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Assessment of Physico-chemical parameters of Mountain River Baldi, Garhwal Himalayas

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Abstract
Physico-chemical parameters of River Baldi was studied for one annual cycle (November 2011-October 2012) at reference site and impacted site. All the physico-chemical parameters were analysed by standard methods. The range of some important parameters were Dissolved oxygen (6.04 -10.32 mg L^{-1}), Turbidity (2-115 NTU), Total Dissolved Solids (30-276 mg L^{-1}), Alkalinity (40-84.6 mg L^{-1}), pH (7.58-7.88), Hardness (124-198 mg L^{-1}), Nitrate (0.058-0.115 mg L^{-1}) and Phosphate (0.015-0.080 mg L^{-1}) recorded. ANOVA between seasons were computed and was found significant (p<0.05). Pearson's correlation coefficient between parameters for seasons was analysed. Conductivity, turbidity, TDS and pH were significantly correlated with each other. On comparison between sites, the water quality was good at reference site as compared to impacted site. Anthropogenic disturbances degrade the water quality at impacted site. The study concludes that water at both sites of Baldi River is suitable for drinking purpose and other human use.

Keywords: physico-chemical parameters, Baldi River, Garhwal Himalayas

1. Introduction
Rivers are the most important freshwater resource in the world. In most of countries, water becomes a commodity [1]. The rapid increase in human population, industrialization influences the environment particularly the freshwater and results in decline in water quality [2-5]. The degraded water quality affects the life of plant, animal and human being. Therefore, it is important to identify the sources that contaminate water quality [6]. The physico-chemical parameter of any aquatic ecosystem indicates the type, composition and diversity of biotic components of that ecosystem [7.8]. The present study was conducted to quantify whether the water quality of Baldi river is suitable for drinking purpose or not and to detect the impact of anthropogenic pressure on Baldi river.

2. Materials and methods
2.1 Study Area
The Baldi is one of major tributary of the River Song River flowing in Doon Valley of Garhwal Himalayas, India. It lies in the coordinate of 30^0 23' N; 78^0 08'E in Raipur Block of Dehradun district of Uttarakhand State, India. Two sampling sites were selected on the basis of disturbances after a thorough survey of the entire stretch of the Baldi River. The reference site (S_1) was identified near Shera Chouki. This site is rich in calcareous rock. Whereas, impacted site (S_2) was identified near the Sahastradhara tourist spot. Number of sulphur springs joins Baldi River at impacted site.

2.2 Collection of Sample and Analysis
Regular monthly sampling was undertaken between 0800 hrs to1000 hrs at each sampling site from November 2011 to October 2012 spreading into three seasons (winter season = November to February; summer = March to June; monsoon = July to October). Five replicates of surface water samples were collected from depth of 10cm for each parameter. All the results were recorded by adopting standards methods [9]. Water temperature was recorded with the Centigrade (0 – 110 ˚C) thermometer. Turbidity was measured with the help of the Metzer Digital Turbidity Meter (Model-5D1M). Conductivity, pH and TDS of the water samples were measured with the help of the Toshcon Multiparameter Analyser. The modified Winkler's method was used for the estimation of dissolved oxygen concentration. Nitrates,

phosphates and sulphates were determined with the help of the Spectrophotometer (Model- UV-VIS Systronics 117 series). Sodium and Potassium analysed by using Flame Photometer (Model–EI 1381E). Alkalinity, Calcium, Magnesium and Hardness were calculated by the titration method. Statistical analysis was performed by using SPSS 16.0.

3. Results and discussion

The Seasonal fluctuations in physico-chemical parameters were represented in Table 1. Pearson correlation represented in Table 2 (Winter Season), Table 3 (Summer Season) and Table 4 (Monsoon Season).

3.1 Water temperature

Water temperature at reference site (S_1) of Baldi River was recorded maximum (14.63±0.84 ˚C) in monsoon season and minimum (10.95±1.3 ˚C) in winter. ANOVA between seasons calculated and F ratio (11.477) was recorded. At impacted site (S_2), maximum (14.80±0.85 ˚C) temperature was recorded in monsoon and minimum (11.10±1.26 ˚C) in winter. F ratio between seasons was found 12.266. In river, water temperature influences the life cycle of aquatic organisms [10]. Water temperature negatively correlated with dissolved oxygen during all seasons (Table 2-4). In monsoon, high temperature and high humidity results in low dissolved oxygen concentration because warm water gets easily saturated with oxygen [11, 12]. High water temperature in monsoon also observed in Ghaghra River, India [13].

3.2 Transparency, Conductivity, Turbidity and Total dissolved solids

Maximum (0.39±0.03m) transparency was recorded in winter and minimum (0.21±0.10 m) in monsoon. F ratio was calculated 4.505 between seasons. At impacted site, Maximum (0.29±0.03m) transparency was recorded in winter and minimum (0.11±0.12m) in monsoon. F ratio of ANOVA was found 3.615 between seasons in impacted site. Conductivity was observed maximum (0.410±0.04) in Monsoon and minimum (0.380±0.0) in winter at reference site whereas at impacted site, maximum (0.610±0.04 mS cm^{-1}) conductivity recorded in monsoon season and minimum (0.580±0.0mS cm^{-1}) in winter. F ratio was found 4.265 between seasons of impacted site.

Maximum (77.93±20.1 NTU) turbidity was recorded in monsoon and minimum (10±10.46 NTU) in winter was recorded at S_1. F ratio between seasons was found 16.661. At S_2, maximum (95.23±17.56 NTU) turbidity was recorded in monsoon and minimum (17±11.49) in winter. F ratio between seasons was found 21.708. Maximum (192.75±46.76 mg L^{-1}) TDS was recorded in monsoon and minimum (45±13.52 mg L^{-1}) in winter was recorded at reference site whereas, maximum (226.75±44.71 mg L^{-1}) TDS was recorded in monsoon season and minimum (63.75±14.1) in winter at impacted site. F ratio between seasons was found 16.910 at impacted site.

Conductivity expresses the ability of water to carry electric current [14]. It directly related to turbidity and total dissolved solids. It has positive correlation with turbidity and TDS (Table 2-4). More the value of dissolve solids more will be ions in water [15]. Maximum conductivity recorded at impacted site. Higher turbidity recorded in monsoon season and low turbidity in winter season on both sites. Similar findings were reported from Chandrabhaga river in Garhwal Himalaya [16] and River Sutlej [17]. Turbidity has positive correlation with TDS in all seasons (Table 2-4). High turbidity in monsoon due to addition of debris from watershed [14]. Lower TDS recorded in winter season on both sites. Similar findings observed from Umshyrpi River, Shillong [18]. In natural sources, TDS concentration varies from less than 30 mg L^{-1} to as higher as 6000 mg L^{-1} [19]. The range of TDS in Baldi River was within limit. Turbidity and TDS has inverse relationship with Transparency. Transparency in river indicates its productivity [14]. More clear water more the productivity. Maximum transparency recorded at S_1 as compare to S_2.

3.3 pH

Maximum (7.83±0.05) pH was recorded in monsoon season and minimum (7.69±0.03) in winter season at reference site S_1. F ratio was calculated 8.708 between seasons. At impacted site, Maximum (7.75±0.09) pH was recorded in monsoon season and minimum (7.63±0.05) in winter. F ratio of ANOVA was found 3.777 between seasons at impacted site. pH of running water is important because it influences biochemical activities of any aquatic ecosystem [20]. The maximum pH recorded at reference site due to geology of reference site which is rich in calcareous rock. Presence of limestone rocks results in higher pH [21]. During winter, low pH values recorded, which may due to decomposition of organic matter in river bed [22, 23].

3.4 Dissolved oxygen

At reference site, Maximum (9.83±0.48 mg L^{-1}) DO was recorded in winter and minimum (7.37±0.87 mg L^{-1}) in monsoon. F ratio was calculated 9.381 between seasons in reference site. Whereas, at impacted site, maximum (8.02±0.42 mg L^{-1}) DO was recorded in winter season and minimum (6.12±0.81 mg L^{-1}) in monsoon season. F ratio was calculated 9.099 between seasons. During the period of study, maximum dissolved oxygen recorded at reference site (S_1) of Baldi River and minimum concentration of dissolved oxygen at S_2. This may be due to maximum anthropogenic disturbances at S_2. DO had negative correlation with TDS, Turbidity, conductivity, nitrate, phosphate and sulphate (p<0.05) Table (2-4). Higher concentration of dissolved concentration was recorded in winter. It may due to high photosynthetic rate of phytoplankton communities that result in higher dissolved oxygen [24, 25]. Lower concentration of dissolved oxygen was recorded in monsoon season. During monsoon, Mountain river Baldi was flooded with high debris received from riparian zone. These suspended materials lowers photosynthetic rate by absorbing sunlight, which could not penetrate under surface water and raise the surface water temperature which results in lower dissolved oxygen [13, 26]. Similar findings were reported from Dhauli ganga [27], Chandrabhaga river [16] and Tons river [28].

3.5 Alkalinity

At reference site, Maximum (84.53±10.54 mg L^{-1}) alkalinity was recorded in monsoon season and minimum (51.23±11.51 mg L^{-1}) in winter. F ratio was calculated 6.394 between seasons whereas, Maximum (72.75±12.54 mg L^{-1}) alkalinity was recorded in monsoon season and minimum (46.08±7.75 mg L^{-1}) in winter season at impacted site. F ratio of ANOVA was found to be 4.672 between seasons at impacted site. Alkalinity of surface water reflects carbonate, hydroxide content, phosphates, sulphates, nitrates [14]. Alkalinity is ability of river to resist changes in pH. Alkalinity values of 20-200 mg/l are common in fresh water ecosystems [29]. The range of Alkalinity at both the sites is within this range. High values of

alkalinity were recorded at reference site. This may be due to carbonates and bicarbonates are mainly responsible for alkalinity [30, 31].

3.6 Calcium, Magnesium and Total Hardness

Maximum (76.5±8.06 mg L^{-1}) calcium was recorded in winter and minimum (50.5±8.7 mg L^{-1}) in monsoon season. F ratio was calculated 8.301 between seasons in reference site. At impacted site, maximum (72.25±6.95 mg L^{-1}) calcium was recorded in winter and minimum (45.5±9.68 mg L^{-1}) in monsoon. Maximum (44.75±4.43 mg L^{-1}) magnesium was recorded in winter and minimum (28.0±9.83 mg L^{-1}) in monsoon at reference site. F ratio was calculated 31.946 between seasons at reference site whereas, maximum (40.0±4.0 mg L^{-1}) magnesium was recorded in winter and minimum (24.0±8.45 mg L^{-1}) in monsoon at impacted site. Total hardness was recorded maximum (171.25±10.31 mg L^{-1}) in winter season and minimum (110.5±16.82 mg L^{-1}) in monsoon season. F ratio was calculated 21.676 between seasons at reference site. At impacted site, maximum (160.25±9.32 mg L^{-1}) hardness was recorded in winter and minimum (109.5±16.76 mg L^{-1}) in monsoon. According to a classification of Payne [32], River water at both sites (S_1 and S_2) of Baldi River considered under "Hard water "category. The high values of Total Hardness recorded during winter at all sites may be attributed to the increased mobilization of hardness causing elements like calcium and magnesium released from subsurface ground waters having higher hardness [33, 34]. The overall high calcium values recorded at both sites of Baldi River. High calcium values are direct attribute of calcium rich rocks [35].

3.6 Nitrates and Phosphates

Maximum (0.083±0.013 mg L^{-1}) nitrates was recorded in monsoon and minimum (0.06±0.004 mg L^{-1}) in winter. F ratio was calculated 6.127 between seasons at reference site whereas, at impacted site, maximum (0.100±0.013 mg L^{-1}) nitrates was recorded in monsoon and minimum (0.076±0.003 mg L^{-1}) in winter. Phosphates was recorded maximum (0.059±0.013 mg L^{-1}) in monsoon and minimum (0.026±0.008 mg L^{-1}) in winter at reference site While, maximum (0.068±0.012 mg L^{-1}) phosphates was recorded in monsoon and minimum (0.040±0.001mg L^{-1}) in winter at impacted site. In the case of inorganic nitrogen, nitrates considered as most stable form [36]. Maximum nitrate concentration recorded at impacted site. It may due to maximum anthropogenic activities at this site. High levels of nitrate showed the effect of anthropogenic activities and agricultural runoffs [37]. Phosphates recorded maximum in monsoon and lowest in winter season during study period. Similar findings of lower concentration of Phosphates in winter season was also reported from different rivers like Dhauli ganga river [27], Tons river [28] and Rapti river [38] Phosphate concentration may be due to agricultural practices in the catchment area of river, soaps and detergents [25]. Phosphate concentration was observed maximum at impacted site (S_2). This may be due to anthropogenic activities like dumpling of organic wastes and addition of municipal waste water was recorded during the period of study at impacted site.

3.7 Sulphates

Maximum (2.0±0.34 mg L^{-1}) concentration of sulphates was recorded in monsoon and minimum 1.21±0.08 mg L^{-1}) in winter at reference site. F ratio was calculated 7.099 between seasons in reference site whereas, at impacted site, maximum (3.46±0.30 mg L^{-1}) sulphates was recorded in monsoon and minimum (2.64±0.11 mg L^{-1}) in winter. Sulphates in river due to runoff water from riparian zone which contains huge amount of sulphur compounds, geology of river bed and also due to anthropogenic activities [14]. Maximum concentration of sulphate recorded at impacted site which may be due to water added from nearby sulphur springs to the Baldi River and also maximum anthropogenic activities at impacted site. Sulphates had positive correlation with Conductivity, Turbidity, TDS and pH in all seasons (Table 2-4).

3.8 Sodium and Potassium

Maximum (10.28±0.39 mg L^{-1}) concentration of sodium was recorded in winter season and minimum (9.55±0.86 mg L^{-1}) in monsoon season. F ratio was calculated 6.669 between seasons at reference site while, at impacted site, maximum (10.64±0.52 mg L^{-1}) sodium was recorded in winter season and minimum (9.85±0.34 mg L^{-1}) in monsoon. Potassium was recorded maximum (4.13±0.45 mg L^{-1}) in summer and minimum (3.50±0.22 mg L^{-1}) in winter. F ratio was calculated 5.991 between seasons at reference site while, Maximum (4.40±0.14 mg L^{-1}) potassium was recorded in monsoon and minimum (3.69±0.36 mg L^{-1}) in winter at impacted site. Potassium and sodium showed irregular distribution in the Baldi River Potassium and sodium in river added by weathering of rocks [39].

4. Conclusion

The study reflects seasonal fluctuations of physico-chemical parameters of Baldi River. Anthropogenic activities affect water quality at impacted site. The water of Baldi River is suitable for drinking purpose and other human use after disinfection. This study also provides a base line data for water quality management of River Baldi.

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Table 1: Seasonal variation in Physico-chemical parameters at reference and impacted site of Baldi River from November 2011- October 2012 (Using ANNOVA)

	S_1 (Reference Site)								S_2 (Impacted Site)							
Seasons	**Winter**		**Summer**		**Monsoon**		**F**	**p**	**Winter**		**Summer**		**Monsoon**		**F**	**p**
Parameters	$\overline{X}$	**SD**	$\overline{X}$	**SD**	$\overline{X}$	**SD**			$\overline{X}$	**SD**	$\overline{X}$	**SD**	$\overline{X}$	**SD**		
Water Temperature (˚C)	10.95	1.3	14.5	1.47	14.63	0.84	11.48	0.003	11.1	1.26	14.73	1.44	14.8	0.85	12.27	0.0027
Transparency (m)	0.39	0.03	0.27	0.1	0.21	0.1	4.51	0.044	0.29	0.03	0.17	0.12	0.11	0.12	3.62	0.07039
Conductivity (mS cm^{-1})	0.38	0	0.43	0.03	0.41	0.04	4.19	0.052	0.58	0	0.63	0.02	0.61	0.04	4.27	0.04976
Turbidity (NTU)	10	10.46	33.55	18.54	77.93	20.1	16.66	0.001	17	11.49	45.2	20.67	95.23	17.56	21.71	0.00036
TDS (mg L^{-1})	45	13.52	81.38	41.39	192.75	46.76	17.42	0.001	63.75	14.1	106.98	53.5	226.75	44.71	16.91	0.00089
pH	7.69	0.03	7.77	0.05	7.83	0.05	8.71	0.008	7.63	0.05	7.7	0.05	7.75	0.09	3.78	0.06441
DO(mg L^{-1})	9.83	0.48	8.48	0.98	7.37	0.87	9.38	0.006	8.02	0.42	7.15	0.61	6.12	0.81	9.10	0.0069
Alkalinity (mg L^{-1})	51.23	11.51	67.18	16.65	84.53	10.54	6.39	0.019	46.08	7.75	61.75	15.63	72.75	12.54	4.67	0.04058
Calcium (mg L^{-1})	76.5	8.06	66	10.33	50.5	8.7	8.30	0.009	72.25	6.95	62	9.93	45.5	9.68	9.09	0.00693
Hardness (mg L^{-1})	171.25	10.31	151.25	12.31	110.5	16.82	21.68	0.0004	160.25	9.32	143.5	12.48	109.5	16.76	22.56	0.00031
Magnesium (mg L^{-1})	44.75	4.43	35.25	2.22	28	9.83	31.95	0.0001	40	4	31.5	5	24	8.45	34.80	0.00005
Nitrates (mg L^{-1})	0.06	0.004	0.076	0.009	0.083	0.013	6.13	0.021	0.076	0.003	0.095	0.01	0.1	0.013	6.89	0.0153
Phosphates (mg L^{-1})	0.026	0.008	0.046	0.018	0.059	0.013	5.89	0.023	0.04	0.01	0.054	0.018	0.068	0.012	3.99	0.0575
Sodium (mg L^{-1})	10.28	0.39	8.68	0.52	9.55	0.86	6.67	0.017	10.64	0.52	10.6	0.07	9.85	0.34	6.11	0.0211
Potassium (mg L^{-1})	3.5	0.22	4.13	0.45	4.12	0.09	5.99	0.022	3.69	0.36	3.86	0.41	4.4	0.14	5.18	0.0318
Sulphates (mg L^{-1})	1.21	0.08	1.67	0.38	2	0.34	7.10	0.014	2.64	0.11	3.14	0.4	3.46	0.3	7.83	0.0107

Table 2: Pearson correlation calculated for physico-chemical parameters of Baldi River for Winter Season

	WT	**Trans**	**Cond**	**Tu**	**TDS**	**pH**	**DO**	**Alk**	**Ca**	**Har**	**Mg**	**Ni**	**Phos**	**Na**	**K**	**Sul**
WT	1															
Trans	-0.514	1														
Cond	0.93	-0.185	1													
Tu	0.831	-0.901	0.594	1												
TDS	0.529	-1.00**	0.204	0.909	1											
pH	0.841	-0.805	0.677	.960*	0.817	1										
DO	-0.654	.983*	-0.343	-.956*	-.985*	-0.859	1									
Alk	0.702	-.961*	0.431	.979*	.967*	0.936	-.980*	1								
Ca	-0.801	0.776	-0.657	-0.929	-0.79	-.994**	0.82	-0.915	1							
Har	-0.788	0.654	-0.707	-0.852	-0.67	-.964*	0.703	-0.827	.983*	1						
Mg	-0.517	0.038	-0.681	-0.338	-0.058	-0.582	0.091	-0.283	0.644	0.772	1					
Ni	-0.23	.953*	0.113	-0.731	-0.947	-0.628	0.882	-0.847	0.613	0.483	-0.11	1				
Phos	0.493	-.991**	0.147	0.875	.988*	0.744	-.979*	0.93	-0.703	-0.565	0.084	-0.944	1			
Na	0.034	-0.175	-0.163	0.064	0.162	-0.209	-0.217	0.025	0.308	0.453	0.831	-0.152	0.308	1		
K	0.88	-0.707	0.667	0.87	0.713	0.749	-0.821	0.777	-0.675	-0.578	-0.074	-0.478	0.739	0.449	1	
Sul	-0.131	-0.161	-0.084	0.103	0.168	0.315	-0.06	0.219	-0.41	-0.492	-0.639	-0.263	0.035	-0.894	-0.391	1

Abbreviations: WT: Water temperature, Trans : transparency, Cond : conductivity, Tu: Turbidity, TDS: Total dissolved solids, pH, DO :Dissolved oxygen, Alk : Alkalinity, Ca : Calcium, Har: Hardness, Mg: Magnesium, Ni : Nitrates, Phos :Phosphates, Na: Sodium, K:Potassium, Sul : Sulphates

Table 3: Pearson correlation calculated for physico-chemical parameters of Baldi River for Summer Season

	WT	Trans	Cond	Tu	TDS	pH	DO	Alk	Ca	Har	Mg	Ni	Phos	Na	K	Sul
WT	1															
Trans	-0.793	1														
Cond	0.945	-0.739	1													
Tu	0.932	-.954*	0.903	1												
TDS	0.889	-.984*	0.84	.992**	1											
pH	.986*	-0.832	.978*	.961*	0.918	1										
DO	-.997**	0.818	-.963*	-.950*	-0.908	-.996**	1									
Alk	.978*	-0.872	.966*	.979*	0.945	.997**	-.991**	1								
Ca	-.966*	0.884	-.965*	-.983*	-.952*	-.993**	.983*	-.999**	1							
Har	-.990*	0.871	-0.928	-.971*	-0.944	-.985*	.992**	-.988*	.981*	1						
Mg	-0.781	0.575	-0.537	-0.649	-0.645	-0.672	0.734	-0.666	0.635	0.773	1					
Ni	.964*	-0.911	0.944	.993**	.970*	.987*	-.979*	.996**	-.997**	-.986*	-0.665	1				
Phos	.997**	-0.763	.964*	0.918	0.866	.988*	-.996**	.976*	-.965*	-.979*	-0.743	.957*	1			
Na	-.956*	0.693	-.995**	-0.877	-0.807	-.973*	.966*	-.955*	0.949	0.926	0.584	-0.927	-.975*	1		
K	0.916	-0.622	.987*	0.825	0.745	0.942	-0.93	0.918	-0.914	-0.877	-0.502	0.883	0.944	-.993**	1	
Sul	0.93	-0.916	0.946	.989*	.966*	.973*	-.954*	.986*	-.993**	-.958*	-0.567	.992**	0.927	-0.918	0.882	1

Abbreviations : WT: Water temperature, trans : transparency, cond : conductivity, Tu: Turbidity, TDS: Total dissolved solids, pH, DO :Dissolved oxygen, Alk : Alkalinity, Ca : Calcium, Har: Hardness, Mg: Magnesium, Ni : Nitrates, Phos :Phosphates, Na: Sodium, K:Potassium, Sul : Sulphates

Table 4: Pearson correlation calculated for physico-chemical parameters of Baldi River for Monsoon Season

	WT	Trans	Cond	Tu	TDS	pH	DO	Alk	Ca	Har	Mg	Ni	Phos	Na	K	Sul
WT	1															
Trans	-0.629	1														
Cond	.970*	-0.632	1													
Tu	0.431	-.971*	0.43	1												
TDS	0.65	-.985*	0.692	0.938	1											
pH	0.565	-.970*	0.513	.968*	0.913	1										
DO	-0.51	.952*	-0.586	-0.936	-.981*	-0.863	1									
Alk	0.649	-.982*	0.695	0.934	1.000**	0.906	-.983*	1								
Ca	-0.3	0.925	-0.344	-.977*	-0.915	-0.893	.954*	-0.914	1							
Har	0.072	0.699	-0.024	-0.817	-0.709	-0.651	0.82	-0.712	0.917	1						
Mg	0.434	0.354	0.302	-0.519	-0.383	-0.299	0.548	-0.388	0.679	0.916	1					
Ni	0.672	-.953*	0.741	0.889	.991**	0.851	-.978*	.993**	-0.88	-0.685	-0.374	1				
Phos	0.58	-.958*	0.653	0.922	.990**	0.864	-.996**	.992**	-0.928	-0.769	-0.479	.992**	1			
Na	-0.677	.977*	-0.724	-0.92	-.999**	-0.897	.977*	-.999**	0.897	0.685	0.357	-.995**	-.990*	1		
K	-0.776	0.912	-0.845	-0.808	-.962*	-0.794	0.928	-.965*	0.784	0.554	0.229	-.985*	-.956*	.974*	1	
Sul	0.558	-0.949	0.638	0.917	.985*	0.85	-.998**	.988*	-0.931	-0.783	-0.503	.989*	.999**	-.985*	-.951*	1

Abbreviations: WT: Water temperature, trans : transparency, cond : conductivity, Tu: Turbidity, TDS: Total dissolved solids, pH, DO :Dissolved oxygen, Alk : Alkalinity, Ca : Calcium, Har: Hardness, Mg: Magnesium, Ni : Nitrates, Phos :Phosphates, Na: Sodium, K:Potassium, Sul : Sulphates

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