A Compact Equipment for Removing Dissolved Iron from Drinking Water

Shaji M Jamal, Femi K M et al, T.R Neelakantan

***Abstract*: Iron is an essential mineral for health, but more than desired content in water may become objectionable as it will give a rusty colour on laundered clothes and affect the taste and may cause odour. A new effective and economic product was developed for removing iron from waterworks on the principle of cascading aeration. It requires only less space, zero maintenance, it is energy efficient and it can be used for water with a range of iron content.**

***Keywords* : Dissolved iron, Drinking water, Iron remover**

I. INTRODUCTION

T Drinking water contains iron, but only in few places, it is found at concentrations above 10 mg/l. However, as per IS code specifications, a little more than 0.3 mg/l can cause water to have rusty taste, odor and if the concentration is more, a reddish brown color may be imparted to water. Iron present in water is of two main forms: (1) as soluble ferrous iron or (2) as insoluble ferric iron. Water will be clear and colourless if it contains ferrous iron, because it is completely dissolved in water. Exposure to air in atmosphere, the water becomes slightly opaque and a reddish-brown precipitate forms which is an insoluble sediment of the oxidized or ferric form of iron. The excess amount of iron in water may cause undesirable turbidity & color of water, bacterial growth in pipes, technical problems/failure of supply systems operation, deterioration in water quality and with a little higher concentrations of oxygen, undesirable incrustations are formed that results in the reduction of flow cross-section. It gives a rusty color to laundered clothes. There are many methods for iron removal/reduction from water. One of the important methods is aeration. The first step for producing drinking water from groundwater or rivers are aeration (gas addition) and stripping (gas removal). Many types of aerators are being used nowadays such as cascade aerator, spray aerator, diffused air aeration systems and mechanical aerators. The objective of the project is to develop an economic and efficient aerator to reduce the content of iron from water. Reducing iron content in water extends the life to other equipments which comes in contact with the water.

II. BACKGROUND

A design of the equipment is made including the sheets and the frame to hold the sheets and the parts are assembled. Water passed through the sheets is collected in an aluminium sheet metal container placed below the set up. Then the iron content present in it is tested before and after passing through the equipment using the phenanthroline method.

The reported iron content in rivers is 0.7mg/l. Ground waters in anaerobic conditions, iron is found to be in iron-II form, concentrations will usually be 0.5–10mg/l, but concentrations up to 50 mg/l are also found sometimes. Iron concentration in potable water is expected to be less than 0.3 mg/l but may be above this limit in places where different iron salts are used as coagulants in treatment process and if distribution is done through cast iron, steel, and GI pipes.

Ferrous-iron-salts get transformed into ferric hydroxide precipitate as they are unstable in potable water distribution systems and the precipitates will settle out to silt having a rusty colour. Ferrous-iron at higher concentrations may be found in an-aerobic ground-waters without discoloration or turbidity when pumped from a well directly, but may develop in piped systems at iron levels above 0.05–0.1 mg/l. Laundry staining and similar problems can happen at concentrations above 0.3 mg/l. In waterworks/distribution systems, iron promotes undesirable growth of bacteria (‘iron bacteria’) which results in forming a slimy coating on pipes.

Iron intake per day from foods which is the major source range from 10 to 14mg. Water containing 0.3 mg/l would contribute about 0.6 mg/day intake. Iron-intake through respiration can be assumed to about 25μg/day in urban places.

Iron gets dissolved and leached into ground water in wells and aquifers used to supply potable water during percolation of rainwater through soil. Iron concentration in well and aquifers is generally ranges from 0.5 to 10mg/l, and after treatment, it reduces to about 0.3mg/l. Humans can notice iron content above 0.3mg/l in drinking.

The main issues connected with the excess presence of iron in water are (1) Rusty taste (2) Brownish-red or black colour (3) Formation of deposits which interferes with the plumbing fixtures (4) Cloth-staining (5) Support for the growth of micro-organisms such as clonothrix and crenothrix, especially with organic matter present, these micro organisms may accentuate deposition problems and may produce sulfides, further affecting taste, odour and colour and (6) introducing difficulty for water softening process for industries, by clogging and coating the softening system.

III. TREATMENT PROCESS FOR IRON REMOVAL

Oxidation is one of the methods of removal of iron. Organic substances found in surface waters and ground waters can form soluble complexes with iron, which may not be satisfactorily oxidized to an insoluble form, thus making the oxidation process ineffective.

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Oxidation process becomes ineffective if organic substances are found in waters, which form soluble complexes instead of insoluble chemicals of iron thus making removal process difficult. Such waters need to be treated with stronger treatment methods. Surface water on the other hand contains oxidized form of insoluble complexes due to the availability of oxygen and can be easily removed.

If iron alone is present, simple-aeration succeeded by filtration is effective but for higher concentrations of iron, sedimentation and rapid-sand filtration are also to be adopted after the former processes. Aeration helps to dissipate free CO_2, oxidation and iron-precipitation. Free CO_2 should be reduced to less than 10mg/l to remove corrosion problems.

Oxidation of iron by oxygen present in air is the basis for the aeration process of different types of aerators. It is applied to raw water with a maximum iron concentration of 0.005g/l, and with no other unfavourable characteristics (Mn, colour, turbidity, humicacids, etc, but a low level of ammonia may be tolerated). The aeration process takes place at atmospheric pressure in gravity aerators and under pressure using compressed air passed through oxidation towers with other required materials.

Aeration at atmospheric pressure usually gives an economic means of aggressive carbon dioxide removal, otherwise requires expensive neutralization methods. The benefit of the latter type (compressed air) is that it can be configured to run at system delivery pressure with no pumping.

Smaller or larger proportions of ferrous carbonate - more crystalline than ferric hydroxide - may be in the precipitate formed depending upon the method of aeration used, which decides the effective size of filter media. Filters with homogeneous layer of sand are suitable for most of the cases, provided the rate of filtration, grain size, and bed depth are suitably designed.

IV. TESTING OF IRON IN WATER

If iron content is less than 0.3 mg/l, though usually present in natural water, it is not objectionable. It may be in:

- true solution,
- colloidal form - true solution,
- colloidal form - peptized by organic material
- inorganic or iron compounds
- any relatively coarse suspended particles.

It may be ferrous or ferric, suspended or filterable.

If phosphate or heavy metal interference is not present, the standard method of testing for iron in water is the 'Phenanthroline method'.

Here iron is brought into solution, by boiling with acid and hydroxylamine iron is reduced to ferrous state. When it is treated with 1, 10-phenanthroline at pH 3.2-3.3, three molecules of phenanthroline chelate each atom of ferrous iron to form an orange red coloured compound. The coloured solution follows Beer's law and is readily measured by visual or photometric testing. From value 3 to 9, its intensity is independent of pH. A pH between 2.9 and 3.5 ensures rapid colour development in the presence of excess phenanthroline. Find out light intensities for the various concentrations using spectrophotometer and a calibration curve can be made.

Since $FeH_8N_2O_8S_2$ is preferred, slowly added 20ml concentrated sulphuric acid to 50ml water and dissolved 1.404g $FeH_8N_2O_8S_2$. Added 0.1N potassium permanganate drop wise till a faint pink colour perish. Then it is diluted to 1000ml water. Now 1ml= 200 µg iron.

Pipette out 50 ml stock solution to 1000ml volumetric flask and dilute up to 1000ml. 1ml = 10 µg iron. Dissolved 100mg 1,10-phenanthroline-monohydrate in 100ml distilled water (2 drops of concentrated hydrochloric acid is added to distilled water). Dissolve 10 mg hydroxyl-ammonium chloride in 100 ml distilled water. Dissolve 250 gm ammonium acetate in 150 ml water. Add 700 ml concentrated acetic acid. Because, even a good grade of ammonium acetate contains large amount of iron, prepare new reference standards with each buffer solution.

V. TESTING OF WATER SAMPLE

1. Pipette out 1ml, 3ml, 5ml, 10ml, 15ml, 20ml, 25ml, 30ml, 35ml, 40ml and 45ml of standard iron solution and dilute it to 50 ml.
2. Add 2ml concentrated HCl and 1ml hydroxylamine solution.
3. Place few glass beads and heat it over a burner until it boils. Boiling was continued till the volume is reduced to 15-20 ml.
4. Cool down the standard solution to atmospheric temperature and pour it to 50ml – 100ml flask.
5. Add 10ml of ammonium acetate buffer solution, 4ml phenanthroline solution.
6. Dilute the solution using distilled water to 50ml.
7. Mix it well and allow at least 10 – 15 minutes for development of color.
8. Steps 2 to 7 are to be repeated for the other samples.
9. Measure the absorbance of prepared solutions in spectrophotometer.
10. Using the readings, plot a calibration-curve of absorbance and concentration and hence find out the content of iron in the tested samples.

VI. THE EQUIPMENT

This aerator is designed in such a manner as to remove some amount of iron from water by making adjustments to its parameters so that the water coming out of the equipment is having reduced iron content. The materials used for the preparation of *Iron-Remover* are aluminium sheet metal, steel square cubes, sheet metal, wire mesh, glass, PVC pipes and hose.

Dimensions of the aerator:

Height of the aerator including stand = 1.5m
Length of the aerator = 73 cm
Breadth of the aerator = 30cm
Length of sheets used = 40cm
Breadth of sheets used = 20cm
Length of glass vessel = 45cm
Breadth of glass vessel =30cm
Height of glass vessel = 30cm
Length of aluminium container =70cm
Breadth of aluminium container =30cm
Height of aluminium container = 30cm

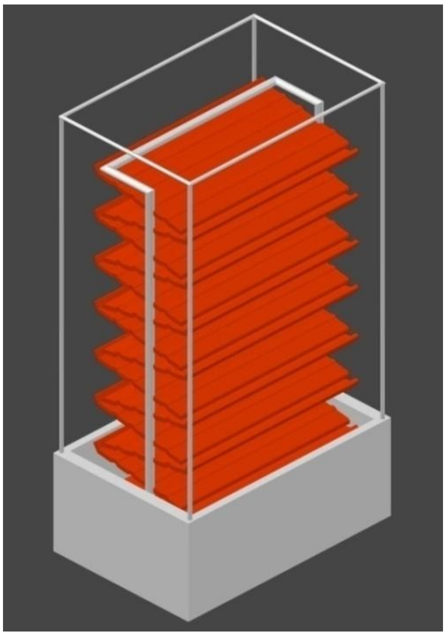

Fig 1: 3-D Model of Iron-Remover

The process occurring here is aeration. The iron present in water is in reduced state ie, ferrous iron. In the presence of oxygen, ferrous will be oxidized to ferric. The reaction is:

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

Ferric hydroxide produced by the oxidation is insoluble and it can be removed by filtration.

In this equipment, the water is allowed to pass through the inlet pipe. The water will get sprinkled through the perforations provided on the PVC pipe and is allowed to fall on the sheets. The water will flow through the sheets which are arranged in a zig-zag manner. The levels of arrangement of sheet that can be given were shown in the picture below. And we opted the second arrangement for easy flow of water.

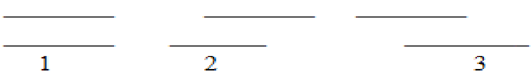

Fig 2: Different Arrangements of Sheets

After passing through the sheets, the water is collected in a collecting tank made of aluminium sheet metal and some time is allowed for settlement. The main advantage of this aerator is that there is a mechanism for changing the inclination of the sheets. For that we connected the alternate sheets together using a wire and pulled it to a corresponding angle marked on the side of the equipment. Here the angle is converted into length format.

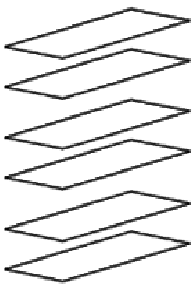

Fig 3: Arrangement of Sheets

It was done by taking the distance between zero degree to ninety degree in length format and the length is divided into degrees.

Fig 4: Provision for Changing Angle of Inclination of Sheet

VII. COMPARISON WITH CONVENTIONAL AERATORS

There are some conventional aerators. Comparing to them this aerator have some advantages that the space required for Iron-Remover is less compared to other aerators and the angle of inclination of sheets can be varied but in slat tray aerator the inclination cannot be varied. So this aerator can be considered as an improved version of slat tray aerator. The flow rate can be controlled in this equipment. The advantages are listed below. (1) It is more efficient than other aerators. (2) It doesn't use any type of powers such as electricity. (3) So it is economical and cost effective. (4) It is easy to handle. (5) It is easy to clean the equipment. (6) It is easy to transport from one place to other. (7) The rate of flow through the pipes can be controlled.

VIII. RESULT AND DISCUSSION

Iron content in the source raw water was tested before and after passing through the remover. The observations are tabulated below.

Table 1: Results Obtained After Testing The Iron In The Samples Provided

No.	Sample	Fe in mg/l
1	Sample from tap water	0.4-0.5
2	after passing through plates at 0° angle	0.4
3	after passing through plates at 10° angle	0.35
4	after passing through plates at 20° angle	0.32

5	after passing through plates at 30° angle	0.33
6	after passing through plates at 40° angle	0.36
7	after passing through plates at 50° angle	0.4
8	after passing through plates at 60° angle	0.4

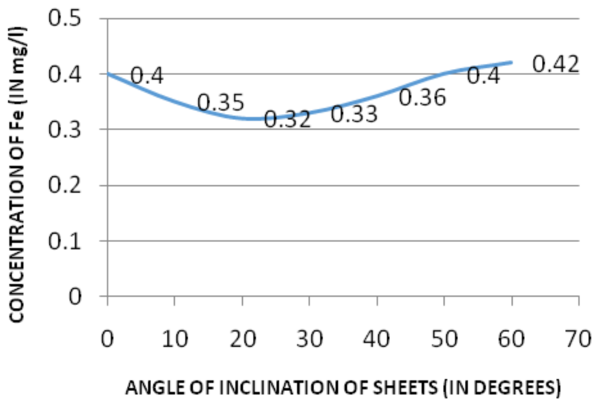

Fig 6: Concentration of Iron in mg/l v/s Angle of Inclination of Sheets in Degrees

From the above tabular column it is clear that the amount of iron can be reduced using this equipment by giving certain modifications such as increasing the width and length of sheets, adding number of sheets, increasing corrugations of the sheet, etc.

IX. CONCLUSION

The permissible amount of iron present in water is 0.3 mg/l as per IS 1300. The amount of iron present in well and aquifers was found to range between 0.5 to 10 mg/l. In anaerobic groundwater where iron is in the soluble (ferrous) form, concentrations will usually be 0.5–10 mg/l, but concentrations up to 50 mg/l can sometimes be found. There are some health effects due to the increase in consumption of iron from foods and drinks where the most harmful disease is hemo-chromatosis which is also known as Iron Overload Disorder. Iron in water is tested using Phenanthroline method. The amount of iron present in the water samples was found to range between 0.4mg/l to 0.5 mg/l. The design of the aerator to be manufactured was prepared and after the collection of materials, the set up was made by different processes such as grinding, cutting, welding and shaping of sheet metal. Equipment which works on the principle of aeration was made and it was named as Iron-Remover. It is an economical, eco-friendly and an efficient aerator. There are many advantages for this aerator over other aerators such as less area requirement, changing of inclination of sheets, easy handling & cleaning capability, easy transportation, etc. The results of Iron-Remover can be increased by providing some modifications such as increasing the no. of sheets, varying the flow rate, increase the dimensions of the equipment, implementing an automatic disinfecting system, etc. The maximum amount of variation in the iron content is shown at angles 20° and 30° of sheets.

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