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Assessment of water quality of Imphal West district, Manipur, India, using Water Quality Index (WQI)

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Abstract

The present study highlights the water quality of Imphal West district, Manipur, India and its suitability for drinking purposes. A total of fifty seven (57) water samples (both surface and groundwater) were collected, during (January – October), 2016 from different locations of Imphal West district, Manipur, and computed the values of WQI of water samples based on physico-chemical parameters like pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity (Turb), dissolved oxygen (DO), total hardness (TH), chloride (Cl^-), nitrate (NO_3^-), total alkalinity (TA), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}). About 43.85% (25), 29.80% (17) and 15.76% (9) of water samples belong to poor, very poor and unsuitability category of WQI. Some variables like conductivity, total dissolved solids, turbidity, chloride, phosphate and sodium were exceeded their desirable limits for drinking water. This study reveals that the overall water quality of Imphal West district is poor and unsuitable for drinking, and needs proper treatment before consumption.

Keywords: WQI, Imphal west district, Manipur, Physico-chemical parameters.

Introduction

Water is an essential requirement of human and Industrial developments and it is the most delicate part of the environment[1]. It is the basis and a fundamental necessity of all living organisms on the earth. It is always required to have a properly functioning water supply to carry out productive agriculture or forestry, livestock, farming or fisheries, trade or industry. The surface of our planet Earth is covered by 71% water, of which 3% is fresh water. Of these 3%, about 75% is tied up in glaciers and polar icebergs, 24% in groundwater and only 1% is available in the form of fresh water in rivers, lakes and ponds suitable for human consumption[2]. In the last few decades, there has been a tremendous increase in the demand for freshwater due to rapid growth of population and the accelerated pace of industrialization[3]. Groundwater is also an important fresh water resource for human consumptions in both urban as well as rural areas[4,5]. Today, water resources (both surface and groundwater) have been severely polluted due to population explosion, unplanned urbanization, overexploitation of available natural resources and release of polluted water at inappropriate places[6]. There are various ways for contamination of water bodies such as use of chemical fertilizers in agricultural practices, seepage from effluent bearing water body[7,8]. The discharge of untreated effluents from industries into nearby open pits or passes them through unlined channels, results in the contamination of water bodies[9]. The incidence of water pollution is highest in urban areas where large volumes of waste are concentrated and discharge into relatively small areas[10]. The hydro-geochemical conditions are also responsible for causing significant variations in water quality[11]. A number of studies on water quality with respect to drinking and irrigation purposes have been carried out in different parts of the country[12-14]. There are plenty of surface water (pond, rivers, and lakes) and groundwater sources in Imphal West district of Manipur. However, because of continuous human interferences the sources of water bodies in this district have been disappearing and water quality has also been a matter of great concern. Little work has so far been done in Imphal West (IW) district, Manipur except Singh's preliminary report on arsenic contamination of groundwater in Imphal West district, Manipur[15,16]. At present there is no major industry in and around the study area, yet household waste and garbage (municipal sewage) are directly discharged into the area and water bodies are being contaminated. Once the water bodies are contaminated, its quality cannot be restored easily by stopping the pollutants from the source. It's therefore, quite imperative to regularly monitor the quality of water and to device ways and means to protect it. Water quality index (WQI) is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. WQI represents the overall water quality of a particular area and time. It has become an important parameter for the assessment and management of water quality for human consumption[17-19]. The objectives of the present work are (i) to assess the water quality by using water quality index (WQI) and (ii) to study correlations among the water variables.

Materials and methods

Study area: The study area lies between latitude 24.30°–25.00° N and longitude 93.45°–94.15° E of Manipur Valley. According

to 2001 census, the area has a geographical area of 558 km^2 with a population of 4, 39,532. The area is characterized by hills, plains, marshes, rivers with their tributaries and it is also surrounded by Senapati in the north, by Thoubal and Bishnupur in the south, by Imphal East in the east, and by Senapati and Bishnupur districts in the western sides (Figure-1).

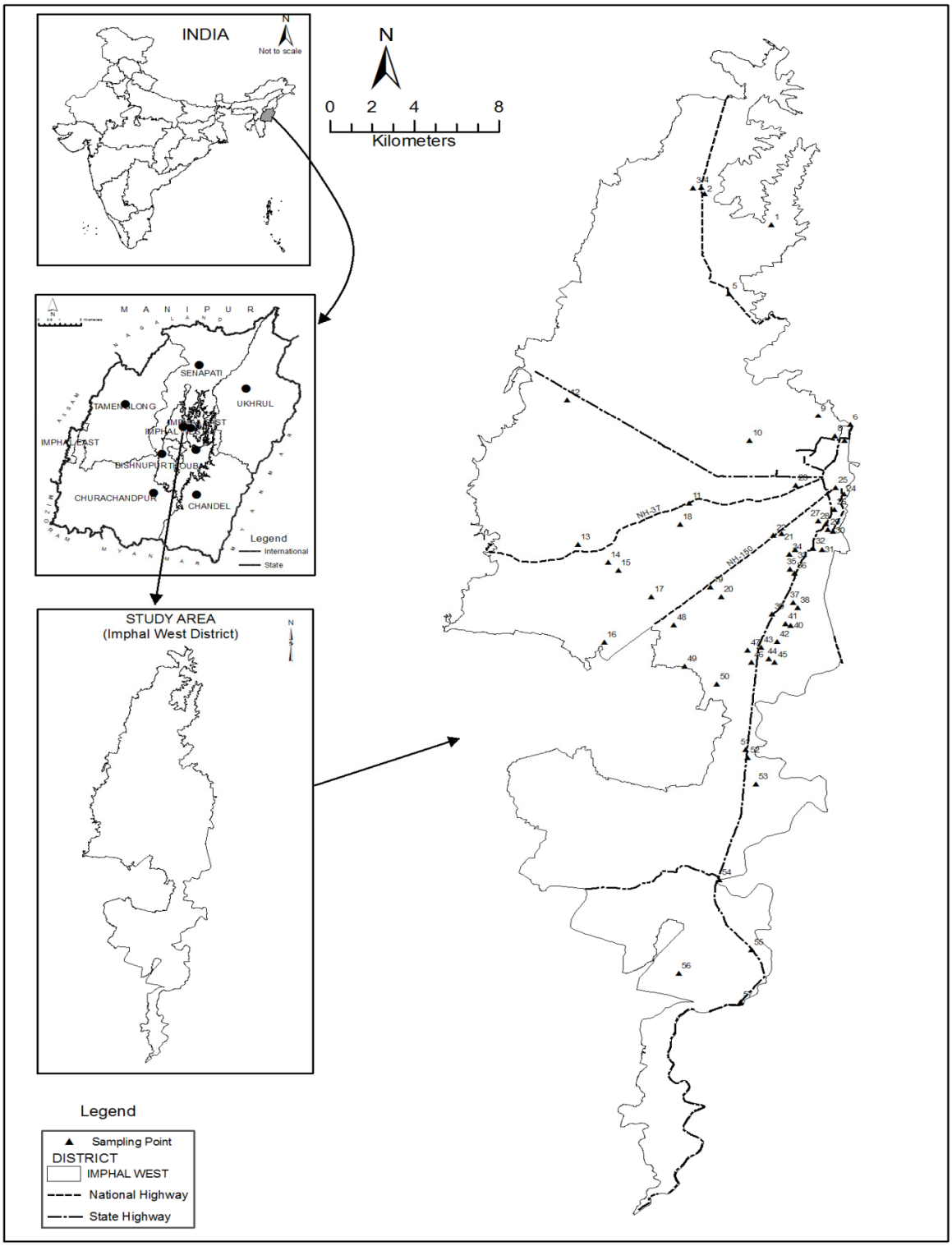

Figure – 1: Location map of the study area showing the sampling points.

Sample collection and analysis: A total of fifty seven (57) water samples of both surface (pond, rivers, lakes) and groundwater were collected during (Jan –October), 2016 from different locations of Imphal West district, Manipur (Figure-1). Geographical co-ordinates of the sampling sites were recorded and illustrated in Table-1. Samples were collected in acid pre-washed polythene bottles (1L). The samples were kept at 4^0C. Physico-chemical parameters like temperature, pH, electrical conductivity (EC), turbidity, TDS, dissolved oxygen (DO) were measured at each sampling point by using field kits like pH meter, conductivity meter, turbidity meter, TDS meter and DO meter. Total alkalinity (TA), chloride (Cl^-), phosphate (PO_4^{3-}), nitrate (NO_3^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+), were measured as per standard methods, and results were compared with the WHO Standards[20].

Table-1: Water sampling locations in different parts of Imphal West district, Manipur, India.

Location	Latitude	Longitude
Tingri	24°55'40.941"N	93°54'41.361"E
Sekmai	24°56'34.126"N	93°52'49.852"E
Sekmai Awang Leikai	24°49'38.457"N	93°56'18.304"E
Sekmai Bazar	24°49'30.52"N	93°54'80.114"E
Khonghampat	24°50'41.638"N	93°49'28.718"E
Sangakphm Bazar	24°46'10.807"N	93°50'31.395"E
Chingmeirong Maning Leikai	24°47'60.804"N	93°52'21.054"E
Thangmeiband Sinam Leikai	24°45'20.635"N	93°51'37.636"E
Langol Tarung	24°45'19.354"N	93°53'80.077"E
Langol Zone-I	24°46'51.609"N	93°54'57.018"E
Patsoi	24°46'48.125"N	93°54'44.366"E
Yurembam Mayai Leikai	24°48'13.454"N	93°55'18.209"E
Khumbong Mayai Leikai	24°47'59.37"N	93°56'32.166"E
Phayeng Umang Lai	24°47'31.403"N	93°56'14.492"E
Phayeng Maning Leikai	24°47'11.831"N	93°55'57.983"E
New Keithelmanbi	24°46'53.963"N	93°56'17.502"E
Nambol Khajiri	24°46'20.448"N	93°55'17.287"E
Bamdiar	24°44'53.335"N	93°55'14.102"E
Malom Makha Leikai	24°44'44.231"N	93°55'20.986"E
Malom Makha Leikai	24°44'33.482"N	93°54'41.893"E
Sangaiprou (Skon)	24°44'13.684"N	93°55'10.802"E
Sangaiprou (BIM)	24°43'31.890"N	93°54'50.038"E
Sagolbang Bijoy Govinda	24°43'36.418"N	93°54'24.964"E
Babupara	24°43'17.162"N	93°54'36.814"E
Kangla Park	24°43'11.242"N	93°54'10.759"E
Elangbam Leikai	24°43'46.188"N	93°54'49.493"E
Huidrom Leikai	24°42'33.157"N	93°53'17.856"E
Pishum Ningom leirak	24°44'14.326"N	93°52'12.073"E
Manipur College Gate	24°43'30.639"N	93°52'28.476"E
Singjamei Super Market	24°56'45.611"N	93°52'42.505"E
Heirangoithong Ahongshangbam Leirak	24°56'44.900"N	93°52'51.340"E
Heirangoithong	24°53'42.780"N	93°53'36.580"E
Chingtham Leikai	24°49'57.910"N	93°56'41.640"E
Chingtham Leikai	24°49'39.850"N	93°56'35.990"E
Mongshangei	24°50'130.670"N	93°55'52.820"E
Mongshangei	24°47'43.600"N	93°52'35.700"E
Langthabal Chingthak	24°46'32.130"N	93°49'44.880"E
Langthabal Chingkha	24°45'48.162"N	93°50'45.612"E
Langthabal Khoupum	24°43'44.61"N	93°50'28.180"E
Langthabal Phuramakhong	24°45'10.911"N	93°53'24.065"E
Langthabal Phuramakhong	24°48'90.868"N	93°56'19.448"E
Heibok Mahadeva Mandir	24°47'30.160"N	93°56'30.180"E
Heibok Chingkhong	24°47'00.613"N	93°56'50.059"E
Hiyangthang Takhellambam	24°46'23.748"N	93°55'59.023"E
Haoreibi	24°46'26.009"N	93°55'45.113"E
Hiyangthang Pallak	24°46'18.667"N	93°55'13.855"E
Hiyangthang Mandir	24°45'50.679"N	93°55'90.456"E
Meijrao Bazar	24°45'47.015"N	93°55'12.514"E

Kodompokpi Mayai Leikai	24°44'160.307"N	93°55'20.537"E
Meitram Awang Leikai	24°43'12.096"N	93°54'36.053"E
Mekola Primary Health Center	24°43'13.107"N	93°54'40.049"E
Kha Sanjenbam	24°40'41.890"N	93°54'10.890"E
Wangoi	24°40'27.318"N	93°54'40.716"E
Yumnam Huidrom	24°39'42.750"N	93°54'17.560"E
Mayang Imphal	24°36'58.544"N	93°53'21.603"E
Uchiwa	24°34'58.513"N	93°54'10.582"E
Sekmaijin	24°33'22.211"N	93°53'55.876"E

Calculation of WQI: Calculation of water quality index (WQI) was carried out by Horton's method[21]. WQI is calculated by using the following expression.

$$WQI = \sum q_n W_n / \sum W_n$$

Where: q_n = Quality rating of n^{th} water quality parameter. W_n = Unit weight of nth water quality parameter.

Quality rating (q_n): The quality rating (q_n) is calculated as;

$$q_n = [(Vn - V_{id})/(S_n - v_{id})] \times 100$$

Where: V_n = Estimation value of nth water quality parameter at a given sample location. V_{id} = Ideal value for nth parameter in pure water. (V_{id} for pH = 7 and 0 for all other parameters), S_n = Standard permissible value of n^{th} water parameter.

Unit weight: The unit weight (W_n) is calculated as;

$$W_n = \frac{k}{S_n}$$

Where, S_n = Standard permissible value of nth water quality parameter. K = Constant of proportionality and it is calculated as;

$$k = [1/(\sum 1/S_{n=1,2....n})]$$

The higher the WQI value, the greater is the level of pollution, and greater the damage to health. The WQI scale was divided into five categories describing the range of water quality and its associated potential health effects. In this study the WQI for drinking purposes is considered and permissible WQI for drinking water is taken as 100[22].

Results and discussion

Drinking water quality based on WQI scale: The status of water quality parameters of the study area is presented in Table-2. For calculating the WQI of water samples, physico-chemical parameters like hydrogen ion concentration (pH), electrical conductivity (EC), total dissolved solids (TDS), turbidity (Turb), dissolved oxygen (DO), total hardness (TH), chloride (Cl^-), nitrates (NO_3^-), phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), total alkalinity (TA), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}), were selected and analyzed.

Table -2 Physico-chemical parameters of water samples of Imphal West district, Manipur, India

Parameters	Mean ± SD	(Min - Max)
T (0C)	27.27 ± 2.15	(23.65 - 32.45)
pH	7.65 ± 0.33	(6.58 - 8.21)
EC (µS/cm)	848.76 ± 655.13	(213 - 3287)
TDS (mg/L)	557.5 ±223.83	(248 - 1330)
Turbidity (NTU)	3.35 ± 1.56	(0.02 - 6.35)
D.O (mg/L)	7.54 ± 7.62	(5.63 - 9.03)
Total hardness (mg/L)	130.13 ± 132	(15.13 - 285)
Chloride (mg/L)	141.28 ± 136.18	(14 - 638.80)
Nitrate (mg/L)	1.03 ± 0.93	(0.13- 3.19)
Phosphate (mg/L)	0.92 ± 0.50	(0.04 - 2.54)
Total Alkalinity (mg/L)	377.83 ± 382.66	(220 - 618)
Sodium (mg/L)	154.31 ± 85.74	(20 - 388)
Potassium (mg/L)	3.05 ± 1.45	(1 - 9.85)
Calcium(mg/L)	7.06 ± 5.98	(1.36 - 22.32)
Magnesium(mg/L)	16.64 ± 3.39	(3.63 - 20.08)

The water temperature (T^0C) varied from 23.65^{0}C to 32.45^{0}C with an average of 27.27^{0}C. The fluctuation in water temperature may be attributed to different timings of sampling and seasonal variation[23]. The pH values of water samples varied from 6.58 to 8.21 with an average of 7.65. pH shows alkaline trend, but the values were well within the prescribed limit of 6.5–9.2[24]. Electrical conductivity (EC) was in the range of 213 µS/cm to 328µS/cm with an average of 848.76µS/cm. EC of most water samples were very high, but fall within the permissible limit of 1500µS/cm. Higher EC in the study area indicate the presence of higher dissolved salts, which may be due to dilution of soluble salts by rainfall or agricultural activities[25]. Total dissolved solids (TDS) were in the range of 248mg/L to 1330 mg/L with an average of 557.5 mg/L and about 30.25% of samples exceeded the desirable limit of 500 mg/L, but within the maximum permissible limit of 2000 mg/L. Water containing TDS more than 500mg/L causes gastro intestinal irritation in the consumers[26]. Turbidity ranged from 0.02mg/L to 6.35mg/L with an average of 3.35mg/L and the

values were within the permissible limit of 5-25NTU. The DO concentration was in the range of 5.36-9.03mg/L with an average of 7.54mg/L and the values were above the recommended value of 4-6mg/L for drinking and 5mg/L for agricultural purposes indicating the suitability of water for drinking, agricultural and fisheries purposes. Total hardness (TH) was in the range of 15.13mg/L to 285mg/L with an average of 130.13mgL^{-1}. The recommended value of hardness is 200mg/L (WHO). In some samples, the total hardness is very high, and exceeded the permissible limit of 200mg/L. Chloride (Cl^-) ranged from 14mg/L to 638.80mg/L with an average of 141.28mgL^{-1}. About 26.67% of samples exceeded the permissible limit of 250mg/L[27]. Excess concentration of Cl^- in drinking water gives a salty taste and has a laxative effect in people not accustom to it[28]. The nitrate (NO_3^-) concentration was in the range of 0.13mg/L to 3.19mg/L with an average of 1.03mg/L and the values were well within the permissible limit of 45mg/L (WHO). Excessive NO_3^- in drinking water can cause a number of health disorders, particularly in infants, such as methemoglobinemia (Blue-baby syndrome), gastric cancer, goitre, birth malformations and hypertension[29]. Phosphates (PO_4^{3-}) varied from 0.04mg/L to 2.54mg/L with an average of 0.92mg/L. Phosphate values were high and exceeded the recommended limit of 0.4mg/L. High phosphate in the study area may be due to application of fertilizers for agricultural practices and leaching of PO_4^{3-} through soil[30, 31]. Total alkalinity (TA) was high in the area and ranges from 220mg/L to 618mg/L with an average of 377.83mg/L. The values were all above the WHO standards of 100–200mg/L. Excess alkalinity in water imparts bitter taste to water and also cause harmful effects on irrigation. Sodium (Na^+) varied between 20mg/L to 388 mg/L with an average of 154.31mg/L. Na^+ in 23.33% (7) of samples exceeded the recommended limit of 200 mg/L (WHO). Potassium (K^+) was in the range of 1mg/L to 9.85mg/L with an average of 3.05mg/L and the values were well within the permissible limit of 10mg/L[32] and 100mg/L[33]. Calcium (Ca^{2+}) was quite low in the area and well within the recommended limit of 200mg/L (WHO). Ca^{2+} varied between 1.36mg/L to 22.32mg/L with an average of 7.06mg/L. Ca^{2+} deficiency may cause rickets, softening of bones and reduction of bone density in children. Magnesium (Mg^{2+}) was in the range of 3.63mg/L to 20.08mg/L with an average of 16.64mg/L. The values were well below the prescribed limit of 150mg/L (WHO).

Table-3 presents the physico-chemical parameters with their (WHO) standards (S_i), relative weight (W_i), quality rating (q_i), and sub-index (W_iq_i). The computed WQI values of each water sample at various locations are shown in Table-4. Table-5 shows the water quality classification based on WQI values and the percentage of water samples that falls under different water quality criteria. The WQI values of all the water samples ranged from 20.43 to 262.65. The minimum and maximum values of WQI were observed at Phayeng Umang Lai (site-14) and Malom Makha Leikai (site–20). The study reveals that the WQI values of most water samples were high and about 43.85% (25), `29.80% (17) and 15.76% (9) of water samples belong to poor, very poor and unsuitability category of WQI. Only 5.25% (2) and 7.02% (4) of water samples belongs to 'Excellent' and 'Good' water quality category i.e., Grade A & B. The high WQI in the study area could be attributed to higher values of TDS, DO, phosphate, and total alkalinity (TA) in the water samples. This could also be attributed to improper disposal of wastes, large quantity of agricultural and urban run-off, sewage, over application of inorganic fertilizer, improper operation and maintenance of septic system[34].

Table-3: Standard values of water quality parameters of Imphal West district, Manipur, India and their corresponding ideal values and unit weights.

Parameters	Si	Ideal value (Vid)	k value	qi	Wi	qiWi
pH	6.5 -8.5	7	0.117	32.67	0.355411	11.609
EC (µS/cm)	1500	0	0.000666	78.83	0.002014	0.158
TDS (mg/L)	500	0	0.002	63.5	0.006042	0.384
Turbidity (NTU)	25	0	0.04	76.52	0.12084	9.247
DO (mg/L)	5	14.6	0.2	82.19	0.6042	49.659
Total hardness (mg/L)	200	0	0.005	69.25	0.015105	1.046
Chloride (mg/L)	250	0	0.004	25.36	0.012084	0.306
Nitrate (mg/L)	45	0	0.0222	1.11	0.067133	0.075
Phosphate (mg/L)	0.4	0	2.5	300	0.75525	226.58
Total Alkalinity (mg/L)	120	0	0.00833	310.42	0.025175	7.797
Sodium (mg/L)	200	0	0.005	101.25	0.015105	1.529
Potassium (mg/L)	12	0	0.0833	33.33	0.25175	8.391
Calcium (mg/L)	75	0	0.0133	6.67	0.04028	0.268
Magnesium (mg/L)	50	0	0.02	35.2	0.06042	2.126

$\sum$ = 3.021; $\sum$ qi = 1216.6; $\sum$ Wi =2.331; $\sum$ qiWi = 319.17, WQI (sample 1) = 319.17/2.331 = 136.92

Table-4: WQI values of the water samples of Imphal West district, Manipur, India.

Sample No.	WQI	Quality Grading	Sample No.	WQI	Quality Grading
1	136.92	E	30	94.22	D
2	79.66	D	31	42.05	B
3	82.20	D	32	120.87	E
4	23.72	A	33	82.58	D
5	48.43	B	34	95.06	D
6	113.81	E	35	216.46	F
7	117.05	E	36	93.32	D
8	100.53	E	37	114.08	E
9	154.5	F	38	78.61	D
10	165.52	F	39	128.67	E
11	92.18	D	40	114.05	E
12	79.33	D	41	80.03	D
13	88.21	D	42	82.76	D
14	20.43	A	43	128.72	E
15	86.45	D	44	124.02	E
16	135.53	E	45	93.17	D
17	163.73	F	46	80.07	D
18	86.27	D	47	181.43	F
19	34.54	B	48	91.42	D
20	262.65	F	49	106.58	E
21	172.52	F	50	97.32	D
22	145.33	E	51	77.24	D
23	132.15	E	52	85.66	D
24	173.53	F	53	26.87	B
25	83.17	D	54	86.41	D
26	115.08	E	55	105.24	E
27	148.43	E	56	98.55	D
28	190.02	F	57	90.51	D
29	83.42	D			

Table-5: Water quality classification based on Water Quality Index (WQI) scale.

WQI	Status	Quality Grading	% Samples
0 -25	Excellent	A	5.25
25 - 50	Good	B	7.02
51 -75	Fair	C	0
76 -100	Poor	D	43.85
101 -150	Very Poor	E	29.80
Above 150	Unfit for Drinking	F	15.76

Table-6: Pearson Correlation among the various physico-chemical parameters of water variables in Imphal West district, Manipur, India.

	T	pH	EC	Turb	DO	PO_4^{3-}	NO_3^-	TH	Cl^-	TDS	TA	Na	K	Ca	Mg
T	1														
pH	-.280**	1													
EC	-0.021	0.096	1												
Turb	0.112	-0.082	-0.024	1											
DO	-0.063	0.056	-.181*	-.293**	1										
PO_4	0.064	-0.021	0.131	0.092	-0.146	1									
NO_3	0.152	0.117	0.041	0.015	0.054	.724**	1								
TH	.223**	-.194*	0.08	0.059	-.206*	.374**	.321**	1							
Cl	-0.058	.187*	.190*	.193*	-0.101	.229**	.187*	0.035	1						
TDS	0.094	-0.102	.736**	0.136	-.292**	0.147	0.148	.201*	0.023	1					
TA	0.159	-0.034	.213**	0.068	-.259**	.390**	.371**	.293**	.280**	.326**	1				
Na	-0.034	-0.122	0.073	0.119	-.235**	.173*	-0.07	0.042	0.068	0.107	.201*	1			
K	0.085	-0.086	0.104	0.162	-.272**	.172*	-0.014	.349**	0.044	.205*	0.156	.287**	1		
Ca	0.005	.165*	0.096	-0.024	-0.08	.171*	0.162	0.056	0.049	0.02	0.073	-0.067	-.203*	1	
Mg	.195*	0.007	0.04	0.128	-.246**	.310**	.271**	.527**	0.043	0.152	.427**	0.092	0.162	0.131	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Correlation analysis: Table-6 presents the Pearson's correlation coefficient (r) among the various physico-chemical parameters of water samples of Imphal West district, Manipur. Both positive and negative correlations were observed among the variables. Positive correlations were observed in total dissolved solids, chloride, total alkalinity, and calcium with conductivity and total hardness; turbidity with total dissolved solids and total hardness; phosphate and potassium with dissolved oxygen and sodium, respectively. Negative correlation was observed in that of conductivity, total hardness, chloride and total alkalinity with dissolved oxygen.

Conclusion

The present study shows that the water quality indices (WQI) were in the range of 20.43 to 262.65 and 43.85% (25) of water samples fall to 'poor' with 29.80% (17) and 15.76% (9) belong to 'very poor' and 'unsuitability' for drinking water category of WQI, which shows that the water quality of the study area is very poor and not suitable for drinking purpose. Only 5.25% (2) and 7.02% (4) of water samples belong to 'Excellent' and 'Good' water quality category i.e., Grade A and B. There is need for proper treatment before consumption and regular monitoring of water quality is also required to detect major changes in physicochemical parameters and to identify the water sources which are safe for drinking and protecting them from further contamination.

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