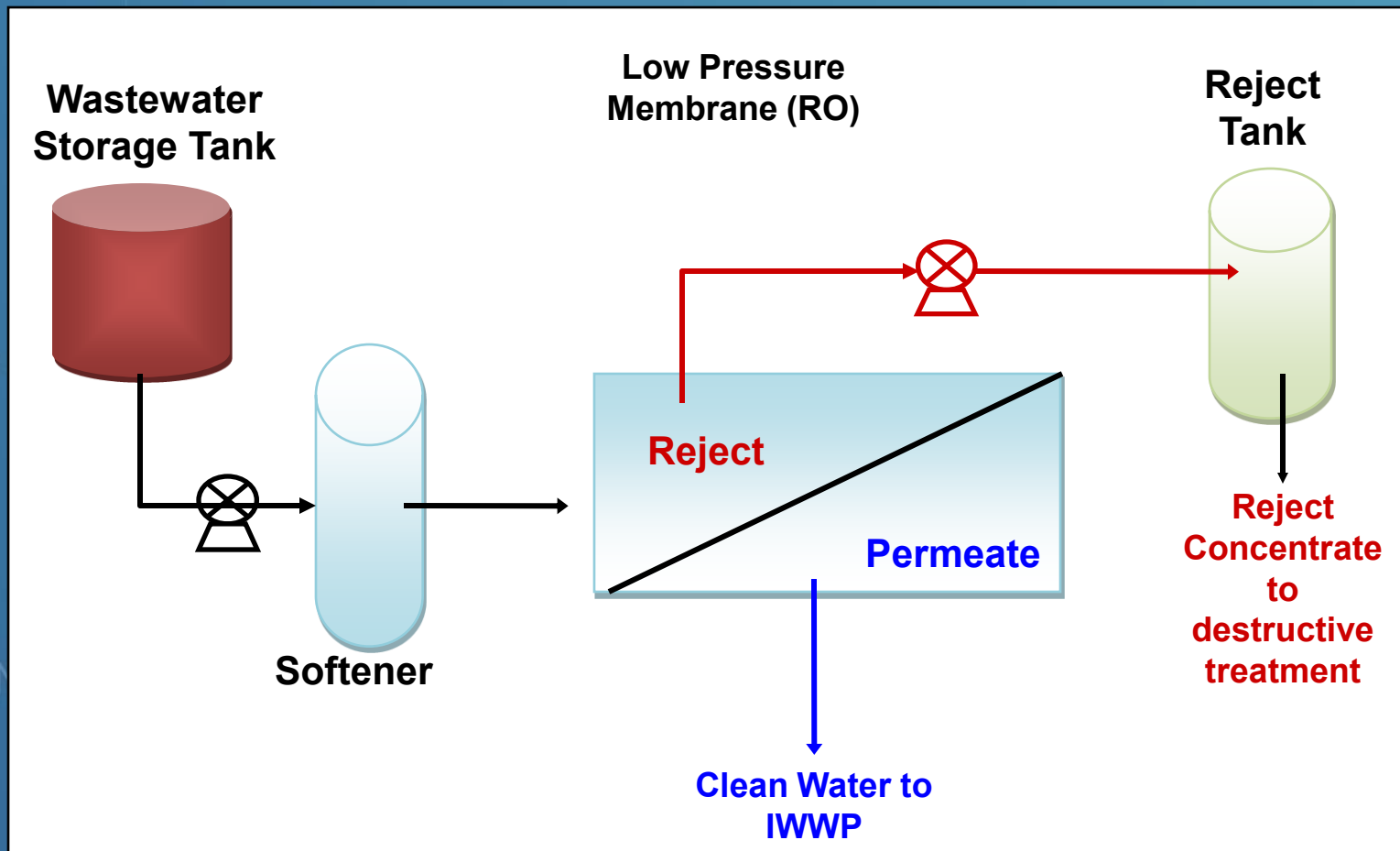
Drawbacks

Potential interferences (contaminants): Cl, F, Nitrates, Sulfates, Nitrites, Ca, Mg, Na

Membranes must be replace periodically < 1 per year



Reverse Osmosis (RO)



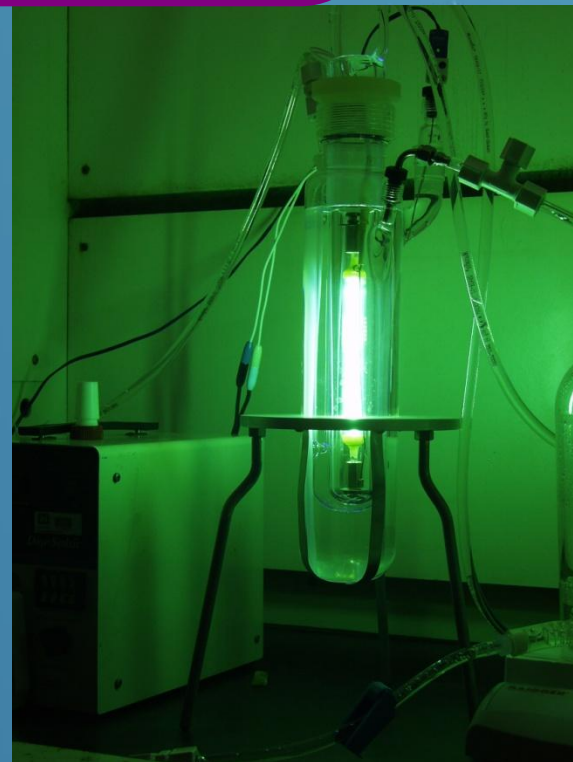
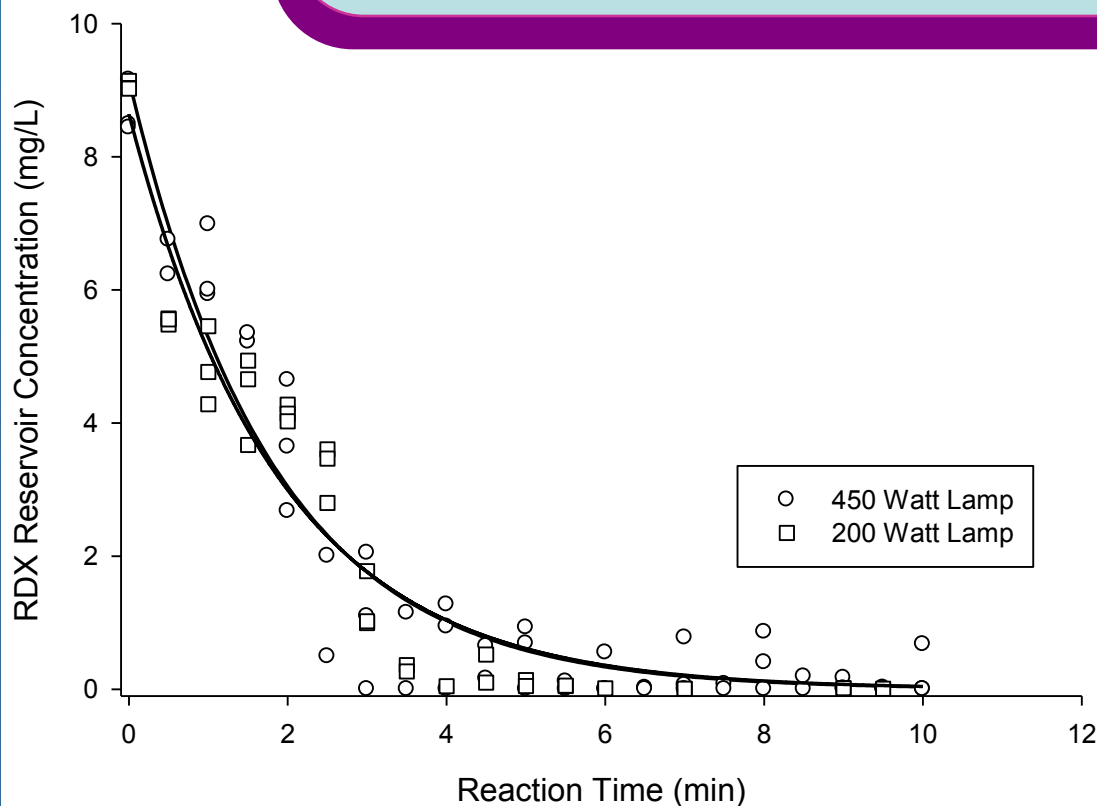
Ultraviolet Oxidation

Benefits

- Very fast. Half life on the order of 1 min

Drawbacks

- High energy per unit treated
- Uses glass jackets
- Maintenance issues – fouling

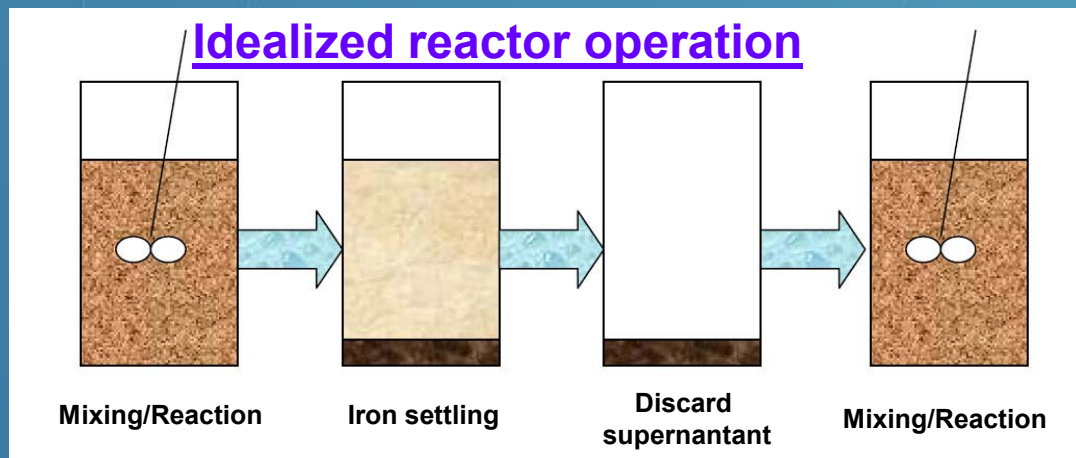
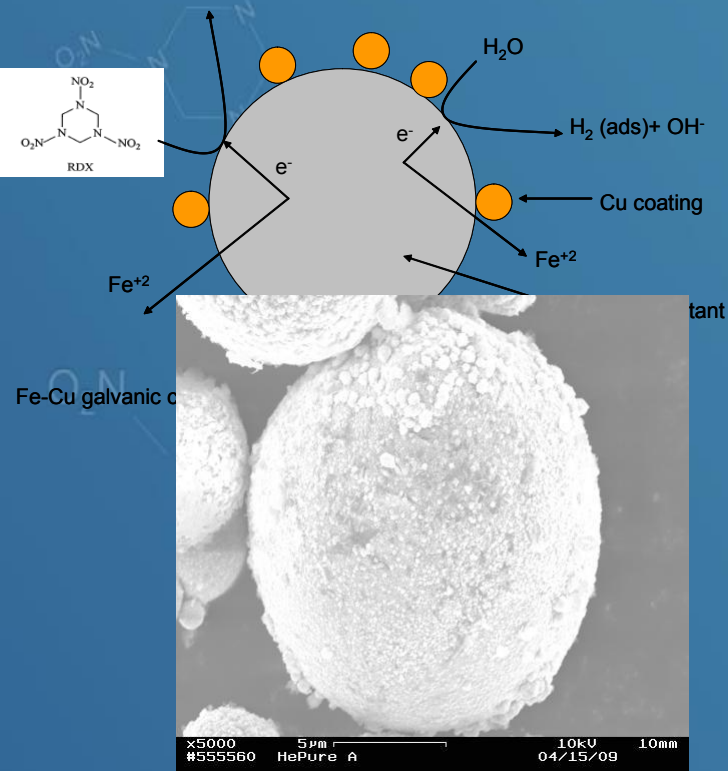


Bi-metal ZVI

Similar processes

Small particles mixed in batch slurry with process water

Bi-metal – enhances the reductive capabilities of ZVI by partially coating iron particles with Cu



Bi-metal ZVI

Benefits

Fast half life - 5 min

Complete degradation of nitrosamines derivatives

Drawbacks

Labor intensive, although process can be made fully automated

Requires adjusting pH to 4 - 4.5. Final pH between 5.6 and 6.5

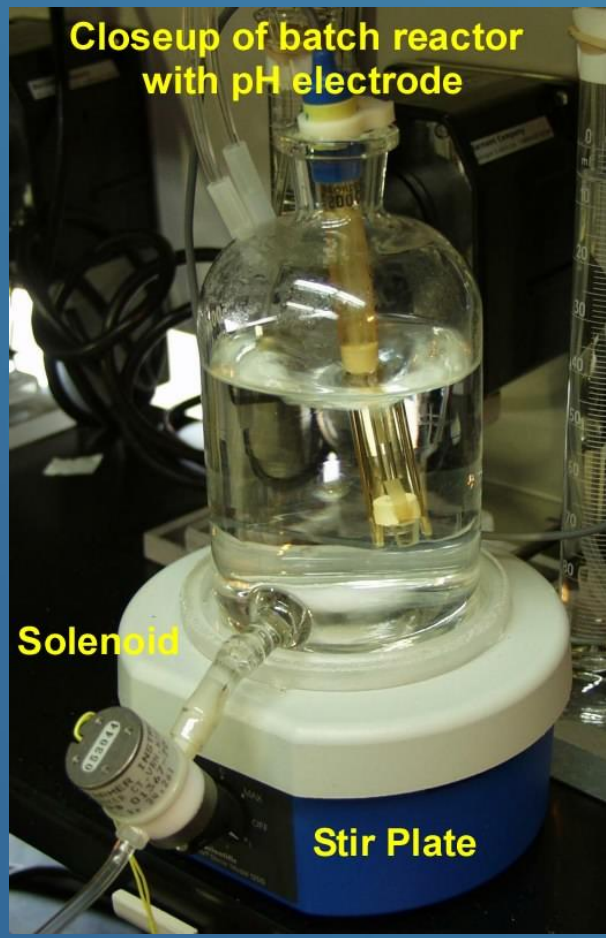
Replacement of bi-metallic particles every 12 cycles

No commercial source of bi-metal material. Simple electroless plating process.



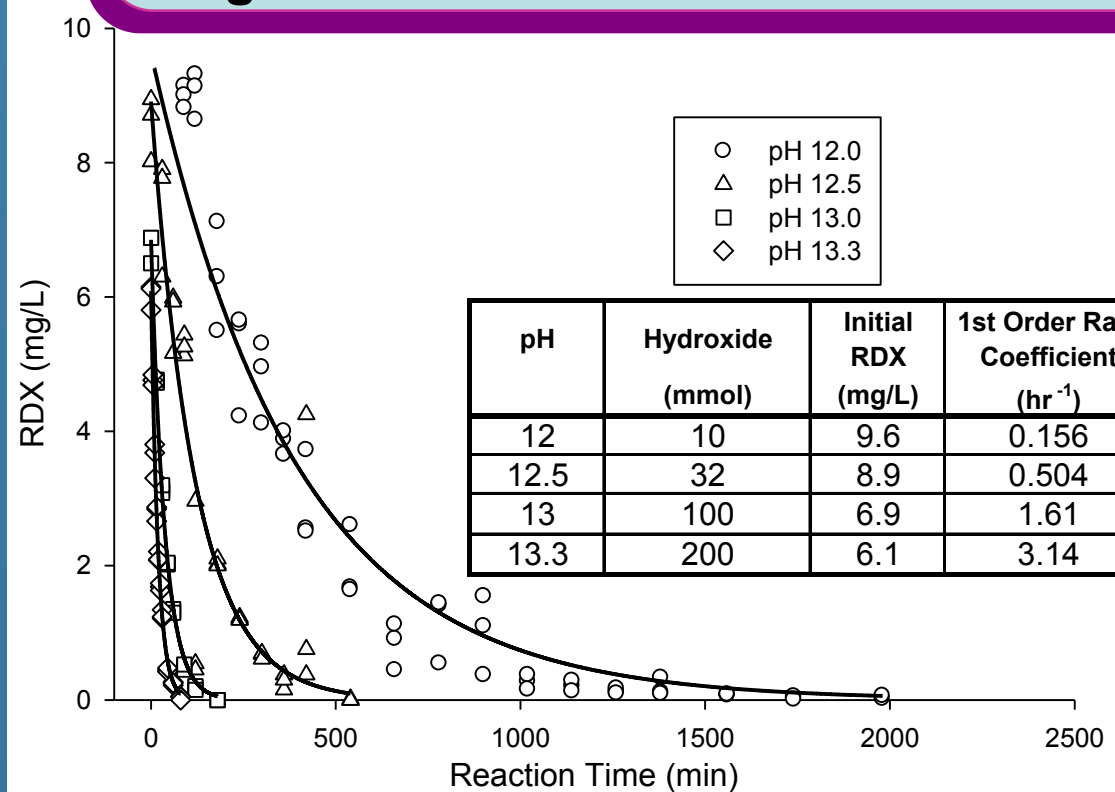
Alkaline Hydrolysis

Hydrolysis - efficient, cheap, and easy to implement
Good for low flow rates or low volumes

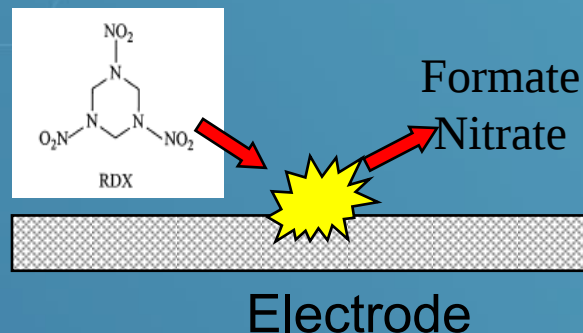
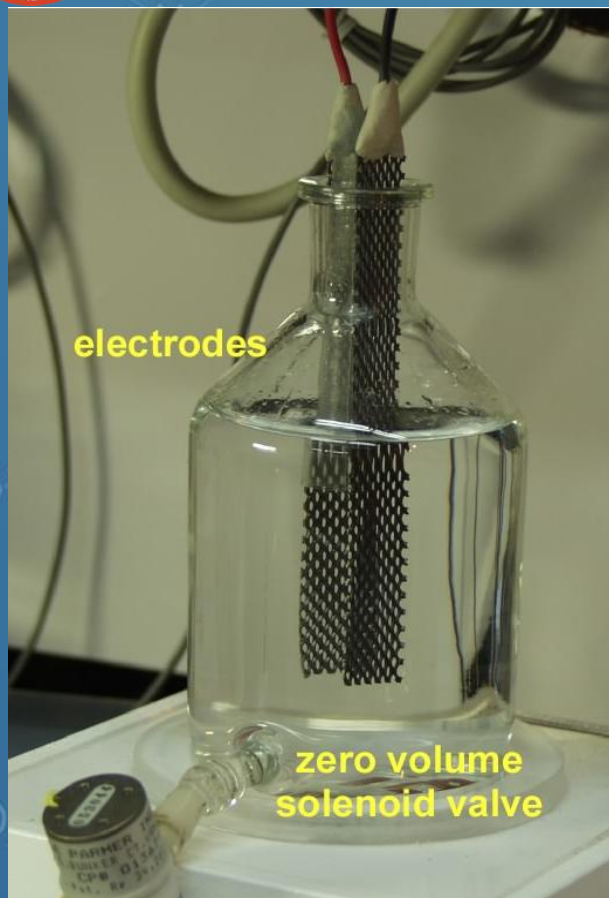


Drawbacks –

chemical handling safety
neutralization – increase anions in water
e.g. chloride or sulfate



Direct Electrochemical Reduction



Benefits

- No chemical additive required
- Batch or flow through systems
- Electrical costs
 - less or similar to chemical costs

Potential disadvantages

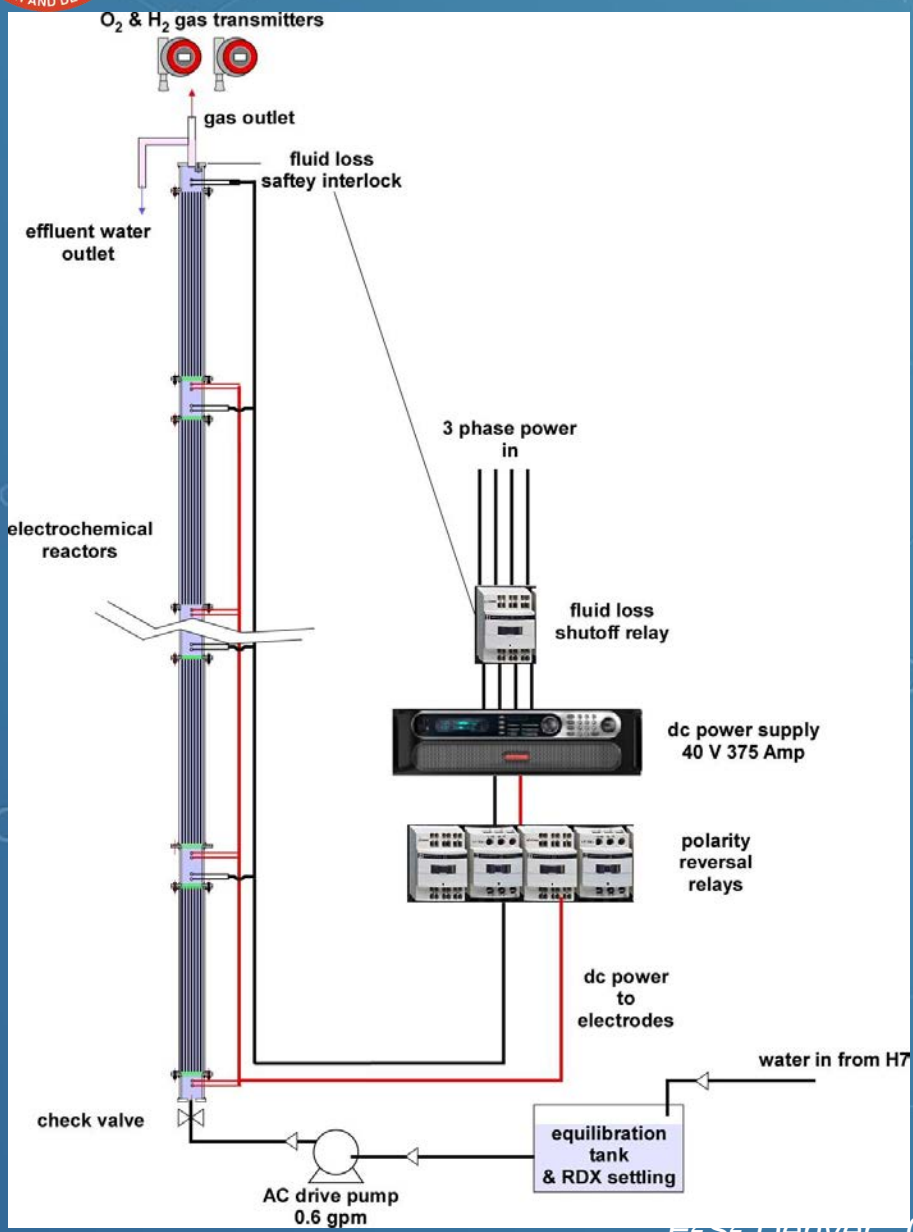
- Not demonstrated at full-scale
- Electrode costs
- Electrode life

System design parameters

- mass transfer
- current density



Conceptual Drawing Modular 5-stack Reactor Unit



Major components

- reactor vessels
- electrodes
- polarity reversal relays
- variable flow peristaltic pump

Safety features

- submitted for safety approval
- float switches
- check valves
- gas sensors
- power interlock
- consulting with BAE Engineering



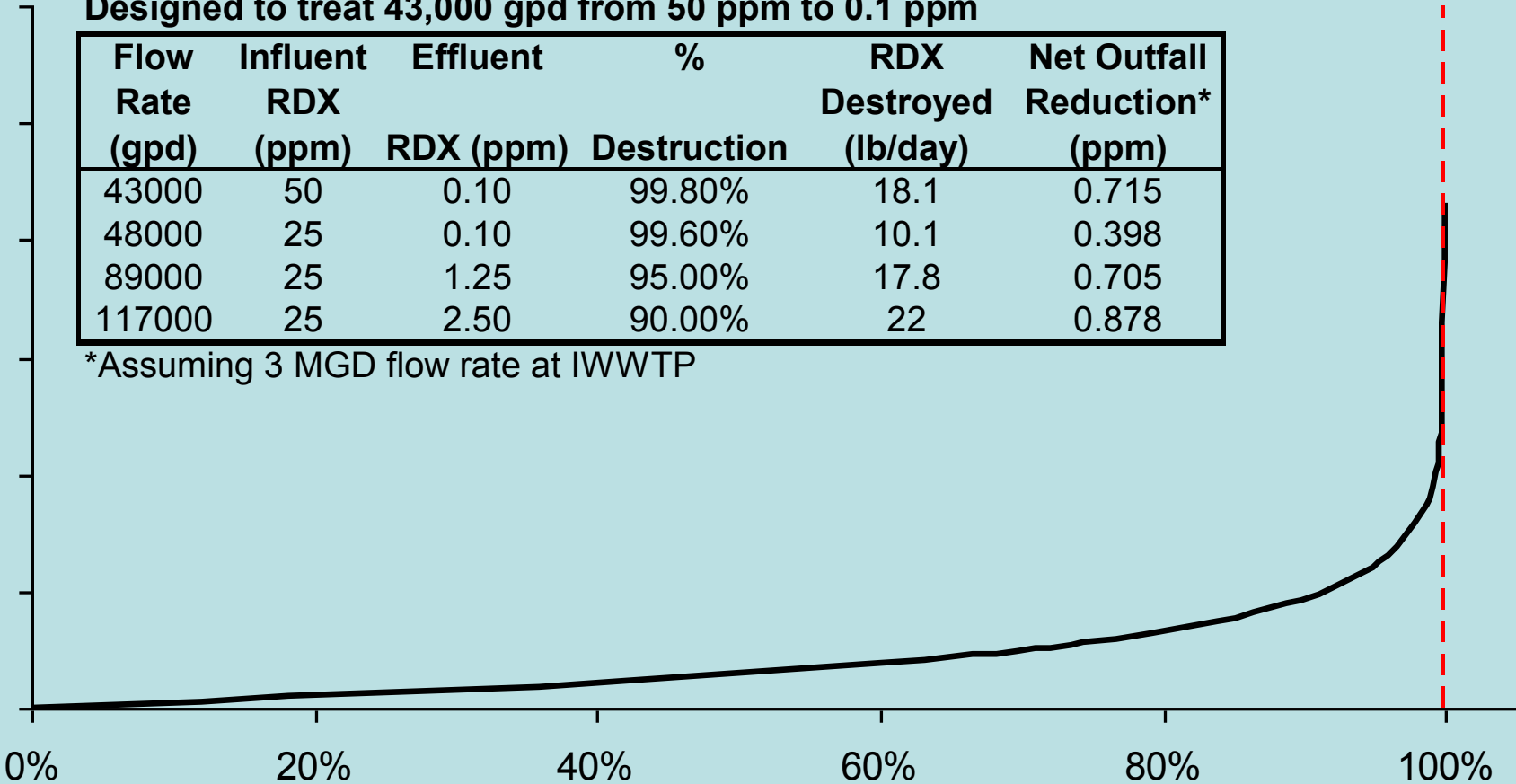
Capital Requirement

Original Pilot Design: 250 Reactor Elements
Designed to treat 43,000 gpd from 50 ppm to 0.1 ppm

Flow Rate (gpd)	Influent RDX (ppm)	Effluent RDX (ppm)	% Destruction	RDX Destroyed (lb/day)	Net Outfall Reduction* (ppm)
43000	50	0.10	99.80%	18.1	0.715
48000	25	0.10	99.60%	10.1	0.398
89000	25	1.25	95.00%	17.8	0.705
117000	25	2.50	90.00%	22	0.878

*Assuming 3 MGD flow rate at IWWTP

Estimated Capital Cost (\$M)



Mass Reduction of RDX in Water



Ultimate goal

- **Build or install full and pilot-scale systems at HSAAP**
 - **Reverse Osmosis**
 - **Electrochemical**
 - **Fluidized bed bio-reactor system**
 - **Bi-metal**



Questions?