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Cost Economics of Iron Removal Plants

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ABSTRACT

Groundwater is the main source of drinking water supply schemes in most of the villages of Tamil Nadu. However in some parts of our country, dissolved iron in groundwater makes it unfit for domestic and industrial water supply. Not only in India, excessive iron in groundwater is a well-known problem in most of parts of the world. Iron shows its presence in the form of bivalent, ferrous iron (Fe2+) and trivalent ferric iron (Fe3+). The ferric iron exhibits in insoluble, precipitate form. The ferrous form is soluble in water and invites scientific interventions. Rainwater leaches the iron from the earth crust and keeps either in colloidal or dissolved state in groundwater. The taste of water with iron becomes metallic bitter . Clothes get stained. The rice cooked in iron rich water becomes blackish as reported by villagers . The adverse effects on dying, paper and film industries are well-known. The excessive iron precipitates and deposits in pipe lines and storage tanks causing trouble in water works. Recent researches report that excessive ingestion of iron may lead to heart problems. Thus the treatment of Iron is inevitable and that the economy of the treatment is of great concern. Various treatment options are available for the removal of iron from water. Aeration and filtration, adsorption, etc are some techniques. Starting from hand pump attached to piped water supply schemes, iron removal plants are installed for the purpose. In this paper , the cost economics of various methods in practice are discussed in detail. Aeration and Filteration method is found to be economical for Rural Water Supply. The Operation and Maintenance may be done with the public participation and necessary institutionalization and capacity building for sustainable use.

KEYWORDS : Water, Iron removal, Cost economics.

Prelude

Groundwater is the main sources of drinking water supply schemes in most of the villages of Tamil Nadu and in India too. However in some parts of our country, dissolved iron in under groundwater makes it difficult to be used for domestic and industrial water supply. Excessive iron in groundwater is a well-known problem at global level. In Tamil Nadu, about 1189 habitations have been identified as no safe source habitations in lieu of presence of excessive iron in the drinking water sources.

Commonly, iron shows its presence in the form of bivalent, ferrous iron (Fe^{2+}) and trivalent ferric iron (Fe^{3+}). The ferric iron exhibits in insoluble, precipitate, form. The ferrous form is soluble in water and invites scientific interventions. Iron forms complexes of hydroxides and other inorganic complexes in solution with substantial amount of bicorbonate, sulphate and phosphate. Pyrites (FeS_2), Oxides (Fe_3O_4) and carbonates (Fe_2CO_3) are some of the identities of iron. Rainwater leaches the iron from the earth crust and keeps either in colloidal or dissolved state in groundwater(Damodara Rao and Sastry, 1986; Kelkar,1999).

Detrimental effects of Iron in Water:

The water containing excessive iron (more than 0.30 mg/l) content appears blackish or turbid in higher ranges. The precipitates settle at the bottom of container. The taste of such water becomes metallic taste. Clothes get stained. High iron bearing water when comes in contact with leaf tea renders blue colour due to reaction with tanin. The adverse effects on dying, paper and film industries are well known. The excessive iron precipitates and deposits in pipelines and storage tanks causing trouble in water works. Recent researches report that excessive ingestion of iron may lead to heart problems.

Iron bacteria become active in such environments. These are rendering dirty odour in anaerobic conditions. The stains produced are yellowish to reddish brown and are very difficult to be removed. The water is not suitable for washing of clothes, since they can become stained and spotted. Even traces of iron in domestic water supply cause deposition in the distribution pipes and reservoirs slowly over a period of time. Due to change in velocity or pressure in water mains these deposits are likely to be flushed out to consumers along with the water supplied which may give rise to complaints of taste, coloration and turbidity.

Bacteria form sticky masses and reduce the carrying capacity of the pipes, and may even clog (small size) valves, nozzles and meters.

Materials and Methods

The detailed cost estimate for the installation and Operation and Maintenance of various methods of iron removal plants are determined with the schedule of rates (2013-14) and local rates. The production cost per Kilo litre (KL) is reckoned using the formula given below.

Cost per KL

Let the Capital (Installation) Cost be Rs. '**A**'

Let the O & M Cost per annum be Rs. '**B**'

Let the Quantity of water produced per annum be '**C**' Kilo Litre (KL)

Equivalent Annual Cost (***EAC***) is given by ,

$$\frac{\text{Capital Cost X Discount rate}}{1- (1 + \text{Discount rate})^{-\text{Life period}}}$$

(Discount Rate at 8% and the Life Period as 30 years are adopted)

Therefore, **Cost per KL** = **(EAC + B) / C**

RESULTS AND DISCUSSION

Iron removal methods:

Various treatment options are in practice (Mariappan,2011). The methods of removal of dissolved iron from groundwater can be grouped under the following four headings:

- Aeration / gas transfer,
- Adsorption,

- Ion exchange, and
- Electro Chemical,
- Desalination.

By aeration, dissolved ferrous iron is oxidized to insoluble, ferric precipitate. Aeration followed by sedimentation and filtration accomplishes the removal of iron. Gravity aeration, spray, air blowing and mechanical aeration are the common ways adopted in the aeration process. The oxidation of the Fe^{2+} state to Fe^{3+} is accomplished by molecular oxygen is reported to involve the initial formation of FeO_2^{2+} which then reacts in the following manner:

$$FeO_2^{2+} + Fe(H_2O)^{2+} = Fe(OOH)^{2+} + Fe(OH)_{2+} \quad \text{----------(1)}$$

$$Fe(OOH)^{2+} = Fe^{3+} + HO_2^- \quad \text{----------(2)}$$

Normally, when iron in ferrous (Fe^{2+}) form is in dissolved state, on oxidation it becomes ferric (Fe^{3+}) and then gets precipitated in the form of ferric oxide . This process goes well in the pH range, 6.7 to 8.4 . In the acidic range, the process retards.

Four types of hand pump attached iron removal plants have been tried and reported so far. They are

- DANIDA (Maharastra state),
- WHO,
- BASTAR, and
- IRP (up flow type)

Raised platform, gravity aeration arrangement, filter media, sludge removal component form the common system in all the said four methods. DANIDA and IRP (Upflow) type function as up-flow and rest use gravity down flow principle. Each type has its own merits and demerits. Bastar type has the provision of a detention chamber for pre aeration and sedimentation besides arrangements for lime addition to raise pH. All the above methods were constructed in different villages and put in to use. The material of construction was brick masonry in cement mortar. Pre fabricated ferro cement plants were also installed under DANIDA programme.

DANIDA type has higher size filter media and flow is upwards. It deserves the advantage of less chocking and easy backwash. However efficiency is low. In WHO type, the media is like slow sand filter. Efficiency is high. Requires frequent cleaning. Backwash is not possible and maintenance cost is also high.

In case of Bastar type, the maintenance needed is still more. Very useful where water is blackish or turbid and has low pH . Needs addition of lime. Frequent and close supervision are essential. Specifications of aeration and filtration process are tabulated (Table 1 and Table 2).

Lepidocrocite and Pyrolusite have been studied for the characteristics of absorption of Fe^{2+} ion. Lepidocrocite (O=Fe-OH) is a ferric oxyhydroxide. The findings confirm that tepidocrocite and pyrolusite are both effective for the removal of dissolved iron including its complexed and organic forms. The pyrolusite, however is reported to be more advantageous in cases where the contaminated waters have low alkalinities. Both of these materials are hygienically safe besides being economical.

Cost wise ion exchange methods are costlier and it further requires high recurring cost for O & M . Removal of iron by the principle of electro-coagulation, flocculation has also been studied at laboratory (Sihorwala and Sharad,1995;Richard et al,2001; Kleuh and Robinson,1988).

A combination of aluminum and graphite electrodes is employed for the electrolysis process. The field test is not yet performed. Removal of dissolved iron from ground water using bio-filtration technique has also been reported (Srinivasa Rao and Sree Rekha, 2004).

As it is evident from the literature, aeration followed by sedimentation and filtration will be the cost effective and simple method. And it involves no handling of chemicals and invites less care.

Table - 1 Specification of Iron removal plant (Using hand pump)

Sl. No	Parameter	Population		
		250	500	1000
1	Design flow, lit./day	10000	20000	40000
2	Tray aerator Number and size Height Media Size of media	2 Nos. of 0.60m X 0.60 m 0.30m Calcite/ Marble/coke 25 – 40 mm	2 Nos. of 0.80m X 0.80 m 0.30m Calcite/ Marble/coke 25 – 40 mm	2 Nos. of 0.80m X 0.80 m 0.30m Calcite/Marble/ coke 25 – 40 mm
3	Sedimentation tank Size Detention time	1.3 m X 1.30 m X 0.75 2.5 hours	1.6 m X 1.60 m X 1.00 2.5 hours	2 Nos. 1.6 m X 1.60 m X 1.00 2.5 hours
4	Sand filter Size Numbers	1.60 m X 1.60 m 2 Nos.	2.35 m X 2.35 m 2 Nos.	2.35 m X 2.35 m 3 Nos.

Table - 2 Specification of Continuous Iron Removal unit for Community water supply

Parameters	Capacity of plant, cu.m/ hour		
Design capacity	5.0	10.0	20.0
Raw water pump,HP	2.0, 2 Nos.	3.0, 2 Nos	7.0, 2 Nos
Overhead reservoir capacity, cu.m size	66 4.7m x4.7mx3.0m	132 6.2m x6.2mx3.50m	264 8.7m x8.7mx3.50m
Tray aerators: Numbers	4	5	6
Collecting trough	1	1	1
Tray size	1.30m x 1.30m	1.60m x 1.60m	2.10m x 2.10m
Height of each tray	0.30m	0.30m	0.30m
Sedimentation tank size	2.9m x2.9mx2.5m	3.7m x3.7mx3.0m	5.25mx5.25mx3.0m
Sand filter size	1.69m x 1.69m	1.85m x1.85m, 2Nos.	2.60m x 2.60m, 2 Nos
Clear water storage tank	4.7m x 4.7m x 3.0m	6.2m x 6.2m x 3.5m	8.7m x 8.7m x 3.50m

Cost Estimation

The installation cost estimate for the hand pump attached and community water supply scheme with the capacity is presented in table 3 and table 4 respectively. Table 5 shows the cost per kilo litre (KL) for the various methods of iron removal plants. It is seen from the figure 1 that the aeration and filtration method is economical.

Table – 3 Installation Cost of Hand pump attached Iron removal unit (Base year 2013) (Amount in Rs.)

Population	**Design flow (m^3/day)**	Capital Cost (Rs)	O & M Cost /Day	Treatment Cost / KL
250	10	68000	248	26.45
500	20	78800	327	17.28
1000	40	88000	448	11.74

Table – 4 Installation Cost of Iron removal plants for Community Water Supply Scheme (Base year 2013) (Amount in Rs.)

Population	Design Capacity(m3/ hour)	Capital Cost	O & M Cost /Day	Treatment Cost / KL
2500	5	380000	942.00	10.34
5000	10	532000	1588.00	8.59
10000	20	860000	2432.00	6.60

Table - 5 Cost per Kilo litre for various iron removal methods

Sl.No.	Method of treatment	Cost /KL (in Rs.)
1	Aeration and filtration	13.50
2	Adsorption	40
3	Ion Exchange	60
4	Electro-chemical	52
5	Desalination	90

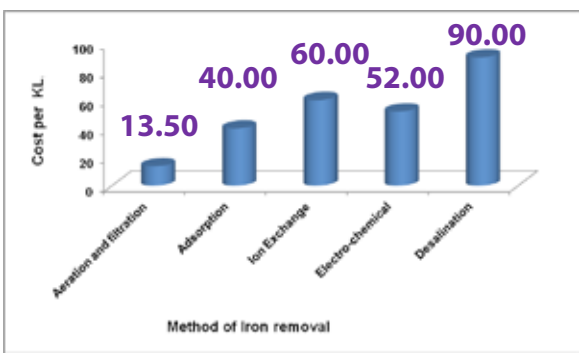


Figure -1 Iron Removal methods Vs Cost per KL

CONCLUSION

The following conclusions are derived from this study.

- It is evident that , the conventional method of Aeration and Filteration is found to be economical for the Removal of Iron.
- Cost wise the order of preference is Adsorption, Ion exchange,Electro chemical and Desalination
- Aeration and Filteration requires less maintenance such as periodic washing of sand bed of the filter.
- Aeration and Filteration method is suitable for Rural Water Supply

if the O&M is done with the public participation..

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