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SEASONAL VARIATION OF GROUNDWATER IRON AND MANGANESE IN DIFFERENT WELL STRUCTURES IN CHANDRAPUR DISTRICT, CENTRAL INDIA

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Abstract

The study was carried out to assess occurrence and distribution of iron and manganese concentration in groundwater from the Chandrapur district, Central India. For this purpose, 36 sampling locations were identified and groundwater sampling was carried out by grab sampling method in winter, summer and post-monsoon season. Heavy metals concentration for iron and manganese were estimated by ICP-OES. Groundwater sources are divided into two types of wells viz. shallow well (<99 ft bgl) and deep well (>100 ft bgl). It is observed that in the summer season from shallow well maximum (n = 3) sampling locations have groundwater above the acceptable standard (IS 10500:2012, <0.3 mg/L). A similar trend of results is observed in the deep well. During summer as groundwater level decreases the heavy metal (e.g. iron) got accumulated in that limited water thus results in elevated iron concentration. In the case of manganese, in the winter season from deep well maximum number (n = 12) of sampling locations have groundwater above the acceptable limit (IS 10500:2012, <0.1 mg/L). A similar trend of results is observed in shallow well also. The dissolution of ores and minerals in the winter season may have resulted in these observations. The shallow well is found to be comparatively safer than deep well in terms of groundwater iron and manganese concentration. Deep well owing to their proximity to minerals and ores present in the earth crust may have elevated iron and manganese concentration. Inhabitants should be made aware of these heavy metals from groundwater and alternative water source should be made available to them.

Key Words: *Iron, Manganese, Groundwater quality, Heavy metal, Chandrapur, Central India*

Introduction

Iron and manganese are the most abundant metals in the Earth's crust. The origin of groundwater iron is attributed to the geogenic source (Hazarika and Bhuyan, 2013). Weathering processes along with corrosion products release iron in the water (Smith, 1981). Elevated manganese concentrations are associated with iron ores as well as lateritic mining (Tiwari *et al.*, 2013). Manganese is naturally occurring in many surface water and groundwater sources, particularly in anaerobic or low oxidation conditions and this is the most important source for drinking water. In rural areas, groundwater exploitation is considered the only realistic option to meet water demand (MacDonald *et al*., 2005). The reason for this is its easy accessibility and with minimum investment cost. Furthermore, it is less susceptible to pollution and seasonal fluctuation and of natural good quality (Habila, 2005; Bresline, 2007).

The high concentration of iron in drinking water can cause hemochromatosis, chronic fatigue, cirrhosis, diabetes, arthritis, heart diseases, thyroid, impotency, and sterility. It also facilitates persistent hepatitis B or C infection, malignant tumours, colorectal, liver and kidney cancers (Huang, 2003). There have been epidemiological studies that report adverse neurological effects following extended exposure to very high levels of manganese in drinking water (Hafeman *et al*., 2007 Khan *et al*., 2012). The objective of the study is to assess iron and manganese occurrence and distribution in different groundwater source depths in the Chandrapur district of Central India to identify the safer well and season for its use for domestic purposes.

Study Area

Chandrapur district (19°25' N to 20°45' N and 78°50' E to 80°10' E) is situated in Maharashtra state of Central India. The district has 15 administrative blocks. The geographical area of the district is 11,364 sq km. The district has a hot climate. In summer maximum temperature reaches up to 47°C in May; whereas, minimum temperature 7°C in December. The annual rainfall in the district is in the range of 1200-1450 mm with an annual number of rainy days 60-65. The atmospheric relative humidity is 70% during monsoon and 20% in summer. Geomorphologically the district can be divided into the plain region and upland hilly region. Groundwater hydrology of the district exists under confined/semi-confined and unconfined conditions. The depth of unconfined aquifer generally extends up to 20 m below ground level (bgl) and can be tapped by dug well. Pre-monsoon reported the depth of the water table in this aquifer in the range of 1.0-19.0 m bgl. Geologically, the district forms a part of the Gondwana sedimentary basin. Lithologically it presents a variety of stratigraphic units from Archean to recent alluvium and laterites. As per the Census of India 2011, the distribution of households by the main source of drinking water in the rural areas of the district is 36.0% (n=126,900) from hand pump followed by 7.2% (n=25,380) by tube-well/bore-well (Census of India, 2011). The combined percentage of these two main sources is 43.2% which highlights rural area inhabitants depends upon groundwater to meet their daily requirement of drinking and domestic purpose.

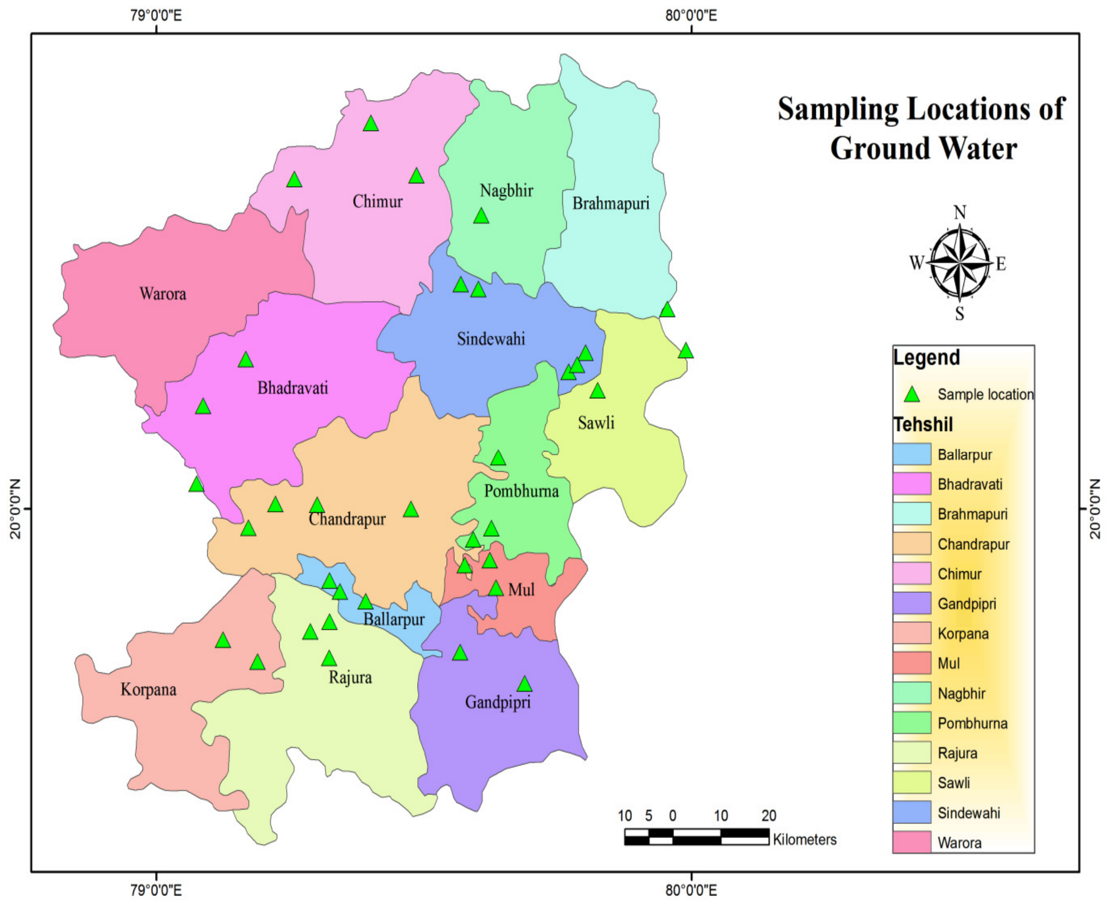

Fig. 1: Groundwater sampling locations from the study area

Methodology

Water Sampling Protocol

To assess the occurrence and distribution of groundwater iron and manganese 36 groundwater sampling locations comprising of hand pumps and dug wells from the Chandrapur district are selected (Figure 1). Of the identified sampling locations, 34 (94.44%) were from the hand pump and 2 (5.55%) from dug well. For the collection of groundwater samples, a stratified sampling methodology was adopted. It was ensured that the maximum study area will be covered. The sampling locations were from rural areas where inhabitants depend upon these groundwater sources to meet their domestic activities. Grab sampling methodology was adopted for the collection of groundwater samples. A narrow mouth polyethylene container of 1000 mL capacity (Poly lab, India) was used for the collection of groundwater samples for physicochemical analysis (general parameters). To collect groundwater samples for iron and manganese a polyethylene container of 100 mL capacity was used. These containers were thoroughly washed first with tap water followed by detergent, then with conc. HNO_3 and finally with double distilled water. Samples for heavy metals assessment were preserved by the addition of 1 mL of conc. HNO_3 (16 *N*, Merck) per 100 mL of sample. Reagents used for assessing physiochemical parameters were AR grade (Merck) and glassware of borosilicate make. All reagents were prepared as per APHA (2005).

Precise hand pump/dug well location for latitude, longitude, and altitude was recorded by using a handheld GPS (Map my India navigation 2.0). In the case of the hand pump, they were pumped for five minutes to avoid stagnation of groundwater into it. At the time of allowing groundwater to flow from a hand pump, the internal and external pipe structure of its outlet was cleaned to remove any solids or foreign material adhere to it. While carrying out groundwater sampling relevant data about hand pump/dug well depth, year of installation, usability, availability of water were also collected from respective inhabitants of the village. The respondent includes males and females having primary or above education background. The age of the individuals who were interviewed was above 18 years.

Heavy Metal Analysis

The acid digested sample was used for the determination of iron and manganese concentrations from groundwater. Heavy metals analysis was carried out by using ICP-OES (ICP-OES, Perkin Elmer, Germany, Dv 7000). The data obtained from analytical results were statistically assessed by employing various statistical tools which include minimum, maximum, average, median, range, standard deviation, variance, skewness, kurtosis, percentiles using Microsoft Office Excel 2007® and SPSS 16.0 (IBM, USA).

Results and Discussion

From the study area, groundwater sampling was carried out from dug well and hand pump. The depth feet below ground level (ft bgl) of these water sources as reported by the inhabitants from the sampling locations which indicates water source with varying depth levels (20 ft bgl-300 ft bgl). At these different depth levels, the distribution of groundwater iron and manganese may be different. Taking into consideration this aspect division of wells from the study area is carried out at two levels, shallow well with depth <99 ft bgl and deep well with depth >100 ft bgl to ascertain the distribution of these two heavy metals.

Iron distribution

Distribution of percent of well samples for winter, summer and post-monsoon for groundwater iron concentration is presented in Table 1. Groundwater iron concentration is divided into two levels taking into consideration Indian Standard Drinking Water-Specification (IS 10500:2012, Iron Acceptable limit, 0.3 mg/L, Max.) as within the acceptable limit (<0.3 mg/L) and above the acceptable limit (>0.3 mg/L). Above the acceptable limit, groundwater iron concentration is further categorised into different concentration ranges.

Ngah and Nwankwoala (2013) reported no defined relationship between the depth of boreholes and iron contents, if anything, the relationship is haphazard. The results obtained for this study are following the authors. From various depths in different seasons, groundwater iron concentration is found to be haphazard in manner except at 251-300 ft bgl where a significant increase in concentration is observed. At 22% sampling locations iron concentration is 0.4-1.0 mg/L and at 20% sampling locations it is >1.0 mg/L (Ngah and Nwankwoala, 2013). These observations on comparison with results obtained from the study revealed that spatial variation in groundwater iron concentration is observed. In the shallow and deep well distribution of iron, concentration is also varying.

Table 1: Iron distribution with well structure

Iron conc. (mg/L)	Shallow well (<99 ft bgl), n (%)			Deep well (>100 ft bgl), n (%)		
	Winter	Summer	Post-monsoon	Winter	Summer	Post-monsoon
<0.3 (Acceptable limit)*	4 (66.66%)	3 (50%)	5 (83.33%)	12 (40%)	10 (33.33%)	18 (60%)
>0.3 (Above the acceptable limit)*	2 (33.33%)	3 (50%)	1 (16.66%)	18 (60%)	20 (66.66%)	12 (40%)
Iron conc. range above the acceptable limit (mg/L)	Total shallow well samples (n=6)	Total shallow well samples (n=6)	Total shallow well samples (n=6)	Total deep well samples (n=30)	Total deep well samples (n=30)	Total deep well samples (n=30)
0.3-1.0	Nil	2 (66.66%)	1 (100%)	8 (44.44%)	16 (80%)	7 (58.33%)
1.1-2.0	Nil	Nil	Nil	5 (27.77%)	2 (10%)	4 (33.33%)
2.1-3.0	Nil	Nil	Nil	2 (11.11%)	Nil	Nil
3.1-5.0	1 (50%)	1 (33.33%)	Nil	Nil	2 (10%)	1 (8.33%)
>5.1	1 (50%)	Nil	Nil	3 (16.66%)	Nil	Nil
	Total shallow well samples (n=2)	Total shallow well samples (n=3)	Total shallow well samples (n=1)	Total deep well samples (n=18)	Total deep well samples (n=20)	Total deep well samples (n=12)

n - Number of sampling locations. *Acceptable limit of IS 10500: 2012 for iron (0.3 mg/L). BDL - Below Detection Limit

As reported by Idoko (2010), 35% of boreholes have elevated iron concentration above the WHO guide limit for drinking water in the rainy season and 7.7% in the dry season. These findings are in disagreement with observations obtained from the study. Sampling locations have shown the trend for groundwater iron concentration as summer > winter > post-monsoon for above the acceptable limit (0.3 mg/L).

As reported by Goyal *et al*. (2010) dilution of groundwater iron concentration due to precipitation in the monsoon season is also observed from the study. Summer season reported the maximum number of sampling locations (n=23) above the acceptable limit of IS 10500:2012 for iron (0.3 mg/L) which reduced to n=13 in post-monsoon season (about 56% reduction). This indicates a dilution of heavy metals concentration in groundwater which got accumulated in the summer season due to precipitation.

Demirel (2007) reported seasonal variation in groundwater iron concentration with maximum concentration in monsoon, minimum in post-monsoon and moderate in summer; whereas, for manganese concentration in post-monsoon reported maximum concentration on the contrary summer and monsoon are comparable. The observations obtained from the study deviates from the observations reported by authors. Winter reported maximum groundwater iron concentration range (BDL-47.100 mg/L) followed by post-monsoon (0.055-4.022 mg/L) and minimum in summer (0.164-3.825 mg/L). In the case of the groundwater manganese concentration range in different seasons, it is observed to be similar to that of iron (winter > post-monsoon > summer).

The wide distribution of groundwater iron from the study area in different ranges of concentrations which have a seasonal influence on it is following the results reported by Hossain and Huda (1997).

Manganese Distribution

Distribution of shallow well and a deep well for groundwater manganese concentrations for winter, summer and post-monsoon is presented in Table 2. The variable distribution of groundwater manganese in different manganese concentration ranges from the different well structure above the guideline value (Hasan and Ali, 2010) is also observed from the study. In all seasons' shallow well reported minimum number of sampling locations above the acceptable limit; whereas, from deep well it is observed to be higher than shallow well.

The summer season has elevated groundwater iron concentration concurs with the findings of Rajmohan and Elango (2005) which reported seasonal variation with high iron concentration during pre-monsoon (summer). The reason assigned to this observation is the flushing/dissolution of lithogenic and non-lithogenic materials by infiltration water. Similar observations are also recorded for groundwater manganese.

Table 2: Manganese distribution with well structure

Manganese conc. (mg/L)	Shallow well (<99 ft bgl), n (%)			Deep well (>100 ft bgl), n (%)		
	Winter	Summer	Post-monsoon	Winter	Summer	Post-monsoon
<0.1 (Acceptable limit)*	4 (66.66%)	5 (83.33%)	5 (83.33%)	18 (60%)	24 (80%)	25 (83.33%)
>0.1 (Above the acceptable limit)*	2 (33.33%)	1 (16.66%)	1 (16.66%)	12 (40%)	6 (20%)	5 (16.66%)
Manganese conc. range above the acceptable limit (mg/L)	Total shallow well samples (n = 6)	Total shallow well samples (n = 6)	Total shallow well samples (n = 6)	Total deep well samples (n = 30)	Total deep well samples (n = 30)	Total deep well samples (n = 30)
0.1-0.5	2 (100%)	1 (100%)	1 (100%)	8 (66.66%)	6 (100%)	4 (80%)
0.51-1.0	Nil	Nil	Nil	3 (25%)	Nil	1 (20%)
1.1-2.0	Nil	Nil	Nil	1 (8.33%)	Nil	Nil
	Total shallow well samples (n = 2)	Total shallow well sample (n = 1)	Total shallow well sample (n = 1)	Total deep well samples (n = 12)	Total deep well samples (n = 6)	Total deep well samples (n = 5)

n - Number of sampling locations. *Acceptable limit of IS 10500: 2012 for manganese (0.1 mg/L).

Conclusion

Distribution of iron and manganese concentration from a shallow well and deep well for different seasons showed that the concentration of these two heavy metals varies according to seasons. An increase in the volume of groundwater due to precipitation during monsoon season may have resulted in a decrease in the concentration of these heavy metals. A decrease in groundwater level during summer leads to the accumulation of these heavy metals into groundwater and thus leads to an increase in its concentration. Winter season and shallow well have maximum groundwater iron concentration; whereas, winter season and deep well have maximum groundwater manganese concentration. Combined concentration of groundwater iron and manganese above the new 'remark' standard in the IS 10500:2012 is observed from several sampling locations. In a natural aquatic environment manganese concentration of >0.4 mg/L is observed from the study area which was the previous WHO standard for it.

From the study area where groundwater iron and manganese concentrations are above IS 10500:2012 standards, inhabitants should be made aware of the presence of these heavy metals and alternative drinking water sources should be made available to them. Special indication marks in the form of colour coding (colour painting) with an appropriate colour should be carried out on these groundwater sources sampling locations so as inhabitants can easily identify these water sources. In those areas where groundwater iron and manganese concentration is present at a higher level in the shallow well deeper well may be constructed for extraction of groundwater.

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