Indonesian Journal of Environmental Management and Sustainability
e-ISSN:2598-6279 p-ISSN:2598-6260

Research Paper

Seasonal Elevated and Variable Groundwater Iron in Chandrapur District, Central India

Rahul K. Kamble[1]*

[1]Centre for Higher Learning and Research in Environmental Science Sardar Patel College, Ganj Ward, Chandrapur 442 402, India
***Corresponding author e-mail**: rahulkk41279@yahoo.com

Abstract

Groundwater iron concentrations were monitored from rural area of the Chandrapur district, Central India during winter, summer and post-monsoon at 36 sampling locations so as to map and quantify its levels. Grab sampling was carried out for groundwater sampling from dug wells (DW) (n=2, 5.55%) and hand pumps (HP) (n=34, 94.44%). Iron concentration was determined by acid digestion method and further analysis by using ICP-OES. Maximum iron concentration in winter was 47.100 mg/L (Ballarpur, HP), 3.825 mg/L (Ballarpur, HP) in summer and 3.714 mg/L (Visapur, HP) in post-monsoon. Average iron concentration in winter, summer, and post-monsoon was 3.522 mg/L, 0.730 mg/L and 0.582 mg/L respectively, which were above the acceptable limit of the Indian Standard (IS) and WHO aesthetic limit for iron (0.3 mg/L). Seasonal variation in groundwater iron concentration was observed in the order of winter¿post-monsoon¿summer. Distribution of iron with IS revealed a number of samples above the permissible limit and in the order of summer>winter>post-monsoon. In case of a distribution on WHO, JECFA and IOM recommendations, number of samples in high to very high category was in the order of winter¿summer¿post-monsoon. It can be concluded that seasonal elevated and variable groundwater iron concentration was observed from the study area. A number of samples had the concentration several times above the IS acceptable limit and WHO aesthetic cut-off. The plausible reasons for these observations can be assigned to geology, water source type (HP/DW), space and time, the proximity of water source to minerals and ores present in the earth crust, physicochemical characteristics of water and dissolution and leaching of metal in groundwater.

Keywords

Chandrapur, Groundwater quality, Heavy metal, Iron, Trace metal

Received: 14 December 2018, Accepted: 03 March 2019
https://doi.org/10.26554/ijems.2019.3.1.29-38

1. INTRODUCTION

Water is an indispensable part of human life and is a most valuable natural resource on the Earth and an integral part of the environment. Of the total freshwater available 97% is stored in underground aquifer within a few kilometers of the Earth's surface almost everywhere, beneath hills, mountains, plains, and deserts. Less than 1% of the Earth's water is available to human being for consumption (Datta, 2008). Drinking water can come from either groundwater sources (e.g. wells, tube wells) or surface water sources (e.g. rivers, lakes, streams, etc.) (Fry, 2005).

More than 50% of the world's population depends on groundwater for drinking (Fry, 2005). For many rural and small communities, groundwater is the only source of drinking water (Hani, 1990). Over 50% of the world's population is estimated to be residing in urban areas and almost 50% of the mega-cities having populations over 10 million are heavily depend upon groundwater and all are in developing world (Datta, 2008). Over one billion people lack access to clean safe water worldwide (Bresline, 2007; NAS, 2008). In sub-Saharan Africa alone, up to 300 million rural people have no access to safe water supplies. Without safe drinking water near dwellings, the health and livelihood of families can be severely affected (MacDonald et al., 2005).

Generally, drinking water containing different anions and heavy metals including Cd, Cr, Co, Hg, Ni, Pb, Zn etc., has significant adverse effects on human health either through deficiency or toxicity due to excessive intake. The excessive ingestion of all these heavy metals including Cd, Cr, Co, Hg, Ni, Pb, and Zn have carcinogenic effects on human health (Muhammad et al., 2011).

Iron is one of the most abundant metals in the Earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/L. Iron may also be present in drinking water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status and iron bioavailability range from about 10 to 50 mg/day (WHO, 2008).

From the review of the related literature and researches, it was observed that Satapathy et al. (2009) only had carried out study pertaining to groundwater heavy metals from the Chandrapur district. However, no emphasis was stressed upon groundwater iron spatiotemporal distribution. This is the identified gap in the research and new knowledge in this regard needs to be added to this subject domain. Hence, this study was proposed to carry out with an objective to assess the distribution of groundwater iron concentration from rural area of the Chandrapur district where inhabitants mostly depend upon groundwater as a source of drinking water.

1.1 Study area

Chandrapur district (19°25' N to 20°45' N and 78°50' E to 80°10' E) is situated in the Vidarbha region of Maharashtra state of central India (Figure 1). The district is the easternmost district of the state. The district covers an area of 11,443 sq km with elevation ranging from 106 m to 589 m asl, the South-West part having a high level and South-East part with low level. The district comprises of 15 administrative blocks and is surrounded by other districts such as Nagpur (North of Northwest), Wardha (Northwest), Yeotmal (West), Adilabad (South), Gadchiroli (East) and Bhandara (North). The district is bestowed with natural bounty in the form of dense forest and wildlife on one hand and on other minerals such as coal, limestone, iron, copper etc. Due to abundant presence of natural resources and minerals, the district has witnessed sprawling coal mines, cement industries, pulp and paper industry and a number of thermal power plants and at the same time Tadoba Andhari Tiger Reserve (TATR) which has one of the largest numbers of tigers in central India.

According to CensusofIndia (2011) the share of urban population of the Chandrapur district to total population was 35.1%. The main source of drinking water from the rural area of the district was 36% of inhabitants depends upon hand pump followed by 7.2% on tube-well which combined together was 43.2%. This data highlight inhabitants from the study area depends mainly upon groundwater as a main source of drinking purpose (CensusofIndia, 2011).

2. EXPERIMENTAL SECTION

2.1 Materials and methods

2.1.1 Groundwater sampling and analysis

Thirty-six groundwater samples comprising of hand pumps and dug wells from the Chandrapur district were collected (Figure 2 and Table 1). Stratified sampling was carried out for groundwater sampling. Of these samples, 34 (94.44%) were from hand pumps and two (5.55%) from dug wells. The

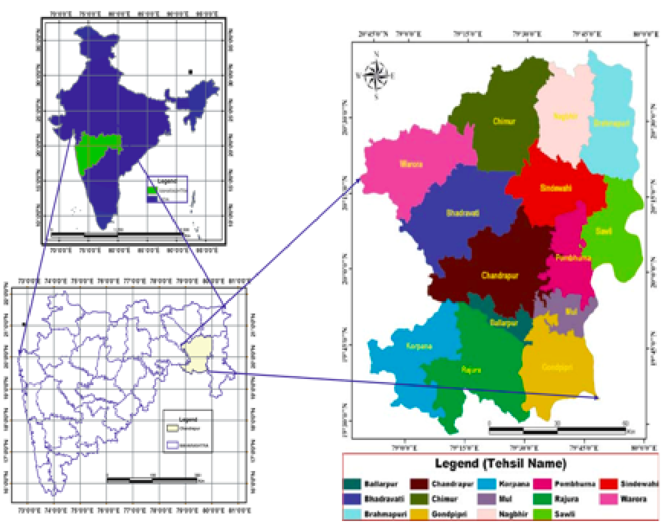

Figure 1. Chandrapur district with administrative blocks (Satapathy et al., 2009)

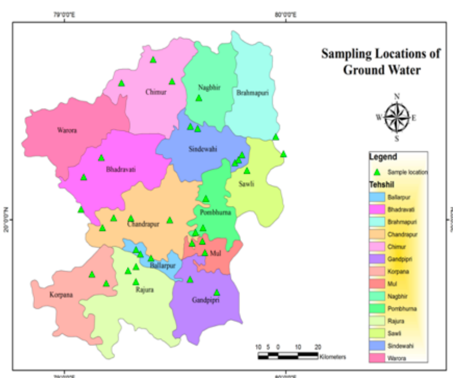

Figure 2. Groundwater sampling locations

samples were selected such that the maximum study area to be covered. Furthermore, these samples were selected from rural areas where inhabitants were mostly dependent upon groundwater as a source of potable water and to carry out other domestic activities. Groundwater sampling was carried out by grab sampling method.

For collecting groundwater samples for analysis, two different capacities of polyethylene containers were selected. For analysis of general parameters (physicochemical), a narrow mouth polyethylene container of 1000 mL capacity (Poly lab, India) was selected; whereas, for heavy metal, a narrow mouth 100 mL capacity polyethylene container (Poly lab, India) was used. These containers were thoroughly washed first with detergent then with distilled water followed by conc. HNO_3 (16 N, Merck) further by repeated washing with distilled water in the laboratory. These containers were rinsed with hand pump or dug well water before groundwater sampling and then the sample was collected into it. Hand pump was pumped for five minutes to remove any residue minerals present inside the pipe and the aquifer source was reached. During this time, hand pump's outlet was cleaned to remove any foreign particles adhere to it. Groundwater temperature was measured in the field itself by using a mercury thermometer (Gera, GIT, India). Heavy metal samples were preserved by adding conc. HNO_3 (16 N, Merck), 2 mL per 100 mL at the time of sampling. All reagents used while carrying out physicochemical analysis was of AR grade (Merck) and glassware was of borosilicate make. Double distilled water was used for the preparation of reagents. All reagents were prepared as stated in APHA (2005).

2.1.2 On-site water source analysis

Precise hand pump/dug well location for latitude, longitude, and altitude was recorded by using a handheld GPS (Map my India navigation 2.0). The hand pump was monitored for corrosion or other anomalies and same was recorded in the field diary. During groundwater sampling, if any suspended matter or colour was observed the same was also recorded. The surrounding platform of groundwater source was examined for its construction type and presence of any red colour patches.

Information pertaining to year of installation and depth of water source (in feet below ground level) was collected from the owners of the water source or regular users of the identified water source. Specific events such as birth, death, famine, and flood were used to establish the year of installation.

2.1.3 Iron analysis

The concentration of total iron was determined by acid digestion method with conc. HNO_3 (16 N, Merck) (Huamain et al., 1999). Groundwater samples especially collected for determination of iron were acid digested in a pre-leached glass beaker on a hot plate at 95oC and evaporated to 5 mL without boiling. While carrying out this, glass beakers were covered with a clean watch glass. This process resulted in the total extraction of iron from groundwater. After cooling, into the digested sample a small quantity of 1:1 conc. HNO_3 (16 N, Merck) was added and further refluxed for 15 min so as to dissolve any precipitate and residue resulting from the evaporation. This digested sample after cooling was transferred into 25 mL volumetric flask and diluted up to 25 mL with double distilled water. This acid digested sample was used for the determination of iron concentrations. The iron concentration was estimated by using ICP-OES (ICP-OES Dv 7000, Perkin Elmer, Germany).

2.1.4 Statistical analysis

Groundwater iron concentration was distributed on the basis of Indian Standard Drinking Water Specification for iron (IS 10500:2012). Groundwater source was distributed within the acceptable limit of the standard (<0.3 mg/L) and above the permissible limit (>0.3 mg/L) for winter, summer and post-monsoon.

Based on established recommendations for iron in water and daily dietary iron intake four categories were defined to describe groundwater iron concentration. Groundwater iron concentration below IS 10500:2012 acceptable limit and WHO aesthetic limit for iron (0.3 mg/L) was defined as 'no or minimal' category. In the case of iron concentration above 0.3 mg/L but below 2.0 mg/L was defined as 'elevated' iron as per Joint FAO/WHO Expert Committee on Food Additives (JECFA). The water source was classified into 'high' category of iron if the concentration was in the range of 2.0 mg/L-22.5 mg/L. This limit represents the daily per litre equivalent, again assuming average daily water intake of 2 L, of the Institute of Medicine (IOM), recommended daily tolerable upper intake level for iron of 45 mg for men and women aged nine years and older WHO (2006); Otten et al. (2006). Finally, a water source with iron concentration >22.5 mg/L were defined as 'very high'.

Pearson correlation coefficient (r) was carried out for water source characteristics viz. altitude, age, and depth of water source with iron concentration so as to establish the strength of the relationship between these variables by using SPSS software 16.0.

3. RESULTS AND DISCUSSION

3.1 Seasonal distribution

Spatial distribution of groundwater iron in different seasons is presented in Table 1 and Figures 3-5 and average concentrations in Figure 6. Minimum iron concentration in winter, summer and post-monsoon was BDL, 0.164 mg/L (Sagra, DW) and 0.055 mg/L (Gunjewahi, DW) respectively; whereas, maximum 47.100 mg/L (Ballarpur, HP), 3.825 mg/L (Ballarpur, HP) and 4.022 mg/L (Visapur, HP) respectively. Maximum average iron concentration was in Ballarpur (HP) 18.213 mg/L and minimum in Gunjewahi (DW) 0.081 mg/L. The iron concentration in Ballarpur was 47.100 mg/L in winter, 3.825 mg/L in summer and 3.714 mg/L in post-monsoon. Seasonal variation in groundwater iron concentration was recorded. Maximum iron concentration was found to be elevated and above the permissible limit of the Indian Standard (2012) and aesthetic limit of WHO (2006) for iron.

Higher iron concentrations from hand pump was in agreement with results reported by Satapathy et al. (2009); Rossiter et al. (2010) Hand pumps owing to their close proximity to ores and minerals present in the Earth crust and water being an universal solvent tends to dissolve these ores and minerals and resulted into such an elevated iron concentrations than dug wells.

Box plots for groundwater iron concentrations pertaining to various statistical analysis for winter, summer, and post-monsoon is depicted in Figure 7. From this figure it can be seen that, winter had a wide range of groundwater iron

Table 1. Seasonal distribution of groundwater iron

Sampling location (Water source)	Altitude (m asl)	Age (Years)	Depth (ft bgl)	Iron concentration (mg/L)			
				Winter	Summer	Post-monsoon	Average
Sonegaon (HP)	215	3	100	0.006	0.188	0.136	0.11
Telwasa (HP)	207	3	100	0.034	0.221	0.499	0.251
Belora (HP)	210	10	100	BDL	0.171	0.156	0.109
Sagra (DW)	240	57	50	BDL	0.164	0.08	0.081
Pethbhansouli (HP)	209	3	100	14.313	0.312	0.644	5.09
Bhisi (HP)	287	1	150	0.337	0.906	0.698	0.647
Pimpalgaon (HP)	246	25	250	0.687	0.466	1.465	0.873
Mowada (HP)	198	10	180	0.117	0.24	0.163	0.173
Dongargaon (HP)	222	30	200	1.7	0.455	0.458	0.871
Lohara (HP)	202	12	60	3.749	0.357	0.265	1.457
Chichpalli (HP)	226	12	70	BDL	0.204	0.167	0.124
Dabgaon (T.) (HP)	215	3	300	1.997	3.084	1.627	2.236
Naleshwar (HP)	215	12	140	0.982	0.446	0.651	0.693
Karwan (HP)	205	8	150	BDL	0.2	0.185	0.128
Chikmara (HP)	214	25	100	0.575	0.571	0.084	0.41
Pathri (HP)	240	20	100	BDL	0.246	0.323	0.19
Gunjewahi (DW)	230	60	35	BDL	0.188	0.055	0.081
Mangali Chak (HP)	224	25	200	0.117	0.266	0.144	0.176
Govindpur (HP)	271	25	150	0.12	0.249	0.215	0.195
Ratnapur (HP)	225	10	100	1.765	0.864	1.695	1.441
Antargaon (HP)	230	15	200	0.117	0.276	0.098	0.164
Visapur (HP)	152	9	100	11.536	1.741	4.022	5.766
Ballarpur (HP)	243	5	60	47.1	3.825	3.714	18.213
Sasti (HP)	198	10	180	5.715	0.892	0.202	2.27
Gowari (HP)	198	6	120	0.378	0.401	0.146	0.308
Arvi (HP)	202	23	100	0.317	0.901	0.354	0.524
Awarpur (HP)	216	2	200	BDL	0.569	0.12	0.23
Lakhmapur (HP)	243	8	200	2.922	0.793	0.124	1.28
Kem (T.) (HP)	178	8	150	2.927	1.134	1.276	1.779
Ganpur (HP)	199	25	160	1.364	0.281	0.157	0.601
Gondpipari (HP)	195	20	100	0.951	3.548	0.186	1.562
Pombhurna (HP)	189	20	100	0.42	0.351	0.16	0.31
Jam Tukum (HP)	174	20	250	0.03	0.627	0.115	0.257
Dongar Haldi (HP)	187	6	120	1.437	0.399	0.29	0.709
Durgapur (HP)	201	4	20	0.241	0.439	0.089	0.256
Morwa (HP)	218	15	100	0.207	0.331	0.215	0.251
Min.	152	1	20	BDL	0.164	0.055	0.081
Max.	287	60	300	47.1	3.825	4.022	18.213
Average	211	15.27	133.2	3.522	0.73	0.582	1.38
SD	26	13	63.55	9.01	0.9	0.92	3.15

HP - hand pump, DW - dug well, Altitude - in meters above sea level (m asl), Age - age of the water source from the year of installation in years, Depth - in feet of water source below ground level (ft bgl). Groundwater iron concentrations are expressed in mg/L, BDL - Below detection limit, Min. - Minimum, Max. - Maximum, SD - Standard deviation.

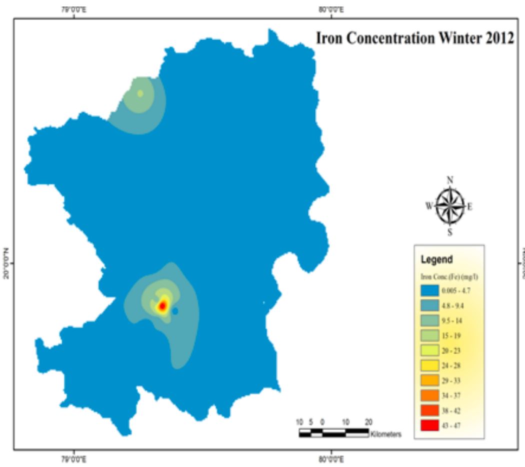

Figure 3. Groundwater iron concentrations (Winter)

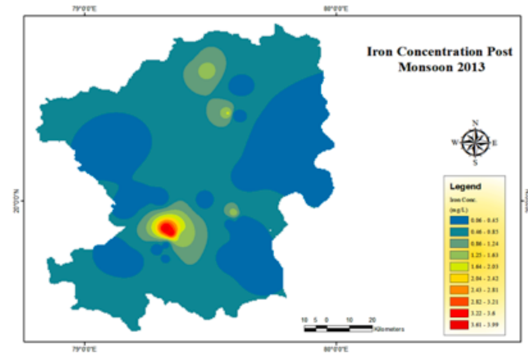

Figure 5. Groundwater iron concentrations (Post-monsoon)

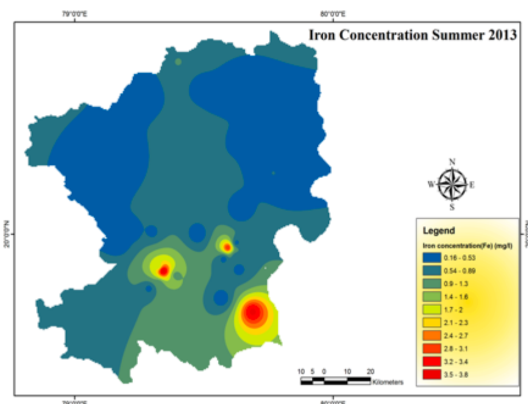

Figure 4. Groundwater iron concentrations (Summer)

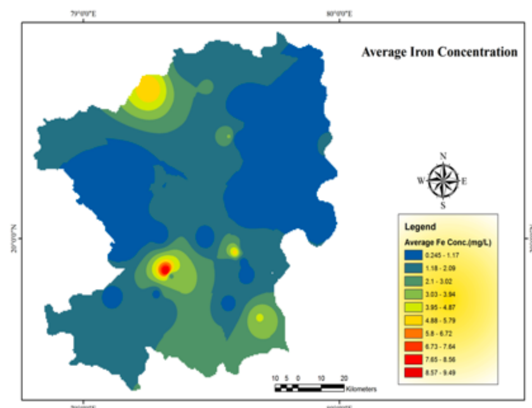

Figure 6. Average groundwater iron concentrations

concentrations followed by summer and minimum in post-monsoon. Temporal variations in iron concentrations can be attributed to groundwater level in different seasons. In summer, with minimum groundwater level, iron got confined into this limited water thus resulted in increase in its concentrations. In post-monsoon, increased groundwater level led to dilution which resulted in decrease in groundwater iron concentration. In winter, relatively stable groundwater level with a reduction in dilution activity as compared with monsoon followed by weathering of rocks and dissolution of minerals and ores present in the Earth crust had resulted into elevated groundwater iron concentration.

Different statistical analysis carried out for groundwater iron concentrations in winter, summer and post-monsoon pertaining to minimum, maximum, average and standard deviation is depicted in Figure 8. From this figure, it can be seen that groundwater iron during winter had elevated statistical analysis into consideration as compared with summer and post-monsoon. Summer and post-monsoon's statistical analysis were comparable and seem that there was no

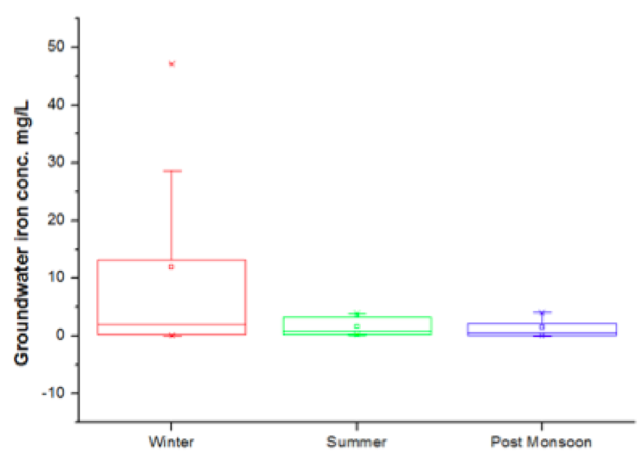

Figure 7. Box plots for iron concentrations

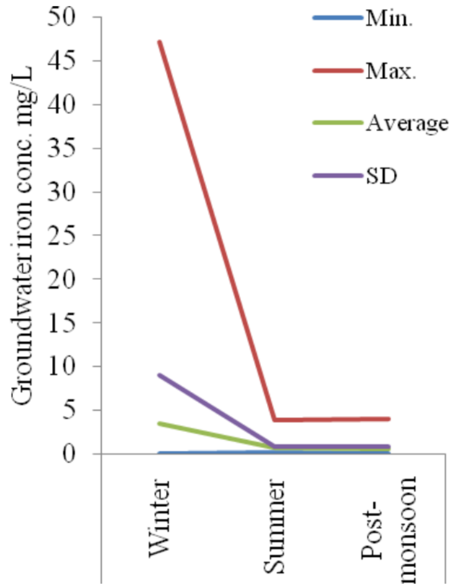

Figure 8. Statistical summary of iron concentrations

significant difference between them.

3.2 Distribution with Indian Standard

Distribution of groundwater iron concentrations in different seasons with Indian Standard (IS 10500:2012) Drinking Water-Specification for iron is presented in Table 2. In winter, 16 (44.44%) samples were within the acceptable limit of the standard (0.3 mg/L); whereas, 20 (55.55%) samples above the permissible limit (no relaxation). During summer, 13 (36.11%) samples were within the acceptable limit; whereas, 23 (63.88%) above it. In post-monsoon, 23 (63.88%) samples had groundwater iron concentration within the acceptable limit of the standard and 13 (36.11%) above the permissible limit.

During post-monsoon maximum samples (n=23, 63.88%) were within the acceptable limit followed by 16 (44.44%) in winter and minimum 13 (36.11%) in summer. For samples above the permissible limit, 23 (63.88%) in summer followed by winter (n=20, 55.55%) and minimum in post-monsoon (n=13, 36.11%). Minimum number of samples within the acceptable limit during summer can be attributed to decrease in groundwater level which had resulted in increase in the concentration of metal ion. The reason for maximum samples in post-monsoon was within the acceptable limit can be assigned to dilution due to precipitation in monsoon. Furthermore, during winter, groundwater iron concentration within the acceptable limit got reduced to 16 (44.44%), which indicated reduction in dilution activity. On comparison of different seasons, it was observed that maximum samples (n=23, 63.88%) in summer were above the permissible limit; whereas, in winter 20 (55.55%) and minimum in post-monsoon (n=13, 36.11%). During summer decrease in groundwater level resulted into increase in iron concentration. In post-monsoon, reduction in number of samples above the permissible limit (n=13, 36.11%) can be assigned to precipitation during monsoon which resulted into increase in groundwater level and further reduction of groundwater iron concentration due to dilution activity. During winter, cessation of dilution activity in groundwater had resulted into stabilization of heavy metal which resulted in 20 (55.55%) samples were above the permissible limit of the standard.

Rajmohan and Elango (2005) reported pre-monsoon samples exceed the permissible limits of EPA (2002) and ISI standard (50 and 100 µg/L); whereas, post-monsoon samples were within the permissible limit. These observations were in accordance with the results obtained in the study which highlight summer had maximum (63.88%) samples above the permissible limit ('no relaxation') and minimum (36.11%) in post-monsoon. Seasonal variation in groundwater iron concentration as summer with maximum locations above the permissible limit and post-monsoon with minimum was in accordance with observations reported by (Demirel, 2007; Laluraj and Gopinath, 2006).

Idoko (2010) reported 35% boreholes had high iron concentration above WHO guide limit for drinking water. This observation on comparison with the findings of the study shows that only post-monsoon (36.11%) had comparable results; whereas, winter and summer were comparatively higher with 55.55% and 63.88% respectively.

Merrill et al. (2010) reported only 3% of surveyed tubewell had below WHO aesthetic cut-off of 0.3 mg/L iron concentration which on comparison with results obtained from the study reported higher percentage of samples within the acceptable limit (winter 44.44%, summer 36.11% and 63.88% in post-monsoon). The finding reported by Haloi and Sarma (2011) as 65% of locations were contaminated by iron was also observed from the study area in summer (63.88%). Cobbina et al. (2012) reported 11% of boreholes had iron concentration above WHO recommended guidelines (0.3 mg/L) which was comparatively lesser than the results obtained from the study area.

Singh et al. (2012) reported iron exceeds the BIS desirable limit (0.3 mg/L) in ~60% samples; whereas, ~33% had iron concentration above 1.0 mg/L. These observations were in accordance with the results obtained from the study. Eight samples had iron concentration more than the desirable limit and 19 within the limit of WHO (Khan et al., 2013) which on comparison with the results obtained from the study showed that 20, 23 and 13 samples for winter, summer and post-monsoon respectively had concentrations above the permissible limit of IS 10500:2012.

Melegy et al. (2014) reported 50% of samples contain high concentration of iron above WHO drinking water guideline value of 300 μg/L. On comparison with the findings of the study, it was 55.55%, 63.88% and 36.11% for winter, summer and post-monsoon respectively. These findings confirm that

Table 2. Iron distribution with Indian Standard Drinking Water-Specification (IS 10500: 2012)

Heavy metal	Season	IS 10500:2012 Acceptable limit (mg/L)	Permissible limit (mg/L)	Observed concentration (mg/L) Min.	Mix.	Average	Number of samples (%) Within the acceptable limit	Above the permissible limit
Iron	Winter	0.3	No relaxation	BDL	47.1	3.522	16 (44.44%)	20 (55.55%)
	Summer			0.164	3.825	0.73	13 (36.11%)	23 (63.88%)
	Post-monsoon			0.055	4.022	0.582	23 (63.88%)	13 (36.11%)

Min. - Minimum, Max. - Maximum, BDL - Below detection limit.

elevated groundwater iron concentration was observed in different parts of the world.

The results obtained in this study were in agreement with results reported by Daughney (2003) for samples above the aesthetic guideline values for iron (0.2 g/m^3) in 36% samples. Huang et al. (2015) reported 81% samples exceeded the groundwater iron concentration limit. This finding indicates that from Chandrapur district above the acceptable limit iron concentrations were comparatively less.

3.3 Distribution on WHO, JECFA and IOM recommendations

Distribution of water source across groundwater iron concentration categories based on existing WHO and JECFA (The Joint FAO/WHO Expert Committee on Food Additives) water-related and Institute of Medicine (IOM) dietary daily iron recommendations are presented in Table 3.

In winter, 16 (44.44%) samples reported groundwater iron concentrations in minimal category (0.0-<0.3 mg/L); whereas, 13 (36.11%) in elevated (0.3-2.0 mg/L) and six (16.66%) from 'high' category (>2.0-22.5 mg/L). Only one (2.77%) sample (Ballarpur, 47.100 mg/L, HP) was in 'very high' category. On comparison with Indian Standard Drinking Water-Specification IS10500:2012. (2012) acceptable limit for iron (0.3 mg/L), 16 (44.44%) samples were in minimal category. From the average groundwater iron concentration it can be pointed out elevated, high and very high concentration categories for winter were above the acceptable limit of the standard. Elevated category reported more than threefold increase in average iron concentration; whereas, in high category ˜23 fold increase and in very high category ˜157 fold increase.

During summer, 13 (36.11%) samples were in minimal category; whereas, 23 (63.88%) above it. Elevated and high category average groundwater iron concentrations were found to be twofold and ˜11 fold more respectively than IS acceptable limit for groundwater iron. The average groundwater iron concentration from minimal category (0.222 mg/L) was more than twofold as compared with winter (0.100 mg/L). In post-monsoon, 23 (63.88%) samples were in minimal category; whereas, 13 (36.1%) above it. Average groundwater iron concentration from elevated and high category was found to be about threefold and 13 fold respectively higher than the Indian Standard into consideration.

During summer, reduction in groundwater level leads to increase in groundwater iron concentration. In monsoon, precipitation led to augmentation of groundwater level which had resulted into dilution of concentrated heavy metal. During winter, reduction in the dissolution of ores and minerals and dilution of groundwater iron concentration had resulted into minimum average concentration (0.100 mg/L). In post-monsoon, leaching activities from different minerals and ores from the Earth crust had resulted into elevated average groundwater iron concentration (0.154 mg/L) as that of winter. The leaching activity perhaps got reduced in winter season as no more precipitation led to percolation, leaching, and accumulation of heavy metal into groundwater.

Merrill et al. (2010) reported maximum contribution (73%) was from categories of high and very high iron concentration; whereas, minimum contribution (27%) from minimal and elevated iron concentration categories which on comparison with results obtained from the study revealed a reverse trend. Minimal and elevated iron concentration categories contributed maximum (∼80%) and high and very high categories contributed minimum (∼20%) in winter. This trend was continued in summer and post-monsoon too.

3.4 Water source characteristics and distribution

Water source characteristics and groundwater iron distribution is presented in Table 4. The water source characteristics include the year of installation, depth of water source (feet below ground level, ft bgl) and altitude (m asl) at which water source is situated. Furthermore, range, average, and median of these variables are also presented.

Groundwater sources identified (n=36) had installation year ranging from one year (Bhisi, HP) to 60 years (Gunjewahi, DW). The depth of water source ranges from 20 ft bgl (Durgapur, HP) to 300 ft bgl (Dabgaon Tukum, HP). The distribution of water source ranges in the altitude of 152-287 m asl. In winter, groundwater iron concentration was in the range of BDL-47.100 mg/L. In summer it was in the range of 0.164-3.825 mg/L; whereas, in post-monsoon it was in the range of 0.055-4.022 mg/L.

Ramesh et al. (1995) reported higher concentration of heavy metals in summer while lower in monsoon was in agreement with findings from the study. Average groundwater iron concentration in summer was 0.730 mg/L which reduced to 0.582 mg/L in post-monsoon. The reason for

Table 3. Iron distribution on WHO, JECFA and IOM recommendations

Iron conc. category	Winter n (%)	Average	Summer n (%)	Average	Post-monsoon n (%)	Average
Minimal 0.0-<0.3* mg/L	16 (44.44%)	0.1	13 (36.11%)	0.222	23 (63.88%)	0.154
Elevated 0.3-2.0† mg/L	13 (36.11%)	0.98	20 (55.55%)	0.647	11 (30.55%)	0.88
High >2.0-22.5‡ mg/L	6 (16.66%)	6.86	3 -8.33%	3.485	2 -5.55%	3.868
Very high >22.5 mg/L	1 -2.77%	47.1	–	–	–	–

n - Number of samples. Average values are reported in mg/L. *WHO (2008) aesthetic cut-off and IS 10500: 2012, Acceptable limit for iron (0.3 mg/L). †JECFA provisional maximum tolerable daily intake for iron in water (WHO, 2008). ‡Per litre equivalent of the Institute of Medicine (IOM) recommended tolerable upper intake level of 45 mg iron/day for daily iron intake for adults (excluding iron supplements) assuming 2 L/day water consumption (Otten et al., 2006).

Table 4. Water source characteristics and iron distribution

Variable	N	Range	Average	Median
Year of installation	36	Jan-60	15.27	11
Water source depth (ft bgl)	36	20-300	133.19	110
Altitude (m asl)	36	152-287	211.77	214.5
Iron (mg/L)				
Winter	36	BDL-47.100	3.522	0.687
Summer	36	0.164-3.825	0.73	0.4
Post-monsoon	36	0.055-4.022	0.582	0.193

n - Number of samples, BDL- Below detection limit.

this reduction can be assigned to increase in groundwater table during monsoon which resulted in dilution of heavy metal concentration.

3.5 Pearson correlation coefficient

During winter (Table 5) it was observed that iron with age and depth of water source was significant at $p<0.05$ level. No correlations were observed between these four variables. In summer (Table 6) groundwater iron concentration with age of water source was significant at p¡0.05 level. Post-monsoon (Table 7) observations pointed iron concentration with age of water source was significant at $p<0.05$ level, iron concentration with altitude and age of water source was significant at $p<0.01$ level.

From Tables 5-7 it can be stated that these four variables were variably correlated with each other. These findings are in accordance with Hasan and Ali (2010) no clear trend between the age of tube-well and manganese concentration. The water source contributing to groundwater iron concentration from wells where casing pipes were very old and corroded was ruled out by Alam and Umar (2013). This observation is in agreement with the findings of the study. Pearson correlation coefficient for the age of water source and iron concentration reported negative weak to moderate

Table 5. Pearson correlation coefficient between water source characteristics (Winter)

	Altitude	Age	Depth	Iron
Altitude	1			
Age	0.172	1		
Depth	0.0718	-0.1707	1	
Iron	-0.0496	-0.2125**	-0.2009**	1

**Significant at 0.05 level.

Table 6. Pearson correlation coefficient between water source characteristics (Summer)

	Altitude	Age	Depth	Iron
Altitude	1			
Age	0.172	1		
Depth	0.0718	-0.1707	1	
Iron	-0.1388	-0.2129**	0.08912	1

**Significant at 0.05 level.

Table 7. Pearson correlation coefficient between water source characteristics (Post-monsoon)

	Altitude	Age	Depth	Iron
Altitude	1			
Age	0.172	1		
Depth	0.0718	-0.1707	1	
Iron	-0.373*	-0.2392**	-0.0129	1

*Significant at 0.01 level; ** 0.05 level.

correlation in all the seasons studied. Pearson correlation coefficient between water extraction depth and iron concentration could not be established which is broadly consistent with Daughney (2003).

4. CONCLUSIONS

The results of the study revealed seasonal elevated and variable groundwater iron concentration from the study area. This concentration can be assigned due to geology, water source type, space and time, the proximity of water source to minerals and ores present in the Earth crust, physicochemical characteristics of water and dissolution and leaching of metal in groundwater. Hand pump samples had elevated iron concentrations as compared with dug wells. Furthermore, those samples which had 'high' and 'very high' category of groundwater iron concentrations, the water source (hand pump/dug well) need to be painted with red colour (or any other suitable colour) as a mark of indication that such groundwater sources are not suitable for drinking purpose. Consequences resulting from the ingestion of this iron-rich groundwater, either positive or negative, of chronic exposure are unknown at this time and needs additional studies in the future. Public awareness by non-governmental organizations as well as government agencies will pave the way for an alternative source of drinking water. Developing a low cost, effective and environmentally friendly technology for removal of iron needs to be attempted.

REFERENCES

Alam, F. and R. Umar (2013). Trace elements in groundwater of Hindon-Yamuna interfluve region, Baghpat district, western Uttar Pradesh. *Journal of Geological Society of India*, **81**; 422–428

APHA (2005). *Standard methods for the examination of water and wastewater (21st ed.)*. Washington D.C.: APHA, AWWA, WPCF

Bresline, E. (2007). Sustainable water supply in developing countries. *Geological Society of America*, **1**; 140

CensusofIndia (2011). Chandrapur district profile. Directorate of Census Operation, Maharashtra. *Ministry of Home Affairs, Government of India. Mumbai*; 1–8

Cobbina, S., F. Nyame, and S. Obiri (2012). Groundwater quality in the Sahelian region of northern Ghana, west Africa. *Research Journal of Environmental and Earth Sciences*, **4**(4); 482–491

Datta, P. (2008). *Water-A key driving force*. Noida: Vigyan Prasar

Daughney, C. (2003). Iron and manganese in New Zealand's groundwater. *Journal of Hydrology (NZ)*, **42**(1); 11–26

Demirel, Z. (2007). Monitoring of heavy metal pollution of ground¬water in a phreatic aquifer in Mersin-Turkey. *Environmental Monitoring and Assessment*, **132**(1); 15–23

Fry, A. (2005). *Water facts and trends*. World Business Council for Sustainable Development

Haloi, N. and H. Sarma (2011). Groundwater quality assessment of some parts of Brahmaputra flood plain in Barpeta district, Assam with special focus on fluoride, nitrate, sulphate and iron analysis. *Intentional Journal of ChemTech Research*, **3**(3); 1302–1308

Hasan, S. and M. Ali (2010). Occurrence of manganese in groundwater of Bangladesh and its implication of safe water supply. *Journal of Civil Engineering (IEB)*, **38**(2); 121–128

Huamain, C., Z. Chunrong, T. Cong, and Z. Yongguan (1999). Heavy metal pollution in soils in China: Status and countermeasures. *Ambio*, **28**; 130–134

Huang, B., Z. Li, Z. Chen, G. Chen, C. Zhang, J. Huang, and G. Zeng (2015). Study and health risk assessment of the occurrence of iron and manganese in groundwater at the terminal of the Xiangjiang river. *Environmental Science Pollution Research International*, **22**(24); 19912–19921

Idoko, O. (2010). Seasonal variation of iron in rural groundwater of Benue state, Middle belt, Nigeria. *Pakistan Journal of Nutrition*, **9**(9); 892–895

IS10500:2012. (2012). Indian Standard Drinking Water-Specification (Second Revision)

Khan, I., A. Javed, and S. Khurshid (2013). Physico-chemical analysis of surface and groundwater around Singrauli coal field, district Singrauli, Madhya Pradesh, India. *Environmental Earth Science*, **68**; 1849–1861

Laluraj, C. and G. Gopinath (2006). Assessment on seasonal variation of groundwater quality of Phreatic aquifers-A river basin system. *Environmental Monitoring and Assessment*, **117**; 45–57

MacDonald, A., J. Davies, R. Calow, and J. Chilton (2005). *Developing groundwater: A guide to rural water supply*. Rugby: Practical Action Publishing Ltd

Melegy, A., A. Shaban, M. Hassaan, and S. Salman (2014). Geochemical mobilization of some heavy metals in water resources and their impact on human health in Sohag Governorate, Egypt. *Arab Journal of Geosciences*, **7**; 4541–4552

Merrill, R., A. Labrique, A. Shamim, K. Schulze, P. Christian, R. Merrill, and K. West (2010). Elevated and variable groundwater iron in rural northwestern Bangladesh. *Journal of Water and Health*, **8**(4); 818–825

Muhammad, S., M. Shah, and S. Khan (2011). Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan. *Microchemical Journal*, **98**; 334–343

NAS (2008). *Overview-safe drinking water is essential.* National Academy of Science

Otten, J., J. Hellwig, and L. Meyers (2006). *Dietary reference intakes: The essential guide to nutrient requirements.* Washington, D.C.: The National Academies Press

Rajmohan, N. and L. Elango (2005). Distribution of iron, manganese, zinc and atrazine in groundwater in parts of Palar and Cheyyar river Basins, south India. *Environmental Monitoring and Assessment*, **107**; 115–131

Ramesh, R., G. Purvaja, and V. Raveendra (1995). The problem of groundwater pollution: A case study from Madras city, India. Man's influence on freshwater ecosystems and water use. *Proceedings of a Boulder symposium, July 1995. IAHS publication*, (230); 147–157

Rossiter, H., P. Owusu, E. Awuah, A. MacDonald, and A. Schafer (2010). Chemical drinking water quality in Ghana: Water costs and scope for advanced treatment. *Science of the Total Environment*, **408**; 2378–2386

Satapathy, D., P. Salve, and Y. Katpatal (2009). Spatial distribution of metals in ground/surface waters in the Chandrapur district (Central India) and their plausible sources. *Environmental Geology*, **56**(7); 1323–1352

Singh, V., D. Bikundia, A. Sarswat, and D. Mohan (2012). Groundwater quality assessment in the village of Lutfullapur Nawada, Loni, district Ghaziabad, Uttar Pradesh, India. *Environmental Monitoring and Assessment*, **184**; 4473–4488

WHO (2006). *Guidelines for Drinking-Water Quality: Incorporating 1st addendum (3rd ed.).* WHO, Geneva

WHO (2008). *Guidelines for drinking-water quality [electronic resource]: incorporating 1st and 2nd addenda, Recommendations. (3rd ed.)*, volume 1. WHO:Geneva