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Original Article

Community Medicine Section

Physico-Chemical and Bacterial Evaluation of Public and Packaged Drinking Water in Vikarabad, Telangana, India - Potential Public Health Implications

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ABSTRACT

Introduction: Humanity highly depends on water and its proper utilization and management. Water has various uses and its use as thirst quenching fluid is the most significant one.

Aim: To assess physical, chemical, trace metal and bacterial parameters of various public and packaged drinking water samples collected from villages of Vikarabad mandal.

Materials and Methods: Public and packaged drinking water samples collected were analysed for various parameters using American Public Health Association (APHA 18th edition 1992) guidelines and the results obtained were compared with bureau of Indian standards for drinking water.

Statistical Analysis: Descriptive statistics and Pearson's correlations were done.

Results: Among bottled water samples, magnesium in 1 sample was >30mg/litre, nickel in 2 samples was >0.02mg/litre. Among sachet water samples, copper in 1 sample was >0.05mg/litre, nickel in 2 samples was >0.02mg/litre. Among canned water samples, total hardness in 1 sample was >200mg/litre, magnesium in 3 samples was >30mg/litre. In tap water sample, calcium was >75mg/litre, magnesium was >30mg/litre, nickel was >0.02mg/litre. Among public bore well water samples, pH in 1 sample was >8.5, total dissolved solids in 17 samples was >500mg/litre, total alkalinity in 9 samples was >200mg/litre, total hardness in 20 samples was >200mg/litre, calcium in 14 samples was >75mg/litre, fluoride in 1 sample was >1mg/litre, magnesium in 14 samples was >30mg/litre. Total coliform was absent in bottled water, sachet water, canned water, tap water samples. Total Coliform was present but *E. coli* was absent in 4 public bore well water samples. The MPN per 100 ml in those 4 samples of public bore well water was 50.

Conclusion: Physical, chemical, trace metal and bacterial parameters tested in present study showed values greater than acceptable limit for some samples, which can pose serious threat to consumers of that region.

Keywords: Bore well water, Coliform count, Tap water, Water standards

INTRODUCTION

Water is believed to be elixir of life. Although it is plentiful in nature, occupying 71% of the earth's surface, only 1% is accessible for human consumption. Thus, the quality of this 1% drinking-water is a powerful environmental determinant of health, as it has an important impact on health of people. Humanity highly depends on water and its proper utilization and management [1]. Drinking water of good quality is of basic importance to human physiology and man's continued existence depends very much on its availability [2]. An average man (53 kg – 63 kg body weight), requires about 3 litres of water daily in liquid and food to keep him healthy [1]. However, despite its abundance, good quality drinking water is not readily available to man. With the global population ever increasing, the need for water has become a global concern. Many human diseases are related to lack of safe and hygienic water [3].

Unavailability of good quality drinking water is wide spread and this has serious health implications. In developing nations of the world, 80% of all diseases and over 30% of deaths are related to drinking water [2]. The United Nations estimated that about 1.2 billion people all over the world lack access to potable water. Water is said to be potable when its physical, chemical and microbiological qualities conform to specified standards. To achieve such standards raw water is subjected to purification processes that range from simple long- term storage to enable sedimentation of some suspended solids to aeration, coagulation, flocculation, filtration and disinfection. Variation in the combination of treatments required varies with the source and quality of the raw water. Sources of water are many and varied, the level of contamination also varies and consequently a high degree of public health hazard can be associated with drinking water [4].

In India, bottled water industry saw virtually no activity till 1993, when Bisleri was launched by Parle. But now, India is among the top ten countries in terms of bottled water consumption [1]. Drinking water supply is a state subject. Funds have been provided in the budgets of the States for the drinking water supply right from the commencement of the first five year plan. The entire programme was given a mission approach when the technology mission on drinking water and related water management, also called the National Drinking Water Mission (NDWM) was introduced as one of the five societal missions in 1986. NDWM was renamed as Rajiv Gandhi national drinking water mission in 1991. The main aim of Rajiv Gandhi national drinking water mission was ground water exploration and recharge along with identification of potable drinking water for problematic habitations [5].

Access to safe drinking water is key to sustainable development and essential to food production, quality health and poverty reduction. Safe drinking water is essential to life and a satisfactory safe supply must be made available to all the people. Though Vikarabad mandal abounds in numerous water resources, not all residents have access to quality drinking water. The supply of municipality tap water is restricted to few communities in and around Vikarabad town. In the light of inadequate or lack of quality potable water supplies from the municipal sources, residents have resorted to public bore well water and private sector providers to fulfil their water needs. Some business entrepreneurs imported machines for filtering the water and putting them in sealed cans.

Most manufacturers today use multi candle pressure filters which employ an active carbon filter that removes sand, rusts, metal sediments, algal films and bacteria from the water [6].

As some people may not afford for bottled water they depend upon sachet water to quench their thirst. Regardless of quality issues associated with sachet water, it is still considered wholesome for drinking purposes. To the best of our knowledge this study is the first of its kind assessing the physical, chemical, trace metal and bacterial parameters of all available drinking water sources in Vikarabad mandal.

AIM

To assess the physical, chemical, trace metal and bacterial parameters of samples of all available drinking water sources in Vikarabad mandal and ascertaining its compliance with bureau of Indian standards for drinking water.

MATERIALS AND METHODS

A cross sectional study was conducted to assess physical, chemical, trace metal and bacterial parameters of various public and packaged drinking water samples collected from villages of Vikarabad mandal.

Sample Collection

One public bore well water sample from each of the 35 villages of Vikarabad mandal was collected. One municipality tap water sample from Vikarabad municipality was collected. Bottled, sachet, canned water samples (one sample of each brand randomly) available in all the villages of Vikarabad mandal were collected.

For physico-chemical evaluation public bore well water samples, municipality tap water samples and canned water samples were collected in sterile white jerry cans (Aditi plastics, Nagpur) of 1 litre capacity. For bacterial evaluation public bore well water samples, municipality tap water samples and canned water samples were collected in sterile jars (HiMedia laboratories, Mumbai) of 100 ml capacity. Bottled water of 1litre capacity was collected and required number of sachets was collected to make 1 litre volume. These samples were used as such for physico-chemical and bacterial evaluation.

All the water samples were collected under sterile conditions, numbered in the sequence in which they were collected and transported under refrigerated conditions in thermocol boxes with ice packs to Telangana state pollution control board, Hyderabad for analysis. Refrigeration was done to preserve the physical, chemical, trace metal and bacterial parameters of drinking water samples. All samples were analysed within 7 days from the time of collection. Sample collection and analysis was carried out in the 1st week of September, 2014. American Public Health Association (APHA 18th edition 1992) guidelines were used for analysis [7]. The parameters assessed and methods used are given in [Table/Fig-1]. Obtained values for various studied parameters were compared with Indian standards 14543 for packaged drinking water (bottled, sachet, canned water), 10500 for drinking water (public bore well water and municipality tap water) and the quality was assessed [8,9]. The maximum permissible limits as per Bureau of Indian Standards are given in [Table/Fig-2].

Optimization of the instruments used for the measurement of these parameters was carried out as detailed in the operating manual. Working standard solutions were prepared by appropriate dilution of stock solutions. Each measurement was made in triplicate and the mean of the three values was taken. Preparation of standards and samples was carried out under clean conditions using deionized water. All chemicals and reagents used were of ultra-pure reagent grade. All glassware and plastic ware (Glasscoscientifics) were washed three times with deionized water, and then soaked in 20% nitric acid overnight. After soaking, the glassware were rinsed three times with deionized water and dried. Quality assurance was achieved by measuring blank test solutions [10].

Physical and Chemical parameters	Method
Colour	Colour Comparator (Comparator 2000 + Lovibond)
Turbidity	Turbidity Meter (Elicoscientifics)
pH	pH Meter (Elicoscientifics)
Electrical Conductivity	Electrical Conductivity Meter (Elicoscientifics)
Total Dissolved Solids	Gravimetric Method
Total Hardness, Total Alkalinity, Calcium, Magnesium, Chloride	Titration Method
Nitrate, Sulphate, Fluoride	Spectrophotometry (Elicoscientifics)
Sodium	Flame Emission Photometric Method (Elicoscientifics)
All Trace Metals	Inductively Coupled Plasma Method (Perkin Elmer)

[Table/Fig-1]: Physico – chemical parameters and methods used to assess the water quality.

S. No	Parameter	IS-10500:2012	IS-14543:2004
1	Colur Hazen Units	5	2
2	Odour	unobjectionable	unobjectionable
3	Turbidity	5	2
4	pH	6.5-8.5	6.5-8.5
5	Total Dissolved Solids, mg/l	500	500
6	Total hardness as $caco_3$, mg/l	300	-
7	Alkalinity mg/l	200	200
8	Calcium as Ca, mg/l	75	75
9	Magnesium as Mg, mg/l	30	30
10	Chloride as Cl, mg/l	250	200
11	Nitrate	45	45
12	Sulphate as So_4, mg/l	200	200
13	Fluoride, mg/l	1	1
14	Sodium as Na, mg/l	-	200
15	Cadmium as Cd, mg/l	0.01	0.01
16	Chromium as Cr6, mg/l	0.05	0.05
17	Copper as Cu, mg/l	0.05	0.05
18	Iron as Fe, mg/l	0.3	0.1
19	Manganese as Mn, mg/l	0.1	0.1
20	Nickel as Ni, mg/l	-	0.02
21	Lead as Pb, mg/l	0.05	0.01
22	Zinc as Zn, mg/l	5	5

[Table/Fig-2]: Maximum permissible limits as per Bureau of Indian Standards [7,8].

Tests for Bacterial Parameters

Presumptive Test

Coliform count was obtained using the three tube assay of the Most Probable Number (MPN) technique [7]. Presumptive coliform test was performed using MacConkey broth (oxoid). The first set of three tubes had sterile 10ml double strength broth and the second and third sets had 10ml single strength broth. All the tubes contained Durham tubes before sterilization. The three sets of tubes received 10ml, 1ml and 0.1ml quantities of water samples using sterile pipettes. The tubes were incubated at 37^{0}c for 24-48 hours for estimation of total coliforms and at 44.5^{0}c for faecal coliforms for 24-48 hours and examined for acid and gas production. Acid production was determined by colour change of the broth from reddish purple to yellow and gas production was checked by entrapment of gas in the Durham tube. The MPN was then estimated from the MPN table for three tube test [11].

Confirmed Test

It was carried out by transferring a loopful of culture from a positive tube from the presumptive test into a tube of Brilliant Green Lactose Bile (BGLB) broth (Oxoid) with Durham tubes. The tubes were incubated at 37°c for 24-48 hours for total coliforms and 44.5°c for faecal coliforms and observed for gas production [11].

Completed Test

It was carried out by streaking a loopful of broth from a positive tube onto Eosine Methylene Blue (EMB) agar plate for pure colonies. The plates were incubated at 37°c for 24-48 hours. Colonies developing on EMB agar, were further identified as coliform or faecal coliforms (*Escherichia coli*) using cultural characteristics, morphology and biochemical tests. For faecal coliforms, colonies with green metallic sheen were Gram stained and the IMViC test was carried out on nutrient agar stock cultures and used to identify the colony as *E.coli*. The MPN per 100ml water was calculated using the completed test [11].

STATISTICAL ANALYSIS

The data was compiled, tabulated and subjected to descriptive statistical analysis and Pearson's correlation using the SPSS package (version 21.0).

Parameter		Bottle	Sachet	Can	Bore well	Tap water
Turbidity	Minimum				0	
	Maximum				10	
	Mean	0	0	0	1.85*	0
pH	Minimum	5.52	5.98	7	5.9	
	Maximum	6.89	7.58	7.5	9.4	
	Mean	6.34	7.13	7.2	6.8*	7.8
Electrical Conductivity	Minimum	47	53	48	49	
	Maximum	181	174	690	1299	
	Mean	104.4	111.5	214.5	658.7	456
Total Dissolved Solids	Minimum	31	34	31	32	
	Maximum	118	113	445	1012	
	Mean	67.8	73	139.5	498.2*	296
Total Hardness	Minimum	16	6	40	38	
	Maximum	48	22	212	424	
	Mean	37.8	13	130.5*	237.6*	184
Total Alkalinity	Minimum	14	15	130	54	
	Maximum	47	43	160	484	
	Mean	33.4	25.5	149	182*	180
Calcium	Minimum	4	1	10	10	
	Maximum	29	30	96	200	
	Mean	14.6	14.25	36.5	70.14*	92*
Magnesium	Minimum	12	2	30	2	
	Maximum	38	17	130	248	
	Mean	23.2*	8	94*	52.3*	92*
Chloride	Minimum	10	6	57	7	
	Maximum	29	117	142	180	
	Mean	17	38	103.7	66.7	51
Nitrate	Minimum	-	-	0	0	
	Maximum			11	28.9	
	Mean			2.75	10.2	8
Sulphate	Minimum	2.1	2.43	2	2	
	Maximum	3.2	3.16	54	74	
	Mean	2.7	2.93	15.5	33.3	4.3
Fluoride	Minimum	0.02	0.02	-	0.04	
	Maximum	0.13	0.07		1.09	
	Mean	0.05	0.03		0.27*	0.34
Sodium	Minimum	5.5	3.9	4	6	
	Maximum	29.9	30.6	33	65	
	Mean	18.6	13.27	12	36.1	20.4
Potassium	Minimum	0.2	0.5	0.1	0.2	
	Maximum	0.6	2.3	2.3	2.9	
	Mean	0.4	0.97	0.75	1.4	2.6

[Table/Fig-3]: Mean values of physico-chemical parameters assessed in drinking water
* Indicates values exceeding the acceptable limit.

RESULTS

A total of 5 bottled water samples, 4 sachet water samples and 4 canned water samples (one sample of each brand randomly) were collected from all the villages of Vikarabad mandal. One sample of Vikarabad municipality tap water was collected. 35 public bore well water samples from each of the 35 villages were collected. The mean values of physico – chemical parameters assessed are given in [Table/Fig-3,4].

All the bottled, sachet, canned, municipality tap and public bore well water samples were colourless and had no objectionable odour and taste. Among different samples of bottled water, magnesium in 1 sample was 38mg/litre (greater than acceptable limit), nickel in 2 samples was 0.227mg/litre and 0.337mg/litre (greater than permissible limit). Among different samples of sachet water, copper in 1 sample was 0.9545mg/litre (greater than acceptable limit), nickel in 2 samples was 0.0653mg/litre, 0.0289mg/litre (greater than permissible limit). Among different samples of canned water, total hardness in 1 sample was 212mg/litre (greater than acceptable limit), magnesium in 3 samples was 100, 116, 130mg/litre (greater than acceptable limit). In tap water sample, calcium was 92mg/litre (greater than acceptable limit), magnesium was 92mg/litre (greater than permissible limit), and

Parameter		Bottle	Sachet	Can	Bore well	Tap water
Cadmium	Minimum	0.0002	0.0001	-	-	
	Maximum	0.0003	0.0003			
	Mean	0.0002	0.0001			0.0001
Cobalt	Minimum	0.0002	0.0002	-	-	
	Maximum	0.0003	0.0004			
	Mean	0.0002	0.0003			0
Chromium	Minimum	0.0011	0.0007	-	-	
	Maximum	0.0032	0.001			
	Mean	0.0018	0.0008			0.0009
Copper	Minimum	0	0.0019	-	-	
	Maximum	0.002	0.9545			
	Mean	0.0006	0.2452*			0.0014
Iron	Minimum	0.0005	0.0034	-	-	
	Maximum	0.0141	0.0171			
	Mean	0.0047	0.0080			0.0359
Lithium	Minimum	0.0003	0	-	-	
	Maximum	0.0021	0.0048			
	Mean	0.001	0.0015			0.0001
Manganese	Minimum	0	0	-	-	
	Maximum	0.0001	0.0006			
	Mean	0.0001	0.0002			0.0024
Nickel	Minimum	0.0026	0.0017	-	-	
	Maximum	0.0337	0.0653			
	Mean	0.0157*	0.0282*			0.0754*
Lead	Minimum	0.0001	0.0007	-	-	
	Maximum	0.0006	0.0026			
	Mean	0.0003	0.0016			0.0015
Strontium	Minimum	0.0048	0.0008	-	-	
	Maximum	0.0315	0.257			
	Mean	0.0142	0.0795			0.2256
Zinc	Minimum	0.0015	0.0001	-	-	
	Maximum	0.0063	2.946			
	Mean	0.0033	0.74			0.0039

[Table/Fig-4]: Mean values of trace metal parameters assessed in drinking water
* Indicates values exceeding the acceptable limit.

Water	*Totalcoliform*	*E.coli*
Bottled water	Absent	Absent
Sachet water	Absent	Absent
Canned water	Absent	Absent
Municipality tap water	Absent	Absent
Bore well water	Present in 4 villages (50 MPN/100ml in each sample)	Nil in those 4 samples

[Table/Fig-5]: Bacterial parameters assessed in various drinking water sources.

nickel was 0.0754mg /litre (greater than permissible limit). Among 35 public bore well water samples, turbidity in 6 samples was 10 NTU (Nephelometric Turbidity Unit) (greater than acceptable limit), pH in 1 sample was 9.46 (greater than permissible limit), total dissolved solids in 17 samples was in between 580-1012mg/litre (greater than acceptable limit), total alkalinity in 9 samples was in between 210- 484mg/litre (greater than acceptable limit), total hardness in 20 samples was in between 204-416mg/litre (greater than acceptable limit), calcium in 14 samples was in between 82-200mg/litre (greater than acceptable limit), fluoride in 1 sample was 1.09mg/litre (greater than acceptable limit), magnesium 34-248 mg/litre (in 14 samples was >30mg/litre and in 6 samples was >100mg/litre). Total coliform and *E.coli* was absent in samples of bottled water, sachet water, canned water, tap water. Total Coliform was present but *E. coli* was absent in 4 samples of public bore well water. The MPN per 100 ml in those 4 samples of public bore well water was 50. The bacterial parameters of various samples assessed are shown in [Table/Fig-5-9].

DISCUSSION

Water suitable for human consumption should be free from harmful chemicals and disease causing micro-organisms [11]. Most of the physico – chemical constituents of drinking water in the present study were within the acceptable limits of Indian Standards. The exception noted was with respect to turbidity (bore well water in 6 villages), pH (bore well water in 1 village), dissolved solids (bore well water in 17 villages), hardness (1 brand of canned water, bore well water in 20 villages), alkalinity (bore well water in 9 villages), magnesium (1 brand of bottled water, 3 brands of canned water, tap water, bore well water in 14 villages), calcium (tap water, bore well water in 14 villages), fluoride (bore well water in 1 village). Most of the trace metal constituents were within the acceptable limits of Indian Standards. The exception noted was with respect to nickel (2 brands of bottled water, 2 brands of sachet water, tap water), copper (1 brand of sachet water). Total coliform was present in bore well water of 4 villages.

A study was conducted by John Mohammad et al., to assess the quality of Wyra reservoir water of Khammam district, Telangana, India. Monthly changes in physico-chemical parameters (air, water temperatures, dissolved oxygen, alkalinity, chlorides, total dissolved solids and hardness turbidity) were analyzed for a period of one year from 2011 January to December. It was found that, some physico- chemical parameters showed seasonal fluctuations. They found that the water can be used for drinking purpose in winter and summer seasons, and also for irrigation and pisciculture. Whereas in the present study, each water sample was collected only once and at one point of time and were transported under refrigerated conditions so as to preserve the physical, chemical, trace metal and bacterial parameters and hence the air and water temperatures were not taken into consideration [12].

Magnesium and nickel in bottled water were found to be exceeding the acceptable limit in the present study. Excess magnesium in drinking water does not pose a health risk because the kidneys eliminate excess amounts in the urine. However in some individuals it may result in diarrhoea, nausea and abdominal cramping. Magnesium, nickel and copper is washed from rocks and enters drinking water sources [13-15]. Excess of nickel in drinking water would cause nausea, vomiting, headache, weakness, skin irritation (Allergic contact dermatitis) hypersensitivity and carcinogenicity. The source of nickel in drinking-water is leaching from metals in contact with drinking-water (pipe lines), industrial effluents [14]. In Lebanon, a study was conducted by Semerjian et al., on bottled water and majority of the brands met the different bottled water standards for physico-chemical parameters except for pH, hardness, and calcium. All samples showed negative growth for faecal coliforms, however few of the samples revealed positive results for total coliforms [16].

	pH	EC	TDS	TA	TH	CA	Mg	F	Cl	SO4	Na	K	Cd	Co	Cr	Cu	Fe	Li	Mn	Ni	Pb	Sr	Zn
pH	1.00																						
EC	0.91	1.00																					
TDS	0.91	1.00	1.00																				
TA	0.98	0.91	0.91	1.00																			
TH	-0.15	-0.02	-0.02	-0.02	1.00																		
Ca	-0.03	0.35	0.35	0.07	0.62	1.00																	
Mg	-0.16	-0.35	-0.35	-0.08	0.69	-0.14	1.00																
F	0.57	0.44	0.44	0.47	-0.89	-0.49	-0.67	1.00															
Cl	0.29	0.65	0.65	0.31	0.10	0.82	-0.63	0.09	1.00														
SO_4	-0.02	-0.23	-0.24	0.11	-0.08	-0.45	0.31	0.14	-0.52	1.00													
Na	0.99	0.95	0.95	0.98	-0.15	0.07	-0.25	0.58	0.40	-0.04	1.00												
K	-0.42	-0.04	-0.04	-0.29	0.55	0.89	-0.13	-0.57	0.64	-0.21	-0.31	1.00											
Cd	0.34	0.08	0.08	0.44	0.44	-0.28	0.82	-0.21	-0.54	0.57	0.26	-0.38	1.00										
Co	0.71	0.83	0.83	0.63	-0.48	0.19	-0.78	0.73	0.69	-0.39	0.77	-0.10	-0.41	1.00									
Cr	0.64	0.34	0.33	0.60	-0.61	-0.72	-0.11	0.80	-0.36	0.52	0.59	-0.82	0.40	0.34	1.00								
Cu	0.06	-0.19	-0.20	0.10	0.55	-0.28	0.96	-0.48	-0.67	0.28	-0.05	-0.36	0.88	-0.62	0.11	1.00							
Fe	0.47	0.25	0.24	0.38	-0.89	-0.71	-0.47	0.95	-0.20	0.34	0.45	-0.73	-0.03	0.50	0.90	-0.27	1.00						
Li	0.69	0.41	0.41	0.75	0.08	-0.38	0.45	0.26	-0.36	0.58	0.62	-0.57	0.88	0.03	0.74	0.61	0.38	1.00					
Mn	-0.64	-0.68	-0.68	-0.74	-0.66	-0.48	-0.39	0.23	-0.31	-0.01	-0.64	-0.15	-0.61	-0.17	-0.04	-0.43	0.31	-0.60	1.00				
Ni	0.39	0.36	0.36	0.52	0.79	0.33	0.70	-0.46	-0.01	0.21	0.36	0.12	0.81	-0.22	-0.02	0.70	-0.43	0.65	-0.92	1.00			
Pb	-0.90	-0.92	-0.92	-0.82	0.09	-0.18	0.28	-0.44	-0.48	0.46	-0.90	0.28	-0.06	-0.81	-0.35	0.07	-0.27	-0.36	0.57	-0.26	1.00		
Sr	0.58	0.74	0.74	0.67	0.65	0.71	0.17	-0.26	0.58	-0.22	0.61	0.37	0.34	0.31	-0.17	0.19	-0.41	0.35	-0.95	0.79	-0.61	1.00	
Zn	-0.55	-0.26	-0.27	-0.39	0.32	0.60	-0.15	-0.41	0.39	0.20	-0.45	0.88	-0.31	-0.25	-0.59	-0.40	-0.48	-0.47	0.09	-0.04	0.58	0.06	1.00

[Table /Fig-6]: Correlation matrix for water quality parameters in the bottled drinking water brands.

	pH	EC	TDS	TA	TH	Ca	Mg	F	Cl	SO4	Na	K	Cd	Co	Cr	Cu	Fe	Li	Mn	Ni	Pb	Sr	Zn
pH	1.00																						
EC	0.74	1.00																					
TDS	0.74	1.00	1.00																				
TA	0.49	0.33	0.34	1.00																			
TH	0.79	0.62	0.62	-0.15	1.00																		
Ca	0.77	0.89	0.89	-0.01	0.89	1.00																	
Mg	0.33	-0.26	-0.25	-0.32	0.57	0.15	1.00																
F	0.23	0.24	0.24	0.95	-0.40	-0.18	-0.56	1.00															
Cl	0.44	0.83	0.82	-0.26	0.70	0.91	-0.11	-0.31	1.00														
SO_4	0.04	-0.43	-0.43	-0.58	0.43	0.01	0.95	-0.76	-0.13	1.00													
Na	0.55	0.92	0.91	-0.07	0.69	0.93	-0.18	-0.13	0.98	-0.25	1.00												
K	-0.99	-0.78	-0.78	-0.59	-0.71	-0.74	-0.20	-0.36	-0.42	0.10	-0.55	1.00											
Cd	-0.92	-0.66	-0.66	-0.10	-0.96	-0.86	-0.56	0.17	-0.58	-0.35	-0.62	0.86	1.00										
Co	-0.10	0.32	0.32	0.63	-0.53	-0.14	-0.93	0.82	-0.02	-0.99	0.11	-0.05	0.43	1.00									
Cr	-0.84	-0.59	-0.59	0.06	-0.99	-0.85	-0.63	0.33	-0.61	-0.46	-0.61	0.76	0.99	0.54	1.00								
Cu	-0.99	-0.76	-0.76	-0.58	-0.72	-0.74	-0.23	-0.34	-0.41	0.07	-0.54	1.00	0.87	-0.02	0.77	1.00							
Fe	0.32	0.11	0.12	0.98	-0.33	-0.23	-0.30	0.96	-0.46	-0.54	-0.28	-0.42	0.07	0.62	0.23	-0.41	1.00						
Li	0.32	0.82	0.82	-0.21	0.54	0.82	-0.32	-0.21	0.98	-0.31	0.97	-0.33	-0.42	0.17	-0.44	-0.31	-0.40	1.00					
Mn	-0.97	-0.61	-0.62	-0.35	-0.85	-0.74	-0.53	-0.06	-0.38	-0.26	-0.47	0.93	0.96	0.31	0.91	0.94	-0.20	-0.23	1.00				
Ni	0.57	0.60	0.60	0.95	-0.01	0.24	-0.46	0.91	0.05	-0.72	0.24	-0.68	-0.21	0.73	-0.04	-0.66	0.86	0.12	-0.39	1.00			
Pb	-0.24	-0.36	-0.35	0.71	-0.77	-0.71	-0.42	0.82	-0.78	-0.50	-0.66	0.14	0.58	0.62	0.69	0.14	0.84	-0.67	0.33	0.52	1.00		
Sr	0.47	0.87	0.86	-0.18	0.68	0.91	-0.17	-0.23	1.00	-0.20	0.99	-0.47	-0.58	0.06	-0.59	-0.45	-0.38	0.98	-0.40	0.14	-0.72	1.00	
Zn	-0.99	-0.75	-0.76	-0.57	-0.72	-0.73	-0.25	-0.34	-0.40	0.05	-0.53	1.00	0.87	0.00	0.78	1.00	-0.41	-0.30	0.95	-0.65	0.15	-0.44	1.00

[Table/Fig-7]: Correlation matrix for water quality parameters in the drinking water sachet brands.

	pH	EC	TDS	TA	TH	Ca	Mg	F	Cl	NO3	SO4	Na	K
pH	1.000												
EC	0.811	1.000											
TDS	0.812	1.000	1.000										
TA	0.388	0.325	0.325	1.000									
TH	0.259	0.770	0.769	-0.002	1.000								
Ca	0.743	0.994	0.994	0.327	0.829	1.000							
Mg	-0.251	0.345	0.345	-0.298	0.864	0.435	1.000						
F	0.789	0.995	0.995	0.409	0.771	0.994	0.347	1.000					
Cl	-0.880	-0.435	-0.436	-0.314	0.224	-0.335	0.662	-0.404	1.000				
NO_3	0.816	1.000	1.000	0.350	0.760	0.993	0.330	0.996	-0.444	1.000			
SO_4	0.822	0.999	0.999	0.367	0.752	0.992	0.318	0.997	-0.452	1.000	1.000		
Na	0.786	0.999	0.999	0.314	0.796	0.997	0.383	0.995	-0.398	0.998	0.997	1.000	
K	0.379	-0.232	-0.231	0.058	-0.774	-0.338	-0.942	-0.267	-0.773	-0.224	-0.216	-0.272	1.000

[Table/Fig-8]: Correlation matrix for water quality parameters in canned drinking water brands.

	TUR	pH	EC	TDS	TA	TH	Ca	MG	F	Cl	NO3	SO4
TUR	1.000											
pH	-0.197	1.000										
EC	0.040	0.018	1.000									
TDS	-0.126	-0.100	0.904	1.000								
TA	0.088	-0.142	0.721	0.556	1.000							
TH	0.221	-0.303	0.815	0.800	0.689	1.000						
Ca	0.026	-0.114	0.733	0.584	0.776	0.804	1.000					
M_G	-0.221	0.023	0.458	0.253	0.672	0.393	0.781	1.000				
F	0.023	0.255	0.412	0.372	0.179	0.333	0.268	0.220	1.000			
Cl	-0.124	0.220	0.763	0.687	0.508	0.573	0.567	0.457	0.419	1.000		
NO_3	-0.053	-0.263	0.683	0.660	0.518	0.614	0.534	0.457	0.132	0.579	1.000	
SO_4	-0.082	0.024	0.712	0.610	0.458	0.516	0.584	0.516	0.334	0.606	0.532	1.000

[Table/Fig-9]: Correlation matrix for water quality parameters in bore well drinking water samples.
*EC: Electrical Conductivity; TDS: Total Dissolved Solids; TA: Total Alkalinity; TH: Total Hardness; Ca: Calcium;Mg: Magnesium;F:Fluorine;Cl: Chlorine;SO4: Sulphate; Na: Sodium;K:Potassium;Cd: Cadmium;Co: Cobalt;Cr: Chromium;Cu: Copper; Fe: Iron; Li: Lithium; Mn: Manganese; Ni: Nickel; Pb: Lead; Sr: Strontium; Zn: Zinc; NO3: Nitrate; TUR: Turbidity.

Copper and nickel in sachet water were found to be exceeding the acceptable limit in the present study. Drinking water with excess of copper may lead to gastrointestinal distress, liver and kidney damage. The major sources of copper in drinking water are corrosion of plumbing systems [15]. In Ghana a study conducted by Ackah et al., on sachet water found lead to be exceeding the WHO guidelines for majority of the samples [6]. In Delhi a study conducted by Hansa Kundu et al., on bottled water and sachet water found the quality of bottled water to be better than sachet water. The mean value of total coliform in bottled water was 0 whereas for sachet water it was 16.75 which showed the unhealthy nature of sachet water [1].

Calcium, magnesium and nickel in municipality tap water were exceeding the acceptable limit in the present study. Calcium from high-calcium water is beneficial to bone health by suppressing bone resorption [13]. A study conducted in Egypt by Mona et al., to compare the chemical quality of tap water with bottled water found that the mean concentrations of metals in bottled drinking water was within the acceptable levels and lower than maximum contaminated levels established by the United States environmental protection agency (USEPA). Tap water had slightly higher levels of lead, arsenic, cadmium, zinc and selenium [17].

Turbidity, pH, total dissolved solids, total alkalinity, total hardness, calcium, magnesium, fluoride and total coliform count of bore well water were exceeding the acceptable limit in the present study. Turbidity refers to fine suspended particles of clay, silt, organic and inorganic matter, plankton and other microscopic organisms. Bacteria, viruses and parasites such as *giardia* and *cryptosporidium* can attach themselves to the suspended particles in turbid water and cause health effects. These particles then interfere with disinfection by shielding contaminants from the disinfectant (e.g. chlorine) [18]. The term pH is a measure of the concentration of hydrogen ions in drinking water. pH control is necessary for satisfactory water clarification and disinfection. Drinking water with an elevated pH can cause skin, eye and mucous membrane irritation. Water with low pH values has unpleasant smell and foul taste [19]. Total dissolved solids (TDS) comprise inorganic salts (calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and some small amounts of organic matter that are dissolved in water. TDS in drinking-water originate from natural sources, sewage, urban run-off, industrial waste water, chemicals used in the water treatment process, and the nature of the piping used to convey the water. Health effects associated with the ingestion of TDS in drinking water have not been identified; however it makes the drinking water unpalatable [20]. Excess of drinking water hardness is not a health hazard, however higher water hardness may worsen sensorial characteristics of drinking water. While numerous studies suggest a correlation between hard water and lower cardiovascular disease mortality, no firm conclusions have been drawn [21].

Excessive consumption of fluoride may lead to increased likelihood of bone fractures, bone pain and tenderness. Children aged 8 years and younger exposed to excessive amounts of fluoride have an increased chance of developing pits in the tooth enamel and cosmetic effects to teeth [22]. A linear relationship exists between fluoride dose and enamel fluorosis. With increasing severity, the subsurface enamel as well as dentin becomes increasingly porous (hypomineralized). The more severe forms of dental fluorosis are subject to extensive mechanical breakdown of the tooth surface. Human and animal studies have shown that it is possible to develop dental fluorosis by exposure during enamel maturation [23]. Some fluoride compounds, such as sodium fluoride and fluorosilicates, dissolve easily into ground water as it moves through gaps and pore spaces between rocks. Fluoride also enters drinking water in discharge from fertilizers and aluminium factories [24]. The presence of total coliform in bore well water may be attributed to improper sanitation. Total coliform may causes diarrhoea, cramps, nausea, jaundice, headaches and fatigue [8]. A study conducted in Ilese-Ijebu by Soyingbe on bore well water. They found that turbidity, iron, manganese, hardness and zinc have exceeded while nitrate and lead values were within WHO standard, E-coli were not detected [25]. A study conducted by SN Ibe et al., in Uli Nigeria on bore well water, found that water from all the bore wells did not meet the world health standards for drinking [11]. A study conducted in Morbi-Malia, Gujarat by BM Bheshdadia et al., on underground drinking water found that TDS, salinity, phosphate, nitrate, pH, total hardness, chloride was higher than tolerance range [26]. In the present study only one drinking water sample from each type of source was collected and analysed. Instead samples collected at different intervals of time and an average value if taken would have been much better. This might be the possible limitation of the study. Further recommendations are made in this direction.

CONCLUSION

The physico-chemical quality of drinking water in Vikarabad from various sources was not within the acceptable limit. The bacterial quality of bore well water in 4 villages was exceeding the acceptable limit making them unfit for human consumption. Bottled water samples were found to be of relatively better quality. Bore well water samples were found to be having poor quality.

SUGGESTIONS

As most of the people of Vikarabad had to depend on bore well water because of lack of other drinking water facilities it becomes important for the authorities to monitor drinking water quality to safeguard consumer's health. The authorities can also take the initiatives to centralise the municipality tap water pipelines throughout Vikarabad mandal also that purified municipality tap water can be supplied to all the people.

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REFERENCES

[1] Ashish S, Hansa K, Basavaraj P. Physico-chemical and bacterial evaluation of packaged drinking water marketed in Delhi - potential public health implications. *J Clin Diagn Res.* 2014;8(3):246-50.

[2] Okonko IO, Adejoye OD, Ogunnusi TA, Fajobi, EA, Shittu OB. Microbiological and physicochemical analysis of different water samples used for domestic purposes in Abeokuta and Ojota, Lagos State, Nigeria. *African J. Biotechnology*. 2008a;7(3):617-21.

[3] Salehi I, Ghiasi M, Rahmani AR, Nouri Sepehr M, Kiamanesh M, Rafati L. Evaluation of microbial and physico-chemical quality of bottled water produced in Hamadan province of Iran. *J Food Qual Hazards Control.* 2014;21-24.

[4] Onweluzo JC, Akuagbazie CA. Assessment of the quality of bottled and sachet water Sold in Nsukka town. *Agro science J Trop Agric Food Environ Exten.* 2010;9(2):104-10.

[5] ARWSP guidelines [Internet] 1999 Apr 1 [updated 2011 Apr 11;cited 2015 Jan 15]. Available from: http:*//www.ctara.iitb.ac.in/water/references/rws/ARWSP guidelines.*

[6] Ackah M, Anim AK, Gyamfi ET, Acquah J, Nyarko ES. Assessment of the quality of sachet water consumed in urban townships of Ghana using physico-chemical indicators: a preliminary study. *Adv Appl Sci Res.* 2012;3(4):2120-27.

[7] Greenberg AE, Clesceri LS, Eaton AD. Standard methods for the examination of water and waste water. 18th edition. Washington D.C: U.S American Public Health Association. American Water Works Association and Water Pollution Control Federation; 1992.

[8] Indian standard drinking water - specification 10500. New Delhi: Bureau of Indian Standards; May 2012. 18p. IS 10500 : 2012

[9] Indian standard packaged drinking water - specification 14543. New Delhi: Bureau of Indian standards; May 2014. 24p. IS 14543 : 2014

[10] Harouny ME, Dakroory SE, Attalla S, Hasan N, Hegazy R. Chemical quality of tap water versus bottled water: evaluation of some heavy metals and elements content of drinking water in Dakhlia Governorate – Egypt. *The Inter J Nutr Wellness*. 2008;9(2):1-7.

[11] Ibe SN, Okplenye JI . Bacteriological analysis of borehole water in Uli, Nigeria. *Afr J Appl Zool & Environ Biol.* 2005;7:116-19.
[12] Mohammad MJ, Krishna PV, Lamma OA, Khan S. Analysis of water quality using limnological studies of Wyra reservoir, Khammam District, Telangana, India. *Int J Curr Microbiol App Sci*. 2015;4(2):880-95.
[13] Calcium and magnesium in drinking water [Internet] 2009 Nov 1[updated 2011 Nov 1;cited 2015 Jan 15]. Available from: http://www.*whqlibdoc.who.int/publications/2009/9789241563550_eng.*
[14] Nickel in drinking water [Internet] 2010 Oct 26 [updated 2012 Apr 11;cited 2015 Jan 15]. Available from: http://www.who.int/water_sanitation_health/gdwqrevision/nickel2005.
[15] Basic information about copper in drinking water [Internet] 2012 Jan 6 [updated 2013 Apr 11; cited 2015 Jan 15]. Available from: http://www.water .epa.gov/drink/contaminants/basicinformation/copper .cfm.
[16] Semerjian L. Quality assessment of various bottled waters marketed in Lebanon. *Environ Monit Assess.* 2011;172:275–85.
[17] El-Harouny MA, El-Dakroory SA, Attalla SM, Hasan NA, Hegazy R. Chemical quality of tap water versus bottled water: evaluation of some heavy metals and elements content of drinking water in Dakahlia governorate - Egypt. *Mansoura J Forensic Med Clin Toxicol.* 2008;16(2):1-15.
[18] Chlorination and turbidity. [Internet] [cited 2015 Jan 15]. Available from: https://www.tnrd.ca/content/chlorination-and-turbidity
[19] TDS and pH - safe drinking water foundation [Internet] 2010 Oct 26 [updated 2011 Apr 11;cited 2015 Jan 15]. Available from:http://*www.safewater.org/PDFS/resourcesknowthefacts/TDS_AND%20_pH.*
[20] Total dissolved solids in drinking water [Internet] 2008 Oct 16 [updated 2011 Apr 11;cited 2015 Jan 15]. Available from: http://*www.who.int/water_sanitation_health/dwq/chemicals/tds*.
[21] Hardness in drinking water [Internet] 2012 Nov 2 [updated 2013 May 2;cited 2015 Jan 15]. Available from: http://*www.who.int/water_sanitation_health/dwq/chemicals/hardness.*
[22] Community water fluoridation [Internet]. 2013 Jul 10 [updated 2015 Aug 17;cited 2015 Jan 15]. Available from: http://www.cdc.gov/fluoridation/factsheets/cwf_qa.htm
[23] Fejerskov O, Larsen MJ, Richards A, Baelum V. Dental tissue effects of fluoride. *Adv Dent Res.* 1994;8(1):15-31.
[24] Basic information about fluoride in drinking water [Internet] 2008 Dec 6 [updated 2014 May 4;cited 2015 Jan 15]. Available from: http://www.*water.epa.gov/drink/contaminants/basicinformation/fluoride.cfm*.
[25] Soyingbe AA, Salako SG, Hammed TB, Amusan T. The physico-chemical and microbiological analysis of borehole water samples in Ogun state college of health technology, Ilese-Ijebu. *Int J Dev Res.* 2014;4(10):2122-26.
[26] Bheshdadia BM, Chauhan MB, Patel PK. Physico-chemical analysis of underground drinking water in Morbi-Malia territor. *Curr World Environ.* 2012;7(1);169-73.

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