

**Filter Media Cementation  
at the Oakwood Water Treatment Plant,  
East Peoria, Illinois**

submitted  
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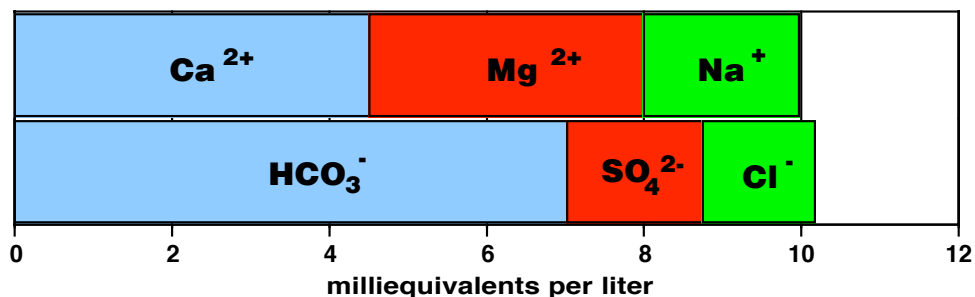
### **Background**

East Peoria's Oakwood Road Water Treatment Plant utilizes well water and provides aeration for ferrous iron oxidation. The aerated water is retained in a detention basin under the aerators to provide time for iron precipitation. Following the in-line addition of potassium permanganate to oxidize manganous ion, the aerated water flows by gravity to two four-cell filter units where precipitated iron and manganese oxides are removed.

The current evaluation was undertaken November 18, 2002 as part of an investigation of the root causes of filter media encrustation. Following replacement of the original anthracite coal and sand filter media after only five years of service, filtration capacity has again progressively been lost over the past two years.

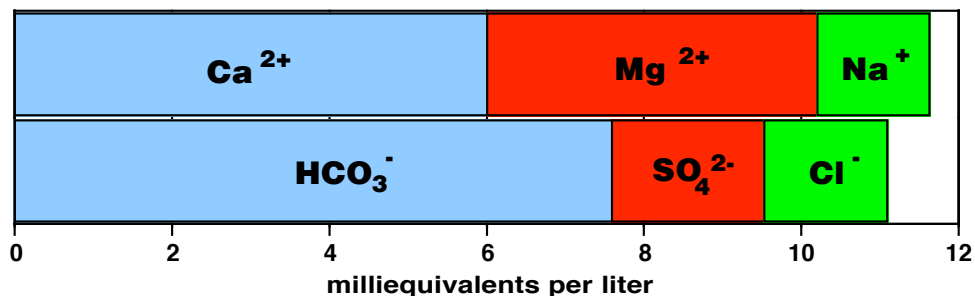
## Well Water Influent to Oakwood Road Water Treatment Plant

Water Composition - Well #10



Well #10 produces water that is hard (approximately 400 mg/l as CaCO<sub>3</sub> equivalent), but very low in iron and manganese (< 0.1 mg/l combined). This water also appears to be non-corrosive (neutral in pH) and has little tendency to deposit scale on the interior of distribution system piping or household plumbing. Accordingly, this water is pumped directly from the well to the distribution system without treatment except for chlorination.

Water Composition - Wells #11 and #12



Wells #11 and #12 serve as influent to the Oakwood Road Water Treatment Plant. While somewhat harder and higher in alkalinity, these well waters are similar in inorganic composition to the water from Well #10 except they contain noticeable amounts of iron and manganese. In these waters, ferrous ion has been measured in the range of 0.7 to 1.8 mg/l Fe, while manganous ion averaged 0.23 mg/l Mn.

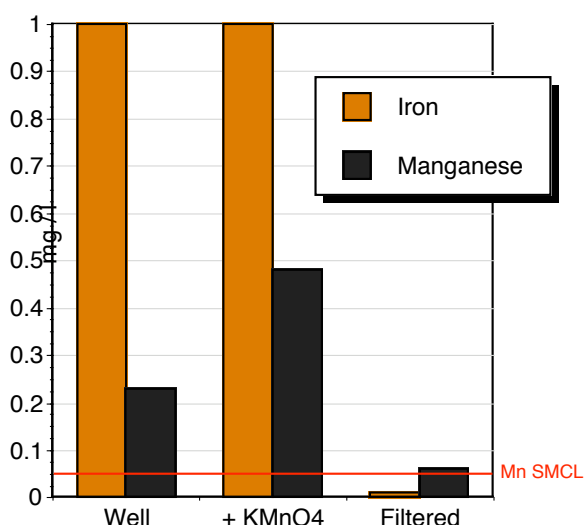
Well #	1993: mg/l Fe	1993: mg/l Mn	2002: mg/l Fe	2002: mg/l Mn
10	0.09	0.07	< 0.03	0.03
11	1.8	0.22	1.3	0.17
12	1.0	0.29	0.69	0.23

Iron concentrations in excess of 0.3 mg/l Fe and manganese levels of 0.05 mg/l Mn are considered a nuisance, because their orange-brown to black precipitates cause noticeable discoloration of water and may result in staining of household plumbing fixtures and laundry. Because of this, iron and manganese are regulated by IEPA under a *secondary MCL*. A secondary MCL is directed at water constituents that create an aesthetic nuisance rather than a health hazard.

### Effectiveness of Iron and Manganese Removal

Accordingly, the Oakwood Road Water Treatment Plant was designed to remove the relatively small quantity of solids formed when iron and manganese are precipitated from Wells #11 and #12. The bar chart shown below illustrates the almost total (99%) removal of iron and the 80% removal of manganese in November 2002.

Manganese removals vary owing to the addition of potassium permanganate to the filter influent. Depending upon variations in feed rate, permanganate addition adds approximately 0.25 mg/l Mn to the influent water, bringing the total to roughly 0.48 mg/l Mn. Any transient overfeed of permanganate can result in the passage of 'pink water' plus increase the manganese concentrations in the filtered water. This suggests that the permanganate feed should be reduced to the minimum consistent with the maintenance of filtered water Mn concentrations less than 0.05 mg/l.

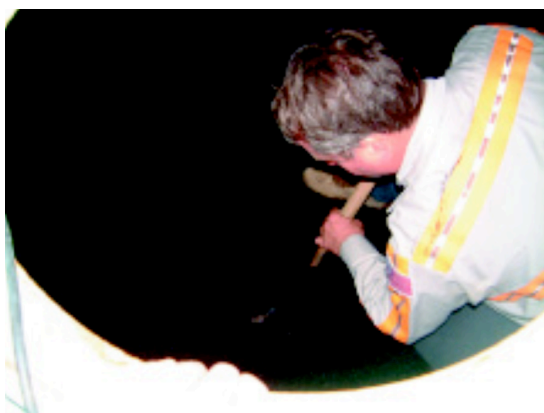




Permanganate is added to aerated water (filter influent) to oxidize manganous ion ( $\text{Mn}^{2+}$ ) to  $\text{Mn}(\text{OH})_4$ , a brown-black precipitate.



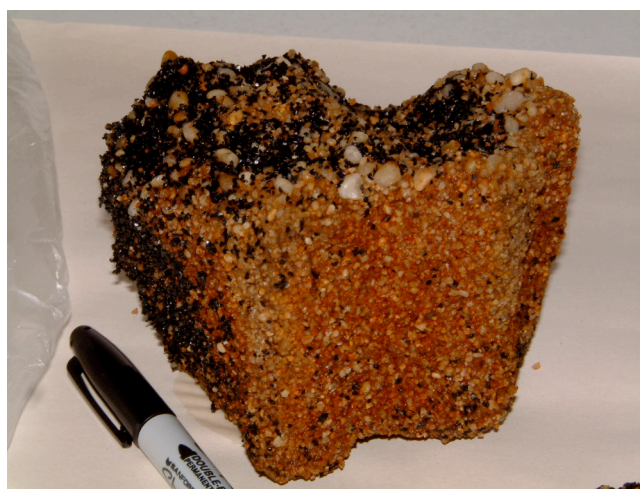
Horizontal pressure filters are divided into four compartments containing dual, crushed anthracite coal and coarse sand, media



Filter media probing and sampling were conducted on November 18, 2002.



Most of the severely cemented (sandy) material appeared to underlie the anthracite layer. The anthracite also showed evidence of a loose aggregation that could be broken up by hand.



The treatment process utilized at the Oakwood plant has long been widely used in the treatment of Illinois ground waters. It begins with aeration to introduce dissolved oxygen to the well water. This oxygen readily oxidizes ferrous ion at the neutral pH (7.5) of the well water to form the familiar orange-brown precipitate, ferric hydroxide. Since manganous ion is not oxidized by oxygen at this pH, potassium permanganate is then added to oxidize the small quantity of manganous ion present in the source water. Shortly after this chemical addition, the water is passed through pressure filters containing crushed anthracite coal over silica sand. It is within these filter beds that chronic problems have arisen.

Normally, when water wash is applied exclusively for filter backwash, an expansion of 20% to 50% is used. For the Oakwood Road Plant, a filter backwash rate of 12 gpm/sf (19 in./min. rise rate) was recommended (Daily and Associates, July 13, 2001). This would result in a 50% expansion of the upper anthracite layer. It was also estimated that the sand layer would expand by 10% at this wash rate. However, there would be no sand expansion at a backwash rate of 10 gpm/sf.

#### **Condition of Filter Media**

The filter media in the Oakwood plant filters is comparatively coarse. A top layer of crushed anthracite coal (0.6 to 0.8 mm) sits atop a support layer of silica sand (0.8 to 1.2 mm). Normally, if the silica sand was to serve as a filter medium as opposed to support for the anthracite layer, it would have an effective size in the range of 0.45 to 0.55 mm. Larger sand sizes require considerably higher backwash flow rates for removal of any attached deposits.

Existing support gravel is in within the ranges specified in the Ten-State Standards. The exclusion of large gravel at the bottom is due to the fact that the gravel does not rest directly on a lateral system.

<b>Gravel Size</b>	<b>Depth (10-State Stds.)</b>	<b>Depth (Existing)</b>
2 1/2 - 1 1/2"	5 - 8"	none
1 1/2 - 3/4"	3 - 5"	4"
3/4 - 1/2"	3 - 5"	3"
1/2 - 3/16"	2 - 3"	3"
3/16 - 3/32"	2 - 3"	3"

#### **Cementation**

Calcium carbonate and iron oxide deposition combined with insufficient cleaning during backwash have resulted in the progressive aggregation of the adjoining media particles until large areas of the filter bed have become unavailable for filtration. Aerated water may then travel along filter walls, through cracks, and bypass much of the filter surface. Poorer effluent quality and shorter filter runs are operational indications of the formation of concretions and the blinding of the filter media.

Previous analysis of encrusted materials removed from the filter beds during filter restoration indicates that the media encrustants (acid-soluble materials) consist of calcium carbonate plus iron, and to a lesser degree, manganese oxides. These precipitates have caused the grains of filter media to aggregate and harden. This sand has already formed a horizontal lens that is rock hard, requiring a crowbar and hammer even to recover a sample for observation and analysis.

From the most recent filter media sampling at the Oakwood Plant, it appears that it is primarily the underlying sand layer that is undergoing cementation. This might be expected since the sand layer, being far greater in density (specific gravity, 2.6) as well as larger than the anthracite (specific gravity, 1.6), would not expand as much, if at all, during backwash. As a result, the surface deposition of calcium carbonate and iron oxides on the sand would be less efficiently removed.

The addition of sulfuric acid to cemented media results in significant effervescence of carbon dioxide. Upon acidification, 25% of the sand layer sample, by weight, was lost. This is in contrast with the loss of 8.5% by weight following acidification of the anthracite layer.

From these analytical results, one can conclude that calcium carbonate and iron and manganese hydroxides, once removed from the flow and attached to the media during filtration, are not being uniformly and effectively removed from the media particles during the backwash process.

#### **Alternative Media**

Alternative media may increase plant performance with respect to manganese removal and be less prone to cementation. A finer sand (0.45 - 0.55 mm) should expand significantly during backwash. A deeper layer of this fine sand overlain by a shallower layer of crushed anthracite should improve the overall hydraulics of filter backwash. Alternately, this layer of fine sand may be even more prone to cementation. Therefore, if the city is interested in evaluating alternative filter media, pilot testing should be undertaken prior to replacing media in all eight filter cells. Either a single cell could be designated as a pilot cell to test a new media configuration, or a set of clear plastic columns could be used to test a variety of configurations.

## Recommendations

### Media Replacement

Under the current circumstances, there seems to be little choice but to remove and discard the cemented filter media before encroaching filter blockage reaches the point where water production is significantly impaired. Attempts to rehabilitate existing media with acid have not exhibited long-term effectiveness. Additionally, acid treatment generates noxious fumes, attacks the filter itself, and still requires the addition of media to make up for the material lost through acidification.

### Installation of Air Scour

Air scour (air-assisted backwash) provides effective scouring action, virtually eliminates mudball formation, and can significantly reduce the amount of water used for backwashing.

The photo at right shows a new pressure filter in Morton, IL. Piping for air scour is visible at the bottom left of the picture.



The existing filter units should be outfitted with an air injection system. PVC distribution piping for the system should be located beneath the sand layer, preferably within the underdrain system. Air holes should be small enough to keep the media out of the air lines. A blower capable of supplying air at a rate of 2 to 4 ft<sup>3</sup>/min/ft<sup>2</sup> should be selected.

Air scouring should take place at least once every week. The operational protocol for the air scour should include the drawdown of the water level in the filter to just above the surface of the media. Although operational experience may lead to a refinement of the air-assisted backwash procedure, initially, the air should be applied at a rate of 3 ft<sup>3</sup>/min/ft<sup>2</sup> for a period of ten minutes. Following the air scour, the filter cell should be backwashed at a rate of 12 gpm/sf until the wash water is clear. Records should be kept of the quantity of wash water required.



**Media Inspection**

After filter media has been replaced, each filter should be opened monthly to look for signs of cementation and to take representative samples of the media. The depth of media in each filter cell should be measured each time to determine whether or not any media has been lost.

**Reduction in Permanganate Addition**

To minimize solids application to the filter units, the permanganate addition should be reduced to the lowest possible effective dose. To determine the lowest effective dosage, the chemical feed should be incrementally reduced while plant influent, filter influent, and finished water are analyzed for manganese.