EWCE 331
Water Supply Engineering

Lecture 8

Instructor

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Lecture outline

Water Treatment Methods

Topics	References
• **Advanced water treatment for heavy metal removal** ✓ **Iron and Manganese removal**	**1. Water and Environmental Engineering** Authors: M. Habibur Rahman, Abdullah Al-Muyeed 1st ed., ITN-BUET **2. Environmental Engineering** Authors: Howard S. Peavy, Donald R. Rowe and George Tchobanoglous International Edition, McGraw Hill Companies **2. Water Supply and Sanitation** Authors: M. Feroz Ahmed, Md. Mujibur Rahman 1st ed., ITN-BUET

Advanced Water Treatment

Purposes:

- To take a water treated by standard processes and to improve it to exceptionally high quality as often required by particular industries.

- To treat a water containing specific chemical or microbiological contaminants to an acceptable standard, i.e removal of iron and manganese, the removal of blue-green algae, the removal of specific organics

Advanced Water Treatment

Used Techniques for Advanced Treatment:

- Iron and manganese removal -
  - ✓ iron is removed by pressure filters
  - ✓ manganese is removed by gravity sand filters

- Ion Exchange and inorganic absorption -
  - ✓ water softening by exchanging undesirable calcium and magnesium cations with sodium.
  - ✓ removal of undesirable cations including barium, strontium and radium
  - ✓removing undesirable anions including fluoride, nitrates, silicates and chromates

Advanced Water Treatment

Used Techniques for Advanced Treatment:

- Adsorption of organics – undesirable contaminants are adsorbed on to solid adsorbents.

- Membrane processes – uses microfiltration, ultrafiltration, reverse osmosis, electrodialysis

- Oxidation including chemical oxidation – two or more chemical species are added with the purpose of increasing the oxidation state of one.

Iron and Manganese in Drinking Water

• Water containing excessive amounts of iron and manganese can –

- ✓ stain clothes
- ✓ dis-color plumbing fixtures
- ✓ sometimes add a "rusty" taste and appearance to the water.

• According to Bangladesh Environment Conservation Act, 1997, drinking water standards:

- ✓ **Iron** : **0.3 – 1.0 mg/L**
- ✓ **Manganese**: **0.1 mg/L**

Problem caused by Iron and Manganese in Water

- Small amounts of iron are often found in water because of the large amount of iron present in the soil and because corrosive water will pick up iron from pipes.

- Clothing washed in water containing excessive iron may become stained a brownish color.

- The taste of beverages, such as tea and coffee, may also be affected by iron.

- Manganese produces a brownish color in laundered clothing, leaves black particles on fixtures, and as with iron affects the taste of beverages, including coffee and tea.

Problem caused by Iron and Manganese in Water



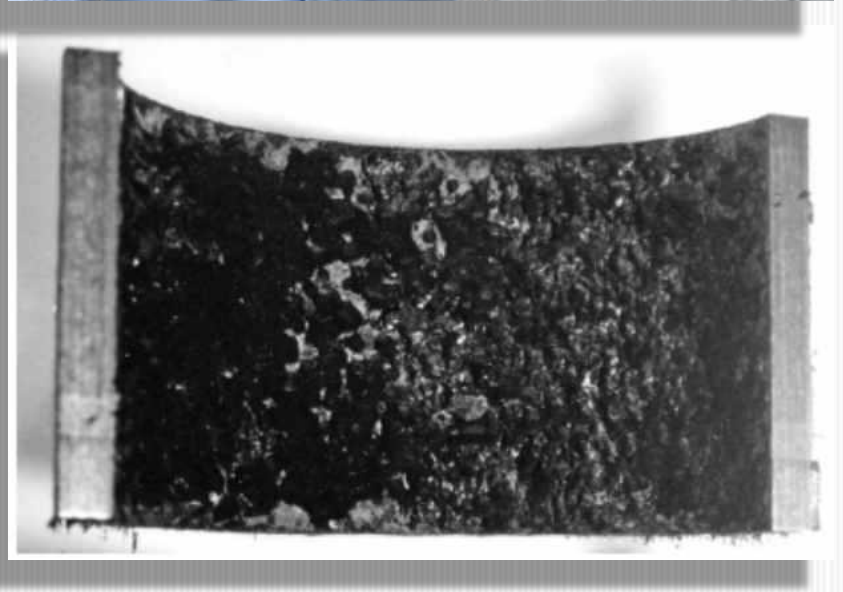




Problem caused by Iron and Manganese in Water







Chemistry of Iron and Manganese in Water

- Iron (Fe) and manganese (Mn) can be present in water in one of three basic forms:

1. Dissolved: ferrous (Fe^{2+}) and manganous (Mn^{2+})
2. Particulate: ferric (Fe^{3+}) and manganic (Mn^{4+}) states
3. Colloidal: very small particles (difficult to settle and filter).

- The predominance of one form over another is dependent on the pH, Eh (redox potential), and temperature of the water.

- Knowledge of the forms or states of iron and manganese can help fine tune a given treatment practice for these metals.

Removal of Iron and Manganese from Water

- The majority of iron and manganese treatment systems employ the processes of oxidation/ filtration.

- The oxidant chemically oxidizes the iron or manganese (forming a precipitate), and kills iron bacteria and any other disease-causing bacteria that may be present.

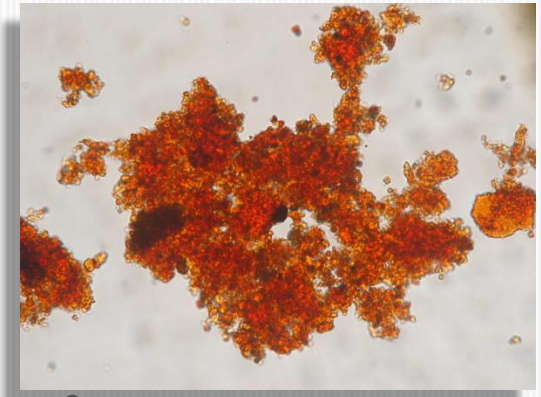
- The filter then removes the iron or manganese precipitates.

Removal of Iron and Manganese – **Chlorination**

- Iron and manganese in water promote the growth of bacteria (including iron bacteria).

- These organisms obtain energy for growth from the chemical oxidation reaction of iron and manganese with dissolved oxygen.

- These bacteria form thick slime growths on the walls of the piping system and on well screens.







Removal of Iron and Manganese – **Chlorination**

- These slimes tend to be are rust-colored from iron and black-colored from manganese.

- Variations in flow can cause these slime growths to separate from pipe walls, resulting in dirty water in the system.





Removal of Iron and Manganese – **Chlorination**

- The growth of iron bacteria can be controlled by chlorination.

- However, when water containing iron is chlorinated, the iron is converted from the ferrous state to the ferric state, producing rust and manganese is converted into black manganese dioxide.

- These materials form a coating on the inside of the water main and when they break loose, a customer will sometimes complain of “dirty” water.

Removal of Iron and Manganese – **Oxidation**

- Before iron and manganese can be filtered, they need to be oxidized to a state in which they can form insoluble complexes.

- Oxidation involves the transfer of electrons from the iron, manganese to the oxidizing agent.

- Ferrous iron (Fe^{2+}) is oxidized to ferric iron (Fe^{3+}), which readily forms the insoluble iron hydroxide complex $Fe(OH)_3$.

- Reduced manganese (Mn^{2+}) is oxidized to (Mn^{4+}), which forms insoluble (MnO).

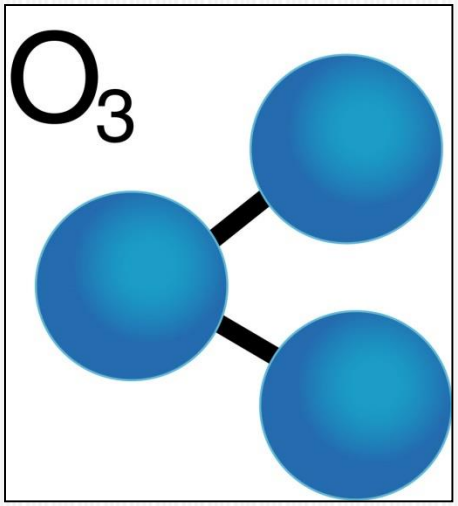
Removal of Iron and Manganese – **Oxidation**

- The most common chemical oxidants in water treatment are chlorine, chlorine dioxide, potassium permanganate, and ozone.





- Oxidation using chlorine or potassium permanganate is frequently applied in small groundwater systems.



- The dosing is relatively easy, requires simple equipment, and is fairly inexpensive.

Removal of Iron and Manganese – **Oxidants**

Chlorine, Chlorine dioxide

- Chlorination is widely used for oxidation of divalent iron and manganese.

Advantages:

- Chlorine feed rates and contact time requirements can be determined by simple jar tests.

Disadvantages/ Limitations:

- Formation of tri-halomethanes (THMs) in highly colored waters may be a problem.

Removal of Iron and Manganese – **Oxidants**

Potassium Permanganate ($KMnO_4$)

Advantages:

- As an oxidant, potassium permanganate ($KMnO_4$) is efficient for iron and manganese removal
- It requires considerably less equipment and capital investment.

Disadvantages/ Limitations:

- Normally more expensive than chlorine and ozone

Removal of Iron and Manganese – **Oxidants**

- The dose of $KMnO_4$ must be carefully controlled, since too little permanganate will not oxidize all the iron and manganese, and too much will allow permanganate to enter the distribution system and cause a pink color.

- Permanganate can also form precipitates that cause mud-ball formations on filters, which are difficult to remove and compromise filter performance.

Removal of Iron and Manganese – **Oxidants**

Ozone (O_3)

- Ozone may be used for iron and manganese oxidation.

Disadvantages/ Limitations:

- Ozone may not be effective for oxidation in the presence of humic or fulvic materials.



- If not dosed carefully, ozone can oxidize reduced manganese to permanganate and result in pink water formation as well.

- Manganese dioxide particles, also formed by oxidation of reduced manganese, must be carefully coagulated to ensure their removal.

Removal of Iron and Manganese – **Oxidation**

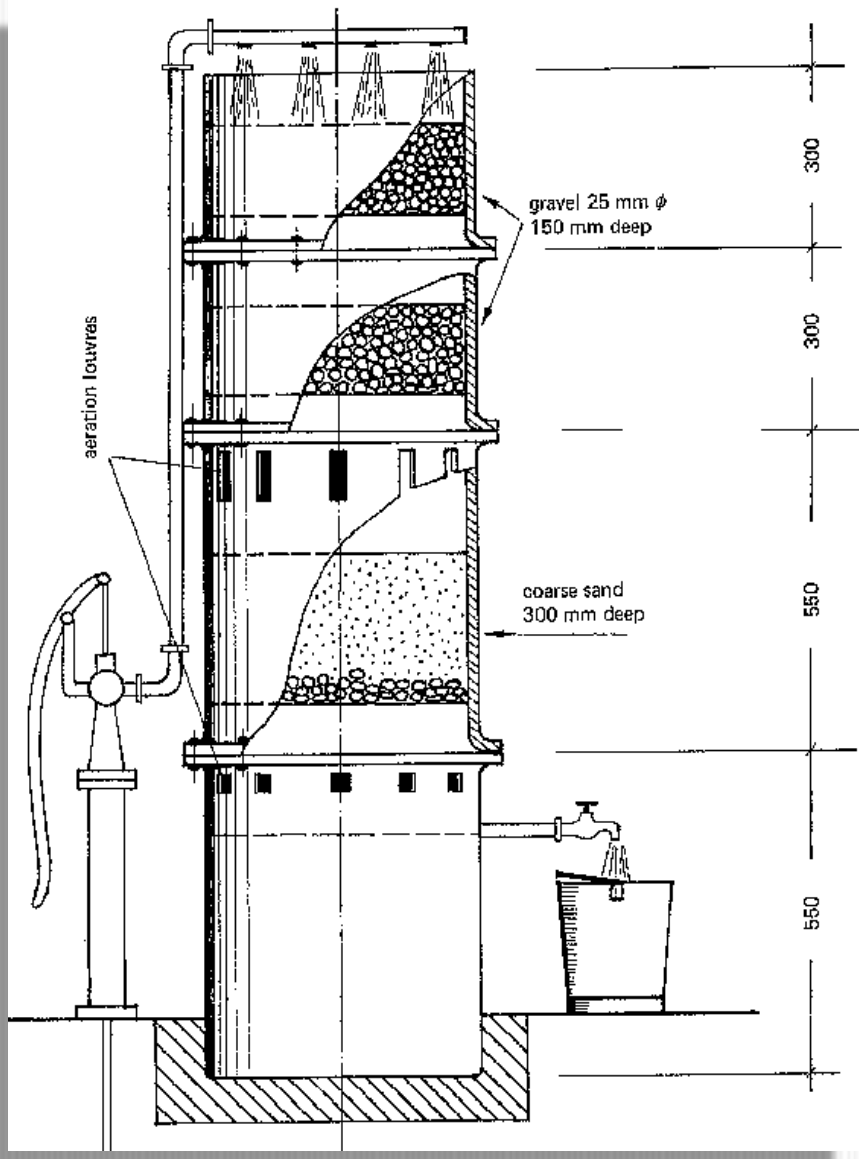
Aeration

- A low-cost method of providing oxidation is to use the oxygen in air as the oxidizing agent in a tray aerator.

- Water is simply passed down a series of porous trays to provide contact between air and water.

Advantages:

- No chemical dosing is required
- Allows for unattended operation.



Removal of Iron and Manganese – **Oxidation**

Aeration

Disadvantages/ Limitations:

- This method is not effective for water in which the iron is complexed with humic materials or other large organic molecules.
- Oxygen is not a strong enough oxidizing agent to break the strong complexes formed between iron and manganese and large organic molecules.
- The rate of reaction between oxygen and manganese is very slow below pH values of 9.5.

Removal of Iron and Manganese – **Oxidation**

Aeration - Filtration

- High concentrations of iron and manganese can be treated with an aeration- filtration system.
- In this system, air is pulled in and mixed with the passing stream of water.
- The air-saturated water then enters a precipitator/aerator vessel where air separates from the water.
- The water then flows through a filter where various filter media screen out oxidized particles of iron, manganese, and some carbonate or sulphate.

Removal of Iron and Manganese – **Oxidation**

Aeration - Filtration

- Pressure-type aerators are commonly used in household water systems.

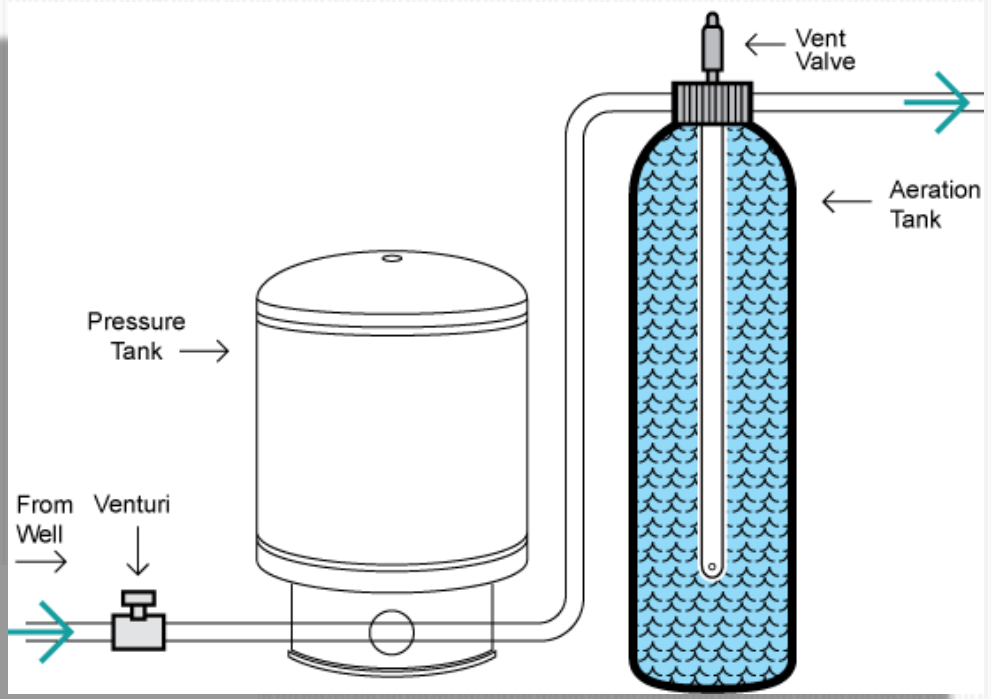
- Backwashing the filter periodically is a very important maintenance step.

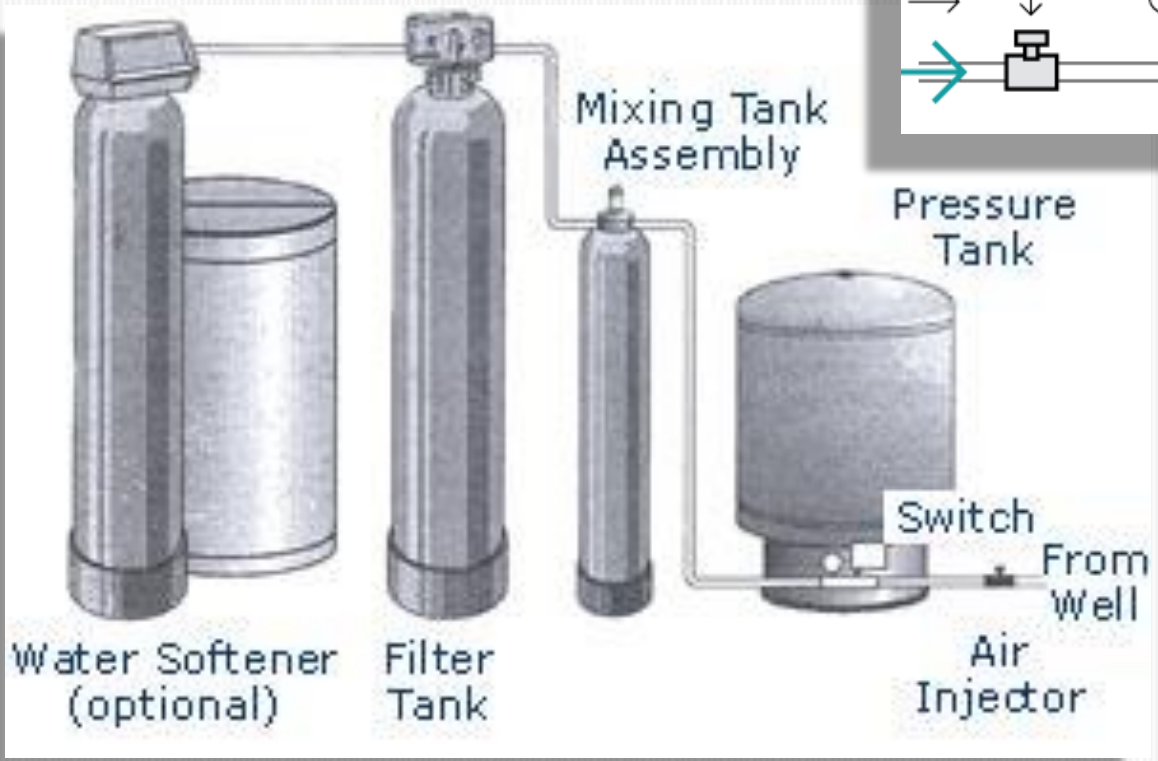
Limitations:

- Aeration is not recommended for water containing iron/manganese bacteria or colloidal (organic complexes of) iron/manganese because they can clog the aspirator and filter.

Removal of Iron and Manganese – **Oxidation**

Aeration - Filtration





Removal of Iron and Manganese – **Oxidation**

Aeration - Filtration

- Iron and manganese in well waters occur as soluble ferrous and manganous bicarbonates.

- In the aeration process, the water is saturated with oxygen to promote the following reactions:

$$4Fe(HCO_3)_2 + O_2 + 2H_2O = 4Fe(OH)_3 + 8CO_2$$

$$2Mn(HCO_3)_2 + O_2 = 2MnO_2 + 4CO_2 + 2H_2O$$

- The oxidation products, ferric hydroxide and manganese dioxide, are insoluble, thus form precipitates.

Removal of Iron and Manganese – **Oxidation**

Aeration - Filtration

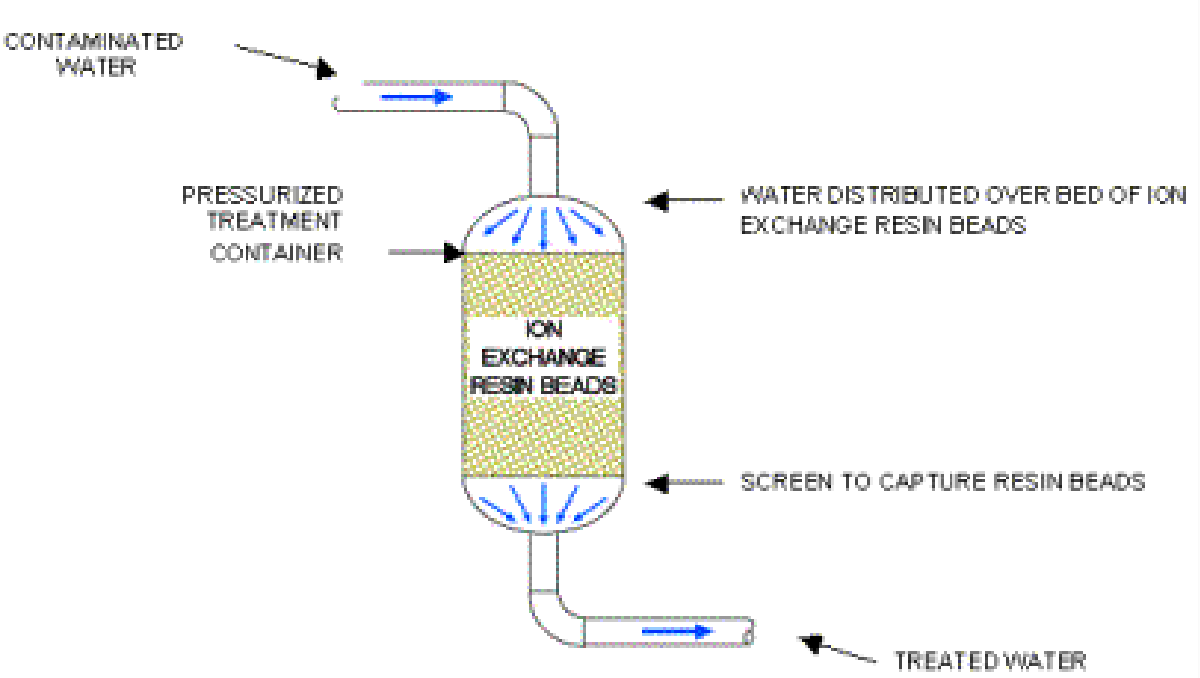
- After aeration, the precipitates are removed by clarification or filtration.

- Occasionally, strong chemical oxidants such as chlorine (Cl_2) or potassium permanganate ($KMnO_4$) may be used following aeration to ensure complete oxidation.

Removal of Iron and Manganese – **Ion Exchange**

- Ion exchange should be considered only for the removal of small quantities of iron and manganese because there is a risk of rapid clogging.

- Ion exchange involves the use of synthetic resins where a pre-saturant ion on the solid phase (the “adsorbent,” usually sodium) is exchanged for the unwanted ions in the water.



ION EXCHANGE TREATMENT PROCESS

Removal of Iron and Manganese – **Ion Exchange**

Limitations:

- One of the major difficulties in using this method for controlling iron and manganese is that if any oxidation occurs during the process, the resulting precipitate can coat and foul the media.

- Cleaning would then be required using acid or sodium bisulphate.