Manifestation, Estimation and Control of Ferric Iron in Groundwater- A Case Study

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Abstract— Amongst the different forms of iron in water, ferrous iron (Fe^{2+}) is the most hazardous. Increased intake of iron rich water may lead to several health disorders. This study was carried out to highlight the manifestation modes, as well as investigate the concentration and contamination levels of ferrous iron in the groundwaters of Bommanahalli, Bangalore, Karnataka. Thirty samples were drawn from various groundwater sources in 2021, during pre and post monsoon seasons. The Fe^{2+} levels in the groundwaters were evaluated using an Atomic Absorption Spectrophotometer using air and acetylene flame. The iron concentration was found to be ranging from nil to 3.11mg/L, with a mean value of 0.85 mg/L during pre-monsoon and nil to 3.15mg/L with a mean of 0.89 mg/L during post-monsoon season. 33.33% of the water samples revealed Fe^{2+} concentrations beyond the maximum permissible limit of 1mg/L prescribed by the Bureau of Indian Standards. The high concentrations of iron can be attributed to the rusting of casing pipes, non-usage of borewells for long periods and disposal of scrap iron in open areas due to industrial activity. Treatment measures to reduce the iron content have also been suggested.

Indexed Terms- Concentration, Ferrous Iron, Groundwater, Nutrition

I. INTRODUCTION

The presence of Fe^{2+} in natural waters is most likely to be due to the dissociation of minerals and rocks, leachates from landfills, sewage, some engineering industries and drainage of acid mines, Fe^{2+} is undesirable for a variety of reasons. Usually, in drinking water supplies, at normal pH ranges, the ferrous state is usually unstable and tends to precipitate as ferric hydroxide ($Fecl_3$), which precipitates as a rusty silt. These waters generally are unpalatable even at very small concentrations (0.3 ppm). They are also found to stain the plumbing fixtures and laundry. The iron distribution system gradually reduces the flow of water. It also promotes the growth of iron bacteria. These microorganisms derive their energy from oxidation of ferrous to ferric and in the process deposit a slimy coating on the piping.

Though Iron is a very vital element required in human nutrition, in excess concentrations, Fe^{2+} is found to cause several health issues such as diabetes, cirrhosis of liver, liver cancer, disorders related to heart, infertility, central nervous system etc. [1]

Haemochromatosis is a metabolic condition that is caused due to increased absorption of iron, which is deposited in the body tissues and organs. The accumulation of iron accumulates over a long period of time where it is deposited in many parts of the body including joints and organs such as the liver, pancreas and heart. Hemosiderosis is a liver disease arising due to continuous ingestion of water having higher Fe^{2+} concentrations [2].It has been expressed that study of dissolved iron in some ground water samples have indicated some undesirable effects if present beyond the prescribed standards [3]. Excessive concentration of iron causes bitter tastes, discoloration and iron bacteria growth [4]. Extended ingestion of iron beyond the prescribed limit results in toxic effects. Other disorders are the mottling of lungs, Siderosis and iron pigmentation. Further, iron rich water is unaesthetically avoidable.

The removal of iron from groundwater should be considered before its application. There are various chemical, physical, and biological techniques that have been proved to be cost-effective and highly efficient in the treatment and simultaneous removal of iron and microorganisms from groundwater. Some of the techniques are adsorption, permeable reactive barrier; membrane distillation, electrocoagulation, and biological remediation are important [5]. Among these techniques, adsorption is favorable and gains more attention for the removal of heavy metals due to the effectiveness and simple process of the treatment [6].

II. DETAILS OF THE STUDY AREA

The Bommanahalli CMC is a cluster of villages located in between Sarjapur road and Kanakapura road. The area covers 43.57 Sq. km and has a population of around 3.5lakh. It has a large percentage of migrants who came to Bangalore in the wake of the software boom in the 1990's. Lying adjacent to the west of the Bangalore- Hosur road and adjacent to the IT corridor, the area has a number of industries, corporate offices of leading software companies and a few upscale residential layouts. The area has 31 wards and although 60 borewells are supposed to be functioning in each ward, only five to ten are actually working. Drinking water from the CMC borewells has become a scarcity and there is a thriving private market for water, with the people paying huge amount to private borewell owners to meet their needs. There are several areas where the sewage and drainage have merged and the huge number of industries in the area is blatantly disposing off their untreated/improperly treated effluents, which have been steadily making their way into the already depleted and contaminated groundwaters of the area. There are repeated complaints of children falling sick, at least once a week, due to the consumption of poor quality water. It is in the wake of these issues that the present study assumes great importance.

III. MATERIALS AND METHODS

Grab samples have been drawn from thirty groundwater sources during the year 2021, both during pre- and post-monsoon seasons. The location map of Bommanahalli with the sample points has been prepared using MAPINFO v 9 GIS software and presented in Fig. 1. So, 60 samples were collected and analyzed for ferrous iron [7]. The groundwater samples were collected in clean glass bottles and preserved by using 2 ml of concentrated HNO_3. Analysis for ferrous iron was done with the help of Atomic Absorption Spectrophotometer using air and acetylene flame. The analysis results have been evaluated as per the 'Indian Standard Drinking Water Specification, IS 10500 [8]. The result of the analyses carried out has been given in Table I.

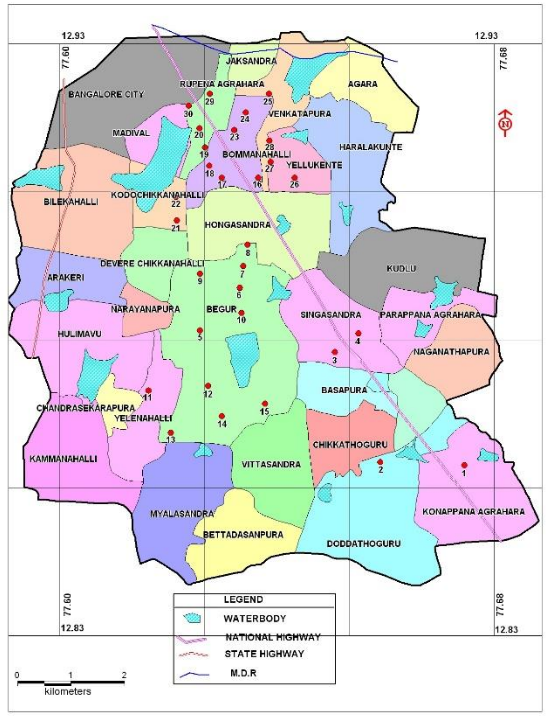

Fig.1. GIS Location map of Bommanahalli industrial area showing the sampling stations

TABLE I: IRON CONCENTRATIONS IN THE STUDY AREA GROUNDWATERS DURING PRE AND POST MONSOON

Sample number	*Source*	*Iron concentration, mg/L Pre-monsoon*	*Iron concentration, mg/L Post-monsoon*
BE 1	HP	0.11	0.10
BE 2	OW	1.28	1.33
BE 3	BW	0.12	0.14
BE 4	BW	0.17	0.13
BE 5	BW	1.01	1.21
BE 6	HP	1.13	1.12
BE 7	OW	1.13	1.22
BE 8	HP	0.13	0.13
BE 9	BW	0.95	0.94
BE 10	BW	0.05	0.13
BE 11	BW	0.00	0.00
BE 12	BW	0.84	0.89
BE 13	HP	0.13	0.12
BE 14	BW	2.90	2.98
BE 15	HP	0.70	0.65
BE 16	BW	1.35	1.39

BE 17	HP	0.71	0.71
BE 18	OW	1.92	2.09
BE 19	BW	0.00	0.00
BE 20	BW	0.15	0.24
BE 21	BW	0.31	0.55
BE 22	BW	0.11	0.11
BE 23	HP	3.11	3.15
BE 24	OW	2.75	2.25
BE 25	BW	0.37	0.45
BE 26	BW	0.31	0.35
BE 27	BW	0.65	0.79
BE 28	BW	0.21	0.29
BE 29	HP	0.35	0.38
BE 30	BW	2.56	2.88

Sl no	*Source*	*No of samples*	*Range of iron concentration, mg/L*		*Mean concentration of iron, mg/L*	
			Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
I	Open well	4	1.13-2.75	1.22-2.25	1.77	1.72
ii	Hand pump	8	0.11-3.11	0.10-3.15	0.88	0.8
Iii	Borewell	18	0-2.90	0-2.98	0.66	0.75

HP: Hand pump, OW: Open well, BW: Borewell

IV RESULTS AND DISCUSSION

IV. DISCUSSION OF RESULTS

The minimum mean and maximum concentrations of Fe^{2+} has been presented in Table II.

TABLE II: MAXIMUM, MEAN AND MINIMUM CONCENTRATIONS OF IRON IN GROUNDWATER SAMPLES

Maximum		*Minimum*		*Mean*	
Pre-monsoon	Post – monsoon	Pre - monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
3.11 mg/L	3.15 mg/L	Nil	Nil	0.85 mg/L	0.89 mg/L

The Fe^{2+} concentrations in the groundwater area ranges from a minimum of 0 to a maximum of 3.11 mg/L during the pre-monsoon, with a maximum statistical mean value of 0.85 mg/L, while in the post-monsoon, the concentration ranges from a minimum of 0 to a maximum of 3.15mg/L with a statistical mean of 0.89 mg/L (Table II).

The desirable limit of iron as per BIS is 0.30 mg/L and maximum permissible limit 1.0mg/L. Beyond this limit, taste and appearance are affected and has adverse effects on domestic uses such as staining of clothes and utensils. Beyond 0.3 mg/L, affects water supply structures as well as promotes iron bacteria [9]. Waters with higher Fe^{2+} levels when used for making coffee and tea interacts with tannin producing an ink black colour with a metallic taste and is unpalatable. The study revealed that 63.33 % (19 groundwater samples) have iron concentrations above 0.3 mg/L, while 33.33 % (10 groundwater samples) are seen to be infested with Fe^{2+} values beyond 1mg/L, as indicated in Table2. Further, from the three sources, where the samples were collected, iron concentration in all the 4 open wells exceeded 1mg/L, the excessive limit as per BIS for potable water as shown in Table III. The larger values of ferrous iron could be attributed to non-usage of the wells for longer periods, rusting of casing pipes, and also, the disposal of scrap iron in open areas due to industrial activity [10]. Fig. 2 shows the seasonal variation of iron in groundwater samples whilst Fig. 3 depicts the potability of groundwater samples with respect to maximum permissible limits.

TABLE III: SOURCE WISE RANGE OF IRON CONCENTRATIONS AND THEIR MEAN VALUES IN GROUNDWATER SAMPLES

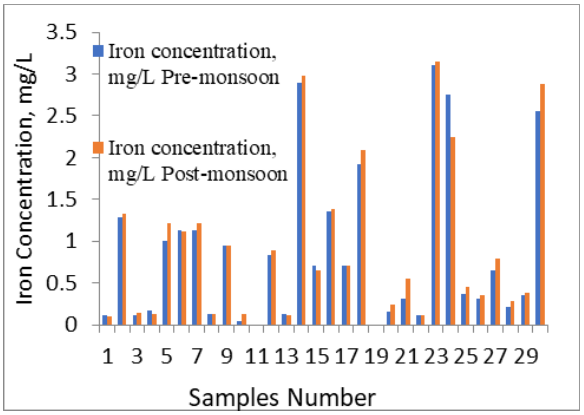

Fig. 2. Seasonal variation of iron in groundwater samples

Horizontal green line indicates the BIS desirable limit range (0.3 mg/L)

Horizontal red line indicates the BIS maximum permissible limit range (1.0 mg/L)

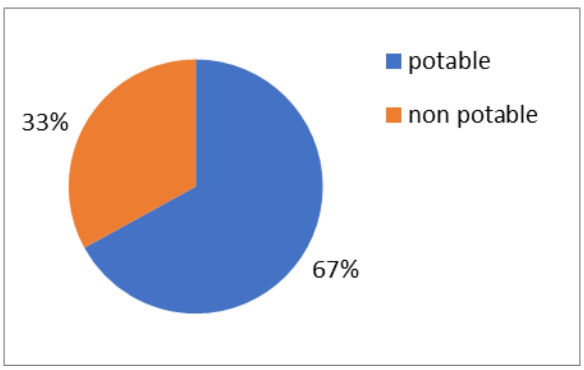

Fig.3. Potability of groundwater samples with respect to maximum permissible limits (1mg/L)

VII. IRON REDUCTION TECHNIQUES

Iron may be present in groundwater either independently or in combination with organic matter. When present without combination with organic matter, iron can be easily precipitated by aeration, whereby the soluble ferrous compounds are oxidized into insoluble ferric compounds, which can be sedimented out. Oxidation followed by filtration alone, or by settling and filtration, can thus bring about the removal of iron from water.

On the other hand, when iron is present in combination with organic matter, the bond linking them may be broken by either the addition of lime, thereby increasing the p^H of water to about 8.5 or 9, or by adding chlorine or potassium permanganate during oxidation, followed by settling and filtration to reduce the concentration of iron in water to within the BIS permissible limits.

In a study conducted in Hingna industrial area in Maharashtra, use of $KMnO_4$ with a constant dose of alum and lime revealed a very high percentage ferrous iron removal from water [11].

Studies carried out by Ling Xin for Fe^{2+} removal from groundwater employing pebble sized marbles revealed excellent removal results [12]. Further, its usage shows promise as marble is a cheap, locally available and effective filter media for mitigation of ferrous iron groundwater.

ACKNOWLEDGMENT

The researchers wish to place on record, a heartfelt thanks to the Management and Principal of Cambridge institute of technology, for providing the necessary facilities whilst this work was under progress.

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