ISSN No:-2456-2165

Hydrochemical Study of Groundwater Qualities of Some Areas of Imphal West District of Manipur, India

Dr. Nandababu Singh Laishram*
Associate Professor (Inorganic Chemistry)
Department of Chemistry
D.M. College of Science, Imphal – 795001, Dhanamanjuri University, Imphal

* Corresponding Author's

Abstract:- **Fifteen groundwater samples were collected from three villages namely Kanglatongbi, Awang Sekmai and Tengdoyan of Imphal West district of Manipur during pre-monsoon period(May) of 2018. They were analyzed for physico-chemical parameters such as temperature, pH, 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 values/concentrations of the different physico-chemical parameters for the fifteen groundwaters were found to be below/ within the acceptable limits / recommended values of BIS standard for drinking water as well as that of WHO. Thus all the fifteen groundwaters were found to be suitable for drinking from physico-chemical analysis point of view. However this does not guarantee that such groundwaters are 100%, safe for drinking as there is need for investigations on some heavy metals such Fe, As, Pb, Cd, Hg etc. and microbiological analysis of such groundwaters. Such groundwaters were found to be suitable for other domestic and irrigation purposes. Further, strong positive correlations of total hardness with Ca^{2+}, Na^+, Cl^- and moderately positive correlation between total hardness and Mg^{2+} were indicative of the fact that the total hardness of the fifteen groundwaters were mainly due to the presence of dissolved chlorides of Ca^{2+}, Mg^{2+} and Na^+. Again correlation coefficient data indicated that Ca^{2+}, Mg^{2+}, Na^+ and K^+ were present mostly in the from of chlorides but to a lesser extent, as bicarbonates in the fifteen groundwaters.**

Keywords: *Physico-Chemical Parameters, Drinking, Domestic, Irrigation, BIS And WHO.*

I. INTRODUCTION

As the population growth increases day by day all over the world, rate of urbanization and hence extension of urban areas also increase to accommodate increasing population growth[1]. Consequently many surface water bodies sites are also losing to a large extent due to construction of residential houses / buildings, office buildings, institutions, commercial areas etc. As a result of such urbanization and expansion of urban areas, there is scarcity of surface water which is mainly required for drinking (after proper treatment), other domestic, irrigation (or agriculture) and industrial purposes. As an impact of such shortage of surface water for human needs, there is a great demand for groundwater for drinking, other domestic, irrigation (or agriculture) and industrial purposes.

Groundwater is about 0.6% of the total global water resources and out of it, only 0.3% is extractable economically[2]. It should not be taken for granted that such ground waters are always safe for drinking, irrigation and industrial purposes. Their qualities have to be monitored from time to time in order to examine whether they are fit for drinking, other domestic, irrigation and industrial purposes just like that of surface water. Therefore many researchers of different countries had carried out investigations on the qualities of groundwaters not only the surface waters in order to examine whether they are fit for drinking, other domestic and irrigation purposes mainly [3-7]. Similarly, in India also, many researchers had carried out extensive researches on the qualities of ground waters besides investigation on the qualities of surface waters from time to time so as to examine whether such groundwaters not only the surface waters, are fit for human consumption including other domestic and irrigation (or agricultural) purposes mainly [8 – 14].

The present aim /objective of the research work is to carry out hydrochemical study of groundwater qualities of some areas of Imphal West district of Manipur so as to examine whether such groundwaters are fit for drinking, other domestic and irrigation purposes mainly.

II. MATERIAL AND METHOD

➢ *Study Area:*

Altogether three villages of Imphal West district namely (i) Kanglatongbi (ii) Awang Sekmai and (iii) Tengdoyan, were selected as most of the people of these villages are very much dependant on groundwater for drinking, other domestic and agricultural purposes. Samples were collected from fifteen (15) different sampling sites of these three villages. The different sampling sites alongwith their geographical locations (longitudes and latitudes) are detailed in table-1 below.

Table 1 Locations of Different Groundwater Samplings Sites

Sample Code (with source)	Sampling sites	Longitude	Latitude
S-1 (Dug well)	Tengdoyan Makha Leikai(1)	$93^0 52' 57'' E$	$24^0 54' 37'' N$
S-2 (Dug well)	Awang Sekmai Nongthombam Leikai	$93^0 52' 52'' E$	$24^0 57' 37'' N$
S-3 (Dug well)	Kanglatongbi Tispari(1) (Bhakta Bahadur Karki's residential area)	$93^0 52' 32'' E$	$24^0 57' 58'' N$
S-4 (Dug well)	Kanglatongbi Tispari (2) (Near Dilip Poudel's residential gate)	$93^0 52' 31'' E$	$24^0 58' 0'' N$
S-5 (Dug well)	Kanglatongbi Tispari(3) (Krishna Prasad Champagain's residential area)	$93^0 52' 29'' E$	$24^0 58' 2'' N$
S-6 (Dug well)	Kanglatongbi Tispari (4) (Khadka Bahadur Thapa's residential area)	$93^0 52' 30'' E$	$24^0 58' 3'' N$
S-7 (Dug well)	Kanglatongbi Tispari (5) (Ramesh Upprety's residential area)	$93^0 52' 29'' E$	$24^0 58' 10'' N$
S-8 (Dug well)	Tengdongyan Makha Leikai (2)	$93^0 52' 59'' E$	$24^0 54' 43'' N$
S-9 (Dug well)	Kanglatongbi Tispari (6) (Moirangthem Inao's residential area)	$93^0 52' 36'' E$	$24^0 57' 49'' N$
S-10 (Dug well)	Kanglatongbi Tispari (7) (Mr. Sanjit Thapa's residential area)	$93^0 52' 28'' E$	$24^0 58' 18'' N$
S-11 (Dug well)	Kanglatongbi Tispari (8) (Near Nandalal Ranjali\s residential area)	$93^0 52' 36'' E$	$24^0 58' 17'' N$
S-12 (Dug well)	Kanglatongbi Tispari(9) (Front of Narmada Ghimraj's residential area)	$93^0 52' 40'' E$	$24^0 58' 18'' N$
S-13 (Dug well)	Kanglatongbi Tispari (10) (Near Kewali Bista's residential area)	$93^0 52' 45'' E$	$24^0 58' 20'' N$
S-14 (Dug well)	Kanglatongbi Tispari (11) (Santosh Budathoki's residential area)	$93^0 52' 29'' E$	$24^0 58' 20'' N$
S-15 (Dug well)	Kanglatongbi Tispari (12) (Rajesh Baskota's residential area)	$93^0 52' 23'' E$	$24^0 58' 23'' N$

➢ *Analysis Of Groundwater Samples:*

The chemicals were of AR grade and were used as received. Chemicals used were HCl, NaOH, phenolphthalein indicator, methyl orange indicator, Eriochrome Black T indicator(EBT), murexide indicator, disodium salt of EDTA, NH_4OH, $MgSO_4.2H_2O$, NaCl, NH_4Cl and K_2CrO_4.

Fifteen (15) groundwater samples (S-1 to S-15) were collected in well sterilized polythene bottles of one litre capacity each during pre-monsoon period (May) of 2018. The samples were analyzed for physico-chemical parameters such as temperature, pH, total dissolved solids (TDS), total alkalinity(TA), electrical conductivity(EC), total hardness (TH), CO_3^{2-}, HCO_3^-, Cl^-, Ca^{2+}, Mg^{2+}, Na^+ and K^+. For sampling and analyses, guidelines of APHA were strictly followed [15]. Parameters like temperature, pH, TDS and electrical conductivity were measured at sampling sites while remaining ones were determined at departmental research laboratory.

Brief procedures / methods and instruments used for the measurements/ determinations of different physico-chemical parameters are shown in table-2 given below.

ISSN No:-2456-2165

Table 2 Instruments and Methods used for Measurements / Determinations of Physico-Chemical Parameters of Fifteen 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 (Dist3: 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_2CrO_4 indicator solution)

For finding out irrigation (agriculture) water quality parameters such as RSC (residual sodium carbonate) and SAR (sodium adsorption ratio), the following relationships were used [16-18]:

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

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

III. RESULTS AND DISCUSSION

All the fifteen (15) groundwater samples were found to be colourless and odourless. The experimental values of different physico-chemical parameters are shown in table-3 given below:

Table 3 Values / Concentrations of Physico-Chemical Parameters of Groundwater Samples

Sample Code	Temperature (^{0}C)	pH	TDS (mg/L)	Electrical conductivity (µS/cm)	Total Alkalinity (as $CaCO_3$) (mg/L)	HCO_3^- (mg/L)	Total hardness (as$CaCO_3$) (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	Cl^- (mg/L)
S-1	21.2	6.8	108	222	49	59.8	42	4.8	7.3	13.8	19.4	17
S-2	21.1	7.3	109	223	58.7	71.6	68	18.4	5.3	17.4	2.1	28.4
S-3	21.8	6.7	68	142	44.1	53.8	44	12	3.4	10.3	0.8	11.3
S-4	22.3	6.7	75	156	44.1	53.8	46	11.2	4.4	12.3	1	12.8
S-5	23.1	6.6	87	183	39.2	47.8	54	11.2	6.3	13.6	1.6	17
S-6	22.9	6.9	79	164	44.1	53.8	50	11.2	5.3	12.5	1	12.8
S-7	22.5	7.1	77	158	58.7	71.6	48	9.6	5.8	12.5	1.1	11.3
S-8	22.7	6.6	95	203	44.1	53.8	54	9.6	7.3	18.2	2.2	22.7
S-9	23.6	6.6	60	124	44.1	53.8	38	8	4.4	9.7	0.6	7.1
S-10	23.4	6.8	70	149	53.8	65.6	46	10.4	4.9	10.8	0.6	8.5
S-11	24	6.6	58	124	44.1	53.8	36	8.8	3.4	9.9	0.5	5.7
S-12	24.2	7.1	57	119	44.1	53.8	38	7.2	4.9	9.5	0.5	5.7
S-13	23.6	6.6	64	142	44.1	53.8	44	10.4	4.4	10.6	0.9	9.9
S-14	23.2	6.7	71	149	53.8	65.6	50	11.2	5.3	10.5	0.5	8.5
S-15	22.9	6.8	67	140	49	59.8	44	11.2	3.9	10	0.5	7.1

ISSN No:-2456-2165

➢ *Physico-Chemical Parameters:*

- *Temperature:*

The temperatures of the fifteen dugwell groundwater samples (S-1 to S-15) are in the range 21.1 – 24.2^0 C. S-12 has the highest temperature (24.2^0 C) while that of S-2 is lowest (21.1^0C).

- *Ph:*

The pH values of the fifteen groundwater samples range from 6.6 to 7.3 S-2 has the highest pH value (7.3) while each of S-5, S-8, S-9, S-11 and S-13 has lowest value of pH (6.6). All these pH values are within the acceptable limit (6.5 – 8.5) of BIS standard for drinking water as well as that of WHO [19, 20]

- *Total Dissolved Solids (TDS):*

The TDS values for all the fifteen groundwaters (S-1 to S-15) are in the range 57 – 109 mg /L. S-2 has the highest value of TDS (109 mg/L) while that of S-12 has the lowest value of it (57 mg/L). All the values of TDS are below the acceptable limit (500 mg/L) of BIS standard for drinking water[19]. Further, as the values of TDS are below 1000 mg/L, such groundwaters may also be used for other domestic purposes [21].

- *Electrical Conductivity (EC):*

The electrical conductivity values for all the fifteen groundwaters (S-1 to S-15) are in the range 119 – 223 μS/cm. S-2 has highest electrical conductivity value (223 μS/cm) while that of S-12 is lowest (119 μS/cm).

- *Total Alkalinity (TA):*

The total alkalinity values for the fifteen groundwaters range from 39.2 mg/L to 58.7 mg/L. Each of S-2 and S-7 has highest value of total alkalinity (58.7 mg/L) while that of S-5 is lowest (39.2 mg/L) All these values of total alkalinity for the fifteen groundwaters (S-1 to S-15) are below the acceptable limit (200 mg/L) of BIS standard for drinking water [19].

- *Carbonate (CO_3^{2-}) and Bicarbonate (HCO_3^-):*

Each of the groundwater samples, has concentration of CO_3^{2-} equal to zero. However, concentrations of HCO_3^- for all the fifteen groundwaters, are in the range 47.8 – 71.6 mg/L. Each of S-2 and S-7 has highest concentration of HCO_3^- (71.6 mg/L) while that of S-5 is lowest (47.8 mg/L).

- *Total Hardness (TH):*

The total hardness values for all the fifteen groundwaters (S-1 to S-15), are in the range 36 – 68 mg/L. S-2 has the highest value of total hardness (68 mg/L) whereas S-11 has the lowest value of it (36 mg/L). All these values of total hardness for the fifteen groundwaters are below the acceptable limit (200 mg/L) of BIS standard for drinking water [19]. All the fifteen groundwaters belong to soft water category (0-75 mg/L) as their values of total hardness are below 75 mg/L [21].

- *Calcium (Ca^{2+}):*

The concentrations of Ca^{2+} for all the groundwaters (S-1 to S-15) range from 4.8 mg/L to 18.4 mg/L. S-2 has the highest concentration of Ca^{2+} (18.4 mg/L) while that of S-1 is lowest (4.8 mg/L). All the concentrations of Ca^{2+} for the fifteen groundwaters are below the acceptable limit (75 mg/L) of BIS standard for drinking water [19].

- *Magnesium (Mg^{2+}):*

The concentrations of Mg^{2+} for all the fifteen groundwaters (S-1 to S-15) range from 3.4 mg/L to 7.3 mg/L. Each of S-1 and S-8 has the highest concentration of Mg^{2+} (7.3 mg/L) while each of S-3 and S-11 has lowest concentration of it (3.4 mg/L). The concentrations of Mg^{2+} for all the fifteen groundwaters (S-1 to S-15), are below the acceptable limit (30 mg/L) of BIS standard for drinking water [19].

- *Sodium (Na^+):*

Regarding the concentrations of Na^+ for all the fifteen groundwaters (S-1 to S-15), they are in the range 9.5 - 18.2 mg/L. S-8 has highest concentration of Na^+ (18.2 mg/L) while S-12 has lowest concentration of it (9.5 mg/L). The concentration values of Na^+ for all the fifteen groundwaters, are below the threshold limit (200 mg/L) of WHO [20].

- *Potassium (K^+):*

The concentrations of K^+ for all the fifteen groundwaters (S-1 to S-15) range from 0.5 mg/L to 19.4 mg/L. S-1 has higest concentration of K^+ (19.4 mg /L) while each of S-11, S-12, S-14 and S-15 has lowest concentration of it (0.5 mg/L).

- *Chloride (Cl^-):*

The concentrations of Cl^- for all the fifteen groundwaters (S-1 to S-15) are in the range 5.7 – 28.4 mg/L. S-2 has highest concentration of Cl^-(28.4 mg/L) while each of S-11 and S-12 has lowest concentration of it (5.7 mg/L). All the groundwaters (S-1 to S-15) have their concentrations of Cl^- below the acceptable limit (250 mg/L) of BIS standard for drinking water [19].

➢ *Groundwater Quality for Irrigation (Agriculture) Purposes:*

For all the fifteen groundwaters (S-1 to S-15), the values of RSC (residual sodium carbonate) and SAR (sodium adsorption ratio) are shown in table-4 given below:

Table 4 Values of RSC and SAR for Different Groundwaters

Sample Code	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)	0.140	-0.180	0.003	-0.038	-0.293	-0.112	0.217	-0.197	0.120	0.153	0.163	0.119	0.001	0.080	0.100
SAR	0.925	0.919	0.675	0.788	0.805	0.770	0.786	1.077	0.683	0.691	0.718	0.669	0.694	0.647	0.655

ISSN No:-2456-2165

From the above table, it is clearly seen that the values of RSC for the fifteen groundwaters (S-1 to S-15) range from – 0.293 meq/L to 0.217 meq/L. S-5 has lowest value of RSC (-0.293 meq/L) while that of S-7 is highest (0.217 meq/L). As all the RSC values of the fifteen groundwaters are less than 1.25 meq/L, they are fit for irrigation purpose [17].

Again the values of SAR for all the fifteen groundwaters are in the range 0.647 – 1.077. S-14 has the lowest value SAR (0.647) while that of S-8 is highest (1.077). So, all these groundwaters belong to excellent category of water for irrigation (SAR value upto 10) [18].

Thus from RSC as well as SAR values point of view, all the groundwaters are fit for irrigation (agriculture) purposes.

- *Statistical Interpretation Based On Correlation Coefficient (r) Values:*

For the fifteen groundwaters (S-1 to S-15), the correlation co-efficient(r) values for different variable pairs of physic-chemical parameters are shown in table-5 given below:

Table 5 Correlation Co-Efficient(R) Values of Different Variable Pairs of Physico-Chemical Parameters of Different Groundwaters

	Temp.	**pH**	**TDS**	**EC**	**TA**	**HCO_3^-**	**TH**	**Ca^{2+}**	**Mg^{2+}**	**Na^+**	**K^+**	**Cl^-**
Temp.	1											
pH	-0.350	1										
TDS	-0.805	0.314	1									
EC	-0.777	0.263	0.996	1								
TA	-0.389	0.661	0.304	0.278	1							
HCO_3^-	-0.390	0.662	0.310	0.278	0.999	1						
TH	-0.556	0.420	0.721	0.725	0.417	0.417	1					
Ca^{2+}	-0.363	0.373	0.267	0.263	0.361	0.360	0.790	1				
Mg^{2+}	-0.346	0.116	0.753	0.765	0.128	0.128	0.424	-0.220				
Na^+	-0.606	0.248	0.883	0.898	0.201	0.202	0.791	0.370	0.715			
K^+	-0.544	0.032	0.613	0.603	0.071	0.072	-0.070	-0.465	0.575	0.284	1	
Cl^-	-0.723	0.306	0.913	0.920	0.216	0.216	0.850	0.505	0.609	0.957	0.306	1

From the above table-5, it is clearly seen that TDS has strong positive correlations with EC, TH, Mg^{2+}, Na^+, K^+ and Cl^- (r=0.996,0.721, 0.753, 0.883, 0.613 and 0.913 respectively). TA also shows strong positive correlation with HCO_3^-(0.999) but moderately positive correlation with TH and Ca^{2+} (r=0.417 and 0.361 respectively). HCO_3^- shows moderately positive correlations with Ca^{2+} and Na^+ (r=0.360 and 0.202 respectively) but weak correlation with Mg^{2+} and K^+ (r=0.128 and 0.072 respectively). Such values of r are indicative of low values of TA. TH shows strong positive correlation with Ca^{2+}, Na^+ and Cl^- (r=0.790, 0.791 and 0.850 respectively) but moderately positive correlation with Mg^{2+}(r=0.424). This shows that TH is mainly due to soluble chlorides of Ca^{2+}, Mg^{2+} and Na^+. Ca^{2+} shows strong positive correlation with Cl^- (r=0.505) but moderately positive correlation with Na^+(r=0.370). Mg^{2+}, also, shows strong positive correlation with Na^+, K^+ and Cl^- (r=0.715, 0.575 and 0.609 respectively). However, Na^+ shows strong positive correlation with Cl^- (r=0.957) while K^+ shows moderately positive correlation with Cl^- (r=0.306). Thus Ca^{2+}, Mg^{2+}, Na^+ and K^+ are mostly present as chlorides but to a lesser extent as bicarbonates in such groundwaters.

IV. CONCLUSION

From the above aforesaid discussions based on the experimental results shown in table-3 and data of tables 4 and 5, the following conclusions are drawn:

- All the values of physico-chemical parameters are within / below the acceptable / recommended limits of BIS standard for drinking water as well as that of WHO. So, all the groundwaters (S-1 to S-15) belong to the category of drinking water from physico-chemical analysis point of view. However, this does not guarantee that they are 100% safe for drinking purpose as there is a need for further analysis of heavy metals such as Fe, As, Pb, Cd, Hg etc and also microbiological analysis of such groundwaters.
- As the TDS values of all the fifteen groundwaters are less than 1000 mg/L, they can be used for other domestic purposes.
- All the fifteen groundwaters are fit for irrigation / agriculture purpose.
- Based on correlation coefficient data, it can be concluded that TH(total hardness) of such groundwaters is mainly due to soluble chlorides of Ca^{2+}, Mg^{2+} and Na^+. Again such correlation coefficient data show that Ca^{2+}, Mg^{2+}, Na^+, and K^+ are mostly present in the form of their chlorides but to a lesser extent, as bicarbonates in such groundwaters.

ACKNOWLEDGEMENT

The author is thankful to the principal, D.M. College of Science, Imphal for some of the laboratory facilities provided for the research work. Further the author is also thankful to local people of different sampling sites, who had extended their cooperations during field visits.

REFERENCES

[1]. Prasad, P.R.C., etal. 2009. Is rapid urbanization leading to loss of water bodies ? *J. Spat. Sci.*,11(2): 43-52.
[2]. Raghunath, H.M. 2007. Groundwater(3rd edn.), New Age International(P) Limited, New Delhi. pp. 1 – 308.
[3]. Aghajadeh, N and A.A. Mogaddam. 2010. Assessment of groundwater quality and its suitability for drinking and agricultural uses in the Oshnavieh area, northeast of Iran. *J.Env. Prot*. 1:30-40.
[4]. Saana, S.B.M.M. etal. 2016. Assessment of the quality of groundwater for drinking purposes in the upper west and northern regions of Ghana. *Springer Plus.* 5: 2001.D01:10.1186/s40064-016-3676-1.
[5]. Elbana, T.A., etal. 2017. Assessment of marginal quality water for sustainable irrigation management: a case study of Bahr El-Baqar area, Egypt. *Water Air Soil Poll*. 228: 214.
[6]. Pathak, D.R., etal. 2013. Statistical analysis of factors affecting groundwater quality in shallow aquifer of Katmandu, Nepal. *Int. J.Water Res.,* 1(1): 12-20.
[7]. Chudaeva, V.A. etal. 2008. The composition of groundwater of Muraviov-Amursky Peninsula Primorye, Russia. *Indian J. Mar. Sci.,* 37(2): 193-199.
[8]. Nandukar, Y.M. 2017. Water quality assessment for drinking and irrigation purpose, in the eastern part of Pune, Maharashtra. *Indian J. Env. Prot.*, 37(5): 392-398.
[9]. Saleem, M. etal. 2016. Analysis of groundwater quality using water quality index: a case study of greater Noida (region), Uttar Pradesh(U.P.), India. *Cogent Eng.,* 3:1, DOI: 10.1080/ 23311916. 2016.1237927.
[10]. Choudhary, S. etal. 2016. Assessment of groundwater quality in central India. *Journal of Water Resource and Protection*,8(1):12-19.
[11]. Sarala, C. and P. Ravi Babu. 2012. Assessment of groundwater quality parameters in and around Jawaharnagar, Hyderabad. *Int. J. Sci. Res. Pub.*, 2(10): 1-5.
[12]. Saha, M., etal. 2017. Assessment of physico-chemical properties, some heavy metals and arsenic of river Teesta in Jalpaiguri district, West Bengal. *Asian J. Res. Chem.*, 10(3): 399 – 404.
[13]. Satyanarayan, P., etal 2013. Urban groundwater quality assessment: a case study of greater Visakhapatnam Municipal Corporation areas (Guvc), Andhra Pradesh. *Int. J. Eng. Sci. Inv*. 2(5): 20-31.
[14]. Hazarika, S. and B. Bhuyan. 2013. Fluoride, arsenic and iron content of groundwater around six selected tea gardens of Lakhimpur district, Assam. *Arch. Appl. Sci. Res.*, 5(1): 57-61.
[15]. Greenberg, A.E., etal. 1992. Standard methods for the examination of water and waste water (18th edn.), APHA, AWWA and WEF, Washington, D.C.
[16]. Laishram N.S. 2019. Assessment of groundwater qualities of some areas of Imphal East district of Manipur during monsoon – 7th phase. *Indian J. Env. Prot*., 39(8): 663-668.
[17]. Wilcox, L.V. 1955. Classification and uses of irrigation waters. USDA, Washington, D.C.
[18]. Todd, D.K. 2004. Groundwater hydrology (2nd edition). John Willy and Sons (Asia) Pte. Ltd., Singapore. pp.300-302.
[19]. BIS. 2012. Indian standard drinking water-specification (second revision) IS10500, Bureau of Indian standards, New Delhi.
[20]. WHO. 2011. Guidelines for drinking water quality, 4th edn. World Health Organisation, Geneva, Switzerland. pp.226-227.
[21]. Manivasakam, N. 2008. Physico–chemical examination of water, sewage and industrial effluents. Pragati Prakashan, Meerut, India. pp.35-66.