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Evaluation of heavy metals (Pb, Cd, Cu and Zn) contamination in underground water of Saurashtra region

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Abstract
An investigation was undertaken to study underground water quality of Saurashtra region of Gujarat state. Total 750 underground water samples were collected from wells or bore wells of all 75 talukas of ten districts of Saurashtra region in Gujarat state during the year of 2021. The water samples were collected by using GPS and analyzed for various heavy metals like Pb, Cd, Cu and Zn. In Saurashtra region the proportions of Pb, Cd, Cu, and Zn ranged from 0.005 to 0.189, 0.001 to 0.016, 0.008 to 0.105 and 0.003 to 0.065 mg/l with a mean value of 0.043 mg/l, 0.005 mg/l, 0.026 mg/l and 0.017 mg/l, respectively. The analytical results showed that the Pb, Cu and Zn concentration were within the permissible limits of 5 mg/l, 0.2 mg/l and 2 mg/l, respectively except Cd. The data showed that 2 per cent of the samples contained Cd concentration of greater than permissible level (>0.01 mg/l) so they categorised as unsafe. Amreli district was found to have the highest mean Cd value (0.006 mg/l) in underground water samples.

Keywords: Underground water, Pb, Cd, Cu, Zn, contamination

1. Introduction

Heavy metals are metallic elements with relatively higher atomic masses and densities equal to or greater than 5.0 g/cm^3 (Zhang *et al*., 2019) [11]. Many people's health is being negatively impacted by the widespread heavy metal pollution that occurs in the world, primarily as a result of human contamination. The major sources of release of heavy metals into the environment are industrial discharge, mining operations, agriculture activities, faculty transportation, damming, tanneries and e-waste disposal. In terms of the sources in the agricultural sector, these can be categorized into fertilization, pesticides, livestock manure and wastewater (Li *et al*., 2014) [3]. These sources dispose different types of organic and inorganic contaminants which get deposited in the natural biota. The most prominent perilous heavy metals of concern are cadmium (Cd), copper (Cu), lead (Pb) and zinc (Zn) which are toxic even at trace concentrations and cause an alarming combination of environmental and health problems (Su *et al*., 2015) [10]. These heavy metals in nature are not biodegradable and tend to accumulate in living creatures leading to adverse effects beyond a certain limit. According to Central Pollution Control Board of India (CPCBI), 80 per cent of hazardous wastes are released from Gujarat, Maharashtra and Andhra Pradesh (Marg, 2011) [4].

The most important source of irrigation in the whole Gujarat is “wells”, followed by “tube wells”. The percentage for both combined comes to 62.42 per cent of total irrigation sources in Gujarat. This is important to look since both depend on groundwater extraction. Depleting groundwater due to excessive exploitation for irrigation in rural areas is further aggravating the threat of toxic constituents for sustainable crop production. Hence exploitation of ground water resources and growing concern for deterioration of ground water quality due to various reasons. In view of this, attempts have been made in the present investigation, to work out the systemic and comprehensive information on the heavy metals contamination in underground water of Saurashtra region using a large number of samples.

2. Materials and Methods

2.1 Collection of underground water samples

To determine the heavy metals contamination load in underground water, the Saurashtra region of Gujarat state was selected as a study area comprising 75 talukas of ten districts (Table 1). The water samples were collected by using GPS and were analysed for various quality parameters. The ten underground water samples from wells/bore wells of each 75 taluka of ten districts of the Saurashtra region of Gujarat were collected during the summer season of year 2021. A total 750 underground water samples were collected.

Table 1: District wise talukas of Saurashtra region

S.N.	Districts	Number of Talukas (75)
1	Rajkot (11)	Rajkot, Paddhari, Lodhika, Jam Kandorna, Kotda Sangani, Jasdan, Vinchhiya, Gondal, Dhoraji, Upleta, Jetpur
2	Jamnagar (06)	Jamnagar, Jam Jodhpur, Jodiya, Dhrol, Lalpur, Kalavad
3	Devbhumi Dwarka (04)	Dwarka, Bhanvad, Kalyanpur, Jamkhambhaliya
4	Morbi (05)	Morbi, Tankara, Halvad, Wankaner, Maliya
5	Surendra Nagar (10)	Chuda, Chotila, Dhrangadhra, Lakhtar, Limbdi, Muli, Patdi, Sayla, Thangadh and Wadhwan
6	Amreli (11)	Amreli, Babra, Dhari, Khambha, Kunkavav, Lathi, Lilia, Savarkundla, Bagasara, Jafrabad, Rajula
7	Bhavnagar (10)	Bhavnagar, Gariadhar, Jesar, Palitana, Sihor, Umrala, Vallabhipur, Ghogha, Mahuva, Talaja
8	Junagadh (09)	Junagadh, Bhesan, Keshod, Malia, Manavadar, Mangrol, Mendarda, Vanthali, Visavadar
9	Gir Somnath (06)	Gir-Gadhada, Kodinar, Sutrapada, Talala, Una, Veraval
10	Porbandar (03)	Porbandar, Kutiyana, Ranavav

2.2 Preparation of water samples
By using standard procedure (Richards, 1954) [9] water samples were collected in clean plastic bottles of one liter capacity and tightly screwed and were brought to the laboratory for further analysis. Collected underground water samples were brought to the laboratory on same day and proper labelling were carried out for each sample.

2.3 Methods of analysis
The Heavy metals mainly Cu, Zn, Cd and Pb were analysed by Atomic Absorption Spectrophotometer (AAS) Model: Elements AS AAS 4141.

3. Results and Discussion
The overall proportions of Pb, Cd, Cu, and Zn in the collected underground water samples from entire Saurashtra region varied from 0.005 to 0.189, 0.001 to 0.016, 0.008 to 0.105 and 0.003 to 0.065 mg/l with a mean value of 0.043 mg/l, 0.005 mg/l, 0.026 mg/l and 0.017 mg/l (Table 2), respectively.
The lowest value of Pb (0.005 mg/l) was registered in water sample collected from Junagadh district and highest value of Pb (0.189 mg/l) was obtained from Devbhumi Dwarka district. Further revealing of data showed that the lowest mean value of Pb (0.034 mg/l) was obtained from water samples of Gir Somnath district. However, highest mean value (0.063) was registered in water samples collected from Jamnagar district (Fig. 1).
The Junagadh district had the highest Cd value (0.016 mg/l), whereas Amreli district had the highest mean Cd value (0.006 mg/l) in underground water samples (Fig. 2).
The highest Cu value (0.105 mg/l) reported in Devbhumi Dwarka district and also highest mean Cu concentration (0.098 mg/l) was also found in the same district (Fig. 3). The lowest Cu value (0.008 mg/l) observed in Gir Somnath, Surendranagar and Rajkot district and Gir Somnath district had the lowest mean Cu value (0.018 mg/l).
The Morbi district had the highest (0.065 mg/l) as well as lowest Zn value (0.003 mg/l) while Rajkot, Surendranagar and Bhavnagar recorded the lowest average Zn value (0.015 mg/l) and highest average Zn value was registered Devbhumi Dwarka district (Fig. 4).
Relatively comparable findings have been also found by Patel and Das (2015) [6] for Vapi industrial belt (Gujarat), by Patel and Manoj (2015) [7] for Surat district, by Patel *et al.* (2019) [5] for Kutch district of Gujarat, by Kumar *et al.* (2007) [2] for Ankaleshwar industrial estate of south Gujarat and by Patel *et al.* (2021) [8] for Vadodara and Chhota Udaipur districts of Gujarat.

Table 2: District wise range and mean values of heavy metals of underground water samples in the Saurashtra region

Name of Talukas	Pb (mg/l)	Cd (mg/l)	Cu (mg/l)	Zn (mg/l)
Junagadh	0.005-0.079	0.001-0.016	0.010-0.040	0.011-0.033
	(0.039)	(0.005)	(0.022)	(0.017)
Gir Somnath	0.011-0.075	0.001-0.014	0.008-0.034	0.009-0.026
	(0.034)	(0.005)	(0.018)	(0.016)
Porbandar	0.010-0.068	0.003-0.008	0.016-0.045	0.011-0.028
	(0.037)	(0.005)	(0.026)	(0.019)
Jamnagar	0.017-0.187	0.001-0.005	0.016-0.101	0.004-0.055
	(0.063)	(0.003)	(0.040)	(0.018)
Devbhumi Dwarka	0.017-0.189	0.001-0.004	0.023-0.105	0.009-0.061
	(0.060)	(0.002)	(0.048)	(0.026)
Morbi	0.010-0.132	0.001-0.005	0.015-0.084	0.003-0.065
	(0.050)	(0.002)	(0.045)	(0.025)
Surendranagar	0.012-0.081	0.002-0.012	0.008-0.073	0.007-0.024
	(0.037)	(0.005)	(0.023)	(0.015)
Amreli	0.010-0.107	0.001-0.011	0.009-0.057	0.008-0.028
	(0.039)	(0.006)	(0.024)	(0.016)
Bhavnagar	0.014-0.094	0.001-0.011	0.009-0.036	0.008-0.026
	(0.042)	(0.004)	(0.019)	(0.015)
Rajkot	0.010-0.077	0.002-0.014	0.008-0.043	0.008-0.029
	(0.043)	(0.005)	(0.019)	(0.015)
Overall	0.005-0.189	0.001-0.016	0.008-0.105	0.003-0.065
	(0.043)	(0.005)	(0.026)	(0.017)

Note: Values in parenthesis indicate mean values

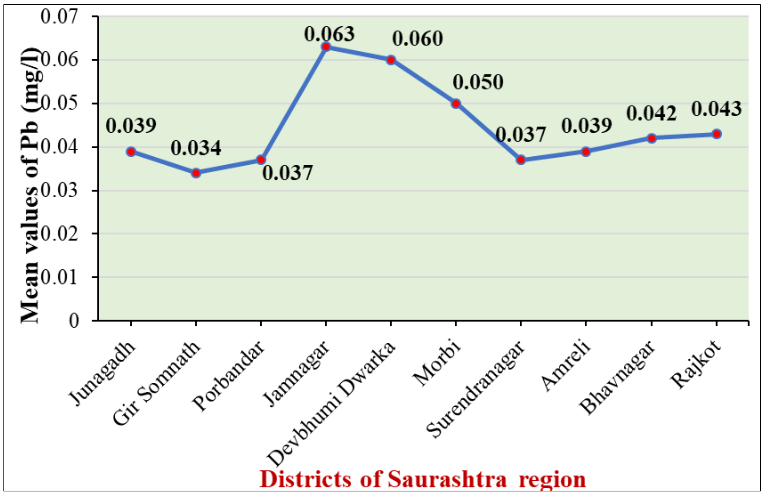

Fig 1: The mean value of Pb (mg/l) concentration of underground water samples of different districts in Saurashtra region

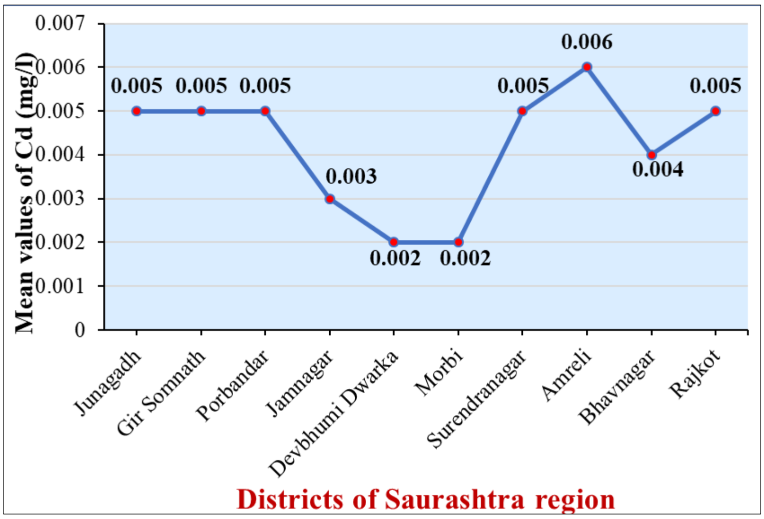

Fig 2: The mean value of Cd (mg/l) concentration of underground water samples of different districts in Saurashtra region

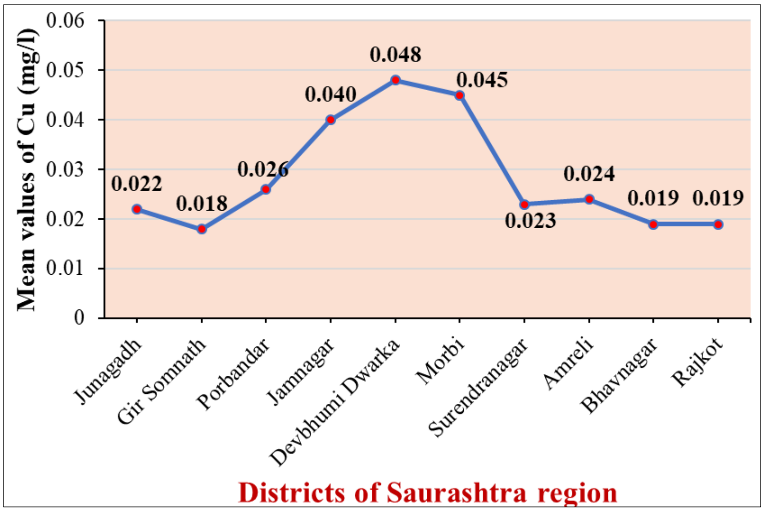

Fig 3: The mean value of Cu (mg/l) concentration of underground water samples of different districts in Saurashtra region

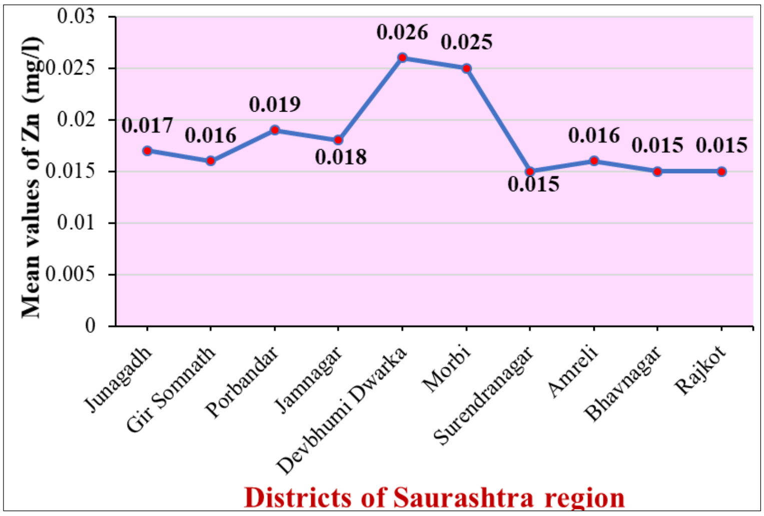

Fig 4: The mean value of Zn (mg/l) concentration of underground water samples of different districts in Saurashtra region

4. Conclusion

Based on analysed data of underground water samples collected from all districts of Saurashtra region of Gujarat, it can be concluded that the heavy metals *viz*. Pb, Cu and Zn concentrations in underground water samples of the Saurashtra region were within the permissible limits so underground water was safe to use for irrigation purposes but 2 per cent samples were detected with Cd content more than the permissible limit of 0.01 mg/l. In order to identify the sources and causes of the excessive concentrations of Cd in the districts and guarantee the safe quality of water through the implementation of appropriate mitigation measures, this study can be utilized in further collaboration with advanced hydrogeological and GIS investigations. We also suggest that continuous monitoring of underground water quality in areas of poor-quality water will be helpful to take immediate steps in minimizing further deterioration of the quality of soils.

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