

HUMASORB®

Solution To Pollution

Low Cost for Simultaneous Cleanup of Heavy

Metals, Radionuclides and Organics

Metals, Radionuclides, Organics

Multi-Purpose Adsorber

High Cation-Exchange Capacity

Can Be Regenerated

Cost-Effective

Environmentally Friendly

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ARCTECH CORPORATE PROFILE

- ❖ Established in 1988 as spin-off company from Atlantic Research Corp., an large U.S. Aerospace Company
- ❖ Headquarter and Technical Center – Chantilly, Virginia
- ❖ Manufacturing Plant – South Boston, Virginia
- ❖ Market Profile: Develops Innovative Solutions from Concept to Implementation for Energy, Environment and Agriculture markets
- ❖ Commercial Products Applications in U.S.A, Egypt, Gulf Countries and S.Korea
- ❖ Creating Biotechnology Solutions since Mid 1970's.
- ❖ Selected as one of the six top bioprocessing firms in the United States (Arthur Young, 1989)



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WATER & SOCIETY ISSUES

- Water, organic matter and heat energy are absolute essentials for sustaining life
- Water is controlled and uncontrolled resource on our planet
- Clean water must be available at affordable cost for everyone

WATER QUALITY TODAY IS A MAJOR ISSUE



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CONTAMINANTS OF CONCERN IN WATER

- 💧 Suspended Solids – Insoluble metal salts, soil and sludge particles
- 💧 Organics – Petroleum and chlorinated hydrocarbons, pesticides
- 💧 Metals – Heavy metals and radionuclides
- 💧 Anions – Nitrate, phosphate, sulfate
- 💧 Microbes – Coliform, Cryptosporidium sp. , Giardia sp.
- 💧 Viruses – Norwalk



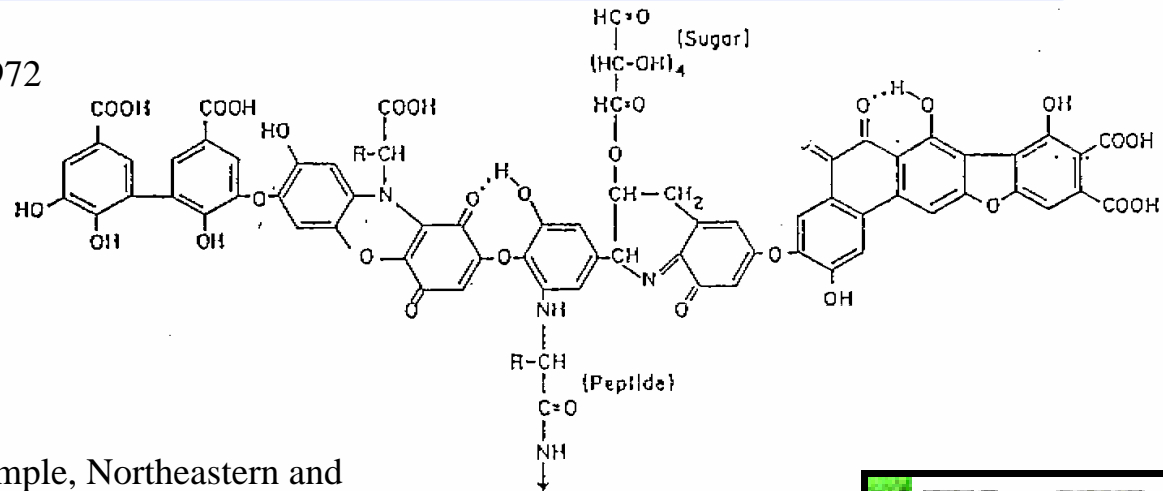
STATE-OF-THE- ART Water Treatment Technology

- Filtration – Charcoal, activated carbon, sand
- Resins – Cation and anion exchange
- Membrane Separation - Reverse Osmosis, hollow fibers
- Chemical Oxidation – Peroxide, ozone, chlorination, UV
- Chemical Reduction
- Chemical precipitation – Lime addition
- Biological – Aerobic and anaerobic

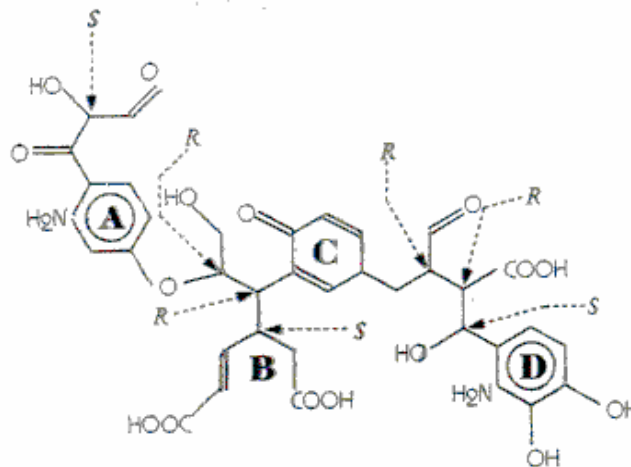


MODELS OF HUMIC ACID MOLECULE

A. Stevenson, 1972

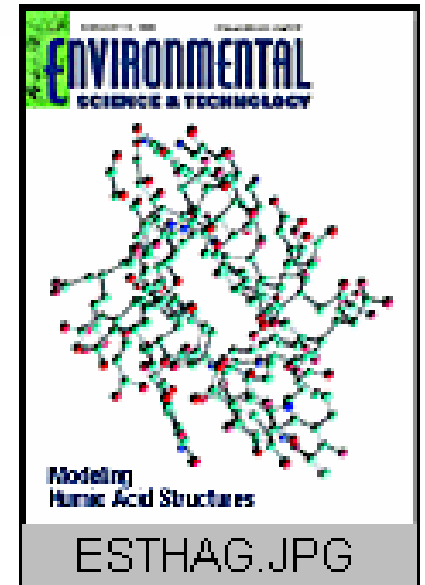


B. TNB, 1998 (Temple, Northeastern and Birmingham)



Empirical Formula: $C_{36}H_{30}O_{15}N_2 \cdot xH_2O$

$x=0-15$



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Why HUMASORB® for Water Application?

Issues of Today

- ❖ 122 Trillion Gallons of Wastewater Per Year Need to be Treated
- ❖ Large Undergrounds Watersheds Remain Contaminated Because of High Costs
- ❖ Safe Drinking Water Becoming Scarce and Costly
- ❖ Impaired Irrigation Water Supply

HUMASORB® Solutions

- ❖ HUMASORB® can Cost-Effectively Treat Toxic Organic, Metals, Radionuclides and Pathogens
- ❖ HUMASORB® for Cost- Effective Subsurface Barrier Treatment
- ❖ HUMASORB® Effective for Removing Toxic Contaminants from Drinking Water
- ❖ HUMASORB® can Recycle Wastewaters into Organic Fertilizers.



HUMASORB® System is Robust to Treat Brines of Varying Characteristics Generated at Chemical Agent Disposal Sites

Successful Operations with Brines of Varying Characteristics at JI

Input Brine



Treated Brine

| Metal | Concentration, mg/L | | |
|-----------|---------------------|-----------|-----------|
| | Brine # 1 | Brine # 2 | Brine # 3 |
| Aluminum | 64 | 4.3 | 7.8 |
| Antimony | 0.79 | 3.5 | 24 |
| Arsenic | 0.25 | 0.22 | 2.7 |
| Barium | ND < 2.0 | 2 | ND |
| Beryllium | ND < 0.02 | 0.02 | ND |
| Boron | 72 | 16 | 76 |
| Cadmium | 0.52 | 0.82 | 0.74 |
| Chromium | 360 | 9.3 | 20 |
| Cobalt | 0.61 | 0.1 | ND |
| Copper | 650 | 12 | 18 |
| Lead | 2.1 | 8.2 | 26 |
| Manganese | 12 | 0.6 | 0.54 |
| Mercury | 0.13 | 0.0049 | ND |
| Nickel | 32 | 1.6 | 0.92 |
| Selenium | ND < 0.2 | 0.2 | ND |
| Silver | 2 | 0.35 | ND |
| Thallium | 0.23 | 0.1 | ND |
| Tin | 0.6 | 0.36 | 0.59 |
| Vanadium | 0.51 | 0.1 | ND |
| Zinc | 78 | 46 | 69 |



| Metal | Concentration, mg/L | | |
|-----------|---------------------|-----------|-----------|
| | Brine # 1 | Brine # 2 | Brine # 3 |
| Aluminum | 1.06 | 2.45 | ND |
| Antimony | 0.061 | 2.1 | ND |
| Arsenic | ND | 0.117 | ND |
| Barium | ND | 0.065 | 0.00433 |
| Beryllium | ND | ND | ND |
| Boron | 46.2 | 14.7 | 50.4 |
| Cadmium | ND | 0.504 | 0.0103 |
| Chromium | 1.84 | 1.65 | 0.0105 |
| Cobalt | ND | 0.015 | ND |
| Copper | 2.02 | 1.47 | 0.0105 |
| Lead | ND | 0.271 | ND |
| Manganese | 0.108 | 0.377 | 3.97 |
| Mercury | ND | ND | ND |
| Nickel | 0.0401 | 0.636 | 0.00766 |
| Selenium | 0.0637 | ND | ND |
| Silver | ND | 0.0223 | 0.143 |
| Thallium | ND | ND | ND |
| Tin | ND | ND | ND |
| Vanadium | ND | ND | ND |
| Zinc | 0.0693 | 29.4 | 0.0518 |

| | Input | Treated |
|------------|--------------|-----------|
| Phosphorus | 14-1,100 PPM | ND-36 PPM |

Operating Conditions

Brine Flow Rate: 8-10 gpm

HUMASORB®: Same dosage for all brines

pH: 4-5 (for all the 36 isotainers)

Additives: Iron compound for some brines

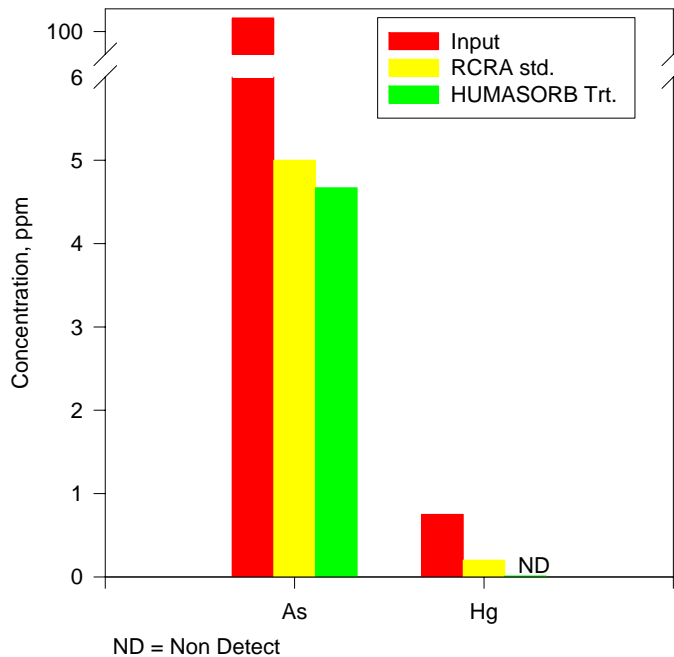
No downtime for HUMASORB® system at JI



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HUMASORB® Technology is Effective for Treatment of Waste Brines at Johnston Island Atoll

Concentration of metals in a composite sample collected at the end of 145 bed volumes



Arsenic was present as an uncharged species, while mercury was present as cationic in the brine water



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HUMASORB® Mobile Unit at Army's Johnston Island Chemical Weapons Destruction Facility



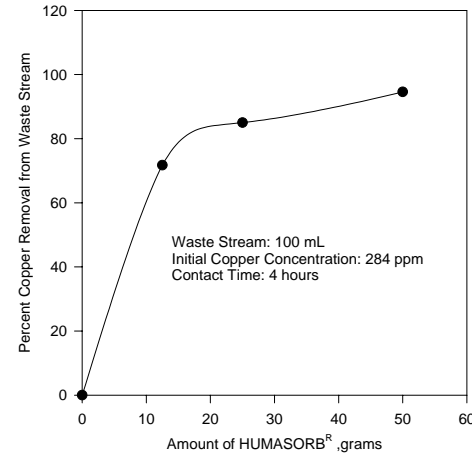
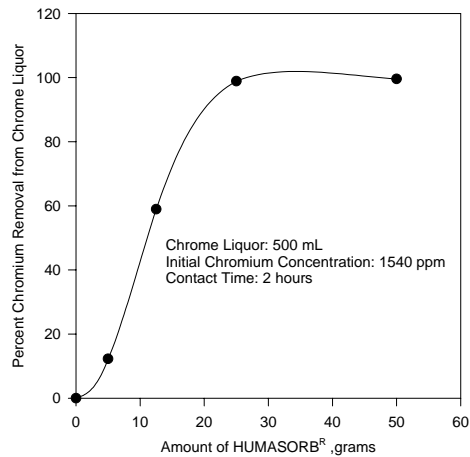
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HUMASORB® TECHNOLOGY DEMONSTRATION UNIT



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HUMASORB[®] DEMONSTRATION SETUP FOR TESTS IN INDIA



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HUMASORB® IS EFFECTIVE IN TREATMENT OF CONTAMINATED WATER IN MATKA TESTS

Tests conducted in Prototype HUMASORB Matka System

| Contaminant | Concentration in Untreated Water, ppm | Concentration in Treated Water , ppm | WHO Guideline for Drinking Water System,ppm |
|-------------|---------------------------------------|--------------------------------------|---|
| Lead | 5-20 | ND | 0.01 |
| Arsenic | 5-20 | ND | 0.01 |
| Chromium | 5-20 | ND | 0.05 |

ECONOMIC FEASIBILITY

& Total System under 300-500 Rupees for a 3-gallon (11 litres) MATKA

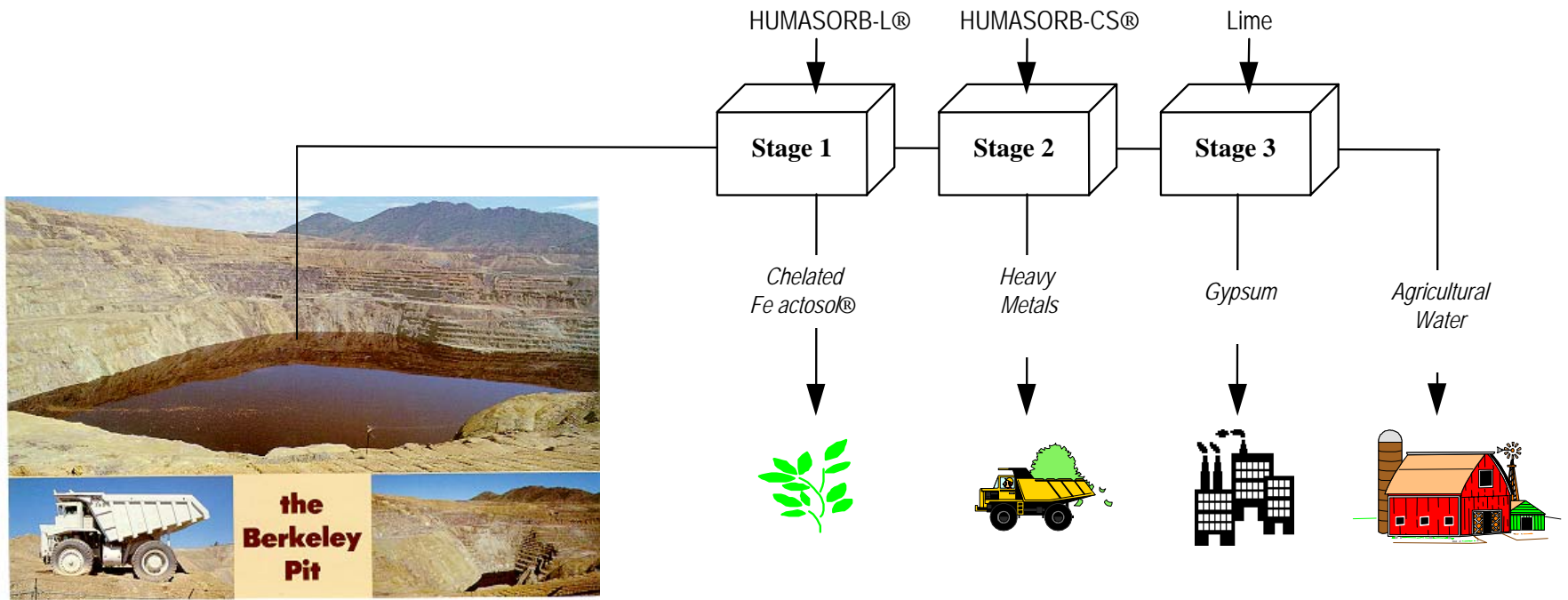
& Provide 300-360 gallons (1,1130-1,360 litres of drinking water

& HUMASORB® recharge cost : less than 500 Rupees



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Simplified Flow Diagram of the ARCTECH Process to Convert Berkeley Pit Water to Fertilizer and Agricultural Water



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Background-Hard Rock Mine-Berkeley Pit, Butte, Montana

Mined for gold, silver, and copper, the region of Butte, Montana, nicknamed "The Richest Hill on Earth" by the end of the 19th century.

The Berkeley Pit is a gigantic former open pit one mile wide and 900 feet deep mine.

Approximately 5-6 million gallons flows into the pit everyday from underground aquifers.

Water is acidic (pH~2) and laden with toxic metals such as As, Cd, Zn.

In 1995, a large flock of migrating snow geese landed on the Berkeley Pit water and were killed, most likely by the high concentration of acid.



HUMASORB® Approach Proven Effective for Resource Recovery of AMD Waters

| Metals | Untreated | treated |
|--------|-----------|------------|
| | ppm | |
| Al | 224 | 0.428 (B) |
| Cd | 1.82 | 0.0016 (B) |
| Cu | 201 | 0.0437 (B) |
| Fe | 660 | 75.1 |
| Ni | 1.02 | 0.124 (B) |
| Zn | 626 | 26.2 |

Micronutrient fertilizer contained
Fe, Zn, Cu, Mn, Mg & Humic Acid

Plant Growth Studies at Montana State Univ.

- actosol® enhanced the development and growth of wheat & alfalfa
- actosol® treatment increased yield of wheat & alfalfa by 40%
- actosol® increased micronutrient uptake by roots of wheat & alfalfa

B: Below method detection limit

Economics

5 million gallon per day capital cost \$25 million

Revenues :\$106 million @\$2 per gallon fertilizer

Costs :\$89 million

Profit Before Tax :\$17 million

Potential Profit of \$10/1000 gallon AMD treated water



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Multi Site *In-Situ* Treatment Approach

HUMASORB®-L
Formulation Facility
In Pennsylvania



Periodic Treatments At
Each Site



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HUMSAORB®-L Treatment Cost Is Function of pH of AMD Water

| pH | Dosage Per 1000 Gallons | Cost, \$/1000 Gallons |
|------------------------------------|------------------------------------|------------------------------|
| High to Slightly Acidic | 1 to 1.5 | 0.50 to 0.75 |
| Near Neutral | 0.5 | 0.25 to 0.35 |

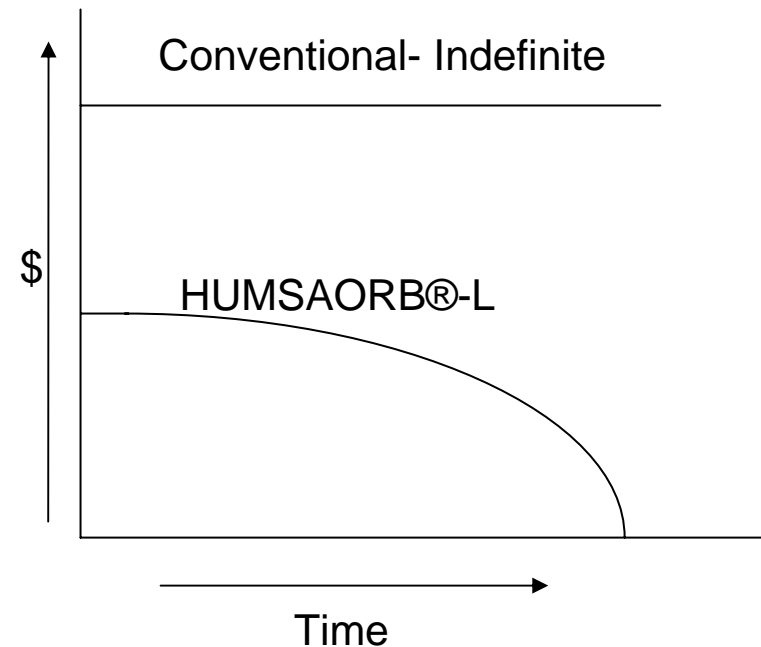
Commercial experience of lime treatment cost for active treatment is estimated at \$1.6-2.00/1000 gallons



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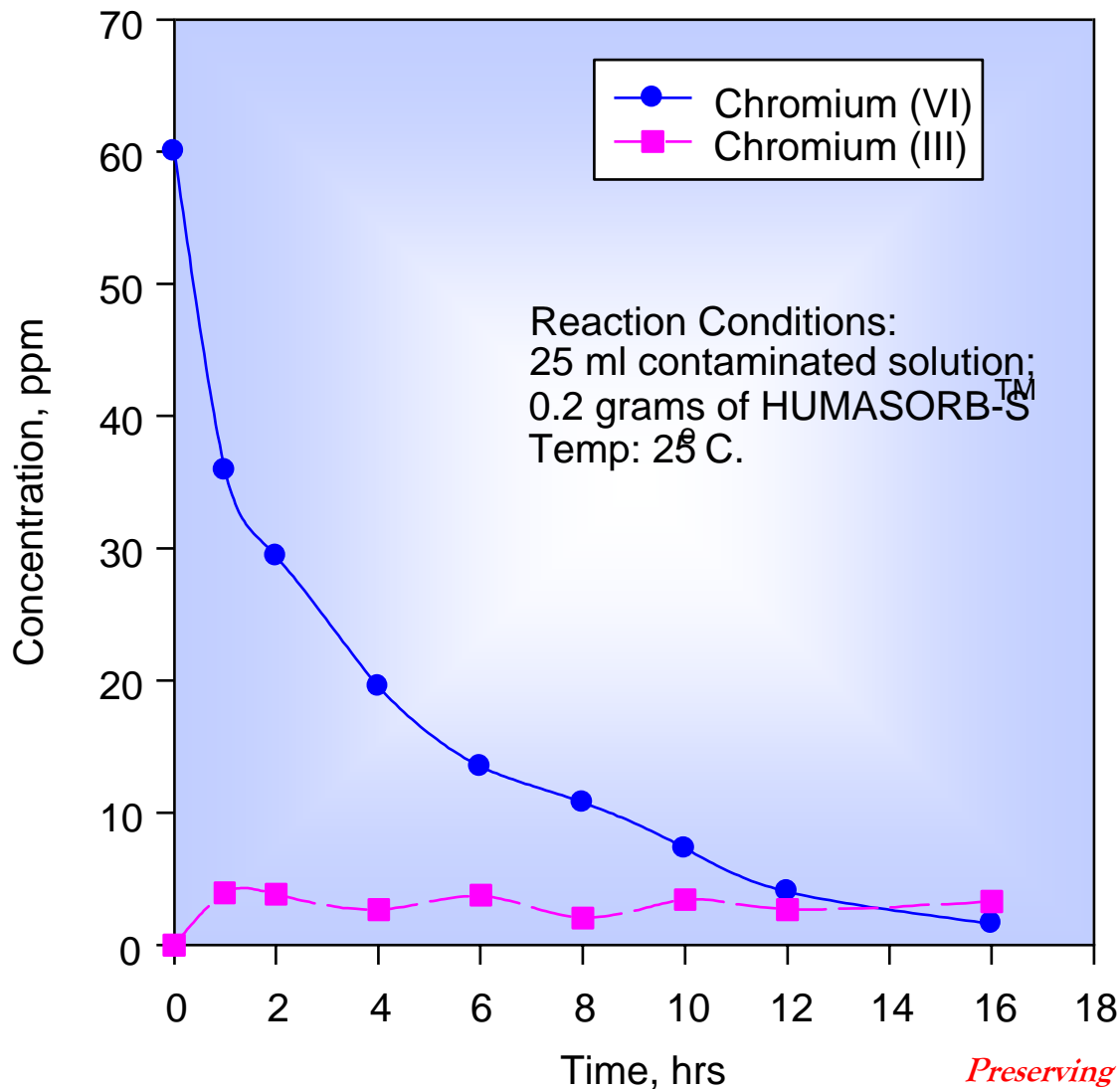
HUMASORB®-L Offers Lower Life Cycle Costs for AMD Treatment

- Current average cost of \$0.50/1000 gallons results in total cost of \$12 million per year for treating 23 billion gallons of AMD in Pennsylvania (PADEP Jan. 2006 Press Release)
- At this rate Life Cycle costs will exceed \$1.2 billion over next 100+years
- HUMASORB®-L Life Cycle cost will be only \$24-60 million over 2-5 years Treatment



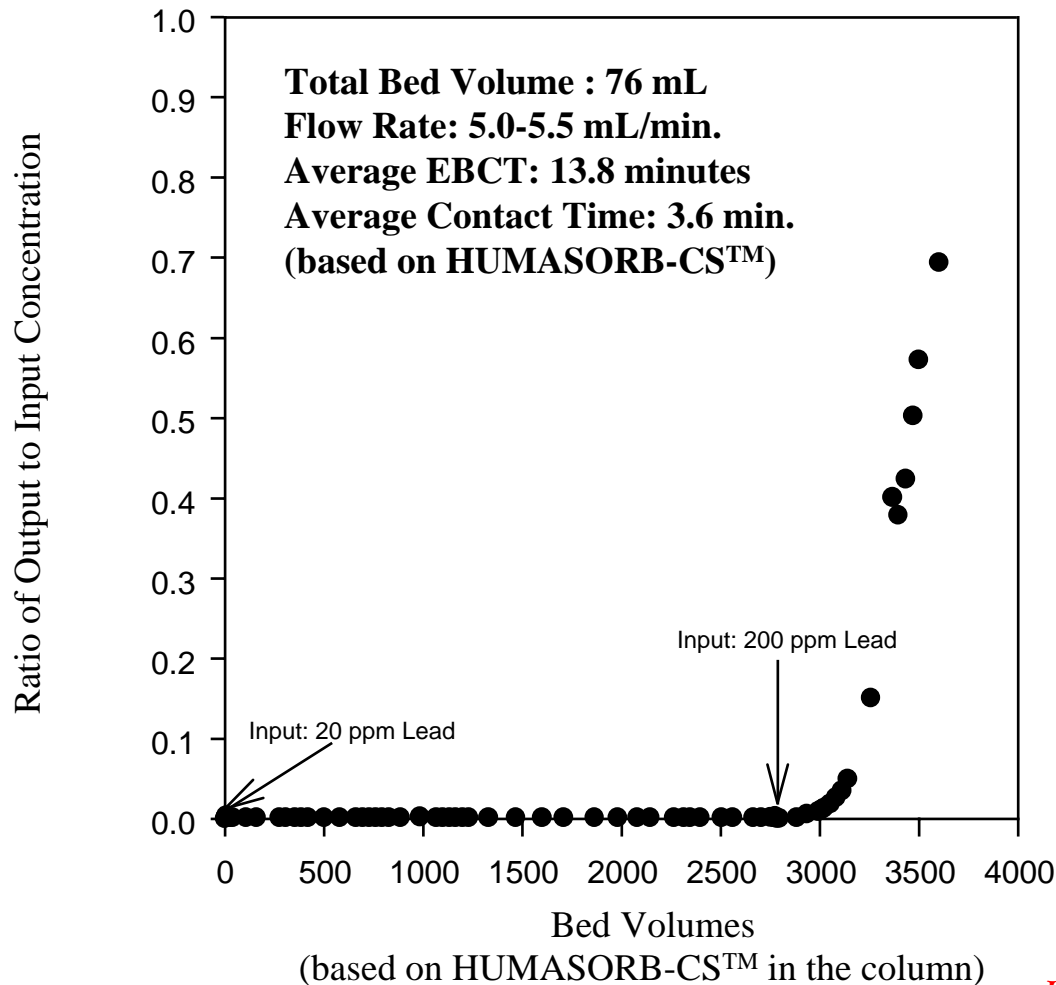
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HUMASORB-S™ Reduced Chromium (vi) to Chromium (iii) and Removed Chromium from Solution

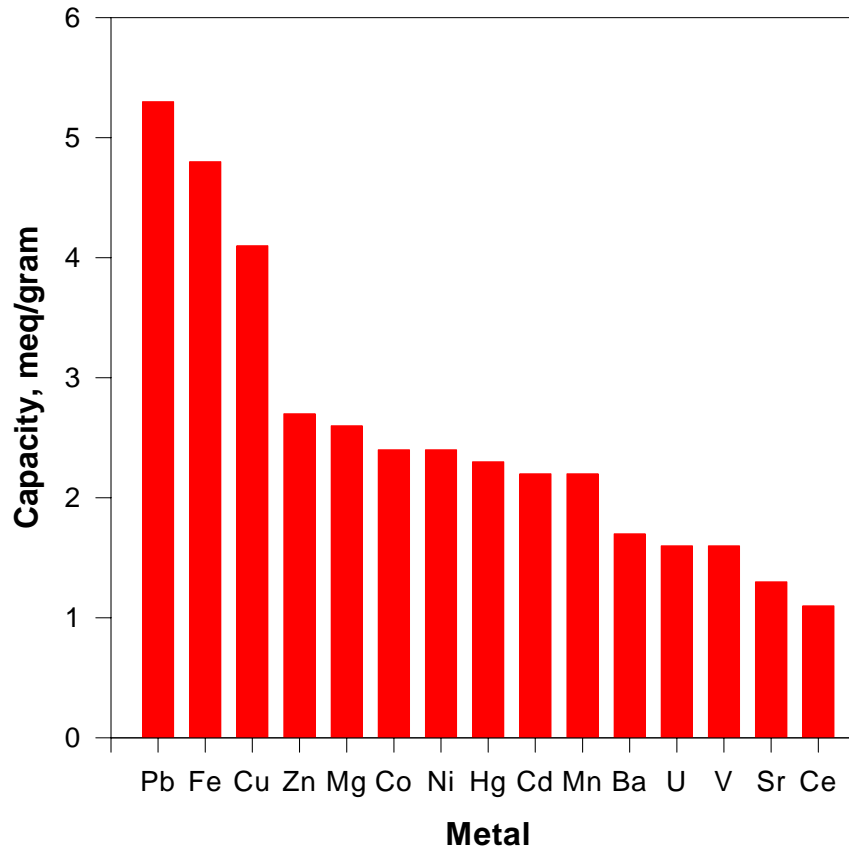


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Breakthrough Curve for Lead in a Column Packed with HUMASORB-cs® (20%) and Sand (80%)



HUMASORB® HAS HIGH CAPACITY FOR METAL REMOVAL

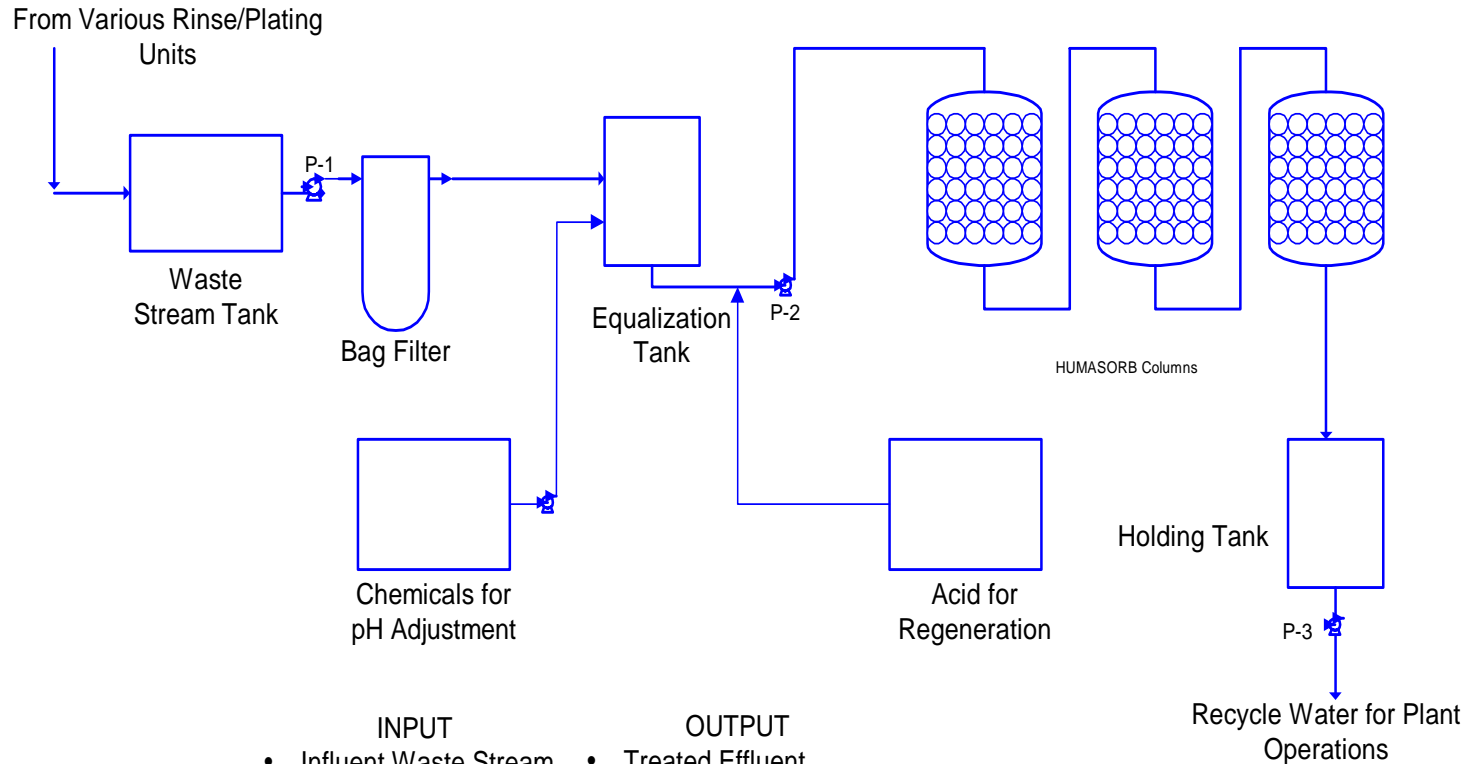


**:
Capacity Estimated from Langmuir Model and/or
Experimental Observation



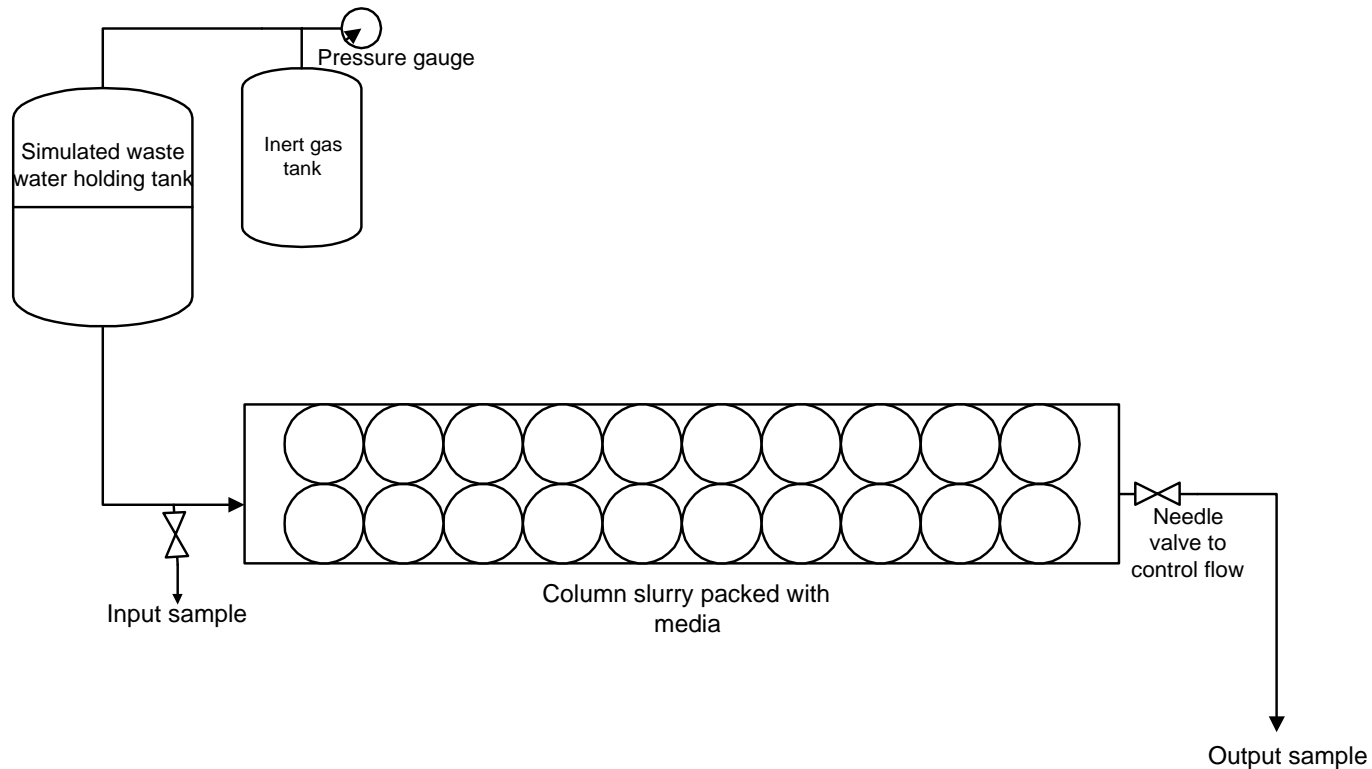
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Simplified Flow Scheme for the Proposed ARCTECH System



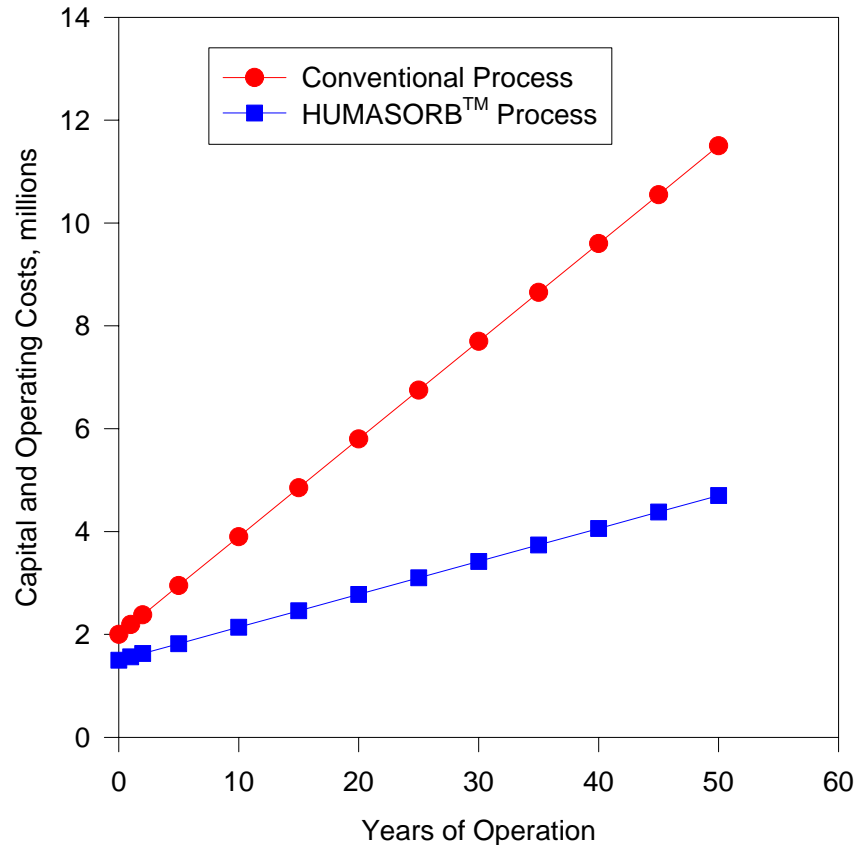
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Simulated Barrier Experimental Setup



HUMASORB® HAS LOWER LIFE-CYCLE COST

Treatment Rate: 30 million gallons per year



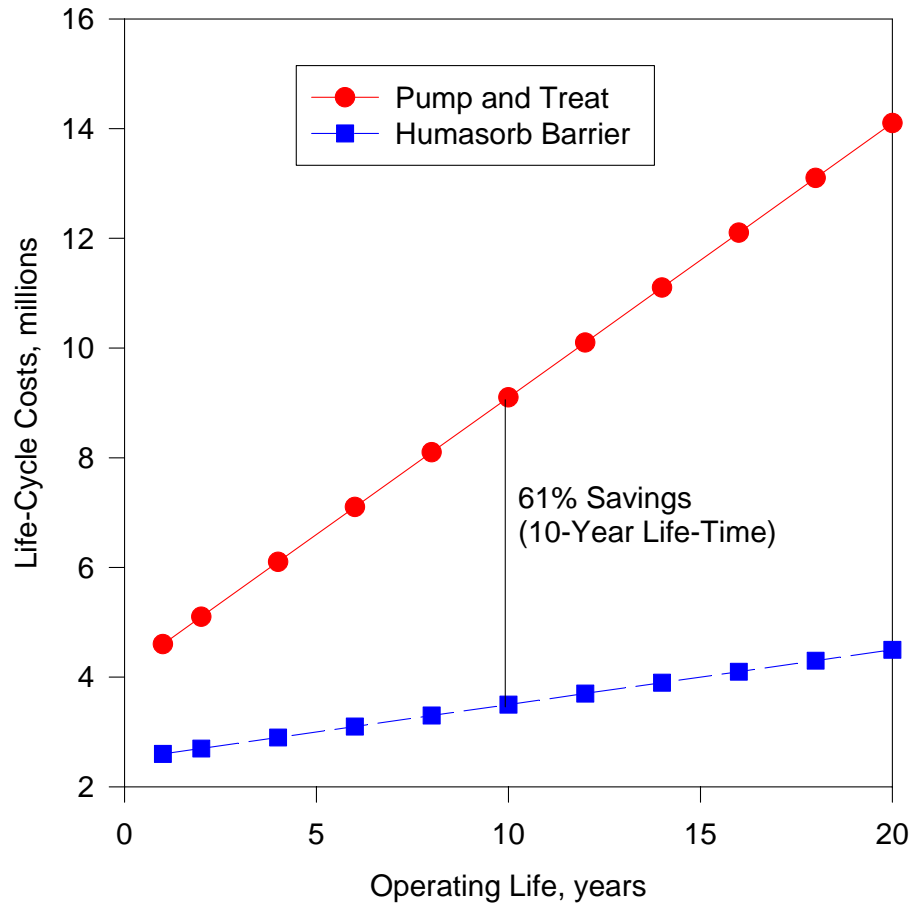
Conventional Process: Electrochemical treatment, filtration and clarification. Costs based on EPA Report 542-R-99-006

HUMASORB™ Process: Estimated Costs for water contaminated with multiple metals and organic compounds



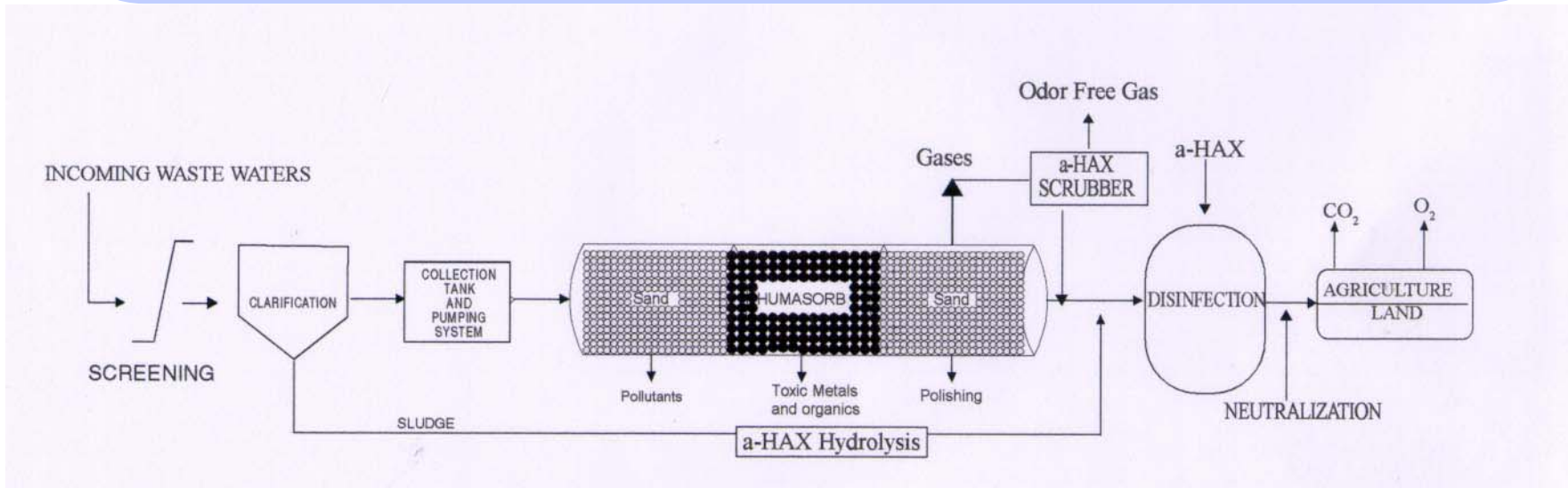
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HUMASORB® BARRIER HAS LOWER LIFE-CYCLE COST COMPARED TO A PUMP AND TREAT SYSTEM



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HUMASORB® SYSTEM WILL CONVERT WASTEWATER INTO AGRICULTURAL WATER AT SADAT CITY, EGYPT



Per Annum Costs \$, million

| | |
|---|------------|
| 1. Operating costs-raw materials, chemicals | 4.9 |
| 2. O & M | <u>1.0</u> |
| Total | 5.9 |

Costs:
 &a-HAX, HUMASORB® and Chemicals and supplies delivered cost at Sadat City (assumes 18,000 m³ per day treatment rate)

Per Annum revenues \$, million

| | |
|---------------------------|------------|
| 1. Tipping fee charge | 1.6 |
| 2. Crops | 5.4 |
| 3. CO ₂ credit | <u>0.1</u> |
| Total | 7.1 |

Revenues:

&Tipping fee charges \$0.25/ m³ average of today's rates in Egypt.
 Net profit of \$1,500 /acre/year from combined forests and edible crops on 3,600 acres. CO₂ credit at average \$10/ton of CO₂ based on 3 tons of capture per acre per year from 3,600 acres of cultivated area



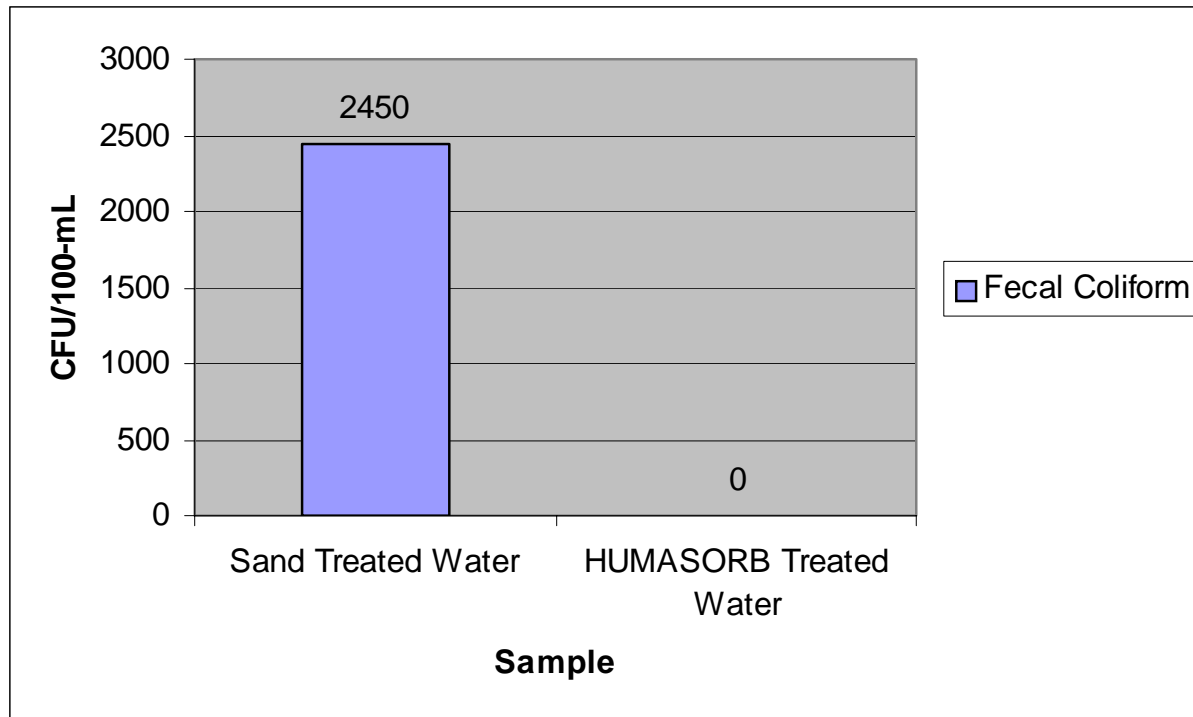
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HUMASORB® UNIT AND STORAGE TANK AT SADAT CITY PROJECT SITE



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HUMASORB® SYSTEM IS EFFECTIVE FOR PATHOGEN REMOVAL FROM WASTEWATER AT SADAT CITY



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HUMASORB® TREATMENT MEETS FAO AND EGYPTIAN NATIONAL LIMITS OF TOXIC METALS IN IRRIGATION WATERS

| | FAO Limit | Egypt Limit | Pond Water | Meet Criteria | HUMASORB ^R Treated Water | Meet Criteria |
|----------------------|------------|-------------|-------------|---------------|-------------------------------------|---------------|
| Concentration in ppm | | | | | | |
| Al | 5 | | 0.19 | Y | 0.18 | Y |
| As | 0.1 | 0.1 | 0.23 | N | 0.08 | Y |
| Ba | | | 3.80 | | 0.07 | |
| B | | | 0.27 | | 0.21 | |
| Cd | 0.01 | 0.01 | 0.00 | Y | 0.00 | Y |
| Ca | | | 49.20 | | 86.73 | |
| Cr | 0.1 | 0.1 | 0.02 | Y | 0.00 | Y |
| Co | 0.05 | 0.05 | BDL | Y | 0.00 | Y |
| Cu | 0.2 | 0.2 | BDL | Y | 0.07 | Y |
| Fe | 5 | 5 | 0.53 | Y | 0.21 | Y |
| Pb | 5 | 5 | 0.03 | Y | 0.00 | Y |
| Li | 2.5 | | 3.70 | N | 0.02 | Y |
| Mg | | | 39.10 | | 19.21 | |
| Mn | 0.2 | 0.2 | 0.20 | Y | 0.02 | Y |
| Mo | 0.01 | 0.01 | BDL | Y | 0.01 | Y |
| Ni | 0.2 | 0.2 | 0.03 | Y | 0.01 | Y |
| Se | 0.02 | | 0.02 | Y | 0.00 | Y |
| Sn | | | | | 0.00 | |
| Ti | | | 0.01 | | 0.01 | |
| W | | | 0.00 | | 0.00 | |
| V | 0.1 | | 0.05 | Y | 0.03 | Y |
| Zn | 2 | 2 | 0.16 | Y | 0.02 | Y |



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ORGANIC FERTILIZER WATER PRODUCED BY HUMASORB® TREATMENT CONTAINS SIGNIFICANT QUANTITIES OF PLANT NUTRIENTS

| Nutrient | Concentration, ppm | Total Available ⁺ , kgs |
|------------|--------------------|---|
| Nitrogen | 6.7 | 32,660 |
| Phosphorus | 23.7 | 264,600 (as P ₂ O ₅) |
| Potassium | 910 | 5,350,000 (as K ₂ O) |
| Humic Acid | 25 | 121,500 |



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HUMASORB® TREATED WATER ENHANCES COTTON PLANT GROWTH



Control Area
(with sand treated water)



Test Area
(with HUMASORB® treated water)



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Organic Fertilizer Water Produced by HUMASORB® Treatment Increased in Height, Weight, Cone Length and Cone Weight of Sorghum Plants

| Treatment | Plant Height | Plant Weight | Cone Length (cm) | Cone Weight |
|-----------------|------------------------|-------------------------|------------------------|-------------------------|
| SAND | 212.833± 1.58 b | 736.50 ± 24.71 b | 22.567 ± 0.79 b | 20.833 ± 0.569 b |
| HUMASORB | 214.733± 2.10 a | 970.83 ± 28.98 a | 26.367 ± 0.80 a | 23.90 ± 0.69 a |
| LSD | 5.277 | 76.252 | 2.259 | 1.799 |



Organic Fertilizer Water Produced by HUMASORB® Treatment Increased in Height of *cupressus* sp. Trees

| Treatment | At Cultivation (Height 1) | At 4 Months (Height 2) | H2 – H1 (cm) | Growth Rate |
|-----------|---------------------------|------------------------|------------------|-------------------|
| SAND | 59.02075 | 71.7915 | 12.77075± 0.511b | 19.5681 ± 0.985 b |
| HUMASORB | 55.5285 | 70.5835 | 15.055 ±0.216 a | 23.89606± 0.497 a |
| LSD | 1.36 | | | 2.70 |



Economic Analysis of HUMASORB® Technology for Wastewater Facility at Sadat City

| Per Annum Costs \$, million | Per Annum revenues \$, million | |
|--|--|-------------|
| Total treatment operation, raw materials, chemicals and agriculture costs 7.5 | 1. Tipping fee charge | 3.2 |
| | 2. Crops | 5.8 |
| | 3. CO ₂ credit | <u>0.04</u> |
| Total 7.5 | Total | 9.0 |
| Costs: ❖ a-HAX, HUMASORB® and Chemicals and supplies delivered cost at Sadat City (assumes 18,000 m ³ per day treatment rate) | Revenues: ❖ Tipping fee charges \$0.5/ m ³ ❖ Revenues of \$2,099 /feddan/year from combined intercropping trees, and crops on 2,770 feddans ❖ CO ₂ credit at average \$5/ton of CO ₂ based on 3 tons of capture per feddan per year from 2,770 feddans of cultivated area | |



HUMASORB® TECHNOLOGY ENHANCES ENVIRONMENT

- & Eliminates discharge of untreated or partially treated wastewater on land / or and water bodies**
- & Frees up fresh water for drinking water purposes from requirements of irrigation**
- & Eliminates Landfills, Waste Impoundments and Associated Environmental Problems**
- & Enhances soils and agricultural productivity**
- & Facilitates capture of greenhouse CO₂ gases**

***CREATES TOTAL SOLUTION FOR RECYCLING OF
WASTEWATER AND SOLID WASTES***



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