CH2MHILL®

Groundwater Treatment Technologies

What's New in Groundwater

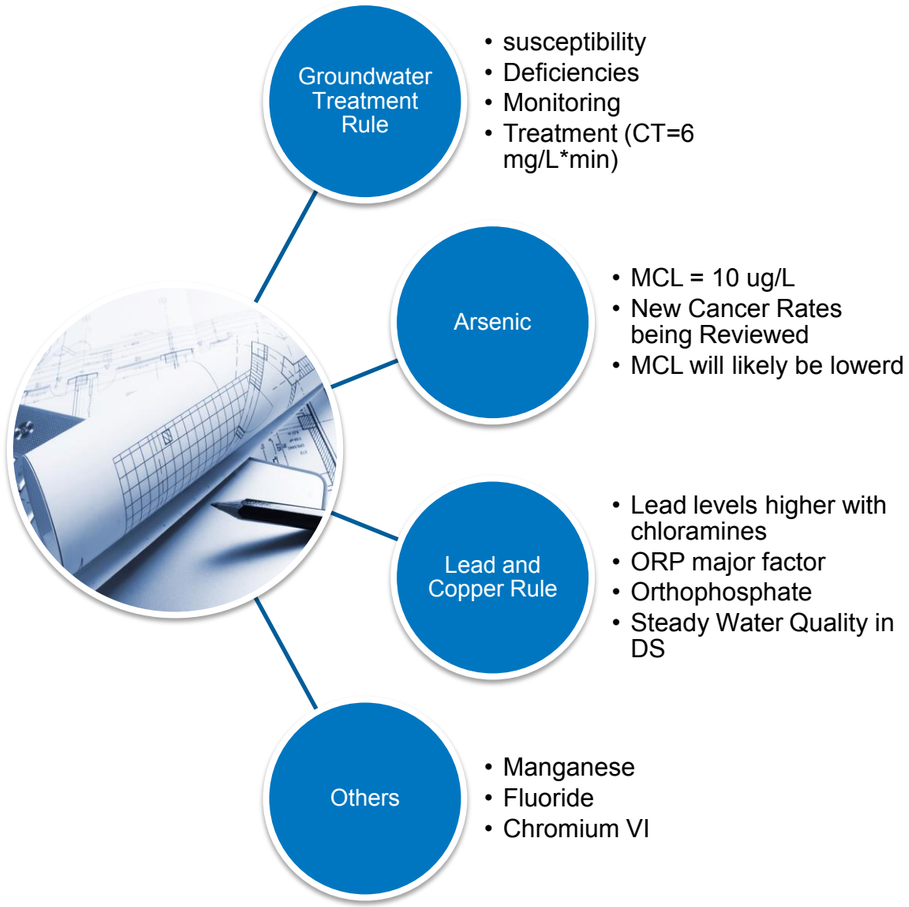
Overview

Topics

Topics	Page
• Regulations	3
• Treatment Technologies	4
• Disinfection	5
• Corrosion Control	7
• VOC Removal	9
• Iron and Manganese	10
• Arsenic	13
• Hydrogen Sulfide	16
• Nitrate	17
• Radionuclides	20
• Chromium VI	22
• Pilot Testing	23

Groundwater Regulations

Regulation	Key Provisions
GW Rule	Vulnerability Significant Deficiencies Monitoring Treatment
Stage 2 DDBP Rule	Identify Worst Sites. MCLs for TTHMs and HAA5
LT2ESWTR	GWI Cryptosporidium monitoring & BIN Class
FBW Rule	FBW Recycling
Arsenic Rule	MCL & MCLG
Radionuclide Rule	MCLs and MCLGs for RA228+228, gross alpha, beta particle and photon radioactivity, and Ur
LCR	Als and Guidance
NPDWS	MCLs
NNSDWS	SMCLs
TCR	MCLs for Total, Fecal & e-coli



Regulations will continue to Affect Groundwater Utilities

Treatment Technologies

Primary Contaminants

Microbial

Category	Technology	Giardia Lamblia	Cryptosporidium	Legionella	Heterotrophic plate count	Turbidity	Viruses	Total coliforms	Fecal coliforms	E. Coli
Filter	Coagulation- filtration		✓	✓	✓	✓	✓	✓	✓	✓
Filter	Biological Filtration		✓	✓	✓	✓	✓	✓	✓	✓
Filter	Hydrous Manganese Oxide Filtration									
Filter	Oxidation/precipitation/filtration				✓		✓			
Membrane Processes	Reverse Osmosis	✓	✓	✓	✓	✓	✓	✓	✓	✓
Membrane Processes	Nanofiltration		✓	✓	✓	✓	✓	✓	✓	✓
Membrane Processes	Ultrafiltraiton		✓	✓	✓	✓	✓	✓	✓	✓
Membrane Processes	Microfiltration		✓	✓	✓	✓	✓	✓	✓	✓
Sorption	Iron Oxides									
Sorption	Manganese Dioxide									
Sorption	Granular Activated Carbon									
IX	Cation Exchange									
IX	Anion Exchange									
IX	Electrodialysis Reversal	✓	✓	✓	✓	✓	✓	✓	✓	✓
Precipitation	Barium Sulfate Precipitation									
Precipitation	Excess Lime Softening									
Precipitation	Pellet Softening									
Precipitation	Aeration									
Chemical Feed Systems	Ozonation	✓		✓			✓	✓	✓	✓
Chemical Feed Systems	Permanganate	✓		✓						
Chemical Feed Systems	Chlorine	✓	✓	✓	✓		✓	✓	✓	✓
Chemical Feed Systems	Chlorine Dioxide	✓	✓	✓	✓		✓	✓	✓	✓
Chemical Feed Systems	Chloramine			✓	✓		✓	✓	✓	✓
Chemical Feed Systems	Ultraviolet	✓	✓		✓					
Chemical Feed Systems	UV - Peroxide	✓	✓	✓	✓		✓	✓	✓	✓
Chemical Feed Systems	Lime									
Chemical Feed Systems	Carbon Dioxide									
Chemical Feed Systems	Soda Ash									
Chemical Feed Systems	Caustic									
Chemical Feed Systems	Silicate									
Chemical Feed Systems	Polyphosphate									
Chemical Feed Systems	Orhtophosphate									
Chemical Feed Systems	Limestone									

Disinfectants & Disinfection By Products

Category	Technology	Bromate	Bromodichloromethane	Bromoform	Chlorite	Chloroform	Dibromochloromethane	Dichloroacetic acid	Haloacetic acids (HAA5)[1]	Trichloroacetic acid	Total Trihalomethanes	Total Organic Carbon (TOC)	Lead and Copper	Lead	Copper
Filter	Coagulation- filtration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Filter	Biological Filtration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Filter	Hydrous Manganese Oxide Filtration														
Filter	Oxidation/precipitation/filtration														
Membrane Processes	Reverse Osmosis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Membrane Processes	Nanofiltration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Membrane Processes	Ultrafiltraiton	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Membrane Processes	Microfiltration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Sorption	Iron Oxides														
Sorption	Manganese Dioxide														
Sorption	Granular Activated Carbon	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
IX	Cation Exchange														
IX	Anion Exchange														
IX	Electrodialysis Reversal	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Precipitation	Barium Sulfate Precipitation														
Precipitation	Excess Lime Softening													✓	
Precipitation	Pellet Softening														
Precipitation	Aeration														
Chemical Feed Systems	Ozonation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Chemical Feed Systems	Permanganate	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Chemical Feed Systems	Chlorine	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	
Chemical Feed Systems	Chlorine Dioxide	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Chemical Feed Systems	Chloramine	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Chemical Feed Systems	Ultraviolet	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Chemical Feed Systems	UV - Peroxide	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Chemical Feed Systems	Lime													✓	✓
Chemical Feed Systems	Carbon Dioxide													✓	✓
Chemical Feed Systems	Soda Ash													✓	✓
Chemical Feed Systems	Caustic													✓	✓
Chemical Feed Systems	Silicate													✓	✓
Chemical Feed Systems	Polyphosphate													✓	✓
Chemical Feed Systems	Orhtophosphate													✓	✓
Chemical Feed Systems	Limestone													✓	✓

Inorganics

Category	Technology	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cyanide	Fluoride	Mercury	Nickel	Nitrate	Nitrite	Selenium	Thallium
Filter	Coagulation- filtration		✓												
Filter	Biological Filtration		✓												
Filter	Hydrous Manganese Oxide Filtration		✓												
Filter	Oxidation/precipitation/filtration														
Membrane Processes	Reverse Osmosis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Membrane Processes	Nanofiltration		✓												
Membrane Processes	Ultrafiltraiton		✓												
Membrane Processes	Microfiltration		✓												
Sorption	Iron Oxides		✓												
Sorption	Manganese Dioxide														
Sorption	Granular Activated Carbon						✓								
IX	Cation Exchange														
IX	Anion Exchange		✓							✓		✓		✓	
IX	Electrodialysis Reversal	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Precipitation	Barium Sulfate Precipitation											✓	✓		
Precipitation	Excess Lime Softening		✓												
Precipitation	Pellet Softening														
Precipitation	Aeration									✓					
Chemical Feed Systems	Ozonation														
Chemical Feed Systems	Permanganate														
Chemical Feed Systems	Chlorine														
Chemical Feed Systems	Chlorine Dioxide														
Chemical Feed Systems	Chloramine														
Chemical Feed Systems	Ultraviolet														
Chemical Feed Systems	UV - Peroxide														
Chemical Feed Systems	Lime									✓	✓				
Chemical Feed Systems	Carbon Dioxide									✓	✓				
Chemical Feed Systems	Soda Ash									✓	✓				
Chemical Feed Systems	Caustic									✓	✓				
Chemical Feed Systems	Silicate									✓	✓				
Chemical Feed Systems	Polyphosphate														
Chemical Feed Systems	Orhtophosphate									✓	✓				
Chemical Feed Systems	Limestone									✓	✓				

Organics

Category	Technology	Volatile Organics	Synthetic Organics	Pesticides	Dissolved organic carbon	DBP Precursors	Pharmaceuticals
Filter	Coagulation- filtration		✓	✓	✓	✓	✓
Filter	Biological Filtration		✓	✓	✓	✓	✓
Filter	Hydrous Manganese Oxide Filtration						
Filter	Oxidation/precipitation/filtration						
Membrane Processes	Reverse Osmosis		✓	✓	✓	✓	✓
Membrane Processes	Nanofiltration		✓	✓	✓	✓	✓
Membrane Processes	Ultrafiltraiton						
Membrane Processes	Microfiltration						
Sorption	Iron Oxides						
Sorption	Manganese Dioxide						
Sorption	Granular Activated Carbon	✓	✓	✓	✓	✓	✓
IX	Cation Exchange						
IX	Anion Exchange		✓		✓		
IX	Electrodialysis Reversal		✓	✓	✓	✓	✓
Precipitation	Barium Sulfate Precipitation						
Precipitation	Excess Lime Softening			✓	✓	✓	✓
Precipitation	Pellet Softening						
Precipitation	Aeration	✓					
Chemical Feed Systems	Ozonation	✓	✓	✓	✓	✓	✓
Chemical Feed Systems	Permanganate	✓					
Chemical Feed Systems	Chlorine	✓					
Chemical Feed Systems	Chlorine Dioxide	✓					
Chemical Feed Systems	Chloramine						
Chemical Feed Systems	Ultraviolet						
Chemical Feed Systems	UV - Peroxide	✓	✓	✓	✓	✓	✓
Chemical Feed Systems	Lime						
Chemical Feed Systems	Carbon Dioxide						
Chemical Feed Systems	Soda Ash						
Chemical Feed Systems	Caustic						
Chemical Feed Systems	Silicate						
Chemical Feed Systems	Polyphosphate						
Chemical Feed Systems	Orhtophosphate						
Chemical Feed Systems	Limestone						

Radionuclides

Category	Technology	Gross alpha	Beta and photon emitters[1]	Iodine-131[2]	Combined Radium 226 & 228[3]	Uranium	Strontium 90[2]	Tritium[2]	Radon
Filter	Coagulation- filtration						✓	✓	✓
Filter	Biological Filtration						✓	✓	✓
Filter	Hydrous Manganese Oxide Filtration				✓		✓	✓	✓
Filter	Oxidation/precipitation/filtration								
Membrane Processes	Reverse Osmosis	✓	✓	✓	✓	✓	✓	✓	✓
Membrane Processes	Nanofiltration								
Membrane Processes	Ultrafiltraiton								
Membrane Processes	Microfiltration								
Sorption	Iron Oxides								
Sorption	Manganese Dioxide				✓				
Sorption	Granular Activated Carbon	✓	✓	✓	✓	✓	✓	✓	✓
IX	Cation Exchange								
IX	Anion Exchange								
IX	Electrodialysis Reversal	✓	✓	✓	✓	✓	✓	✓	✓
Precipitation	Barium Sulfate Precipitation	✓	✓	✓	✓	✓	✓		
Precipitation	Excess Lime Softening						✓	✓	✓
Precipitation	Pellet Softening								
Precipitation	Aeration						✓		
Chemical Feed Systems	Ozonation								
Chemical Feed Systems	Permanganate								
Chemical Feed Systems	Chlorine								
Chemical Feed Systems	Chlorine Dioxide								
Chemical Feed Systems	Chloramine								
Chemical Feed Systems	Ultraviolet								
Chemical Feed Systems	UV - Peroxide								
Chemical Feed Systems	Lime								
Chemical Feed Systems	Carbon Dioxide								
Chemical Feed Systems	Soda Ash								
Chemical Feed Systems	Caustic								
Chemical Feed Systems	Silicate								
Chemical Feed Systems	Polyphosphate								
Chemical Feed Systems	Orhtophosphate								
Chemical Feed Systems	Limestone								

Secondary Contaminants

Category	Technology	Hardness	Iron	Manganese	Total Dissolved solids	Chloride	Sulfate	Zinc	Color	Taste and Odor	Aluminum	Copper	Corrosivity	Fluoride	Foaming agents	Odor	pH	Silver
Filter	Coagulation- filtration		✓	✓					✓	✓						✓		
Filter	Biological Filtration		✓	✓					✓	✓					✓	✓		
Filter	Hydrous Manganese Oxide Filtration		✓	✓					✓	✓								
Filter	Oxidation/precipitation/filtration		✓	✓					✓									
Membrane Processes	Reverse Osmosis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓				✓
Membrane Processes	Nanofiltration	✓	✓	✓	✓				✓									
Membrane Processes	Ultrafiltraiton		✓	✓														
Membrane Processes	Microfiltration		✓	✓														
Sorption	Iron Oxides																	
Sorption	Manganese Dioxide		✓	✓					✓									
Sorption	Granular Activated Carbon								✓	✓					✓			
IX	Cation Exchange	✓	✓	✓														
IX	Anion Exchange						✓		✓		✓							
IX	Electrodialysis Reversal	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓				✓
Precipitation	Barium Sulfate Precipitation																	
Precipitation	Excess Lime Softening	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓			✓
Precipitation	Pellet Softening	✓																
Precipitation	Aeration															✓		
Chemical Feed Systems	Ozonation								✓	✓					✓	✓		
Chemical Feed Systems	Permanganate								✓	✓						✓		
Chemical Feed Systems	Chlorine									✓						✓		
Chemical Feed Systems	Chlorine Dioxide								✓	✓						✓		
Chemical Feed Systems	Chloramine									✓								
Chemical Feed Systems	Ultraviolet									✓								
Chemical Feed Systems	UV - Peroxide								✓	✓					✓	✓		
Chemical Feed Systems	Lime												✓				✓	
Chemical Feed Systems	Carbon Dioxide												✓				✓	
Chemical Feed Systems	Soda Ash												✓				✓	
Chemical Feed Systems	Caustic												✓				✓	
Chemical Feed Systems	Silicate		✓	✓									✓				✓	
Chemical Feed Systems	Polyphosphate		✓	✓									✓					
Chemical Feed Systems	Orhtophosphate												✓					
Chemical Feed Systems	Limestone												✓				✓	

Disinfection

Disinfection Alternatives

Treatment Objective	General Disinfection and Residual Disinfection	Disinfection of Viruses and Residual Disinfection	Disinfection for Systems Under the Influence of Surface Water
Primary disinfectant	Chlorine Ozone Chlorine dioxide	Chlorine Ozone UV	Chlorine* Ozone Chlorine dioxide UV
Secondary (residual) disinfectant	Chlorine Chloramine	Chlorine Chloramine	Chlorine Chloramine

On-Site Sodium Hypochlorite Generation

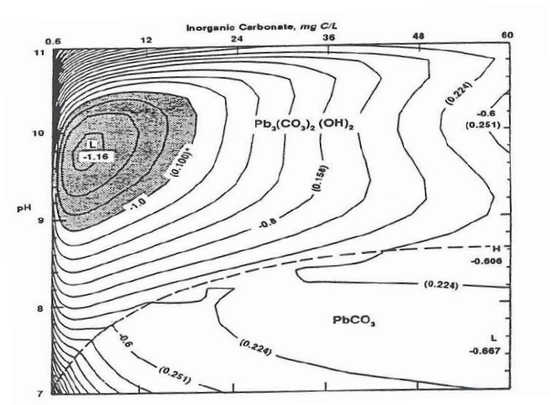
ClorTec

OSEC

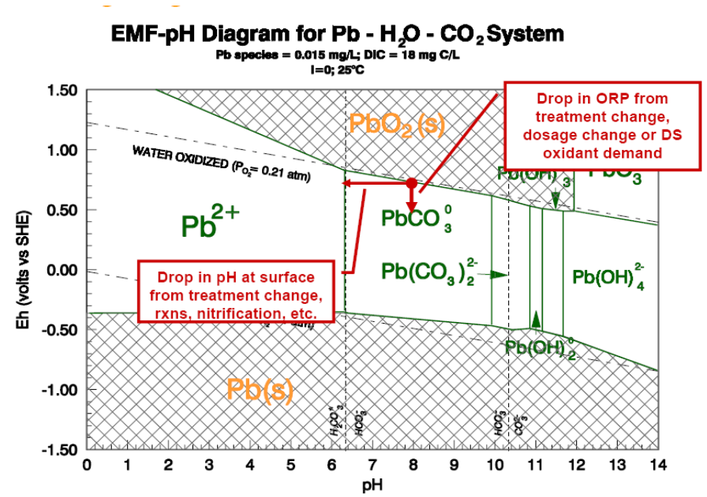
MIOX

MicroClor

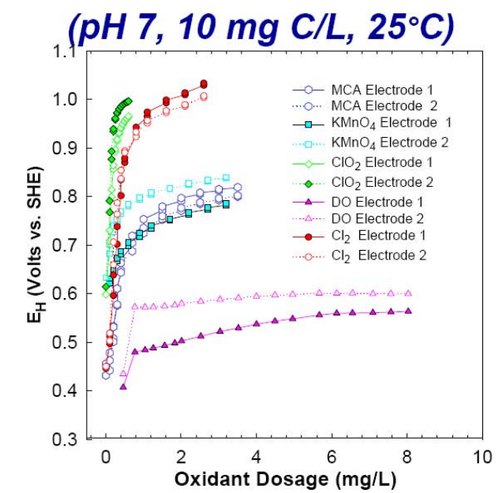
Corrosion Control



Lead Solubility Contour Diagram, pH vs DIC, I=0.01,
Source, Lead Control Strategies, AWWARF



Source: New Insights into Lead and Copper Corrosion Control and Treatment Change Impacts, Michael Schock, USEPA, ORD, NRMRL, WSWRD



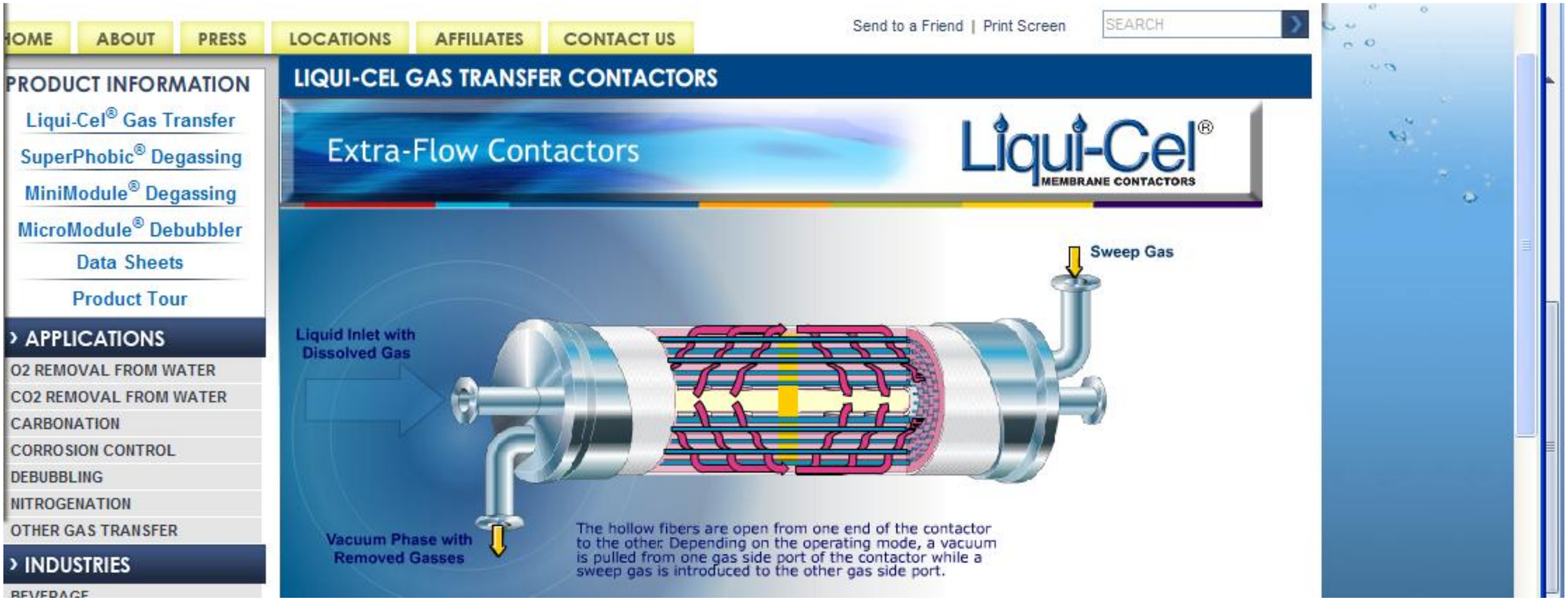
Source: New Insights into Lead and Copper Corrosion Control and Treatment Change Impacts, Michael Schock, USEPA, ORD, NRMRL, WSWRD

Oxidation Reduction Potential has a Significant Impact on Lead

Chloride to Sulfate Ratio <0.58

Liquicel – Degasser

(equipment cost approx $150k for 2,000 gpm well)



Look for opportunities to strip CO2 and eliminate caustic application, also for VOC Removal

VOC Treatment Alternatives

Example TCE Removal for 2,000 gpm Well

Alternative	Effectiveness	Equipment	Footprint	Major Electrical & Control Requirements	Safety Issues	Maintenance	Building Requirement	Neighborhood Issues	Equipment Costs(1)	Annual O&M Cost (2)
Packed Tower Aeration	▪ >95%	▪ 12' by 28' Packed Tower ▪ Low sound blower ▪ Pump Well ▪ Booster Pump w/VFD ▪ PLC & SCADA	▪ 20' by 50'	▪ Blower ▪ Booster Pump ▪ PLC Package ▪ SCADA Integration	▪ Climbing ▪ Mechanical Equipment ▪ Cleaning Chemicals	▪ Periodic Media Cleaning ▪ Pump and Blower Maintenance	▪ Booster Pump and Electrical Equipment ▪ PLC &SCADA	▪ Visual Impact of Tower ▪ Noise from Blower and Air Exiting Tower	▪ $310,000 Packed Tower and Blower	▪ $90,000 for electrical, monitoring, labor
Tray Aeration	▪ >90%	▪ 6 tray aerator ▪ Pump Well ▪ Booster Pump w/VFD ▪ PLC & SCADA	▪ 20' by 50'	▪ Blower ▪ Booster Pump ▪ PLC Package ▪ SCADA Integration	▪ Mechanical Equipment ▪ Cleaning Chemicals	▪ Periodic Tray Cleaning ▪ Pump and Blower Maintenance	▪ Booster Pump and Electrical Equipment ▪ PLC & SCADA	▪ Visual Impact of Aerator ▪ Noise from Blower	▪ $180,000 for Tray aerator and Blower	▪ $90,000 for electrical, monitoring, labor
Low Profile Aerator	▪ >80%	▪ 3 - 2,000 gallon low profile aerator ▪ Air blower ▪ Diffusers ▪ Booster pumps w/VFD ▪ PLC & SCADA	▪ 30' by 30'	▪ Blower ▪ Booster Pump ▪ PLC Package ▪ SCADA Integration	▪ Mechanical Equipment	▪ Periodic Cleaning ▪ Pump and Blower Maintenance	▪ Aerators, Blower, Booster Pump and Electrical Equipment ▪ PLC & SCADA	▪ Additional Building	▪ $240,000 for low profile aerator and blower	▪ $90,000 for electrical, monitoring, labor
GDT Degasser	▪ >50%	▪ Side stream injection pump ▪ Eductor ▪ Degasser	▪ 20' by 20'	▪ None	▪ Mechanical Equipment	▪ Side stream Pump Cleaning ▪ Degasser Cleaning	▪ Side Stream Injector, Degasser ▪ PLC & SCADA	▪ Could potentially fit in existing building	▪ $150,000 for degassing system	▪ $35,000 for electrical, monitoring, labor
Liqui-Cel Degasser	▪ >50%	▪ 10 – 14" by 28" degassers ▪ 10 micron cartridge Filter	▪ 10' by 30'	▪ None	▪ Mechanical Equipment	▪ Periodic Cleaning (Estimated at 6 mo)	▪ Cartridge Filter ▪ Degassers ▪ PLC & SCADA	▪ Building Addition Impact	▪ $148,0000 for degassers ▪ $78,000 for prefilter	▪ $90,000 per year for semiannual cleaning and integrity testing by manufacturer. ▪ $25,000 for electrical, monitoring, labor
GAC Contactor	▪ >95%	▪ 2-8'D by 10'H Contactors ▪ 20,000 gallon backwash surge tank	▪ 20' by 50'	▪ None	▪ Climbing ▪ Valve Operation	▪ Weekly or Monthly Backwashing ▪ Annual or Every Two Year GAC Replacement	▪ None	▪ Visual Impact of Tanks	▪ $410,000 for two contactors and GAC	▪ $110,000 for GAC replacement and disposal annual or every two years ▪ $15,000 for electrical, monitoring, labor
UV AOP	▪ >95%	▪ 400 mJ/cm2 UV reactor ▪ Peroxide feed system ▪ ORP meter ▪ PLC & SCADA	▪ 10' by 30'	▪ UV Reactor Power ▪ PLC Package ▪ SCADA Integration	▪ Electrical Shock ▪ Strong Oxidant	▪ UV bulb cleaning ▪ Electrical maintenance ▪ Routine Equipment Calibration	▪ UV Electrical ▪ UV reactors ▪ Cleaning Equipment ▪ Peroxide System ▪ PLC & SCADA	▪ Building Addition Impact	▪ $525,000 for UV Reactor and peroxide feed system	▪ $250,000 for electrical, monitoring, labor ▪ $30,000 for chemical
Ozone AOP	▪ >95%	▪ Liquid oxygen ▪ Evaporator ▪ Ozone generator ▪ Destruct unit ▪ Side stream pump ▪ Eductor, injector ▪ Reactor pipe ▪ Ozone analyzers ▪ Gas flow meter ▪ Control system ▪ PLC & SCADA	▪ 50' by 70'	▪ Ozone Generator Power ▪ Destruct Unit ▪ PLC Package ▪ SCADA Integration	▪ Air Quality ▪ Electrical Shock ▪ Strong Oxidant	▪ Oxygen canister replacement ▪ Generator ▪ Analyzer cleaning and calibration ▪ Pump ▪ Destruct system	▪ All Equipment except liquid oxygen and evaporator	▪ Building Addition, Liquid Oxygen Storage	▪ $770,000 for ozone system and peroxide feed system	▪ $190,000 for electrical, monitoring, labor ▪ $40,000 for oxygen and chemical
Down Well Air Sparging	▪ Unknown	▪ Submersible pump ▪ Air sparger ▪ Air Compressor ▪ Off -gas GAC canisters	▪ 10' by 10'	▪ Air Compressor	▪ Mechanical Equipment	▪ Increased biological growth and well screen clogging may require periodic rehabilitation	▪ Air Compressor	▪ Building Addition	▪ $535,000 for submersible pump and air sparger	▪ $25,000 for electrical, monitoring, labor

Iron and Manganese Removal
10 MGD Plant Completed June 2010
$4.5 Million

Southlake Water Treatment Plant

Clark Public Utilities,Vancouver, WA

Treatment Technology	Benefits	Drawbacks
Aeration followed by filtration	•No chemical use •Easy to operate	•Entrained air can interfere with filtration if not broken •May require breaking head and repumping •Not effective for manganese removal or iron complexed with organic material •Low filter loading rates for effective removal •High capital cost
Chlorination followed by filtration	•Chlorine often used for disinfection and present at treatment plant	•May require pH adjustment for manganese removal because of slow reactions at low pH •Low filter loading rates for effective removal •Easy to operate •High capital cost
Ozone followed by filtration	•Strong oxidant, requires little reaction time	•May oxidize manganese to permanganate •May oxidize manganese dioxide–containing media to permanganate •Difficult to operate •High capital and operations and maintenance costs
Chlorine dioxide followed by filtration	•Effective for iron complexed with organic material •No trihalomethane formation	•Generated on site with variety of chemicals •Requires careful operation and maintenance •Chlorite is a by-product •High capital cost
Potassium permanganate followed by filtration	•Strong oxidant, requires short reaction times •Can reform manganese dioxide coating on media	•Causes staining if spilled •May be overfed, resulting in pink or purple water
Biological filtration	•Easy to operate •Low operating cost	•Requires start-up period initially and after prolonged shutdowns •May require two stages for iron and manganese removal •High capital cost
Ion exchange	•Easy to operate	•Only effective on reduced forms of iron and manganese •No preoxidation should occur before ion-exchange unit •Fouling is common •Taste may be less palatable than with other methods •High capital and operating costs
Manganese greensand filtration	•Very effective for manganese •Can achieve high loading rates, but often not done	•Often used in combination with anthracite media for iron filtration •Media may crack •Recommended use with permanganate feed
Oxide coated sand filtration	•Effectiveness depends on type, thickness, and oxidation state of coating •Easy to operate	•Effectiveness depends on type, thickness, and oxidation state of coating AU//correct to have this entry for both Benefit and Drawback •Moderate capital cost
Pyrolusite media filtration	•Easy to operate •Can achieve high loading rates •Low operating costs •Very effective for manganese	•Moderate capital cost
Membrane filtration	•Easy to operate •Can achieve high loading rates	•May cause fouling •Chemical preoxidation must be carefully controlled •Moderate to high capital and operating costs
Stabilization, sequestering	•May reduce precipitation in parts of the distribution system	•Iron and manganese will still precipitate in the distribution system, especially where water stays in the system several days or in hot water systems and appliances •Not effective for high levels of iron and manganese
Lime softening	•Can effectively precipitate iron and manganese	•High capital and operating costs •High levels of solids produced •Requires significant operational oversight and maintenance

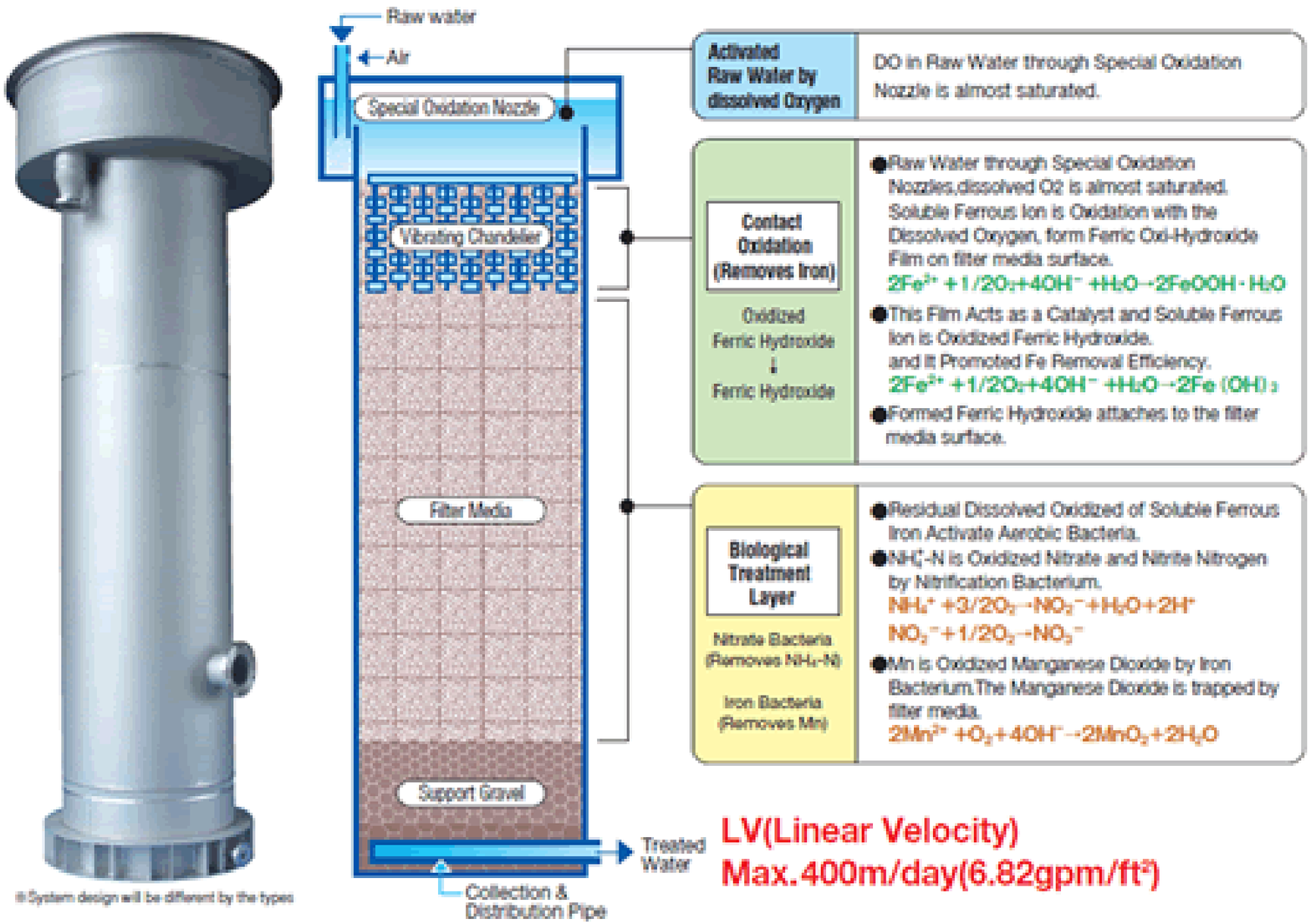
Southlake WTP

- 22 Acre Site
- Manganese Dioxide Media, 10 gpm/sq ft loading rate
- Backwash Water Reused on Site
- Two – 3,500 gpm wells on site
- On-Site chlorine generation
- Ground source heating & cooling

Clark Public Utilities

Vancouver, WA

Nagaoka Biological Iron, Manganese, Nitrate and Arsenic Removal



- Biological System
  - 40 mg/L Iron
  - 2 mg/L manganese
  - 1 mg/L ammonia
  - 50 ug/L arsenic
- Deep Bed Filter System
- Can backwash top part independent of remaining filter

EPA ETV Testing Via NSF

Woodland, WA

Arsenic Removal

Longley Lane WTP

Truckee Meadows Water Authority, Reno, NV

Technology	Benefits	Drawbacks
Conventional filtration	•Common technology Effective, especially when arsenic pre-oxidized and pH kept below 8	•Performance declines above pH 8Arsenic should be pre-oxidized •High coagulant doses sometimes required. •Alkalinity addition may be needed for soft waters and high coagulant doses.
Reverse osmosis membrane filtration	•Removal of As(III) and As(V) •Inorganic, microbial, and organic removal also achieved	•Low recovery and flux rates are typical •Pretreatment and posttreatment required
Nanofiltration	•Removal of As(V) •Microbial and organic removal also achieved •Removal of calcium and magnesium may be achieved	•Sensitivity to water quality •Low recovery and flux rates are typical •Pretreatment and posttreatment required •May not be effective for As(III)
Ultrafiltration	•Flux and recovery rates higher than with reverse osmosis or nanofiltration •Microbial removal achieved •Waste stream can often be sent to wastewater treatment plant	•Removal of particulate As only, unless pretreatment with a coagulant is needed for removal •Preoxidation and pH adjustment may be needed
Coagulation/microfiltration	•Highest flux and recovery rates of membrane processes •Some microbial removal achieved •Waste stream can often be sent to wastewater treatment plant	•Pretreatment with a coagulant is needed for removal •Preoxidation and pH adjustment may be needed
Activated alumina	•Less sensitive to water quality than ion exchange •Longer run times than ion exchange	•pH adjustment often needed •Aluminum levels may increase in finished water •Hazardous chemicals needed for regeneration •Residuals handling is difficult with concentrated high-pH liquid stream
Ion exchange (anion exchange)	•Works better at higher pH levels than activated alumina •Nitrate removal can also be achieved	•Sulfate levels may reduce run times •Higher arsenic levels may leach from resin near end of run •Requires regeneration and handling of concentrated brine solution
Iron-based sorbents	•Arsenic in backwash water is usually very low •Relatively easy disposal of solids •Some adsorbents have a fairly high sorption capacity	•Periodic media replacement required •Cost and length of media use before replacement is needed is dependent on water quality •Capacity decreases with increasing pH
Titanium-based sorbents	•Arsenic in backwash water is usually very low •Relatively easy disposal of solids •Some adsorbents have a fairly high sorption capacity •Works over wide range of pH	•Periodic media replacement required •Cost and length of media use before replacement is needed is dependent on water quality
Lime Softening	•Effective removal at pH above 11. •Coagulants can be added to aid co-precipitation.	•High concentration of solids produced •Some systems can require significant operational oversight

Arsenic Strategies for Future

Media	Initial Arsenic, µg/L	Water Source	BV to 10 µg/L	mg As Absorbed per g Media	g Iron per g Media	Source
Iron–citric acid preloaded GAC	50–60	Rutland, Mass. pH 6	150,000	4.96	0.0054	AwwaRF, 2007
Ferrichite ($FeCl_3$ + chitosand)	3,580	Superfund Tacoma, Wash.	700	1.1	0.61	Chen et al., 2000
Chemical coating onto absorption media G2	200	Spiked distilled water	5,000	2	-	Winchester et al., 2000
Granular ferric hydroxide; Wasserchemie	16	Wildeck, Germany	85,000–7 µg/L	0.82	0.58	Driehaus, 2000
Granular ferric hydroxide	21	Stadtoldentrof, Germany	75,000–7 µg/L	1.08	0.58	Jekel and Seith, 2000
Granular ferric oxide media; US Filter/Siemens	18	Stockton, Calif.	25,000	0.2	0.58	McAuley, 2004
Granular ferric oxide media; Severn Trent	18	Stockton, Calif.	25,000	0.2	0.63	McAuley, 2004
Granular ferric oxide media; Wasserchemie	8	Barkersfield, Calif.	80,000–4 µg/L	0.26	0.58	McAuley, 2004
Granular ferric oxide media; Severn Trent	8	Barkersfield, Calif.	80,000–4 µg/L	0.26	0.63	McAuley, 2004
Granular ferric oxide media; Wasserchemie and US Filter/Siemens	15	Deionized water spiked with As	60,000–7 µg/L	0.58	0.58	Bradruzzaman et al., 2001
Zirconium-loaded activated carbon	500	Carbonate buffer spiked with As	5,900	2.8	0.028 g Zr/g	Daus et al., 2004
Absorptionsmittel 3	500	Carbonate buffer spiked with As	1,000	2	0.075	Daus et al., 2004
Iron hydroxide granules	500	Carbonate buffer spiked with As	13,100	2.3	0.323	Daus et al., 2004
Iron-impregnated polymer resin	50	Deionized water with anions, pH 7.5	4,000	0.32	0.09–0.12	DeMarco et al., 2003
Iron oxide–impregnated activated alumina	500	Deionized water with As, pH 12	500–50 µg/L	0.29	0.066	Kuriakose et al., 2004

Owner-Purchased Tanks

Contract for Media Supply and Performance

Arsenic Strategies for Future

FIGURE 1: CHLORINE/ACID/FERRIC/CONTACT TANK

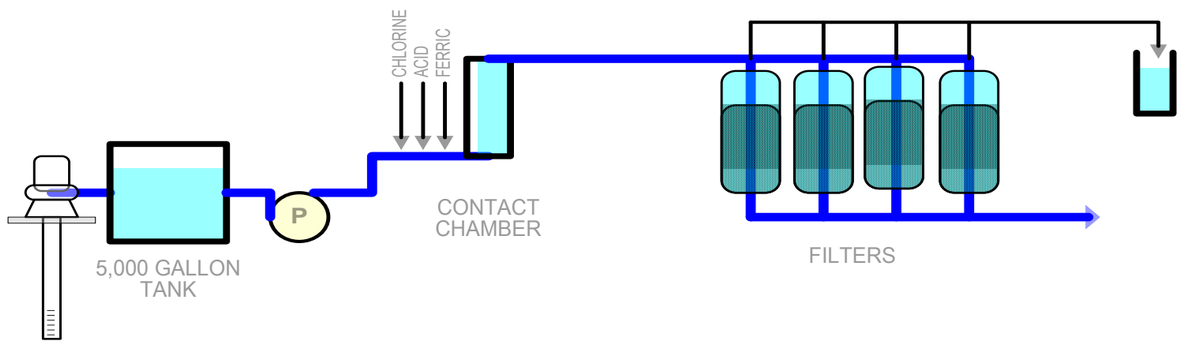
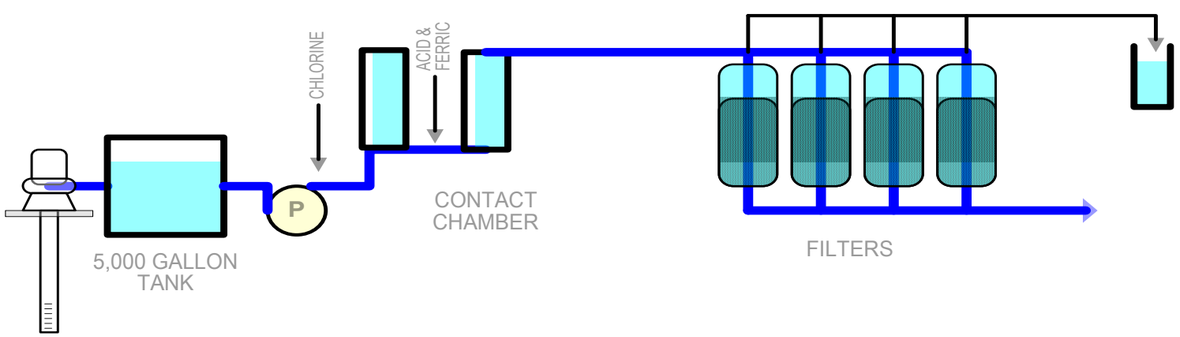


FIGURE 2: CHLORINE/CONTACT TANK/ACID/FERRIC/CONTACT TANK



	Non Optimized	Optimized
Process	See Figure 1	See Figure 2
Raw Water Arsenic, ug/L	158	158
Finished Water Arsneic, ug/L	9.02	1.24
Percent Removal	94.3%	99.2%
Number of Samples	23	19
Raw Water pH	7.7	7.7
Ferric Chloride Dose, mg/L	26	21
Treated Water pH	6.7	6.72
Filter Loading Rate, gpm/sq ft	6.0	6.0
Media Type	Manganese Dioxide	Manganese Dioxide
Media Depth, In	42"	42"

TMWA I-Street Well

Sparks, NV

Hydrogen Sulfide Treatment

GAC Adsorbers

Golden States Water, Los Angeles, CA

Treatment	Benefits	Drawbacks
Catalytic carbon–granular activated carbon	•Effectively controls hydrogen sulfide tastes with proper carbon selection	•Carbon must be replaced periodically •Dissolved oxygen level of 4 mg/L or greater is needed •Moderate capital cost and moderate to high operating cost
Greensand	•Reduces tastes and odors •Low operating cost	•Moderate capital cost •Media must be regenerated •Media subject to cracking at high head loss
Pyrolusite	•Reduces tastes and odors •Low operating cost	•Moderate capital costs •Requires chlorine residual on media bed
Ion exchange	•Effectively controls hydrogen sulfide tastes with proper selection and maintenance	•Requires salt regeneration •High capital and operations and maintenance costs
Chlorination	•Reduces hydrogen sulfide smell	•Generates polysulfides, which also have tastes and odors •Can revert to form hydrogen sulfide if reducing conditions exists (dead-end mains, customer hot water tanks)
Aeration	•Reduces tastes and odors	•Must repump water after aeration •May require acid feed to lower pH and improve effectiveness •High capital cost •Moderate operating cost
Oxidation/reduction	•Effectively controls hydrogen sulfide tastes with proper design and maintenance	•Requires second chemical feed •Requires effective blending and reaction period •Reducing chemical dose must be carefully controlled

Nitrate Treatment

Anion Exchange Vessels Under Construction

Glendale, AZ

Nitrate Treatment Alternative	Benefits	Drawbacks
Anion exchange	•Many commercially available systems •Lowest capital cost •Relatively easy to operate •Easy to automate •Also removes arsenic	•High total dissolved solids liquid waste stream •Efficiency is dependent on water quality
Biological removal	•No brine waste	•Requires postfiltration •Few commercially available systems •Requires carbon source and nutrients
Nanofiltration	•Relatively easy to operate •Also softens water and removes some inorganics and organics	•May require extensive pretreatment •Requires significant maintenance •Operates at high pressure •Relatively high capital and operating costs
Reverse osmosis	•Relatively easy to operate •Also softens water and removes many inorganics and organics	•May require extensive pretreatment •Requires significant maintenance •Operates at high pressure •Relatively high capital and operating costs
Electrodialysis reversal	•Lower pressure requirements than other membrane systems •Provides softening and removal of other inorganics and organics	•May require extensive pretreatment

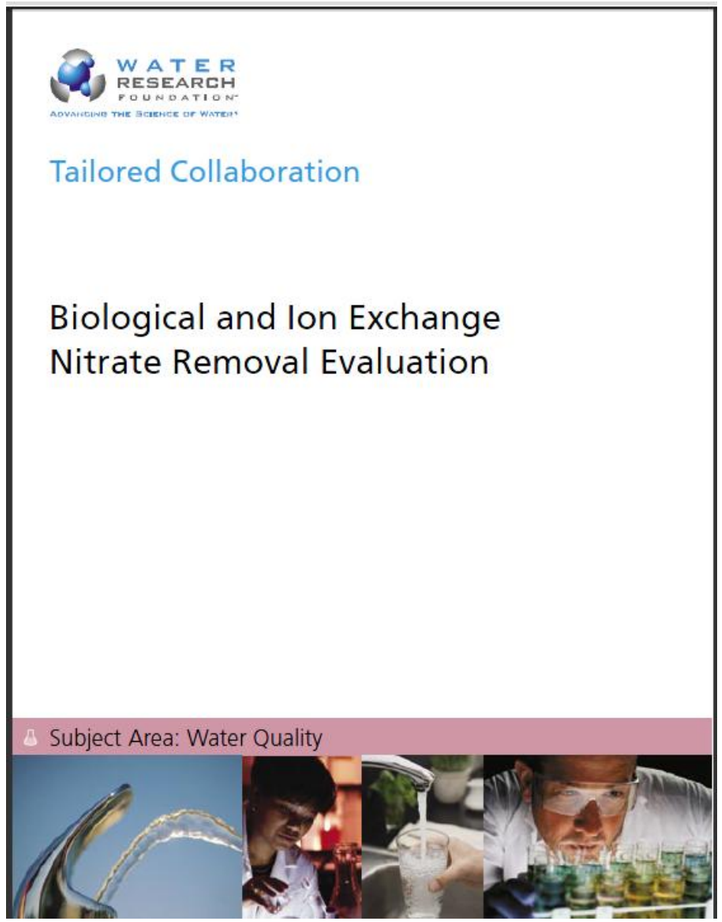
Glendale AZ Nitrate and Arsenic Removal Plant

- 10 MGD Capacity
- Nitrate and Arsenic Removal
- Five, Twelve foot Diameter Vessels, 4.5 feet of Standard SBA Resin
- Two 75 Ton Brine Makers
- Recycles Waste Water
- Discharges 0.5% of Production
- S::CANs monitor Nitrate, pH, TOC and Turbidity

Zone 4 Groundwater Treatment Plant

Glendale Arizona

Water Research Foundation Report



- Autotrophic and heterotrophic biological denitrification worked well.
- Phosphorous addition aided removal
- Biological treatment better from Triple Bottom Line approach than Ion Exchange

Biological and Ion Exchange Nitrate Removal Evaluation

City of Glendale

Radionuclides Treatment

Radium Removal

Treatment Alternative	Benefits	Drawbacks
Cation exchange	•Many commercially available systems •Lowest capital cost •Relatively easy to operate •Easy to automate •Also removes calcium and magnesium	•High total dissolve solids liquid waste stream •Efficiency is dependent on water quality, especially sulfate •High brine concentration is needed for regeneration to remove radium •Produces liquid brine stream with elevated radium levels
Lime softening	•Also softens water and removes some inorganics and organics	•Requires significant operations and maintenance •Relatively high capital and operating costs •Produces sludge with elevated radium levels
Reverse osmosis	•Relatively easy to operate •Also softens water and removes many inorganics and organics	•May require extensive pretreatment •Requires significant maintenance •Operates at high pressure •Relatively high capital and operating costs •Produces liquid brine stream with elevated radium levels
Hydrous manganese oxide	•Low-cost alternative for radium removal, especially in systems with existing filters •Works with many filter removal media	•Requires monitoring and operations oversight •Made on site and must remain mixed •Careful design of chemical feed systems is needed •Produces radium-concentrated backwash water

Uranium Removal

Treatment Alternative	Benefits	Drawbacks
Anion exchange	•Many commercially available systems •Lowest capital cost •Relatively easy to operate •Easy to automate •Also removes arsenic	•High total dissolved solids in liquid waste stream •Efficiency is dependent on water quality
Cation exchange	•Many commercially available systems •Lowest capital cost •Relatively easy to operate •Easy to automate •Also removes arsenic	•High total dissolved solids in liquid waste stream •Efficiency is limited above pH 8
Nanofiltration	•Relatively easy to operate •Also softens water and removes some inorganics and organics	•May require extensive pretreatment •Requires significant maintenance •Operates at high pressure •Relatively high capital and operating costs
Reverse osmosis	•Relatively easy to operate •Also softens water and removes many inorganics and organics	•May require extensive pretreatment •Requires significant maintenance •Operates at high pressure •Relatively high capital and operating costs
Lime softening	•Provides softening and removal of other inorganics and organics	•Requires significant operational oversight •Requires frequent maintenance
Activated alumina	•Moderate cost	•Sensitive to water quality •Requires regeneration with hazardous chemicals •

Hydrous Manganese Oxide Feed System
Batavia, IL

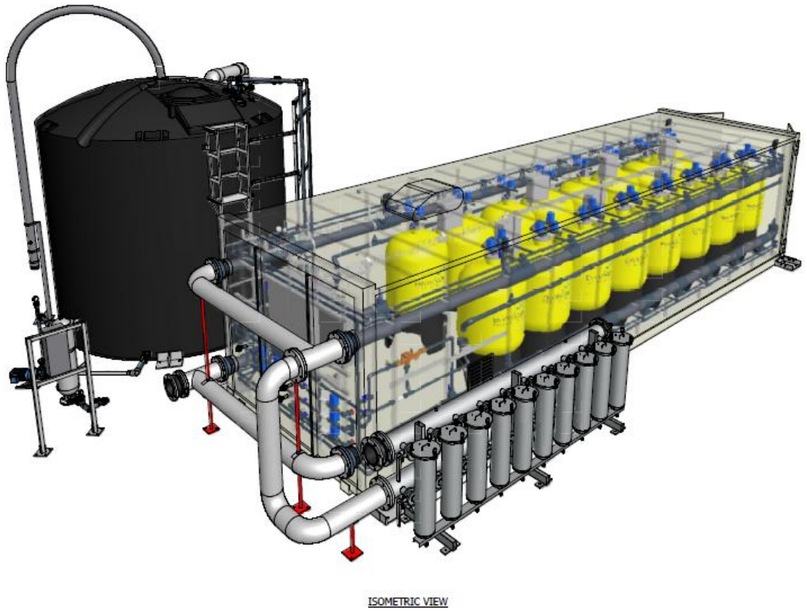
Other Radionuclides in the News

Iodine 131

- Ferric Chloride has some effectiveness
- GAC/PAC
  - Impregnated with potassium iodide

Cesium and Strontium

- Anion Exchange



Chrome VI Fact Sheet

CH2MHILL

Groundwater Treatment
Hexavalent Chromium
Chromium VI
Fact Sheet

Monitoring Guidance

The USEPA developed guidance on monitoring for hexavalent chromium.

Information is available at the following links:

USEPA Guidance:

http://water.epa.gov/drink/info/chromium/guidance.cfm

Systems that are considering monitoring for hexavalant chromium should understand the sampling and analytical techniques needed to conduct testing and have a strategy for how they will provide public education about the results they obtain

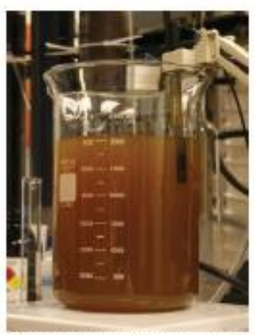
Treatment and mitigation for groundwaters containing hexavalent chromium can be accomplished using some well defined treatment methods, but the treatment process is often complex (see sidebar).

In-Situ Treatment of Hexavalent Chromium

In-situ mediation of hexavalent chromium most often is designed to form chromium hydroxide ($Cr(OH)_3$ which has a low solubility in water and can often be immobilized in the aquifer matrix. Methods to remediate hexavalent chromium in the groundwater matrix include:

- Sulfur reduction methods
- Calcium polysulfide reduction
- Sodium dithionate reduction of ferrous iron
- Aerobic microbial reduction
- Anaerobic microbial reduction

The effectiveness and complexity of in-site treatment vary from site to site. A thorough understanding of the aquifer conditions, the source of chromium and the local conditions are needed to assess these alternatives.



Reduction of Chromium VI can be accomplished with ferrous iron

Above-Ground Treatment Alternatives

Treatment alternatives to remove chromium from water supplies vary with concentrations. Treatment technologies commonly used in industrial wastewater applications; chemical reduction, coagulation, softening, filtration and activated carbon adsorption can effectively remove high concentrations of chromium from water supplies, but drinking water treatment technologies to produce very low levels of chromium are still developing. Current technologies are presented in Table 1, but treatment technologies for chromium should be considered a developing technology.

C03209006BDS

Treatment Process	Benefits	Drawbacks
Reduction/Coagulation/Filtration	Uses readily available technologies General familiarity with process	Residuals handling Control of Reduction step important for removal
Anion Exchange with WBA Resins	High removal capacity in some resins	Resin disposal pH dependent Varies among manufacturers Not well understood
Anion Exchange with SBA resins	Well understood technology and process	Brine disposal Loss of capacity after multiple regenerations
Granular Activated Carbon	Effective removal at low pH	pH adjustment required may not work well for very low concentrations
Reverse Osmosis	Very effective	High costs High energy use Brine disposal
Reduction/Microfiltration	Should be effective	Little installed capacity Reject water disposal
Nanofiltration	Very effective	High costs High energy use Brine disposal
Electrodialysis	Very effective	High costs High energy use Brine disposal
Zero-Valent Iron Adsorption	Should be effective	Little installed capacity
Biological Reduction/Filtration	Reduction occurs with IRB and SRB	Little installed capacity

Bench & Pilot Testing

CH2MHILL
Applied Sciences Laboratory

Treatability Studies: A Cost-Effective Investment

Innovative and creative methods are often required to improve treatment processes and facilities. Treatability studies offer the means to help develop treatment approaches that respond to tougher regulations, meet the need for improved treatment, and satisfy your requirements for practicality and cost-effectiveness. For decades, CH2M HILL has provided creative solutions for clients by offering treatability studies as part of its many consulting services.

Tailored to Individual Needs

Treatability studies are lab-screening, bench-scale, or pilot-scale tests designed to obtain specific information that will aid in the selection and implementation or optimization of a treatment process.

One of the values of the treatability study is its ability to effectively reduce the uncertainty associated with a treatment process. Reducing uncertainty to a manageable level can reduce the investment required for full-scale treatment facility design, construction, and operations.

Treatability studies offer these typical outcomes:

- Performance data
- Process reliability data
- Appropriate operating parameters
- Design criteria
- Operations and maintenance requirements
- Cost information

We design treatability studies that focus on your cli unique objectives to develop a treatment strate and cost-effective.

CH2MHILL
Applied Sciences Laboratory

Taste and Odor Treatment Evaluations

Finding both an effective and practical solution is important to our clients.

Combining our expert process engineering and laboratory staff, CH2M HILL can provide a treatability team to tackle these challenges.

We have been conducting taste and odor treatment evaluations for many years and have a broad base of experience finding effective and practical solutions. We conduct bench- and pilot-scale testing to aid in the selection or implementation of a treatment process for a specific water source. We have optimized existing plants and designed new plants to address taste and odor treatment using the following options:

Powdered Activated Carbon (PAC) – Evaluated in the lab using an isotherm test to provide taste and odor compound adsorption capacity information. PAC offers treatment on an as-needed or "event" basis.

Granular Activated Carbon (GAC) – Evaluated by the isotherm test or in combination with a Rapid Small Scale Carbon Treatment (RSSCT) test to provide both adsorption capacity and design criteria, such as bed life.

Ozone – Often used in combination with advanced oxidation options such as peroxide, this test provides taste and odor and demand/decay information for treating a specific water source.

UV – Evaluated using a bench-level collimated beam system in combination with advanced oxidation options.

Taste and odor events can present a significant challenge to a water treatment team.

Our analytical laboratory provides ongoing support to our clients through system monitoring and treatability studies. We analyze for taste and odor compounds using Standard Method 6040D. This extremely sensitive technique is used to achieve reporting limits at the 1 ng/L parts per trillion level for taste and odor compounds.

Contacts

For more information on this and other services CH2M HILL's ASL can provide, please contact:

Kathy McKinley
(kathy.mckinley@ch2m.com)
CH2M HILL Laboratory
Client Services Manager
541-758-3144

Tim Maloney
(tim.maloney@ch2m.com)
CH2M HILL Treatability
Laboratory Manager
541-758-3124

CH2MHILL®

Lee Odell, PE
Vice President
Water Business Group
lee.odell@ch2m.com