

Using Iron to Remove Arsenic

There are numerous options in removing arsenic from groundwaters. Some of which include activated alumina, reverse osmosis, and ion exchange. This particular article looks to discuss the option of coprecipitation of arsenic using iron followed by Manganese Greensand filtration. This process is a relatively simple technology, but offers another option in the treatment for arsenic and may prove to be more feasible than most others. The actual feasibility of the process depends on the initial water quality and the effluent quality desired. For some, there may be no change in the current water treatment process employed as it may already be effectively working to reduce arsenic to acceptable levels.

Arsenic removal by this means is dependant on the presence of iron. Where iron is naturally present in the influent water, it may be present in adequate quantities to reduce the arsenic to acceptable levels, else an artificial source, such as a ferric chloride feed, will have to be considered. Utilizing an oxidant pre-feed to oxidize the iron, the arsenic tends to complex with metal salt and thereby coprecipitate with it. A discussion of the actual chemistry is beyond the scope of this discussion and will be reserved for another.

One plant that is successfully removing arsenic with the process is the Kelliher Water treatment facility in Saskatchewan. Kelliher operates Manganese Greensand with a pre-feed of potassium permanganate. The treatment process was optimized to treat for iron and manganese. As a result, it was found that the process removes over 90% of the arsenic, keeping it well below 10 µg/L, or 0.010 mg/L.

Research has been done to determine the suitability of Manganese Greensand for arsenic removal. One study, conducted by the New Mexico State University, focused on the Intermittent Regeneration (IR) process in the removal of arsenic. The study concluded that Manganese Greensand can effectively remove arsenic from contaminated waters. The study also concluded that the best arsenic removal occurred at a pH of 5 and that iron concentration had little, or no impact on arsenic removal. Unfortunately, operating Manganese Greensand at a pH of 5 is not really an option as the minimum recommended influent pH is 6.2. Waters with a pH below the recommended minimum are aggressive towards the media and can cause its deterioration.

Most indicators show that with coprecipitation and filtration, arsenic can be reduced to levels less than 0.010 mg/L and that it may be difficult to regularly meet limits set lower than 0.010 mg/L. Given this fact, coprecipitation and filtration may be the only part of the answer where lower arsenic levels are set. This process would then serve as a form of pretreatment which could be followed by a higher technology process to polish the water. By use of pretreatment, the load on the polisher would be lessened, thereby potentially reducing the overall operating cost(s) of a given facility.

The acceptability of the effluent depends on the regulations and the established MCL. The MCL for arsenic is currently at 0.05 mg/L and is currently being reevaluated. Coprecipitation with iron can bring arsenic levels within the current MCL. Whether or not stricter arsenic levels can be met, for a given application, requires pilot testing.

There are numerous benefits to employing this scheme when compared to the other technologies that are available. Generally, the capital and operating costs tend to be lower since it is a simpler technology. There is no regenerant or concentrated brine as there would be with ion exchange or reverse osmosis. The actual waste stream can usually be handled as common sludge and be sent directly to the sewer (actual disposal is governed by the local authorities). Minimum training for the operators would be required, again, because this is a simpler technology. Because there are so many technologies and options available, it is not practical to compare them all, but coprecipitation and filtration is an option worthy considering for arsenic removal.

With the consideration of Manganese Greensand, the following is offered as a general guideline in utilizing this particular media.

Manganese Greensand has been a staple for the removal of iron, manganese and hydrogen sulfide for over 40 years. Manganese Greensand is made from glauconite – an iron, potassium, aluminosilicate material of marine origin. It was originally used as a natural zeolite for water softening due to its relatively high ion exchange capacity (approximately 3,000 grains/ft³). Until the development after World War II of synthetic gel-type ion exchange resins, which had a capacity of about six to seven times that of glauconite, the greensand zeolites were an efficient and reliable part of the softening industry.

When treating for iron and arsenic with Manganese Greensand, the Continuous Regeneration (CR) process is recommended, as opposed to the Intermittent Regeneration (IR) process. CR involves feeding an oxidant or combination of oxidants – such as potassium permanganate and chlorine – to the raw water prior to contact with the Manganese Greensand bed. Chlorine, which is recommended, should be fed at a suitable distance ahead of the potassium permanganate injection point. The chlorine will oxidize the bulk of the iron and any sulfide. Potassium permanganate will then complete the oxidation of trace amounts of iron and soluble manganese. In the IR method, iron and manganese are removed by contact oxidation. Generally, the CR method is used where iron predominates with only small amounts of manganese, while the IR process is used for water where manganese removal, with or without the presence of iron, is required.

The IR process, though capable of removing iron, has detrimental effects on Manganese Greensand when used in applications where iron removal is the primary role, or is present in significant quantities. The iron once oxidized by the media can not be regenerated off, unlike manganese. The iron essentially stains the media, reducing its capacity to oxidize soluble constituents on subsequent filter runs. Eventually, there would be enough staining that a significant reduction in the filter run length and effluent quality would be seen. Furthermore, the amount of permanganate remaining after a regeneration would increase as less would be utilized on each subsequent regeneration. Operating under these conditions would necessitate the eventual replacement of the media.

Generally, many POU customers elect to operate IR regardless of the iron concentration. The capital cost of an IR system is less. Commercial customers cannot typically afford the CR capital cost and the necessary staffing. Because the POU customer has a smaller system, periodic replacement costs associated with the media may not be too burdensome.

The mechanism for iron and manganese removal by Manganese Greensand in the CR method is oxidation followed by physical removal of the resulting precipitates by filtration using a Manganese Greensand or Manganese Greensand and anthracite bed. This process can remove iron from water in concentrations up to 15 milligrams per liter (mg/L) or more. However, with such high concentrations, the run length between backwashings would be as little as 4 to 6 hours, based on a service flow rate of 1.5 to 2.5 gallons per minute per square foot (gpm/ft²).

With high iron concentrations, low flow rates are required to produce an acceptable run length. Waters having iron concentrations in the low range of 0.5 to 3.0 mg/L would have run lengths of 18 to 36 hours at a more acceptable design flow rate of 3.0 to 5.0 gpm/ft². Flow rates greater than 5.0 gpm/ft² can be used if the shorter run lengths are acceptable. Pilot plant tests are recommended and usually specified by various regulatory agencies for operation at these higher rates.

Enough chlorine can be fed to provide the desired residual in the treated water. Also, if the iron and manganese levels are low (less than 1 mg/L Fe and/or Mn), permanganate is usually not required with pre-chlorination. Since permanganate is a strong oxidant, manganese can be completely oxidized even at the minimum recommended pH of 6.2.

The Dual Function of Manganese Greensand

The Manganese Greensand bed performs a dual function to complete the removal of iron and manganese. First, correct operation of CR filter requires a slight excess of permanganate prior to the filter, indicated by an influent water having a light pink-orange color. This will ensure that the oxidant demand, whether using

permanganate alone or in combination with chlorine, has been met. Any slight excess permanganate will be reduced to manganese oxide by the Manganese Greensand.

The manganese oxides will then precipitate onto the grains, maintained in a continually regenerated state. Conversely, a temporary underfeed of oxidant would use the oxidizing capacity of the regenerated greensand to complete the oxidation of iron and manganese. With CR, the greensand acts as a redox buffer with capabilities of both oxidation and reduction as required by influent water conditions.

Second, when removing iron and manganese by oxidation, the presence of manganese oxide will act as a catalyst – whether the oxidizing agent is oxygen, chlorine, ozone or permanganate – insuring that the reaction goes rapidly to completion.

Extended service with an underfeed of permanganate before the CR filter will eventually exhaust the oxidative capacity of the media, resulting in manganese leakage into the treated water, even if the raw water contained no manganese. The media must remain in a continually regenerated form at all times. This is accomplished by a visual check for the “pink-orange” color in the filter influent and/or the presence of chlorine in the effluent.