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Topic: ASSESSMENT OF DUG WELL WATER QUALITY
A Case Study of Raipur City, Chhattisgarh (India)

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INTRODUCTION

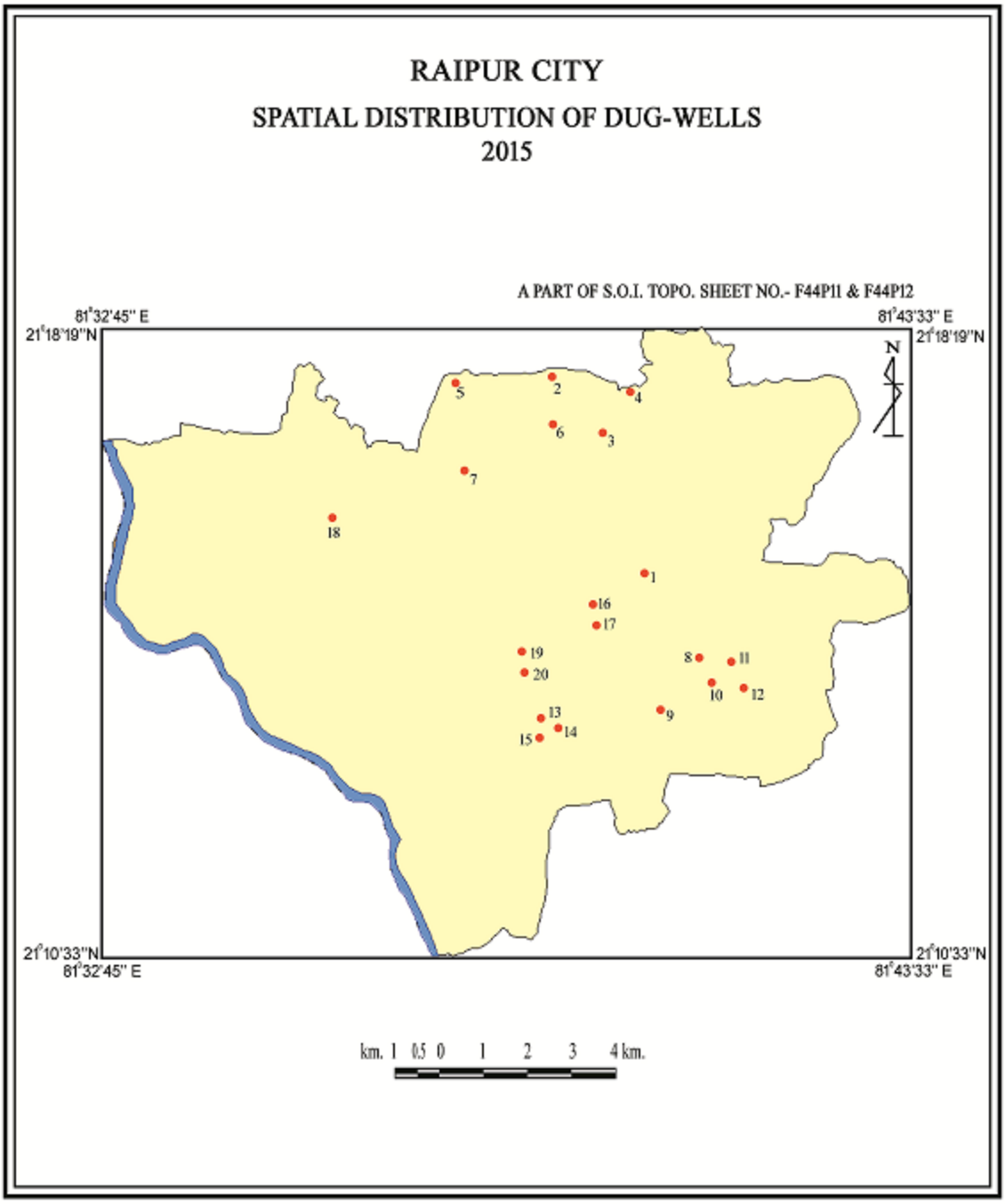
The traditional and still most common method of obtaining groundwater in rural area of the developing world is by means of dug wells. Its water is acquired by means of rope and bucket, Persian wheels and electric/diesel pump not only for domestic use, but also for irrigation purpose. In, India, it is believed to be sacred, and therefore, is used as one of the materials of Hindu pujas. But, now-a-days, the scenario of its use has drastically decreased favour of other methods of water availability for domestic and irrigation uses. One has to understand the importance groundwater of this juncture first.

Groundwater serves as a major source for drinking, domestic use, irrigation and industry. Groundwater is generally considered to be much cleaner than surface water (Patil and Patil, 2011). In many cases groundwater is polluted by the inflow of pollutants such as sewage and industrial wastewater (Freeze and Cherry, 1979). However, several factions such as discharge of industrial, agricultural and domestic water, land use practices, geological formation, rainfall patterns and infiltration rate affects the groundwater quality (Narayanpethkar and Deshpande, 2011).

The United Nations Report, 2015 revels that more than 3 million people die for water borne diseases annually in the World, and 1 lakh in India. In India, one third of 600 districts is not fit for drinking as the concentration of fluoride, iron and salinity etc. The water borne diseases like cholera, diarrhoea and jaundice are very common in Chhattisgarh. Near about 50,000 people have fallen Sick for use of degraded water from January to June in 2013. Quality assessment is earnestly necessary to have enjoyed water borne disease free health (Mukhopadhyay and Pal, 2010). The knowledge of hydro-geochemistry is very essential as it seeks to determine the origin of the chemical constituents in groundwater and the relationship between water and rock chemistry (Zaparozec, 1972).

OBJECTIVES

1. To find out the quality of dug well water.
2. To analyse water quality of dug wells during pre- and post-monsoon periods.


RAIPUR CITY
SPATIAL DISTRIBUTION OF DUG-WELLS
2015
A PART OF S.O.I. TOPO. SHEET NO.- F44P11 & F44P12
81°32'45" E
21°18'19"N
81°43'33" E
21°18'19"N
N
5
2
4
6
3
7
18
1
16
17
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8
11
10
12
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13
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15
21°10'33"N
81°32'45" E
21°10'33"N
81°43'33" E
km. 1 0.5 0 1 2 3 4 km.

Fig. No. : 1

MATERIALS AND METHODS

Ground water samples have been collected from 20 dug wells for two points of times, pre- and post- monsoon periods. The parameters of Total Dissolved Solids (TDS), Conductivity, Salinity, pH, Turbidity and DO of these samples were determined with the help of EI make Delux Water and Soil Analysis Kit Model 191. Sodium (Na) and Potassium (K) have been determined by Systronics Flame Photometer.

STUDY AREA

The study area Raipur City, Chhattisgarh (India), is included in the Survey of India topographical sheet numbers 64 G/11 and 64 G/12 which fall under the open series map (new map) numbers F 44 P11 and F 44 P 12. The City is located between 21^{o} 10' 33" N to 21^{o} 18' 19" N Latitude and 81^{o} 32' 45" E to 81^{o} 43' 33" E Longitude. The City has an altitude of 298 meters above mean sea level. It forms a part of the upper Mahanadi basin known as Chhattisgarh plain.

RESULTS AND DISCUSSION

Total Dissolved Solids (TDS)

The study reveals that TDS is low in most of the samples in both the periods, pre- and post-monsoon; the respective figures come to 36.85 & 45.00 per cent. Other hand the minimum percentage of sample, 2.00 per cent during pre- and 5.00 per cent during post-monsoon has been found in very low and high categories. Sample numbers 2 and 11 during pre-monsoon and 3 and 11 during post-monsoon has crossed the permissible limit as shown in Table 1.

Table 1 Raipur City: TDS of Dug Wells Water: Pre- & Post- Monsoon Periods.

Sl. No.	Range (ppt)	Categories	TDS (ppt)					
			Pre-monsoon			Post-monsoon		
			Sample no.	Total Sample	% of Sample	Sample no.	Total Sample	% of Sample
1	<0.4	Very Low	15,16	2	10.53	13	1	5
2	0.4-0.8	Low	12,13,14, 17,18,19, 20	7	36.83	1,5,14, 15,16,17, 18,19,20	9	45
3	0.8-1.2	Medium	3,4,6,9,10	5	26.32	2,4,6,7, 8,10,12	7	35
4	1.2-1.6	Moderately High	1,7,8	3	15.79	9,11*	2	10
5	1.6 & Above	High	2*,11*	2	10.53	3*	1	5
Total			-	19	100	-	20	100

N.B. – * (These samples has crossed the permissible limit and not suitable for drinking)

The principal ions contributing to TDS are carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium (EPA, 1976). Organic matter and various dissolved gases are also present in small amount (Jain et al., 2010). TDS- Palatability of water decreases when concentrations exceed from permissible limit and may cause "gastro-intestinal" irritation (ISI, 1983).

TDS varies from 0.35 ppt to 1.95 ppt and average is 0.95 ppt during pre-monsoon. Other hand it's varies from 0.34 ppt to 1.77 ppt and average is 0.85 ppt during post-monsoon. With respect to TDS, 10.53 per cent of samples during pre- and 10.00 per cent during post-monsoon exceeding the permissible limit and it's not suitable for drinking (Table 2). Limit of TDS concentration in drinking water is specified as 1.5 ppt (Wilcox, 1955).

Coefficient of variation of TDS in the observed samples is 45.98 per cent during pre-monsoon and 47.98 per cent during post-monsoon periods. Total Dissolved Solids shows highly positive correlation with conductivity (r = 0.980 during pre-monsoon and r = 0.837 during post-monsoon) and salinity (r = 0.968 during pre-monsoon and r = 0.759 during post-monsoon).

Table 2 Raipur City: Statistical parameters, Standard limits and Hydro- geochemical samples: Pre- & Post-monsoon Periods.

Variables	Minimum		Maximum		Mean		Standard Deviation		C.V. (%)		Permissible Limits	% of Samples exceeding the limits	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post		Pre	Post
TDS (ppt)	0.35	0.34	1.95	1.77	0.95	0.85	0.43	0.41	45.06	47.98	1.5	10.53	10.0
Conductivity (ms/cm)	0.54	0.52	2.90	2.43	1.42	1.20	0.68	0.52	47.99	43.33	1.5	42.11	30.0
Salinity (ppt)	0.2	0.4	2.6	2.0	1.15	1.08	0.67	0.51	58.30	47.61	-	-	-
pH	6.94	7.07	8.52	7.93	7.63	7.51	0.44	0.25	5.83	3.35	6.5-8.5	5.26	Nil
Turbidity (NTU)	-1	-3	14	3	1.53	-0.25	3.73	1.59	244.53	634.12	10.0	5.26	Nil
Na (ppm)	32	29	155	165	112.84	106.68	33.94	33.83	30.07	31.72	200	Nil	Nil
K (ppm)	21	7	125	110	47.89	39.00	30.92	29.44	64.57	75.49	-	-	-

Electrical Conductivity (EC)

Electrical Conductivity is a measure of ability of the materials to conduct an electrical current so that the higher EC indicates enrichment of salty in the ground water (Subba Rao et al., 2011). Conductivity concentration varies from 0.54 ms/cm to 2.90 ms/cm during pre-monsoon and 0.52 ms/cm to 2.43 ms/cm during post-monsoon. Like TDS the concentration of conductivity of well water is slightly lower during post-monsoon period than pre-monsoon period.

Table 3 Raipur City: Conductivity of Dug Wells Water: Pre- & Post- Monsoon Periods.

Sl. No.	Range (ms/cm)	Categories	Conductivity (ms/cm)					
			Pre-monsoon			Post-monsoon		
			Sample no.	Total Sample	% of Sample	Sample no.	Total Sample	% of Sample
1	<0.6	Very Low	15,16	2	10.53	13	1	5
2	0.6-1.2	Low	12,13,14, 17,18,19, 20	7	36.83	1,3,5,7 14,15,16 17,18,19 20	11	55
3	1.2-1.8	Medium	1*,3*,4,6, 10*	5	26.32	2*,4*,6, 8*,10,12*	6	30
4	1.8-2.4	Moderately High	7*,8*,9*	3	15.79	9*	1	5
5	2.4 & Above	High	2*,11*	2	10.53	11*	1	5
Total			-	19	100	-	20	100

Average conductivity of the samples during pre- and post-monsoon periods is 1.42 ms/cm and 1.20 ms/cm respectively. With respect to conductivity, 42.11 per cent of samples during pre- and about 30 per cent of samples during post-monsoon has exceeding the permissible limit and not suitable for drinking. The permissible limit of conductivity for drinking water is specified as 1.5 ms/cm (WHO, 1963). The coefficient of variation of conductivity in the observed samples is 47.99 per cent during pre-monsoon and 43.33 per cent during post-monsoon periods have been found.

Most of the samples, 36.85 per cent during pre-monsoon and 55.00 per cent during post-monsoon have been found in low category of conductivity. On the other hand, a few samples (2.00 per cent) during pre-monsoon display both very low and high categories. During post-monsoon, both the upper categories of moderately high and high categories comprises of 5 per cent samples each. Sample numbers 1, 2, 3 and 7 to 11 during pre-monsoon and 2, 4, 8, 9, 11 & 12 during post-monsoon has cross the permissible limit as shown in Table 3. Electrical Conductivity shows highly positive correlation with salinity (r = 0.943 during pre-monsoon (Table 4) and r = 0.941 during post-monsoon (Table 7)).

Table 4 Raipur City: Correlation matrix of hydro-geochemical variables: pre-monsoon Period.

Parameters	TDS	Conductivity	Salinity	pH	Turbidity	Na	K
TDS	1						
Conductivity	0.980	1					
Salinity	0.968	0.943	1				
pH	0.122	0.095	0.043	1			
Turbidity	0.049	0.012	0.141	-0.226	1		
Na	0.289	0.231	0.322	0.252	0.252	1	
K	0.109	0.108	0.186	-0.639	-0.011	-0.133	1

Salinity

Maximum samples during pre- and post-monsoon periods, 42.10 per cent and 45.00 per cent respectively have been found in medium category of salinity. Opposed to it, hardly 1 per cent sample during pre-monsoon has been found under moderately high category. This picture has got reverted in case of post-monsoon where two categories of cover only about 5 per cent samples. So far as salinity is concerned, more than one-third samples during pre-monsoon and about one-sixth samples during post-monsoon is not suitable for drinking as shown in Table 5.

Table 5 Raipur City: Salinity of Dug Wells Water: Pre- & Post- Monsoon Periods.

Sl. No.	Range (ppt)	Categories	Salinity (ppt)					
			Pre-monsoon			Post-monsoon		
			Sample no.	Total Sample	% of Sample	Sample no.	Total Sample	% of Sample
1	<0.5	Very Low	13,15,16	3	15.79	1,13	2	10
2	0.5-1.0	Low	12,14,17,19, 20	5	26.32	3,5,7,14, 15,16,17	7	35
3	1.0-1.5	Medium	1*,3,4, 6,8*,9*, 10,18*	8	42.10	2,4,6,8*,10 12,18,19,20	9	45
4	1.5-2.0	Moderately High	7*	1	5.26	9*	1	5
5	2.0 & Above	High	2*,11*	2	10.53	11*	1	5
Total			-	19	100	-	20	100

Salinity varies from 0.2 ppt to 2.6 ppt during pre-monsoon and 0.4 ppt to 2.0 ppt during post-monsoon. Average salinity is 2.6 ppt during pre-monsoon and 2.0 ppt during post-monsoon. Maximum and also average value of salinity is found slightly lower during post-monsoon than pre-monsoon. Standard deviation is 0.67 during pre- and 0.51 during post-monsoon. Coefficient of variation of salinity in the observed samples in the study area is more than 50 per cent during pre-monsoon and 47.61 per cent during post-monsoon.

Potential Hydrogen (pH)

pH is denoting to the character of acidity or alkalinity of water. Natural water (H_2O) contains H^+ and OH^- ions. But the process of disassociation called hydrolysis takes place in water becomes acidic (pH < 7), when H^+ ions are in excess then OH^- ions and becomes alkaline (pH > 7) when reverse is the case. In the natural water pH is 7; in this water the concentration of H^+ and OH^- ions are equal (Sundaraiah, et al., 2013). In ground water, mainly the pH value is controlled by CO_2-CO_3-HCO_3 equilibrium.

Table 6 Raipur City: pH of Dug Wells Water: Pre- & Post- Monsoon Periods.

Sl. No.	Range	Categories	pH					
			Pre-monsoon			Post-monsoon		
			Sample no.	Total Sample	% of Sample	Sample no.	Total Sample	% of Sample
1	<7.0	Very Low	18	1	5.26	00	00	00
2	7.0-7.5	Low	1,8,9,10, 11,12,14,17	8	42.10	1,3,4,5,7, 8,14,15,17 18,20	11	55
3	7.5-8.0	Medium	6,13,15,16 1	5	26.32	2,6,9,10,11, 12,13,16,19	9	45
4	8.0-8.5	Moderately High	2,3,7,20	4	21.06	00	00	00
5	8.5 & Above	High	4*	1	5.26	00	00	00
Total			-	19	100	-	20	100

pH concentration varies from 6.94 to 8.52 during pre-monsoon and 7.07 to 7.93 during post-monsoon. Average value of pH during pre-monsoon is 7.63 and post monsoon is 7.51. With respect to pH 5.26 per cent samples during pre-monsoon has crossed the permissible limit and not suitable for drinking. It is found that none of the samples during post-monsoon croses the permissible limit of pH standard. The permissible limit of pH concentration for drinking water is 6.5 to 8.5 (ISI, 1983).

Coefficient of variation of pH in the observed samples is very low during pre- and post-monsoon periods, 5.83 per cent and 3.35 per cent respectively. Like TDS and conductivity, a high phase of samples during pre- and post-monsoon periods (42.10 per cent and 55.00 per cent respectively) has been found in low categories. No sample is found in the moderately high and high categories during post-monsoon period. During pre-monsoon only sample number 4 is exceed the permissible limit so it's not suitable for drinking as shown in Table 6.

Table 7: Raipur City: Correlation matrix of hydro-geochemical variables: post-monsoon period.

Parameters	TDS	Conductivity	Salinity	pH	Turbidity	Na	K
TDS	1						
Conductivity	0.837	1					
Salinity	0.759	0.941	1				
pH	0.270	0.339	0.319	1			
Turbidity	0.162	0.182	-0.008	0.204	1		
Na	0.199	0.220	0.177	-0.232	0.270	1	
K	0.439	0.672	0.711	0.345	-0.019	-0.106	1

Turbidity

Turbidity concentration varies from -1 to 14 NTU (Nephelometric Turbidity Unit) during pre-monsoon and -3 to 3 NTU during post monsoon. Average turbidity is 1.53 NTU during pre- and -0.25 NTU during post-monsoon. With respect to turbidity 5.26 per cent samples during per-monsoon has crossed the permissible limit. The permissible limit of turbidity concentration in drinking water is 10 NTU (BIS, 1991). The coefficient of variation of turbidity in the observed samples is very high (244.53 per cent during pre-monsoon and 634.12 per cent during post-monsoon) during both periods.

Table 8 Raipur City: Turbidity of Dug Wells Water: Pre- & Post- Monsoon Periods.

Sl. No.	Range (NTU)	Categories	Turbidity (NTU)					
			Pre-monsoon			Post-monsoon		
			Sample no.	Total Sample	% of Sample	Sample no.	Total Sample	% of Sample
1	<1.0	Very Low	2,3,4,6,7,8, 10,12,14, 16,17,19	12	63.16	1,2,3,4,7, 8,9,10,12 To 20	17	85
2	1.0-1.5	Low	9,11,13	3	15.79	11	1	5
3	1.5-2.0	Medium	15	1	5.26	00	00	00
4	2.0-2.5	Moderately High	00	00	00	00	00	00
5	2.5 & Above	High	1*,18,20	3	15.79	5,6	2	10
Total			-	19	100	-	20	100

The maximum sample, 63.16 per cent during pre-monsoon and 85.00 per cent during post-monsoon has been found in very low category of turbidity. No sample is found in moderately high category during both periods. Only one sample (sample number 1) is cross the permissible limit as shown in Table 8.

Sodium (Na)

Sodium concentration varies from 32 ppm to 155 ppm during pre-monsoon and 29 ppm to 165 ppm during post-monsoon. Average sodium is 112.84 ppm during pre- and 106.68 ppm during post-monsoon in dug wells due to chemical weathering of calcium bentonite in limestone.

Table 9 Raipur City: Sodium of Dug Wells Water: Pre- & Post- Monsoon Periods.

Sl. No.	Range (ppm)	Categories	Na (ppm)					
			Pre-monsoon			Post-monsoon		
			Sample no.	Total Sample	% of Sample	Sample no.	Total Sample	% of Sample
1	<30	Very Low	00	00	00	16	1	5
2	30-60	Low	16,17	2	10.53	17	1	5
3	60-90	Medium	10	1	5.26	8,9,10,20	4	20
4	90-120	Moderately High	7,8,9,11, 12,13,20	7	36.83	1,3,5,7, 12,13,19	7	35
5	120 & Above	High	1,2,3,4,6,14, 15,18,19	9	47.38	2,4,6,11, 14,15,18	7	35
Total			-	19	100	-	20	100

No sample is found which is crossed the permissible limit in the study area during both periods. Permissible limit of sodium in drinking water is 200 ppm (CDWQ, 1996). Coefficient of variation of Na in the observed samples is 30.07 per cent during pre-monsoon and 31.70 per cent during post-monsoon. The maximum sample, 47.38 per cent during pre-monsoon has found in high category and 35 per cent sample during post monsoon has found in the both moderately high and high categories (Table 9). According to sodium all samples are in permissible limit. Sodium shows negative correlation with pH (r = - 0.232) during post-monsoon period.

Potassium (K)

Potassium intoxication by ingestion is rare, because potassium is rapidly excreted in the absence of pre-existing kidney damage and because large single doses usually induce vomiting (Gosselin, Smith & Hodge, 1984). Potassium concentrations vary from 21 ppm to 125 ppm during pre-monsoon period and 7 ppm to 110 ppm during post-monsoon period. The average of potassium during pre-monsoon is 47.89 ppm and 39.00 ppm during post-monsoon. The Coefficient of variation of potassium in the study sample is very high, 64.57 per cent during pre-monsoon and 75.49 per cent during post monsoon has been found.

Table 10 Raipur City: Potassium of Dug Wells Water: Pre- & Post- Monsoon Periods.

Sl. No.	Range (ppm)	Categories	K (ppm)					
			Pre-monsoon			Post-monsoon		
			Sample no.	Total Sample	% of Sample	Sample no.	Total Sample	% of Sample
1	<25	Very Low	6,7	2	10.53	2,3,4,5,7, 16,17	7	35
2	25-50	Low	1,2,3,4,8,9, 13,14,15,16, 17,19,20	13	68.42	1,6,8,12, 13,14,15, 19,20	9	45
3	50-75	Medium	18	1	5.26	18	1	5
4	75-100	Moderately High	11	1	5.26	10	1	5
5	100 & Above	High	10,12	2	10.53	9,11	2	10
Total			-	19	100	-	20	100

The maximum sample (68.42 per cent and 45 per cent respectively) of potassium during pre- and post-monsoon are found in low category, and minimum samples (1 per cent and 5 per cent respectively) are found in medium and moderately high category as shown in Table 10.

Potassium shows highly negative correlation with pH (r = - 0.639), & also negative with turbidity (r = - 0.011) and sodium (r = - 0.133) during pre-monsoon period. Also post-monsoon period the negative correlation is found between sodium (r = - 0.106) and turbidity (r = - 0.019) and sodium with potassium (r = - 0.106).

CONCLUSION

The study reveals that the 50 per cent of dug wells during pre-monsoon and 35 per cent of dug wells during post-monsoon is not suitable for drinking. During pre-monsoon the ground water level goes down up to 40 feet below the ground level. Declining ground water contains high quantity of minerals, chemicals and dissolved rocks. It is also noted that there is substantial increase of the physico-chemical parameters in ground water during pre-monsoon (cent per cent samples) as compared to that of the post-monsoon period. Despite that dug wells water is suitable for domestic uses (except drinking).

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