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Physicochemical Assessment and Water Quality of Surface Water in Chandel and Tengnoupal Districts, Manipur for Domestic and Irrigational Uses

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Abstract: *The study aims to validate the water quality for domestic and irrigational uses based on the physico chemical properties of the surface waters in parts of Chandel and Tengnoupal districts of Manipur. The sources of the dissolved constituents in the samples suggest Mg-Ca-HCO_3-Cl as the dominant hydro-facies and are magnesium bicarbonate water types. The dominant geochemical process that governs the water chemistry is rock weathering dominance. WQI of the water samples ranges from 76.18 to 155.33 and is well within the limits of the BIS and WHO guidelines for drinking water. All the samples are suitable for irrigational uses based on the determined values of EC, TDS, SSP and SAR. Hence, these perennial rivers and streams hold the potential to provide uninterrupted supply of drinking and irrigational water to Chandel, Tengnoupal, Kakching and Thoubal districts of Manipur without any major treatment.*

Keywords: *Physico-chemical, hydrochemical facies, Water Quality, Manipur*

1. Introduction

Urbanisation catalyst the human dependency on the water consumption either for domestic or irrigational uses. Rivers and streams show spatial heterogeneity in the physico-chemical indices which enable to categorize the water for different uses or to detect toxicity. Singh et al [1] indicated that most of the physicochemical parameters from Manipur river system were within the WHO limits for drinking water purposes. Subsequently, Singh et al. [2], [3] and Singh and Gupta [4] have also studied the physicochemical parameters of surface waters of Nambul River and Loktak Lake. Ranu & Wazir [5] showed physicochemical water quality parameters (Fe^{3+} and Po_4^{3-}) of Nambul river exceeds the desirable and permissible standards prescribed by the WHO and BIS. Water quality Index of Nambul River are categorized to very poor to unsuitable classes by Ranu & Wazir [5] with highest value (212.83) observed at the confluence of Nambul River with Naga nala near the main city market and commercial establishment

Nearly 90% of the drinking water supply in urban area of Manipur is from the three major rivers; Imphal River, Nambul River and Iril River. However, water scarcity being pertinent phenomena in these rivers during dry season, water from other rivers and streams in the east of Imphal Valley provide as alternative sources. Poor water quality as well as limited water volume conditions of main rivers in the urban areas specially Nambul and Imphal rivers, a thorough research on the alternative water sources becomes vital. Hence, the present study provides a way forward to assess the physico-chemical properties of the streams in Chandel and Tengnoupal districts of Manipur to validate the water quality for domestic and irrigational uses.

2. Methodology:

The study area is drained by three main rivers; Sekmai, Chakpi and Lokchao. Based on the basin analysis and human approachability nine representative stream water samples (W1-W9) have been collected at different sites from various tributaries of these rivers during the month of February and March, 2019 (fig.1). The geographic sample locations were measured using hand-held Etrex Gramin GPS and are listed in Table-1.

Each sample have been collected in cleaned chemical grade polyethylene bottles that have been pre-washed with HNO_3 and thoroughly rinsed with deionised water. The physico-chemical parameters of these water samples such as pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured using field test kits while the major ion concentrations were determined in the laboratories.

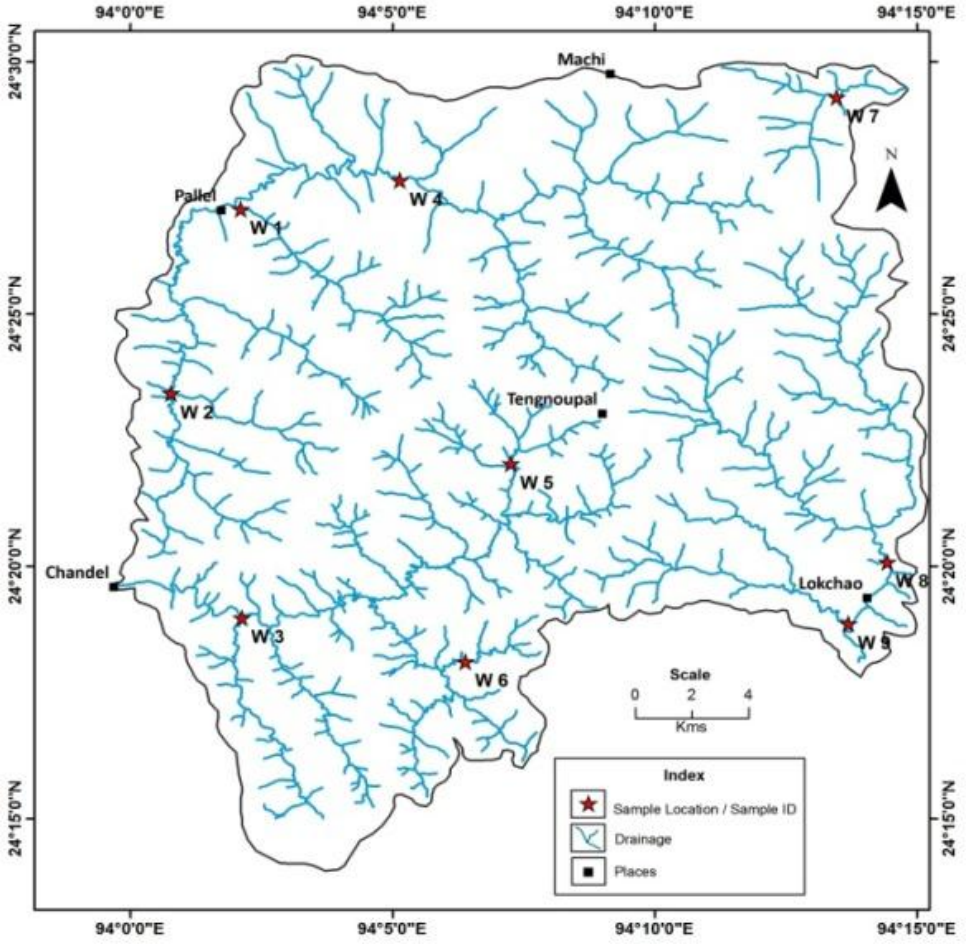

Fig.1: Sampling sites in Chandel and Tengnoupal districts, Manipur

Table-1: Stream water sample details

Sample ID	River Name	Latitude	Longitude
W1	Tisa Lok	24°27'05.0"N	94°02'05.7"E
W2	Maha River	24°23'26.0"N	94°00'46.0"E
W3	Khumji Lok	24°18'59.0"N	94°02'07.0"E
W4	Sekmai River	24°27'39.0"N	94°05'08.0"E
W5	Chakpi River A	24°22'02.0"N	94°07'15.0"E
W6	Chakpi River B	24°18'07.0"N	94°06'23.0"E
W7	Wangphu Lok	24°29'18.0"N	94°13'28.0"E
W8	Lokchao River	24°20'05.0"N	94°14'26.0"E
W9	Tuivai Lok	24°18'51.9"N	94°13'41.3"E

3. Result and Discussion

All the stream water samples (W1-W9) are found colourless and odourless. The values of various physicochemical parameters of the water samples are listed in Table-2.

Piper [6] suggested diagrammatic representation of the constituent ions to determine the sources of the dissolved constituents in water. The Piper plot of the samples is prepared to understand the hydrochemical facies of the water samples (fig. 2). All the samples are magnesium bicarbonate type except one sample (W2) which shows mixed type (Table-3).

Table-2: Physicochemical parameters for the water samples of Chandel and Tengnoupal districts, Manipur

Sample No	W1	W2	W3	W4	W5	W6	W7	W8	W9
pH	7.5	7.6	7.6	7.7	7.8	7.7	8.3	8	7.9
EC in µ simens/cm at 25 °C	171	288	205	223	270	270	256	260	256
HCO_3^-(ppm)	110	185	140	140	185	165	190	220	200
SO_4^{2-} (ppm)	7.48	7.7	5.72	7.92	7.7	8.36	6.16	16.16	6.16
NO_3^- (ppm)	0.409	1.424	1.502	0.896	0.59	1.013	1.193	1.213	0.931
Cl^- (ppm)	40.0	30.0	40.0	80.0	50.0	40.0	40.0	65.0	35.0
Total Hardness as $CaCo_3$ (ppm)	190	180	170	230	220	190	210	280	210
Ca^{2+} (ppm)	16.0	36.0	28.0	28.0	40.0	32.0	32.0	28.0	32.0
Mg^{2+} (ppm)	24.0	21.6	24.0	38.4	28.8	26.4	31.2	50.4	31.2
Na^+ (ppm)	5.65	10.7	4.79	5.18	5.86	5.74	4.5	5.4	5.89
K^+ (ppm)	0.37	0.91	0.46	0.4	0.42	0.39	0.25	0.3	0.42
Po_4^{3-} (ppm)	0.208	0.206	0.363	0.356	0.292	0.513	0.331	0.193	0.204
Sio_2 (ppm)	7.3	6.7	5.3	8.1	5.2	5.6	12.048	12.058	10.941
TDS (ppm)	102	173	123	134	162	162	154	156	154
F^- (ppm)	0.103	0.167	0.1	0.116	0.078	0.084	0.146	0.093	0.133

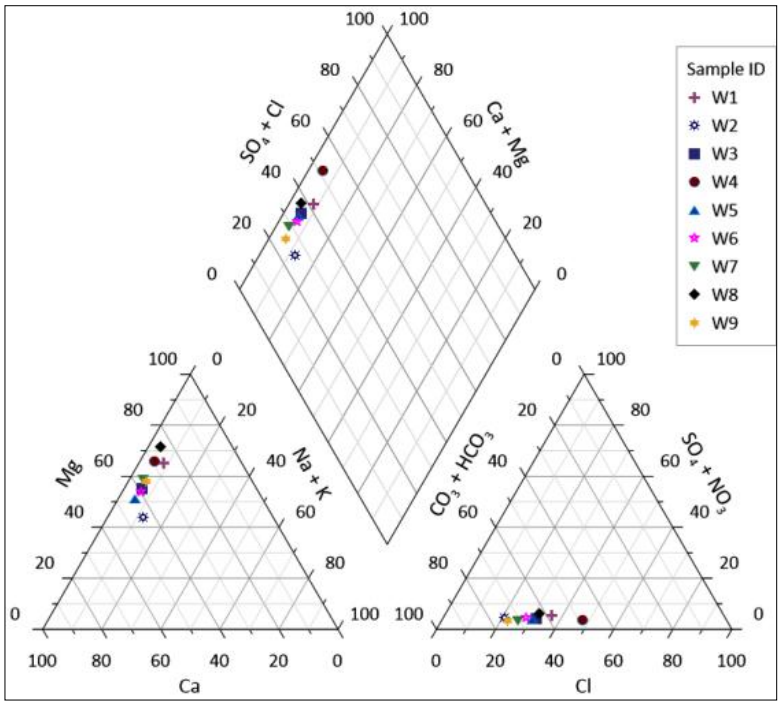

Fig.2: Piper plot for the water samples of Chandel and Tengnoupal districts, Manipur

3.1 Physicochemical assessment

Atmospheric precipitation, rock weathering dominance and the evaporation process are the major factors controlling the composition of the dissolved salts of the world's waters [7]. The dominant geochemical process that governs the water chemistry and major source of the cations and anions in the river water of the area were recognised as rock-weathering dominant types using Gibb's diagram (fig. 3A & B).

Table-3: Hydrochemical facies /water type of samples

Sample ID	Hydrochemical facies / water type
W1	Mg-Ca-HCO_3-Cl = $Mg(HCO_3)_2$
W2	Ca-Mg-HCO_3-Cl = $Ca(HCO_3)_2$
W 3	Mg-Ca-HCO_3-Cl = $Mg(HCO_3)_2$
W 4	Mg-Ca-HCO_3-Cl = $Mg(HCO_3)_2$
W 5	Mg-Ca-HCO_3-Cl = $Mg(HCO_3)_2$
W 6	Mg-Ca-HCO_3-Cl = $Mg(HCO_3)_2$
W 7	Mg-Ca-HCO_3-Cl = $Mg(HCO_3)_2$
W 8	Mg-Ca-HCO_3-Cl = $Mg(HCO_3)_2$
W 9	Mg-Ca-HCO_3-Cl = $Mg(HCO_3)_2$

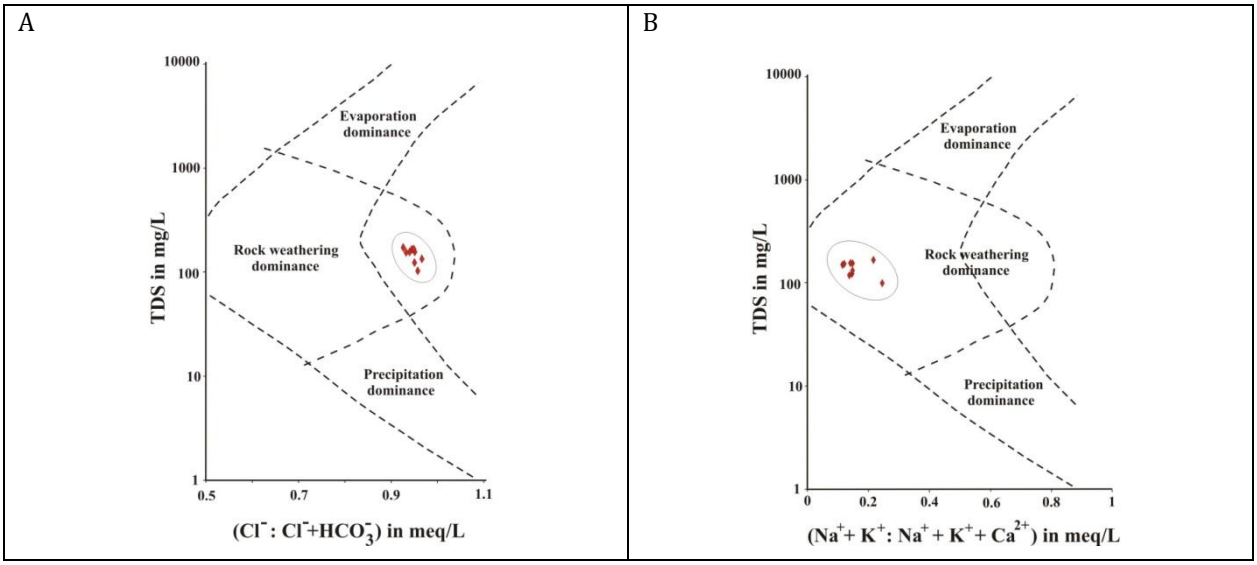

Fig. 3: Gibbs's Diagram (a) Cations and (b) Anions to identify the major geochemical process governing the water type modified after Gibb's, 1970.

3.2 Water quality index (WQI)

13 parameters i.e. pH, TDS, HCO_3^-, Po_4^{3-}, SO_4^{2-}, NO_3^-, Cl^-, Total Hardness as $CaCo_3$, Ca^{2+}, Mg^{2+}, Na^{2+}, K^+ & F^- are used for calculating water quality index (WQI). After Ramakrishnaiah et al. [8] the following steps are used for **WQI** calculation. In first step, each of 13 parameters is assigned a weight (***wi***) according to its relative importance in the overall quality of water for drinking purposes. In the second step, the relative weight ***(Wi)*** is computed from the following equation:

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \quad \text{.....(1)}$$

where (***wi***) is the assigned weight of each parameter and ***(Wi)*** is the relative weight of each parameter and ***(n)*** is the no. of parameters.

In the third step, a quality rating scale (***qi***) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS and the result multiplied by 100:

$$qi = \frac{Ci}{Si} X100 \quad \text{.....(2)}$$

where (***qi***) is the quality rating, (C***i***) is the concentration of each chemical parameter in each water sample in ppm, and (***Si***) is the Indian drinking water standard for each chemical parameter in mg/L according to the guidelines of the BIS, 2012.

Table-4: Relative weight (Wi) & WQI calculation for the samples

				SI (qi x Ci) for each sample (sample W1-W9)								
	wi	Wi	Si (BIS)	SIW1	SIW2	SIW3	SIW4	SIW5	SIW6	SIW7	SIW8	SIW9
pH	4	0.097561	7	10.45	10.59	10.59	10.73	10.87	10.73	11.57	11.15	11.01
TDS	4	0.097561	500	1.99	3.38	2.40	2.61	3.16	3.16	3.00	3.04	3.00
HCO_3^-	3	0.073171	244	3.30	5.55	4.20	4.20	5.55	4.95	5.70	6.60	6.00
SO_4^{2-}	4	0.097561	200	0.36	0.38	0.28	0.39	0.38	0.41	0.30	0.79	0.30
NO_3^-	5	0.121951	45	0.11	0.39	0.41	0.24	0.16	0.27	0.32	0.33	0.25
Cl^-	3	0.073171	200	1.46	1.10	1.46	2.93	1.83	1.46	1.46	2.38	1.28
TH	2	0.048780	600	1.54	1.46	1.38	1.87	1.79	1.54	1.71	2.28	1.71
Ca^{2+}	2	0.048780	75	1.04	2.34	1.82	1.82	2.60	2.08	2.08	1.82	2.08
Mg^{2+}	2	0.048780	30	3.90	3.51	3.90	6.24	4.68	4.29	5.07	8.20	5.07
Na^+	3	0.073171	200	0.21	0.39	0.18	0.19	0.21	0.21	0.16	0.20	0.22
K^+	2	0.048780	25	0.07	0.18	0.09	0.08	0.08	0.08	0.05	0.06	0.08
Po_4^{3-}	3	0.073171	0.03	50.73	50.24	88.54	86.83	71.22	125.12	80.73	47.07	49.76
F^-	4	0.097561	1	1.00	1.63	0.98	1.13	0.76	0.82	1.42	0.91	1.30
			WQI	**76.18**	**81.13**	**116.22**	**119.26**	**103.29**	**155.13**	**113.59**	**84.82**	**82.06**

For computing the ***WQI***, the ***SIi*** is first determined for each chemical parameter, which is then used to determine the ***WQI*** as per the following equations (Table-4)

$$SIi = WiXqi \quad \text{.....(3)}$$

$$WQI = \sum SIi \quad \text{.....(4)}$$

The WQI are generally classed into five categories, excellent water to unsuitable for drinking [8], [9]. In the present study, the WQI values ranges from 76.18 to 155.13. WQI for samples from Lokchao River, Tisa Lok, Maha River and Tuivai Lok are less than 100 and falls under good water category while others are poor water category (Table-5). The higher WQI values are mainly attributed to the high values of phosphate in the water samples.

Table-5: Water quality classification based on WQI values

River Name	WQI value	Water quality		WQI range	Water quality class
Tisa Lok	76.18	Good water		<50	Excellent water
Maha River	81.13	Good water			
Khumji Lok	116.22	Poor water		50-100	Good water
Sekmai River	119.26	Poor water			
Chakpi River A	103.29	Poor water		100-200	Poor water
Chakpi River B	155.13	Poor water			
Wangphu Lok	113.59	Poor water		200-300	Very poor water
Lokchao River	84.82	Good water			
Tuivai Lok	82.06	Good water		>300	Unsuitable for drinking

3.2 Irrigation quality

The water quality suitability for irrigation purposes, the irrigation indices -Electrical Conductivity (EC), Soluble Sodium Percentage (SSP) and Sodium Absorption Ratio (SAR) are considered. The EC, TDS and SSP concentrations in water influences the irrigation water quality as these parameters represent the measure of salinity or salt concentration that have profound effects on soil osmotic pressure. The irrigation water quality parameters (EC, TDS, SSP and SAR) for the water samples are listed in table -6. EC concentration ranges between 171-288 µS/cm which falls under excellent to good water quality classes according to Richards [10]. All the samples are fresh water as TDS is less than 1000 mg/l [11]. SSP values vary from 12.03 to 4.19 which fall under excellent category [12]. According to Bouwer [13], SAR values of all the water samples fall in the category of less alkali hazards problem (SAR<6). Table-7 shows the classification of the water samples of the study area for irrigational uses based on EC, TDS, SSP and SAR.

Table-6: Irrigational water quality parameters (EC, TDS, SSP and SAR)

Sample ID	River Name	EC (µS/cm)	TDS (mg/l)	SSP	SAR
W1	Tisa Lok	171	102	8.427	0.208
W2	Maha River	288	173	12.029	0.348
W3	Khumji Lok	205	123	6.127	0.160
W4	Sekmai River	223	134	4.914	0.149
W5	Chakpi River A	270	162	5.735	0.172
W6	Chakpi River B	270	162	6.444	0.181
W7	Wangphu Lok	256	154	4.629	0.135
W8	Lokchao River	260	156	4.191	0.141
W9	Tuivai Lok	256	154	6.024	0.177

Table-7: Classification of Water for Irrigational Use based on EC, TDS, SSP, SAR

Parameter	Range	Water Quality Class	% of samples
EC (µS/cm) (Richards, 1954)	<250	Excellent	33.3
	250-750	Good	66.7
	750-2000	Permissible	0
	2000-3000	Doubtful	0
	>3000	Unsuitable	0
TDS (mg/l) (Freeze and Cherry, 1979)	<1000	Freshwater	100
	1000-3000	Slightly Saline	0
	3000-10000	Moderately saline	0
	10000-35000	Highly Saline	0
	>35000	Brine	0
SSP (Wilcox, 1995)	<20	Excellent	100
	200-40	Good	0
	40-60	Permissible	0
	60-80	Doubtful	0
	>80	Unsuitable	0
SAR (Bouwer, 1978)	<6	No problem	100
	6-9	Increasing Problem	0
	>9	Severe Problem	0

4. Conclusions

The analysis of different physico-chemical parameters of the water samples in parts of Chandel and Tengnoupal districts of Manipur depict the following concluding remarks:

1. The hydro facies of the samples is Mg-Ca-HCO_3-Cl and are of magnesium bicarbonate water types.

2. The dominant geochemical process that governs the water chemistry and major source of the cations and anions in the river water is rock weathering dominance process.

3. WQI of the water samples ranges from 76.18 to 155.13. Hence, all are potable water as per the guidelines of BIS [14] and WHO [15].

4. All the samples are suitable for irrigational uses based on EC, TDS, SSP and SAR values determined from the physico-chemical parameters.

The suitability of the stream waters for drinking and irrigational uses holds for a future scope to supply not only in Chandel and Tengnoupal districts but also in the Imphal Valley districts viz. Thoubal and Kakching. As the rivers are perennial, the uninterrupted supply is warranted.

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