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Quality Evaluation of Ground Water from Borewell for Its Drinking and Agricultural Use

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ABSTRACT

Ground water is charminganddistinctconsideration as it has turned out to be a life-threatening resource for socio-economic progress of any country. However, it is catering a foremostbit of the demandfrom domestic, irrigation and industrial sectorsin India. Unplanned and fast-tracked development is creating alarm among scientists, users and policy makers. The main fear is the exhausting resources volumetrically, and lowering of water levels. Ground water is the back bone of drinking water supply in rural areas as well as supplement supply in urban areas, one moremomentous concern is quality of ground water which is influenced by nature and extent of rock-water interaction, formations and varying climatic conditions. Due to ground water contamination it become non-potable as exceeds the limitsprescribed by Bureau of Indian Standards (BIS). Mundra taluka lies in coastal area of Kachchh. Present study of pH, Electrical conductivity (EC), Total Dissolved Solids (TDS), Nitrate (NO_3^-) and Fluoride (F^-) was conducted to assess suitability of groundwater for irrigation and domestic purpose by comparing with the World Health Organization (WHO) and Indian standards. The sample analysis reveals thatgroundwater is not entirely fit for drinking with respect to pH, TDS and F^-. In some of collected samples; concentrations of these parameters exceed the permissible limits of WHO and Indian standards.

Keywords: Groundwater quality; physiochemical; BIS; Mundra; Kachchh

1. INTRODUCTION

Safe drinking water is essential for life and a satisfactory safe supply must be made available to consumers (Ackahet al., 2012). Hence good drinking water is not a luxury but one of the most essential requirements of life itself (Ajewole, 2005). However, developing countries, have suffered from a lack of access to safe drinking water from improved sources and to adequatesanitationservices. World Health Organization (WHO) revealed that seventy-five percent of all diseases in developing countries arise from polluted drinking water (WHO, 2006).

The problem(s) associated with chemical constituents of drinking water arise primarily from their ability to cause adverse health effects. Prolonged exposure of particular contaminants such as heavy metals that have cumulative toxic properties which may cause harm to health. Most common problems in household water supplies may be attributed to hardness, iron, sulfides, sodium chloride, alkalinity, acidity and pathogens. This makes drinking water a mobile source of disease transmission (Degremont, 1991).

Therefore, it is desirable to control intake of these potentially toxic chemicals from drinking

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water because the intake from other sources which may be food or air (Danish, 2003). Like other developing countries drinking water quality is major issue in India and studies related to drinking water quality of Mundra (India) have not been conducted so far. The aim of this study was to examine the levels of some physico-chemical parameters of drinking water of Mundra Taluka. The suitability of groundwater for agricultural and domestic purposes were evaluated by comparing values of different water quality parameters with those of the World Health Organization (WHO, 2006) and Indian standards specification (BIS, 1991, reaffirmed during 2005, 2012 and 2015) guidelines values for drinking water.

2. MATERIALS AND METHODS

2.1 General description of study area

Kachchh is virtually an island, as it is surrounded by the Arabian Sea in the west; the Gulf of Kachchh in south and southeast & Rann of Kachchh in north and northeast. Hence it has extreme climatic and geographical condition and it suffers both the problems of quantity and quality of water. Kachchh has low water resources i.e. 0.1% of the country's resources. Mundra taluka has total 60 Panchayat Villages. Review on the literature showed that by & large, no studies have been undertaken in each & every village(s) of Mundra taluka with regard to physico-chemical analysis of water yet. Hence main objective of this study was to investigate the quality of ground water in most rural habitations of Mundra area (CGWB, 2018; Citypin-code, 2018; Wikipedia, 2018).

2.2 Sample collection

The total area of the Mundra taluka is estimated about 888.15 square kilometer. Groundwater samples were collected from 60 panchayat villages of Mundra. Samples were collected before monsoon. The location of sampling points is shown in Table 1. Pre-cleaned and rinsed polythene fresh carboys of two litre capacity with necessary precautions, were used for sample collection. (Brown et al., 1974). The samples were collected from manually operated hand pumps, open wells and bore wells. The samples were filled up to the brim and were immediately sealed to avoid exposure to air and were labeled systematically. The labeled samples were analyzed in laboratory for various physicochemical parameters. During sample collection, handling and preservation standard procedures recommended by the American Public Health Association (APHA, 2012) were followed to ensure data quality and consistency. Samples were kept in ice box till analysis was performed.

2.3 Sample analysis

Analytical grade (AR) chemicals were used for analysis of collected samples. NIST (National Institute of Standard and Technology) standard and double distilled water was used throughout the study. The pH and electrical conductivity (EC) were measured *in situ*, while Total Dissolved Solids (TDS), Nitrate and Fluoride were analyzed using the standard methods suggested by APHA (2012).

2.3.1 pH measurement

The potentia hydragenia (pH) of sample was measured by Digital pH meter, Model: Systronics-361, with an accuracy of ± 0.01. The buffer solution of pH 4.0, 7.0 & 9.2 were used for standardization.

2.3.2 Electrical conductivity

The Electrical conductivity (EC) at 25^{o}C of sample was measured by Digital Conductivity meter, Model: Systronics-306, with an accuracy of ± 0.01. The std. solution of 0.01 M KCl has been used for standardization.

2.3.3 Total dissolved solids

Total dissolved solid (TDS) are the solids present in water in the dissolved state and are measured as the residue left after evaporation of sample in Hot Air Oven at 103°C to 105°C. TDS were analyzed by using gravimetric method. The difference in weight over that of pre-weight beaker represents the TDS in mg/L.

2.3.4 Nitrate

Nitrate (NO_3^-) is measured by colorimetric method, specifically followed by Phenol Di-Sulfonic Acid (PDA) Method using Spectrophotometer, Model: Systronics-2202 was used for measurement of Nitrate. Standard graph was plotted before analysis of nitrate.

2.3.5 Fluoride

Fluoride (F^-) is measured by SPAND Method using Spectrophotometer, Model: Systronic-2202. Standard graph was plotted before analysis of fluoride.

2.3.6 Calculation

Instrument gives direct reading of pH and EC value. However, Nitrate and Fluoride were calculated by (O.D x Factor ÷ sample taken), while TDS by (Final weight - Initial weight ÷ sample taken). EC is represented in mS/cm, while rest parameters are noted in mg/L (except: pH).

3. RESULTS AND DISCUSSION

pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS) of water are very important indication of its quality and provides information in many types of geochemical equilibrium or solubility calculations. The analytical results of pH, EC, TDS, NO_3^- and F^- for the groundwater samples in the study area are represented in Table 2 along with statistical analysis as noted in Table 3 and Table 4. Graphical analysis of these results is shown in Figs. 1-2. The analytical findings have been evaluated to ascertain the suitability of groundwater in the study area for drinking and agricultural uses, with World Health organization (WHO), Bureau of Indian Standards (BIS) and Indian council for medical research (ICMR) standards for which are represented in Table 1.

3.1 pH

pH is an extent of the hydrogen ion concentration in water. Drinking water pH between 6.5 to 8.5 is considered satisfactory. In this study, pH range is recorded between 7.92 to 9.02 (Table 2 and 3 and Fig. 1) with average mean of 8.65. pH value of 7.4 was a safe range for drinking as well as for the growth of plants (Jain et al., 1995). While aggregation with total salinity, temperature, calcium content and total alkalinity is used to determine whether a water is corrosive in nature or having scale forming propensity.

Table 1 Drinking water quality standards

Parameter	BIS:1999	ICMR:1975	WHO:2006
pH	6.5-8.5	7.0-8.5	6.5-8.5
EC (mS/cm)	-	-	1.4
NO_3^- (mg/L)	100	50	45
F^- (mg/L)	1.5	1.5	1.5
TDS (mg/L)	2000	1500	500

Table 2 Analysis of ground water quality parameters in villages of Mundra Taluka (Kachchh, Gujarat, India)

Vill. No.	Vill. Name	pH	E.C mS/cm	TDS mg/L	NO_3^- mg/L	F^- mg/L	Vill. No.	Vill. Name	pH	E.C mS/cm	TDS mg/L	NO_3^- mg/L	F^- mg/L
M1	Babiya	8.61	2.016	928	5.00	0.36	M31	Lakhapar	8.54	0.927	422	1.57	0.79
M2	Bagda	8.44	1.082	628	0.14	BDL	M32	Lifara	8.37	1.523	838	6.36	0.05
M3	Baraya	8.83	2.689	1450	1.11	0.75	M33	Luni	8.96	6.534	3004	1.97	BDL
M4	Baroi	8.40	4.555	2296	7.14	BDL	M34	Mangra	8.67	1.140	612	2.00	0.01
M5	Beraja	8.36	3.691	1924	1.01	1.36	M35	Mokha	8.82	2.436	1418	4.95	2.10
M6	Bhadresar	8.30	3.587	2464	2.07	0.34	M36	Mota Kapaya	8.47	0.782	340	1.02	0.58
M7	Bhorara	7.92	1.087	520	2.00	0.90	M37	Mundra	8.81	1.859	896	1.12	0.29
M8	Bhujpar Moti	8.87	2.849	1818	1.84	1.92	M38	Nana Kapaya	8.68	4.182	2270	0.29	1.91
M9	Bhujpar Nani	8.40	3.603	2084	3.51	1.34	M39	Navinal	8.56	2.901	1396	0.33	1.20
M10	Bocha	8.84	2.411	1402	2.25	0.11	M40	Patri	8.14	3.919	2656	5.76	1.02
M11	Borana	8.78	3.554	2298	0.28	2.64	M41	Pavdiara	8.84	4.334	2250	2.89	1.95
M12	Chhasra	8.90	2.768	1860	4.27	0.60	M42	Pragpar	8.90	2.564	1518	3.91	1.24
M13	Depa	8.38	6.641	3832	0.64	2.35	M43	Pratapar	9.02	3.173	2094	0.64	1.47
M14	Deshalpar	8.19	1.096	642	6.54	0.53	M44	Raga	8.86	6.975	3188	1.70	0.41
M15	Dhrub	8.86	4.025	2032	4.98	2.06	M45	Ramaniya	8.83	3.386	1702	2.09	1.15
M16	Fachariya	8.17	1.470	936	7.71	BDL	M46	Ratadiya	8.88	3.766	2408	3.07	BDL
M17	Gelda	8.72	3.081	1672	4.22	2.14	M47	Sadau	8.56	1.123	592	2.28	1.68
M18	Goyersama	8.52	2.035	858	1.71	BDL	M48	Samagoga	8.49	3.836	2356	1.79	1.25
M19	Gundala	8.90	2.896	1686	2.06	1.29	M49	Shekhdiya	8.66	1.249	594	6.03	0.14

M20	Hamirmora	8.82	2.947	1330	1.50	2.89	M50	Shiracha	8.78	4.449	2240	0.84	2.05
M21	Hatdi	8.87	2.198	1696	1.61	1.12	M51	Tappar	8.32	1.515	774	8.70	0.81
M22	Jarpara	8.07	4.388	2262	1.20	1.08	M52	Toda	8.51	1.215	804	1.68	0.79
M23	Kandagara Mota	8.89	3.425	1808	1.18	1.34	M53	Tumbadi Moti	8.01	2.354	1616	1.29	0.65
M24	Kandagara Nana	8.19	0.943	1046	1.39	2.27	M54	Tumbadi Nani	8.69	3.681	2110	9.95	1.21
M25	Kanjra	8.63	1.827	950	1.54	BDL	M55	Tunda	8.94	3.316	1800	1.27	0.21
M26	Karagoga	8.81	3.209	1708	0.17	2.09	M56	Vadala	8.50	1.032	664	0.13	0.98
M27	khakhar Moti	8.74	4.362	2242	21.0	1.11	M57	Vagura	8.39	1.082	740	0.23	BDL
M28	Kukadsar	8.78	4.746	2720	2.61	2.71	M58	Vanki	8.34	1.761	904	1.91	0.57
M29	Kundrodi	8.33	1.158	618	0.18	0.91	M59	Viraniya	8.36	1.190	606	1.40	0.90
M30	Ku-vaipadhar	8.88	3.864	2240	6.21	2.39	M60	Vovar	8.52	3.749	2250	5.12	1.05

Source: http://www.citypincode.co.in/gujarat/kachchh/bhuj; https://www.census2011.co.in/data/subdistrict/3726-bhuj-kachch-gujarat.html

Table 3 Statistical analysis: ground water quality of Mundra

Parameter	**Minimum**	**Maximum**	**Average**	**Standard Deviation**
pH	7.92	9.02	8.6	0.271
EC (mS/cm)	0.782	6.975	2.836	1.474
TDS (mg/L)	340	3832	1584	790
NO_3^- (mg/L)	0.13	21	2.989	3.319
F^- (mg/L)	0.01	2.89	1.213	0.753

Table 4 Statistical analysis of ground water in Mundra area

Parameter↓	**No. of samples beyond prescribed limits from below Standard (Total samples = 60)**			**% of samples beyond prescribed limits from below Standard**		
STD →	WHO:2006	BIS:1999	ICMR:1975	WHO:2006	BIS:1999	ICMR:1975
pH	38	38	38	63%	63%	63%
TDS	58	21	33	97%	35%	55%
NO_3^-	00	00	00	0%	0%	0%
F^-	15	15	15	25%	25%	25%

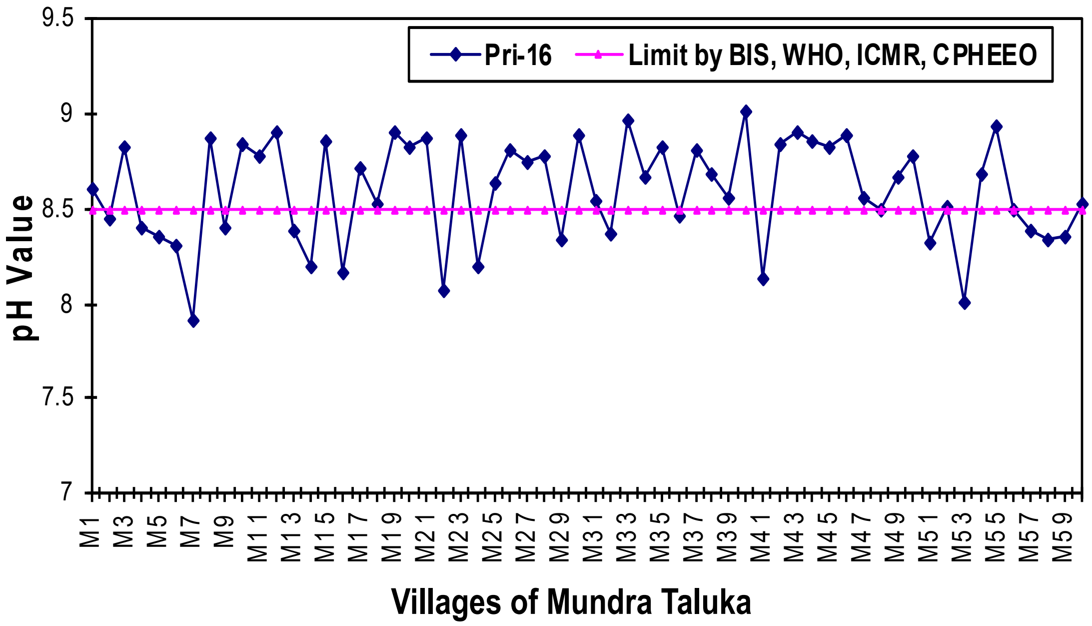

Figure 1 Graphical analysis of pH in groundwater of Mundra area

As per World Health Organization (WHO), Bureau of Indian Standards (BIS), Indian Council of Medical Research (ICMR) (Table 1) standards, pH concentration of 38 samples was measured which was beyond prescribed limits. pH range between 6.5 to 8.5 indicates that, the measured pH values of the 63% water samples were not within permissible value i.e. pH value of Mundra area is slightly alkaline in nature. Water with pH above 8.5 may tend to have a biter or soda-like taste which will cause harmful effect to the consumers. Maximum pH 9.02 was recorded at Pratapar village. The pH of water is very important indication of its quality and provides information in many types of geochemical equilibrium or solubility calculations (Mitharwal et al., 2009). pH above 8.0 would be disadvantageous in the treatment and disinfection of drinking water with chlorine (Oyem et al., 2014). Higher pH brings the formation of toxic trihalomethane (Trivedy and Goel, 1986). Excess use of detergents, soap-based items and fertilizersis the common cause which may enhance pH levels of surface and groundwater. Generally high pH and TDS is due to, low recharge, and over-exploitation of the ground water resource.

3.2 Total dissolved solids (TDS)

TDS include all mineral constituents and other solids dissolved in water. TDS in water is a general indicator of overall suitability of water for many applications. Like, high TDS values influence taste, hardness and corrosive property of the water (Burrough, 1988). Water with more than 500 mg/L of dissolved solids usually has a disagreeable taste and may have laxative effect or makes the water undesirable for drinking and many industrial uses. High TDS concentrations is due to presence of bicarbonates, carbonates, sulphates, chlorides and calcium, which may originate from natural sources, sewage, urban runoff, and industrial wastewater (Gabriel and Khan, 2010; Sergey, 2001). TDS can be removed by reverse osmosis, electro dialysis, exchange and solar distillation. To determine suitability of groundwater for any purpose, it is important to classify it according to its hydro-chemical properties based on TDS values, which are represented in Table 2; it depicts TDS contamination concentration level in collected samples according to WHO, ICMR, BIS criteria. These results show that TDS level is higher than described standards in some parts of study area and need treatment for its use for drinking purpose.

WHO recommended that waters containing more than 500 mg/L of dissolved solids should not be used for drinking. Only 02 villages (Mota kapaya and Lakhapar) qualified using WHO standards (Balakrishnan et al., 2011). The maximum contaminant level (MCL) for TDS in drinking water is given, 1500 mg/L and 2000 mg/L by ICMR and BIS, respectively.

33 villages of this area having TDS values beyond prescribed limits from ICMR Standard (>1500 mg/L) and 21 villages are the apparent source of High TDS (>2000 mg/L) i.e. not within limit as per BIS. Hence, all above scenario indicate that total 97%, 55% and 35% of the analyses groundwater samples were classified as not acceptable using WHO, ICMR and BIS, respectively. The highest TDS concentration (3832 mg/L) was recorded for village Depa. The high TDS occur in Mundra area may be due to over exploitation and low recharge. Based on our study of TDS, the water samples need treatment before its use because most of values exceed the WHO limits. There is an instant need to take necessary steps to reduce dissolved solid in this region and to take preventive action for the population from adverse health effects like kidney stone and constipation.

3.3 Electrical conductivity

Electrical conductivity (EC) is a measure of water capacity to convey electric current. The most desirable limit of EC in drinking water is prescribed as 1.4 mS/cm (WHO, 2006). EC of the groundwater is varying from 0.782 to 6.975 mS/cm with an average value of 2.836 (Table 2 and Table 3). Higher EC in the study area indicates the enrichment of salts in the groundwater. EC value may be an approximate index of the total content of dissolved substance in water. It depends upon temperature, concentration and types of ions present (Hem, 1989; Seybatou et al., 2014). The EC can be classified as type I, if the enrichments of salts are low (EC <1.5 mS/cm); type II, if the enrichment of salts are medium (EC 1.5 and 3.0 mS/cm); and type III, if the enrichments of salts are high (EC >3.0 mS/cm). According to the above classification of EC, 27% of the total groundwater samples come under the type I (low enrichment of salts) and 73% under type II & III (medium & High enrichment of salts). The effect of saline intrusion may be the reason for medium and high enrichment of EC in the study area. The effect of pH may also increase the dissolution process, which eventually increases the EC value.

3.4 Nitrate

During the study, reading for Nitrate fluctuated between 0.13 to 21 mg/L with average value 2.989 mg/L (Table 2 and Table 3). As per BIS, WHO and ICMR, No sample (village) was found beyond prescribed limit for Nitrate concentration (Table 2 and Fig. 2). Nitrate is the primary anthropogenic source of groundwater contamination from sewage disposal, agriculture, and industry in India (Chakraborti et al., 2011; Saha et al., 2014). No such anthropogenic contamination is observed in Mundra area during this research. The excessive usage of nitrogenous fertilizers for agricultural items and inadequate sanitary system may be the reason for higher nitrate values (ArockiaRaj and NagaRajan, 2015). Above study reveal no such anthropogenic activity is acute in this area.

3.5 Fluoride

Literature reported that fluoride in a minute quantity is an extremely crucial part for normal mineralization of bones and formation of dental enamel (Edmunds et al., 2005). Average concentration of fluoride was recorded 1.213 mg/L, and 75% of Mundra villages having fluoride concentration within limit as per WHO, BIS and ICMR Standards (i.e., 1.5 mg/L)

(Tables 2 & 3, Fig. 2).

In other hand Fluoride is a very toxic element and priority pollutant known to cause adverse health effects (Cabral et al., 2008; Chae et al., 2006). Higher concentration of fluoride in ground water appears to create dental, skeletal and non-skeletal fluorosis (Saxena and Saxena, 2015). Our study reveals that 25% sample having fluoride concentration greater than 1.5 mg/L fluoride.

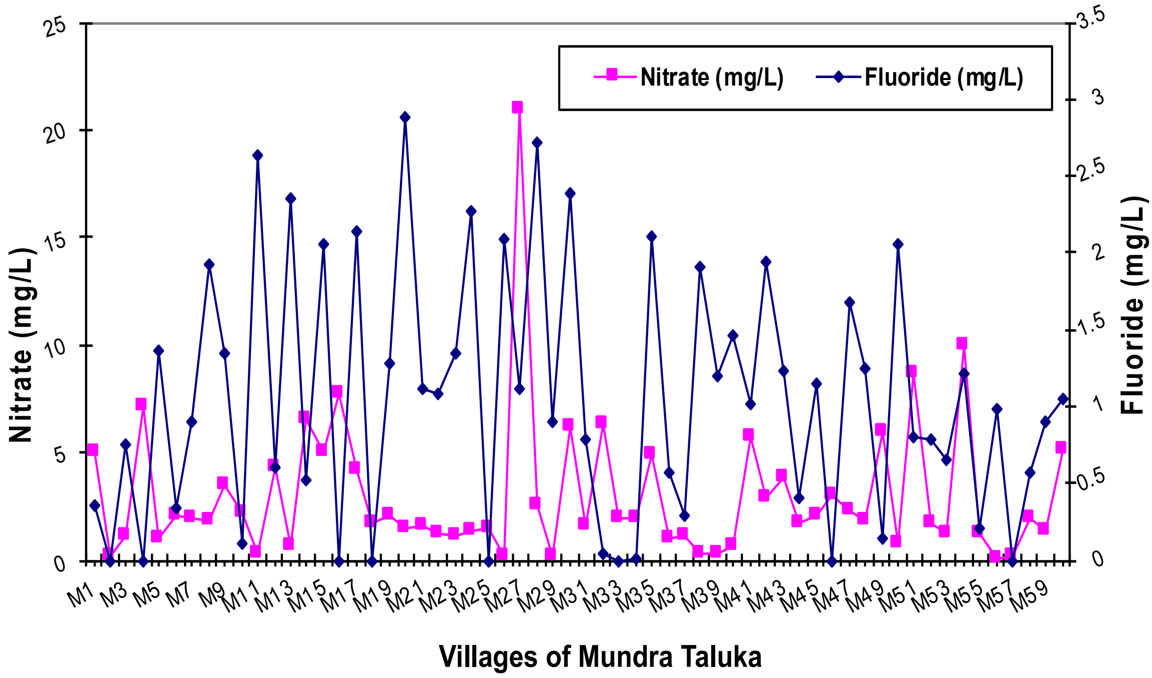

Figure 2 Graphical analysis of fluoride and nitrate in groundwater of Mundra area

In India fluoride concentration was first detected at Nellore district of Andhra Pradesh in 1937 (Chakraborti et al., 2011; Hiemstra and Van Riemsdijk, 2000; Kundu et al., 2002; Saha et al., 2014) has reported fluoride as a Geogenic contaminant, In the Mundra area highest fluoride concentration is recorded at village Hamirmora with value 2.89 mg/L.

Groundwater fluoride concentration value more than 1.5 mg/L (according to WHO 1984 and addenda in 1998, 1999, 2002 and 2005), is affecting 260 million people around the world (Amini et al., 2008). Total 15 sample out of 60 (i.e., 25%) showed fluoride concentration more than the permissible limit as per BIS, WHO and ICMR standards. Fluoride concentration in our study was recorded from 0.01 to 2.89 mg/L (Dibal et al., 2012; Dutta et al., 2010).

Fluorides in natural occurs is mainly in three forms *viz*. Fluorspar (CaF_2), Rock phosphate [$Ca_5F(PO_4)_8$] and Sodium aluminum fluoride [Na_3AlF_6]. The fluoride minerals are nearly insoluble. Hence, fluoride is usually not present in ground water until the conditions favor their solution i.e. contamination of water. (Deshmukh et al., 1995; Handa, 1975; Jacks et al., 2005; Mamatha and Rao, 2010; Rao and Mamatha, 2004).

"Anthropogenic or geogenic contamination" refers to human activity or naturally occurring elevated concentration of fluoride elements in ground water having negative health effect. For that technology of de-fluoridation is adopted for future plan. The objective of fluoride removal meant the treatment of contaminated water to bring down fluoride concentration to acceptable limits, Pretreatment is classified into 2 classes, specifically membrane (Reverse Osmosis) and surface assimilation techniques (Kagne et al., 2008; Sujana et al., 2009;

Viswanathan and Meenakshi, 2010). Fluoride removal efficiencies up to 98% by Reverse Osmosis have been documented by many researchers (Bason et al., 2006; Cervera et al., 2003; Lefebvre et al., 2004; Lefebvre and Palmeri, 2005; Szymczyk et al., 2006; Szymczyk and Fievet, 2005).

Nalgonda technique (Camacho et al., 2010; Maliyekkal et al., 2006; Nawlakhe et al., 1975; Tang et al., 2009) involves addition of Aluminium salts, lime and bleaching powder followed by rapid mixing, flocculation, sedimentation, filtration and disinfection. It is opined that this technique is preferable at all levels because of the low price and ease of handling, is highly versatile and can be used in various scales from household level to community scale water supply (Gadhari et al., 2011; Gaichore and Srivastava, 2010; Mobin et al., 2010; Vaze and Srivastava, 2007).

The Nalgonda technique can be used for raw water having fluoride concentration between 1.5 and 20 mg/L (Gaichore and Srivastava, 2010; Vaze and Srivastava, 2007) and the total dissolved solids should be <1500 mg/L, and total hardness <600 mg/L (Agarwal et al., 2003; Kamble et al., 2009; Kiurski et al., 2012).

3.5.1 Findings

The spatial distribution analysis of groundwater quality in the study area indicates that currently groundwater in most of the villages of Mundra does not falls within the standards for drinking water set by World Health Organization (WHO) and Bureau of Indian Standards (BIS). However, there is a wide disparity between the standards set by WHO and BIS. In our study TDS, pH and Fluoride values exceeded with respect to WHO standards in 97%, 63% and 25% villages. However, TDS, pH and Fluoride values exceeded with respect to BIS standards in 35%, 63% and 25% villages.

Groundwater will continue to be the major source of drinking water in all over India, the resource must be managed and protected. The findings of the current study would help general public, local administrators and government agencies to recognize the current and future threats to groundwater quality of Mundra Taluka. It is suggested to set up groundwater monitoring system and develop methods for dealing with current and future depletion and pollution of the resources.

We present the following recommendations for preventing further groundwater quality deterioration and developing a strategy for sustainable development.

i. Identify groundwater recharge locations and structures and ensure that these are protected from surface pollution. Agricultural activities, particularly those using large quantities of fertilizers and pesticides must be excluded from the recharge sites.
ii. Continuously monitor groundwater levels and quality so that problems can be recognized and dealt quickly.

CONCLUSIONS

pH values of 63% Borewell sample was observed slightly alkaline (>8.5) in nature. EC Values (>1.4 mS/cm) found in 73% Borewell samples, indicates the enrichment of salt in groundwater, the effect of saline intrusion may be the reason for same. The effect of pH may also increase dissolution process, which eventually increases the EC value. Due to overexploitation of groundwater and water mismanagement the results were not falling in the range of standards. All of these problems will only become worse unless steps are taken in the very near future. It is expected that the present study provides some guides for the development of a comprehensive land use and water management program. It is recommended that to use the groundwater of the study area for drinking purpose only after boiling and filtering or by Reverse Osmosis treatment. This may be useful for a good guide to individual well owners.

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