Research Article

Physico-Chemical Properties of Hot Water Spring In The Rajgir Region of Nalanda District Bihar State

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ABSTRACT
Physical, chemical, and ionic studies were conducted at Rajgir hot springs of Nalanda district Bihar State India. Objective- This paper aims to study the Physico- Chemical parameters of hot spring of Rajgir for which analysis were done as per APHA and WHO standard method. The Physical parameters included total Solid, Total Suspended Solid, Chemical parameters included – Dissolved Oxygen, Chemical Oxygen Demand and Ionic parameters included – Sodium, Potassium, Iron, Silica, Fluoride, Nitrate and Sulphide.

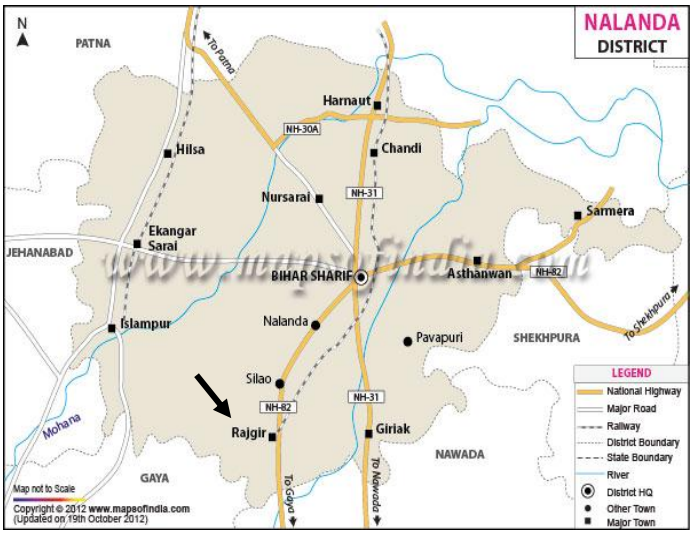
Key words: APHA,WHO, Physico – chemical parameters.

1. INTRODUCTION

Rajgir hot spring is located in the Nalanda district of Bihar having 25^0 02' N latitude and 85^0 25' E longitude . Apart from world peace pagoda it is also famous for numerous water hot spring namely Suraj Kund, Brahm kund, Vishwamitra Kund, Bharatdwaj muni Kund, Gautam muni Kund, Vashistha muni Kund & Makhdum Kund etc. Gautam Budha spent so many years and delivered sermon in Rajgir. The older name of Rajgir was Girivraj.

Our present objective to study the Physico-chemical properties of Vishwamitra Kund Brahm Kund as well as Makdum Kund. Both Viswamitra as well as Brahm kund are situated at the base of Vaibhava hills while Makhdum kund lies on the foothill of Vipula hills. Many of the springs are the result of long cracks or joint in sedimentary rock (young M.C. *et. al.* 2007). The water of the spring is very clear, colour is transparent. Rajgir hills are also known as Rajhara hills lies near the city of Rajgir in the central region of Bihar State. Rajgir is surrounded by five hill namely Ratnagiri, Vilpalanchal, Vaibhagiri, Songiri, and Udaygiri. It is also famous for Buddhist, Hindu and Jain piligrimage site. The hot spring of Rajgir are medically as well as sociologically important . It is believed that water from these hot spring can cure several skin related diseases (Das,S.:Sherpa,M.T.,Thakur S.,Thakur,U.,Thakur 2012). Rajgir hot spring is Sulphur containing hot spring. The spring usually emerged along the deep faults as fissure of earth along which the ground water comes out the high temperature of hot spring water because of geothermal energy, exothermic reactions and disintegration of radioactive element (Mahala *et. al.*, 2013). The Sulphurous odour of the hot spring water may be due to the presence of H_2S and low amount of oxygen gases. The thermal spring having temperature range of 30^0C-50^0C are Euthermal springs and having 50^0C-70^0C temperature ranges are considered as Acrothermal spring. Thus the thermal spring of Rajgir hot spring is Euthermal spring. The energy extracted from the earth's heat called geothermal energy (Thompson *et. al.2005*). The water can be present within cracks and crevasses of rock, sand, day, gravel, in spaces between adjacent particles of material (Brenda wilmoth *et. al.2009*).The physical, chemical composition of water is influenced to a great extent by different factors including climate geomorphology and geology. The Physical variable which included Total Solid, Total Suspended Solid . Chemical variable include Dissolved Oxygen, Chemical Oxygen Demand and Ionic variable like Sodium, Potassium, Iron, Silica, Fluoride, Nitrate, Sulphide *etc*. The objective of present work are to analyze and discuss the suitability of water for drinking and sanitation.

2. Map of selected site



2.1 Map showing Rajgir hot spring site of district Nalanda Bihar

2.1. Picture of selected site

2.1(a):Brahm kund hot spring Rajgir

2.1(b): Saptdhara Rajgir showing Vishwamitra kund

2.1(c): Makhdum Kund Rajgir

3.-MATERIALS AND METHODS

Thermal spring water samples were collected on an interval of four month during the period of Ocober. 2014 to June -2016 at Brahm Kund, Vishwamitra kund and Makhdum Kund of Rajgir hot spring of Nalanda district Bihar. The samples were collected in 1.5 liter pre cleaned plastic bottles and each bottle was rinsed by several times with sample water before collection. All the physico- chemical parameters of water sample were estimated by using standard method given by APHA and WHO (Trivedy and Goel 1986). Total Solid, Total Suspended Solid of water sample were measured using evaporation method. Sodium and Potassium ion concentration were measured using flame photometer. The fluoride ions were estimated by SPANDS method. The Iron, Nitrate, Silica were estimated by using Ultraviolet-Visible spectrophotometer. Dissolved Oxygen (DO) were analyzed according to modified Wrinkler's method and Chemical Oxygen Demand (COD) and Sulphide ion concentration were analyzed using Titrimetric method.

4.RESULTS AND DISCUSSIONS

The water from Brahm kund, Vishwamitra Kund and Makhdum Kund of Rajgir hot spring seeps out as transparent and colourless. The **Total Suspended Solid** concentration observed during period Oct 2014 to June 2016 (within an interval of four month) of site Vishwamitra kund, Brahmkund and Makhdum kund varies from 16mg/l to32mg/l, 36mg/l to 38mg/l and 18mg/l to 26mg/l respectively, which is well within permissible limit as per APHA and WHO standard. **Total Solid** concentration observed in above all three kunds varies from 42 mg/l to 70mg/l, 94mg/l to 154 mg/l and 40 mg/l to 54 mg/l respectively .All concentration lies within permissible range (500mg/l). The concentration of Total Solid is more in post monsoon period than the pre monsoon period. **Sodium** ion concentration in all three sites observed during the period October 2014 to June20 16 varies from 1.62 mg/l to 3.8.5 mg/l, 2.84 mg/l to 6.35 mg/l and 1.03 mg/l to 3.02 mg/l respectively, which is well within permissible limit as per APHA and WHO standard (200 mg/l).Whereas **Potassium** ion concentration varies 0.86 mg/l to 1.41 mg/l, 1.03 mg/l to 2.63 mg/l and 0.70 mg/l to1.92 mg/l respectively, all concentration lies within permissible limit (12 mg/l). Concentration of **Sodium** and **Potassium** are lower in post monsoon period where as higher in pre monsoon periods. **Silica** concentration of all three kund of Rajgir hot spring varies from 2.12 mg/l to5.24 mg/l, 2.68 mg/l to 3.86 mg/l and 2.12 mg/l to 2.96 mg/l respectively, which is well within permissible limit as per WHO standard (50mg/l) ,Whereas **Iron** concentration varies from 0.62mg/l to1.52 mg/l, 0.67 mg/l to 1.24 mg/l and 0.48 mg/l to 0.86 mg/l respectively ,all concentration are well within permissible limit. **Nitrate** and **Fluoride** are very low in concentration. **Nitrate** concentration varies from 1.54 mg/l to 2.62 mg/l, 2.06 mg/l to 3.28 mg/l and 1.74 mg/l to 4.73 mg/l. Whereas **Fluoride** concentration varies from 1.28 mg/l to 1.44 mg/l, 1.35 mg/l to 2.65 mg/l and 1.36 mg/l to1.62 mg/l respectively, Both Nitrate and Fluoride concentration are well within permissible limit as per WHO standard (45mg/l, 1.5mg/l)

Nitrate is the end product of aerobic decomposition of organic nitrogenous matter (Gichuki.*et. al.*), its excess concentration can lead to blue baby diseases whereas excess concentration of fluoride lead to Fluorosis (Dental degrading diseases).

The observed **Dissolved Oxygen** concentration of Viswamitra, Brahm and Makhdum Kund of Rajgir hot spring during

period (October 20 14 to June 2016) varies from 5.55 mg/l to 7.77 mg/l, 4.44 mg/l to 6.66 mg/l and 5.55 mg/l to 6.66 mg/l respectively. All concentration lies within permissible limit (7 mg/l).

So, far **Chemical Oxygen Demand** is concerned the observed concentration of COD in all three kund of Rajgir varies from 8 mg/l to20mg/l, 16 mg/l to8mg/l and 10 mg/l to20mg/l respectively,lies within permissible range as per APHA and WHO standard (250 mg/l).

As we know Rajgir hot spring is Sulphur containing hot spring so, that the observed **Sulphide** concentration varies from 1.48 mg/l to2.56 mg/l, 1.48 mg/l to 2.58 mg/l and 1.44 mg/l to 2.64 mg/l respectively, which is well within permissible limit as per APHA and WHO standard (10mg/l).

Rajgir hot spring is Euthermal spring (Vouk 1950) and provided stable environment to ecosystems which may have remained unchanged (Brock 1967).

4.1. Table 1: Result of Physico- Chemical analysis of sample of Rajgir hot water spring of district Nalanda Bihar – Site 1st- Vishwamitra Kund

Parameter	T.S	T.S.S	Na	K	Fe	Silica	F	NO_3	DO	COD	Sulphide
Oct-14	70	30	3.68	1.37	1.52	5.24	1.38	2.62	7.77	20	2.56
Feb-15	54	18	3.85	1.41	0.95	2.94	1.31	2.62	5.55	16	1.84
June-15	58	28	2.02	1.24	1.05	3.12	1.28	2.36	6.66	16	1.66
Oct-15	42	16	1.62	0.86	0.62	2.51	1.36	1.94	6.66	8	1.48
Feb-16	58	22	2.08	1.16	0.92	2.75	1.44	1.54	7.77	20	1.66
June-16	66	32	2.52	1.21	0.88	2.12	1.34	2.17	5.55	12	1.74

4.2.Table 2: Result of physico chemical analysis of sample of Rajgir hot water spring of district Nalanda Bihar – Site 2nd Brahm Kund

Parameter	T.S	T.S.S	Na	K	Fe	Silica	F	NO_3	DO	COD	Sulphide
Oct-14	104	38	5.24	1.84	1.24	2.68	1.46	2.15	5.55	24	2.58
Feb-15	96	38	4.86	1.96	0.76	3.86	1.48	3.28	6.66	16	1.64
June-15	94	40	2.84	1.03	0.82	3.22	1.36	2.84	5.55	16	1.48
Oct-15	154	88	5.48	1.84	1.05	3.28	1.35	2.26	5.55	28	1.85
Feb-16	104	36	6.35	2.63	0.68	2.76	2.65	2.22	4.44	28	1.85
June-16	102	42	5.68	2.57	0.67	2.65	1.48	2.06	5.55	18	1.62

4.3. Table 3: Result of physico chemical analysis of sample of Rajgir hot water spring of district Nalanda Bihar – Site 3rd - Makhdum Kund

Parameter	T.S	T.S.S	Na	K	Fe	Silica	F	NO_3	DO	COD	Sulphide
Oct-14	46	22	3.02	1.92	0.48	2.80	1.40	4.73	5.55	20	2.64
Feb-15	46	20	2.24	1.23	0.62	2.96	1.56	1.84	5.55	12	1.82
June-15	54	22	2.24	1.47	0.86	2.55	1.62	1.74	6.66	10	1.62
Oct-15	52	26	2.05	1.22	0.64	2.48	1.48	2.26	6.66	12	1.65
Feb-16	40	18	1.03	0.85	0.58	2.12	1.36	2.04	5.55	12	1.48
June-16	44	22	1.66	0.70	0.61	2.50	1.36	1.84	6.66	18	1.44

Note- All concentrations of parameter expressed in mg/l

5. Correlation Coefficient - showing different parameters of Vishwamitra kund Rajgir ,Nalanda

5.1Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance		
T.S	6	348	58	96		
T.S.S	6	146	24.33333	43.86667		
Na	6	15.77	2.628333	0.859537		
K	6	7.25	1.208333	0.038297		
Fe	6	5.94	0.99	0.088		
Silica	6	18.68	3.113333	1.207107		
F	6	8.11	1.351667	0.003137		
Nitrate	6	13.25	2.208333	0.176417		
DO	6	39.96	6.66	0.98568		
COD	6	92	15.33333	21.86667		
Sulphide	6	10.94	1.823333	0.144227		

5.2ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	18037.96	10	1803.796	120.0815	1.23E-33	2.007792
Within Groups	826.1787	55	15.02143			
Total	18864.14	65				

5.3 Correlation Coefficients(Concentration in mg/l)

	T.S	T.S.S	Na	K	Fe	Silica	F	NO3	DO	COD	Sulphide
T.S	1										
T.S.S	0.8876	1									
Na	0.5064	0.1578	1								
K	0.7009	0.4295	0.8540	1							
Fe	0.7954	0.5985	0.6511	0.7290	1						
Silica	0.5187	0.3142	0.5765	0.4978	0.9158	1					
F	0.1021	-0.1096	-0.1274	-0.2424	0.0530	0.1348	1				
Nitrate	0.3538	0.2720	0.7626	0.6815	0.5796	0.5409	-0.6562	1			
DO	0.1826	0.0675	-0.1471	-0.1028	0.4598	0.5963	0.6787	-0.3354	1		
COD	0.6286	0.3186	0.4850	0.7067	0.7555	0.6171	0.3411	0.1297	0.5738	1	
Sulphide	0.7310	0.4829	0.7607	0.6583	0.9366	0.9164	0.1464	0.6142	0.3768	0.6051	1

6. Correlation Coefficient - showing different parameters of Brahm kund Rajgir ,Nalanda

6.1.-Anova: Single Factor

SUMMARY						
Groups	**Count**	**Sum**	**Average**	**Variance**		
T.S	6	654	109	503.6		
T.S.S	6	282	47	407.6		
Na	6	30.45	5.075	1.44487		
K	6	11.87	1.978333	0.342537		
Fe	6	5.22	0.87	0.052		
Silica	6	18.45	3.075	0.22303		
F	6	9.78	1.63	0.25312		
Nitrate	6	14.81	2.468333	0.234017		
DO	6	33.3	5.55	0.49284		
COD	6	130	21.66667	32.66667		
Sulphide	6	11.02	1.836667	0.153147		
6.2 ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	66002.59	10	6600.259	76.66112	1.31E-28	2.007792
Within Groups	4735.311	55	86.09657			
Total	70737.9	65				

6.3 Correlation Coefficients(Concentration in mg/l)

	T.S	T.S.S	Na	K	Fe	Silica	F	NO3	DO	COD	Sulphide
T.S	1										
T.S.S	0.9720	1									
Na	0.3196	0.1290	1								
K	0.0233	-0.1312	0.9192	1							
Fe	0.4213	0.3684	-0.0685	-0.4028	1						
Silica	0.0636	0.1986	-0.3994	-0.4214	-0.1077	1					
F	-0.1736	-0.3383	0.5635	0.6093	-0.4308	-0.3407	1				
Nitrate	-0.3650	-0.2214	-0.5867	-0.4930	-0.2435	0.8981	-0.2479	1			
DO	-0.1127	0.0313	-0.3920	-0.3620	0.1109	0.7366	-0.7354	0.6929	1		
COD	0.6643	0.4818	0.6605	0.3729	0.3744	-0.3949	0.5022	-0.6397	-0.6639	1	
Sulphide	0.1421	-0.0238	0.3628	0.1027	0.8017	-0.4427	0.0425	-0.4716	-0.1697	0.5216	1

7. Correlation Coefficient - showing different parameters of Makhdum kund Rajgir ,Nalanda

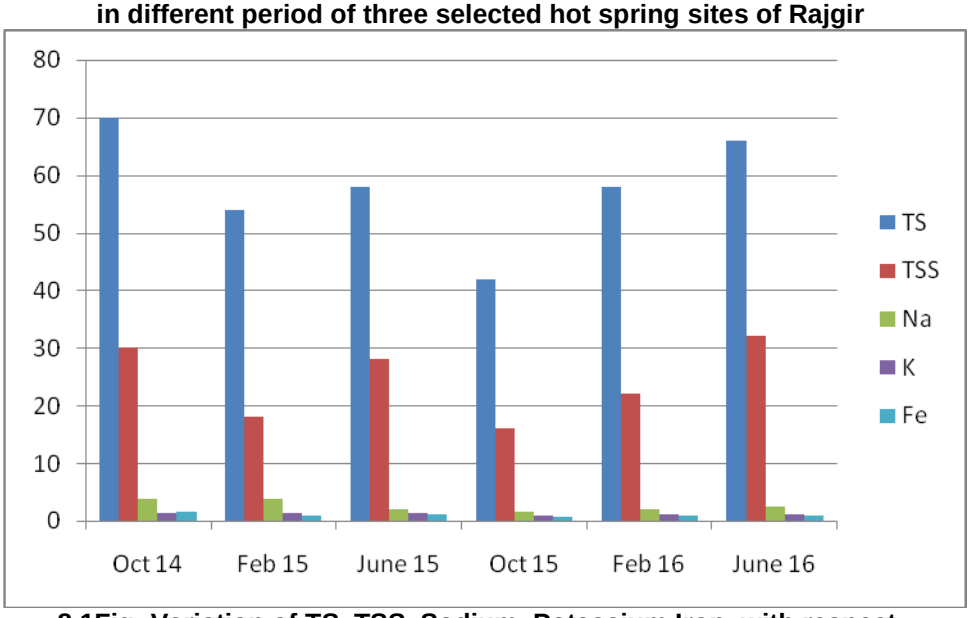
7.1-Anova: Single Factor

SUMMARY						
Groups	**Count**	**Sum**	**Average**	**Variance**		
T.S	6	282	47	26.8		
T.S.S	6	130	21.66667	7.066667		
Na	6	12.24	2.04	0.441		
K	6	7.39	1.231667	0.191817		
Fe	6	3.79	0.631667	0.015697		
Silica	6	15.41	2.568333	0.084177		
F	6	8.78	1.463333	0.011907		
Nitrate	6	14.45	2.408333	1.328097		
DO	6	36.63	6.105	0.36963		
COD	6	84	14	16		
Sulphide	6	10.65	1.775	0.19783		
7.2 ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	12060.82	10	1206.082	252.6701	3.34E-42	2.007792
Within Groups	262.5341	55	4.773347			
Total	12323.35	65				

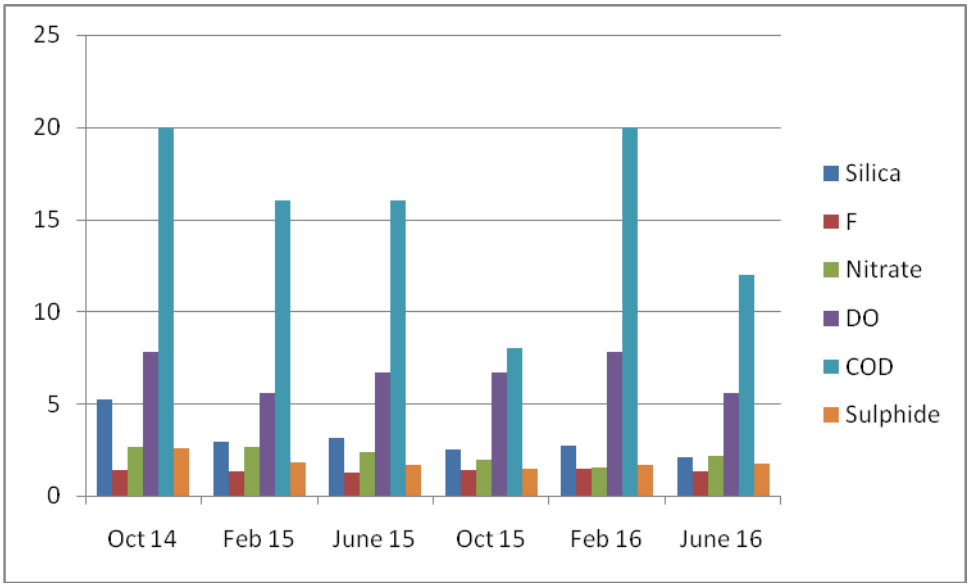
7.3 Correlation Coefficients(Concentration in mg/l)

	T.S	**T.S.S**	**Na**	**K**	**Fe**	**Silica**	**F**	**NO3**	**DO**	**COD**	**Sulphide**
T.S	1										
T.S.S	0.7267	1									
Na	0.4933	0.4169	1								
K	0.4578	0.2548	0.9003	1							
Fe	0.6876	0.1581	-0.1077	-0.0686	1						
Silica	0.2863	0.1703	0.8093	0.5712	-0.1100	1					
F	0.7718	0.1977	0.3654	0.3673	0.7602	0.4563	1				
Nitrate	-0.0969	0.1317	0.6832	0.7466	-0.6482	0.3257	-0.3378	1			
DO	0.6348	0.6868	-0.0935	-0.2543	0.6266	-0.2202	0.2342	-0.4388	1		
COD	-0.3863	0.0752	0.3885	0.2101	-0.7184	0.2551	-0.6598	0.7159	-0.1826	1	
Sulphide	0.0391	0.0998	0.8462	0.8733	-0.5227	0.5999	-0.0482	0.9379	-0.5049	0.5868	1

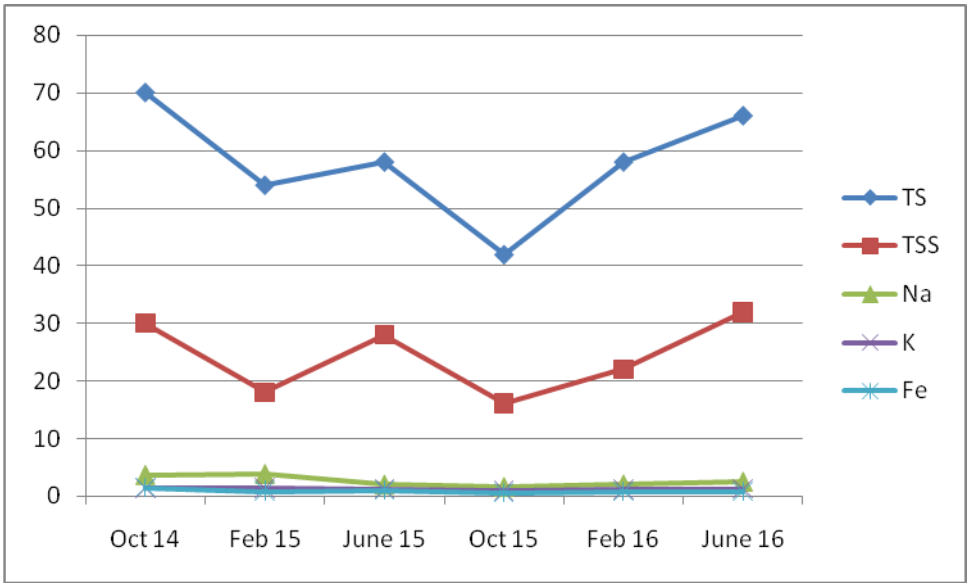
8.Graphical representation of different parameters in different period of three selected hot spring sites of Rajgir



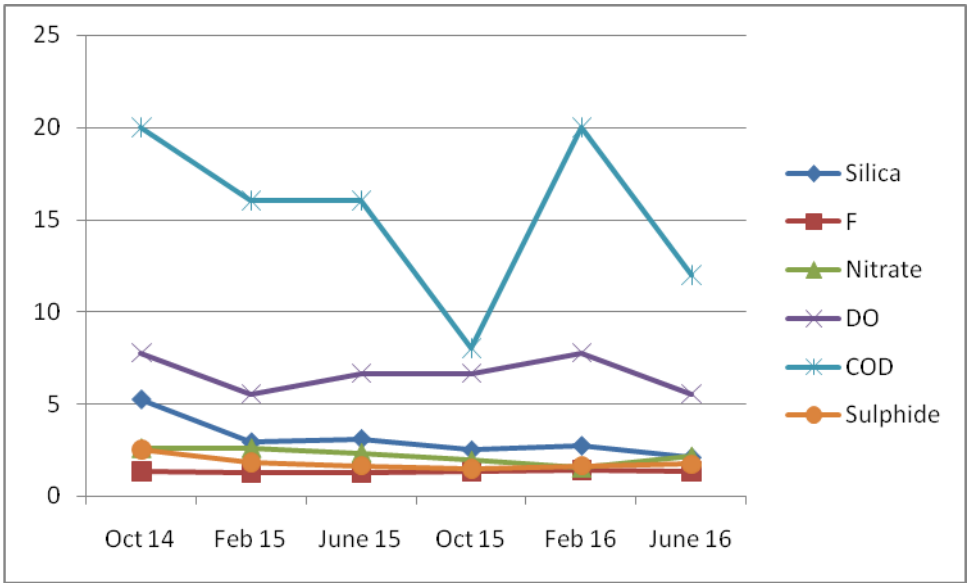
8.1Fig: Variation of TS ,TSS, Sodium, Potassium,Iron with respect to Period Oct-2014 to June-2016 at Vishwamitra kund Nalanda district Bihar



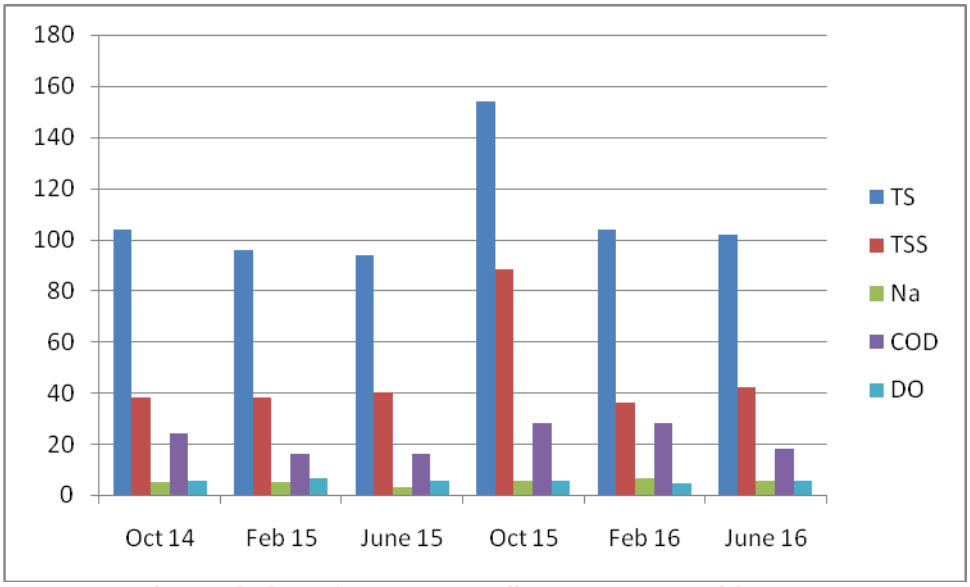
8.2 Fig: Variation of Silica,Fluoride,Nitrate,DO,COD,Sulphide, with respect to Period from Oct-2014 to June-2016 in Vishwamitra kund Nalanda Bihar



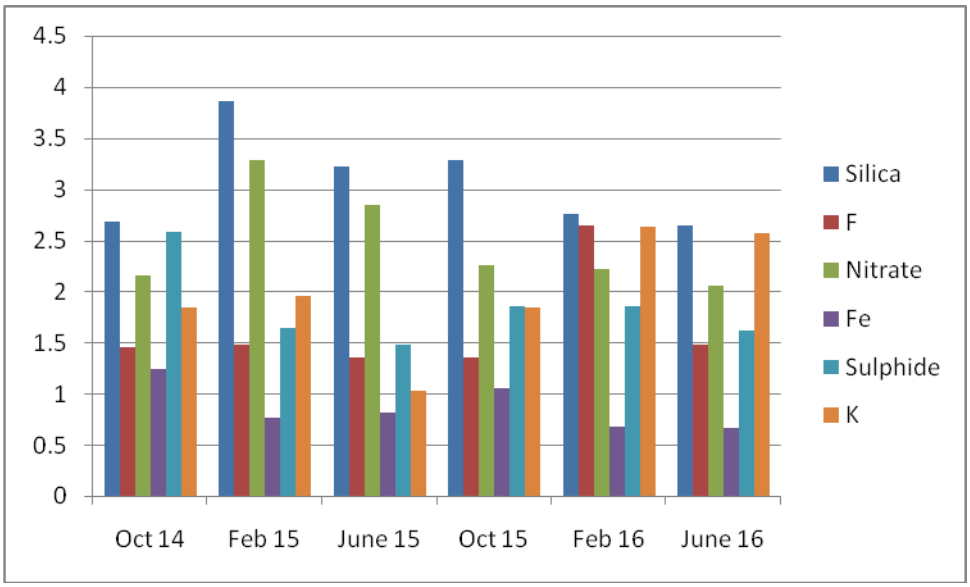
8.3-Fig: Line graph showing variation of TS, TSS, Na, K ,Fe with respect to different season in Vishwamitra kund Nalanda district Bihar



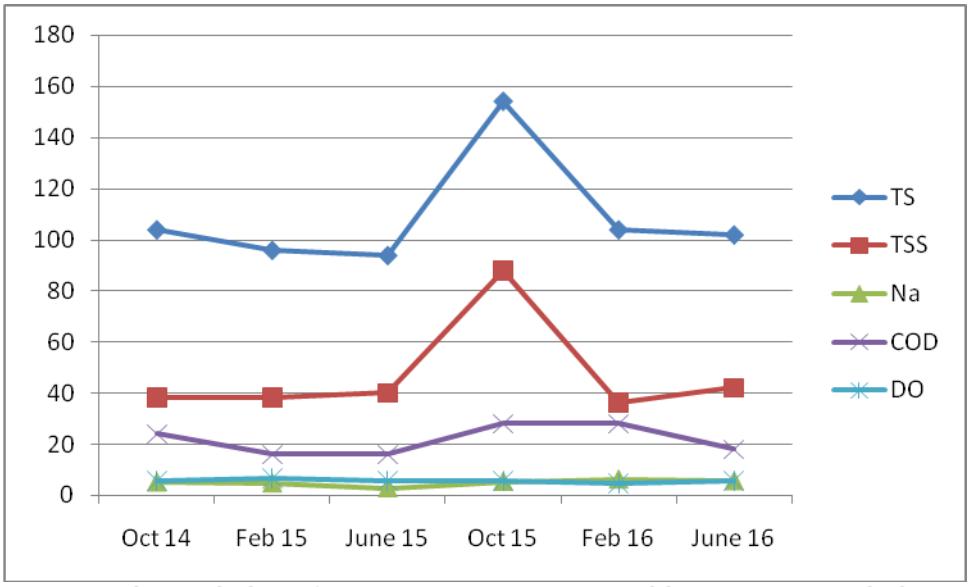
8.4-Fig: Line graph showing variation of Silica ,Fluoride, Nitrate ,DO , COD , Sulphide with respect to Seasonal Variation from Oct 2014 to June 2016 in Vishwamitra Kund Rajgir Nalanda



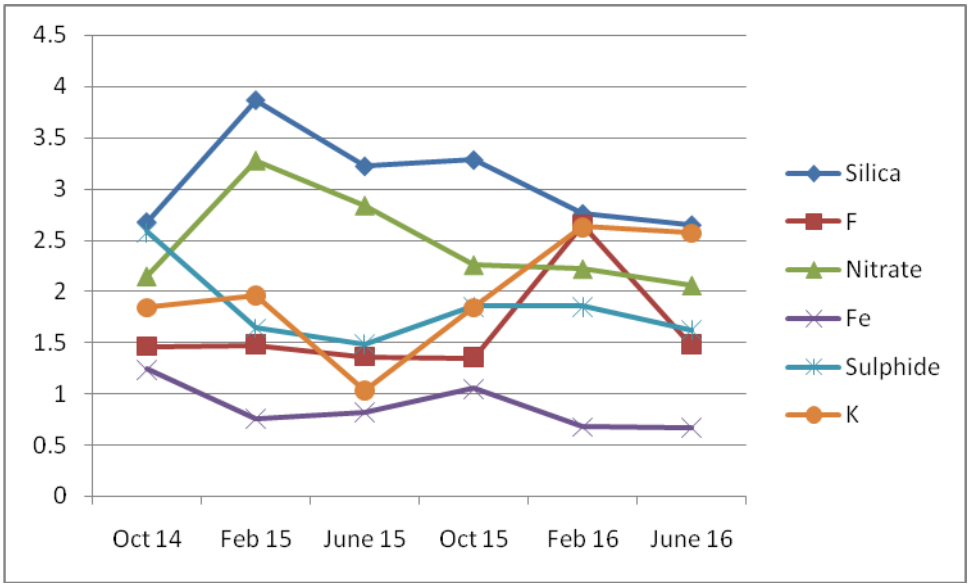
8.5- Fig: Variation of TS ,TSS, Sodium, COD,DO, with respect to period Oct-2014 to June-2016 in Brahm kund Nalanda Bihar



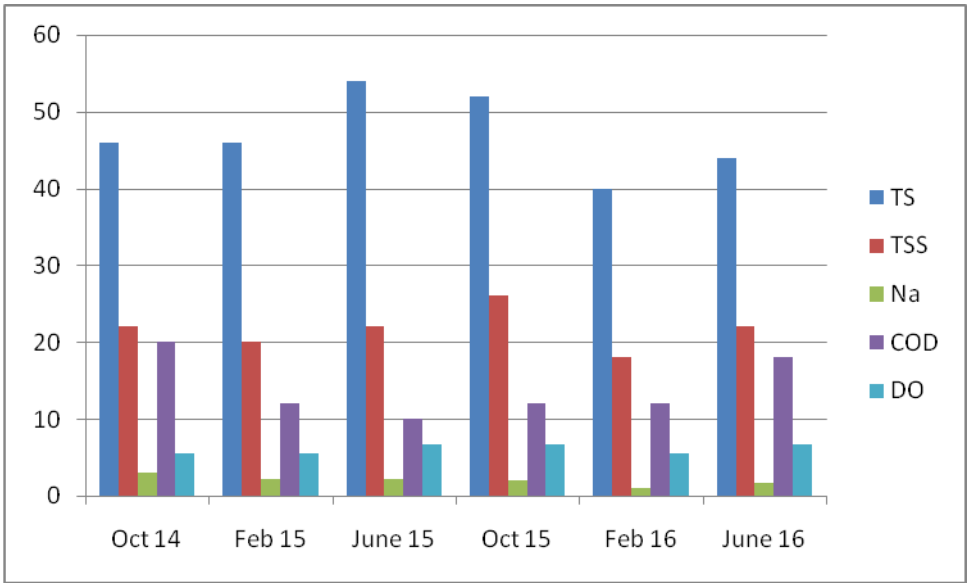
8.6 Fig: Variation of Silica ,Fluoride ,Nitrate ,Iron, Sulphide, Potassium with respect to period Oct-2014 to June-2016 in Brahm kund Nalanda Bihar



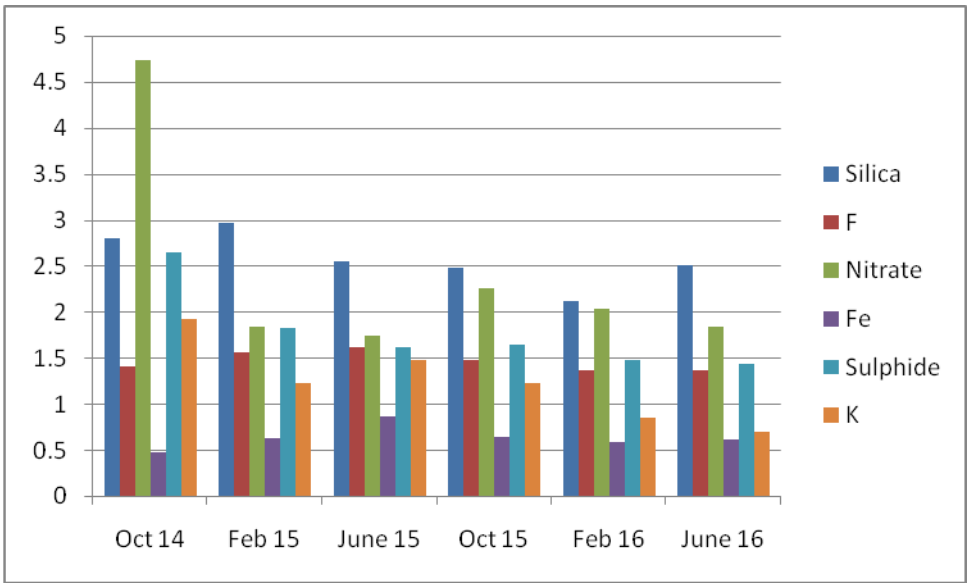
8.7- Fig: Variation of TS, TSS, Na, COD, DO with respect to Period Oct 2014 to June 2016 in Brahm kund Nalanda district Bihar



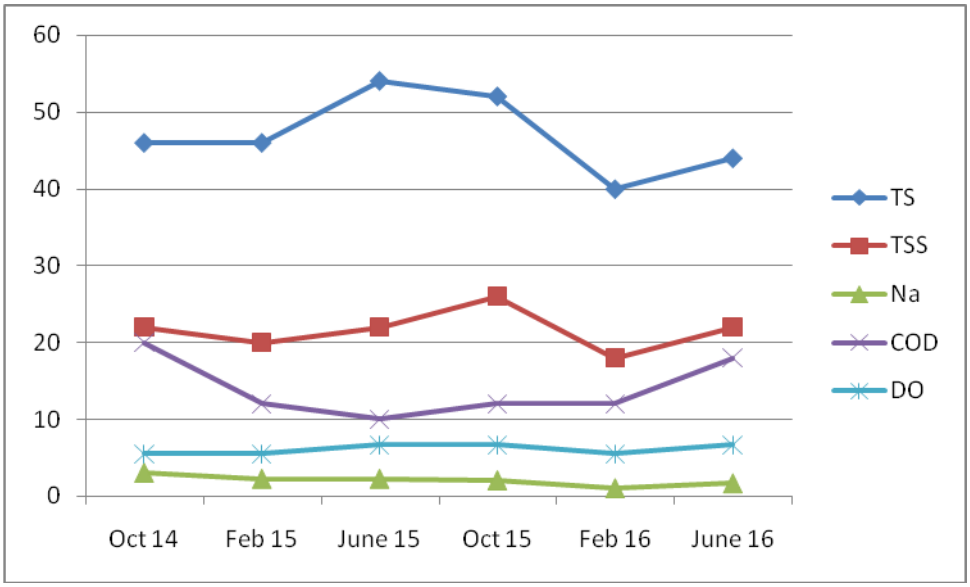
8.8 Fig: Line graph showing variation of Fluoride, Nitrate, Silica, Sulphide , Iron ,Potassium with respect to period Oct 2014 to June 2016 in Brahm kund Nalanda district Bihar



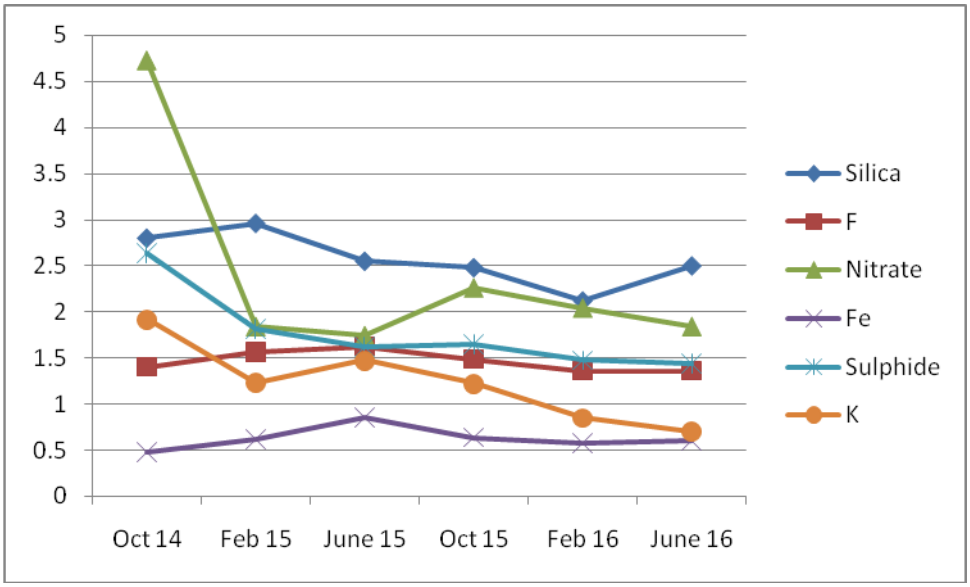
8.9 Fig: Variation of TS ,TSS, Sodium, COD, DO with respect to Period Oct-2014 to June-2016 in Makhdum kund Nalanda Bihar



8.10 Fig: Variation of Silica ,Fluoride ,Nitrate ,Iron, Sulphide ,Potassium with respect to Period Oct-2014 to June-2016 in Makhdum kund Nalanda Bihar



8.11 Fig: Variation of TS, TSS, Na, COD, DO with respect to period Oct 2014 to June 2016 in Makhdum kund Nalanda district Bihar



8.12 Fig: Variation of Silica ,Fluoride ,Nitrate ,Iron, Sulphide ,Potassium with respect to Seasonal Variation from Oct 2014 to June 2016 in Makhdum Kund Rajgir Nalanda

9. CONCLUSION

From the results of Physico-Chemical analysis of this study it is concluded that all the parameters lies within potability range as per WHO and APHA Standard. The concentration of all the parameters are more in Brahm kund as compared to Vishwamitra and Makhdum kund. Due to the presence of Sulphide in good concentration ranges from 1.44 mg/l to 2.64 mg/l at different site of Rajgir hot water spring reveals that this hot spring is Sulphur containing hot spring.

However, concentration varies with season due to dilution of water in monsoon period.

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