EPA United States Environmental Protection Agency
Office of Water

Ground Water a
Drinking Wat

ARSENIC IN DRINKING WATER

Treatment Technologies: Removal

Background

In water, the most common valence states of arsenic are As(V), or arsenate, which is more prevalent in aerobic surface waters and As(III), or arsenite, which is more likely to occur in anaerobic ground waters. In the pH range of 4 to 10, the predominant As (III) compound is neutral in charge, while the As (V) species are negatively charged. Removal efficiencies fo (III) are poor compared to removal As(V) by any of the technologies evaluated due to the negative charge.

In September, 1993, EPA developed, with contractor support, a document entitled "Treatm and Occurrence-Arsenic in Potable Water Supplies". This document summarized the result pilot-scale studies examining low-level arsenic removal, from 50 parts per billion (ppb or µ down to 1 ppb or less. EPA convened a panel of outside experts in January 1994 to review document and comment on the ability of the technologies to achieve maximum contaminan levels (MCLs) under consideration. Key findings of this report are summarized below. EP the process of gathering new information with contractor support on the technologies to up the report since it has been four years when it was created. Stakeholders are welcomed to provide inputs to this process by sending information concerning technologies to remove a from drinking water to Amit Kapadia, U. S. EPA, 401 M St SW (4607), Washington DC 2 In a future stakeholders meeting EPA will inform stakeholders of new information from thi effort. Information on prospective technologies were obtained from more recent studies an results of the studies are also summarized below.

Technologies

The technologies under review perform most effectively when treating arsenic in the form (V). As (III) may be converted through pre-oxidation to As(V). Data on oxidants indicate t chlorine, ferric chloride, and potassium permanganate are effective in oxidizing As(III) to (V). Pre-oxidation with chlorine may create undesirable concentrations of disinfection by-products. Ozone and hydrogen peroxide should oxidize As(III) to As(V), but no data are available on performance.

Coagulation/Filtration (C/F), is an effective treatment process for removal of As(V) accor to laboratory and pilot-plant tests. The type of coagulant and dosage used affects the efficie of the process. Within either high or low pH ranges, the efficiency of C/F is significantly reduced. Alum performance is slightly lower than ferric sulfate. Other coagulants were als effective than ferric sulfate. Disposal of the arsenic-contaminated coagulation sludge may concern especially if nearby landfills are unwilling to accept such a sludge.

Lime Softening (LS) operated within the optimum pH range of greater than 10.5 is likely provide a high percentage of As removal for influent concentrations of 50 µg/L. However, i may be difficult to reduce consistently to 1 µg/L by LS alone. Systems using LS may requi secondary treatment to meet that goal.

Activated Alumina(AA) is effective in treating water with high total dissolved solids (TD However, selenium, fluoride, chloride, and sulfate, if present at high levels, may compete f adsorption sites. AA is highly selective towards As(V); and this strong attraction results in regeneration problems, possibly resulting in 5 to 10 percent loss of adsorptive capacity for run. Application of point-of-use treatment devices would need to consider regeneration and replacement.

Ion Exchange (IE) can effectively remove arsenic. However, sulfate, TDS, selenium, fluor and nitrate compete with arsenic and can affect run length. Passage through a series of colu could improve removal and decrease regeneration frequency. Suspended solids and precipit iron can cause clogging of the IE bed. Systems containing high levels of these constituents require pretreatment.

Reverse Osmosis (RO) provided removal efficiencies of greater than 95 percent when ope pressure is at ideal psi. If RO is used by small systems in the western U. S., 60% water rec will lead to an increased need for raw water. The water recovery is the volume of water produced by the process divided by the influent stream (product water/influent stream). Discharge of reject water or brine may also be a concern. If RO is used by small systems in western U. S., water recovery will likely need to be optimized due to the scarcity of water resources. The increased water recovery can lead to increased costs for arsenic removal.

Electrodialysis Reversal (EDR) is expected to achieve removal efficiencies of 80 percent. study demonstrated arsenic removal to 3 µg/L from an influent concentration of 21 µg/L.

Nanofiltration (NF) was capable of arsenic removals of over 90%. The recoveries ranged between 15 to 20%. A recent study showed that the removal efficiency dropped significantl during pilot-scale tests where the process was operated at more realistic recoveries. If nanofiltration is used by small systems in the western U. S., water recovery will likely need be optimized due to the scarcity of water resources. The increased water recovery can lead increased costs for arsenic removal.

Point of Use/Point of Entry (POU/POE)The 1996 SDWA amendments specifically identi Point-of-Use (POU) and Point-of-Entry (POE) devices as options that can be used for compliance with NPDWRs. POU and POE devices can be effective and affordable complia options for small systems in meeting a new arsenic MCL. A Federal Register notice is bein prepared by EPA to delete the prohibition {§141.101} on the use of POU devices as compl technologies. Because of this prohibition, few field studies exist on the application of POU POE devices. One such case study was performed by EPA, in conjunction with the Village San Ysidro, in New Mexico (Rogers 1990). The study was performed to determine if POU Reverse Osmosis (RO) units could satisfactorily function in lieu of central treatment to rem arsenic and fluoride from the drinking water supply of a small rural community of approximately 200 people. A RO unit, a common type of POU device, is a membrane syste that rejects compounds based on their molecular properties and characteristics of the revers osmosis membrane. The RO units removed 86% of the total arsenic.

Prospective Technologies

Ion Exchange with Brine Recycle. Research recently completed by the University of Hou (Clifford) at McFarland, CA and Albuquerque, NM has shown that ion exchange treatment reduce arsenic (V) levels to below 2 µg/L even with sulfate levels as high as 200 mg/L. Sul does impact run length, however; the higher the sulfate concentration, the shorter the run le to arsenic breakthrough. The research also showed the brine regeneration solution could be reused as many as 20 times with no impact on arsenic removal provided that some salt was added to the solution to provide adequate chloride levels for regeneration. Brine recycle rec the amount of waste for disposal and the cost of operation.

Iron (Addition) Coagulation with Direct Filtration. The University of Houston (Clifford recently completed pilot studies at Albuquerque, NM on iron addition (coagulation) follow direct filtration (microfiltration system) resulting in arsenic (V) being consistently removed below 2 µg/L. Critical operating parameters are iron dose, mixing energy, detention time, a pH.

Conventional Iron/Manganese (Fe/Mn) Removal Processes. Iron coagulation/filtration a iron addition with direct filtration methods are effective for arsenic (V) removal. Source wa containing naturally occurring iron and/or manganese and arsenic can be treated for arsenic removal by using conventional Fe/Mn removal processes. These processes can significantl reduce the arsenic by removing the iron and manganese from the source water based upon t same mechanisms that occur with the iron addition methods. The addition of iron may be required if the concentration of naturally occurring iron/manganese is not sufficient to achi the required arsenic removal level.

EPA Research Activities

EPA' s Office of Research and Development(ORD) is in the process of funding three arseni treatment research activities. First, a field study will be conducted to evaluate the effectiver of eight full scale drinking water treatment plants to remove arsenic from their source wate sustained basis for six to twelve months. The processes included in this field study will be t large system technologies, conventional coagulation/ filtration, and lime softening, and two small system technologies, ion exchange and the iron/manganese, oxidation/filtration proce These evaluation studies will also include characterization and quantification of the residua produced by each process. A second project will consist of laboratory and pilot plant studie characterize the kinetics of oxidation of arsenic III to arsenic V by various oxidants and oxidation processes. And finally, a workgroup meeting is being planned for February, 1998 review the state of the science of existing and developing drinking water treatment technolo effective for arsenic removal. Future work will entail additional full scale field studies on o small system treatment alternatives, such as activated alumina treatment, residuals characterization and management studies, and treatment cost and evaluation studies.

Issues

Coagulation/Filtration and Lime Softening:

- Not appropriate for most small systems--high cost, need for well trained operators, ar variability in process performance
- CF & LS alone may have difficultly consistently meeting a low-level MCL. IE may b useful as a polishing step.
- Disposal of sludge may be a problem

Activated Alumina:

- Lack of availability of F-1 alumina. Testing of substitute not yielding same results.
- Chemical handling requirements may make this process too complex and dangerous many small systems
- AA may not be efficient in the long term, as it seems to lose significant adsorptive capacity with each regeneration cycle
- Highly concentrated waste streams-disposal of brine may be a problem

Ion Exchange:

- Highly concentrated waste by-product stream- disposal of brine may be a problem. B recycling might reduce the impact.
- Sulfate levels affect run length
- Recommended as a BAT primarily for small, ground water systems with low sulfate TDS and as the polishing step after filtration for low-level options

Reverse Osmosis/Nanofiltration:

- Extensive corrosion control could be required for low-level option--ability to blend w be limited
- Water rejection (about 20-25 percent of influent) may be an issue in water-scarce reg

Electrodialysis Reversal:

- Water rejection (about 20-25 percent of influent) may be an issue in water-scarce reg
- May not be competitive with respect to costs and process efficiency when compared RO and NF, although it is easier to operate

Point of Use/Point of Entry:

- Adopting a POU/POE treatment system in a small community requires more recordkeeping to monitor individual devices than does central treatment.
- POU/POE systems require special regulations regarding customer responsibilities, w utility responsibilities, and the requirement of installation of the devices in each hom obtaining water from the utility.

Waste Disposal:

Disposal of the arsenic-contaminated coagulation sludge from the C/F and LS technologies be a concern. For large treatment plants, a large body of water would likely be needed to discharge the contaminated brine stream from the RO/NF technologies. Inland treatment pl would possibly need either some pretreatment prior to discharge or would need to discharg the sanitary sewer due to the increase in salinity. Discharge to sanitary sewers may require pretreatment to remove high arsenic levels. The waste stream produced by IE/AA technolo is a highly concentrated brine with high TDS. These brine streams may required some pretreatment prior to discharge to either a receiving body of water or the sanitary sewer.

Questions

- Are there other feasible candidates for treatment technologies for removal of arsenic drinking water?
- What are the best technology options for small ground water systems?
- How cost effective and efficient are point-of-use and point-of-entry treatment units fo arsenic?
- Are other field studies available on the application of POU or POE devices for arseni removal?
- What new treatment technology performance data are available, especially for achiev arsenic concentrations in finished water below 5 µg/L?