AGRICULTURAL WATER QUALITY OF SHALLOW GROUNDWATER IN THE UPPER ALLUVIAL PLAINS OF NARMADA VALLEY BETWEEN HOSHANDABAD AND BHILARIA, M.P., INDIA

SUNIL KUMAR SHARMA, VINOD KUMAR PARASHAR

Abstract: Water is a valuable contribution of nature to human beings. Water is required not only for domestic use but also for the evolving needs of any nation for its better agricultural growth.
The main objective of the present study is to evaluate and assess the water quality of shallow groundwater of Hoshangabad city and its suitability for irrigation purposes. In the present study, the hydro chemical investigation is restricted to the major ions' concentration like Ca, Mg, Na. K. CO_3, HCO_3, Cl, NO_3 etc. In order to assess the water quality, 22 shallow groundwater samples were collected from the different shallow aquifers of the study area and analyzed by using the methods as proposed by APHA (1995).

Introduction: The area of present study lies between lat. 22°45' to 22°35' North and longi. 77°42' to 77°18' East, extending over a stretch of about 45 kms from Hoshangabad to Bhilaria. The study area falls in the toposheets Nos. 55F/9, 55F/10, 55F/6. The most fringing rocks of the alluvial plains are the Deccan trap lava flows of Basaltic composition of Cretaceous-Eocene age. During recent past, studies on agricultural water quality have been reported by various workers in India like **Subba Rao (2006),** Jayalakshmi Devi et al.(2009), Ravikumar et al.(2011), Sharma et al. (2011), Jhariya et al. (2012), Maghanga et al. (2013), Dhiman (2014) including M.K.Shrivastava (1980) , R.K Jain , V.K. Parashar (1994, 2001) in the alluvial plains of Narmada valley.

Material and Methods: In order to evaluate the agricultural quality, 22 representative groundwater samples from shallow aquifers were collected from the study area. The collected water samples were analyzed by using the standard methods as proposed by APHA (1995). The analysis of water samples was carried out by using HECK Spectrophotometer, Flame photometer and titration methods.

Results and Discussion: The results demonstrated that majority of the groundwater samples are well within the permissible limit as per the guidelines proposed by WHO and BIS. The groundwater of the study area was found to be clear, colour less and having no objectionable taste. The ranges of major cations and anions of ground water are given in **Table 1.**

The range of pH value of shallow ground water of the study area varies from 7.4 to 8.2 in pre-monsoon and 7.2 to 8.0 in post-monsoon period. The Electrical conductivity (EC) values in shallow groundwater vary from 390 µmohs/cm to 930 µmohs/cm in pre-monsoon and 360 µmohs/cm to 900 µmohs/cm in post-monsoon period.

Calcium content in shallow ground water varies from 32 mg/l to 56 mg/l and 27 mg/l to 52 mg/l in pre-monsoon and post-monsoon periods respectively. The Magnesium concentration in shallow ground water varies from 10 mg/l to 31 mg/l in pre-monsoon and 09 mg/l to 30 mg/l in post-monsoon period. The sodium content in shallow ground water varies from 18 mg/l to 72 mg/l in pre-monsoon and 13 mg/l to 65 mg/l in post-monsoon period. The Potassium content in shallow groundwater is varies from 0.8 mg/l to 14 mg/l in pre-monsoon and 0.6 mg/l to 13 mg/l in post-monsoon period. The total hardness in terms of $CaCO_3$ ranges from 132 mg/l to 263 mg/l in pre-monsoon and 118 mg/l to 250 mg/l in post-monsoon period. The Carbonate content is found to be absent in all the samples of shallow ground water, collected during the pre-monsoon and post-monsoon periods. Bicarbonate is the predominant anion in the shallow ground water of the study area. Bicarbonate concentration in the shallow ground water varies from 104 mg/l to 227 mg/l in pre-monsoon and 85 mg/l to 210 mg/l in post-monsoon period.

The chloride concentration in shallow ground water varies from 32 mg/l to 97 mg/l in pre-monsoon and 26 mg/l to 93 mg/l in post-monsoon period. The Sulphate concentration in the shallow ground water of the study area varies from 18 mg/l to 58 mg/l in pre-monsoon and 15 mg/l to 53 mg/l in post-monsoon period. The Nitrate in the irrigation water serves as a nutrient to plants and crops. In the present investigation, the Nitrate content in the shallow groundwater varies from 16 mg/l to 72 mg/l in pre-monsoon and 13 mg/l to 65 mg/l in post-monsoon period. The Phosphate concentration in shallow groundwater of the study area varies from 0.16 mg/l to 0.51 mg/l in pre-monsoon and 0.15 mg/l to 0.49 mg/l in post-monsoon period.

Irrigational Water Quality: The suitability of shallow groundwater have been evaluated on the basis of analytical results. Various specifications have been proposed from time to time by different workers including A.G.Asgar, A.N.Puri and H.M Taylor (1936); W.P. Kelley et al. (1940); L. V. Wilcox (1948, 1955); Eaton (1950); US Soil Salinity Laboratory Staff (1954); V. K. Saligram (1961); N. L. Uppal (1964); B. Ramamoorthy (1964); Federal Water Pollution

Control Authority (1968); K. V. Paliwal (1972); Environmental Protection Agency (1973) and R. S. Ayers and D. W. Westcot (1976, 1997). In the present study the specifications as proposed by W. P. Kelley et al. (1940); L. V. Wilcox (1948, 1955); Eaton (1950); US Soil Salinity Laboratory Staff (1954); K. V. Paliwal (1972) have been used to assess the suitability of shallow ground water for agricultural purposes.

Table 1 : Premonsoon and Postmonsoon Hydrochemistry of Shallow groundwater of the study area between hoshangabad and bhilariya

		Pre Monsoon												Post Monsoon										
Well No.	Name Of the Village	pH	ECX10^3 at 25^{0}C	CONCENTRATIONS IN Mg/l										pH	ECX10^3 at 25^{0}C	CONCENTRATIONS IN Mg/l									
				CATIONS				T.H. as $CaCO_3$	ANIONS							CATIONS				T.H. as $CaCO_3$	ANIONS				
				Na^+	K^+	Ca^{++}	Mg^{++}		HCO_3	Cl^-	NO_3	SO_4	PO_4			Na^+	K^+	Ca^{++}	Mg^{++}		HCO_3	Cl^-	NO_3	SO_4	PO_4
1	2	3	4	6	7	8	9	10	11	12	13	14	15	16	17	19	20	21	22	23	24	25	26	27	28
1	Phepartal	7.8	690	46	1	56	30	263	210	52	56	22	0.35	7.7	650	39	0.8	52	29	250	195	47	52	18	0.32
2	Kherla	7.6	850	35	0.8	48	25	225	204	61	36	43	0.28	7.5	830	28	0.6	44	24	211	190	58	32	40	0.25
3	Hasulpur	7.8	840	20	0.9	52	31	257	227	73	16	25	0.38	7.5	820	15	0.7	48	30	243	210	69	13	22	0.36
4	Barandur	7.7	760	29	0.9	54	21	220	170	36	42	54	0.23	7.6	730	22	0.6	50	19	205	155	32	38	46	0.21
5	Khoksar	7.7	670	40	1.2	47	18	190	180	42	42	31	0.26	7.5	640	33	1	43	16	174	168	38	38	26	0.24
6	Ganora	7.6	630	36	0.9	40	21	186	210	50	30	37	0.31	7.6	620	31	0.6	36	19	170	195	45	27	33	0.3
7	Palanpur	7.9	750	33	1.7	34	13	140	182	39	46	18	0.21	7.6	730	28	1.4	30	12	125	170	36	43	15	0.19
8	Kajlas	8	650	25	1.8	54	19	213	205	72	37	24	0.42	7.8	630	19	1.3	49	18	198	155	68	32	20	0.41
9	Nanpa	7.8	750	18	2.6	41	21	188	164	34	72	45	0.31	7.6	720	13	2.1	37	20	174	150	30	65	40	0.29
10	Kulhara	7.8	480	42	1.9	39	26	206	222	63	43	29	0.51	7.3	450	36	1.4	35	25	190	210	59	37	25	0.49
11	Rehra	7.6	470	20	2.2	38	21	180	105	67	64	46	0.29	7.4	440	13	1.7	33	20	164	85	63	59	40	0.28
12	Aawali	7.6	630	23	3.7	43	25	209	124	45	45	32	0.22	7.2	600	18	3.1	39	23	191	111	41	41	26	0.21
13	Bundara	7.7	710	49	1.4	42	26	210	207	32	34	58	0.35	7.4	690	43	0.8	37	25	195	194	26	30	53	0.33
14	Amlara	7.6	630	56	1.3	52	24	230	225	35	29	42	0.42	7.5	610	51	0.7	47	23	214	210	31	25	37	0.41
15	Kharar	7.4	390	72	3.2	45	15	176	182	40	45	25	0.38	7.2	360	65	2.5	40	15	162	190	34	37	21	0.36
16	Dimawar	7.4	620	25	1.3	56	17	210	160	82	70	20	0.47	7.3	590	19	0.7	52	16	196	145	76	65	15	0.46
17	Pathora	7.7	450	48	3.4	50	15	186	158	90	42	45	0.3	7.5	420	42	2.8	45	14	171	140	85	36	41	0.28
18	Sahejkui	7.9	840	37	2.9	36	10	132	135	44	52	33	0.37	7.6	810	31	2.4	32	9	118	121	39	46	29	0.35
19	Kajli	8.2	810	42	3.7	39	16	164	118	97	56	25	0.36	8	790	35	2.9	35	15	152	101	93	51	20	0.34
20	Basaniya	7.6	750	20	3	32	15	140	104	56	62	27	0.16	7.5	730	13	2.1	27	14	126	90	51	57	22	0.15
21	Bhainsadeh	7.8	710	57	1.9	44	21	198	164	49	50	52	0.28	7.6	680	51	1.1	40	20	183	150	44	42	47	0.25
22	Shivpur	8.1	930	63	14	36	14	150	170	68	70	29	0.46	8	900	56	13	32	13	135	186	63	65	25	0.42

Results and Discussion: In order to evaluate the agricultural water quality, various irrigational specifications have been suggested by various workers. In the present study, irrigational specifications like Salt Index, Kelly's Ratio, Residual Sodium Carbonate, Magnesium Hazard have been used to assess the suitability of shallow groundwater for irrigational purposes. Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Kelly's Ratio and Magnesium hazard are the prominent specifications for determining the suitability of Shallow ground water for agricultural purposes and are presented in **Table-2.** The recommended classification of irrigation water quality with respect to EC, SAR, Kelly's Ratio, Mg. Ratio, RSC and Na% are presented in **Table – 3.** Salinity hazard is evaluated on the basis of Electrical conductivity and it reflects the total dissolved solids (TDS) in shallow groundwater. High salt content in irrigation water affects the soil structure, permeability and plant growth. As per the classification proposed by Richards (1954), the water is **Low** (if EC below 250 µmohs /cm), the water is **Medium** (if EC between 250 to 750 µmohs/cm), the water is **High** (if EC content between 750 to 2250 µmohs/cm), the water is **Very High**(if EC is more than 2250 µmohs/cm) with respect to salinity in water. When the shallow groundwater samples compared with this classification, **Table-2** clearly indicates that the shallow groundwater varies from 390 to 930 µmohs/cm in pre monsoon period and 390 to 930 µmohs/cm in post monsoon period respectively and thus they belongs to Medium to High Salinity class**. Table-3,** further shows that 76% of shallow groundwater in pre-monsoon and 84% in post-monsoon period belongs to Medium salinity class.

Table 2: Irrigational Specification of the Shallow Groundwater of the study area

Well No.	Name of Village	Pre Monsoon						Post Monsoon					
		RSC	Na%	PI	SAR	Mg Hazard	Kelly Ratio	RSC	Na%	PI	SAR	Mg Hazard	Kelly Ratio
1	Phepartal	-1.82	34.58	53.03	1.23	34.88	0.53	-1.77	32.28	52.22	1.08	35.8	0.48
2	Kherla	-1.12	32.16	56.11	1.02	39.68	0.48	-1.06	28.98	55.45	0.84	35.29	0.41
3	Hasulpur	-1.42	19.24	46.49	0.54	37.35	0.24	-1.43	16	45.45	0.41	38.46	0.19
4	Barandur	-1.63	27.64	51.49	0.85	28	0.38	-1.52	24.01	50.97	0.67	27.53	0.32
5	Khoksar	-0.88	37.66	62.07	1.26	27.69	0.61	-0.72	35.48	63.15	1.09	27.12	0.56
6	Ganora	-0.29	36.77	64.73	1.15	34.42	0.59	-0.16	35.79	66.78	1.04	34.54	0.56
7	Palanpur	0.21	40.39	75.15	1.22	27.66	0.7	0.3	39.21	78.11	1.09	28.57	0.67
8	Kajlas	-0.89	25.05	54.74	0.75	26.03	0.34	-1.39	21.76	51.02	0.59	28.86	0.28
9	Nanpa	-1.09	21.79	53.19	0.56	33.87	0.29	-1.03	18.03	52.67	0.43	35.09	0.23
10	Kulhara	-0.45	38.56	63.24	1.28	40	0.64	-0.37	36.96	63.89	1.14	41.67	0.6
11	Rehra	-1.91	24.63	48.58	0.64	35.59	0.34	-1.9	19.2	45.31	0.44	37.73	0.24
12	Aawali	-2.18	24.28	46.54	0.69	36.76	0.34	-2.02	21.66	46.08	0.56	37.09	0.29
13	Bundara	-0.85	41.38	62.44	1.46	38.23	0.72	-0.73	40.64	63.31	1.34	40.32	0.69
14	Amlara dongar	-0.87	42.01	62.06	1.62	31.78	0.74	-0.8	41.9	63.17	1.53	32.86	0.73
15	Kharar	-0.5	53.25	73.46	2.38	25	1.2	-0.12	53.06	75.8	2.24	27.27	1.18
16	Dimawar	-1.57	25.17	51.3	0.75	23.29	0.34	-1.53	21.66	50.16	0.59	23.53	0.28
17	Pathora	-1.14	41.23	63.67	1.53	23.08	0.74	-1.11	40.46	64.05	1.4	23.73	0.71
18	Sahejkui	-0.41	43.07	73.2	1.41	21.74	0.8	-0.36	41.66	74.71	1.25	21.95	0.75
19	Kajli	-1.34	41.7	63.24	1.44	29.09	0.76	-1.32	39.81	62.27	1.24	30	0.7
20	Basaniya	-1.13	28.57	58.75	0.73	31.91	0.42	-1.03	23.17	58.06	0.51	34.15	0.32
21	Bhainsadeh	-1.24	46	64.38	1.77	32.31	0.87	-1.18	45.49	64.65	1.65	33.33	0.85
22	Shivpur	-0.16	49.64	77.65	2.26	28	1.26	-0.38	48.95	81.25	2.11	28.89	1.24

Sodium or alkali hazard is measured on the basis of SAR. The relativity of sodium ion in the exchange reaction with soil is expressed in terms of a ratio known as Sodium Adsorption Ratio (SAR) which is defined as:

$SAR = \frac{Na}{\sqrt{Ca+Mg/2}}$ (Where all concentrations are expressed in epm.)

Excess sodium content in irrigation water produces the undesirable effects on soil properties and it reduces soil permeability. As per the classification based on SAR, the sodium hazard is **Low,** if SAR content is less than 10; **Medium**, if SAR content is in between 10 to 18; **High**, if SAR content is in between 18 to 26 and **Very High** if SAR content is more than 26. When the shallow groundwater samples compared with this classification and refer Table-3, it clearly indicates that the shallow groundwater belongs to Low Sodium waters in pre and post monsoon respectively. Kelly's et al. (1940) has proposed the specification in which the potential sodium hazard in irrigation water can be evaluated on the basis of the following ratio:

Kelley's ratio = $\frac{Na}{Ca+Mg}$, where all the conc. expressed in epm

Kelly et al. mentioned that if this ratio is less than unity the water is suitable, more than two the water is unsuitable and in between one and two the water is marginal for irrigational purposes. It is seen from the **Table 2**, the Kelly's ratio varies from 0.24 to 1.26 in pre-monsoon and 0.19 to 1.24 in post-monsoon period. **Table-3** shows that 91% of shallow groundwater in pre and post monsoon belongs to suitable class and 9% belongs to marginal class in pre and post monsoon period. Thus the majority of shallow groundwater are suitable for agricultural purposes.

Eaton (1950) recommended that water having Carbonate and Bicarbonate ions in excess of Calcium and Magnesium will lead to much greater alkali formation. The carbonate and bicarbonate hazards in agricultural water quality are measured in terms of

Residual Sodium Carbonate (RSC) by the following equation:

RSC= $(CO_3+ HCO_3)$ – (Ca+Mg), where all concentration are expressed in epm

Based on RSC the irrigation Waters are classified as **Safe** (if RSC is less than 1.25), **Marginal** (if RSC is in between 1.25–2.5) and **Unsuitable** (if RSC is more than 2.5). RSC of shallow groundwater of the study area varies from -2.18 to 0.21 in pre-monsoon and -2.02 to – 0.30 in post-monsoon period respectively. After imperative examination of **Table 2 and 3**, it reveals that all the shallow groundwater of the study area belongs to Safe class and thus they are suitable for agricultural purposes.

Table 3: Tabular Classification of Shallow Groundwater of the Study Area

Irrigational Specifications	Range	Class	Type of Water			
			Pre Monsoon		Post Monsoon	
			No. of Samples	%	No. of Samples	%
EC	<250	Low	0	Nil	0	Nil
	250-750	Medium	16	73%	17	77%
	750-2250	High	6	27%	5	23%
	>2250	Very High	0	Nil	0	Nil
	Total		**22**	**100%**	**22**	**100%**
SAR	<10	Low	22	100%	22	100%
	18-Oct	Medium	0	Nil	0	Nil
	18-26	High	0	Nil	0	Nil
	>26	Very High	0	Nil	0	Nil
	Total		**22**	**100%**	**22**	**100%**
Kelly's Ratio	< 1	Suitable	20	91%	20	91%
	1-2	Marginal	2	9%	2	9%
	> 2	Unsuitable	Nil	Nil	Nil	Nil
	Total		**22**	**100%**	**22**	**100%**
Magnesium Ratio	< 50	suitable	22	100%	22	100%
	>50	Unsuitable	Nil	Nil	Nil	Nil
	Total		**22**	**100%**	**22**	**100%**
Residual Sodium Carbonate (RSC)	<1.25	Safe	22	100%	22	100%
	1.25-2.50	Marginal	Nil	Nil	Nil	Nil
	>2.50	Unsuitable	Nil	Nil	Nil	Nil
	Total		**22**	**100%**	**22**	**100%**

Paliwal (1972) has proposed the ratio Mgx100/Ca+Mg as an index of magnesium hazards to irrigation waters. As per the classification, if the Mg Ratio less than 50% the waters are suitable and if Mg ratio is more than 50% the water belongs to Unsuitable. The magnesium ratio of shallow groundwater of the study area varies from 21.74 to 40 in pre-monsoon and 21.95 to 41.67 in post-monsoon period respectively. After vital examination of **Table-3**, it reveals that all the shallow groundwater of the study area belongs to suitable class and there are no magnesium hazards in shallow groundwater of the study area.

Asgar et al. (1936) has suggested the salt index as a parameter for evaluating the quality of irrigation water. Salt index is negative for all good waters and positive for suitable waters. In the present study, the values of all the shallow groundwater samples are negative indicating the suitability of water for irrigation purposes. Sodium problem in irrigation water can be evaluated on the basis of Kelly's ratio. If this ratio is below one, water is suitable .I f this limit is in between one and two, the water is marginally suitable and if this ratio is beyond two, water is unsuitable. In the present study, the majority of shallow groundwater samples have less than one Kelly's ratio, indicating the suitability of water. Eaton (1950) proposed that the indirect effect of carbonate and bicarbonate on water quality and it is expressed in terms of Residual Sodium Carbonate (R.S.C.). As per the guidelines of US Soil Salinity Laboratory Staff (1956), the majority of shallow groundwater samples have RSC more than 1.25 which clearly suggests that

the water is safe for irrigational purposes. When the EC and SAR values of shallow groundwater samples of the area were plotted in the US Soil Salinity diagram, it clearly indicate that the shallow ground waters showing no sodium hazard and the water belongs to good category. As per Paliwal (1972), the magnesium hazard is likely to be developed in soil when this ratio exceeds 50%. In the present study the value of index of magnesium hazard is less than 50% which clearly indicates that the majority of shallow groundwater samples can be profitably applied for irrigation. Ayers and Westcot (1995) proposed modified water quality guide lines based on Sodicity, Toxicity and Salinity. A comparison of EC, SAR, TDS, Cl, and NO_3, values of shallow groundwaters with the values of the parameters as proposed by Ayers and Westcot, reveals that the majority of shallow groundwaters belongs to 'Slight to Moderate Restriction' category.

On the basis of various water quality guidelines proposed by BIS and WHO and various irrigational specifications such as Salt index, Kelly's Ratio, Residual Sodium Carbonate, Sodium Adsorption Ratio and Magnesium ratio it can be concluded that the majority of shallow groundwater samples are quite suitable for irrigational purposes. However, marginal and 'slight to moderate restriction' water can be used for irrigation after proper management and selection of crops.

Conclusions: Agricultural water quality was determined on the basis of Salinity hazard, Sodium hazard and Bicarbonate hazard. According to the classification of shallow groundwater with respect to SAR and EC, the majority of shallow groundwater of the study area belongs to belongs to Medium to High Salinity class and Low sodium water. Kelly's ratio shows that 91% of shallow groundwater in pre and post monsoon belongs to suitable class. As per Wilcox classification the shallow groundwater in pre-monsoon period and post-monsoon period belongs to Good to Permissible class. Classification based on RSC clearly indicates that that all the shallow groundwater of the study area belongs to Safe class and thus they are suitable for agricultural purposes. As per the magnesium ratio classification, all the shallow groundwater of the study area belongs to suitable class and there are no magnesium hazards in shallow groundwater of the study area.

From the above mentioned discussion and interpretation of the hydrochemistry and irrigational specifications, it can be concluded that the shallow groundwater of the study area is quite appropriate for irrigational purposes.

References:

1. APHA (1995), Standard methods for the examination of water and waste water (19thed.) American Public Health Association, Washington, 1467 pp.
2. Asgar, A. G., Puri, A. N., Taylor, E. M. (1936). Soil deterioration in irrigated areas of Punjab, part I-III, Irrigation Research Inst. Memoirs, Amritsar.
3. Ayers, R. S. and Westcot, D. W. (1994), Water Quality for Agriculture, FAO Irrigation and Drainage, paper 29, Rev. 1, Rome.
4. Dhiman, S. D., (2014). "Groundwater quality assessment for irrigation use in Rajkot district", Journal of Indian Water Resources Society, 34 (1), pp. 34-39.
5. Doneen L. D., (1964). Notes on water quality in agriculture. Published as a Water Science and Engineering Paper 4001. Department of Water Science and Engineering , University of California
6. Eaton, F. M. (1950). Significance of Carbonate in irrigation water, soil Sci., Vol. 69, No. 2, Pp 123-133.
7. Environmental Protection Agency, (1973). Water quality criteria, 1972, EPA Publication, E.P.A. R. 3-73-033, pp: 594.
8. FAO, (2012). Corporate Document Repository. Food and Agriculture Organization of the United Nations. (Online). Available: http:/www.fao.org/docrep.
9. Federal Water Pollution Control Authority U. S. A. (1968) Report of the committee on water quality criteria. Washington, D.C., : 234.
10. Jayalakshmi Devi et. al (2009). "Evaluation of groundwater quality for irrigation and drinking purpose in selected taluks of Dakshina Kannada district in Karnataka, India". Assessment of Groundwater Resources and Management, (Edited by A. L. Ramanathan et. al) I. K. International Publishing House Pvt. Ltd., New Delhi, pp. 301-318.
11. Jhariya D. C., Shandilya Arun K. and Dewangan Rakesh. (2012), Nitrate Pollution in the groundwater around Sagar Town, Madhya Pradesh, India. International Conference on Chemical, Ecology and Environmental Sciences.
12. Maghanga, J.K., Kituyi, J.L., Kisinyo, P.O. and Ng'etich W.K. (2013), Impact of Nitrogen fertilizer applications on Surface water Nitrate levels within a Kenyan Tea Plantation. Journal of Chemistry pp 1-4.
13. Paliwal, K. V. (1972). Irrigation with Saline water I. A. R. I. Monograph No. 2, (New Series), New Delhi, : 198
14. Parashar, V. K. (2001), Excssive use of Fertilizers and its impact on the quality of Surface and Subsurface waters around Hoshangabad area.

Project report submitted to University Grants Commission, Central Region Bhopal.
15. Parashar, V.K. (1994), Study of Quality of Surface and Subsurface Waters and their Agricultural Utility in the Lower Alluvial Plains of Narmada Valley between Khalghat and Haribphal Distt. West Nimar M.P., Ph.D. Thesis Barkatullah University Bhopal.
16. Ramamoorthy, B. (1964). Some aspects of the management of soil water plant climatic complex in the arid zone, Proc. GeneralSympo. Problems of Indian arid zones, CAZRI, Jodhpur, : 276-285.
17. Ravikumar, P. et. al (2011), "Hydrochemistry and evaluation of groundwater suitability for irrigation and drinking purposes in the Markandeya River basin, Belgaum District, Karnataka State, India". Environmental Monitoring and Assessment, vol. 173, pp 459-487, ISSUE 1-4, DOI 10.1007/S12517-013-0940-3.
18. Saligram, V. K. (1961). Standards of suitability of underground irrigation water with special reference to tubewells in North Gujrat, paper presented at seminar on Irrigation, Drainage and water logging, Bombay.
19. Sharma Shraddha, Vishwakarma Rakesh, Dixit, Savita and Jain Praveen. (2011), Evaluation of Water Quality of Narmada River with reference to Physicochemical parameters at Hoshangabad city, M.P., india. Res. J. Chem. Sci. Vol. 1 (3) pp 40-48.
20. Shrivastav, M.K. (1980), Study of quality and agricultural quality of groundwater in the Inner Narmada Valley between Hoshangabad and Jabalpur, Madhya Pradesh, unpublished Ph.D Thesis Barkatullah University, Bhopal.
21. U. S. Salinity Laboratory Staff, (1954). Diagnosis sand improvement of saline and alkali soils, U.S.D.A. Handbook No. 60, : 160.
22. Uppal, H. L. (1964). Soil and groundwater survey of Punjab, Vol. I, Amritsar Dist. And Vol. II, Kapoorthala Dist. Land reclamations, Irri. And Power Res. Inst. Amritsar, Punjab.
23. Wilcox, L. V., 1955. Classification and use of irrigation waters. U. S. Dept. Agri., Circular, no. 969, 19 pp.

Sunil Kumar Sharma
Dept. of Civil Engineering, AISECT University, Bhopal (M.P.), India
Vinod Kumar Parashar
Dept. of Geology, Govt. Holkar Science College, Indore (M.P.) India.