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Seasonal assessment of irrigation water suitability of river Damodar in West Bengal, India

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ABSTRACT

Rivers have always been the most important freshwater resources and conductive to various developmental activities and rapid urbanization has resulted in the degradation of quality of river water. The present research work deals with the assessment of irrigation water suitability of river Damodar. The major physico-chemical parameters were analyzed for a period of consecutive two years 2007 and 2008 .The SAR, Na % and RSC have been utilized to verify the water quality for irrigation use. The concentration of different parameters of Damodar river water ranges between 0.01 mg l^{-1} to 1.32 mg l^{-1} (PO_4^{3-}), 0.09 mg l^{-1} to 4.19 mg l^{-1} (NO_3^-), 56 mg l^{-1} to 176 mg l^{-1} (HCO_3^-), 4.21 mg l^{-1} to 63.92 mg l^{-1} (Ca^{2+}), 3.73 mg l^{-1} to 49.1 mg l^{-1}(Mg^{2+}), 5.35 mg l^{-1} to 45.62 mg l^{-1} (Na^+), 0.1 mg l^{-1} to 34.9 mg l^{-1} (K^+) and 7.69 mg l^{-1} to 81.09 mg l^{-1} (SO_4^{2-}). Na% value of Damodar river water samples ranges from 11.58 to 66.13 with an average of 33.64. The RSC values of water samples of river Damodar range from the -4.52 to 1.80 with an average of 0.06. The SAR concentration of Damodar river water samples ranges from 0.28 to 1.57 with an average of 0.72. From the study of Damodar river water quality in relation to irrigation water quality standards it was found that at the site of majhermana there are high Na% and RSC indicating unsuitability for agricultural purpose. The quality assessment shows that in general the water in the study area are suitable for irrigation purposes with respect to Na %, RSC and SAR values in case of pre-monsoon, monsoon and during post-monsoon season.

Keywords: Damodar river, irrigation water quality, Na%, RSC and SAR

River Damodar, a tributary of holy river Ganga flows through a vast track of eastern India with variable topography and geology and is considered to be the lifeline the Damodar river basin. Damodar river water has been used as, drinking water, industrial activities and irrigation water for agriculture. The river receives considerable amounts of waste every day in the study area from various industries, mining and municipal areas. The wastewater from urban areas, industrial discharges reduces agriculture production and affects public health. Therefore, comprehensive river water quality monitoring program is becoming a necessity in order to safeguard public health and to protect the agricultural resources. The ions and other substances carried into the rivers in elevated concentrations may result in pollution (de Vlaming *et al.*, 2004; Izonfuo and Bariweni, 2001). Irrigation water quality is a key environmental issue faced by the agricultural sector.

The Damodar river basin serves as a major source of domestic and industrial water supply and the basin receives untreated municipal sewage and effluents from industries directly during its course. Anthropogenic influences and natural processes deteriorate surface water quality and impair their use for drinking, industrial and agricultural purposes (Carpenter *et al.* 1998). Sulphate, phosphate and nitrate are important parameters of river water show the pollution status and anthropogenic load in river water. Surface runoff carries residues of human activities from the land into river systems and is affected by the land use type. Discharge of sewage into rivers and storm water are common ways that various nutrients enter the aquatic ecosystems resulting the pollution of those systems (Sudhira and Kumar, 2000; Adeyemo, 2003).

Unused fertilizers, pesticides, effluents discharged from industries, coal mines and sewage water are the main contaminants of the Damodar river water. The Damodar river system contains many point and non-point sources of pollution. Agricultural waste is another factor contributing to pollution of the Damodar river water. Present study was performed to monitor seasonal variation in water quality parameter and assessment of irrigation water suitability along the upstream to downstream stretches of river Damodar, in West Bengal.

MATERIALS AND METHODS

The river water samples were collected (during the year 2007 and 2008 in premonsoon, monsoon and postmonsoon season) in plastic bottles rinsed three to four times with the water sample before filling it to capacity and then labeled accordingly. Water quality monitoring of the river Damodar was done from Disgergarh upto Pallaroad, Burdwan from 8 sampling sites (Site1. Dishergarh, Site 2. Ramghat, Site3. Durgapur Barrage, Site 4. Majhermana, Site 5. Randiha, Site 6. Sikarpur, Site 7. Sadarghat, Site 8. Pallaroad). EC and pH of water samples were measured in the field immediately after the collection of the samples using pH and Electrical Conductivity meters.

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Water samples were analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS), sulfates (SO_4^{2-}), nitrates (NO_3^-), phosphates (PO_4^{3-}), bicarbonates (HCO_3^-), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) according to standard methods (APHA, 1998). In the laboratory water samples were filtered through 0.45 millipore filter to separate the suspended sediments. Nitrate and phosphate content were determined spectrophotometrically. Sulphate content was determined by $BaCl_2$ method. Na^+ and K^+ were measured by flame photometric method. Calcium and magnesium were determined titrimetrically by the standard ethylene diamine tetra acetic acid (EDTA) were analyzed using UV–Visible spectrophotometer.

RESULTS AND DISCUSSION

Physicochemical analysis of Damodar river water

The results of the physico-chemical analysis of the Damodar river water are presented in table 1 and 2. pH of the study area ranges between 7.3-8.9 indicating an alkaline type of water. The pH of the water bodies indicates the degree of deterioration of water quality. Water having pH beyond the normal range may cause a nutritional imbalance. Electrical conductivity is the most important measure of salinity hazard to crops and determines the suitability of water for irrigation use. Electrical conductivity and Na^+ play important roles in suitability of water for irrigation. High level of EC in water creates a saline soil. According to Subba, 2006 the salts, besides affecting the growth of plants also affects the soil structure and permeability which indirectly affect plant growth. The Electrical Conductivity varies between 210 to 690 µS cm^{-1} in premonsoon, 90 to 320 µS cm^{-1} in monsoon and 170-360 µS cm^{-1} postmonsoon period. Conductivity of the river water decreases during monsoon season as compared to premonsoon and postmonsoon season which might be due to dilution caused by the precipitation.

Table 1 : Physicochemical characteristics of Damodar river water 2007

Parameter	Pre- monsoon			Monsoon			Post monsoon		
	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
pH	7.50	8.90	8.20	7.50	8.10	7.80	7.40	8.50	8.00
EC	230.00	690.00	321.25	100.00	260.00	180.00	170.00	360.00	225.00
TDS	134.90	452.30	206.28	65.40	172.60	123.95	108.50	242.50	147.68
Ca^{2+}	9.30	36.20	16.20	4.20	36.20	14.40	8.40	63.90	20.70
Mg^{2+}	4.90	23.50	10.00	3.70	16.90	8.70	5.00	44.00	12.70
SO_4^{2-}	11.45	81.09	34.00	8.32	42.45	16.79	10.25	41.65	19.06
HCO_3^-	76.00	152.00	102.00	56.00	176.00	104.75	56.00	140.00	92.00
NO_3^-	0.21	4.19	1.13	0.20	2.45	0.67	0.09	1.90	0.50
Na^+	6.30	39.40	14.24	8.25	45.62	16.25	9.32	28.35	14.96
K^+	8.90	34.90	14.01	1.40	5.50	2.53	2.40	9.10	4.67
PO_4^{3-}	0.04	1.32	0.28	0.02	0.34	0.14	0.01	0.35	0.13
Na%	30.05	66.13	39.64	22.80	54.38	34.53	16.40	45.71	31.30
RSC	-1.25	0.38	0.04	-2.23	1.80	0.29	-4.52	0.81	-0.57
SAR	0.40	1.25	0.65	0.49	1.57	0.82	0.47	1.18	0.69

Except pH and EC other physicochemical parameters expressed as mg l^{-1}, RSC and SAR as meq/l

Total dissolved solids (TDS) in water varies between 134.9 to 452.3 mgl^{-1} in premonsoon, 60.5 to 210.5 mgl^{-1} in monsoon and 108.5 – 242.5 mgl^{-1} postmonsoon periods. Total dissolved solids (TDS) in natural water indicate the nature of the water quality or salinity. The bicarbonate values of Damodar river water ranges from 56 to 176 mg l^{-1}. The bicarbonate content of analyzed river water is within the limit (600 mg l^{-1}) of FAO irrigation standards (Pescod, 1992). The Ca^+ and Mg^+ concentration of Damodar river water stretches from Dishergarh to Pallaroad ranged from 4.21 to 63.92 mg l^{-1}, 3.73 to 49.1 mg l^- respectively throughout the study period.

Table 2 : Physicochemical characteristics of Damodar river water 2008

Parameter	Pre monsoon			Monsoon			Post monsoon		
	Min.	Max.	Average	Min	Max.	Average.	Min.	Max.	Average
pH	7.30	8.70	7.95	7.40	8.20	7.80	7.90	8.50	8.10
EC	210.00	540.00	292.00	90.00	320.00	166.25	180.00	290.00	223.75
TDS	136.50	344.30	177.48	60.50	210.50	111.34	117.00	190.20	145.04
Ca^{2+}	9.30	30.30	15.90	4.20	18.50	10.00	8.40	37.80	15.60
Mg^{2+}	4.90	18.20	9.60	3.10	28.50	8.50	5.00	49.10	13.20
SO_4^{2-}	11.40	53.50	26.29	8.32	18.35	12.96	7.69	34.35	17.42
HCO_3^-	84.00	176.00	111.50	72.00	116.00	100.50	56.00	140.00	94.50
NO_3^-	0.15	2.09	0.74	0.08	2.72	0.75	0.35	1.50	0.73
Na^+	7.50	25.60	15.98	5.35	18.90	10.74	8.35	17.85	12.95
K^+	1.20	5.40	2.64	0.10	5.80	1.80	0.40	4.50	2.30
PO_4^{3-}	0.04	1.25	0.33	0.01	1.09	0.23	0.04	0.16	0.08
Na%	21.18	47.28	33.37	13.53	55.59	33.35	11.58	50.17	29.67
RSC	-0.35	1.31	0.43	-1.43	1.10	0.45	-3.63	0.55	-0.31
SAR	0.50	1.36	0.81	0.28	1.36	0.69	0.38	1.21	0.67

Except pH and EC other physicochemical parameters expressed as mg l^{-1}, RSC and SAR as meql^{-1}

Phosphorus is an essential and often limiting nutrient in freshwater ecosystems; it plays a significant role in many environments due to its role in eutrophication (Thomas, 1973). Several studies related to eutrophication report the deteriorating quality of surface waters due to pollution (Bukit, 1995, Drolc and Zagorc, 2002, Ekholm *et al.*, 2000). Phosphates are derived from leaching of phosphorus rich bedrock and additionally from human wastes, industrial wastes, decomposing organic matter. The phosphate concentration in the study area varies between 0.04-1.32 mgl^{-1} in premonsoon, 0.01-1.09 mgl^{-1} in monsoon and 0.01-0.35 mgl^{-1} postmonsoon period. Phosphate concentration is maximum (1.32 mgl^{-1}) at station Majhermana due to the discharge of industrially polluted water stream. Nitrogen is a plant nutrient, an essential constituent of proteins and stimulates crop growth. The nitrates are extremely soluble in water and can easily move through soil into the drinking water (Saba *et al.*, 2006). According to Ayers and Westcot, 1994 crops are relatively unaffected until nitrogen exceeds 30 mgl^{-1}. The concentration of nitrate in the Damodar river ranged from 0.15 to 4.19 mgl^{-1} during premonsoon, 0.08 to 2.72 mgl^{-1} during monsoon, 0.09 to 1.9 mgl^{-1} during post-monsoon. Nitrate concentration is maximum (4.19 mgl^{-1}) at Ramghat probably due to the discharge of agricultural wastes.

The concentration of Na^+ is often taken as an important parameter in deciding the suitability of water for irrigation. The sodium concentration is significant in classifying the water for irrigation purposes as because sodium concentration can reduce the soil permeability and soil structure (Todd 1980, Domenico and Schwartz, 1990). According to Karanth, 1989 the high sodium percentage causes deflocculation and impairment of the tilth and the permeability of soils.

Table 3. Classification of irrigation water on the basis of Na %, EC and TDS

Parameters	Range	Water Class
Na %	20	Excellent
	20-40	Good
	40-60	Permissible
	60-80	Doubtful
	80	Unsuitable
EC	250	Excellent
	250–750	Good
	750–2,000	Permissible
	2,000–3,000	Doubtful
	3,000	Unsuitable
TDS	<1,000	Fresh
	1,000–3,000	Slightly saline
	3,000–10,000	Moderately saline
	10,000-35,000	High saline

Wilcox (1955)

The average sodium concentration is minimum during the monsoon season (13.49 mgl^{-1}) due to diluting effect and maximum during the premonsoon season (15.10 mgl^{-1}) reflecting the concentrating effects. The average sulphate concentration is minimum during the monsoon season (14.87 mgl^{-1}) due to diluting effect and maximum during the premonsoon season (30.14 mgl^{-1}) reflecting the concentrating effects and the postmonsoon season is characterised by intermediate values (18.23 mgl^{-1}).

The sulphate content of analyzed river water is within the limit (1000 mg l^{-1}) of Indian Standards for irrigation (IS, 1986). Classification of irrigation water on the basis of Na %, EC and TDS are presented in table 3. Saptial variation and seasonal varations in physicochemical characters are presented in table 6 and table 7 respectively.

Table 4. Classification of irrigation water on the basis of RSC

RSC Value	Water Quality
<1.25	Water can be used Safely
1.25-2.5	Water can be used with certain management
>2.5	Unsuitable for irrigation purposes

Das, D.K. (1996).

Table 5. Classification of irrigation water on the basis of Sodium Adsorption Ratio (SAR)

Water Class	SAR Value	Remarks
S_1- Low Sodium hazard	0-10	Little or no hazard
S_2- Medium Sodium hazard	18-26	Appreciable hazard, but can be used with appropriate management
S_3- High Sodium hazard	18-26	Unsatisfactory for most of the crops
S_4- Very high Sodium hazard	>26	Unsatisfactory for most of the crops

Water quality for irrigation use

Sodium percentage (Na%)

The percent sodium in water is an important parameter computed to evaluate the suitability for irrigation as agricultural purposes (Wilcox 1948; Tiwari and Manzoor 1988a). Na% can be calculated by the following relation where the concentration of ions is expressed in $meql^{-1}$

$$Na\% = \frac{(Na+K)}{(Ca+Mg+Na+K)} \times 100$$

The percent sodium values in the year 2007 varied from 30.05 to 66.13 (Fig. 1), with an average 39.64 for premonsoon, from 22.79 to 54.38 with an average 34.53 for monsoon and from 16.40 to 45.71 with an average 31.30 in postmonsoon period. The per cent sodium values in the year of 2008 (Fig. 2) varied from 21.18 to 47.28 with an average 33.36 for premonsoon, 13.53 to 55.59 with an average 33.35 for monsoon and from 11.58 to 50.17 with an average 29.67 in postmonsoon period. The maximum tolerance limit of Na% for inland surface water used for irrigation is 60 (ISI, 1974). The high Na% (66.13) found at Majhermana and it cross maximum tolerance limit of Na% for inland surface water used for irrigation. The water samples at other sites in the study area are suitable for irrigation purposes with respect to Sodium percentage (Na %) values in case of pre-monsoon, post-monsoon and during monsoon season in both 2007 and 2008.

Table 6: Spatial variation in physicochemical characteristics of Damodar river water

Parameters	Places									
	Dishergarh	Ramghat	Durgapur Barrage	Majher Mana	Randiha	Sikarpur	Sadarghat	Pallaroad	SEm (±)	LSD(0.05)
pH	7.850	7.917	8.000	8.317	7.967	7.750	8.200	7.883	0.122	0.356
EC	181.667	251.667	186.667	408.333	206.667	190.000	206.667	230.000	19.535	57.011
TDS	114.333	161.850	120.650	268.383	137.200	125.700	136.917	150.633	12.740	37.182
Ca2+	9.812	15.282	14.577	33.363	14.158	14.158	11.775	10.513	2.789	8.139
Mg2+	5.327	10.652	7.710	27.468	8.255	8.998	6.333	8.695	1.559	4.549
SO4	13.833	33.768	15.433	36.985	19.962	20.747	15.763	12.187	4.896	14.289
HCO3-	94.000	127.000	96.667	116.667	106.667	85.333	88.667	92.000	9.362	27.324
NO3	0.537	1.413	0.468	1.725	0.528	0.487	0.438	0.403	0.240	0.701
Na+	11.135	10.212	16.212	25.387	14.175	12.683	11.922	11.743	3.300	9.631
K+	3.638	3.617	4.450	10.022	4.462	3.855	4.117	3.100	2.306	6.731
PO4	0.107	0.095	0.082	0.263	0.360	0.320	0.118	0.233	0.127	0.372
Na%	37.982	29.483	36.785	28.128	34.373	32.825	36.145	33.427	4.872	14.219
RSC	0.613	-0.037	0.222	-1.287	0.363	-0.048	0.345	0.270	0.344	1.004
SAR	0.698	0.560	0.862	0.783	0.763	0.703	0.722	0.687	0.150	0.438

Table 7: Seasonal variation in physicochemical characteristics of Damodar river water

Parametrs	Seasons			SEm (±)	LSD(0.05)
	Pre-monsoon	Monsoon	Post monsoon		
pH	8.106	7.794	8.056	0.075	0.218
EC	296.25	177.5	224.375	11.962	34.912
TDS	191.875	117.644	146.356	7.802	22.77
Ca2+	16.034	12.196	18.135	1.708	4.984
Mg2+	9.761	8.573	12.956	0.955	2.786
SO4	30.146	14.874	18.235	2.998	8.75
HCO3-	106.75	102.625	93.25	5.733	16.732
NO3	0.93	0.707	0.613	0.147	0.43
Na+	15.106	13.493	13.951	2.021	5.898
K+	8.325	2.163	3.485	1.412	4.122
PO4	0.305	0.184	0.103	0.078	0.228
Na%	36.506	33.938	30.486	2.984	8.707
RSC	0.236	0.373	-0.443	0.211	0.615
SAR	0.732	0.756	0.679	0.092	0.269

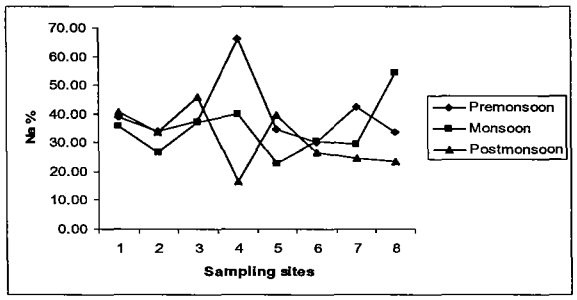

Fig.1 Seasonal variation of Na% of Damodar river water 2007

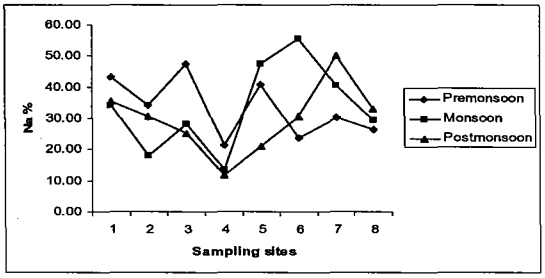

Fig. 2 Seasonal variation of Na% of Damodar river water during 2008

Residual sodium carbonate (RSC)

The effect of CO_3^{-2} and HCO_3^{-1} ion on quality of water was expressed in terms of the Residual Sodium Carbonate (RSC) by Eaton, (1950). Carbonate levels when exceed the total amount of calcium and magnesium, the water may be poor in quality.

$$RSC = (CO_3^{-2}+HCO_3^{-1}) - (Ca^{+2} + Mg^{+2})$$

Where the concentration of all cations are expressed in meq/l. In 2007 the RSC content of Damodar river water samples (Fig. 3) ranges from -1.24 to 0.38 with an average of 0.04 for premonsoon and from -2.27 to 1.80 with an average 0.29 in monsoon, and -4.5 to 0.81 with an average -0.57 in postmonsoon. The RSC content in 2008 of Damodar river water samples (Fig.

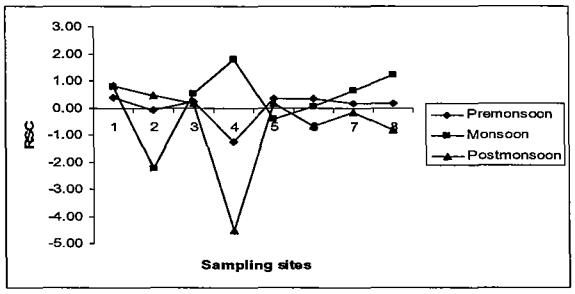

Fig. 3 Seasonal variation of RSC of Damodar river water 2007

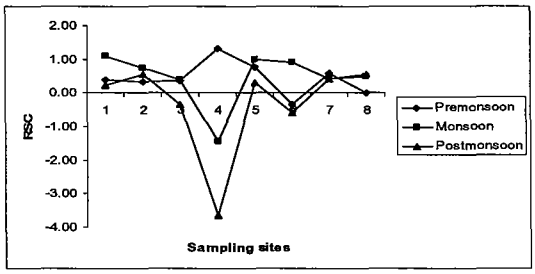

Fig. 4 Seasonal variation of RSC of Damodar river water 2008

4) ranges from -0.35 to 1.31 with an average of 0.45 for premonsoon, from 1.43 to 1.10 with an average of 0.45 for monsoon and from -3.63 to 0.55 with an average of -0.31 in postmonsoon season. The high RSC content (1.31) found at Majhermana and it is not suitable for irrigation use and need adequate treatment. On the basis of residual sodium carbonate (RSC), irrigation waters were divided into three categories presented in Table 4. The water samples in the study area are suitable for irrigation purposes with respect to RSC values in case of pre-monsoon, monsoon, and during post-monsoon season.

Sodium adsorption ratio (SAR)

Sodium concentration is very important parameter for irrigation water quality because high level of sodium concentration in irrigation water produces an alkaline soil. The sodium hazard of Damodar river irrigation water is usually specified by two indices like sodium adsorption ratio (SAR) and sodium percentage (Na %). The sodium through the process of Base Exchange may reduce calcium in the soil and thereby may reduce the permeability of the soil to the water and adverse effect on plant growth occurred over a long period of time. The Sodium adsorption ratio (SAR) is computed where the Na, Ca and Mg concentrations are expressed in meq/l as shown below:

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$$

High concentrations of sodium in soils affect physical condition and soil structure. Todd, 1980 describes that SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard. Classification of irrigation water on the basis of Sodium Adsorption Ratio (SAR) is presented in table 5.
Das, D.K. (1996).

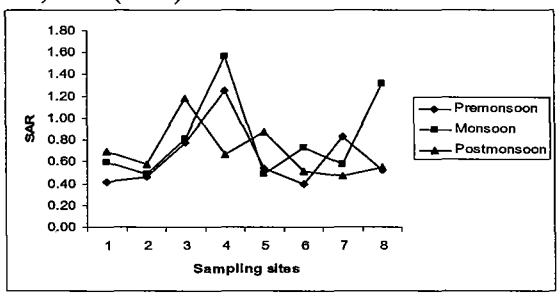

Fig. 5 Seasonal variation of SAR of Damodar river water 2007

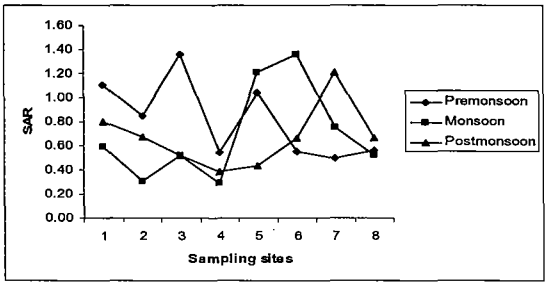

Fig. 6 Seasonal variation of SAR of Damodar river water 2008

In 2007 the SAR concentration of Damodar river water samples (Fig. 5) ranges from 0.39 to 1.25 with an average of 0.68 for premonsoon, from 0.48 to 1.57 with an average 0.86 in monsoon, and 0.466 to 1.18 with an average 0.69 in postmonsoon. The SAR concentration in 2008 of Damodar river water samples (Fig. 6) ranges from 0.49 to 1.36 with an average of 0.81 for premonsoon, from 0.28 to 1.36 with an average of 0.69 for monsoon and from 0.38 to 1.21 with an average of 0.67 in postmonsoon season. The water samples in the study area are suitable for irrigation purposes with respect to SAR values in case of pre-monsoon, monsoon, and during post-monsoon season.

The seasonal data of Damodar River shows pH of the study area indicating an alkaline type of water. The high RSC content and Na% were recorded at majhermana due an industrially polluted water stream which joins into the river as a result of which the water is not suitable for irrigation use. Study of river Damodar shows a minimum concentration of most of the ions in monsoon season, due to diluting effect and a maximum concentration in pre-monsoon seasons, reflecting the concentrating effects. The quality assessment of Damodar river water shows that in general the river water in the study area is suitable for irrigation purposes with respect to, Na %, RSC content and SAR during pre-monsoon, monsoon, and post-monsoon season.

REFERENCES

Adeyemo, O.K. 2003. Consequences of pollution and degradation of Nigerian aquatic environment on fisheries resources,.*The Environmentalist,* **23**: 297-06.

APHA, AWWA, WEF 1998. *Standard Methods for the Examination of Water and Wastewater (20th ed.).* Washington, DC: American Public Health Association.

Ayers, R. S., and Westcot, D. W. 1994. *Water Quality for Agriculture*: FAO Irrigation and Drainage Paper 29. Rev. 1,pp. 1–130.

Bukit, N. T. 1995. Water quality conservation for the Citarum river in west Java, *Water Sci. Tech.* **31**: 1–10.

Carpenter, S. R., Caraco, N. E., Correll, D. L., Howarth, R. W. and Smith, V. H. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications.*, **8**: 559–68.

Das, D.K. 1996. *Introductory Soil Science.* Ludhiana:Kalyani Publishers pp.241

De Vlaming, V., Di Giorgio, C., Fong, S., Deanovic, L. A, de la Paz Carpio-Obeso, M. D. and Miller, J. L. 2004. Irrigation runoff insecticide pollution of rivers in the Imperial Valley, California, USA. *Env. Poll.*, **132**: 213–29.

Domenico, P. A., and Schwartz, F. W. 1990. *Physical and Chemical Hydrology.* New York: John Wiley and Sons.

Drolc, A. and Zagorc, K. J. 2002. Estimation of sources of total phosphorus in a river basin and assessment of alternatives for river pollution reduction, *Env. Inter.* **28**: 393–400.

Eaton, F. M. 1950. Significance of carbonates in irrigated waters. *Soil Sci.* **69**: 127– 28.

Ekholm, P., Kallio, K., Salo, S., Pietil¨ainen, O. P., Rekolainen, S., Laine, Y. and Joukola M. 2000. Relationship between catchment characteristics and nutrient concentrations in an agricultural river system. *Water Res.,* **34** : 3709–16.

IS 2490 Part I: 1981. *Tolerance limits for industrial effluents discharged into inland surface waters: Part I – General limits*, Bureau of Indian Standards.

ISI. 1974. *Indian standard tolerance limits for surface waters subject to pollution*, IS: 2296. New Delhi: ISI.

Izonfuo, L. W. A., and Bariweni, A. P. 2001. The effect of urban runoff water and human activities on some physico chemical parameters of the Epic Creek in the Niger Delta. *J. Appl. Sci. Env. Management.*, **5:** 47–55.

Karanth, K. R. 1989. *Groundwater assessment, Development and Management.* New Delhi: Tata McGraw-Hill Publ. Com. Ltd.

Pescod, M.B. 1992. *Wastewater treatment and use in Agriculture.* FAO Irrigation and Drainage Paper 47, Rome, FAO of the United Nations.

Saba, S., Nalan, K., Umran, Y., Muserref, A. and Mithat, Y. 2006. Removal of nitrate from aqueous solution by nitrate selective ion exchange resins. *Reactive and Functional Polymers*, **66**: 1206–14.

Subba Rao N. 2006. Seasonal variation of groundwater quality in a part of Guntur district, Andhra Pradesh, India. *Environ Geol* **49**:413–29

Sudhira H.S. and Kumar V.S. 2000. Monitoring of lake water quality in Mysore City. *In: Proc. Int. Sym. on Restoration of Lakes and Wetlands (Eds.).* Ramachandra, T.V., Rajasekara, M.C and Ahalya, N. Bangalore, India: Centre for Ecological Sciences, Indian Institute of Science,pp. 1-10.

Thomas EA .1973. *Phosphorus and Eutrophication.* In: Griffith EJ, Beeton A, Spencer JM, Mitchell DT (Eds) Environmental phosphorus handbook. Wiley, New York, NY.

Tiwari, T. N., and Manzoor, A. 1988a. River pollution in Kathmandu valley (Nepal) suitability of river water for irrigation. *Indian J. Env. Prot., 8:* 269–74

Todd, D. K. 1980. *Groundwater Hydrology* (2nd ed.), pp. 535. New York: Wiley.

Wilcox, L. V. 1948. *The quality of water for irrigation use.* Washington, DC: US Department of Agriculture, Technical Bulletin. pp.19

Wilcox, L. V. 1955. *Classification and use of irrigation waters.* U.S. Department of Agriculture Circular 969. Washington, DC: U.S. Department of Agriculture. pp 19