IJTA © Serials Publications

National Academy of Agricultural Science (NAAS) Rating : 3. 03

Hydochemical Investigation and Groundwater Quality Evolution for Irrigation Purpose in Some Blocks of Varanasi District, Uttar Pradesh, India

Shishu Pal Singh[1], Sandeep Kumar Tripathi[2], Vimal Kumar[3], Ashok Kumar[4] and Priyankar Raha[5]

ABSTRACT: *Assessment of water quality has been carried out for the Varanasi district to determine the sources of dissolved ions in groundwater. Forty two water samples were collected from well, shallow hand pump and deep hand pump during the month of June to September 2008 from different locations under four block of study area. The quality assessment was made through the estimation of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl, SO_4, CO_3, HCO_3, total hardness, total dissolved solids (TDS), electrical conductivity (EC), and pH. Based on these analyses, parameters like sodium adsorption ratio (SAR), percent sodium, residual sodium carbonate (RSC), permeability index and Magnesium hazards. On the bases of these determined and calculated parameters, it is concluded that the groundwater in the Varanasi area is fit for agricultural purposes.*

Key words: Varanasi District, sodium adsorption ratio (SAR), % sodium, residual sodium carbonate, permeability index

INTRODUCTION

Groundwater is the main source for drinking, irrigation and industrial purposes. During last two decades the indiscriminate disposal of industrial waste on mother earth slowly makes groundwater susceptible to pollution. Groundwater is one of earth's most vital renewable and widely distributed resources as well as an important source of water supply throughout the world. Its use in irrigation, industries and domestic usage continues to increase where perennial surface water sources are absent. The quality of groundwater is more significant as the case of quantity for all purposes (Mariappan *et al.*, 2005). The pollution of groundwater is of major concern, firstly because of increasing utilization for human needs and secondly because of the ill effects of the increased industrial activity (Jain *et al.*, 2006). Improper waste disposal and unscientific anthropogenic practices over the decades have adversely affected the surface and groundwater quality (Dash *et al.*, 2006). Industries consume large quantities of water, consequently depleting the available resources and at the same time produce wastewater containing organic chemicals and toxic heavy metals depending upon the various chemicals used in the industries (Vaishnav *et al.*, 2007). Even after aerobic or anaerobic treatment, disposal of the industrial wastes and effluents contain toxic substances to be leached and seep into the soil and affect groundwater course (Madhusudana et al., 2001; Jain *et al.*, 2004). Storing liquid petroleum products above ground or underground presents a potential threat to public health and the environment. Gasoline, diesel and fuel oil can move rapidly through surface layers and into ground water. A few quarts of gasoline in the ground water may be enough to severely pollute drinking water (Harris *et al.*, 2001). Therefore, regular monitoring of groundwater pollution in an industrial area assumes paramount importance to maintain environmental safety. Water quality is dependent on several parameters. Groundwater geochemistry is an interdisciplinary science concerned with the human consumption, crop production and industrial usages. The natural state of ground water is generally of excellent quality although harmful concentrations of certain ions such as iron and sodium, which can occur naturally and lead to problems. Groundwater quality is the physical and chemical characterization of groundwater, which measures its suitability for human and animal consumption, irrigation and other purposes. The chemical comparison of the water that

[1,2,3,4,5] Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi
* *E-mail: shishupal_bhu@yahoo.co.in*

enters in the ground water reservoir and reactions with the minerals present in the rocks and soils that may modify the water composition. So, groundwater is a main source of drinking water and its quality has made it is well known source of water, However, the advancement of human civilization and agriculture has put serious question to the safe use of groundwater for drinking due to production and release of diverse wastes into the environment, which can contaminate groundwater 's. Continued development and increasing use of groundwater combined with its reuse, quality suffers unless consideration is given to protecting it. Any purpose for which water is required, its quality is a matter of great importance. The chemical quality of water is a factor. Which is of paramount importance in its utilization for drinking, municipal, irrigation and industrial uses in its utilization for drinking, municipal, irrigation and industrial uses (Abdul et al., **2000)** and (Amlathe et al., 1995). Suitability of groundwater for irrigational purposes depends upon the salinity, conductivity and hardness of water **(**Atekwand and Estella 2004**) and** Ayers and Westcat 1985). These parameters are increasing due to the poor sanitation, release of waste and sewage. In the recent years, the concern for groundwater quality in irrigation water supplies, there must be sound planning to ensure that the quality of water available is put to the best use (APHA, 1985) **and (**Ayers and Westcat 1985). Groundwater contains a varying amount of different kinds of ions such as carbonate, bicarbonate, calcium, magnesium, sulphate, hardness, etc (Choudhary et al., 2007). Among them, the major cations are Calcium, Magnesium and sodium (which influence the suitability of groundwater for human consumption, agricultural irrigation and other purposes. Some of these cations are beneficial to crop production at expected concentration, otherwise cause toxicity to plant, affect properties of soil and management practices (Mitra et al., 2007)**.**The soil properties, crop yield and quality will be deteriorate in flow quality water is used for irrigation (Prakash and Rao 1989) The physiochemical analysis of ground water evaluate of drinking water quality (Choudhary et al., 2007).

MATERIALS AND METHODS

Study Area

Geographically the district Varanasi is situated at $25^{0}18'$ of Northern latitude, $83^{0}03'$ of Eastern longitude and at an altitude of 128.83 m above the mean sea level in the Indo-Gangatic plain of eastern Uttar Pradesh. The district Varanasi having alluvial soil lies in semi arid region to sub humid belt of Northern India. It is often subjected to extreme of weather condition. The mean annual precipitation is 1100 mm. The area occasionally experiences winter cyclonic rain during December to February .In term of percentage of total rainfall, about 84% is received from June to September, 0.7% October to December, 6% from January to February and 9.3 % from March to May as premonsoonic rain .The mean relative humidity of this area is about 68% with maximum 82% and minimum 30% during July to September and April to early June, respectively. The minimum and maximum average temperature of the area range from 4.4^{0} to 28.2^{0}C, respectively. The temperature begins to rise from February onward until the summer often exceeding 45^{0}C in the month of May and June. During these extremely hot months desiccating winds blow from west to east and dust storm frequently occurs. The location map of study is represented in figure 1.

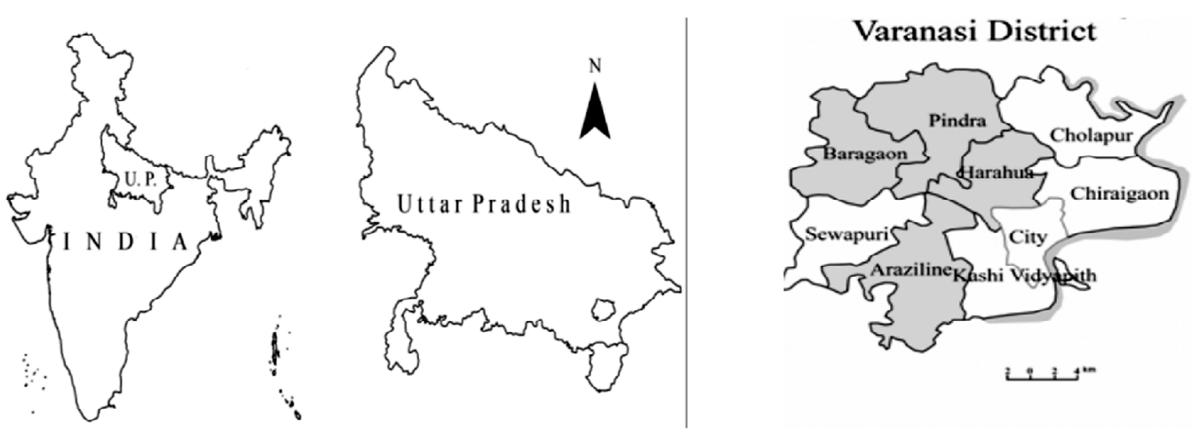

Figure 1. Geographical Representation of Study Area

Table 1
Location and Global Position of Groundwater Samples of Varanasi

S. No.	Location	Global Position	S. No.	Location	Global Position
1	Pura Raghunathpur	N24^{0}15.039' E 83^{0}54.081'	22	Deura	N 24^0 24.538' E 83^{0}53.112'
2	Pura Raghunathpur	N24^{0}15.039' E 83^{0}54.081'	23	Deura	N24^{0}24.433 ' E 83^{0}52.936'
3	Pura Raghunathpur	N 24^0 14.926' E 83^{0}53.282'	24	Kashipur	N 24^0 24.590' E 83^{0}52.988'
4	Raghunathpur	N 24^0 14.994' E 83^{0}53.315'	25	Kashipur	N 24^0 24.259 'E 83^{0}52.676'
5	Raghunathpur	N 24^0 14.879' E 83^{0}53.321'	26	Kashipur	N 24^0 24.578 'E 83^{0}52.978'
6	Raghunathpur	N 24^0 14.932 'E 83^{0}42.901'	27	Gaura	N 24^0 25.278' E 83^{0}51.678'
7	Sagunaha	N 24^0 14.816 'E 83^{0}52.419'	28	Gaura	N 24^0 25.647' E 83^{0}51.223'
8	Sehmalpur	N 24^0 27.636 'E 83^{0}50.727'	29	Gaura	N 24^0 14.221 'E 83^{0}52.110'
9	Sehmalpur	N 24^0 27.737' E 83^{0}50.302'	30	Gaura	N 24^0 14.918' E 83^{0}52.313'
10	Sehmalpur	N 24^0 27.767 'E 83^{0}50.411'	31	Pura Raghunathpur	N 24^0 15.069'E 83^{0}54.181'
11	Sehmalpur	N 24^0 27.678 'E 83^{0}51.179'	32	Pura Raghunathpur	N 24^0 14.239' E 83^{0}53.481'
12	Bhatauli	N 24^0 27.676' E 83^{0}51.312'	33	Raghunathpur	N 24^0 14.894 'E 83^{0}53.415'
13	Awashanpur	N 24^0 16.379 'E 83^{0}56.176'	34	Raghunathpur	N 24^0 14.779 'E 83^{0}53.221'
14	Awashanpur	N 24^0 14.932' E 83^{0}42.901'	35	Sagunaha	N 24^0 14.616' E 83^{0}52.619'
15	Ghamahapur	N 24^0 27.767' E 83^{0}54.419'	36	Bhatauli	N 24^0 27.69 'E 83^{0}52.512'
16	Dharmalpur	N 24^0 24.282' E 83^{0}52.120'	37	Bhatauli	N 24^0 27.66' E 83^{0}50.612'
17	Dharmalpur	N 24^0 24.220 'E 83^{0}52.089'	38	Gaura	N 24^0 14.718 'E 83^{0}51.313'
18	Dharmalpur	N 24^0 24.179 'E 83^{0}52.147'	39	Kashipur	N 24^0 24.359' E 83^{0}51.576'
19	Sahapur	N 24^0 25.734 'E83^{0}250719'	40	Kashipur	N 24^0 24.269' E 83^{0}51.476'
20	Sahapur	N 24^0 25.994 'E 83^{0}50.362'	41	Gaura	N 24^0 14.918' E 83^{0}52.313'
21	Sahapur	N 24^0 25.694 'E 83^{0}50.462'	42	Gaura	N24^{0}14.918' E 83^{0}52.313'

SAMPLING AND ANALYSIS

Forty two groundwater samples were collected from different villages of four blocks from Varanasi District, Utter Pradesh after the South - West monsoon (more than 80% rainfall) during 2008. The Location map shown in figure 1. The samples location and Global Position shown in table 1. The Global Position of each sample was recorded with Global Positioning System (GPS). The samples were collected from drinking and irrigation well, shallow hand pump and deep hand pump in area of high intensity cropping system where, the long history of phosphatic fertilizer application which are extensively used for drinking, irrigation and other domestic purposes. Water samples are collected in clean plastic bottles of 500 mL capacity. The sampling bottles are soaked in 1:1 diluted HCl solution for 24 hours, washed with distilled water, and are washed again prior to each sampling the filtrates of sample. In the case of bore wells, water samples are collected after pumping the water for 10 minutes. The collected samples were immediately transported to the laboratory where they stored at 4æ%C until analysis. The water samples were analyzed at the Soil and Water Testing Laboratory of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences Banaras Hindu University, Varanasi. all samples, electrical conductivity (EC) and pH values were obtained using EC and pH meters (ELICO). The parameters analyzed include the major ions sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), chloride (Cl^-), sulphate ($SO4^{2-}$), carbonate ($CO3^-$), bicarbonate (HCO_3^-) and fluoride (Fl-). Total dissolved solids (TDS), which were computed by multiplying the EC with a factor (EC X 640) that depend on the relative concentrations of ions. Total alkalinity (TA), CO_3 and HCO_3 were estimated by titrating with HCl. Total hardness (TH), Calcium (Ca), and Magnesium (Mg) were analyzed titrimetrically using standard EDTA; Sodium (Na^+) and Potassium (K^+) were measured by flame photometry; chloride (Cl) was estimated by standard AgNO3 titration; sulphate ($SO_4^{2-)}$ was analyzed by spectrophotometer; fluoride (F) concentrations in mg/l in groundwater samples is determined using Ion Selective Electrode Meter (Orion 96-09 model, Thermo electron Corporation).

RESULTS AND DISCUSSIONS

Major Ion Chemistry in Groundwater

The concentration of Calcium in ground water samples of investigated area varies from 18 mg/liter to 80 mg/liter with an average of 44 mg/liter found below permissible limit of drinking standard The range of Calcium content in ground water largely depends on the solubility of Calcium carbonates, Magnesium is also one of the alkaline earth metals and Magnesium also occurs in all kind of water with Calcium.The concentration of Mg^{2+} found in the ground water samples of the study area ranged from 22 mg/L to 56.80 mg/L with an average value of 145 mg/L and 90% samples of groundwater exceed the desirable limit (30 mg/L) of WHO (2004) for magnesium, but within the maximum permissible limit (100 mg/L). Magnesium source in the groundwater is mainly due to ions exchange of minerals in rocks and soils by water (Ahmadi, 2013). Sodium concentration varied from 131 to 695 mg/L with an average value of 401 mg/L. 95% sample of the study area exceed the desirable permissible limit of WHO (2004) 200 mg/L. The concentration of Potassium in groundwater varied from 4-105mg/l with an average value of 40 mg/L.95 % of the samples crossed the desirable limit for potassium 12mg/L (WHO). The chloride values were ranging between 11 to 170 mg/L in all water samples, which was found within the permissible limit for drinking water (600 mg/L) and irrigation (500 mg/L) prescribed by IS: 10500 and BIS, FAO. Sulphate concentration was found in the range of 3.5 to 46.6 mg/L with an average value of 15 mg/L. The values of sulphat all the samples are within the permissible limit of 250 mg/ L, shows that the ground water is free from possible sulphate toxicity. The same result was also inferred by (Majolabe 2011). The values of Ca^{+2} and Mg^{+2} ions in ground water were found 18 - 80 mg/L and 22 to 283 mg/L respectively resulted from dissolution or weathering of respective minerals from rocks It may be attributed to dilution effect of rain through seepage and percolation of surface or sub-surface water (Sengupta, 1993). Similarly the Chloride ion concentration varied from 11 to 170 mg/L due to accumulation of salt concentration Chloride especially from evaporation or loss of water in unsaturated zone during summer season. Bicarbonate and Bicarbonate concentration varies from 12 mg/L to 66 mg/L and 146 mg/L to 494 mg/L respectively in the water samples and this is well within the permissible limit of 600 mg/L of ISI standard. Bicarbonate is mainly derived from rock weathering (80 %), pollution contributing only 2% (Maybeck 1979). While in the case of Na+, the concentrations were found in the range of 131 to 695 mg/L due to percolation or seepage of agricultural and domestic waste water (Saxena & Ahmed, 2001). Total Alkalinity of water having capacity to neutralize a strong acid and it is normally owing to the existence of bicarbonate, carbonate and hydroxide compound of calcium, sodium and potassium. Total alkalinity values for all the investigated samples were found to be in the standard limit during course of investigation. It is in range of 193 mg/l to 581 mg/l. The Statistics of Chemical Indices Derived From Hydro geochemical Constituents are shown in Table 8.

Irrigation water quality

The groundwater in the study area is being used for agriculture purposes in the western outskirts of the city, as the surface water resources are polluted. Water used for irrigation should meet the requirements for crop growth to achieve maximum crop productivity. EC and sodium play a vital role in suitability of water for irrigation. Several methods are available to ensure the suitability of the water used for irrigation purpose, such as magnesium hazard (MH), residual sodium carbonate (RSC), sodium absorption ratio (SAR), permeability index (PI), and United States Department of Agriculture (USDA) classification. If EC of irrigated water is high, it will affect root zone and water flow. A guideline has been established by USDA Salinity Laboratory as given in Freeze and Cherry (1979) to determine the suitability of water for irrigation based on EC. Table 2 indicates that all the samples were found suitable for irrigation.

Table 2
Suitability for irrigation water based on USDA classification

EC (µ S/cm)	*Salinity Class*	*Number of samples*	*Percentage of samples*	*Remark on quality*
250	C_1	Nil	-	Excellent or low
250-750	C_2	31	73.80	Good or medium
750-2250	C_3	12	26.19	Permissible
2250-5000	C_4	Nil	-	Unsuitable or very

Table 3
Suitability for irrigation based on Residual Sodium Carbonate (RSC)

Residual Sodium Carbonate mgL^{-1}	*Classification*	*Number of samples*	*Percentage of samples*
<1.25	Good	15	35.57
1.25 -2.50	Doubtful	12	28.51
>2.5	Unsuitable	15	35.57

Residual Sodium Carbonate (RSC)

Residual sodium carbonate is calculated to determine the hazardous effect of carbonate and bicarbonate on the quality of water for agricultural purpose, (Eaton 1950). RSC was determined by using the equation given below, where all concentrations are expressed in meq/L. RSC is considered unsuitable if it is greater than 2.5 meq/L (Table 3). Residual sodium carbonate in ground water samples varied from 0.23 to 6.07 with an average value of 2.19 meq/L. The present study indicates that 28.51% of ground water is fall in doubtful category, 35.57 % samples were found unsuitable for irrigation and 35.57 % samples good category suitable for irrigation purpose.

$$RSC = (HCO^{3-} + CO3^{2-}) - (Ca2+ + Mg^{2+}$$

Sodium Adsorption Ratio

Sodium absorption ratio (SAR) is the measure of alkali/sodium hazard to crops. SAR quantifies the proportion of sodium to calcium and magnesium ions in a sample. The SAR value was calculated by the following equation, (**Richard 1954**).

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

All the concentrations are expressed in meq/L. The SAR values varied from 1.74 to 15.49 meq/L with an average value of 6.95 meq/L shown in (Table 4**)**. It is observed that the 83.33% samples of groundwater fall in excellent and 16.16% samples fall in good category resulting there is no Sodium hazards.

Table 4
Suitability for irrigation based on Sodium Adsorption Ration(SAR)

Sodium Adsorption Ration (meq/L)	*Classification*	*Number of samples*	*Percentage of samples*
<10	Excellent	35	83.33
10-18	Good	7	16.66
>26	Unsuitable	Nil	Nil
	Unsuitable	Nil	Nil

Sodium percentage (Na %)

Sodium concentration is important in classifying irrigation water because sodium causes an increase in the hardness of the soil because it tends to be absorbed by clay particles, displacing magnesium and calcium ions, when high in irrigation water. This exchange process reduces the permeability and results in soil with poor internal drainage **(Tijani, 1994).** Na% was calculated by using the formula (**Wilcox 1995**) given below. All the concentrations are expressed in meq/L.

$$Na\% = \frac{(Na^+ + K^+)100}{Ca^{2+} + Mg^{2+} + K^{2+}}$$

The concentration of Na% ranges between 23 % to 80 % with an average value of 55 % as shown in (Table 5**)**. It is observed that the 10% samples of groundwater fall in good, 10% samples fall in permissible and 80% sample fall in doubtful category.

Table 5
Suitability for irrigation based on Na%

Sodium Percentage	*Classification*	*Number of samples*	*Percentage of samples*
20	Excellent	Nil	Nil
20-40	Good	19	20
40-60	Permissible	30	30
60-80	Doubtful	50	50
80	Unsuitable	Nil	Nil

Table 6
Suitability for irrigation based on Magnesium Hazards

Mangnecium Hazards (meq/L)	*Classification*	*Number of samples*	*Percentage of samples*
<50	suitable	5	11.90
>50	Unsuitable	37	88.09

Magnesium Hazard (MH)

Magnesium Hazard (MH) denoted by MH, calculated using the formula.

$$MH = Mg^{2+} / Ca^{2+} + Mg^{2+}) X 100$$

Where the concentrations are in meq/l (Szabolcs and Darab 1964). Magnesium hazard above 50 meq/l is considered to be unsuitable for irrigation. A comparatively smaller percentage (11.90%) of groundwater samples was fit for irrigation, whereas 88.09 % samples were found unfit for irrigation.

PERMEABILITY INDEX (PI)

The soil permeability is affected by the long term use of irrigation water as it is influenced by Na+, Ca^{2+}, Mg^{2+} and HCO3" content of the soil. Doneen (1964) and WHO (1989) gave a criterion for assessing the suitability of groundwater for irrigation based on the PI, where concentrations are in meq/L.The PI will be calculated as fallow formula.

$$PI = \frac{(Na + K) + \sqrt{HCO_3}}{Ca + Mg + Na + K} \times 100$$

Accordingly, the PI is classified under class I (>75%), class II (25–75%) and class III (<75%) orders. Class I and class II waters are categorized as good for irrigation with 75% or more of maximum permeability. Class III waters are unsuitable with 25%

Table 7
Suitability for irrigation based on Permeability Index

MH (meq/l)	*Classification*	*Class*	*Number of samples*	*Percentage of samples*
>75	Excellence	I	5	11.90
25-75	Moderate	II	37	88.09
<75	Unsuitable	III	Nill	Nill

of maximum permeability. Table 7 indicates that the study area has a moderate irrigation quality according to the PI values.

Table 8
Statistics of Chemical Indices Derived From Hydro geochemical Constituents

Chemical Parameters	*Units*	*Range (mg/L) Min.*	*Max.*	*Mean*	*SD*	*CV*
Na	%	23.38	80.36	55.64	1.91	3.43
RSC	($meqL^{-1}$)	0.23	6.07	2.19	0.075	3.42
SAR	($meqL^{-1}$)	1.74	15.49	6.95	0.238	3.42
MH	($meqL^{-1}$)	21.63	99.07	6.95	2.23	32.09
KI	($meqL^{-1}$)	0.5	14.0	5.0	2.82	56.40
PI	($meqL^{-1}$)	49.93	98.23	82.31	0.172	0.21
TDS	(mgL^{-1})	162.56	604.16	401.31	24.25	6.04
Hardness	(mgL^{-1})	216.32	1236.43	707.31	13.76	1.95

RESULTS AND DISCUSSIONS

The measurement of electrical conductivity is directly related to the concentration of ionized substance in water and may also be related to problem of excessive hardness and other mineral contamination. EC of groundwater of study area ranges from 0.254 dSm^{-1} - 0.944 dSm^{-1} with mean value 0.627 dSm^{-1}. A high value of EC indicates a high salt content, so this results in loss of soil productivity and contamination of groundwater (Silva-García *et al*. 2006). Salinity conditions limit the irrigation with these waters at the germination stage; therefore, the option is to cultivate plants that are salt-tolerant, hence the importance of classification of both irrigation water and soil, to determinate the appropriate use. Concentration of total dissolved solids (TDS) in the groundwater of the study area ranged from 163 to 604 mg L-1 with an average value of 401 mg L-1.Water can be classified in to fresh (TDS <1000 mg L-1), brackish (>1,000 mg L-1), saline (>10,000 mg L-1) and brine (1, 00,000 mg L-1) categories on the basis of TDS concentration (Freeze and Cherry 1979). Based on this classification all the groundwater of the study area belongs to fresh water. The low TDS content observed could be either a result of the slow decomposition of most metamorphic and igneous rocks, since terrain is underlain by mostly phyllite and granite gneissic rocks, or due to the short residence time of the groundwater Total Hardness values of 95% samples exceed the highest desirable limit of 300 mg/l.) Hardness has no particularly adverse effect on human health, but it can prevent the formation of lather with soap and increases the boiling point of water. Long-term consumption of very hard water might lead to an increased incidence of urolithiasis, anecephaly, prenatal mortality, some types of cancer and cardio-vascular disorders (Agarwal and Jagetia 1997). Hardness of the water is the property attributed to the presence of alkaline earths. Water can be classified into soft (75 mg L-1), moderately hard (75–150 mg L-1), hard (150–300 mg L-1) and very hard (>300 mg L-1) based on hardness (Sawyer and McCarty 1967). The alkalinity concentration in the groundwater varied from 138mg/L to 658.67 mg/L. All the samples were within the maximum permissible limit salt concentration as measured by EC, relative proportions of Na+ Na%, sodium absorption ratio (SAR) ,residual sodium carbonate (RSC) and permeability index (PI) are the general parameters for assessing the suitability of groundwater for agricultural uses (Aghazadeh 2010, Gowd 2005, Raju 2006). High salt content in irrigation water causes osmotic pressure in soil solution. EC is a good measure of salinity hazard to crops as it reflects the TDS in groundwater. According to the classification of groundwater by US salinity laboratory (1954) for electrical conductivity 90% samples belongs to good category and 10% to doubtful category. High electrical conductivity reduces the osmotic activity of plants and interferes with absorption of water and nutrients from the soil. The irrigation water quality criteria are shown in table 9.

Table 9
Irrigation Water Quality Criteria

Parameters Samples	*Range*	*Water Class*	*Samples*
EC	0-250	Excellent	Nil
dSm^{-1}	250-750	Good	All
	750 – 2000	Permissible	Nil
	2000 – 3000	Doubtful	Nil
	>3000	Unsuitable	Nil
TDS	<1000	Fresh	All
MgL^{-1}	1000 – 3000	Slightly saline	Nil
	3000 – 10,000	Moderately saline	Nil
	10,000-35,000	High saline	Nil
Total	<75	Soft	Nil
Hard-	75 – 150	Moderately Hard	Nil
ness	150 – 300	Very hard	All
MgL^{-1}	300		
%Na	20	Excellent	Nil
	20 – 40	Good	8 Out of 42 Sample
	40 – 60	Permissible	13out of 42 Sample
	60 – 80	Doubtful	21 Out of 42 Sample
	80	Unsuitable	Nil
SAR	10	Excellent	35 Out of 42 Sample
MgL^{-1}	18	Good	7 Out of 42 Sample
	18 – 26	Doubtful	Nil
	26	Unsuitable	Nil
RSC	<1.25	Good	15 Out of Samples 42
MgL^{-1}	1.25 – 2.50	Doubtful	12 Out of Samples 42
	2.5	Unsuitable	15 Out of Samples 42

CONCLUSIONS

Interpretation of hydro chemical analysis of groundwater samples reveal that the groundwater in Varanasi is within the class of excellent to good based on TDS with reference to water class, soft to moderately hard base on total hardness and fresh with regards to the nature of groundwater based on TDS. The pH values reveal that the groundwater is alkaline in nature. The sequence of the abundance of the major ions is in the following order: $Na^{+} > Mg^{2+} > Ca^{2+} > K^{+} > HCO_3 > Cl > SO_4 > CO_3 > F^{-}$.The concentrations of major ions in groundwater are within the permissible limits for irrigation. Based on SAR has indicated that excellent groundwater. The amount of total dissolved solids was less than 300 mg/L, indicating a "fresh environment". The assessments of water for irrigation use show that the water is of good to permissible quality. The hydro chemical analyses reveal that the present status of groundwater in Varanasi is good for irrigation and drinking purposes.

REFERENCES

Abdul, A.J. (2000), Evolution of drinking water quality in Tiruchirapalli, Ind. J. Environ. Hlth., 44 (2), 108-112.

Aghazadeh, N., Mogaddem, A. A. (2010), Assessment of ground water quality and its suitability for drinking and agricultural uses in the Oshnavieh Area, North west of Iran. Journal of Environmental Protection, (1): 30 — 40. S. Sci, 69(2): 123—133.

Agrawal, V., Jagetia, M. (1997), Hydro geochemical assessment of groundwater quality in Udaipur city, Rajasthan, India. In: Proceedings of National conference on dimension of environmental stress in India, Department of Geology, MS University, Baroda, India, 151- 154.

Ahmadi, M .E. (2013), Hydrochemical characteristic and evaluation of groundwater quality in Wadi As Sab'an, Western Saudi Arabia. International Journal of Scientific and Engineering, 4(1): 1-10.

Amlathe, S., Padmakar, C. and Tirupati B., (1995), Groundwater quality evaluation shallow aquifer- Tawa Canal Command area, BHU-Jal News,19-21.

Anderson, M.A., Zelazny, L.W.M. & Bertsch, P.M. (1991), Fluoro-Aluminium complexes on model and soil exchangers. Crop Science Society of America Journal, 55(1) 71-75.

APHA. (1985), Standard Methods for examination of water and wastewater, 16th ed. APHA Washington D.C.,1268.

Atekwand, E.A., Estella, E.A., Rowe, R.S., Werkema, Jr. D.D. and Legall, F.D., (2004), The relationship of total dissolved solids measurements to bulk electrical conducting in a aquifer contaminated with hydrocarbon, Jour. of applied Geophysics, 56,28-294.

Ayers, R.S. and Westcat, D.W. (1985), Water quality for agriculture- F.A.O., Irrigation and Drainage Paper No. 29(1).

Choudhary, P., Dagankar, A. and Praveen, S., (2007), Physiochemical analysis of groundwater for evaluation of drinking water quality at Dhar, M.P., National environmental and Pollution Technology, Technoscience Pub, 6 (1), 109-112.

Dash, J.R., Dash, P.C. and Patra, H.K. (2006), A correlation and regression study on the groundwater quality in rural areas around Angul-Talcher industrial zone. Indian J. Environ. Prot., 26(6), 550-558.

Deshmukh, A.N., Shah, K.C. and Sriram, A. (1995), Coal Ash: A Source of Fluoride Pollution, A Case Study of Koradi Thermal Power Station, District Nagpur, Maharashtra. *Gondwana Geological Magazine,* 9 21-29.

Doneen, L.D. (1964), Water quality for Agriculture. Department of Irrigation, University of California, Davis, p 48

Eaton, F. M, (1950), Significance of carbonate in irrigation water.

Freeze, R. A. and Cherry, J. A. (1979), Groundwater, Prentice-Hall, Englewood Cliffs.

Handa, B.K. (1975), Geochemistry and genesis of fluoride containing ground waters in India. *Groundwater,* 3(3) 275–281.

Harris, B.L, Hoffman, D.W. and Mazac, F.J. Jr. (2001), Reducing Contamination by Improving Petroleum Product Storage. USEPA/625/6-87. If and Lagos, Southwestern Nigeria. *Pelagia Research Library*, 2(1): 289—298.

Indian Standard (ISI: 10500). (1993), Drinking Water Specification (Reaffirmed).

I.S.I., (1983), Drinking water standards substance and characteristics affecting the acceptability of water for domestic use 18, 10500. Indian standard institute, New Delhi.

Jain, A. and Nidhi, S. (2004), Effect of industrial wastewater on groundwater of Jabalpur. Indian J. Environ. Prot. 24(9), 689-694.

Jain P, Sharma JD, Sohu D and Sharma P (2006), Chemical analysis of drinking water of Nitrate Botanica Publishers, New Delhi, 289-300.

Kundu, N., Pamgrahi, M.K., Tripathy, S., Munshi, S., Powell, M. A. and Hart, B.R. (2001), Geochemical appraisal of fluoride contamination of groundwater in the Nayagarh District of Orissa, India. Environmental Geology Volume 41, Issue 3-4, 451- 460.

Majolagbe A O, Kasali A O, Ghaniyu L O, (2011), Quality assessment of groundwater in the vicinity of dumpsites in Ifo and Lagos, Southwestern Nigeria

Mariappan, V., Rajan, M.R., David, Ravindran A. and Prabakaran, P. (2005), A systemic study of water quality index among the physicochemical characteristics of groundwater in and around Thanjavur Town. Indian J. Environ. Prot. 25(6), 551-554.

Mitra, B.M., Sasaki, C., Enari , K., Matsuyama, M. and Fujita, M., (2007), Suitability assessment of shallow groundwater for agriculture in sand dune area of Northwest Honshu Island, Japan, Applied Ecology and Environmental Research, 5(1) , 177-188.

Page, A.L. (1991), Methods of soil Analysis, 2nd Edn. Am. Soc. Agron. & Soil Sci. America, Madison, Wisconsin, USA on the content of fluorides in soil and grass. (In Slovak.) Polnohospodarstvo, 10: 257-262.

Prakash, S.R. and Rao, G.K., (1989), The chemistry of Ground waters in Paravada area with regard to their suitability to domestic and irrigational purposes, Ind. Jour. of Geochemistyr, 4(1), 40-54.

Raju, N. Dey, S. and Das, K. (2009), Fluoride contamination in Groundwaters of Sonbhadra District, Uttar Pradesh, India. Current Science, 96(7) 979-985.

Rango, T,. Bianchini, G., Beccaluva, Ayenew, Tenalem and Colombani, N. (2008), Hydro geochemical study in the Main Ethiopian Rift: new insights to the source and enrichment mechanism of fluoride. Environmental Geology, 58 109-118.

Richard, (1954), Diagnosis and improvement of saline and alkali soils, Agricultural Handbook 60, Washington USDA DC: 160.

Sawyer, C. N. and McCarty, P. L., (1967), Chemistry of sanitary engineers, 2nd ed. McGraw Hill, New York, pp 518.

Saxena, V.K . and Ahmed, S. (2001), Dissolution of fluoride in ground-water: a water–rock interaction study. Environmental Geology, 40(9) 1084-1087.

Sengupta, M. (19930 Environmental Impacts on Mining, Monitoring, Restoration and Control. *Lewis Publishers,* Boca Raton, Florida 194.

Shaji, E. Bindu , J.V. and Thambi, D.S. (2007), High fluoride in ground-water of Palghat District, Kerala. *Current Science,* 92(2) 240-245.

Smith, F.A. and Hodge, H.C. (1979), Airborne fluorides and man. Part I Critical Reviews in Environmental Control, 8(2) 241-245.

Tailor, G.S. and Chandel, C.P.S. (2010), To Assess the Quality of Ground water in Malpura Tehsil (Tonk, Rajasthan, India) with emphasis

Tijani, M. N., (1994), Hydrochemical assessment of groundwater in Moro area, Kwara State, Nigeria. *Environ. Geol*, 24, 194—202. to Fluoride Concentration. *Nature and Science,* 8(11) 20-26.

Vaishnav, S.N. and Shrivastava, V.S. (2007), Assessment of pollution status of industrial wastewater, Correlation and Regression study, Indian J. Environ. Prot. 27(6), 554-558.

World Health Organization, (2004), Guidelines for drinking water quality Vol. 1,3rd ed. Geneva: World Health Organization.

Wilcox L V, (1955), Classification and use of irrigation water. US Department of Agriculture Circular No. 969: 19.