United States Environmental Protection Agency

Removing Multiple Contaminants from Drinking Water: Issues to Consider

Public water systems that need to add treatment for one contaminant may find that they also have other water quality concerns. Choosing a treatment technology that can remove several co-occurring contaminants may be more efficient and cost effective. This table describes treatment technologies that can remove multiple contaminants, identifies the contaminants that can be removed, and summarizes related operational and waste disposal issues.

Removal Technology	Arsenic	Fluoride	Microbes	Nitrate	Radium	Uranium	Other	Operational Issues	Waste Disposal Issues
Activated Alumina (AA) Uses a porous aluminum-based material to adsorb certain contaminants.	✓	✓				✓	selenium	• Other ions may competitively adsorb and displace contaminant; AA is optimized at a pH of 6.0 to 6.5. pH 5.0-6.0 is optimal for anion removal. Other ions, or removal of multiple ions will cause more frequent regeneration and require careful monitoring to prevent breakthrough. • When arsenic is present in the form As(III), pre-oxidation is necessary to convert it to the form As(V). • Must be backwashed periodically to prevent clogging. • Must be periodically regenerated. • System is low cost, easy to operate, and requires minimal operator attention.	• Wastes include backwash water, brine, rinse water, and acid neutralization water as well as spent filter media. • Levels of arsenic and radionuclides will likely dictate options for spent media disposal. • Pretreatment may be needed for disposal to a sanitary sewer.
Anion Exchange A physical-chemical process in which ions are swapped between a solution phase and a solid resin phase. The solid resin adsorbs anions and releases chloride into the water.	✓	0		✓		✓		• pH of 6-8 in the treated water will maximize uranium removal and optimize resin regeneration. pH 6.5 to 9.0 is optimal for resins. • When arsenic is present in the form As(III), pre-oxidation is necessary to convert it to the form As(V). • Uranium is the strongest binding contaminant, followed by arsenic and then nitrate. Uranium is so strongly adsorbed that it may be difficult to regenerate the resin. Less strongly binding contaminants may breakthrough if not carefully monitored. • Sulfates, nitrates, and other ions compete for adsorption sites. • Total dissolved solids levels >500 mg/L can adversely affect treatment performance. • Pre-filtration is recommended if source water turbidity is >0.3 NTU. • Contaminant breakthrough can be avoided by careful monitoring and by running several columns in series, keeping the most recently regenerated column last. • Required operator skill level is intermediate.	• Wastes include backwash water, regenerant brine, rinse water, and spent media. • Resins have a high capacity for absorbing arsenic, radium, and uranium which will likely dictate options for spent media disposal. • Pretreatment for spent brine may be needed for disposal to the sanitary sewer.
Iron-Based Adsorptive Media Uses an iron-based media to adsorb contaminants.	0				0	0	antimony	• When arsenic is present in the form As(III), pre-oxidation is necessary to convert it to the form As(V). • Reducing source water pH will increase the arsenic removal capacity of most adsorptive media. • If pH adjustment or pre-oxidation step is lost, treated water may have an arsenic spike. • Phosphate and silica compete with As(V) for adsorption sites. • Backwash is required to remove particulates and to redistribute media. Frequent or improper backwash can result in media loss. • Bacteria can accumulate in the media during low flow and hot weather. • When removing multiple contaminants the weaker adsorbing contaminant can breakthrough if not carefully monitored. • System is low cost, easy to operate, and requires minimal operator attention.	• Backwash water can be easily recycled through the treatment plant to minimize waste generation, or it can be discharged to a sewer, septic system, or surface water. • Testing is needed to ensure spent media is not hazardous or radioactive.
Mixed Bed Ion Exchange Anion and cation exchange resins can be combined in a single ion exchange unit to remove cationic (e.g. radium) and anionic (e.g. arsenic, uranium) contaminants.	✓				✓	✓	sulfate, magnesium, calcium	• Optimum operating pH is >10.5 for radium removal and 6-10 for uranium. • Sulfate and uranium can displace arsenic from the resin, causing a spike of arsenic in the treated water. • Contaminant breakthrough can be avoided by careful monitoring and by running several columns in series, keeping the most recently regenerated column last. • May be necessary to increase treated water alkalinity after ion exchange to reduce corrosion in the distribution system. • Intermediate operator skill level required.	• Wastes include spent regenerate and spent media that may have elevated concentrations of radium and arsenic which will dictate disposal methods. • Pretreatment may be needed for disposal to the sanitary sewer.
Greensand Filtration Uses manganese-coated filter media to oxidize and adsorb contaminants.	✓				✓		iron, manganese (up to 10 ppm)	• High iron to manganese ratio may lower radium adsorption on greensand filters, but the presence of iron is beneficial to arsenic adsorption. • Arsenic removal by greensand requires a pH >6.8. Radium removal improves as pH increases over the range from 5 to 9. • Minimal operator attention and maintenance requirements; required operator skill level is basic. • Cost-effective for radium removal at small systems.	• Wastes generated include sludge and supernatant from the filter backwash as well as spent filter media. Radium and arsenic levels will dictate disposal options.
Oxidation/Coagulation/Filtration Involves adsorption of contaminants to an aluminum or ferric hydroxide precipitate and removal of these particles by filtration.	✓		0			✓	iron, manganese	• When arsenic is present in the form As(III), pre-oxidation is necessary to convert it to the form As(V). • 20:1 iron to arsenic ratio will improve iron removal. • Ferric chloride is typically used as the source of iron. • Arsenic removal is less effective at higher pH. • Operating costs are relatively low. • Advanced operator skill level required. • Optimum pH for Uranium removal is 6.0.	• Wastes generated include iron and alum sludges from the contact and settling basins, the supernatant from the sludge, filter backwash, and spent filter media. Additional liquid waste may be generated when the sludge is de-watered prior to landfill disposal. • Backwash water is typically discharged to a sewage or septic system. • High concentrations of uranium may dictate disposal options.
Lime Softening Removes hardness by precipitating out calcium and magnesium carbonates.	✓				✓	✓	hardness	• pH >10 is needed for radium removal. Uranium removal requires pH >10.6 and is improved by adding magnesium carbonate. • Advanced operator skill level required. • Treatment costs are high and may not be a cost-effective alternative for small systems. • It may be necessary to increase alkalinity for corrosion control.	• Wastes include a high volume of lime sludge which precipitates with radium and/or uranium, supernatant from the sludge, and filter backwash. • Testing is needed to ensure spent media is not hazardous or radioactive.
Reverse Osmosis (RO) A pressure-driven membrane separation process that removes contaminants larger than the membrane pores.	✓	✓	✓	✓	✓	✓	TOC, most metals, sulfate, calcium, magnesium, potassium, phosphorous	• RO membranes foul easily, so pretreatment to remove particulates and organics may be necessary. • Calcium and magnesium can cause membrane fouling. • Cellulose acetate membranes are susceptible to biological fouling, free chlorine can be beneficial up to 1 mg/L. • Polyamide membranes can be damaged by chlorine, high iron, and chloramines. • Depending on operating parameters, 20 to 40% of raw water can be lost in the reject stream. • Advanced operator skill level required. • Treatment costs are higher than other treatment options.	• Wastes consist of concentrated waste stream and spent membranes which may contain elevated levels of radionuclides. • Testing is needed to ensure spent media is not hazardous or radioactive.

Notes: Best Available Technologies (BATs) specified in regulations are indicated by ✓. Technologies that are effective but not currently listed as a BAT are indicated by 0.

TIPS

- ✔ More frequent monitoring and shorter run times may be necessary to prevent breakthrough of weaker absorbing contaminants for certain technologies.
- ✔ While a technology may be able to remove multiple contaminants, operating parameters such as optimal pH may vary for each contaminant. Adjustments may be necessary to maximize treatment for the combined contaminants.
- ✔ In addition to cost, ease of operations and operator qualifications should be considered.
- ✔ Pre-oxidation may be necessary for maximum removal of certain contaminants.
- ✔ When considering treatment efficacy, evaluate whether a series or parallel configuration will work best to prevent breakthrough of contaminants.
- ✔ Testing may be needed to determine if spent media is hazardous or radioactive. If waste residuals contain certain radionuclides such as uranium or thorium, they may be subject to the Nuclear Regulatory Commission's licensing requirements.

For more information:

EPA Office of Water Safewater site – http://www.epa.gov/safewater

EPA Office of Research and Development Drinking Water Research site - http://www.epa.gov/ord/dw/

Safe Drinking Water Hotline – 1-800-426-4791

Office of Water
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