TECHNICAL APPLICATION BULLETIN

Selenium

Recognized Treatment Techniques For Meeting Drinking Water Regulations For The Reduction Of Selenium From Drinking Water Supplies Using Point-of-Use/Point-of-Entry Devices And Systems

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Water Quality® ASSOCIATION

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Recognized treatment techniques for meeting drinking water regulations for the reduction of selenium using point-of-use and point-of-entry (POU/POE) devices and systems.

Occurrence

Selenium is a metal found in natural deposits as ores containing other elements. The greatest use of selenium compounds is in electronic and photocopier components, but they are widely used in other products as well. Selenium releases to the environment have been primarily from copper smelting industries. The largest releases from 1987 to 1993 occurred in Utah. The largest direct releases to water occurred also at that time period in Indiana.

The main source of selenium intake for humans is through plant foods in which the plants concentrate the selenium found in soil or taken from groundwater used for irrigation. Selenium (Se) contamination of potable water supplies at concentrations above the current MCL of 0.05 milligram per liter (mg/L) is rare. In a 1982 study AWWA concluded that only 44 water supplies needed to treat for this contaminant.

At typical groundwater pH values (7.0 to 9.5) only anionic forms of selenious (Se IV) or selenic (Se VI) acid are found.

Se (IV) Selenious Acid Dissociation Equilibria: $H_2SeO_3 = H^+ + HSeO_3^-$
$HSeO_3^- = H^+ + HSeO_2^-$

Se (VI) Selenic Acid Dissociation Equilibria: $H_2SeO_4 = H^+ + HSeO_4^-$
$HSeO_4^- = H^+ + HSeO_2^-$

Under oxidizing conditions, Se (VI) will predominate at pH values less than 8.15 and the divalent selenate (Se^{2-}) anion will be found demonstrating chemical behavior similar to the sulfate ion. The predominant species under reducing conditions will be the Se (IV) species. At pH less than 8.15 the monovalent biselenite anion ($HSeO_3^-$) will dominate and at pH values greater than 8.15, the divalent selenite (SeO_3^{2-}) will form.

Health Effects

In trace quantities, selenium appears to be essential for nutrition of human beings while larger concentrations produce definite toxic symptoms. Although retained in the liver and kidney in small amounts, selenium salts, for the most part, are excreted. Signs of selenium toxicity occur at selenium ingestion levels of 0.7 –7.0 mg/day while 200 µg/day (0.2 mg/day) is nutritionally adequate

The USEPA has set the Maximum Contaminant Level (MCL) and the Maximum Contaminant Level Goal (MCLG) in drinking water for selenium at 0.05 mg/L.

EPA has found selenium to potentially cause the following health effects when people are exposed to it at levels above the MCL for relatively short periods of time: hair and fingernail changes; damage to the peripheral nervous system; fatigue and irritability.
Long-term, selenium has the potential to cause the following effects from a lifetime exposure at levels above the MCL: hair and fingernail loss; damage to kidney and liver tissue, and problems with the nervous and circulatory systems.

Treatment Alternatives

Several techniques may be used to reduce the level of selenium from drinking water: anion exchange, activated alumina (AA), reverse osmosis (RO), and distillation.

Anion Exchange can reduce selenium by 90-95%, where the selenate ion is strongly preferred. Although Se (IV) is more difficult to oxidize than As (III) is to As (V), this can readily be accomplished with free chlorine. The optimal rate of oxidation is found to be between pH 6.5 and 8.0 where Se (IV) can be converted to Se (VI) within 5 minutes at a free chlorine concentration of 2 mg/L. At pH 9.0, only 15% of the Se (IV) has been found to be converted with 2 mg/L of free chlorine. Pure oxygen was found to be ineffective at oxidizing Se (IV) to Se (VI). The run lengths that can be achieved when using oxidation prior to a strong base anion exchange resin system in chloride form are approximately 275 bed volumes (BV's). While this may not be considered an outstanding capacity, it should be noted that anion exchange resin's high affinity for the selenate ion will prevent chromatographic dumping and runs could be safely terminated at sulfate breakthrough.

Other techniques used for selenium removal include distillation (> 98% reduction), reverse osmosis (RO) (> 90% reduction), and activated alumina (85-95% reduction). Several point-of-use (POU) RO and POU distillation products have been tested and certified by ANSI-accredited third party organizations for selenium reduction.

Between pH 5 - 6, AA is very effective in removing Se (IV). But when the predominant species is Se (VI), AA is poor due to competition from the sulfate ion. In general, AA can be used from pH 3.0 – 8.0 for biselenite, Se (IV), removal. The media in such systems can be removed and recycled using the standard acid-base regeneration procedure normally employed when AA is used for fluoride removal.

At the present time, it appears that any of these methods can be made practical, feasible, and economical for selenium reduction when considering point-of-entry (POE) or POU devices.

The treatment methods listed below are generally recognized as techniques which can effectively reduce listed contaminants sufficiently to meet or exceed the relevant MCL. Selection of a particular device or system for health contaminant reduction should be made only after a careful

consideration of its performance capabilities based on results from competent equipment validation testing for the specific contaminant to be reduced.

As part of the POE installation procedure, system performance characteristics should be verified by tests conducted under established test procedures and water analyses. Thereafter, the resulting water should be monitored periodically to verify continued performance. The application of the water treatment equipment must be controlled diligently to ensure that acceptable feed water conditions and equipment capacity are not exceeded.

Contaminant	**MCL mg/L**	**Treatment Methods**
Selenite SeO_3^{2-}	0.05 (total selenium)	Activated alumina adsorption (85-95% reduction)
Selenate SeO_4^{2-}		Strong Base Anion type I Cl^- exchange (60-95% reduction),
		Distillation (>98% reduction)
		Reverse Osmosis (>90% reduction)

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