

Seasonal Variation of Some Physico-chemical Characteristics of Three Major Rivers in Imphal, Manipur: A Comparative Evaluation

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DOI : <http://dx.doi.org/10.12944/CWE.8.1.10>

(Received: March 22, 2013; Accepted: April 10, 2013)

ABSTRACT

Documentation on water quality based on seasonal distribution pattern of physico-chemical characteristics of the three major rivers flowing in Imphal, Manipur were carried out during July, 2011 to June, 2012. Three main seasons were classified based on the ombothermic information for ten years weather data of Imphal. Significant seasonal variations of the different parameters were observed and the study has a great value in terms of river ecosystem as well as water quality in different seasons.

Key words: Anthropogenic, Eutrophication, Allochthonous, Seasonal variation, River ecosystem, population growth, pollution.

INTRODUCTION

Water, by means of its physical, chemical and biological characteristics, reflects the significance as potent ecological factor and quality for sustenance. However, the increasing anthropogenic influences in recent years, in and around aquatic ecosystem and their catchment areas have contributed to a large extent to various nutrient enrichment which leads to deterioration of the water quality. The increasing trend of nutrient enrichment in the system accelerates eutrophication and growth of many aquatic organisms, which exerts a great surge to the ecosystem of many fresh water bodies. The very source of potable water contains both micro and macro nutrients in permissible limit but quality of drinking water changes due to human interference and get contaminated through percolation and seepage, drains and domestic sewage (Pandey and Kumar, 1995).

Now-a-days due to rapid industrialization and human population growth most of the Indian

rivers are polluted (Sahu, 1991). The physico-chemical characteristics are also greatly affected due to discharge of domestic, municipal, industrial and other several factors like religious offerings, recreational and constructional activities in the catchments areas (Panda *et al.*, 1991). Hill and Webb (1958) reported that rainfall pattern influences in changing the physical and chemical environment of water and helps in increasing input of pollutants. Thus, necessary knowledge of the water quality for framing, restoration and management could result only after determining the distribution patterns of ever increasing enrichment of nutrients.

Therefore, the present investigation has been carried out with the objectives to assess the seasonal variation as well as water quality status based on some physico-chemical characteristics of three major rivers of Imphal, Manipur.

MATERIAL AND METHODS

Samples for the characterization of different physico-chemical parameters were

collected at monthly intervals from five (5) experimental sites of three rivers namely Imphal river, Nambulriver and Iril river within Imphal area of Manipur during July, 2011 to June, 2012. Water samples from different sites were collected by means of shallow water sampler in a polystyrene bottle. Some physico-chemical parameters like water temperature, conductivity, total dissolved solid, dissolved oxygen, free CO₂ and pH were analyzed and recorded on the spots immediately after collection of the water samples. Analysis for the remaining physico-chemical parameters were carried out in the laboratory. The methods used for the estimation of the variables were standard methods of APHA (1989) and Trivedy and Goel (1984).

For statistical analysis of seasonal variation, different seasons were classified according to ombrothermic information based on ten years data of air temperature, rainfall and humidity. Based on the informations, March to May is considered as summer season, June to October as rainy season and November to February as winter season.

Accordingly, the mean values of different parameters from five different sites of each river were used for the calculation of ANOVA (Analysis of variance) in different seasons. The methods of parker (1973) and Trivedi, Goel and Trisal (1987) were used in computing and analysis of ANOVA seasonally in different rivers.

RESULTS

The results of the physico-chemical analysis for five sites of three different rivers are depicted in table 1-3. Values are mean for five different sites for each river during July, 2011 to June, 2012.

Water Temperature

Temperature of water of Imphal river ranges from 19.39 °C (January) to 25.33 °C (June) as compared to ranges of 21.00°C (January) to 26.34°C (August) of Nambul river and 19.50°C (January) to 25.43°C (July) of Iril river. Seasonally, the average maximum mean value was recorded as 25.02 ±0.75°C in Nambul river during rainy

season and minimum as 20.82 ±1.34°C in Imphal river during winter season .

Conductivity

Average mean conductivity from all the sites of different rivers was found maximum during summer. Maximum value is 369.78 ±32.72m Siemens cm⁻² in Nambulriver and minimum value is during winter i.e. 94.50 ±22.60m Siemens cm⁻² in Iril river. Ranges of conductivity values from across the sites were 67.33m Siemens cm⁻² (Irilriver during January) to 401.33m Siemens cm⁻² (Nambul river during May).

Total Dissolved Solid

Total dissolved solid concentration from all the sites of different river varied from 40.67 mg l⁻¹ (Imphalriver during January) to 181.94 mg l⁻¹ (Iril river during August). Highest concentration of T.D.S. was recorded as 131.59 ±31.74mg l⁻¹ in Iril river during rainy season and minimum as 51.67 ±7.93mg l⁻¹ in Imphal river during winter.

Turbidity

Turbidity from all the sites of different rivers fluctuated from 18.40 NTU (Imphalriver during January) to 95.47NTU (Imphal river during September). Seasonally, the highest and lowest concentration of turbidity was recorded as 75.93 ±18.81 NTU in Imphal river during rainy season and 20.98 ±2.15 NTU in Imphal river during winter season .

pH

The pH value of different river water shows a mark fluctuation for the different sites. The range of pH value shows a variation from 6.56 (Nambul river during January) and 8.36 (Nambul river during August). However, the highest average mean value was recorded as 8.01 ±0.26 in Iril river during rainy season and lowest 6.78 ±0.20 in Nambul river during winter season.

Free CO₂

During the studies, Free CO₂ concentration of the rivers for different sites also shows mark fluctuation. The ranges of Free CO₂ were found to be fluctuated from 2.93 mg l⁻¹ (Irilriver during November) to 33.84 mg l⁻¹ (Nambul river during January). The average mean concentration of Free

Table 1: Monthly variations in physico-chemical characteristics of Imphal river (IMR), Nambul river (NR) and Irliriver (IR), (July 2011 to June 2012). Values are mean for five different sites of each river.

Parameter	River Code	2012											
		Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Temp. (°C)	IMR	25.30	24.60	24.86	24.572	22.61	20.41	19.39	20.876	22.88	23.76	24.344	25.33
	NR	25.23	26.34	24.22	24.32	23.70	21.35	21.00	21.69	23.32	24.39	24.58	25.28
	IR	25.43	25.20	24.61	24.59	24.15	22.03	19.50	20.58	21.69	23.09	23.57	24.79
Cond.(μ Siemens/cm ²)	IMR	144.00	134.00	150.67	182.00	164.00	146.67	124.00	136.67	159.33	182.00	200.00	230.00
	NR	282.66	347.33	312.00	308.67	309.33	254.67	226.67	314.00	336.00	372.00	401.33	398.00
	IR	169.33	182.00	174.67	136.67	122.00	98.67	67.33	90.00	142.00	156.00	190.67	228.67
TDS (mg/l)	IMR	114.00	101.33	86.67	72.67	58.67	51.33	40.67	56.00	72.67	84.168	92.00	116.00
	NR	74.00	157.33	108.67	134.00	86.67	68.00	52.67	86.67	96.00	102.67	126.67	144.00
	IR	128.00	181.94	123.33	94.00	85.33	56.67	50.00	70.67	90.00	101.33	122.67	130.67
Turbidity (NTU)	IMR	54.65	91.7	95.47	58.10	21.13	20.73	18.40	23.66	27.97	37.15	55.28	79.73
	NR	86.62	43.35	36.72	47.95	48.71	31.15	28.59	37.76	65.34	70.17	89.07	98.40
	IR	67.18	75.03	57.91	52.64	49.84	31.73	29.00	36.49	54.53	60.00	70.91	83.92
pH	IMR	7.59	7.67	8.42	7.88	7.48	7.29	7.18	7.30	7.41	7.48	7.54	7.72
	NR	7.72	8.36	7.89	6.97	7.04	6.79	6.56	6.73	6.97	7.09	7.43	7.59
	IR	8.39	8.14	7.97	7.82	7.64	7.34	7.22	7.37	7.40	7.59	7.68	7.74
FreeCO ₂ (mg/l)	IMR	15.69	8.36	8.21	10.07	12.76	10.12	10.27	10.56	12.91	12.46	15.99	17.18
	NR	11.73	19.91	18.60	20.81	25.05	29.14	33.84	29.99	25.67	20.03	17.77	15.82
	IR	5.09	6.16	4.25	3.08	2.93	3.37	3.96	5.72	7.18	4.55	5.28	4.99
DO (mg/l)	IMR	6.82	4.66	4.20	4.72	5.26	5.10	5.06	5.43	5.50	5.28	5.41	5.45
	NR	4.71	4.28	4.94	4.24	4.33	3.21	3.61	3.97	3.67	4.57	4.60	5.78
	IR	6.80	5.22	5.29	6.27	5.53	5.13	5.29	5.22	5.26	5.19	6.02	6.63

Table 2: Monthly variations in physico-chemical characteristics of Imphal river (IMR), Nambul river (NR) and Irirriver (IR), (July 2011 to June 2012). Values are mean for five different sites of each river

Parameter	River Code	2012											
		Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
BOD (mg/l)	IMR	3.60	1.90	3.61	4.03	1.71	4.70	5.07	4.09	4.40	4.88	5.92	5.62
	NR	9.12	6.58	8.83	10.72	4.32	5.83	7.26	9.73	8.40	10.96	9.01	6.94
Hardness (mg/l)	IR	6.28	7.23	5.54	4.70	4.33	3.41	2.85	3.46	3.69	3.30	3.81	4.96
	IMR	70.26	37.34	53.47	53.33	54.53	49.60	55.33	65.33	72.00	85.33	95.60	100.26
Calcium (mg/l)	NR	85.33	118.93	116.53	99.47	62.13	55.60	75.20	93.47	104.80	111.33	114.40	126.80
	IR	54.00	51.07	44.80	40.67	38.53	36.13	37.20	45.47	48.93	67.07	83.60	86.13
Magnesium (mg/l)	IMR	13.08	8.33	7.87	12.64	15.18	9.40	13.09	14.25	16.41	18.82	21.91	20.46
	NR	19.81	23.86	24.20	23.10	11.65	10.69	19.76	21.36	22.54	22.87	24.26	25.60
Nitrate (mg/l)	IR	8.76	11.60	9.14	7.86	7.21	6.97	7.38	8.23	8.22	12.76	19.28	19.50
	IMR	8.56	4.01	8.15	5.65	4.79	6.01	5.15	6.98	7.84	8.91	10.96	12.21
Inorganic PO ₄ (mg/l)	NR	8.49	10.91	13.35	9.76	7.73	7.04	7.26	10.21	11.64	11.82	13.64	15.40
	IR	4.09	5.38	5.53	5.60	5.53	4.22	4.03	5.19	6.54	7.35	9.65	7.71
Potassium (mg/l)	IMR	0.22	0.19	0.36	0.29	0.14	0.18	0.17	0.21	0.21	0.26	0.32	0.38
	NR	0.26	0.29	0.40	0.19	0.37	0.29	0.35	0.50	0.45	0.53	0.60	0.63
Inorganic PO ₄ (mg/l)	IR	0.39	0.51	0.38	0.28	0.22	0.07	0.07	0.12	0.15	0.13	0.13	0.26
	IMR	0.032	0.023	0.028	0.032	0.021	0.019	0.015	0.018	0.016	0.013	0.017	0.024
Potassium (mg/l)	NR	0.252	0.388	0.284	0.204	0.198	0.164	0.158	0.220	0.208	0.246	0.378	0.508
	IR	0.082	0.032	0.032	0.031	0.027	0.020	0.013	0.019	0.024	0.028	0.034	0.028
Potassium (mg/l)	IMR	4.46	3.40	3.67	4.00	3.20	3.73	4.13	2.87	4.93	4.80	7.87	8.60
	NR	13.67	13.00	13.80	10.00	15.00	10.93	12.87	13.80	11.93	13.34	15.07	17.67
	IR	3.67	3.33	3.20	3.80	5.60	3.00	3.00	3.67	4.33	6.93	7.07	5.67

Table 3 :Seasonal variations in physico-chemical characteristic of Imphal river (IMR), Nambul river (NR) and Irilriver (IR), (July 2011 to June 2012). Values are from the average mean of five different sites of each river

Parameter	River Code	Summer	Rainy	Winter	Total Annual
Temperature (°C)	IMR	23.66 ±0.74	24.93 ±0.37	20.82 ±1.34	23.24 ±2.03
	NR	24.10 ±0.68	25.02 ±0.75	21.78 ±0.91	23.71 ±1.64
	IR	22.78 ±0.98	24.92 ±0.37	21.57 ±2.01	23.27 ±1.92
Conductivity (μ simens/cm ²)	IMR	180.44 ±20.38	168.13 ±38.96	142.84 ±16.90	162.78 ±30.79
	NR	369.78 ±32.72	329.73 ±44.56	276.17 ±42.60	321.89 ±53.15
	IR	162.89 ±25.06	178.27 ±33.08	94.50 ±22.60	146.50 ±46.55
T.D.S. (mg/l)	IMR	82.95 ±9.72	98.13 ±18.45	51.67 ±7.93	78.85 ±24.50
	NR	108.45 ±16.13	123.60 ±32.96	73.50 ±16.44	103.11 ±32.15
	IR	104.67 ±16.59	131.59 ±31.74	65.67 ±15.69	102.88 ±36.91
Turbidity (NTU)	IMR	40.13 ±13.90	75.93 ±18.81	20.98 ±2.15	48.66 ±28.31
	NR	74.86 ±12.54	62.61 ±27.90	36.55 ±8.98	56.99 ±24.23
	IR	61.81 ±8.34	67.34 ±12.64	36.77 ±9.25	55.77 ±17.21
pH	IMR	7.48 ±0.07	7.86 ±0.33	7.31 ±0.12	7.58 ±0.33
	NR	7.16 ±0.24	7.71 ±0.50	6.78 ±0.20	7.26 ±0.54
	IR	7.56 ±0.14	8.01 ±0.26	7.39 ±0.18	7.69 ±0.35
FreeCO ₂ (mg/l)	IMR	13.79 ±1.92	11.90 ±4.23	10.93 ±1.24	12.05 ±2.99
	NR	21.16 ±4.07	17.37 ±3.67	29.51 ±3.61	22.36 ±6.46
	IR	5.67 ±1.36	4.71 ±1.14	4.00 ±1.22	4.71 ±1.29
Dissolved Oxygen (mg/l)	IMR	5.40 ±0.11	5.17 ±1.03	5.21 ±0.17	5.24 ±0.63
	NR	4.28 ±0.53	4.76 ±0.66	3.78 ±0.48	4.31 ±0.68
	IR	5.49 ±0.46	6.04 ±0.74	5.29 ±0.17	5.65 ±0.61
B.O.D (mg/l)	IMR	5.07 ±0.78	3.75 ±1.33	3.89 ±1.51	4.13 ±1.30
	NR	9.46 ±1.34	8.44 ±1.70	6.79 ±2.30	8.14 ±1.99
	IR	3.60 ±0.27	5.74 ±1.03	3.51 ±0.61	4.46 ±1.33
Hardness (mg/l)	IMR	84.31 ±11.83	62.93 ±23.90	56.20 ±6.59	66.03 ±19.38
	NR	110.18 ±4.90	109.41 ±16.75	71.60 ±16.70	97.00 ±23.12
	IR	66.53 ±17.34	55.33 ±17.99	39.33 ±4.21	52.80 ±17.25
Calcium (mg/l)	IMR	19.05 ±2.76	12.48 ±5.06	12.98 ±2.54	14.29 ±4.55
	NR	23.22 ±0.91	23.31 ±2.16	15.87 ±5.47	20.81 ±4.83
	IR	13.42 ±5.56	11.37 ±4.75	7.45 ±0.55	10.58 ±4.47
Magnesium (mg/l)	IMR	9.24 ±1.59	7.72 ±3.13	5.73 ±0.98	7.44 ±2.49
	NR	12.37 ±1.11	11.58 ±2.79	8.06 ±1.46	10.60 ±2.69
	IR	7.85 ±1.61	5.662 ±1.30	4.74 ±0.73	5.90 ±1.67
Nitrate (mg/l)	IMR	0.26 ±0.06	0.23 ±0.08	0.17 ±0.03	0.24 ±0.078
	NR	0.53 ±0.08	0.35 ±0.17	0.38 ±0.09	0.41 ±0.14
	IR	0.14 ±0.012	0.36 ±0.10	0.12 ±0.07	0.23 ±0.14
Inorganic Phosphate(mg/l)	IMR	0.015 ±0.002	0.028 ±0.004	0.018 ±0.001	0.022 ±0.01
	NR	0.277 ±0.090	0.327 ±0.12	0.185 ±0.029	0.267 ±0.11
	IR	0.029 ±0.005	0.041 ±0.023	0.020 ±0.006	0.031 ±0.02
Potassium (mg/l)	IMR	5.87 ±1.74	4.83 ±2.15	3.48 ±0.56	4.64 ±1.79
	NR	13.45 ±1.57	13.63 ±2.74	13.15 ±1.72	13.42 ±2.01
	IR	6.11 ±1.54	3.93 ±1.00	3.82 ±1.23	4.44 ±1.49

CO₂ was found to be highest in Nambul river during winter season i.e. 29.51 ±3.61 mg l⁻¹ and lowest 4.00 ±1.22mg l⁻¹ in Iril river during winter season. In the annual average, Free CO₂ concentration was highest in Nambul river than the other two rivers.

Dissolved Oxygen(DO)

Dissolved oxygen concentration was found to be fluctuated in each sites of the rivers and it was observed that average concentration was high in Iril river than the remaining two rivers. The ranges of dissolved oxygen varied from 3.21 mg l⁻¹ (Nambul river during December) to 6.82 mg l⁻¹ (Imphal river during July) . Average mean concentration was found to be highest in Iril river during rainy season as 6.04 ±0.74mg l⁻¹ and minimum of 3.78 ±0.48 mg l⁻¹ in Nambul river during winter season.

Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD) values fluctuated from 1.71 mg l⁻¹ (Imphal river during November) to 10.96 mg l⁻¹ (Nambul river during April). Average BOD value shows highest in Nambul river during summer season i.e. 9.46 ±1.34mg l⁻¹ and lowest value as 3.51 ±0.61mg l⁻¹ in Iril river during winter season.

Hardness

The concentration of hardness recorded minimum of 36.13 mg l⁻¹ (Iril river during December) to 126.80 mg l⁻¹ (Nambul river during June). The average mean values of hardness from across the site of the rivers found maximum as concentration of 110.18 ±4.90 mg l⁻¹ in Nambul river during summer season and minimum value of 39.33 ±4.21 mg l⁻¹ in Iril river during winter season .

Calcium

The values range from 6.97 mg l⁻¹ (Iril river during December) to 25.60 mg l⁻¹ (Nambul river during June). The average mean concentration of calcium was found to be highest in Nambul river during rainy season i.e. 23.31 ±2.16mg l⁻¹ and lowest 7.45 ±0.55mg l⁻¹ in Iril river during winter season. For annual average, the highest calcium value was observed in Nambul river as compared to the remaining rivers.

Magnesium

The maximum value recorded was during

summer i.e. 12.37 ±1.11mg l⁻¹ in Nambul river and minimum during winter as 4.74 ±0.73mg l⁻¹ in Iril river. Magnesium values from across the sites ranges from 4.01mg l⁻¹ (Imphal river during August) to 15.40mg l⁻¹ (Nambul river during June).

Nitrate

Nitrate concentration of the three river water of different sites ranged from 0.07 mg l⁻¹ (Iril river, January and December) to 0.63 mg l⁻¹ (Nambul river, June). Seasonally, the average maximum mean value was recorded as 0.53 ±0.08 mg l⁻¹ in Nambul river during summer season and minimum as 0.12 ±0.07 mg l⁻¹ in Iril river during winter season.

Inorganic Phosphate

The concentration ranges from 0.013 mg l⁻¹ (Iril river in January, Imphal river in April) to 0.508 mg l⁻¹ (Nambul river in June). Seasonal maximum mean value was 0.327 ±0.12 mg l⁻¹ (Nambul river in rainy season) and minimum as 0.015 ±0.002 mg l⁻¹ (Imphal river in summer season).

Potassium

The concentration of potassium in all the different sites of the river exhibits variation ranging from 2.87 mg l⁻¹ (Imphal river during February) to 17.67 mg l⁻¹ (Nambul river during June). The average seasonal maximum mean concentration of 13.63 ±2.74 mg l⁻¹ of Potassium was observed in Nambul river during rainy season and minimum value of 3.48 ±0.56 mg l⁻¹ in Imphal river during winter season. Annually, Nambul river has got maximum concentration of Potassium than the other rivers.

DISCUSSION

Gradient in the water temperature is closely associated with ambient temperature (Munawar, 1970) and it is one of the most important factors because of its requirements in different metabolic activities of organisms in the ecosystem of different water bodies. In the present studies, the range of water temperature (19.39°C to 26.34 °C) is very much comparable with finding of Srivastava and Singh (1995). The different thermal stratification at different rivers might be due to exposure to wind (Buckley and Sublette, 1964) and small difference between surface and bottom water temperature (Hickling, 1961; Sreenivason, 1968). Therefore,

seasonal variation at different significant level of the three river shows at $p < 0.05$ and $p < 0.01$. However, insignificant variations were observed in Iril and Imphal river during rainy season which might be due to lack of thermal exposure during rainy season.

Water conductivity is mainly attributed to the dissolved ions liberated from the decomposed plant matter (Sarwar and Majid, 1997) and input of organic and inorganic waste (Wright, 1982). In the present study, the significant level of conductivity in Iril and Imphal river was found always at $p < 0.05$ and $p < 0.01$ in all the seasons whereas in Nambal river significant level of $p < 0.05$ was observed only during winter season. This pattern of variation was in support of the finding of Antwi and Ofori-Danson (1993) that liberation of ions results in the increase of conductivity. Total dissolved solids had a cyclic pattern of seasonal changes and maximum during rainy season and minimum in winter. This indicated that the dissolved materials were of allochthonous origin, which was brought into the river system with surface runoff. Johnson (1988) observed that total dissolved solid proportionately enhanced the electrical conductance in water and ran parallel to each other. In the present study, total dissolved solid concentration was found high during rainy season. However significant variation could not be well established during the season.

During the study water turbidity was found low during the winter season and high in rainy season. It might be due to the high silt content of the water carried down into the river by the feeder streams from the catchment areas. Therefore, this signifies the variation level of $p < 0.05$ to $p < 0.01$ in Imphal and Iril river. But, significant level of $p < 0.01$ was observed only in winter season. According to Khan and Chowdhury (1994) high value of turbidity during rainy seasons may be due to heavy load of silt into the river water from the feeder streams.

Measurement of pH gives the intensity of acidic or basic nature of water. Changes in the pH of water may be the result of various biological activities (Gupta *et al.*, 1996). If the water body is neither highly alkaline nor highly acidic, the pH of water is generally governed by the carbon dioxide - bicarbonate - carbonate system (Hutchinson,

1975). However fluctuation in pH is also related with input loads of pollutants in the river system (Sahu *et al.*, 1995). The high value of pH during rainy season in the present work possibly resulted from increased rate of pollutant from the surrounding areas along with the rain water, but significant variation could not be established in this case also in all the seasons.

Free carbon dioxide present in water is mainly originated from the respiration of aquatic biota, decomposition of organic matters and infiltration through the soil. It is an input parameter of the buffer system and influences the concentration of carbonates, bicarbonates, pH and total hardness in water. Higher level of free carbon-dioxide during winter season may be attributed to increased decomposition rate under the river bed following slowdown of river water current. In the findings of Gupta *et al.* (1996) and Gupta and Mehrotra (1991) maximum value of free CO_2 was found in the month of January and minimum in August. This is in gross agreement with the present finding that free CO_2 values were relatively higher in summer and winter. However, significant variation was observed in two rivers namely Imphal river and Iril river at $p < 0.01$ and $p < 0.05$ during rainy season only. For Nambal river actual significant level could not be established.

The rather high dissolved oxygen content during rainy season was largely attributed due to increase in aeration level with increased flow current of river water. Similar observation was also found by Gupta *et al.* (1996) that the DO content in river water is higher in monsoon as compared to summer season. The same result was also reported by Gupta and Mehrotra (1991). So, the present observation of higher DO level in rainy season than summer and winter is in conformity with the above findings by other researchers. Significant variation level at $p < 0.01$ was found in two river (Imphal and Iril), but insignificant level of $p > 0.05$ was observed in Nambal river.

Biochemical oxygen demand in water indicates the level of organic waste pollution. According to Akpata *et al.*, (1993), microbial oxidization of organic sub-surface leads to the increase in the level of biochemical oxygen demand

in water bodies. Das (1978) and Das and Pande (1980) reported that high organic materials deposition promotes natural oxidation and thereby depletion of oxygen occurs when anaerobic bacteria take over the process of decomposition. This increases in the value of biochemical oxygen demand level. Higher value during summer season might be due to biological as well as natural oxidation process with increase in temperature. Even though the significant variation could not be established, the BOD level in present observation was found high in summer than rainy and winter season in the three rivers.

Level of carbonates was higher during early monsoon i.e. during summer season of the present study, which is similar to the observation of Desai (1991). Kollman and Wali (1976), they observed that maximum value of carbonate was found during the month June which is early monsoon season and minimum during winter. Thus, the concentrations of hardness, calcium and magnesium were found higher during summer season and lower during winter season which is in agreement with the above findings. Significant variation was observed at $p < 0.01$, during rainy season for the two river-Imphal and Iril, whereas for Nambul river it was observed to be at a level of $p > 0.05$.

Higher concentration of nitrate was observed during summer and rainy season and lower concentration during winter which shows resemblance with the finding of Bhattacharya *et al.*, (2002). In the present study, there was no significant variation in all the seasons.

Phosphorus is an important factor in ecological studies and often regarded as a limiting element in water ecosystem (Hecky and Kilhan,

1988). Both organic and inorganic forms are involved in transformation (Holtan *et al.*, 1988). The high values of phosphate during rainy season might be due to transport from the surrounding catchment areas. Significant variation at the level of $p < 0.05$ and $p < 0.01$ were also observed during rainy season except for Nambul river. The low values of the nutrient during winter season might be probably due to lowering in input of pollutant in the river system which conforms the findings of Clarke (1924).

In general, concentration of potassium in natural water is low, but high value being an indication of pollution by domestic waste (Trevedy & Goel, 1984). Potassium value exhibit high during summer and rainy season and low during winter season. It was due to rain runoff of decomposed plant materials from surrounding catchment area of the river, which help in increasing in the concentration of potassium in the water. In rainy season analysis of variance shows significance at a level of $p < 0.01$ and $p < 0.05$ for Imphal and Iril river whereas Nambul river at $p > 0.05$ insignificance level.

CONCLUSION

The seasonal distribution pattern of different parameters were found to be influenced by different environmental factors for the three major rivers in Imphal valley. The presence of nutrient at different levels in the river water throughout the study period offer an excellent opportunity to characterize the quality of the water of the three major rivers in different seasons. This will be highly relevant because these three rivers are the main water resource for the people inhabiting around the Imphal city.

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