Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2015, 7(12):424-429

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Physico-chemical investigation of ground water qualities of some areas of Imphal West district of Manipur during pre-monsoon–3rd phase

Nandababu Singh Laishram

Department of Chemistry, D. M. College of Science, Imphal, Manipur, India

---

ABSTRACT

Fifteen ground water samples (S-1 to S-15) were collected from different hand pumps of Imphal West district of Manipur during pre-monsoon period of 2015. They were analyzed for physico-chemical parameters such as temperature, p^H, TDS (total dissolved solids), electrical conductivity (EC), total alkalinity (TA) (and hence CO_3^{2-} and HCO_3^-), total hardness (TH), Ca^{2+}, Mg^{2+}, Na^+, K^+ and Cl^-. Most of the parameters for many of the ground water samples, have their values/concentrations below the acceptable and threshold limits of BIS standard for drinking water as well as that of WHO. But the total alkalinity values for S-1 to S-15, total harness values for S-7 to S-9 and S-12, concentrations of Mg^{2+} for S-7, S-9 and S-12, concentration of Na^+ for S-3, S-14 and S-15, and concentration of Cl^- for S-3 are above their corresponding acceptable limits but below the permissible limits of BIS standard for drinking water and threshold limit of WHO (in case of Na^+). However, ground waters (S-1 to S-15) are fit for drinking in absence of alternate sources. But some suitable treatments are necessary so as to keep the values/concentrations of the above mentioned parameters below their corresponding acceptable limits/threshold limit of BIS standard for drinking water and that of WHO. All the ground water (S-1 to S-15) are fit for other domestic and irrigation purposes. Further correlation coefficient data reveals that high TDS values for different ground water samples are due to presence of $NaHCO_3$, NaCl, $KHCO_3$ and KCl mainly. Again high values of total alkalinity for different ground waters, are due to presence of $NaHCO_3$ and $KHCO_3$ mainly in such ground waters. Further, both Ca^{2+} and Mg^{2+} show strong positive correlations with total hardness (r=0.974 and 0.984 respectively) showing dependence of total hardness (TH) on concentrations of both Ca^{2+} and Mg^{2+}.

Keywords: Physico-chemical parameters, drinking, irrigation, BIS, WHO and correlation co-efficient.

INTRODUCTION

All over the world, the population growth increases day by day. As a result of it, rate of urbanization as well as expansion of urban areas increase leading to decrease in many surface water bodies in numbers as well as in area [1]. This is due to the encroachment of such surface water bodies for construction of new houses, buildings, offices, institutions, commercial areas etc. Consequently, it leads to more demand for ground water to meet the requirements for people for drinking, other domestic, irrigation, industrial purposes etc.

Ground water is about 0.6% of the total global water resources and out of this, only 0.3% is extractable economically [2]. Such ground waters may not always be safe for drinking, other domestic, irrigation and industrial purposes. It is, therefore, necessary to monitor the qualities of such ground water from time to time. With a view to this objective, many researchers of different countries, had carried out extensive researches on qualities of ground water so as to examine whether such ground waters are fit for drinking, other domestic, irrigation and industrial purposes [3–7].In India also, many researchers of different states, had carried out extension investigations on ground water qualities for drinking, other domestic and irrigation purposes mainly [8–14].

The present aim of this research work is to carry out physico-chemical investigations on ground water qualities of some areas of Imphal West district of Manipur during pre-monsoon period (April-May) of 2015.

EXPERIMENTAL SECTION

All the chemicals were of AR grade and were used as received. Fifteen ground water samples were collected in well sterilized polythene bottles of one litre capacity each from the hand pumps of fifteen different locations of Imphal West district during pre-monsoon (April-May) of 2015. The different locations along with their geographical positions (measured with a GPS instrument), are detailed below in table – 1 :

Table – 1 : Locations of different sampling sites for different ground water samples

Sample code no.(with source)	Locations of different sampling sites	Longitude	Latitude
S – 1(Hand Pump)	Ningombam Khul Anouba Chingya (1),(near foothill)	$93^0 54' 21.80''$E	$24^0 44' 45.06''$N
S – 2(Hand Pump)	Ningombam Chingya Leikai (2), (near foothill)	$93^0 54' 21.10''$E	$24^0 44' 56.15''$N
S – 3(Hand Pump)	Hiyangthang Lairembi Mamang	$93^0 54' 16.10''$E	$24^0 43' 35.87''$N
S – 4(Hand Pump)	Hiyangthang Mayai Leikai(Lairembi Maning)	$93^0 54' 07.67''$E	$24^0 43' 36.74''$N
S – 5(Hand Pump)	Naran Konjil Mamang Leikai (1),(near foothill)	$93^0 55' 28.72''$E	$24^0 43' 35.82''$N
S – 6(Hand Pump)	Naran Konjil Mamang Leikai (2)	$93^0 55' 23.72''$E	$24^0 43' 47.79''$N
S – 7(Hand Pump)	Naran Konjil Mayai Leikai (1)	$93^0 55' 20.67''$E	$24^0 43' 53.48''$N
S – 8(Hand Pump)	Naran Konjil Mayai Leikai (2),(near foothill)	$93^0 55' 07.38''$E	$24^0 43' 57.51''$N
S – 9(Hand Pump)	Naran Konjil Mayai Leikai (3),(near foothill)	$93^0 55' 05.51''$E	$24^0 43' 52.01''$N
S – 10(Hand Pump)	Naran Konjil Mayai Leikai (4),(Champrabon)	$93^0 54' 56.31''$E	$24^0 43' 44.39''$N
S – 11(Hand Pump)	Naran Konjil Makha Leikai (1)	$93^0 54' 53.78''$E	$24^0 43' 33.74''$N
S – 12(Hand Pump)	Naran Konjil Makha Leikai (2)	$93^0 54' 52.08''$E	$24^0 43' 28.59''$N
S – 13(Hand Pump)	Takhellambam Konjil (1),(near Takhellambam Primary School)	$93^0 54' 37.50''$E	$24^0 43' 14.03''$N
S – 14(Hand Pump)	Takhellambam Konjil (2),(near paddy field)	$93^0 54' 37.69''$E	$24^0 43' 23.41''$N
S – 15(Hand Pump)	Takhellambam Konjil (3),(near foothill)	$93^0 54' 32.88''$E	$24^0 43' 34.11''$N

For sampling and preservation of samples (S-1 to S-15), strict guidelines were followed [15]. The ground water samples (S-1 to S-15) were analyzed for physico-chemical parameters such as temperature, p^H, TDS (total dissolved solids), electrical conductivity (EC), total alkalinity (TA), CO_3^{2-}, HCO_3^-, total hardness (TH), Ca^{2+}, Mg^{2+}, Na^+, K^+ and Cl^-. The First four parameters – temperature, p^H, TDS and electrical conductivity were measured during sampling while parameters like total alkalinity, total hardness, Ca^{2+} and Cl^- were determined in departmental research laboratory using standard methods [15]. Concentrations of CO_3^{2-} and HCO_3^- were found out by calculation from total alkalinity values for different ground water samples while that of Mg^{2+} was calculated from the difference of total hardness and calcium hardness values for each ground water sample. The concentrations of both Na^+ and K^+ for each ground water sample, were determined using a flame photometer. Different instruments and brief methods used for measurements and determinations of various physico-chemical parameters, are detailed in table-2 given below :

Table-2 : Instruments and brief methods used for measurements and determinations of physico-chemical parameters of ground water samples

Physico-chemical parameters measured / determined	Instruments and brief methods used
Temperature	TDS Meter (TDS-3) (TDS/Temp.) (HIMEDIA, India)
pH	pHep® Pocket-sized pH Meter (HI98107) (HANNA Instruments, Romania)
TDS (Total dissolved solids)	TDS Meter (TDS-3) (TDS/Temp.) (HIMEDIA, India)
Electrical conductivity (EC)	Conductivity Tester (Dist 3: HI 98303) (HANNA Instruments, Romania)
Total alkalinity (TA)	Titrimetric method with standard HCI solution using phenolphthalein and methyl orange indicators
CO_3^{2-} and HCO_3^-	By calculation method from total alkalinity values
Total hardness (TH)	EDTA titrimetric method (using Eriochrome Black T Indicator)
Calcium (Ca^{2+})	EDTA titrimetric method (using Murexide indicator)
Magnesium (Mg^{2+})	By calculation method
Sodium (Na^+) and Potassium (K^+)	Flame Photometer 128 (Systronics, India)
Chloride (Cl^-)	Argentometric titrimetric method (Using K_2Cr0_4 indicator solution)

Values of parameters such as RSC (residual sodium carbonate) and SAR (sodium adsorption ratio) which were used for ascertaining irrigation water quality for ground waters (S-1 to S-15), were calculated using the relationships [16-17] :

$$\text{RSC} = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

$$\text{and SAR} = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$, where ionic concentrations were expressed in milli-equivalents/litre (meq/L).

RESULTS AND DISCUSSION

All the fifteen ground water samples (S-1 to S-15), are found to colourless and odourless. The experimentally found values for different physico-chemical parameters for the fifteen ground water samples (S-1 to S-15), are shown in table – 3 given below :

Table – 3 : Values of physico-chemical parameters for ground water samples

Sample Code No.	Temperature (^{0}C)	pH	TDS (mg/L)	Electrical conductivity (EC) (μ S/Cm)	Total alkalinity (TA) (as $CaCO_3$) (mg/L)	CO_3^{2-} (mg/L)	HCO_3^- (mg/L)	Total hardness (TH) (as $CaCO_3$) (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	Cl^- (mg/L)
S-1	22.3	7.1	375	849	439.4	0	536.1	198	40.9	23.3	112.4	1.4	39.7
S-2	22.5	7.2	334	760	434.3	0	529.8	158	28.1	21.4	109.4	2.1	5.7
S-3	22.3	7.3	778	1691	535.3	0	653.1	164	28.8	22.4	303.3	1.8	286.4
S-4	22.3	7.2	456	1023	510.1	0	622.3	176	29.7	24.8	189	2	68.1
S-5	23.8	7.4	360	824	434.3	0	529.8	60	11.2	7.8	176.1	1.5	29.8
S-6	23.5	7.3	326	776	363.6	0	443.6	160	36.1	17	109.8	0.9	42.5
S-7	23.8	7.2	461	1062	313.1	0	382	300	54.5	39.9	104.9	1.3	173
S-8	23.9	7.3	240	576	303	0	369.7	224	40.9	29.6	40.1	0.7	15.6
S-9	24.5	7.3	414	944	363.6	0	443.6	220	36.9	31.1	115.3	1.1	119.1
S-10	23.3	7.4	199	471	262.5	0	320.3	174	32.1	22.8	37.5	0.9	5.7
S-11	23.5	7.2	211	503	277.5	0	338.6	172	31.3	22.8	43.6	1	7.1
S-12	23.2	7.1	403	926	333.3	0	406.6	280	50.5	37.4	95.6	1.2	114.9
S-13	24	7.5	407	929	343.4	24.2	369.7	110	24.8	11.7	162.4	1.6	119.1
S-14	23.3	7.7	546	1235	500	18.2	573	58	10.4	7.8	234.8	1.2	144.6
S-15	23.8	7.4	504	1150	479.8	12.1	560.7	154	26.5	21.4	206.5	1	121.9

On the basis of the above table-3, the following discussion has been made :

Temperature :
The temperatures for the fifteen ground water samples (S-1 to S-15) are in the range 22.3 – 24.5^{0}C (table-3). S-9 has highest temperature (24.5^{0}C) while those of S-1, S-3 and S-4 are lowest (22.3^{0}C).

pH values :
The pH values for the fifteen ground water samples (S-1 to S-15) range from 7.1 – 7.7 (table-3). All these pH values for the fifteen ground waters are within the acceptable limit (6.5 – 8.5) of BIS standard for drinking water as well as that of WHO [18-19]. S-1 and S-12 have lowest pHvalue (7.1) while S-14 has highest value of it (7.7). All the ground waters (S-1 to S-15) are very slightly alkaline in nature as their pH values are greater than 7.

TDS (Total dissolved solids) :
The TDS values for the fifteen ground waters (S-1 to S-15) are in the range 199 – 778 mg/L (table-3). S-10 has the lowest value of TDS (199 mg/L) while S-3 has highest value of it (778 mg/L).The TDS values for S-1, S-2, S-4 to S-13 are below the acceptable limit (500 mg/L) of BIS standard for drinking water while that S-3, S-14 and S-15 are above the acceptable limit but below the permissible limit (2000 mg/L) of BIS standard for drinking water [18].

As all the TDS values for all the ground waters (S-1 to S-15) are less than 1000 mg/L, they may be used for other domestic purposes [20].

Electrical conductivity (EC) :
The electrical conductivity values for all the fifteen ground water samples (S-1 to S-15) are in the range 471 – 1691 μS /cm(table-3). S-10 has the lowest value of electrical conductivity (471 μS /cm) while that of S-3 is highest (1691 μS /cm).

Total alkalinity (TA) :
The total alkalinity values for the fifteen ground water samples (S-1 to S-15) range from 262.5 mg/L to 535.3 mg/L (table-3). All the total alkalinity values for the fifteen ground water (S-1 to S-15) are above the acceptable limit (200 mg/L) but below the permissible limit (600 mg/L) of BIS standard for drinking water [18].

CO_3^{2-} and HCO_3^- :

The concentrations of carbonate (CO_3^{2-}) for S-1 to S-12 are found to be zero but for S-13 to S-15, the concentrations of CO_3^{2-} are 24.2 mg/L, 18.2 mg/L and 12.1 mg/L respectively (table-3).

However, concentrations of HCO_3^- for the fifteen ground waters (S-1 to S-15) are in the range 320.3 – 653.1 mg/L (table-3). S-10 has lowest concentration of HCO_3^- (320.3 mg/L) while that of S-3 is highest (653.1 mg/L).

Total hardness (TH) :
The total hardness values for the fifteen ground waters (S-1 to S-15) range from 58 – 300 mg/L (table-3). S-1 to S-6, S-10, S-11 and S-13 to S-15 have total hardness values below the acceptable limit (200 mg/L) while S-7 to S-9 and S-12 have total hardness values above the acceptable limit but below the permissible limit (600 mg/L) of BIS standard for drinking water [18]. Further, S-5 and S-14 belong to soft water category (0 – 75 mg/L); S-13 belongs to moderately hard water category (75 – 150 mg/L) while S-1 to S-4, S-6 to S-12 and S-15 belong to hard water category(150 – 300 mg/L) [20].

Calcium (Ca^{2+}) :
The concentrations of Ca^{2+} for the fifteen ground water samples (S-1 to S-15) are in the range 10.4 – 54.5 mg/L (table-3). All these concentration values for the fifteen ground water samples, are below the acceptable limit (75 mg/L) of BIS standard for drinking water [18]. S-14 has lowest concentration of Ca^{2+} (10.4 mg/L) while that of S-7 is highest (54.5 mg/L).

Magnesium (Mg^{2+}) :
The concentrations of Mg^{2+} for the fifteen ground water samples (S-1 to S-15) range from 7.8 mg/L to 39.9 mg/L (table-3). The concentrations of Mg^{2+} for S-1 to S-6, S-8, S-10, S-11 and S-13 to S-15 are below acceptable limit (30 mg/L) of BIS standard for drinking water while those of S-7, S-9 and S-12 are above the acceptable limit but below the permissible limit (100 mg/L) of BIS standard for drinking water [18].

Sodium (Na^{+}) :
Regarding the sodium contents for different ground water samples (S-1 to S-15), the concentrations of Na^{+} are in the range 37.5 – 303.3 mg/L (table-3). S-10 has lowest concentration of Na^{+} (37.5 mg/L) while that of S-3 is highest (303.3 mg/L). S-1, S-2 and S-4 to S-13 have concentrations of Na^{+} below the threshold limit (200 mg/L) of WHO while that of S-3, S-14 and S-15 are above it [19].

Potassium (K^{+}) :
The concentrations of K^{+} for different ground water samples (S-1 to S-15) range from 0.7 mg/L to 2.1 mg/L (table-3). Thus, all the ground waters (S-1 to S-15), have low concentrations of K^{+}. S-8 has lowest concentration of K^{+} (0.7 mg/L) while that of S-2 is highest (2.1 mg/L).

Chloride (Cl^{-}) :
The concentrations of Cl^{-} for the fifteen ground water samples (S-1 to S-15) are in the range 5.7 – 286.4mg/L (table-3). S-2and S-10 have lowest concentration of Cl^{-} (5.7 mg/L) while that of S-3 is highest (286.4 mg/L). S-1, S-2 and S-4 to S-15 have concentrations of Cl^{-} below the acceptable limit (250 mg/L) while S-3 has concentration of Cl^{-} above the acceptable limit but below the permissible limit (1000 mg/L) of BIS standard for drinking water [18].

Ground water quality for irrigation :
The values of RSC (residual sodium carbonate) and SAR (sodium adsorption ratio) for the fifteen ground water samples (S-1 to S-15) are shown in table-4 given below :

Table-4 : Values of RSC and SAR for ground water samples

Sample code no.	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15
RSC (meq/L)	4.83	5.52	7.43	6.68	7.48	4.07	0.26	1.59	2.87	1.77	2.11	1.07	4.67	8.84	6.51
SAR	3.5	3.8	10.3	6.2	9.9	3.8	2.6	1.2	3.4	1.2	1.4	2.5	6.7	13.4	7.2

The values of RSC for S-1 to S-15, are in the range 0.26 – 8.84meq/L (table-4). S-7 and S-12 belong to excellent category for irrigation as their RSC values are less than 1.25 meq/L while S-8, S-10 and S-11 belong to good category for irrigation water quality (RSC value in the range 1.25 – 2.50 meq/L) [1,16].

The values of SAR for S-1 to S-15 range from 1.2 to 13.4 (table-4). S-8 and S-10 have lowest value of SAR(1.2) while S-14 has highest value of it (13.4) . S-1, S-2, S-4 to S-13 and S-15 belong to excellent category of water for irrigation (SAR value upto to 10). However, the SAR values for S-3 and S-14 are above the excellent category but below the good quality category (SAR above 10 but upto 18) [1, 17]. So, all the ground waters (S-1 to S-15) are fit for irrigation purpose.

Statistical analysis based on correlation co-efficient (*r*) values :
The calculated values of correlation co-efficient (*r*) of different variable pairs of various physico-chemical parameters for the fifteen different ground water samples (S-1 to S-15), are detailed in table-5 given below :

Table-5 : Correlation co-efficient (*r*) values between variable pairs of different physico-chemical parameters for various ground water samples

	Temp.	pH	TDS	EC	TA	CO_3^{2-}	HCO_3^-	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-
Temp.	1												
pH	0.369	1											
TDS	-0.298	0.200	1										
EC	-0.273	0.210	0.999	1									
TA	-0.533	0.198	0.763	0.756	1								
CO_3^{2-}	0.277	0.746	0.252	0.266	0.184	1							
HCO_3^-	-0.583	0.090	0.738	0.729	0.989	0.037	1						
TH	0.030	-0.734	-0.117	-0.110	-0.452	-0.524	-0.381	1					
Ca^{2+}	0.023	-0.737	-0.177	-0.168	-0.507	-0.482	-0.443	0.974	1				
Mg^{2+}	0.033	-0.705	-0.064	-0.060	-0.391	-0.537	-0.317	0.984	0.917	1			
Na^+	-0.298	0.409	0.916	0.913	0.882	0.395	0.838	-0.478	-0.526	-0.422	1		
K^+	-0.620	-0.164	0.448	0.427	0.599	0.024	0.606	-0.208	-0.249	-0.167	0.509	1	
Cl^-	-0.059	0.186	0.918	0.922	0.447	0.264	0.415	0.103	0.050	0.142	0.733	0.232	1

From the above table-5, it is clearly seen that TDS shows strong positive correlations with EC, TA, HCO_3^-, Na^+ and Cl^- having *r* equal to 0.999, 0.763, 0.738, 0.916 and 0.918 respectively. But TDS shows moderate positive correlation with K^+ (*r* = 0.448).

Na^+ shows strong positive correlations with HCO_3^- and Cl^- (*r* = 0.838 and 0.733 respectively). And K^+ shows strong positive correlation with HCO_3^-, (*r* = 0.606) but weak positive correlation with Cl^- (*r* = 0.232). Thus it may inferred that both Na^+ and K^+ are present in the forms of $NaHCO_3$, NaCl, $KHCO_3$ and KCl mainly in such ground waters and consequently high values of TDS (and hence EC) are mainly due to the presence of them in such ground waters.

Further strong positive correlations of TA (total alkalinity) with Na^+, K^+ and HCO_3^- (*r* = 0.882, 0.599 and 0.989 respectively) establish the fact that total alkalinity for various ground waters are due to presence of $NaHCO_3$and $KHCO_3$ mainly. Again, strong positive correlations of TH (total hardness) with Ca^{2+} and Mg^{2+}(*r* = 0.974 and 0.984 respectively) show that total hardness values for different ground water samples, are dependent on concentrations of both Ca^{2+} and Mg^{2+}.

CONCLUSION

On the basis of the above discussion based on various experimental results for different ground water samples, the following conclusions are drawn –

(1) All the ground waters (S-1 to S-15) are fit for drinking in absence of alternate sources.
(2) Suitable treatments are necessary so as to keep total alkalinity values for S-1 to S-15, total hardness values for S-7 to S-9 and S-12, concentrations of Mg^{2+} for S-7, S-9 and S-12, and concentration of $Cl^-$for S-3 within the corresponding acceptable limits of BIS standard for drinking water. Further, it is also necessary to keep the concentrations of Na^+ for S-3, S-14 and S-15 below the threshold limit of WHO by applying suitable treatment.
(3) All the ground waters (S-1 to S-15) are found to be fit for other domestic and irrigation purposes.
(4) Correlation co-efficient (*r*) values between various pairs of physico-chemical parameters reveal that high TDS values(and hence EC) for different ground waters (S-1 to S-15) are due to presence of $NaHCO_3$, NaCl, $KHCO_3$ and KCl salts mainly in such ground waters. High values of total alkalinity for different ground water samples (S-1 to S-15), are due to presence of $NaHCO_3$ and $KHCO_3$ mainly in such ground waters. And both Ca^{2+} and Mg^{2+} show strong positive correlations with total hardness(TH) showing dependence of total hardness(TH) on concentrations of both Ca^{2+} and Mg^{2+}.

Acknowledgements
The author is thankful to the principal, D.M. College of Science,Imphal for the laboratory facilities provided for the research work and also to those local people of different sampling sites, for their cooperation extended to the author.

REFERENCES

[1] P.R.C. Prasad; K.S. Rajan; V.Bhole; C.B.S. Dutta, *Journal of Spatial Science*, **2009**, II (2), 43-52.

[2] H.M. Raghunath, Ground Water, 3rd Edition, New Age International (P) Limited, Publishers, New Delhi, **2007**, 1 – 308.
[3] LX Guang; HH Yang; SQFa, *J.Chem.Pharm.Res.*,**2013**, 5 (11), 290 – 295.
[4] E. Ramirez; E. Robles; M.E. Gonzalez; M.E. Martinez, *Air, Soil Water Res.*, **2010,** 3, 105-112.
[5] B.A. Adebo; A.A. Adetoyinbo, *Scientific Research and Essay*, **2009,** 4 (4), 314 – 319.
[6] D.A. Mohammed Barjinji; D.G.A. Ganjo, *Indian J. Environmental Protection*, **2014,** 34 (1), 29 – 36.
[7] D.R. Pathak; R. Yatabe; N.P. Bhandhari, *Int. J. Water Res.*, **2013,** 1 (1), 12 – 20.
[8] G. Vijaykumar; G. Baskar; K.P. Senthilnathan, *J. Chem. Pharm. Res.*, **2014**, 6 (10), 184-188.
[9] S.P. Mote; H.A. Mahajan, *Res. J. Chem. Sci.*, **2013**, 3 (8), 83 – 85.
[10] K.M. Anwar; V. Aggarwal,Curr. *World Environ*., **2014**,9 (3), 851 – 857.
[11] R.K. Tatawat; C.P. Singh Chandel,*Applied Ecology and Environmental Research*, **2008,** 6 (2), 79 – 88.
[12] G.S. Achary, *J. Chem. Pharm. Res.*, **2014**, 6 (6), 55 – 59.
[13] M. Khajuria; S.P.S. Dutta, *J. Env. Sci. Eng.*, **2011**,53 (4), 475 – 480.
[14] J. Borah, *Int. J. Chem. Sci.*, **2011,** 9 (4), 1613 – 1618.
[15] AE Greenberg; L Clesceri; A D Eaton (eds). Standard Methods for the Examination of Water and Waste water, 18th Edition, APHA, AWWA and WEF, Washington, D.C. 200005, 1992.
[16] LV Wilcox. Classification and Uses of Irrigation Waters, USDA, Washington, D.C., **1955**.
[17] DK Todd. Ground Water Hydrology, 2nd Edition, John Wiley & Sons (Asia) Pte. Ltd., Singapore, **2004**, 300 – 302.
[18] BIS IS 10500 : **2012**. Indian Standard Drinking Water – Specification (Second Revision) Bureau of Indian Standards, New Delhi, **2012**.
[19] WHO. Guidelines for Drinking Water Quality, 4th Edition, World Health Organization, Geneva, Switzerland, **2011,** 226 – 227.
[20] N Manivasakam. Physico-Chemical Examination of Water, Sewage and Industrial Effluents, Pragati Prakashan, Meerut, India, **2008**, 35 – 66.