Iron Impact Management in Nile River: On October 31st To November 4th 2009

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1. Introduction

Iron is a common metallic element found in the earth's crust. Water percolating through soil and rock can dissolve minerals containing iron and hold it in solution. Occasionally, iron pipes also may be a source of iron in water. Iron does not clearly alter in pure water or in dry air, but when both water and oxygen are present (moist air), iron corrodes [1]. Its silvery color changes to a reddish-brown, because hydrated oxides are formed. Dissolved electrolytes accelerate the reaction mechanism, which is as follows:

$$4 \text{Fe} + 3 \text{O}_2 + 6 \text{H}_2\text{O} \rightarrow 4 \text{Fe}^{3+} + 12 \text{OH}^- \rightarrow 4 \text{Fe(OH)}_3 \text{ or } 4 \text{FeO(OH)} + 4 \text{H}_2\text{O}$$

Dissolved iron is mainly present as Fe (OH)\(^{2+}\) (aq) under acidic and neutral oxygen-rich conditions, iron(II) hydroxide often precipitates in natural waters, but under oxygen-poor conditions it mainly occurs as binary iron. Iron is part of many organic and inorganic chelating complexes that are generally water soluble. Seawater contains approximately 1-3 ppb of iron; the amount varies strongly, and is different in the Atlantic and the Pacific Ocean. Rivers contain approximately 0.5-1 ppm of iron, and groundwater contains 100 ppm. Drinking water may not contain more than 200 ppb of iron [2]. Most algae contain between 20 and 200 ppm of iron, and some brown algae may accumulate up to 4000 ppm.

World Health Organization recommended that the guideline value of iron in treated water shouldn't exceed 0.3 mg L\(^{-3}\).

Oxidation of dissolved iron particles in water changes the iron to white, then yellow and finally to red-brown solid particles that settle out of the water. Iron that does not form particles large enough to settle out and that remains suspended (colloidal iron) leaves the water with a red tint responsible for the staining properties of water containing high concentrations of iron [3]. These precipitates or sediments may be severe enough to plug water pipes; Iron deposits will build up in pipelines, pressure tanks, water heaters and water softeners, this reduces the available quantity and pressure of the water supply. Iron accumulations become an economic problem when water supply or water softening equipment must be replaced. Iron can affect the flavor and color of water. It may react with tannins in coffee, tea and some alcoholic beverages to produce a black sludge, which affects both taste and appearance also iron, will cause reddish-brown staining of laundry, porcelain, dishes, utensils and even glassware [4]. Soaps and detergents do not remove these stains, and use of chlorine bleach and alkaline builders (such as sodium and carbonate) may intensify the stains.

A problem that frequently results from iron in water is iron bacteria. These nonpathogenic (not health threatening) bacteria occur in soil, shallow aquifers and some surface waters. The bacteria feed on iron in water [5]. These bacteria form red-brown (iron) slime in toilet tanks and can clog water systems.
2. Experimental

Collection, storage and pretreatment of all samples were carried out as illustrated in 20th edition of the Standard Methods for the Examination of Water and Wastewater.

Absorbance measurements were carried out using 6405 UV-Vis Jenway at 510 nm with 10 mm matched quartz cells using phenanthroline method.

The turbidity measurements were carried out using 2100N Hach turbidimeter using Nephelometric method.

3. Results and discussion

On October 31st to November 4th 2009, there is a dramatic shook of iron concentration in Nile water due to the dump of high quantities of wastes of iron-steel Helwan factories and coke factories; the iron concentration in Nile water increasing from the average value of about 0.1 mg L⁻¹ to a level of about 5.0 to 7.0 mg L⁻¹ in the form of colloidal particles which cause what we call red water and the turbidity reaches more than (200 NTU), this serious problem transfer from one drinking water supply plant to another along the stream of Nile water knowing that the speed of Nile water is between 3 to 5 km/h. This temporary problem has been continued for four days.

<table>
<thead>
<tr>
<th>Plants</th>
<th>Distance between intakes(km)</th>
<th>The time(in hour) to achieve the other plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>El-Tebin to Kafir El Elw</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Kafir El Elw to North Helwan</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>North Helwan to El-Fostat</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>El-Fostat to Al Maadi</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>El-Fostat to Al Roda</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Al Roda to Rod El Farag</td>
<td>10</td>
<td>2.5</td>
</tr>
<tr>
<td>Rod El Farag to Al Ameyria</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Al Ameyria to Mostorad</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Mostorad to Al Obeer</td>
<td>22</td>
<td>5.5</td>
</tr>
<tr>
<td>Rod El Farag to Shubra El Kheima</td>
<td>6</td>
<td>1.5</td>
</tr>
<tr>
<td>Al Obeer to El Asher</td>
<td>55</td>
<td>14</td>
</tr>
<tr>
<td>Al Obeer to El Marg</td>
<td>13</td>
<td>3</td>
</tr>
</tbody>
</table>

The responsibility of Cairo Water Supply Company is to provide biologically and chemically safe water that has most objectionable taste and odor causing substances removed. An ordinary method is used for water treatment; chlorine added to keep water safe during distribution and Alum is the most coagulant used to remove undesirable impurities in water.

\[
\begin{align*}
\text{Cl}_2 + H_2O & \rightarrow OCl^- + H^+ + HCl \\
\text{Al}_2(SO_4)_3 + 6\text{HCO}_3^- & \rightarrow 2\text{Al(OH)}_3 (\downarrow) + 3\text{SO}_4^{2^-} + 6\text{CO}_2
\end{align*}
\]

3.1. Which water purification technologies can be applied to remove iron from water?

Iron removal from wastewater may be achieved by oxidation of binary iron to tertiary iron. Hydrolysis subsequently causes flake formation, and flakes can be removed by sand filtration. Oxidation may be achieved by adding oxygen or other oxidants, such as chlorine or potassium permanganate. The reaction rate depends upon pH values, and is slower under acidic than under alkaline conditions. To speed up the reaction under acidic conditions, the water may be aerated for carbon dioxide removal and pH recovery. The total reaction causes acid formation and thereby diminishes itself. Iron is often reduced together with manganese. Applying ion exchangers for iron trace removal from drinking water and process water is another option, but this is not very suitable for removing high iron concentrations. Iron compounds are applied in wastewater treatment, usually as coagulants. One example is iron sulphate application in phosphate removal.
3.2. Management of the problem

Raw water from the intakes plants in Greater Cairo water supply were used in jar-test coagulation experiments with variations of chlorine dosages from 3.0 to 5.5 mg/L. The obtained results showed that binary iron converted to ferric chloride which reacts with the alkalinity of water and acts as a coagulant.

\[
2FeCl_3 + 6HC\text{O}_3^- \rightarrow 2Fe(OH)_3 (\text{↓} + 6Cl^- + 6CO_2
\]

This achieved when each plant increase the chlorine dose by 1.0 mg L\(^{-1}\) and the alum dose was approximately 30 mg L\(^{-1}\).
Under uncontrolled pH conditions the ferric chloride and the alum each act to form flocks that attract suspended matter which can be settle out or can be filtered out of water by a treatment system and could effectively remove turbidity in the supernatant by approximately 96% and the percentage removal of Iron in tape water was approximately 97% under the examined conditions. Table (2) shows the main average of physical, chemical and microbiological investigation of Nile water and Tap water before and during the impact of the Iron. Samples are tacking from Kafr El Elw plant intake before and during the shook.

It can be observed that there is a highest increase in the turbidity and total iron contents, compared by the main average during October month before the shook, also there is an increase in Ammonia, Nitrate, TDS and Total Hardness. Tap water parameters during the impact are still under the Guide lines of drinking-water quality depends to a large extent on the good management.

4. Conclusion

These results indicate that alum and ferric chloride coagulation at uncontrolled pH could produce very clear drinking water and iron reduction to levels below internationally approved guidelines is possible using conventional treatment technology.

Acknowledgements

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References

[3] Iron (Fe) and water, Lenntech Water Treatment and Purification Holding B.V, 998, 2009.