5: GROUNDWATER POLLUTION

5.1 Extent of Groundwater Pollution by Budha Nala in Ludhiana District (Ludhiana Centre)

To study the areal extent and severity of groundwater contamination/ pollution by Budhanala, a waste water drain, which carries effluents from agro, non-agro based industries and flows through Ludhiana city, Wallipur village was selected for groundwater quality analysis. Forty eight groundwater samples were collected from the study area along both sides (Site A and Site B) of Buddha nala within the vicinity of 1 km during first fortnight of June (pre-monsoon), first fortnight of November (post-monsoon) and first fornight of January (winter season). The chemical analysis of groundwater samples collected was analyzed for heavy metals with the help of ICAP-AES and presented in table 5.1.

The quality of groundwater can be assessed with the use of heavy metal pollution index (HPI) (Mohan et al., 1996), and calculated as

$$HPI = \frac{\sum_{n}^{n}=1\ W_i Q_i}{\sum_{n}^{n}=1\ W_i} \quad \text{.....1}$$

Where W_i = Unit Weightage of i^{th} parameters, Q_i = sub index of the i^{th} parameter, n = is the number of parameters considered. Weighted arithmetic index method has been used for calculation of HPI. The unit weight (W_i) has been found out by using formula

$$W_i = \frac{K}{S_i} \quad \text{.....2}$$

Where K = proportionality constant, S_i = maximum permissible value of i^{th} parameter.

The sub-index of (Qi) of the parameter is calculated by

$$Q_i = \frac{\sum_{n}^{n}=1\ M_i}{S_i} \quad \text{.....3}$$

Where M_i = is the monitored value of heavy metal of i^{th} parameter

Generally, the critical heavy metal pollution index value is 100.

Chemical characteristics of groundwater
Pre-monsoon, June month

About 50 and 37.5 % of the groundwater samples from site A and site B respectively had As concentration beyond the maximum permissible limit of 0.01 mg/l. The maximum concentration of As at site A was 0.025 mg/l and at site B was 0.051 mg/l which is 50.9 % more than at sampling site A. The mean concentration of As at sampling site A and B was 0.071 and 0.013 mg/l, respectively. Similarly about 87.5 and 62.5% of the groundwater samples at sampling site A and site B respectively had Mn concentration beyond the maximum permissible limit of 0.1 mg/l. The maximum concentration of Mn at site A and site B was 0.831 and 1.221 mg/l, respectively. The mean concentration of B at site A and site B was 0.21 mg/l and 0.26 mg/l, respectively. About 37.5 % of the samples had Ca concentration more than the maximum permissible limit of 75 mg/l. The maximum concentration of Ca was found to be 114.6 mg/l which was 52.8 % higher than the maximum permissible limit. The concentration of Pb at site A was within the permissible limit and at site B, 62.5 % samples were above permissible limit. The mean concentration of Pb at site A and site B was 0.005 mg/l and 0.011 mg/l, respectively. It has been observed that the concentration of heavy metals like As, Mn, B Ca and Pb at sampling site B (on other side of Buddha Nala towards Ludhiana city) was found to be more than that at sampling site A.

Post-monsoon, November month

The concentration of As, boron, calcium, iron and Pb at sampling site A were within the permissible limit where as at sampling site B, 25, 12.5 , 50 , 12.5 and 25 % of the samples were found to have concentration more than the maximum permissible limit respectively. The maximum concentration of As at sampling site B was 0.022 mg/l. The mean concentration of As at sampling site A and B was 0.004 and 0.007 mg/l, respectively. Similarly the Mn concentration of 62.5 % samples at site A and 50 % samples at site B was found to be more than the maximum permissible limit of 0.1 mg/l. The maximum concentration of Mn at site A and site B was 0.66 and 0.78 mg/l, respectively. The mean concentration of Mn at site A and site B was 0.022 mg/l and 0.32 mg/l, respectively which was higher than the maximum permissible limit of 0.1 mg/l. About 25 % samples had Ca concentration higher than maximum permissible limit. The maximum concentration of calcium was 130.2 mg/l which was 75 % higher than the maximum permissible limit of 75 mg/l. The mean concentration of calcium at site A and site B was 41.13 mg/l and 64.30 mg/l, respectively. The mean concentration of boron at site A and site B was 0.25 mg/l and 0.34 mg/l, respectively. Similarly the maximum concentration of Pb was 0.013 mg/l which was higher than the maximum permissible limit of 0.01 mg/l. Maximum boron was found out to be 0.521 mg/l which was higher than the maximum permissible limit of 0.50 mg/l. The maximum concentration of iron was found to be 7.42 mg/l which was higher than the maximum permissible limit of 0.30 mg/l. It has been observed that the concentration of metals like As, Mn, boron and calcium at sampling site B (on other side of Buddha Nala towards Ludhiana city) was higher than that at sampling site A.

Winter Season, January month

The concentration of boron, calcium and Pb at sampling site A and site B were found to be within the permissible limit. The concentration of As of 12.5% samples at site A and 25% samples at site B were found higher than the maximum permissible limit of 0.01 mg/l. The mean concentration of As at sampling site A and B was 0.004 and 0.008 mg/l, respectively. The concentration of Mn of 37.5% samples at site A and 62.5% samples at site B was found higher than the maximum permissible limit of 0.1 mg/l. The maximum concentration of Mn at site A and site B was 0.27 and 0.49 mg/l, respectively. The mean concentration of Mn at site A and site B was 0.11 mg/l and 0.20 mg/l, respectively. The

mean concentration of iron at site A and site B was 0.03 mg/l and 0.61 mg/l, respectively. It has been observed that the concentration of heavy metals like As, Mn and iron at sampling site B (on other side of Buddha Nala towards Ludhiana city) was higher than that at sampling site A.

The pre-monsoon, post-monsoon and winter season concentration of metals in groundwater samples reveals that the average concentration of boron and iron for post-monsoon season was higher than the pre-monsoon and winter seasons but the average concentration of As and Mn for pre-monsoon season was higher than average concentration of post-monsoon and winter season. The mean concentration of sulphur, potassium and sodium for post-monsoon season are higher than pre-monsoon and winter season. It may be due to the fact that there was leaching of soluble cations in groundwater due to availability of higher discharge during monsoon season effect of which is reflected in post monsoon season.

Table 5.1 Seasonwise concentration of heavy metals in groundwater

Parameter (mg/l)	Range	Mean	Std. Dev	Coefficient of variation (%)	BIS Std: 2004 (IS:10500)
Pre-monsoon					
Arsenic	0.0-0.025	0.01	0.14	1400	0.01
Manganese	0.005-0.889	0.40	0.35	87.5	0.1
Lead	0.0-0.017	0.01	0.005	50.0	0.01
Iron	0.003-0.174	0.16	0.22	137.5	0.3
Post-monsoon					
Arsenic	0.0-0.022	0.01	0.006	60.0	0.01
Manganese	0.007-0.782	0.27	0.27	100.0	0.1
Lead	0.004-0.013	0.01	0.002	20.0	0.01
Iron	0.081-0.225	0.60	1.70	283.3	0.3
Winter season					
Arsenic	0.001-0.033	0.007	0.009	128.57	0.01
Manganese	0.004-0.493	0.16	0.14	88.12	0.1
Lead	0.0-0.004	0.002	0.001	50.0	0.01
Iron	0.003-1.956	0.31	0.63	203.22	0.3

Health hazards

Water containing As shows deleterious effect on human health. It can cause stomach pain, nausea, vomiting; diarrhea; numbness in hands and feet; partial paralysis; and even blindness. Studies have also shown that excessive dissolved Mn concentrations in groundwater result in bad taste and precipitation problems. Metals such as magnesium, Pb and Mn have also been reported at excessive levels in groundwater in parts of Ludhiana due to the addition of effluents from electroplating, dye and finishing units, vanaspati and chemical industries brought through Buddha Nala. Pb is a naturally occurring heavy metal. The presence of Pb in water can result in health effects including neurological damage, reduced IQ, anemia, and nerve disorders, among others.

Heavy metal pollution index (HPI)

Heavy metal pollution index is an effective tool to characterise the groundwater pollution as it combines several parameters to arrive at a particular value which can be compared with the critical value to assess the level of pollution load. Mean concentrations of the four heavy metals were used for the HPI determination. Overall HPI for the groundwater samples was found to be 113.3 and 109.5 for pre-monsoon and post-monsoon respectively which is above the critical value of 100 and for winter season 21.76. HPI was also calculated separately for each sampling location to compare the pollution load and assess the groundwater quality of the selected sites (Fig. 5.1). Overall HPI value indicates that the groundwater quality in village Wallipur on both sides of Buddha Nala for pre-monsoon and post-monsoon season is critically polluted with respect to these heavy metals. The highest HPI was 281.2 at site S11, 173.7 at site S10 and 159.6 at S1 for pre-monsoon, post-monsoon and winter season respectively. HPI values for pre-monsoon season were higher than post-monsoon season at all sites except at sites S1, S5, S9, S10, S12 and S13 as shown in fig. 5.1.

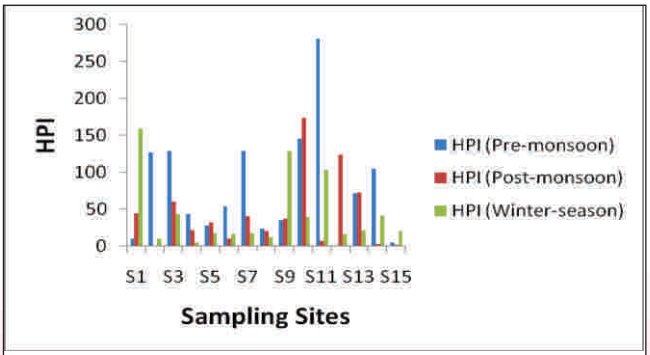

Fig. 5.1. HPI for pre-monsoon and post-monsoon seasons at different groundwater sampling sites

The study recommended that, industrial effluent should be treated before it is been discharged into the Buddha Nala. This will safeguard the health of the people especially those that depend on groundwater source for drinking purpose. Strict laws should be imposed on the industries which release their effluents directly into the water. Regular monitoring of the quality of discharge from small scale industries a major contributor for polluting the surface water and ultimately contaminates the groundwater is the need of the hour.

5.2. Spatial Studies on Groundwater Quality in South West Punjab (Ludhiana Centre)

In Punjab, out of 142 blocks 110 are overexploited, 3 are critical, 2 semi critical and 23 safe blocks. Out of 23 safe blocks, most of the blocks fall in southwest Punjab which comprises 32% of total area of Punjab. In south west Punjab which includes districts of Ferozpur, Faridkot, Muktsar and Bathinda, the groundwater is of poor quality and cannot be used for irrigation. During the last two decades, water table has risen by more than 10 m in 30 % and 10 % area of Muktsar, Mansa and Bhatinda districts, respectively. Groundwater up to 15 m depth is brackish/ saline and unfit for irrigation in about one fourth of south western districts; the quality generally deteriorates with depth. The south-west Punjab is facing a problem of brackish water which varies spatially and its trend is quite erratic. The study was planned to understand spatial variations in groundwater quality to facilitate farmers with safe use of irrigation water.

The present investigation has been carried out through collection of 181 groundwater samples during February to May 2013 (pre-monsoon), 343 groundwater samples during June to September 2013(monsoon) and 74 samples during October 2013 to January 2014 (post-monsoon). The water samples were analyzed for EC and RSC. All the samples were tested in Water Testing laboratory established in Regional Research Station, Bathinda. Based upon the values of EC and RSC, the groundwater samples were classified into different categories, following the criteria given in (Table 5.2).

Chemical composition of groundwater for Pre-monsoon season

The samples collected from the Bathinda district showed that EC ranged from 0.3-8.0dS/m. Blockwise analysis showed maximum EC range (0.4-12.0) in Talwandi Sabo block, while in Sangat block, EC ranged from 0.9-8.1 with mean of 2.43 dS/m. A fairly high value of EC in the groundwater samples suggested the dissolution co-efficient of minerals present in the substratum to be very high, thereby contributing to high salinity. RSC values in Bathinda district ranged from -22.1 to +42.0 meq/l. Blockwise analysis showed maximum RSC range (-205.0 to +12.8) in Talwandi Sabo block, while in Phul block showed minimum RSC range (-0.6 to +6.7)with mean value of 0.7 meq/l. In various blocks of district Muktsar, EC values were in the range of 0.0 to 10.3 dS/m, whereas RSC values ranged from (-11.9 to+3.6). The concentration of chloride ions in Bathinda district ranged from 1.0 to 86.5 meq/l and average higher concentration more than 10 meq/l was found in blocks Talwandi Sabo (11.8 meq/l) which means that there is severe restriction of use of irrigation water. Whereas in other blocks the average concentration of chloride ion was below10 meq/l, so there is no restriction of use of water for irrigation. In district Muktsar, the concentration of chloride ions in blocks Lambi and Gidderbaha ranged from 10.0 to 96.0 and 14.8 to 86.0 meq/l, respectively.

Table 5.2 Criteria used for rating of groundwater based on salinity and sodicity

Category	Groundwater Quality		Suitability for Irrigation
	EC(dS/m)	RSC(me/l)	
01	<2.0	<2.5	Suitable for all conditions
02	<2.0	2.5-5.0 or 5.0-7.5 <2.5	Suitable after applying recommended gypsum Can be used after mixing
04	2.0-4.0	2.5-5.0	Unsuitable for irrigation(unfit)
	2.0-4.0	5.0-7.5	---do---
	2.0-4.0	>7.5	---do---
	>4.0	<2.5	---do---
	>4.0	2.5-5.0	---do---
	>4.0	5.0-7.5	---do---
	>4.0	>7.5	---do---

Category*01-Fit; 02-Marginal Saline/Sodic; 04- Unfit

Chemical composition of groundwater for monsoon season

The chemical analysis of groundwater revealed that the samples collected from the Bathinda district had maximum range of EC 0.2-15.0 dS/m. While in Maur block EC was found in the range of 0.9-6.8 with mean of 2.7 dS/m suggesting that water can be used either in conjunction or in cyclic mode with canal water. In all blocks of Bathinda district, average EC values were higher than 2.0 dS/m, except in block Phul where EC (1.2 dS/m) was less than 2.0 dS/m, so water in this block is safe for use as irrigation water in all conditions. Average EC values in district Faridkot and Muktsar was more than 2.0 dS/m but less than 5, which means that water can be used after mixing with canal water. RSC values in Bathinda district ranged from -23.1 to +26.8 meq/l. while in Phul block showed minimum RSC range (-0.7 to +1.9) with mean value of 0.78 meq/l. In various blocks of district Muktsar, RSC values ranged from (-16.0 to+11.1). The concentration of chloride ions in Bathinda district ranged from 0.8 to 65.0 meq/l and average higher concentration more than 10 meq/l was found in blocks Talwandi Sabo (13.8 meq/l) and Sangat (10.4 meq/l) which means that there is severe restriction of use of irrigation water. Whereas in other blocks the average concentration of chloride ion was below10 meq/l, so there is no restriction of use of water for irrigation.

Chemical composition of groundwater for post-monsoon season

The chemical analysis of groundwater revealed that the samples collected from the Bathinda district had EC ranged from 0.8-7.0dS/m. Blockwise analysis showed average maximum EC in Bathinda and Mour block (3.6 and 3.42 dS/m respectively), which means water can be used after mixing with canal water. In all blocks of Bathinda district, EC were higher than 2.0 dS/m, except in blocks viz., Phul, Nathana and Sangat where EC value was less than 2.0 dS/m, so water in this block is safe for use as irrigation water in all conditions. Average EC in district Faridkot and Muktsar was more than 2.0 dS/m but less than 5, which means that water can be used after mixing with canal water. RSC in Bathinda district ranged from - 4.6 to + 9.7 meq/l. Blockwise analysis showed maximum RSC range (-28.6 to +14.8) in Talwandi Sabon block, while in Phul block showed minimum RSC range (-0.7 to +1.9) with a mean of 0.78 meq/l. The concentration of chloride ions in Bathinda district ranged from 2 to 32.6 meq/l and average higher concentration of Cl ions more than 10 meq/l was found in blocks Talwandi Sabo (13.0 meq/l) and Bathinda (13.8 meq/l) which means that there is severe restriction of use of irrigation water. Whereas in other blocks the average concentration of chloride ion was below 10 meq/l, so there is no restriction of use of water for irrigation.

Quality of groundwater for irrigation

During pre-monsoon season on the basis of sodicity and salinity, 12 % groundwater samples were found fit, 28% were marginally fit and 60% were unfit for irrigation in Bathinda district. Similarly,18 % groundwater samples were found fit, 27% were marginally fit and 55% were unfit for irrigation in Muktsar district. Whereas in Faridkot, 17 % groundwater samples were found fit, 58% were marginally fit and 25% were unfit for irrigation. During monsoon season on the basis of sodicity and salinity, 21 % groundwater samples were found fit, 39% were marginally fit and 40% were unfit for irrigation in Bathinda district whereas 9 % groundwater samples were found fit, 31% were marginally fit and 60% were unfit for irrigation in Muktsar district. During post monsoon season on the basis of sodicity and salinity, 25 % groundwater samples were found fit, 54% were marginally fit and 21% were unfit for irrigation in Bathinda district and 89 % groundwater samples were found fit, and 11% were unfit for irrigation in Muktsar district.

To provide solution to the salinisation and sodicity problems due to irrigation with poor quality waters, following points should be taken into consideration:

- Proper land leveling of the soils is a pre-requisite to ensure uniform distribution of water and amendment in the soil and to avoid problems of salinity and/or alkalinity in the localized areas.
- Salt tolerant and semi-tolerant crops and their cultivars should be grown to obtain sustainable yields even when irrigated with brackish groundwaters (Choudhary, 2003).
- Farmer of the affected area should also be given incentive for installation of skimming wells as their installation cost is much higher than single well (Hira et al, 1998). The pumping of water will help in lowering the water table and create a storage space in the soil profile to receive salt free rainwater during rainy season.
- Adequate drainage should be ensured where poor quality groundwater is to be used.
- The adverse effect of tubewell waters containing high concentrations of carbonates and bicarbonates can also be offset by applying gypsum to soil followed by irrigation after the harvest of crop and before sowing the next crop.

5.3 Development of Low Cost Nano Filter for Removal of Arsenic from Groundwater (Ludhiana Centre)

In Punjab state groundwater serves as the primary source of drinking water for more than 95% of the population. The extraction of groundwater has increased by 200 times during the last three decades. Arsenic in groundwater could be attributed to anthropogenic as well as result of minerals dissolving from weathered rock and soils. The most important anthropogenic factor responsible for groundwater pollution is urban and industrial waste water. This waste water is often not treated before its release into sewerage drains. Direct releases of untreated effluents to water bodies can potentially contaminant groundwater. The contamination of groundwater by heavy metals is a serious ecological problem as some of these like arsenic and lead are toxic even at low concentrations, are non-degradable and can bio-accumulation through food chain. The undergroundwater content elevated arsenic concentration which is usually above the WHO (1996 permissible safe limit of 0.1 mg/l). The problem is more serious at several sites in south western districts of Punjab as reported where the arsenic concentration exceeded more than 20 to 30 folds of the WHO safe limit. In the northern and central parts of Punjab, variation in the concentration of arsenic from 0.003 to 0.042 mg/l and 0.009 to 0.042 mg/l respectively in groundwater has been reported.

Arsenic naturally occurs in over 200 different mineral forms. Of these, approximately 60% are arsenate, 20% sulphate and sulphosalt while remaining the other 20% include arsenite, arsenate, oxides, silicates and elemental arsenic. The two oxidation state of As (III) and As (V) are common in natural environmental. The toxicity of a given arsenical is related to the rate of its clearance from the body and therefore to its degree of accumulation in tissue. In general, toxicity increases in the sequence: organic arsenical<As (V) <As (III) <arsine (AsH_3).

Arsenic in drinking water can impact human health and it is considered to be one of the prominent environmental causes of cancer mortality in the world. Arsenic has been known to cause a variety of adverse human health effects, including skins and several internal cancer and cardiovascular and neurological effects. For the last decade, cancer mortality is increased with alarming proportion in many villages in south-

western district of Punjab due to elevated arsenic content in drinking water.

While providing access to safe drinking water remains an urgent problems, the application of nanotechnology may prove a boon to the mankind by providing an advance way for groundwater treatment. The principal way nanotechnologies might help alleviate water problems is by solving the technical challenges by removing water contaminants, including pathogenic bacteria, viruses, harmful chemicals arsenic, mercury, pesticides and insecticides altogether. Numerous methods are available for removal of arsenic from water including iron-modified activated carbon, chitosan-coated biosorbent, oxides, clay minerals, etc.. Various adsorption materials have been used for this purpose such as activated alumina, activated carbon, fly ash, ferric hydroxide and zero valent iron. Adsorption of arsenic on iron oxide-coated sand method is one of the emerging technologies for arsenic removal. An attempt has been made to develop suitable filter which can reduce concentration of heavy metals and other contaminants from groundwater to improve its potability.

Preparation of nano-material

Nano-material was prepared by selecting different types of material like fine sand: 0.18 to 0.30 mm diameter, coarse sand: 0.18 to 0.60 mm diameter, blue stone (Powdered form): 0.30 mm diameter, gravel: 1.18 mm diameter (Plate 5.1). The finished product was stored in capped bottles as shown in plate 5.2.

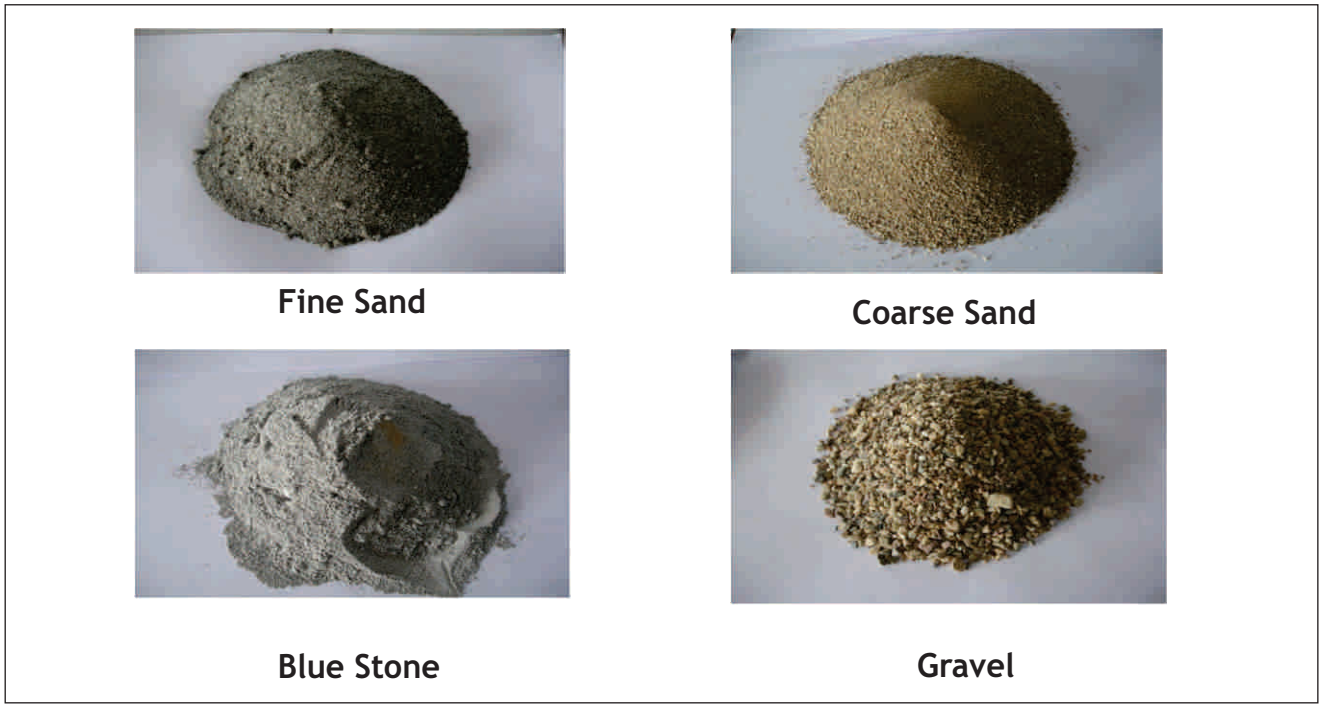

Plate 5.1 Different types of substances used to prepare nano - material

Plate 5.2 Finished product

5.4 Study on Groundwater Pollution due to Industries in Kashipur Industrial Cluster of Uttarakhand State (Pantnagar Centre)

People living near major industrial areas are facing complex situations of environmental exposure, multi exposure to chemicals combined with exposure to noise and visual pollution. Similar cluster of industries comprised of Indian Glycol Limited, Cheema Paper and Multiwal pulp and board mill are present near Kashipur town of Uttarakhand. a study was conducted to investigate physico-chemical characteristics of effluent and groundwater in vicinity of industrial area.

Study Area

The study area is located in near of Kashipur town in Udham Singh Nagar district of Uttarakhand. It is situated at 79° 0' 7.76"E longitude and 29°10'24.49"N latitude. Three industries *i.e.* Indian Glycol limited (IGL), Cheema Paper Mill and Multiwal pulp and board mill are located in this cluster. The location of streams flow path in Fig 5.4 and 5.5. Sugarcane research centre of Pantnagar University and Indian institute of Management (IIM) are located very nest to this cluster of industries. Effluent from IGL is being discharged in Bahela River through channel 1 which is passing at the boundary of university farm. Large area of university farm is being polluted by effluent during rainy season every year. The effluent, of Cheema paper mill and Multiwal paper mill, is being discharge in Kosi River about 3-4 kilometers away from mills through channel 2. Both the channels are polluting land and water resources of the region. The study area covers two channels. The water sampling, for 30 locations including 13 locations of effluent, 17 for groundwater samples, was carried out on November 26th, 23rd December 2013 and 18th January 2014. The sampling points for surface and groundwaters are shown in fig 5.2 and 5.3.

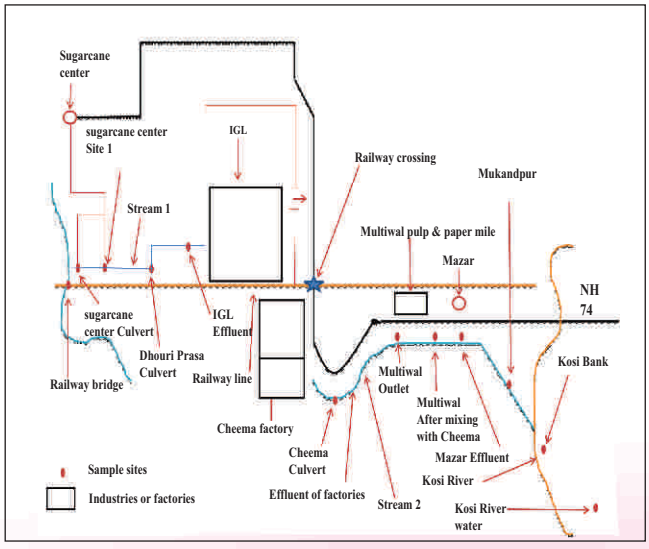

Fig 5.2. Location of sampling points for effluents

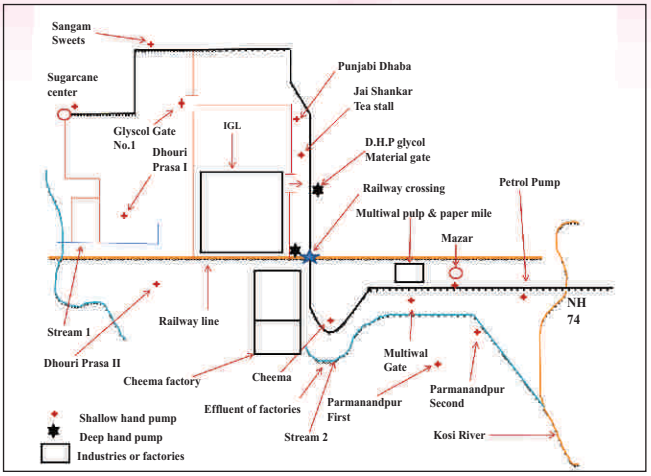

Fig. 5.3. Location of sampling points for groundwater

Physico-chemical characteristics

The effluents of IGL, Cheema paper mill and Multiwal Pulp and Board mill and groundwater of nearby area were analyzed for their physico-chemical properties. Channel wise results of physico-chemical properties in channel I and in channel II are presented in table 5.3 and 5.4 respectively and the physico-chemical properties of groundwater along western and eastern side of IGL are presented in table 5.5 and 5.6.

The average pH was observed out of permissible limit (less than 5.5 standard for discharging effluent in water body) at Dhouri Prasa, Sugarcane centre and Sugar cane culvert along the channel 1. It was also observed that pH was less than 6 at all the points of observation in channel 1. It showed acidic nature of effluent of IGL. The pH of groundwater of this region was also acidic in nature which was due to acidic effluent polluting the groundwater even in deep aquifers. The average pH observed in the effluent channel 2 was higher than in channel 1.

The TDS of groundwater at Sugarcane centre, Glycol gate No1, Dhouri Prasa , Cheema, Pertol pump, Parmanand pur I and II were above the desired limit. The alkalinity in groundwater was higher than the permissible limit of 200 mg/l at all the points except artesian well and railway crossing. This might be due to seepage of effluent to groundwater all along the channel as well as factory wash and in the factory compound.

As BOD, COD of effluents were beyond the permissible limits showed this effluent channels were heavily loaded with pollutants. Further, it is observed that the effluent coming out of IGL, Cheema and Multiwal Paper mills were not treated properly.

The groundwater at Petrol pump, Paramanand Pur I & II was having higher concentration of most of the parameters, since these two places were at downstream side of this industrial cluster. It can also be interpreted that groundwater at these places was significantly affected by effluent. Therefore, it can be inferred that the polluted surface water is contaminating groundwater as the groundwater in the *Tarai* belt is very shallow i.e. less than 5 m deep.

Table 5.3. Average physico-chemical properties of stream I.

Sl. No.	Parameter	Permissible limit for discharge into water body	IGL Effluent	Dhouri Prasa Culvert	Sugarcane Center	Sugarcane Center Culvert	Railway Bridge
1	pH	5.5-9	5.6	5	5.4	5.4	5.9
2	EC	3400	970	843	1320	1176	1060
3	TDS	2000	630	520	846	740	666
4	Acidity	-	132	164	185	178	146
5	Alkalinity	-	175	180	365	283	275
6	Total hardness	500	112	90	124	108	93
7	Ca	-	28	23	35	32	25
8	Mg	-	9	7	8	6	7
9	Cl	1000	184	137	187	197	137
10	Na	300	38	43	62	53	53
11	K	-	5	8	31	10	11
12	Total Solid	-	1510	1226	1583	1303	1573
13	Total suspended Solid	100	760	430	430	540	1250
14	BOD	30	372	201	201	258	222
15	COD	250	1056	653	653	787	880

All parameters are in mg/l except pH and EC, EC in µs/cm

Table 5.4. Average physico-chemical properties of stream II.

Sl. No.	Parameter	Permissible limit for discharge into water body	Cheema outlet	Mutiwal Outlet	Mutiwal After mixing with cheema effluent	Jindal Farm	Mazar	Mukandpur	Kosi bank	Kosi River
1	pH	5.5-9	7	**6.6**	6.9	7	7.5	7.2	7.3	7.1
2	EC	3400	1313	1293	1273	1260	1240	1215	**1170**	500
3	TDS	2000	853	833	820	740	785	775	**745**	320
4	Acidity	-	145	190	138	232	**118**	140	207	20
5	Alkalinity	-	**221**	286	340	490	360	352	302	220
6	Total hardness	500	145	170	167	108	129	135	**120**	70
7	Ca	-	46	39	**49**	38	28	42	35	24
8	Mg	-	**6**	17	10	3	14	7	7	2
9	Cl	1000	126	**109**	110	134	99	107	113	14
10	Na	300	43	29	35	**26**	30	34	32	10
11	K	-	**4**	7	5	7	7	5	7	7
12	Total Solid	-	1453	1730	1910	**1310**	1660	1510	1490	460
13	Total suspended Solid	100	693	936	**541**	580	705	892	725	380
14	BOD	30	316	240	267	193	**191**	217	193	186
15	COD	250	1075	955	1053	860	861	923	**806**	806

All parameters are in mg/l except pH and EC, EC in µs/cm

Table 5.5. Average physico-chemical properties of stream II.

Sl. No.	Parameter	Desirable - Permissible limit for drinking water	Artesian well Sugarcane center	Sugarcane Center gate	Glyscol Gate No.1	Dhouri Prasa I	Dhouri Prasa II	Dhouri Prasa D.T.W	Sangam Sweets
1	pH	6.5-8.5	**6.5**	6.7	6.8	6.5	7.7	7.5	6.9
2	EC	2000	380	933	896	790	405	390	696
3	TDS	500-2000	**230**	596	573	500	255	240	440
4	Acidity	-	**42**	159	165	130	**42**	272	111
5	Alkalinity	200-600	**180**	420	311	290	280	320	328
6	Total hardness	300-600	**40**	90	111	88	68	58	84
7	Ca	75-200	**10**	18	22	27	17	16	24
8	Mg	30-100	**3**	10	13	4	5	4	5
9	Cl	250-1000	26	57	73	30	**9**	12	33
10	Na	-200	6	24	25	13	7	**3**	14
11	K	10-12	**2**	8	10	3	4	4	6
12	Total solid	-	**260**	806	823	636	215	370	610
13	Total suspended solid	-	**280**	308	603	450	300	500	583

All parameters are in mg/l except pH, EC and Turbidity, EC in µs/cm

Table 5.6. Average physico-chemical properties of groundwater (eastern side of IGL)

Sl. No.	Parameter	Desirable - Permissible limit for drinking water	Punjabi Dhaba	D.H.P Glycol Material Gate	Jaishankar Tea stall	Railway Crossing	Cheema	Multiwal Gate	Petrol pump	Parmanandpur I	Parmanandpur II	Mazar
1	pH	6.5-8.5	7.1	7.1	6.7	7.2	6.9	**6.6**	6.9	7	7	7.7
2	EC	2000	496	376	630	363	1126	835	1050	690	1300	**355**
3	TDS	500-2000	310	236	400	223	753	446	680	815	805	**220**
4	Acidity	-	66	50	122	42	110	119	260	173	222	**55**
5	Alkalinity	200-600	213	201	228	**181**	310	285	475	440	420	250
6	Total hardness	300-600	75	67	70	68	138	98	86	102	147	**56**
7	Ca	75-200	19	20	22	19	33	29	23	36	24	**11**
8	Mg	30-100	6	4	3	5	13	10	6	**2**	20	6
9	Cl	250-1000	16	10	27	14	116	84	102	117	122	**10**
10	Na	-200	9	10	12	**8**	32	23	36	58	62	**8**
11	K	10-12	2	2	4	4	6	13	3	3	5	4
12	Total solid	-	353	283	510	340	1063	563	1410	1110	1105	**275**
13	Total suspended solid	-	320	270	300	316	426	500	860	368	314	**225**

All parameters are in mg/l except pH, EC and Turbidity, EC in µs/cm

Assessment of groundwater Quality for Irrigation

Richards (1954) suggested water suitability criteria for irrigation on the basis of salinity hazard (which depends on EC value) and sodium alkalinity hazard. The classification of groundwater depending upon it's quality for irrigation, it may be classified under different classes for irrigation. On the basis of these criteria the groundwater samples collected from different places have been classified for their suitability for irrigation and presented in table 5.7.

Table 5.7. Classification of groundwater for irrigation

Sl no.	Location	Quality on the basis sodium % and SAR	Alkali hazard	Salinity Hazard	Class
1	Artesian well Sugarcane center	Excellent	Low	Medium	C2-S1
2	Sugarcane Center gate	Excellent	Low	High	C3- S1
3	Glycol Gate No.1	Excellent	Low	High	C3- S1
4	Dhouri Prasa I	Excellent	Low	High	C3- S1
5	Dhouri Prasa II	Excellent	Low	Medium	C2- S1
6	Dhouri Prasa D.T.W	Excellent	Low	Medium	C2- S1
7	Sangam Sweets	Excellent	Low	Medium	C2- S1
8	Punjabi Dhaba	Excellent	Low	Medium	C2- S1
9	D.H.P Glyscol Material Gate	Excellent	Low	Medium	C2- S1
10	Jaishankar Tea stall	Excellent	Low	Medium	C2- S1
11	Railway Crossing	Excellent	Low	Medium	C2- S1
12	Cheema	Excellent	Low	High	C3- S1
13	Multiwal Gate	Excellent	Low	High	C3- S1
14	Petrol pump	Excellent	Low	High	C3- S1
15	Parmanandpur I	Medium	Medium	Medium	C2-S2
16	Parmanandpur II	Medium	Medium	High	C3-S2
17	Mazar	Excellent	Low	Medium	C2- S1

Wilcox (1955) categorized water for its suitability for irrigation on the basis of percent Na and EC values. Considering percent Na, groundwater at Punjabi Dhaba, D.H.P Glycol Material Gate , Jaishankar Tea stall, Railway Crossing, Artesian well at Sugarcane center, Dhouri Prasa I, Dhouri Prasa II, and Dhouri Prasa D.T.W was under “Good” class; groundwater at Multiwal Gate, Petrol pump , Mazar , Sugarcane Center gate , Glycol Gate No.1, Sangam Sweets was under the class “permissible” and at Parmanandpur I, Parmanandpur II it was doubtful. There was not any observation point in class excellent or unsuitable.

The groundwater at Punjabi Dhaba, D.H.P glyscol Material Gate, Jaishankar Tea stall, Railway Crossing, Parmanandpur First, Mazar, Artesian well at Sugarcane center, Dhouri Prasa II, Dhouri Prasa D.T.W, Sangam Sweets under the class “Good', where as groundwater near Cheema, Multiwal Gate, Petrol pump, Parmanandpur Ii, Sugarcane Center gate, Glycol Gate No.1, Dhouri Prasa I were under the class “Permissible,” No water sample was found under the classes Excellent , “Doubtful” or unsuitable' for irrigation as for as classification on the basis of EC value is concerned.

Ayers and Westcot (1984) suggested classifications of suitability of water for irrigation, on the basis of salinity (EC and TDS), specific ion toxicity (SAR) and permeability (SAR and EC).

On the basis of EC values the groundwater at Artesian well at Sugarcane center, Dhouri Prasa II, Dhouri Prasa D.T.W, Sangam Sweets, Punjabi Dhaba, D.H.P Glycol Material Gate, Jaishankar Tea stall, Railway Crossing, Parmanandpur I, Mazar were showing salinity hazard class none, groundwater near Sugarcane Center, Glycol Gate No.1,

Dhouri Prasa I, Cheema, Multiwal Gate, Petrol pump, Parmanandpur II were found under “slight to moderate” class of salinity hazard.

On the basis of specific ion toxicity which depends on SAR value showed that groundwater at Artesian well at Sugarcane center, Dhouri Prasa II, Dhouri Prasa D.T.W , Punjabi Dhaba, D.H.P Glycol Material Gate, Railway Crossing, Mazar was found under the 'None' class of toxicity; groundwater near Sugarcane Center, Glycol Gate No.1 , Dhouri Prasa I, Sangam Sweets, Jaishankar Tea stall, Cheema, Multiwal Gate, was found under the class “slight to moderate”; and groundwater at Petrol pump, Parmanandpur I, Parmanandpur II , was found under the class “severe” for specific ion toxicity.

On the basis Permeability criteria (SAR and EC values) the surface water sample collected near Glycol Gate No.1, Dhouri Prasa I, Sangam Sweets, Jaishankar Tea stall, Multiwal Gate, were found under the class 'slight to moderate'. The groundwater samples near Sugarcane Center gate , Cheema , Petrol pump , were found under the 'severe' class.

Suitability of water for domestic and industrial Uses

The groundwater of study area was assessed for its suitability for domestic and industrial uses, on the basis of concentration of physiochemical parameters recommended by American Water Works Association, (1971).

The groundwater at Artesian well at Sugarcane center was found suitable for drinking, air conditioning, baking, food processing, textile and while it was not suitable for brewing, confectionaries, Pulp and Paper industry, sugar and food canning and freezing industries.

The groundwater at Sugarcane center gate was found suitable for, air conditioning, baking, textile and while it was not suitable for drinking, brewing, confectionaries, Pulp and Paper industry, food processing, food canning and freezing, Sugar industries.

The groundwater at Glycol Gate No.1, Dhouri Prasa I, Sangam sweets, Cheema, Multiwal gate, Petrol pump, Parmanand Pur I, Parmanand pur IIwere found suitable for air conditioning, baking ,drinking and while it was not suitable for textile, brewing, confectionaries, Pulp and Paper industry, food processing, food canning and freezing and sugar industries.

The groundwater at Dhouri Prasa II, Dhouri Prasa D.T.W were found suitable for confectionaries, air conditioning, baking, drinking, textile, sugar industries and while it was not suitable for brewing, Pulp and Paper industry, food processing, food canning and freezing.

The groundwater at Punjabi Dhaba ,D.H.P at Glyscol Material gate, Railway crossing were found suitable for confectionaries, air conditioning, baking , drinking, textile, sugar industries, food processingand while it was not suitable for brewing, Pulp and Paper industry,food canning and freezing.

The groundwater at Jaishankar Tea stall was found suitable for air conditioning, baking, drinking, food processing and while it was not suitable for, textile , brewing, confectionaries, Pulp and Paper industry, food canning and freezing and sugar industries.

The groundwater at Mazar was found suitable for confectionaries, air conditioning, baking , drinking, textile, sugar industries, food processing, food canning and freezing and while it was not suitable for brewing, Pulp and Paper industry.

5.5 Effect of Polluted Groundwater due to Sugar Factory Effluent on Yield of Wheat Crop and Soil Properties (Rahuri Centre)

The untreated effluents from Rahuri Sugar Factory and its distillery and paper mill are dumped into lagoons and Nag drain (Odha), respectively. These effluents seep into the adjacent wells and thus the well water is being polluted day by day. The irrigation wells in adjoining areas of lagoon are highly polluted and pollution level reduces with distance away from lagoon. Polluted waters of the wells are used for irrigation and yields of crops are being affected depending on the concentrations of different anions and cations in polluted groundwater. Therefore, an experiment was undertaken to know the effect of use of polluted groundwaters of different levels (low, medium and high) and normal water different combinations and their effects on soil properties and crop yields.

Effect of low polluted groundwater due to sugar factory effluent on yield of wheat crop and soil properties

The experiment was repeated on the farmer's field in Survey No. 465 of village Deolali Pravara located near Rahuri sugar factory area. The experiment was conducted with five treatments viz., T1: Irrigation with polluted groundwater due to sugar factory effluent; T2: Irrigation with normal well water; T3: One irrigation with normal well water followed by two irrigations with polluted groundwater due to sugar factory effluent; T4: One irrigation with polluted groundwater due to sugar factory effluent by two irrigations with normal well water; T5: Alternate irrigation-One irrigation with polluted groundwater due to sugar factory effluent and other by normal well water was conducted in RBD replicated four times and each plot size was 4 m x 4m.

Textural class of the experimental field was clay with clay percentage as 52.95 with field capacity and permanent wilting point at 35.17 and 21.30 percent of moisture content (%). The wheat crop of variety Trimbak (NIAW-301) was sown on 05.12.2013 with row to row spacing as 22.5 cm and seed rate was 100 kg/ha. Fertilizer dose was applied as per the recommendation ($60N:60P_2O_5:40K_2O$ kg/ha). The groundwater was C_2S_1 class indicating low level of pollution. The quality parameters of groundwater and normal water are given in table 5.8. The water requirement of the wheat crop was calculated based on field capacity, permanent wilting point, bulk density of soil and the root zone depth (75 cm) throughout the growing season. The irrigation was applied at 50 percent depletion level and at the critical growth stages.

Table 5.8 Quality parameters of low, medium, high polluted groundwater (LPGW, MPGW, HPGW) and normal well water

Sl. No.	Parameters	LPGW	MPGW	HPGW	Normal Well water	Unit
A.	**Physical parameters**					
1.	Total Dissolved Salts (TDS)	--	--	--	339.2	mgL^{-1}
2.	Electrical conductivity (EC)	0.44	1.61	5.47	0.53	dSm^{-1}
3.	Temperature				24	
B.	**Chemical parameters**					
1.	Acidity / basicity, pH	7.30	7.50	7.20	7.19	--
2.	Concentration of cations					
	Calcium	5.8	9.5	15.9	5.6	meL^{-1}
	Magnesium	1.7	4.2	22.9	2.3	meL^{-1}
	Sodium	3.35	12.17	19.13	1.2	meL^{-1}
	Potassium	0.01	0.02	0.03	0.8	meL^{-1}
3.	Concentration of anions					
	Carbonate	--	--	--	--	meL^{-1}
	Bicarbonate	6.3	5.9	10.0	0.8	meL^{-1}
	Chloride	5.4	16.00	37.4	3.0	meL^{-1}
	Sulphate	--	--	--	0.6	meL^{-1}
4.	Sodium adsorption ratio (SAR)	1.73	4.66	4.34	0.60	
6.	Irrigation class	C_2S_1	C_3S_1	C_4S_1	C_1S_1	

The trace metal and heavy metal concentration in polluted groundwater viz., Fe, Mn, Cu, Zn, Cr, Cd, Pb and Ni was estimated as 0.276, 1.302, 0.107, 0.075, 0.062, 0.074, 0.114, 0.093 mg/l respectively.

Effect of medium polluted groundwater due to sugar factory effluent on yield of wheat crop and soil properties

In this study an experiment was repeated on the farmer's field in Survey No. 100 of village Chinchvihire located near Rahuri sugar factory area. Textural class of the experimental field was clay with clay percentage as 49.03 with bulk density of 1.29 Mg/m^3 . The field capacity and permanent wilting point was recorded at 31.00 and 17.30 percent of moisture content (%). The experiment design and treatments are as explained in the above experiment. The quality parameters of medium polluted groundwater and normal water are presented in Table 5.8.

The trace metal and heavy metal concentration in polluted groundwater viz., Fe, Mn, Cu, Zn, Cr, Cd, Pb and Ni was estimated as 0.247, 0.974, 0.008, 0.061, 0.071, 0.053, trace and 0.062 mg/l respectively.

Effect of high polluted groundwater due to sugar factory effluent on yield of wheat crop and soil properties

The experiment is conducted on the farmer's field in Survey No. 79 of village Chinchvihire located near Rahuri sugar factory area. The Wheat crop of variety Trimbak (NIAW-301) was sown on 02.12.2013. Fertilizer dose was applied as per the recommendation. Experimental design and treatments were similar to earlier two experiments. Textural class of the experimental field was clay with clay percentage as 50.98 with field capacity and permanent wilting point at 33.00 and 19.80 percent of moisture content. The quality parameters of high polluted groundwater and normal water are given in table 5.8.

The trace metal and heavy metal concentration in high polluted groundwater viz., Fe, Mn, Cu, Zn, Cr, Cd, Pb and Ni was estimated as 0.235, 1.550, 0.123, 0.007, 0.102, 0.084, 0.603, 0.058 mg/l respectively.

5.6 Water Quality of Tribal Districts (Jabalpur Centre)

Block wise groundwater quality in Jabalpur ,Mandla and Dindori districts of M.P. in terms of pH, EC, NO_3, total hardness, Ca, Mg, Na, K, CO_3, HCO_3, Cl, P, micronurient and heavy metals was obtained from records (1970-75) of Water resources Department of M.P. These parameters are being assessed during the year 2013-14. The change in water quality of different districts is determined through comparison of past data.

In Jabalpur district all six physio-chemical parameters (pH, EC, CO_3, HCO_3, Ca+Mg, Cl) were found increased as compared to data available for the year 1970, however the values at present are within the permissible limit. Study revealed that pH, EC and CO_3 has slightly increased. The HCO_3, Cl and Ca+Mg content were found as 172.83 ppm, 936.03 ppm, 837.76 ppm respectively as compared to previous data 22.73 ppm, 42.63 ppm, 99.22 ppm respectively.
The average pH for the Mandla district was 8.5 during 1973-75 which is now reduced to 7.4 during year 2013-14. EC was found 257.68 µS/cm and HCO_3 (147.96 ppm) which has decreased. The concentration of Cl (513.8 ppm) and Ca+Mg (516.98 ppm) was found slightly increased over the past concentraion 172.14 ppm (Cl) and 375.06 ppm (Ca+Mg).

The average pH of groundwater at Dindori district was found to be 8.36 and 7.07 in the year 1973-75 and 2013-14 respectively. The EC values decreased in the year 2013-14 (378.62 µS/cm) as compared to values obtained during 1973-75 (1545.61µS/cm). Carbonate was not present in water sample during year 1973-75 however it is now present in the year 2013-14. The concentration of HCO_3 (197.24 ppm), Cl (594.95 ppm) and Ca+Mg (513.6 ppm) is now higher than the previous values of HCO_3 (22.57 ppm), Cl (219.28 ppm) and Ca+Mg (137.66 ppm).

Water samples were collected from four blocks of Seoni district namely Chhapara, Kurai, Keolari and Ghansore. The pH (7.45) and EC (850.38 µS/cm) were found decreased in 2013-14 as compared to 1973-75. The CO_3 (204.4 ppm) and HCO_3 (290.01ppm) increased in the year 2013-14 as compared to 1973-75 (7.35 ppm and 180.14 ppm respectively). Similar trend was observed for Cl and Ca+Mg content.

Block wise quality of groundwater

During the year 1973-75 the pH of groundwater samples of all the blocks under consideration were beyond the permissible range of 6.5-8.5 (Fig.5.4). The average pH were found 8.68 in Karanjia block of Dindori and 8.66 Kurai block of Seoni district respectively, which was on higher side. In recent sampling the average pH of all blocks are within the permissible limit. During the seventies the EC values ranged between 360 µS/cm to 2550 µS/cm (Fig. 5.5), which were all within permissible limit. During 2013-14 EC ranges increased in Kurai (from 360 to 582.67 µS/cm) and Keolari block (from 760 to 1567.67 µS/cm) of Seoni district. The bicarbonate content increased in all districts except Mandla district but under the safe limit (Fig 5.6) and carbonate content increased in Keolari (382.2 ppm) and Ghansour block (220.5 ppm) but within permissible limit.

High Chloride concentration is found in groundwaters where the temperature is high and rainfall is less. Soil porosity and permeability also has a key role in building up the chlorides concentration. During the year 1973-75, the Cl content in groundwater samples of all blocks were found under the safe limit. The chloride content increased beyond the permissible limit in Bichiya block of Mandla District, all blocks of Dindori district, Kundam block of Jabalpur district and Keolari and Ghansore of district Seoni. In seventies the Ca+Mg content of groundwater sample of all the blocks under consideration did not fall within the permissible range. The average Ca content were found as 226.73 ppm in Bajag of Dindori District and 384.13 ppm in Mohgaon block, and 366 ppm in Bichhia of Mandla district . But During 2013-14 the average Ca content of all blocks were found beyond the permissible limit (Fig 5.7).

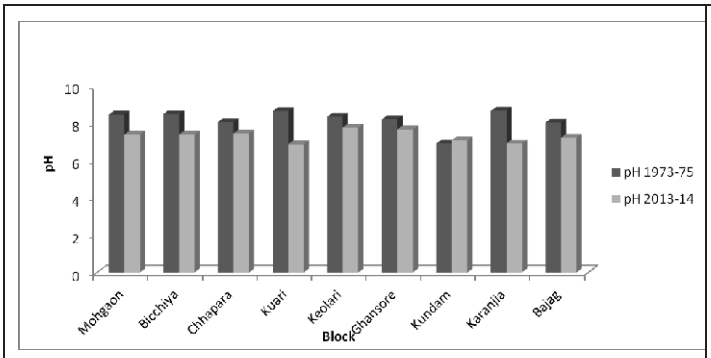

Fig 5.4 Block wise concentration of pH- present and Past values

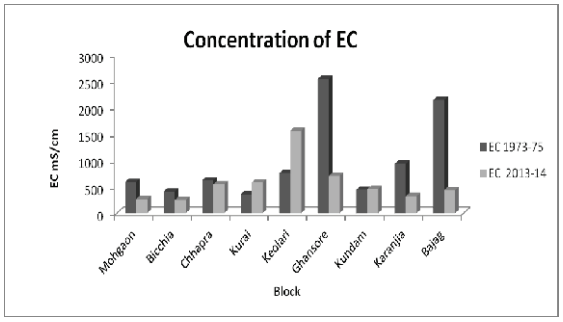

Fig 5.5 Block wise concentration of EC- present and Past values

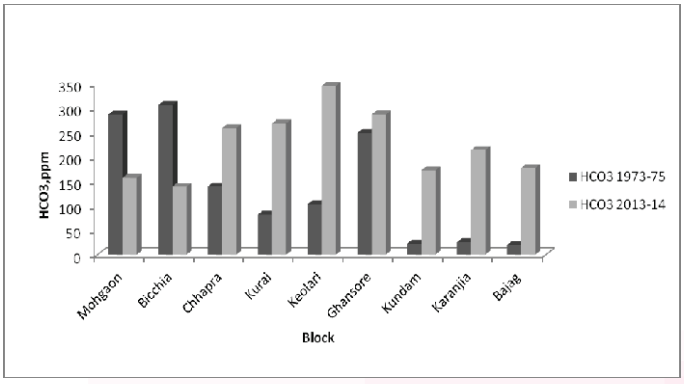

Fig 5.6 Block wise concentration of HCO_3- present and Past values

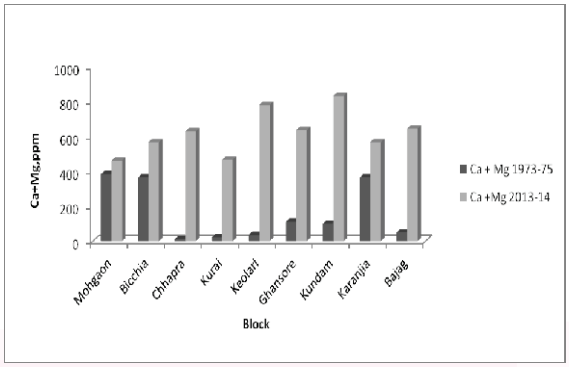

Fig 5.7 Block wise concentration of Ca+Mg- present and Past values

5.7 Assessment of Surface and Groundwater Quality and Wastewater Reuse in Amaravathy Basin and Developing Management Strategies for Agriculture (Coimbatore Centre)

Preliminary survey was made in the Amaravathy basin area and sampling locations were identified and delineated. The sources of water contamination and industries located in the basin were identified. Thirty five water and soil samples were collected (groundwater, surface water and bore well water samples) from the Amaravathy basin during this period (2013-2014). The soil samples were analysed for EC, pH, physical parameters like bulk density, particle density and porosity, available macro nutrients like N, P and K, available micro nutrients such as Fe, Zn, Mn and Cu and water samples were analyzed for chemical properties like EC, pH, cations and anions. For mapping the extent of poor quality irrigation water and soil nutrient status and health in the Amaravathy basin through remote sensing and GIS techniques, the coordinates of the observation wells and sampling places were collected using the Geographical Positioning System (GPS).

Salinity

Electrical conductivity ranged from 0.24 to 2.42 dS m^{-1}, 0.23 to 2.40 dS m^{-1}, 0.10 to 2.38 dS m^{-1}, 0.15 to 2.42 dS m^{-1} during summer, south west, north-east monsoon and winter seasons of 2013-14, respectively. The samples were classified according to USSL classification (Table 5.9). Most of the samples were under high salinity class (C_3) followed by medium salinity class (C_2), very high salinity class (C_4), low salinity class (C_1) during summer south west, north east monsoon and winter respectively.

Table 5.9. Classification of irrigation water quality based on EC

EC (dS m^{-1})	Category	Summer		SW		NE		Winter	
		No. of samples	Frequency (%)	No. of samples	Frequency (%)	No. of samples	Frequency (%)	No. of samples	Frequency (%)
<0.25	Low Salinity Class (C_1)	1	2.85	1	2.85	3	8.57	1	2.85
0.25-0.75	Medium Salinity Class (C_2)	8	22.85	8	22.85	8	22.86	10	28.57
0.75-2.25	High Salinity Class (C_3)	24	68.57	24	68.57	22	62.86	22	62.86
>2.25	Very High Salinity Class (C_4)	2	5.71	2	5.71	2	5.71	2	5.71

pH

The pH values ranges from 7.44 to 8.75, 7.05 to 8.53, 7.00 to 8.48 and 1.65 to 3.92 during summer, south west, north east monsoon and winter season respectively.

Cations

The samples were analysed for cations like calcium, magnesium, sodium and potassium. Calcium content ranged from 1.25 to 7.70 m.e L^{-1}, 0.69 to 6.63 m.e L^{-1}, 0.49 to 9.92 m.e L^{-1} and 1.39 to 10.82 m.e L^{-1} during summer, south west, north east monsoon and winter of 2013 - 14, respectively. Magnesium content varied from 0.61 to 7.25 m.e L^{-1}, 0.41 to 6.62 m.e L^{-1}, 0.36 to 6.56 m.e L^{-1}, 1.06 to 7.26 m.e L^{-1} during summer, south west, north east monsoon and winter of 2013 - 14, respectively. Sodium content was observed from 1.50 to 9.27 m.e L^{-1}, 0.95 to 8.27 m.e L^{-1}, 0.75 to 8.07 m.e L^{-1} and 1.65 to 8.97 m.e L^{-1} during summer, south west, north east monsoon and winter of 2013 - 14, respectively. Potassium content varied from 0.17 to 1.90 m.e L^{-1}, 0.15 to 1.88 m.e L^{-1} ,0.13 to 1.86 and 0.18 to 1.91 during summer, south west, north east monsoon and winter of 2013 - 14, respectively. Most of the samples were found to be sodium dominating water.

Anions

Anions like carbonate, bicarbonate, chloride and sulphate were analysed in the water samples. Bicarbonates dominated and it ranged from 1.60 to 10.00 m.e L^{-1}, 1.10 to 9.00 m.e L^{-1} , 1.00 to 8.01 m.e L^{-1} and 1.50 to 8.51 m.e L^{-1} during summer, south west, north east monsoon and winter respectively. Chloride content varied from 0.51 to 4.85 m.e L^{-1}, 0.11 to 4.35 m.e L^{-1}, 0.04 to 4.20 m.e L^{-1} and 0.56 to 5.60 m.e L^{-1} during summer, south west, north east monsoon and winter of 2013 - 14, respectively. With regard to chloride concentration, all the samples wereunder excellent category during all seasons. Sulphate concentration varied from 0.76 to7.15 m.e L^{-1}, 0.26 to 6.15 m.e L^{-1} , 0.06 to 5.95 m.e L^{-1} and 1.06 to 6.95 m.e L^{-1} during summer, south west, north east monsoon and winter of 2013 - 14, respectively.

Total Hardness

Total hardness in the study area varied from 8.58 to 34.10 m.e L^{-1}, 5.83 to 29.64 m.e L^{-1} , 5.12 to 32.63 m.e L^{-1} and 10.24 to 37.75 m.e L^{-1} during summer, south west, north east monsoon and winter of 2013 - 14, respectively.

Residual sodium carbonate (RSC) and Residual sodium bi carbonate (RSBC)

RSC values varied from -4.2 to 3.7 m.e L^{-1}, -3.91 to 4.61 m.e L^{-1}, -6.67 to 4.75 m.e L^{-1}, and -7.76 to 3.65 m.e L^{-1} during summer, south west, north east monsoon and winter of 2013 - 14, respectively. When considering RSC and RSBC, most of the samples are coming under safe category.

Sodium Adsorption Ratio (SAR)

SAR values ranged from 0.8 to 7.5 m.e L^{-1}, 0.82 to 7.46 m.e L^{-1}, 0.43 to 9.51 m.e L^{-1} and 0.84 to 7.28 m.e L^{-1} during summer, south west, north east monsoon and winter of 2013 - 14, respectively. Most of the samples come under low sodium category and two samples were under medium category. There is no sodicity problem exist among the irrigation waters.

Langlier Saturation Index (LSI)

The Langlier saturation level approaches the concept of saturation using pH as a main variable. LSI values were calculated and it ranged from 1.37 to 2.74, 0.78 to 2.43, 0.62 to 2.39 and -4.45 to -2.17 during summer, south-west, north-east monsoon and winter of 2013 - 14, respectively. It showed that probability of salt encrustation in irrigation pipes was common in the study area.

Permeability Index

Permeability Index ranged from 38 to 96, 36 to 108, 35 to 111 and 37 to 96 during summer, South west, north east monsoon and winter of 2013 - 14, respectively. Majority of the samples exhibited that there was no permeability hazard and all the water samples had negative Puri,s salt index representing good quality water.

Table 5.10. Characteristics and composition of Post Methanated Spent Wash

S. No.	Characteristics	Values*
1.	Colour	Reddish brown
2.	Odour	Unpleasant burnt sugar
3.	pH	7.23
4.	EC (dS m^{-1})	36.0
5.	Total suspended solids (mg L^{-1})	6,500
6.	Total dissolved solids (mg L^{-1})	44,100
7.	Total solids (mg L^{-1})	50,600
8.	Organic carbon (%)	13.8
9.	BOD (mg L^{-1})	8,500
10.	COD (mg L^{-1})	30,500
11.	Nitrogen (mg L^{-1})	920
12.	Phosphorous (mg L^{-1})	80
13.	Potassium (mg L^{-1})	10,500
14.	Calcium (mg L^{-1})	3600
15.	Magnesium (mg L^{-1})	1500
16.	Sodium (mg L^{-1})	420
17.	Chloride (mg L^{-1})	9550
18.	Carbonate (mg L^{-1})	Nil
19.	Bicarbonate (mg L^{-1})	1960
20.	Sulphate (mg L^{-1})	950
21.	Iron (mg L^{-1})	73.0
22.	Manganese (mg L^{-1})	4.5
23.	Zinc (mg L^{-1})	6.2
24.	Copper (mg L^{-1})	4.7
25.	Bacteria (x 10^6 CFU ml^{-1} of effluent)	10
26.	Fungi (x 10^4 CFU ml^{-1} of effluent)	17
27.	Actinomycetes (x 10^3 CFU ml^{-1} of effluent)	Nil

** Mean of triplicate samples*

Characterization of post biomethanated spentwash

The biomethanated spentwash collected from the Amaravathy Sugar Mills Ltd, Krishnapuram, Udumalpet was dark brown in colour with unpleasant odour of burnt sugars. Some important characteristics of spentwash samples are presented in table 5.10. The spentwash was found to be neutral in reaction (7.23). The sample carries large amounts of dissolved salts (TDS), and soluble salts. The dissolved salts were very high in the spentwash, reflecting its possible salinity hazard. Due to higher salt loading, the spentwash had very high electrical conductivity (36 dSm^{-1}).

Soil quality of Amaravathy basin

Bulk density of surface soils and sub surface soils ranged from 1.94 to 1.30 Mg m^{-3}, 1.11 to 1.35 Mg m^{-3}, respectively. Particle density of surface and sub surface soils ranged from 1.64 to 1.93 Mg m^{-3}, 1.68 to 1.97 Mg m^{-3}, respectively. Soil pH varied from 7.45 to 7.91 in surface soils and 7.50 to 7.99 in subsurface soils. As per the USDA classification, 88 per cent of the surface sample comes under slightly alkaline and 12 per cent of the samples come under moderately alkaline. Among the sub surface soil samples, 83 per cent of the samples come under slightly alkaline and 17 per cent under moderately alkaline. EC ranged from 0.02 to 0.32 dS m^{-1} in surface samples and 0.05 to 0.35 dS m^{-1} in subsurface soil samples.

Available N ranged from 135 to 207 Kg ha^{-1} in surface and 131 to 203 Kg ha^{-1} in sub surface soils. Available P ranged from 20 to 44 Kg ha^{-1} in surface and 16 to 41 Kg ha^{-1} in sub surface soils. Available K ranged from 136 to 296 Kg ha^{-1} in surface and 130 to 290 Kg ha^{-1} in sub surface soils. 72 per cent of the surface samples and 86 per cent of sub surface sample come under low available N category, 28 and 14 per cent of surface and sub surface samples come under medium available N status. In surface soil, the organic carbon content was medium (57 %) followed by low (43 %). In sub surface soil, the organic carbon status was dominated with medium (55 %) followed by low (45 %). Fe, Zn, Mn and Cu was deficient in both surface and subsurface soils. It indicates that all the soil samples are deficient in micronutrients. Few samples contain marginal amount of nutrients. The heavy metals content in most of the soil samples are below detectable limit only few samples contain very less amount of heavy metals.

5.8 Assessment of Groundwater Quality of Rajsamand District of Rajasthan (Udaipur)

This study was continued with the objectives of evaluation of spatio-temporal variability of groundwater quality of Rajsamand district and preparation of groundwater quality maps of Rajsamand district. Rajsamand district is located in the southern part of Rajasthan State and extends between north latitudes 24°43'32" and 26°01'36" and east longitudes 73° 28'30" and 74°28'55". It covers an area of 4768.10 Sq. km. Rajsamand district covers 1.39 percent of total area of state and is divided into 7 Tehsils and 7 blocks.

The maximum water level (16.58 m) in pre-monsoon season was recorded in Railmagra block whereas the minimum water level (7.69 m) was found in Kumbhalgarh block. In other words we can say that minimum energy will be required for pumping/withdrawal of groundwater in Kumbhalgarh and

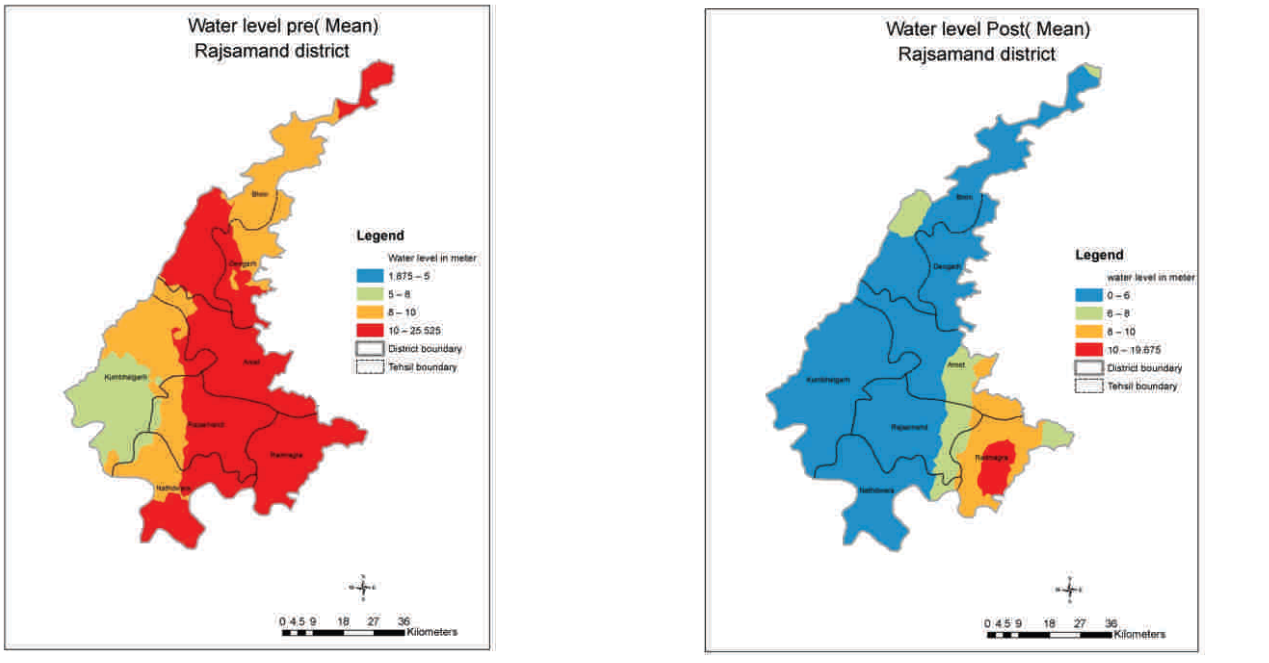

Fig 5.8 Water level fluctuation in pre and post monsoon seasons

maximum will be required in Railmagra block. The traditional irrigation with *Rahat* is more common in Kumbhalgarh block which may be due to shallow water level.

Maximum water level (10.44 m) in post-monsoon season was recorded in Railmagra block whereas the minimum water level (2.88 m) was found in Kumbhalgarh block (Fig.5.8).

The pH of groundwater in pre-monsoon seasons in all the blocks of the Rajsamand district was found near neutral(Fig 5.9). Perceptible variations were observed in TDS and EC in different blocks in pre-monsoon seasons. Highest salinity was observed in Rajsamand block followed by Railmagra and Nathdwara blocks which is not suitable for irrigation on long term basis.

As in case of pre-monsoon seasons the pH of groundwater in post monsoon seasons in all the blocks of the Rajsamand district was also found near neutrality. Much variation was observed in TDS and EC in different blocks in post-monsoon seasons (Fig. 5.10 & 5.11 respectively). Comparatively higher salinity was observed in Rajsamand, Railmagra and Nathdwara blocks which is much lower than the values in pre-monsoon season.

This information of the average groundwater levels and its quality may be highly useful in many ways for the selection of the water lifting devices, selection of the crops for particular block, distribution of seed minikits, management and methodology of application of fertilizers, drinking water supply and other management of quality related problems on priority basis in the whole district.

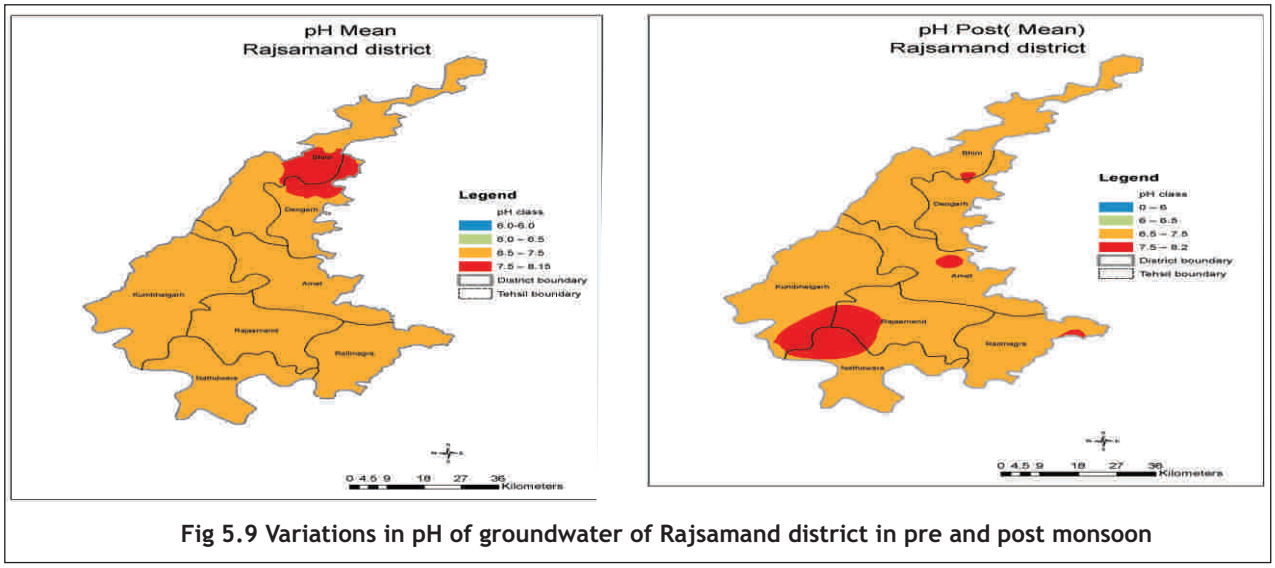

Fig 5.9 Variations in pH of groundwater of Rajsamand district in pre and post monsoon

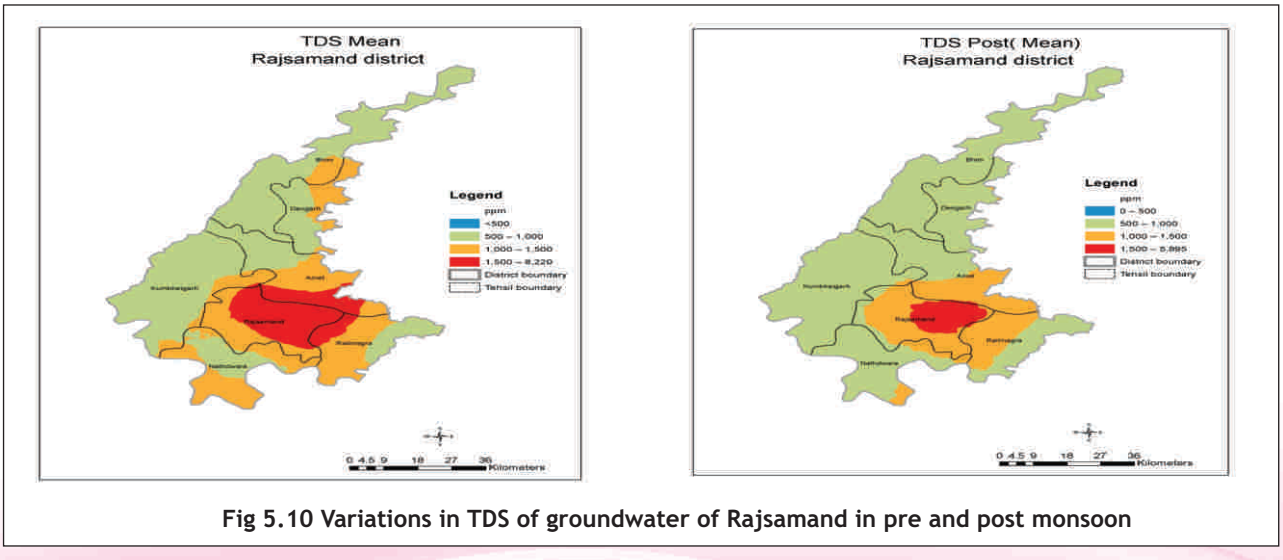

Fig 5.10 Variations in TDS of groundwater of Rajsamand in pre and post monsoon

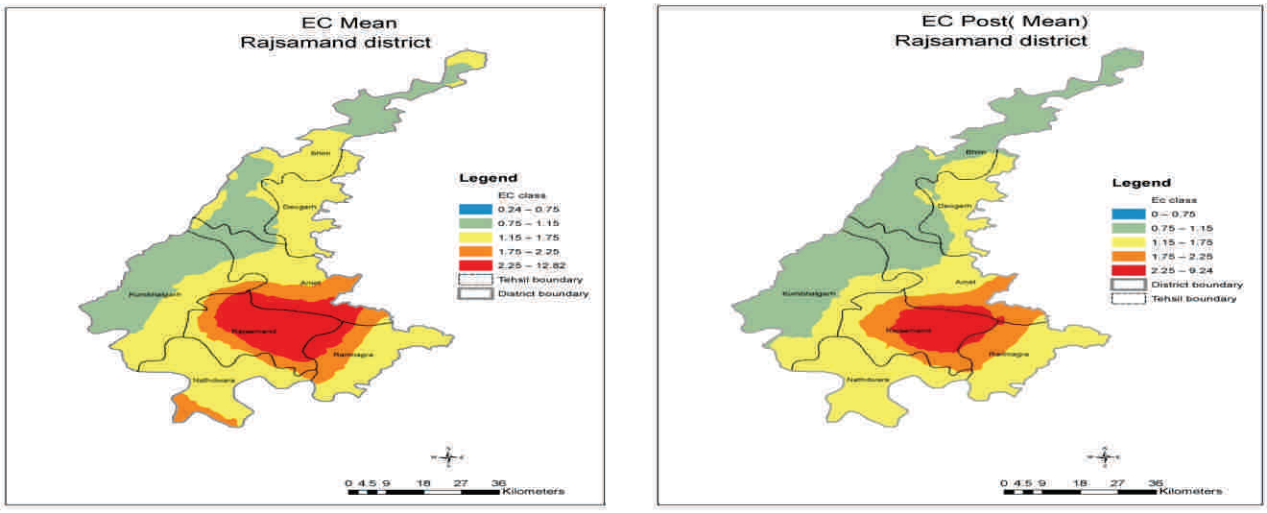

Fig 5.11 Variations in EC of groundwater of Rajsamand district in pre and post monsoon

5.9 Characterization and Utilization of Wastewater in Vegetable Growing Areas of Haroti Region of Rajasthan (Udaipur Centre)

To characterize the wastewater in the Haroti region of the Rajasthan consisting of four districts of Rajasthan namely Bundi, Baran, Jhalawar and Kota a survey has been conducted selecting 34 sites (8 in Bundi, 9 in Kota, 9 in Baran & 8 in Jhalawar district) covering the whole Haroti region.

Wastewater quality

Wastewater sampling was done from the selected sites and analyzed for electrical conductivity (EC), pH and total dissolved salt (TDS) using portable instruments in the fields itself. Heavy metals viz. iron, manganese, copper, zinc, cadmium, lead, chromium and nickel analyzed using standard method with the help of Atomic Absorption Spectrophotometer (AAS; Model EC 4141-8). The analytical results of the wastewater are given in the table 5.11.

Table 5.11 Quality of wastewater in *Haroti* region of Rajasthan

Location code	EC (dSm^{-1})	pH	TDS (ppm)	Fe	Mn	Cu	Zn	Cd	Pb	Cr	Ni
B-1	1.62	7.1	1030	0.065	0.047	0.039	0.078	0.008	0.050	0.095	0.009
B-2	2.30	6.9	1470	0.160	0.042	0.088	0.179	0.009	0.083	0.150	0.061
B-3	2.00	6.8	1260	0.142	0.144	0.086	0.160	0.006	0.066	0.123	0.073
B-4	1.86	7.0	1180	0.075	0.048	0.055	0.111	0.002	0.072	0.095	0.066
B-5	1.66	7.1	1060	0.085	0.038	0.064	0.122	0.007	0.054	0.077	0.005
B-6	1.92	6.8	1220	0.134	0.033	0.074	0.149	0.002	0.087	0.087	0.074
B-7	2.10	6.6	1340	0.148	0.154	0.088	0.179	0.006	0.093	0.100	0.096
B-8	2.00	6.5	1270	0.145	0.131	0.079	0.165	0.002	0.087	0.091	0.084
K-1	1.44	6.9	921	0.096	0.100	0.077	0.154	0.001	0.088	0.071	0.083
K-2	2.60	6.7	1650	0.187	0.198	0.173	0.349	0.510	1.130	0.591	0.696
K-3	2.30	6.3	1460	0.174	0.184	0.099	0.198	0.006	0.057	0.082	0.097
K-4	2.20	6.6	1400	0.163	0.178	0.100	0.197	0.731	0.114	0.133	0.411
K-5	2.80	6.7	1780	0.177	0.192	0.106	0.200	0.002	0.062	0.074	0.152
K-6	2.80	6.5	1770	0.156	0.173	0.099	0.191	0.327	0.071	0.056	0.073
K-7	2.90	6.5	1850	0.179	0.166	0.108	0.211	0.007	0.094	0.085	0.094
K-8	3.40	6.4	2170	0.195	0.203	0.166	0.245	0.003	0.046	0.053	0.064
K-9	2.10	6.8	1330	0.174	0.188	0.111	0.210	0.641	0.068	0.052	0.055
A-1	0.76	6.9	486	0.055	0.045	0.045	0.089	0.012	0.023	0.020	0.004
A-2	0.86	7.0	549	0.059	0.037	0.049	0.099	0.032	0.045	0.032	0.001
A-3	0.65	7.2	414	0.044	0.048	0.045	0.095	0.100	0.037	0.035	0.054
A-4	0.88	7.1	561	0.070	0.036	0.053	0.103	0.003	0.058	0.059	0.037
A-5	0.78	7.2	489	0.065	0.040	0.054	0.109	0.042	0.050	0.054	0.004
A-6	1.85	6.8	1170	0.081	0.044	0.068	0.144	0.121	0.096	0.099	0.007
A-7	2.10	7.1	1340	0.100	0.034	0.069	0.139	0.135	0.121	0.110	0.011
A-8	1.62	7.2	1020	0.094	0.048	0.060	0.120	0.068	0.074	0.098	0.003
A-9	1.76	6.9	1110	0.087	0.046	0.075	0.155	0.066	0.082	0.089	0.002
J-1	0.83	7.3	530	0.067	0.035	0.042	0.088	0.045	0.045	0.042	0.010
J-2	0.75	7.3	471	0.068	0.041	0.040	0.078	0.046	0.049	0.033	0.001
J-3	0.64	7.1	402	0.081	0.038	0.064	0.111	0.055	0.035	0.021	0.010
J-4	0.72	7.2	456	0.055	0.020	0.045	0.089	0.058	0.056	0.011	0.004
J-5	0.81	7.2	511	0.063	0.039	0.055	0.109	0.054	0.066	0.020	0.007
J-6	0.67	7.1	422	0.074	0.046	0.053	0.100	0.066	0.053	0.032	0.007
J-7	1.22	6.9	772	0.100	0.046	0.075	0.142	0.144	0.122	0.097	0.011
J-8	0.84	7.2	526	0.086	0.047	0.067	0.130	0.067	0.076	0.079	0.003
MPL for irrigation				**0.300**	**0.050**	**2.00**	**0.030**	**0.003**	**0.05**	**0.05**	**0.01**

on the basis of total salt concentration (EC), the wastewater of Bundi and Kota city falls under high to very high salinity (C_3 and C_4) classes whereas the wastewater of the Baran (Anta) and Jhalawar cities falls under medium to high salinity (C_2 and C_3) classes. Further in reference to the data in Table- the pH of the wastewater in whole region was found near neutral. The TDS ranges from 921 to 2170 ppm in Bundi and Kota cities whereas in Baran and Jhalawar it ranges from 402 to 1340 ppm. This again indicated the high salt load in wastewater of Bundi and Kota cities as compared to Anta and Jhalawar cities.

The concentration of iron, copper and zinc metals are found within the maximum permitted levels in the wastewater but the manganese found beyond the maximum permitted levels in wastewater at three sites at Bundi and all selected site at Kota.

The contamination of cadmium, lead, chromium and nickel was found almost in all the cities. These four heavy metals were found beyond the MPL in wastewater for irrigation at most of the sites of Bundi and Kota but the wastewater of many sites at Anta and Jhalawar were also found contaminated to a large extent.

The above variation in the salt load, pH and metal contamination of the wastewater may be due to different sources of wastewater having different concentration and composition of these undesirable things. The major sources of wastewater in Bundi and Kota cities are: Domestic wastewater, industrial and their muddles (mix-up) having high salt load and undesirable heavy metals. The chief sources of wastewater in Anta (Baran) are domestic wastewater and canal seepage water whereas in Jhalawar the major source of wastewater is domestic effluent only which have comparatively less pollutants (Plate 5.3 & 5.4).

Plate 5.3 Domestic wastewater at Bundi

Plate 5.4 Mixed domestic wastewater & seepage water at Anta (Baran)

Contamination in vegetables

On the basis of non-essential heavy metal (Cd, Pb Cr and Ni) content in the wastewater, out of total 34 selected sites 11 sites were found polluted. After the characterization of wastewater on the basis non-essential heavy metal contaminants one most polluted site in each city was selected and vegetables viz., spinach, cabbage, cauliflower and garlic crop samples were collected and analysed for estimation of trace and heavy metal content (Table 5.14). The maximum permitted limit (MPL) of Fe, Cu, Zn, Mn, Cd, Pb, Cr and Nickel is 425, 10, 100, 500, 0.02, 2.0, 1.3 and 10 mg/kg as prescribed by WHO in the edible portions, leaves and cloves.

The data (Table 5.12) revealed that wastewater irrigated spinach and garlic at B-2 site which is the most polluted site of Bundi contained the copper, cadmium and chromium more than the maximum permitted level. The cabbage and cauliflower crops grown at B-2 site of Bundi were also found to accumulate copper and cadmium beyond the MPL. The data clearly exposed that the spinach grown at K-2 site of Kota accumulated the copper, zinc, cadmium, lead and chromium more than the level of toxicity. The cabbage at this site built-up the copper, zinc, cadmium and chromium more than the MPL prescribed by WHO. The cauliflower grown at K-2 site with wastewater irrigation accumulated the copper, cadmium and chromium which crossed the maximum permitted level in the edible portion (head). At this site the garlic crop also accumulated the four heavy metals (Cu, Zn, Cd and Cr) in the edible portion more than the MPL. Spinach grown A-7 site of Anta irrigated with wastewater contained Cd and Cr whereas cabbage contained only Cd more than the MPL. The cauliflower and garlic crops grown with the wastewater at most polluted site of Anta were found within the safe limits for human consumption.

The study revealed that Cu, Zn, Cd and Cr accumulation is a major problem at Kota for spinach, cabbage, cauliflower and

Table 5.12 Heavy metal accumulation (mg/kg) in common vegetable crops at most polluted sites in Haroti region

Crop	Metal	B-2 site of Bundi	K-2 site of Kota	A-7 site of Anta	J-7 site of Jhalawar
Spinach	Fe	336.48	394.25	312.28	310.02
	Mn	152.06	168.72	139.56	142.27
	Cu	13.96	18.36	9.16	9.45
	Zn	96.84	106.78	72.81	72.72
	Cd	0.08	0.12	0.04	0.06
	Pb	0.12	2.06	0.22	0.20
	Cr	1.44	2.74	1.40	1.22
	Ni	2.26	2.44	0.85	0.72
Cabbage	Fe	92.33	118.76	88.52	82.14
	Mn	144.74	156.33	148.26	152.66
	Cu	14.68	20.54	8.44	7.54
	Zn	82.24	100.96	75.35	73.78
	Cd	0.06	0.08	0.03	0.02
	Pb	0.15	1.76	0.11	0.10
	Cr	0.96	1.40	1.26	1.00
	Ni	1.18	2.87	1.10	1.18
Cauliflower	Fe	84.54	97.29	80.68	88.22
	Mn	112.62	147.62	108.25	102.58
	Cu	11.78	15.86	7.85	8.12
	Zn	75.38	92.34	72.98	74.24
	Cd	0.05	0.11	0.01	0.01
	Pb	0.10	0.44	0.12	0.10
	Cr	0.80	1.32	0.67	0.56
	Ni	1.00	2.15	0.89	0.88
Garlic	Fe	330.12	414.32	326.42	338.47
	Mn	68.88	81.14	66.20	70.08
	Cu	12.66	16.48	9.16	9.44
	Zn	57.45	108.92	55.69	58.82
	Cd	0.10	0.14	0.02	0.01
	Pb	1.02	1.42	1.25	1.38
	Cr	1.58	1.88	1.22	1.06
	Ni	1.33	1.59	1.33	1.58

garlic crops grown with wastewater irrigation. At Bundi, Cu and Cd contamination is the main limiting factor for the use of wastewater for irrigation in vegetables. The wastewater of Anta and Jhalawar cities is comparatively good for vegetable production except Cd and Cr build-up in leafy vegetables (spinach and cabbage). The spinach crop at all the four selected most polluted site of Haroti region grown with wastewater irrigation found to accumulate cadmium more than the maximum permitted levels prescribed by WHO. Further it can be inferred that leafy vegetables (spinach and cabbage) accumulated more cadmium than cauliflower and garlic.

5.10 Effect of Sewage Sludge Disposal in Soils and Crops (Pusa Centre)

The Patna bye-pass area is situated in both sides of National highway No. 30. The whole area is receiving a continuous use of sewage sludge for a period of over 50 years. The farmers grow a variety of vegetables and field crops by lifting sewage water through pumps and open wells. Altogether, 30 sampling sites were selected for collecting surface soils and various crop species during the year 2013. All these soils, plants and water samples were studied for micronutrients including heavy metal cations.

Sewage water quality

The physico-chemical characteristics of sewage water being used by the farmers at Patna by-pass area are presented in table 5.13. The experimental data revealed that sewage water was contained higher amount of micronutrients and heavy metals except Pb which on continued application to agricultural lands may contaminate surface soils to the greater extent.

Soils

The sewage sludge treated soils were found sufficiently rich in DTPA extractable micronutrients (viz. Zn, Cu, Fe and Mn) and heavy metal cations like Cd, Cr, Ni and Pb with maximum accumulation at the point of discharge. The study also revealed that concentration of Zn, Cu, Fe and Mn were in the range of 1.08 - 5.60, 5.31 - 37.6, 10.25 - 24.7 and 7.05 - 15.9 ppm, respectively. The sites nearer to the sewage discharge point contained appreciably high amount of these trace metal cations as compared to the distant points. Similar trends were also recorded in case of heavy metals in soils where concentration of DTPA extractable Cd, Cr, Ni and Pb varied in the range 0.02-3.13 ppm, 0.02 - 0.38 ppm, 0.14 - 4.8 ppm and 1.02 – 0.38 ppm, respectively which are considered quite high.

Crops

Plants growing on such soils accumulate excess amount of micronutrients and heavy metals in their tissues which may enter in the system of animal and human being. Accumulation of trace metal cations in different plant species differed widely which varied from crop to crop and place to place. The relative accumulation of these metals in different plant species was as follows.

i. Poi (247)>Red spinach (180)>Brinjal (164.7)>Chilli (156.6)> Bhindi (145.2) >Bitter gourd (144)>Pumpkin (142) >Cowpea (127.5) > Sponge gourd (126.3) > Cabbage (124) ppm for **Zn.**
ii. Poi (58.8)>Red spinach (38.8)>Brinjal (37.2)>Cowpea (34.0)>Pumpkin (33.7)> Sponge gourd (33.5) > Bitter gourd (33.0)>Cabbage (32.5)>Bhindi (32.2)>Chilli (23.0) ppm. for **Cu**.
iii. Poi (1151)>Red spinach (1123)>Brinjal (1119)> Bhindi (1096)>Sponge gord (1093)>Chilli (1063)>Cabbage (1053)> Cowpea (1037)>Pumpkin (1023)> Bitter gord (948) ppm for **Fe.**
iv. Sponge gourd (124)>Bhindi (113)>Brinjal (109)>Cow pea (107)>Chilli (102)>Cabbage (99)>Red spinach (91)> Pumpkin (82)> Bitter gourd (57) ppm for **Mn.**
v. Poi (59)>Red spinach (55.2)>Brinjal (52.8)> Bitter gourd (51.0)>Chilli (49.2)>Cabbage (48.7)>Cow pea (44.8)>Sponge gourd (42)> Bhindi (41.5)>Pumpkin (32.1) ppm for **Ni.**
vi. Poi (130)>Red spinach (62.3)>Brinjal (60.6)>Bhindi (60.2)>Bitter gourd (59.0)>Chilli (58.8)>Sponge gourd (56.5)>Cow pea (54.1)>Cabbage (53)>Pumpkin (52.5) ppm for **Cr.**
vii. Poi (11.7)>Red spinach (9.82)>Cabbage (9.5)>Bhindi (8.5)>Chilli (8.3)>Sponge gourd (8.17)>Cow pea (7.8)>Brinjal (7.4)>Bitter gourd (7.3) >Pumpkin (7.24) ppm for **Cd.**
viii. Red spinach (105.5)> Brinjal (99.7)> Bhindi (73.0)=Chilli (73.0)> Cow pea (57.0)>Cabbage (50.3)> Bitter gourd (46.2) >Pumpkin (33.5) and

Table 5.13 Physico-chemical characteristics of sewage water

S. No.	Parameters	Contents	S. No.	Parameters	Contents
1.	pH	8.21	10.	Zn (ppm)	0.36
2.	EC (dSm^{-1})	1.42	11.	Cu (ppm)	0.19
3.	Na (me/L)	5.28	12.	Fe (ppm)	7.56
4.	Ca + Mg(me/L)	7.66	13.	Mn (ppm)	0.47
5.	CO_3+HCO_3^-(me/L)	6.32	14.	Ni (ppm)	0.18
6.	TDS (ppm)	908	15.	Cr (ppm)	0.06
7.	Cl^-(me/L)	7.2	16.	Cd (ppm)	0.09
8.	NO3 N (ppm)	8.9	17.	Co (ppm)	0.03
9.	SAR	2.76	18.	Pb (ppm)	0.00

>Sponge gourd (25.0) ppm for **Pb.**

In general it was noticed that leafy vegetables viz. poi and red spinach accumulated most of trace metal cations to the greater extent in comparison to other crops. However, toxic concentration of these trace metal cations in plants and soils should be the matter of concern and indicating the need for continuous monitoring or treatment of sewage water before it is laid down into the field. Though, the study during last three years confirms that sewage water (domestic and urban origin) can certainly and effectively increase water resource for irrigation but there is need for regular monitoring of the concentrations of trace metal cations and potentially toxic elements in soils as well as in plants. Moreover, it is pointed out that continued monitoring or treatment of sewage water before disposal into the land or integrated water management might be some of the suitable measures for effective utilization of poor quality water in sustainable agricultural production.

5.11 An Assessment of Suitability of Groundwater for Drip Irrigation in Saurashtra Region (Junagadh Centre)

The Gujarat state has 1600 km of seacoast, among which Saurashtra is having 1100 km. The coastal belt area is having sandy and lime aquifer which is dominant in calcium element while the inner side the geological formation is mainly made of basaltic rocks formation with limestone, clay, sand stone and red, black and green colored rocks like mix formation common in this region's aquifer. The geological formations affecting the groundwater quality dissolving anion and actions like carbonate, bicarbonate chloride and sulphate of calcium, magnesium, sodium and iron which are responsible for dripper clogging. A water quality analysis helps to identify the various physical, biological and chemical factors that can prevent the drip irrigation system from working as desired. Good maintenance practices, which include flushing and occasional treatment with chemicals, can keep the system working efficiently.

During the winter season-2013, five districts viz Jamnagar, Rajkot, Surendranagar, Junagadh and Porbandar of Saurashtra were selected for the groundwater sampling. Total 327 groundwater samples were collected from wells (W) as well as Tube wells(B). Collected water samples were analyzed by standard method for Groundwater quality parameters like EC, pH, Na^{+} Ca^{++}, Mg^{++}, CO_3^{--}. HCO_3^{-},and Cl^{-} and are presented in table 5.14. The contour maps of water table depth below ground level (bgl) along with groundwater quality parameters for all five districts were developed. The contour maps for Jamnagar district is presented in fig 5.13.

The TDS of groundwater of major part of the Jamnagar district falls in moderate class, except few pockets. Total permanent hardness of the groundwater of the district falls under good class (<150 mg/l). The major area of the district falls under bad class of the pH. It shows that the use of acidic fertilizer can be applied without any problems of fertigation. However, use of phosphoric acid can lead precipitation under higher class of hardness of groundwater.

Table: 5.14 Water quality parameters and Water table of well/bore of five districts

Sr. No	Distict	Value	EC dS/m	pH	Na me/l	Ca me/l	Ca+Mg me/l	Mg me/l	CO3 me/l	HCO3 me/l	Cl me/l	SAR	RSC me/l	SSP %	TDS (gm/l)	Total Hardness mg/L	Water table m
1	**Jamnagar**	Average	2.68	8.21	14.87	4.75	13.81	9.06	1.6	5.4	38.2	5.7	-6.7	47.4	1715	49	26.8
		Max.	9.85	8.97	59.70	22.08	50.28	31.88	5.6	11.9	178.	18.0	8.5	86.3	6304	177	182.0
		Min.	0.46	7.73	1.90	0.84	2.92	0.20	0.0	1.6	4.0	1.2	-45.2	16.7	294	9	3.5
2	**Rajkot**	Average	2.25	7.70	9.75	6.14	13.58	7.44	2.1	3.4	28.1	3.9	-8.1	35.5	1440	46	6.6
		Max.	9.30	8.66	59.70	36.04	64.40	28.36	8.8	6.7	162.	19.8	9.7	85.4	5952	206	28.5
		Min.	0.61	7.02	1.36	1.28	3.56	1.84	0.0	0.6	2.3	0.7	-61.0	14.3	390	12	3.0
3	**Surendra Nagar**	Average	3.43	7.97	22.23	13.50	26.23	12.73	2.2	5.5	50.6	6.4	-18.5	42.0	2196	86	22.0
		Max.	11.07	9.03	74.21	43.52	88.32	44.80	5.5	11.1	179	27.5	7.9	84.2	7085	292	62.0
		Min.	0.31	7.05	0.72	3.80	4.52	0.72	0.6	2.9	7.3	0.3	-81.5	5.0	198	12	2.0
4	**Junagadh**	Average	2.09	8.18	10.52	5.61	14.46	8.85	1.4	6.2	19.3	3.5	-6.8	34.5	1340	50	14.5
		Max.	8.98	8.93	70.45	38.48	68.80	32.68	6.4	14.0	103	16.6	12.0	80.1	5747	221	45.0
		Min.	0.41	7.21	0.97	0.76	2.96	1.40	0.0	1.3	1.9	0.5	-57.8	9.2	262	10	4.0
5	**Porbandar**	Average	3.17	8.23	19.15	6.25	15.92	9.67	0.5	7.5	27.8	6.8	-7.4	51.5	2027	55	11.7
		Max.	8.76	8.65	51.76	21.76	51.40	29.64	3.0	13.7	85.8	21.1	4.5	81.1	5606	176	32.0
		Min.	0.51	7.84	2.04	2.00	4.80	2.40	0.0	2.2	6.4	0.9	-45.2	18.1	326	16	3.5

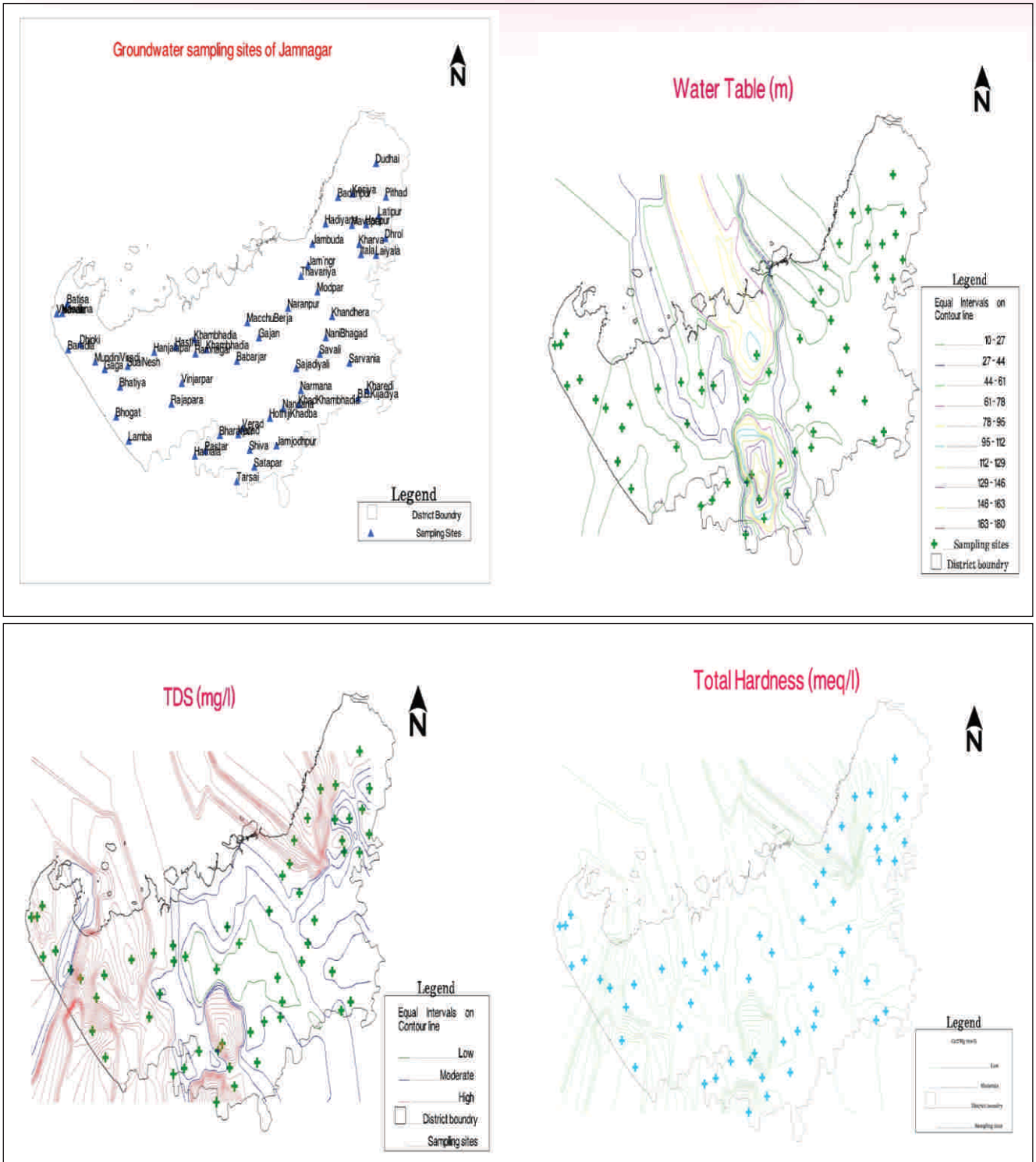

Fig.5.13 : Location map of groundwater sampling sites along with contour maps of water table, TDS and total hardness of groundwater of Jamnagar District

6. TRANSFER OF TECHNOLOGIES

6.1 Transfer of Technology to Farmers (Ludhiana Centre)

6.1.1 Seminars / Conference / Symposia / Workshop

Scientists working in AICRP participated in 11 seminars, conferences, symposia, workshops etc. The scientist also delivered 23 invitation lectures to the user departments and farmers in 18 training programmes. They also delivered four lectures in "In house training for B. Tech. Final year students. In addition to this scientist attended six Kisan melas.

6.1.1 Participation in seminars, conferences, symposia, workshops etc.

SN	Programme	Date	Name of Scientist
1.	Brainstorming workshop on "Climate Change and Sustainability of Agriculture" At-PAU, Ludhiana	6th Feburaury.,2013	Dr. R. Aggarwal
2.	Talk on IPR and Commercialization of Technologies	March 6.,2013	Dr. R. Aggarwal
3.	Panel discussion on "Scenario of Water resources in Punjab" At-Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahaib	March 22.,2013	Dr. R. Aggarwal
4.	Workshop on "Capacity building in national planning for food security" At- PAU, Ludhiana	July 4, 2013	Dr. Sunil Garg
5.	Research and Extension Specialists Workshop for Soil &Water Conservation. At- PAU, Ludhiana	July 8, 2013	Dr. R. Aggarwal
6.	A National Workshop on "Water quality issues, opportunities and sociocultural concerns of wastewater use in agriculture" At- Directorate of Water Management, Bhubaneswar, Odisha	7-8 August.,2013	Dr. R. Aggarwal
7	Research and Extension Specialists Workshop for *Rabi* crops At- PAU, Ludhiana	23-24 August,2013	Dr. Sunil Garg
8	Sensitisation Workshop on Enhancing Water Use Efficiency in the Yamuna Basin At- NASC Complex, New Delhi	30th August.,2013	Dr. R. Aggarwal
9	Advances in water resources development and management 2013 At- Panjab University, Chandigarh	23-27, October, 2013	Dr. Samanpreet Kaur
10.	India Water Forum 2013 International Convention on Water use efficiency. At- India Habitat Centre, New Delhi	28-30, October, 2013	Dr. R. Aggarwal
11.	Exhibition organized by Punjab Govt. At-Govt. College for girls, Ludhiana	1-3, Nov, 2013	Dr. Sunil Garg

6.1.2 Scientists conducted and participated in training programmes and delivered lecturers and interacted with the beneficiaries

Sr. no	Programme	Venue/Organiser	Days	Date	Participants (Nos)	Name of Scientist
1.	Field evaluation of drip irrigation system	PFDC, Soil & Water Engginering, PAU, Ludhiana	1	26/4/2013	20	Dr. Sunil Garg
2.	In-house Training Programme to B.Tech. Final	College of Agril. Engg. & Tech.	2	23/12/13 & 30/12/13	24	Dr. Rajan Aggarwal Dr. Sanjay Satpute
3.	In-house Training Programme to B.Tech. Final	College of Agril. Engg. & Tech.	2	24/12/13 & 31/12/13	23	Dr. Sunil Garg

6.1.3 Invited lectures

Scientists delivered a total of twenty invited lectures on different aspects of natural resource management, integrated watershed management, rain water harvesting, groundwater utilization and participatory irrigation water management in canal commands.

6.1.4 Technology dissemination

Irrigation scheduling of drip irrigated spring maize by Dr. Rakesh Sharda, Dr. Sunil Garg and other scientists from other departments was recommended by REC.

A committee constituted by Punjab State Power Corporation limited, Patiala for deciding the current taken by motors due to voltage fluctuation and declining of water table in Agricultural pumping system. Report was prepared and submitted to Punjab Govt by Dr A K Jain, Dr Sunil Garg and other members from PSPCL.

Plate 6.1 Demonstration on rain water harvesting through roof top for groundwater recharge

6.1.5 Kisan melas

All the scientist of the scheme participated in Kisan Melas at the main campus in 16-17 March, 2013. Also Dr. Rajan Aggarwal at Amrirsar on 5th March, 2013, Dr. Sunil Garg at Ballowal Saunkri on 1st March, 2013, Dr. (Mrs.) Samanpreet Kaur at Gurdaspur on 7th March, 2013. All the scientist participated at PAU, Ludhiana Kissan Mela on 13-14 September, 2013 and Dr. Rajan Aggarwal at Ballowal Saunkri on 4th September, 2013, Dr. Sunil Garg and Dr (Mrs.) Samanpreet Kaur at Bathinda on 20th September, 2013, Er. Chetan Singla at Rauni, Patiala on 18th September, 2013 regional stations to show various technologies developed in the scheme.

6.2 Transfer of Technology (Pantnagar Centre)

6.2.1 Kisan mela

Technology developed in the projects and other related technology were displayed at the Kisan Mela and Industrial exhibition held from 8 to 11 March 2013 and 4 to 7 October 2013 as shown in Fig 4.1 & 4.2. Each fair was visited by more than 5000 farmers and people from Agro based industries. Department of Irrigation and Drainage Engineering took this opportunity to educate farmers regarding various aspects related to technology developed in the project like Foot valves, Propellor pump beside use of various irrigation methods like drip irrigation and micro- Irrigation *etc.*.

6.2.2 Farmers' trainings

To acquaint the farmers of Uttarakhand and visitors of other states, with the development of propeller pump, foot valves, and to educate them regarding the selection of pumps and pipe fittings to achieve the high efficiency of the pumping system, optimal utilization of available land and water resources, and their efficient management, invited lectures

Plate 6.2 Pantnagar Propellor pump (developed by GWU Pantnagar) at Kisan Mela

Plate 6.3 Pantnagar Foot valve (developed by GWU Pantnagar) at Kisan Mela

were delivered to the farmers with the collaboration of extension department of the University. Scientists of the centre have delivered lectures on various occasions on pumps, wells as well as pollution aspects of water resources.

6.2.3 Kisan gosti

The Kisan Gosti was organized in all four days in both the Kisan Mela. The question answer session were organised and discussions on various questions of farmers related to wells, pumps and irrigation issued were discussed.

6.3 Transfer of Technology (Rahuri Centre)

6.3.1 Demonstration

Recharge techniques for artificial groundwater recharge of open well and bore well were demonstrated at Instructional Farm of Department of Irrigation and Drainage Engineering, Dr.ASCAE, MPKV, Rahuri

6.3.2 Training

Two days training of recharge techniques for artificial groundwater recharge was conducted at Grampanchayat Hall, Village-Nimboni, Tal-Nandurbar, Dist- Nandurbar on 24.9.2013 and 25.9.2013.

Sr.No.	Activity	Period	Details of farmers visited
1.	1. Groundwater recharges technique for open well. 2. Groundwater recharges technique for bore well.	October 2013 to December 2013	• Approximately 200-250 farmers from the different districts of Maharashtra state visited the demonstration site of AICRP on Groundwater Utilization Project. • 20_25 Gov ernment officers from the Department of Horticulture, Goa State visited the demonstration plots.

Sr. No.	Activity	Duration	Details of farmers attended the training
1.	Groundwater recharge technique for open well & bore well	Two day	70 farmers of villages Nimboni, Karanjani, Borchek, Dongitwai of Nandurbar District attended the training at Nimboni village. Training was inaugurated by Dr. P.A.Turbatmath, AssociateDean, Dr.Annasaheb Shinde College of Agril. Engineering, MPKV,Rahuri. Dr.S.D.Dahiwalkar,RE, GWP, Er.K.G.Pawar, JRA, GWP, Shri.E.K.Kadam, Agril.Asst. conducted and delivered lectures/practicals to the farmers.

Plate 6.4 & 6.5 Farmers training programme and discussion meet 24.9.2013 and 25.9.2013

6.3.3 Radio talks

The programme "Groundwater recharge technique" on AIR, Pune was delivered by Dr.S.D.Dahiwalkar broadcasted on 5/5/2013.

6.3.4 Meetings

1. The Research Review Committee Meeting of Agricultural Engineering group held on April.22-23, 2013 at Meeting Hall, Directorate of Research, MPKV, Rahuri.
2. A meeting with farmers of Nimboni, Borchek, Karanjani, Dhong Itwai villages of Nandurbar Tahsil and staff of KVK, Nandurbar regarding planning and implementation of Tribal Sub Plan activities under AICRP on Groundwater Utilization for the benefit of farmers was held at KVK, Nandurbar on 25.09.2013 at 11.00 AM under the chairmanship of Associate Dean, Dr.Annasaheb Shinde College of Agricultural Engineering, MPKV, Rahuri. During this meeting the discussion was held on implementation of Tribal Sub Plan activities in four villages. The farmers expressed their views regarding the facilities needed on their farm specifically regarding provision of drip and sprinklers irrigation sets
3. The Research Review Committee Meeting of Agricultural Engineering group held on January.06-07, 2014 at Audio visual Hall, MPKV, Rahuri.

6.3.5 Workshop

1. Dr. S. D. Dahiwalkar, Dr. S. D. Gorantiwar, Er. S. A. Kadam and Er. K. G. Pawar attended the Biennial Workshop of AICRP on groundwater Utilization and AICRP on Water Management were held at Navsari Agricultural University, Navsari (Gujarat) during 29th July to 1st August 2013.

6.3.6 Conference

1. Dr.S.D.Dahiwalkar, Research Engineer and Er. S.A. Kadam attended SWARDAM-2013, two days National conference on Sustainable water resources: Development and Management held at Government Engineering College, Aurangabad during Sept.30-Oct.1, 2013 and presented four research papers.
2. Er. S. A. Kadam attended VISHOTECH-2014 two days National Technical Symposium held at Vishwabharti Academy's College of Engineering, Ahmednagar, held during February, 2014 and presented a research paper.

6.3.7 Visits

1. Dr. Budhajirao Mulik an expert Agricultural Engineering consultant & founder of private Agril. Engg. College visited the project and discussed the activities of the project.
2. The staff of AICRP on Groundwater Utilization visited the command area (Nimboni, Karanjani, Borchek and Dong-Itwai villages of Nandurbar District) selected for TSP programme and discussed the planning and implementation of TSP programme with the authorities of KVK, Nandurbar in the month of October2013.
3. The staff of Groundwater project has visited the farms of Department of Horticulture, Agriculture Science and Dairy Science and pathology for resistivity survey of the bore well spot selection and to provide the guidance for artificial groundwater recharging .The farmers from the Rahuri and Newasa Tahsil visited this project for guidance in respect of artificial groundwater recharging of open wells. The necessary guidance and literature provided to the farmers.

6.3.8 Awards

1. Er. S. A. Kadam was awarded the first prize (Certificate, Memento and cash prize Rs. 5000/-) for the best paper presentation in VISHWOTECH-2014, two days National Level Conference held at Vishwabharti Academy's College of Engineering, Ahmednagar during 21-22 February, 2014.

6.3.9. Human Resources Development

1. Er. K. G. Pawar, Junior Research Assistant, completed the training on Participatory Training Management, held at Directorate of Extension, MPKV, Rahuri, during 23-25 January 2014 (3 days)
2. Dr. S. D. Dahiwalkar attended the training on, "MATLAB Applications for Soft Computing and Simulation in Agriculture", heat at Department of Farm Structure and Rural Electrification, Dr. ASCAE, MPKV, Rahuri during Feb. 3-11, 2014
3. Er. S. A. Kadam attended the training on, "MATLAB Applications for Soft Computing and Simulation in Agriculture", heat at Department of Farm Structure and Rural Electrification, Dr. ASCAE, MPKV, Rahuri during Feb. 3-11, 2014

6.4 Transfer of Technology (Jabalpur Centre)

6.4.1 Farmers /WUA Meeting

A farmers meeting was organized at village Mohgaon, a tribal village of Kundam block of Jabalpur district, on 26th February 2014. Farmers of the villages Mehgawan, Sanjari, Supawara, Khitola, Hinota, Padariya, Bichua, Nawargawan, Tikaria, Keolari and other neighbouring villages were actively participated. They were made aware of efficient utilization of natural resources, storage and conservation of rain water which may be used to improve crop production. They were informed about scientific techniques of water conservation with available government subsidy on the well and tubewell digging. The farmers were explained the importance of increasing water productivity.

Plate 6.6 Farmers Meeting at Mohgaon village

Plate 6.7 WUA meeting at Imaliya village

WUA meeting for improving water productivity

In the context of capacity building of WUA for increasing water productivity in command area, a meeting was arranged in Imaliya village of Mala command in Jabera block of Damoh district. This command covers 27500 ha area of 14 villages. About 50 WUA members/ farmers with RAEO's of three villages namely – Mala, Bhamhori and Imaliya were gathered for this meeting. Emphasise was given on enhanced production in limited supply of water by the use of improved quality inputs with sprinkler and Drip irrigation methods.

WUA meeting for improved irrigation management

A WUA meeting on improved irrigation management was organized on 3rd march of 2014 in Bhonhari Village of Sagar district. Total 73 WUAs participated in this meeting. Farmer's field visit was conducted and interactions were made with farmers and scientists on different water management aspects.

6.4.2 Trainer's training for improving water productivity

A two days training on improving water productivity was held on May 23-24, 2013 at department of Soil and Water Engineering, College of Agricultural Engineering, JNKVV Jabalpur. Development of techniques and education of farmers about the integrated use of water with the aim to improve water productivity in the selected basin was emphasised.

Discussions was focused on -

- Productivity improvement through variety replacement
- Increasing WUE through Improved irrigation Management
- Diversified cropping system for higher water productivity
- Nutrient and Crop protection measures to achieve better WUE

Plate 6.8 & 6.9 Trainer's training program

Training of Officers

Four trainings in which three are of five day duration and another one was one day, conducted at CAE Jabalpur. Total 50 officers were trained as trainers training. Following were the titles of the trainings-

- Agricultural Thematic mapping using RS & GIS.
- Modern Techniques of Agricultural & Horticultural Crop Production
- Agricultural Water Management for water productivity
- SRI Cultivation of Paddy.

6.4.3 Capacity building of Water Users Association (WUAs)

WUA trainings at KVKs – There were 23 trainings of 1-2 days duration were conducted in different KVKs. The main topics discussed were 1) Quality measure for improvement of produce role of water, 2) Post harvest of technique of food grain storage, 3) Organic farming and IPM in irrigated agriculture, 4) Improved technology of wheat cultivation in command areas, 5) Enhancing water productivity in wheat crop, 6) Improve production techniques of horticultural crops and water management, 7) Critical stage of crops and suitable water management, 8) Organic farming and Integrated Nutrient Management, 9) Rain water management in *Kharif* crop for increasing the water productivity. Use of water with special reference to Drip Irrigation, Sprinkler irrigation system to enhance the Productivity of Horticultural crops. Total 1150 farmers participated at nine locations during *Kharif* and *Rabi* season.

6.4.4 Demonstration and trainings

Demonstrations of water measuring devices were given to farmers, Agriculture and Horticulture Officers, Students of Agricultural Engineering, Civil Engineering, Forestry. The laboratory is equipped with live true to the size measuring devices like V-notch, Parshall flume, cut throat flume, rectangular weir, Pump testing unit and H-flume.

Plate 6.10 & 6.11 Trainer's training program

6.5 Transfer of Technology (Coimbatore Centre)

6.5.1 Field demonstration

Demonstration on Water Management for Higher Productivity of Crops for Tribal Farmers was conducted at Bellathy village, Manjur Taluk, The Nilgiris which is a Tribal village only. 100% population is tribal people. It is a hilly region and the crops grown in the village are Tea and vegetables (carrot, cabbage, cauliflower etc)

Plate 6.12 Demonstration

Plate 6.13 Demonstration

Plate 6.14 Training

6.5.2 Conferences

Dr. C. Mayilswami, Dr. P.Jothimani and Dr.A.Valliammai, ICAR-AICRP- Groundwater Utilization Scientists attended the National Groundwater Conference (NGWC 2013) held at Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore on December 09-11, 2013.

6.6 Transfer of Technology (Udaipur Centre)

6.6.1.Trainings

- Organized five days training programme of WDT, Integrated Watershed Development Project, Govt. of Rajasthan during 08th - 12th July, 2013 at CTAE, Udaipur.
- Organized fifteen days PARA Engineers Training Programme sponsored by ITC Limited, Jaipur during 11th - 25th September, 2013 at CTAE, Udaipur.
- Organized three days training programme of Farmers on Watershed Management sponsored by World Vision India, Tonk during 11th - 13th November, 2013 at CTAE, Udaipur.
- Organized seven days Refreshers PARA Engineers Training Programme on Watershed Management sponsored by IGWDP, NABARD, Jaipur during 22nd - 28th December, 2013 at CTAE, Udaipur.
- Organized fifteen days PARA Engineers Training Programme on Watershed Management sponsored by ITC Limited, Jaipur during 23rd December, 2013 - 06th January, 2014 at CTAE, Udaipur.
- Organized fifteen days PARA Engineers Training Programme on Watershed Management sponsored by IGWDP, NABARD, Jaipur during 06th - 20th January, 2014 at CTAE, Udaipur.

Plate 6.15 Participated in Kisan Mela organized by ATMA at KVK, Badgaon

Plate 6.16 Participated in Agriculture Science Fair organized by NAIP at Banswara on 28.03.2014

6.6.2 Human Resource Development

National Conference / Seminar

The following staff members attended the national training programme / seminar / conference to improve their skill and understanding in the respective field.

S.No.	Name of the Staff	Training / Seminar
1.	Dr. P.K. Singh	• Attended Annual Conventional of ISAE organized at CTAE, Udaipur during 21-23 February, 2014.
2.	Dr. K.K. Yadav	• Attended the training programme on Remote Sensing and GIS Applications in Natural Resource Management organized by NBSS & LUP, Regional Centre, Udaipur and sponsored by ISRO under NNRMS Programme during 10th-30th September, 2013. • Attended the 7 8th Annual Convention of the Indian Society of Soil Science (ISSS) held during October 23 -26, 2013 at the Central Arid Zone Research Institute (CAZRI), Jodhpur. • Attended the "Base -map Preparation Training on GIS Plateform" organized by Arid Communities and Technologies, Bhuj under MARVI-ACIAR Project during 20th May to 23rd May 2013.
3.	Er. Manjeet Singh	• Attended Annual Conventional of ISAE organized at CTAE, Udaipur during 21-23 February, 2014.

6.7 Transfer of Technology (Pusa Centre)

6.7.1 Participation in kisan mela -2014

Kisan Mela was organized by Rajendra Agricultural University during 08-10 March, 2014. A stall was arranged by the scientists and technical staffs of the GWU scheme to increase the awareness in safe exploration and utilization of groundwater. The farmers were educated on the various aspects like care and maintenance of diesel pumping systems, an application of Raingun irrigation systems and their queries about the availability and Government's schemes for promotion of such technology etc. Farmers were also acquainted with importance of various groundwater quality parameters, their application in field crops, causes of groundwater contamination and their remedies in relation to human health and better sustainable crop production, through pictorial presentation. The scientists of the centre participated in the *Kisan Gosthi* organized on this occasion and replied to the queries of participating farmers.

6.7.2 Organization of a field day

A field day was organized at the tribal village *Katraon* of West Champaran District of Bihar jointly with 'Water Management' team. A total of 45 tribal farmers (34 male + 11 female) participated. The scientists of the centre interacted with the farmers and responded to the various problems of the farmers.

Plate 6.17 Field Day

Plate 6.18 Kisan Mela

6.8 Transfer of Technology (Raipur Centre)

6.8.1 Demonstration of technology

Various working models of surface water conservation and groundwater recharging were prepared and displayed in the "National level Krishi Vigyan Mela" held at IGKV, Raipur from 22/02/2014 to 25/02/2014. Many farmers and general public have been aware of these models by receiving knowledge of surface water conservation and groundwater recharging. Several lectures related to technology generated under AICRP on GWU were also delivered during the training programme and Krishi Mela organized by the IGKV, Raipur.

6.8.2 Activities under tribal sub plan

Activities related to the upliftment of tribal farmers of the region by increasing the water use efficiency and in turn get better returns were conducted. In these context, four sites were selected *viz*. 1. Vill - Parsadih, Block - Mahasamund, Dist. Mahasamund, 2. Vill - Dhangaon, Block - Bemetara, Dist. Bemetra, 3. Vill - Aturgaon, Dist. Kanker and 4. Vill. - Aurang, Block - Charama, Dist. Kanker. Diesel operated pumps of 5 and 3 HP were provided to the farmers on group basis for better utilization of the given items. The pumps in conjunction with PVC pipes were used to lift water from distant nala and water bodies and will help in providing irrigation water with minimum losses. Drip and Sprinkler system were also provided to the farmer groups for efficient utilization of stored water.

Plate 6.19 & 6.20 Lift irrigation system installed and brought to operational at Vill. Parsadih

Plate 6.21 Technology demonstrated and transferred to farmers

Plate 6.22 *Krishak Sangosthi* organized at Vill. - Parsadih, Dist. & Block - Mahasamund on 12/02/2014 for creating awareness regarding optimal use of water

Plate 6.23 Visit of Dr. Ashwani Kumar, PC, AICRP on GWU, Bhubaneswar along with Dr. Anwar Alam, Ex VC and Board member IGKV, Raipur to the integrated farming system model at Vill. Markatola, Dist. - Kanker on 02/03/2014

Plate 6.24 - Distribution of 3 HP diesel pump set to the Farmers group of Vill. - Aturgaon, Dist. - Kanker by Dr. Ashwani Kumar, PC, AICRP on GWU, Bhubaneswar in the presence of Dr. Anwar Alam, Ex VC and Board member IGKV, Raipur and other dignitaries on02/03/2014

6.9 Transfer of Technology (Junagadh Centre)

6.9.1 Human resources development

Participation in Krushi mahostav and mela's :
The scientist of AICRP scheme participated in the one month mega event "Krishi-Mahotsav 2013". Krishi-Mahostav was organized by Government of Gujarat from 14/05/2013 to 10/06/2013. During 'Krishi-Mahostav' scientists along with the staff of line departments, bank, forest, health and NGO's visited different villages and transferred innovative agro techniques & knowledge to the farmers.

Plate 6.25 Hon'ble Chief Minister, Govt of Gujarat Shri Narendra Modi inaugurated month-long Krishi Mahotsav-2013 at Jamjodhpur Taluka of Jamnagar District.

Plate 6.26 Scientists of AICRP Junagadh Center Participated in Krushi Mahostav-2013.

6.9.2 Technology demonstration

Demonstrated live models of drip, sprinkler and watershed based soil water conservation technologies along with recharge techniques in Krushi mela-2013 at Jam Jodhpur Taluka of Jamnagar District during 25-26/05/2013.

Plate 6.27 Live demonstration of drip and sprinkler irrigation system in Krushi mela-2013 at Jam Jodhpur

Plate 6.28 Demonstration of live watershed model and water recharge techniques at Jam Jodhpur krushi mela during 25-26/05/2013

Successfully demonstrated conjunctive use of surface water with groundwater for irrigating wheat crop in 3 hectare area at instructional farm college of Agricultural Engineering and Technology, JAU, Junagadh.

Plate 6.29 Conjunctive use demonstration

Sprinkler set distribution to TSP farmers by Mr. Babubhai Bokhiriya, Hon. Min. of Agric., Gujarat Govt., Gandhinagar on 16.08.2013

Plate 6.30 Sprinkler set distribution to TSP farmers, by Mr. Babubhai Bokhiriya, Hon. Min. of Agric., Gujarat Govt., Gandhinagar

6.9.3 Trainings / Workshop

Two- Days Farmers training program on "BHUGARBH JAL SANCHAY ANE TENO KARYAKSAM UPAYOG" was organized during March 4-5th - 2013 Total 63 farmers from Rajkot and Junagadh district have participated the training program During the training program, lectures on importance of water for agriculture, various methods of groundwater recharge, Modern water use efficient irrigation methods, use of poor quality of water for agriculture and its effects on soils, applications of plastics in water management, cultivation in net house and green house, Proper selection of pumping machinery for the minimization of energy inputs, importance of selection of pure quality of seeds, scientific approach in cultivation of major crops of this region like cotton, wheat and groundnut were delivered by concerned experts and discussion was held between experts and among farmers. The visits of campus museum, green house, net house, cattle breeding farm, instructional farm of CAET etc were held.

Seminar organized on " Pakmaa Sukshm Tatavo ni Agatyata" on 25/05/2013 during Krushimela-13 at krushi Gyan Vatika – Jamjodhpur.

Training program on Sprinkler irrigation for the tribal farmers on 16.08.2013 at JAU, Junagadh jointly by NICRA and AICRP-GWU, Junagadh centers

Plate 6.31 Field visit During farmers training at fields of progessive farmers

Plate 6.32 Krishi Mela 2013

Review meeting of NICRA project

The review meeting for the different centers of NICRA under DWM, Bhubaneshwar was organized by NICRA, AICRP on Groundwater Utilizations, JAU Junagadh centre at JAU, Junagadh during November, 22-23, 2013. Total 38 delegates/scientists attended the meeting. Dr. Ashwani Kumar, Director, DWM, Bhubaneshwar, in his inaugural speech, emphasized the development of location specific technologies to make the agriculture climate resilient. He highlighted various issues and challenges for the sustainable agriculture under changed climate. Dr. N. C Patel, Hon. Vice Chancellor, JAU, Junagadh highlighted the outcomes of the NICRA, Junagadh centre.

6.9.4 Human Resource Development

Participation in workshop/ seminar/ conference/ Group meet etc (State /National/International level) :

1.	Dr. H. D. Rank, Research Engineer
	1. Workshop on "Groundwater Resource management with emphasis on artificial recharge and rainwater harvesting." Organized by CGWB, Ahmadabad on March 5, 2013. 2. National Conference on capacity building of farmer on tools techn iques and application of weather forecasting - an integrated adaption perspective organized during March 15 -17, 2013, held at AAU Anand. 3. Workshop of AICRP on Application of Plastics in Agriculture organized by JAU and CIPET, ICAR, Junagadh during September 7-8, 2013. 4. "Pradhyapak Samelan" on "Present Problems and Solutions in Education" to be organized by PGIABM, JAU, Junagadh on 30.09.2013. 5. Seminar on "Bio -safety and changing needs of the nation" organized by BioTechnology deptt., JAU, Junagadh, National Mission on Biotechnology and GUJCOST, Deptt. of Science and Technology, Gandhi agar on 01.10.2013. 6. National Seminar on "Climate Change Impacts on Water Resources System" organized by PIET, Vadodara during November 27 -29, 2013. 7. Workshop on "New Dimensions in Extension Education" organized by EEI, Anand and DEE, Junagadh during December 05-07, 2013.
2.	P. B. Vekariya, Asstt. Professor.
	1. Orientation programme on all subject from 2 nd December 2013 to 29 December 2013 at Academic staff college, Saurastra University, Rajkot. 2. Workshop of AICRP on Application of Plastics in Agriculture organized by JAU and CIPET, ICAR, Junagadh during September 7-8, 2013.
3.	P.G. Vadher, Assoc. Professor.
	1. Symposium on managing natural resources for enhancing agricultural and a llied productivity in coastal regime under changing climate during December 11 -14, 2013 at RRS CSSRI Bharuch. 2. Workshop of AICRP on Application of Plastics in Agriculture organized by JAU and CIPET, ICAR, Junagadh during September 7-8, 2013.

6.9.5 Awards

Best Teacher Award: Dr. H. D. Rank, Research Engineer won best Teacher award for the year 2011-12 instituted by JAU and ICAR

Research Paper Award : Dr. H. D. Rank, Research Engineer won Nagesh Kumar Award for the paper on "Climate Change Impact on Crop Water Requirements in South Saurashtra Region Of Gujarat State" authored by *Harji D. Rank, Pankaj J. Rathod and Hiren P. Patel.(2013)* presented in National Seminar on Climate Change Impacts On Water Resources System India (Nov 27-29, 2013 at PIET, Vadodara) and published in book : Shete D T. (2013). Climate Change Impacts On Water Resources System. Execll India Publishers, New Delhi.

Plate 6.33 Best teacher award to Dr. H D Rank, by Mr. Govindbhai Patel, State Agric. Min., GOG, Gandhinagar

Plate 6.34 Award giving away to Dr. H D Rank, by Dr. B S Arya, Professor, IIT, Roorkee.

6.9.6 Visitors

Prof Ainamensa Mchau, Dean Agriculture, University of Venda, South Africa Visited AICRP on GWU Junagadh Center on September, 25-27, 2013 and appreciated work of project.

Plate 6.35 Prof Ainamensa Mchau, visiting AICRP on GWU Junagadh Center

6.9.7. Lectures/ Radio talks

Dr. H. D. Rank, Research Engineer

1) Live telecast lecture through BISAG studio Gandhinagar on "Suksma piyat padhdhti naa faayadao" on 22/04/2013 under ATMA Project
2) Live telecast lecture through BISAG studio Gandhinagar on "Jalsanchay and Teno Karyaksham Upyog" on 20/05/2013 under ATMA Project

Dr. P. B. Vekariya, Assistant Professor

1) Live telecast lecture through BISAG studio Gandhinagar on "Bhugarbh jal recharge ni vividh padhdhtiyo" on 22/04/2013 under ATMA Project.

Dr. P.G. Vadher, Assoc. Professor

1) Radio Talk on Piyat Pani ni Gunavata, All India radio,Rajkot, on date 13/09/2013, Forum question reply on 23/09/2013

7. LIST OF PUBLICATIONS DURING 2013-14

7.1 Publications of Ludhiana Centre

1. Kaur S, Lubana P P S and **Aggarwal Rajan** (2013) Groundwater management for adaptation under changing climate conditions in Indian Punjab. Journal of Water and Climate Change 04.1: 38-51.
2. **Satpute S T,** Singh Man, Khanna M, Singh A K and Ahmad T (2013) Response of drip irrigated onion (*Allium cepa* L.) crop to irrigation intervals and fertigation strategies. Indian Journal of Horticulture, 70(2): 293-295.
3. Singh M C, Jain A K and **Garg S** (2013). Simulation of soil moisture movement under rice field using HYDRUS-2D. Crop Res**. 45**(1,2 & 3):45-53
4. **Garg S**, Bhardwaj A, Taneja D S and Sondhi S K (2013). Performance evaluation of solar photovoltaic (SPV) pumping system under field conditions. Water and Energy International. **70** (8):16-21

Invited Paper:

1. **Aggarwal Rajan.** 2013, Management of wastewater use through integrated application of irrigation system, land modifications and cropping in a National Workshop on "Water quality issues, opportunities and socio-cultural concerns of wastewater use in agriculture" at Directorate of Water Management, Bhubaneswar, Odisha. August 7-8., 2013.
2. **Aggarwal Rajan.** 2013, Issues & Opportunities in Integrated Water Management in Punjab in a "Sensitisation Workshop on Enhancing Water Use Efficiency in the Yamuna Basin" at NASC Complex, New Delhi. 30th August, 2013

Paper Presented and abstract Published:

1. **Kaur S,** S K Jalota and **Rajan Aggarwal** (2013). Impact of Climate Change Scenario on yield and irrigation water requirements of Rice-wheat cropping system in central Punjab. International conference on Advances in water resources development and management 2013 held at Panjab University, Chandigarh. In Souveneir. PP56
2. Rangaranjan R, **Rajan Aggarwal, Samanpreet Kaur** and Harinder Singh (2013). Impact of Precision Land Levelling of Irrigated field as an effective water conservation measure-a case study in overexploited central Punjab region. International conference on Advances in water resources development and management 2013 held at Panjab University, Chandigarh. In Souveneir. PP40-41
3. **Singla Chetan, Garg Sunil, Aggarwal Rajan** and Jutla Antarpreet (2012). Are Industrial Towns Safe for Human Dwelling? Poster presented at American Geophysical Union's Annual Meeting, San Fransisco, December 3 - 7, 2012
4. Press Release

Hindustan Times e-Paper

PAU researcher gets Netherland's fellowship

HT Live Correspondent
ludhiana@hindustantimes.com

LUDHIANA: Chetan Singh, assistant research engineer at department of soil and water engineering, Punjab Agricultural University (PAU), has been awarded a fellowship under the Netherlands Fellowship Programme (NFP).

A university spokesperson on Monday said that Singh would be attending a short course on "Groundwater Resources and Treatment" as a part of this fellowship from March 4 to March 22 at Delft, the Netherlands.

The course will be hosted by UNESCO-IHE Institute for Water Education, The Netherlands.

Singh is the only Indian scientist who has been selected for the fellowship this year. At present, he is working on all India coordinated research project on "Groundwater Utilisation."

Newspaper: Hindustan Times

Asst research engineer shortlisted

Punjab Agricultural University

Assistant research engineer, department of soil and water engineering, PAU, Samanpreet Kaur Baweja, has been selected for international training under the human resource development programme of national agricultural innovation project, Indian Council of Agricultural Research. She shall attend the two-month training programme on "Geoinformatics for natural resource management" under the guidance of Rattan Lal of Carbon Management and Sequestration Centre at Ohio State University, US. Baweja is currently working at PAU on the All India Coordinated Research Project on groundwater utilization.

Newspaper: Times of India

Rainwater harvesting yet to take root in city

Even as large amount of water goes down the drain everytime it rains, MC has failed to ensure that rainwater harvesting plants are installed in city

HT | Ive Correspondent

In monsoon, a lot of water goes down the drain. It damages the roads and sewerage system. All this can be solved with RWHP plants

RAJAN AGARWAL
soil research engineer, PAU

Newspaper: Hindustan Times

पी.ए.यू. को मिला करोड़ों का प्रोजैक्ट

लुधियाना, 24 मई (सलूजा): पंजाब कृषि यूनिवर्सिटी को ग्राऊंड वाटर रिसोर्स मैनेजमैंट विषय से संबंधित बहुकरोड़ी खोज प्रोजैक्ट मिला है। यह जानकारी देते हुए सीनियर रिसर्च इंजीनियर डा. राजन अग्रवाल ने बताया कि 1 करोड़ 25 लाख के इस प्रोजैक्ट के अधीन वैज्ञानिक यह खोज करेंगे कि वातावरण में व्यापक स्तर पर आ रही तबदीली का पंजाब व हरियाणा पर क्या प्रभाव पड़ रहा है। उन्होंने बताया कि इस प्रोजैक्ट का समय 4 साल निर्धारित किया गया है।

Newspaper: Punjab Kesari

7.2 Publications of Pantnagar Centre

Research article

Kadam Satish Arjun; Shiv Kumar; **Yogendra Kumar and H.C. Sharma** (2013) Effect of fertilizer factory efficient on wheat crop A case study. Access ***International Journal of Agricultural Sciences***, Vol. 1(7) pp 81-90.

Singh, Ramesh; Ambrish Kumar and **H.C. Sharma** (2013) Modelling of reference evapotranspiration using Fuzzy logic rule based algorithm for sub-humid climate in mid-Himalayas. ***Indian Journal of Soil Conservation***, 41(3) : 227-233.

Seminar/Symposia/Conference/Workshop

Rupak Sarkar, Shiv Kumar, **Yogendra Kumar and H.C. Sharma** (2013) Water Table Fluctuations and groundwater Budget in Ramganga-Bahgul Interbasin of Western Uttar Pradesh Paper presented in ***International Symposium on "Bio-Energy - Challenges and Opportunities"*** held on January 2013, 28-30, at Hyderabad, India (SWC-GWM-02)

Yogendra Kumar, Shiv Kumar and **H.C Sharma** (2013) Ground and Surface Water Pollution in Vicinity of Industries In Tarai Region of Uttarakhand. Paper presented in ***International Symposium on "Bio-Energy - Challenges and Opportunities"*** held on January 28-30, 2013, at Hyderabad, (INDIA SWC-GWM-03)

Harish Chandra and **H.C. Sharma** (2013) Optimal Resource Management in Khaziya Minor Command In; Souvenir 47th Annual convention of Indian Society of Agricultural Engineers and ***International Symposium on "Bio-Energy - Challenges and Opportunities"*** held at Acharya N.G. Ranga Agricultural University, Hydrabad from January 28-30, SWC-OFWM-03, PP-146.

Harish Chandra; H.C. Sharma and P.K. Singh (2013) Assessment of surface water supply, groundwater balance and crop water requirement for conjunctive use in Mahadev distributary command area. In; Souvenir of ***National seminar on Conservation and Protection of groundwater*** held at Dehradun on September, 19-21.

Mishra S Sangita, **H.C Sharma** and Ambrish Kumar (2013) Rainfall Analysis for Crop Planning in Upland Watershed in Sub-Humid Climate of North- West Himalayas. Paper presented *in* ***International Symposium on "Bio-Energy - Challenges and Opportunities"*** held on January 28-30, 2013, at Hyderabad, India (SWC-HYDRO-07)

Ramesh Singh, R.K Tewari, S.K Dhyani and **H.C Sharma** (2013) Impact of Watershed Interventions on Runoff, Soil Loss and Water Availability in Drought Prone Bundelkhand Region Paper presented in ***International Symposium on "Bio-Energy - Challenges and Opportunities"*** held on 28-30 January, 2013, at Hyderabad, INDIA (SWC-WSHD-04)

Sharma, H.C. and Ambrish Kumar, (2013). Estimation of specific yield for Budaun district using lithological data. Proceedings of the All India Seminar on ***"Conservation and Protection of Undergroundwater"*** held at Dehradun on

September 20 - 21, 2013, pp. 114 - 127.

Ambrish Kumar and **H.C. Sharma**, (2013). Unsteady groundwater flow optimization strategies in lower Ghaggar Basin in Trans - Gangetic plains. Proceedings of the All India Seminar on ***"Conservation and Protection of Undergroundwater"*** held at Dehradun on September 20 - 21, 2013, pp. 128 - 146.

Shrivastava, R.K., **H.C. Sharma** and Ambrish Kumar, (2013). Morphometric analysis for watershed prioritization. Proceedings of the All India Seminar on ***"Conservation and Protection of Undergroundwater"*** held at Dehradun on September 20 - 21, 2013, pp. 160 - 178.

Mishra S., **H. C. Sharma** and Santosh Pingle (2013) Morhometric characterization of Henvel water shed of Uttarakhand using GIS. All India Seminar on ***" Recent advances in watershed Development Programme"*** Institution of Engineers (India) held on August 5-7, 2013. at Ahamad Nagar

7.3 Publications of Rahuri Centre

Research article

Kadam S. A. and S. D. Gorantiwar. 2013. Estimation of different Vegetation Indices based on Hyperspectral data. Proceedings of National Conference SWARDAM-2013, Department of Civil Engineering, Government College of Engineering, Aurangabad, Maharashtra, Mumbai. (ISBN: 978-93-82880-63-9)

Kadam S. A., S. D. Dahiwalkar, S. D. Gorantiwar and K. G. Pawar. 2013. Impact of Municipal Waste Water on groundwater Quality. Proceedings of National Conference SWARDAM-2013, Department of Civil Engineering, Government College of Engineering, Aurangabad, Maharashtra, Mumbai. (ISBN: 978-93-82880-63-9)

S. D. Gorantiwar and S. A. Kadam. 2014. GIS and Remote Sensing Applications in Natural Resources Management. (Lead Paper in Technical Session III in State Level Seminar on Soil Health: A Key to Food Security). Organized by Rahuri Chapter, Indian Society of Soil Science & Department of Soil Science and Agricultural Chemistry. Mahatma Phule Krishi Vidyapeeth, Rahuri. Soil Water Management in Irrigated Agriculture and Co chairman of the Technical Session III on Precision Farming and Micro irrigation).

Bhagyawant R.G., S. D. Gorantiwar and S. D. Dahiwalkar. 2013. Yield Response Factor for Onion (Allium cepa. L) Under Deficit Irrigation for Rahuri Region of Maharashtra. Proceedings of National Conference SWARDAM-2013, Department of Civil Engineering, Government College of Engineering, Aurangabad, Maharashtra, Mumbai. (ISBN: 978-93-82880-63-9)

Gorantiwar S. D., S.D.Rathod, S.A.Kadam and S. D. Dahiwalkar. 2013. Determination of Surface Drainage Coefficient for Poorly Drained Soils through Rainfall Analysis for Rahuri, Maharashtra. Proceedings of National Conference SWARDAM-2013, Department of Civil Engineering, Government College of Engineering, Aurangabad, Maharashtra, Mumbai. (ISBN: 978-93-82880-63-9)

S. A. Kadam and S. D. Gorantiwar. 2013. Spectral reflectance characteristics, vegetation and leaf area indices for Sorghum (*Sorghum bicolor* L.). Jr. of Agrometeorology. Manuscript No. JAM/2013/086 (ISSN No. 0972-1665, NASS Rating: 6.15, NASS No. J025)

S.D.Dahiwalkar S.A.Kadam and S.D.Gorantiwar (2013). "Effect of municipal waste water of Rahuri Tahsil on groundwater quality" International groundwater Conference, Aurangabad, Maharashtra Dec. 18-21, 2013.

Bulletin

- The technical bulletin on 'Artificial groundwater recharge through percolation tank in hard rock region of Maharashtra" & Marathi folder on "Well recharge" published with the auspicious hand of Hon. Minister for Agriculture ,Govt. of Gujarat and Dr. A. K. Sikka, DDG, NRM, ICAR New Delhi and Dr. Ashwani kumar Director, Directorate of Water Management Bhubaneshwar in Biennial Workshop of AICRP on groundwater Utilization and AICRP on Water Management held at GAU Navsari during 29th July to 1st August 2013.

Popular articles:

- The Marathi article on well recharge by AICRP on Groundwater Utilization published in MPKV publication Shri Sugi *Kharif* -2013
- The Marathi article on Well and Bore well recharge by AICRP on Groundwater Utilization published in MPKV publication "Krishidarshani-2014"
- The Marathi article on "Well recharge" by AICRP on Groundwater Utilization published in MPKV publication "Krishi Vasant 2014"
- The Marathi article on "Reuse of Wastewater for crop irrigation" by AICRP on Groundwater Utilization published in MPKV publication "Krishi Vasant 2014"
- The Marathi article on "Tantra Plastic Achadanache" by Dr.S.D.Dahiwalkar, Research Engineer, AICRP on Groundwater Utilization published in 'Agrowon' on 21.1.2013
- The Marathi article on "Gerbera production under Polyhouse" by Dr.S.D.Dahiwalkar, Research Engineer, AICRP on Groundwater Utilization published in 'Agrowon' on 3.3.2013

7.4 Publications of Coimbatore Centre

Books / Abstract / Proceedings Volume

A.Valliammai, C.Mayilswami 2013. Paper on "Impact of Rainwater harvesting structure in hard rock regions of Coimbatore District, Tamil Nadu, India" was presented in Conference on FFCSWR – 2013 to be held at Karnataka Veterinary Council (KVC), Hebbal Campus, Bangalore from 14th to 16th March 2013.

A.Valliammai, C.Mayilswami, P.Jothimani and B.J.Pandian. 2013. Paper on Remote Sensing and GIS Approach for Demarcation of Groundwater Potential zone for Kinathukadavu block of Coimbatore District was presented in conference on NGWC – 2013 to held at Water technology centre, TNAU, Coimbatore from 9 to 11 December 2013

A.Valliammai, C.Mayilswami, P.Jothimani and B.J.Pandian. 2013. Paper on Study on Groundwater recharge through percolation tank in hard rock regions of Coimbatore district, Tamil Nadu was presented in conference on NGWC – 2013 to held at Water technology centre, TNAU, Coimbatore from 9 to 11 December 2013

P.Jothimani, C. Mayilswami, A. Valliammai and B.J. Pandian. 2013. Paper on Amelioration of groundwater quality and soil health in Parambikulam-Aliyar-Palar basin through management strategies was presented in conference on NGWC – 2013 to held at Water technology centre, TNAU, Coimbatore from 9 to 11 December 2013

P.Jothimani, C. Muthusankari, C. Mayilswami, and B.J. Pandian. 2013. Paper on Assessment of Fluoride contamination in the groundwater of western zone of Tamil Nadu was presented in conference on NGWC – 2013 to held at Water technology centre, TNAU, Coimbatore from 9 to 11 December 2013

P.Jothimani, C. Mayilswami, A. Valliammai and B.J. Pandian. 2013. Paper on Groundwater quality status of Parambikulam-Aliyar Palar basin of Tamil Nadu was presented in conference on NGWC – 2013 to held at Water technology centre, TNAU, Coimbatore from 9 to 11 December 2013

7.5 Publications of Udaipur Centre

Papers Published in Journals/Proceedings

D.P. Singh, **K.K. Yadav** and F.M. Qureshi (2013). Available micronutrient status, their relationship with soil physico-chemical properties and content in wheat crop of semi arid eastern plain zone of Rajasthan. *Green Farming*, 4 (2): 137-142

K.K. Yadav, **P.K. Singh** and S.K. Sharma (2013). Consequences of Wastewater Recycling in Lower Reaches of Ahar River - A Case Study. Presented in the 78th Annual Convention of the Indian Society of Soil Science (ISSS) held during October 23-26, 2013 at CAZRI, Jodhpur.

P.S. Rao, **K.K. Yadav** and S.S. lakhawat (2013). Value Addition in Safed Musli (Chlorophytum borivilianum), a Medicinal Plant in Udaipur District of Rajasthan. Presented in National seminar on "New vistas in food processing with quality assurance for augmenting rural prosperity" held during June 21-22, 2013 at Department of PFE, CTAE, Udaipur.

Pravin Dahiphale, R.C. Purohit, **P.K. Singh** and J. P. Shukla (2014). Transmissivity and Storage Coefficient Estimation in Wakal River Basin of Rajasthan. Presented in 48th Annual Convention of Indian Society of Agricultural Engineers (ISAE) held during 21-23, February, 2014 at CTAE, Udaipur. pp : 166.

J. P. Shukla, H.K. Mittal, **P.K. Singh** and Pravin Dahiphale (2014). Impact of Loose Stone Check Dams on Silt Deposition in Suawato Ka Guda Watershed of Udaipur Region. Presented in 48th Annual Convention of Indian Society of Agricultural Engineers (ISAE) held during 21-23, February, 2014 at CTAE, Udaipur. pp : 225.

S.R. Bhakar, Chitra Shukla, S.S. Lakhawat and **K.K. Yadav** (2014). Irrigastion Scheduling of Drip Irrigated Capsicum Grown under Protected Cultivation. Presented in 48th Annual Convention of Indian Society of Agricultural Engineers (ISAE) held during 21-23, February, 2014 at CTAE, Udaipur. pp : 182.

K.K. Yadav, P.K. Singh and R.C. Purohit (2014). Resue of Wastewater in Peri-Urban Areas of Udaipur City, India - A Case Study. Accepted for oral presentation in Internation Conference on Peri-Urban Landscapes : Water, Food and Environmental Security schdeuled to be held during 08-11 July, 2014 at University of Western Sydeny, Australia.

Book Chapter

K.K. Yadav and **P.K. Singh**, (2013) Groundwater Resources Management, In:" Food & Nutritional Security by Sustainable Agriculture: Methods to Attain & Sustain," Edited by B.K. Mishra, Sunil Kumar and J.K. Tiwari. Published by New India Publishing Agency, New Delhi. pp.103-117.

Popular Articles

K.K. Yadav, S.S. Lakhawat and P.S. Rao (August, 2013). Mahua ki unnat kheti. Rajasthan Kheti Pratap. pp 27-28.

K.K. Yadav, D.P.S. Dudi and Virendra Singh (Jan.-March, 2013). Upnagariya krishi ke mahatavapurna pahalu. Keshva Kheti. pp 17-18.

7.6 Publication of Pusa Centre

Singh, A.K., Jain, S. K. and Chandra R. (2012). Studies on impact of municipal, Industrial & Agrochemical pollutants on quality of groundwater. *RAU Journal Res*. 22(1 & 2) 48-56.

7.7 Publications of Raipur Centre

Tripathi, M. P., Katre, P. and **Khalkho, D.** (2014). Technical Manual on "Groundwater Flow and Mass Transport Modelling". Published by Departmentof Soil and Water Engineering, Faculty of Agricultural Engineering, Indira Gandhi Agricultural University, Raipur (C.G.), ***Publication No. IGKV/Pub./T.BI./2014/09***.

Tripathi M.P., **Katre P.**, Madhuri Sawarkar and Priti Tiwari (2014). Groundwater Planning and Management of Kharun Watershed of Seonath Sub-basin. In Workshop on Water Conservation Practices in Chhattisgarh–A futuristic vision, held at Central groundwater Board, North Central Chhattisgarh Region, Raipur from 24, March 2014, P: 39-50.

Tripathi M.P., Katre P., Khalkho D., Jyotsana Khakha and Mukherjee A.P. (2014). Identification of Suitable Locations for Groundwater Recharge Structures in Dhamtari District of Chhattisgarh Using GIS. In Proceedings of 48th Annual Convention of Indian Society of Agricultural Engineers (ISAE) and Symposium on "Engineering Interventions in Conservation Agriculture" held at CTE, MPU&T, Udaipur, from February 21-23, 2014,P: 229.

Pali, A. K., Katre, P. & **Khalkho, D.** (2014). An unsteady subsurface drainage equation incorporating variability of soil drainage properties. *Springer, Water Resources Management*. DOI 10.1007/s11269-014-0631-1

Thakur, D. S., Sharma, G.K., Naik, R. K., **Khalkho, D.,** Choudhary, J. L. and Patil, S. K. (2014). Evaluation of rice establishment methods with nutrient and weed management options under rainfed farming situations of Bastar plateau. *Journal of Soil and Water Conservation*. Vol. 13(1):36-41

Tripathi, M. P., Nigam, G.K., **Khalkho, D.** and Priti Tiwari (2014). Practical Manual on "Hydrological Measuring Instruments". Published by Soil and Water Engineering, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), ***Publication No. IGKV/Pub./P.MI./2014/08***.

Khalkho, D., Raghuwanshi, N. S., Khalkho, S. and Singh, R. (2013). A computer model for designing of permanent gully control structures. *African Journal of Agricultural Reearch* 8(29): 3860 – 3872.

Khalkho, D., Naik, R. K., Thakur, A. K., Bisen, Y. and Chandrakar, A. K. (2013). Effective irrigation water management in *rabi* chilli for Bastar agro climatic zone. *Scientific Research and Essays*. 8 (48): 2332-2335

Khalkho, D., Patil, S. K., Patel, S. and Pali, G. P. (2013).Cadastral level Mapping for Efficient Natural Resources Management of Turenar cluster villages using Remote Sensing and GIS Technologies. *Journal of Agricultural Issues*. 18(1&2): 55-60

Chandraker, A. K., Dave, A. K., **Khalkho, D**. and Naik, R. K. (2013). Status of farm power availability and implements in selected villages of Bastar district of Chhattisgarh. *International Journal of Agricultural Engineering*, 6(2): 555-557.

Katre P., Tripathi M.P., Mukherjee A.P., Gautam and Choubey P. (2013). Conjunctive Water Use Planning of a Distributory Command of Mandhar Branch Canal. In Proceedings of Workshop on "Management of groundwater for Sustenance of Agriculture and Industries in the State of Chhattisgarh, held at Central groundwater Board North Central Chhattisgarh Region, Ministry of Water Resources Government of India, Raipur, from 15 March 2013, P:48-55.

Tripathi M.P., **Katre P.,** Rana Nilu, Sawarkar Madhuri and Tiwari Priti (2013). Groundwater Use Planning of Upper Mahanadi Watershed Using, Visual ModFlow. In Proceedings of Workshop on "Management of groundwater for Sustenance of Agriculture and Industries in the State of Chhattisgarh, held at Central groundwater Board North Central Chhattisgarh Region, Ministry of Water Resources Government of India, Raipur, from 15 March 2013, P:76-83.

Tripathi M.P., Priti Tiwari and Gauravkant Nigam (2013). Estimation of Water Requirement and Irrigation Water Requirement for Crops in Canal Command Areas. In Training course on Conjunctive use of Surface and groundwater on held at Govt. of India, Rajiv Gandhi National groundwater Training & Research Institute, Central groundwater Board from 11-14 November 2013, P: 100-120.

Bisen, Y., Thakur, A. K. and **Khalkho, D**. (2013). "*Dhan ki katar padhati fasal ka kharpatwar niyantran*", Krishak Doot, 14(10): 7

Bisen, Y., Thakur, A. K. and **Khalkho, D**. (2013). "*Low lift pump - manav chalet sinchai yantre*", Krishak Doot, 14(10): 7

7.8 Publications of Junagadh Centre

Research Papers

Rank, H D, Rathod, P J and Patel H P.(2013). Climate Change Impact on Crop Water Requirements In South Saurashtra Region Of Gujarat State. Proc. Nat. Sem. On Climate Change Impacts On Water Resources System. Pp.:18-25. In : Shete D T. (2013). Climate Change Impacts On Water Resources System. Execll India Publishers, New Delhi. India (Nov 27-29, 2013 at PIET, Vadodara)

Rank, H D, Rathod, P J and Patel H P. Vekariya P B, Patel R J and Paradava D M. (2013). Climate Change Analysis for the Coastal Belt Area of Saurashtra. Proc. Nat. Sem. On Climate Change Impacts On Water Resources System. Pp.:128-34. In : Shete D T. (2013). Climate Change Impacts On Water Resources System. Execll India Publishers, New Delhi. India (Nov 27-29, 2013 at PIET, Vadodara).

Rank, H D, Rathod, P J and Patel H P.and Vekariya P B.. (2013). Climate Change Impact on Rainfall in Junagadh District of Gujarat State, India. Proc. Nat. Sem. On Climate Change Impacts On Water Resources System. Pp.:170-78. In : Shete D T. (2013). Climate Change Impacts On Water Resources System. Execll India Publishers, New Delhi. India (Nov 27-29, 2013 at PIET, Vadodara).

Vadher P.G., Rank H.D. and Gontia N.K. (2013) Intensive water harvesting has reduced sea water intrusion in Saurashtra region of Gujarat : Success story, Symposium proceeding on managing natural resources for enhancing agricultural and allied productivity in coastal regime under changing climate during December 11-14, 2013 at RRS CSSRI Bharuch.

Rank H.D., Yadav T, Pandya P.A., Sondarva K. N., Vekariya P.B., Vadher P. G., Subbaiah R., Gontia N.K. (2013). Water management for summer sesame crop in costal district of Junagadh. Symposium proceeding on managing natural resources for enhancing agricultural and allied productivity in coastal regime under changing climate during December 11-14, 2013 at RRS CSSRI Bharuch.

Wandre S. S. and Rank H. D. (2013). Assessment of morphometric characteristics of Shetrunji River basin using remote sensing and geographical information system (GIS). African Journal of Agricultural Research Vol.8(18) , pp. 2003

Wandre S. S. and Rank H. D. (2013). Assessment of morphometric characteristics of Shetrunji River basin using remote sensing and geographical information system (GIS). International Journal of Agriculture, Environment and Biotechnology 6(3): 503

Wandre S.S. and Rank H.D. (2013) Prioritization of Watersheds of Shetrunji River Basin Based on Morphometric Analysis using Remote Sensing and GIS. World Research Journal of Tropical Agriculture, ISSN: 2322

Books:

Wandre S S and Rank H D. Morphometric Characteristics: Shetrunji River Basin Using RS and GIS. , LAMBERT Publishing, Germany.

ANNEXURE - I

STAFF POSITION DURING 2013-14

Project Coordinating Unit, DWM, Bhubaneswar

1. Dr. Ashwani Kumar (Director)
2. Dr. Mausumi Raychaudhuri (Principal Scientist)
3. Dr. M. J. Kaledhonkar (Principal Scientist) (till 24.08.2013)

I. P.A.U., LUDHIANA

1. Dr. Rajan Aggarwal, Res. Engr & I/C
2. Dr. Sunil Garg, Res. Engr.
3. Dr. (Mrs) Samanpreet Kaur, Asstt. Res. Engr.
4. Er. Chetan Singla, Asstt. Res. Engr. (till 01-12-2013)
5. Dr. Sanjay Satpute, Asstt. Res. Engr. (02-12-2013)
6. Mr. Manpreet Singh, Helper to Electrician
7. Mr. Darshan Singh, Mechanic
8. Mr. Balbir Singh, Mechanic
9. Mr. Tarseem Lal, Sr. Scale Steno.
10. Mr. Talwinder Singh, Clerk-cum-Store Keeper
11. Mr. Nachattar Pal, Tracer/ Jr. Drafts man
12. Mr. Harjeet Singh, Driver
13. Mr. Mrs. Parminder Kaur, Messenger

II. G.B.P.U.A.T., PANTNAGAR

1. Dr. H. C. Sharma, Professor & I/C
2. Dr. Yogendra Kumar, Professor
3. Dr. Harish Chandra, S.R.O.
4. Mr. Janardan Singh, Tech. Asstt.
5. Mr. Ashok Kumar, Field Asstt.
6. Mr. M. C. Chimwal, Accounts Clerk
7. Mr. Ramu, Survey Mate8. Mr. Laxmi Kant, Messenger

III. M.P.K.V., RAHURI

1.Dr. S.D. Dahiwalkar, Associate Professor & I/C
2.Er. S.A. Kadam, Assistant Professor
3.Er. K.G. Pawar, Jr. Research Asstt. (AE)
4.Mr. E.K. Kadam, Agril. Asstt.
5.Mr. S.D. Kulthe, Clerk-cum-Storekeeper

IV. J.N.K.V.V., JABALPUR

1. Dr. R. K. Nema, Irrigation Engineer & I/C
2. Dr. M. K. Awasthi, Junior Scientist
3. Er. Y. K. Tiwari, Junior Scientist
4. Er. Abhishek Soni, Technical Assistant
5. Mr. S.C. Bagdare, Sr. Mechanic
6. Mr. Amit Shukla, Junior Clerk
7. Mr. Balwant, Messenger

V. W.T.C, T.N.A.U., COIMBATORE

1. Dr. C. Mayilswami, Professor & I/C
2. Er. A. Valliammai, Asstt. Professor (SWCE)
3. Dr. P. Jothimani, ENS
4. Ms. B. Kavitha, Field Technician
5. Mr. D. Nitya, Field Assistant
6. Mr. N. Krishnaveni, Jr. Clerk
7. Mr. A. Selvambal, Jr. Steno
8. Mr. K. Nagarajan, Messenger

VI. M.P.U.A.T., UDAIPUR

1. Dr. P.K. Singh, Associate Professor & I/C
2. Dr. K.K. Yadav, Asstt. Professor (Soil science)
3. Mr. Jeet Singh, Field Technician
4. Mr. Sombir Singh, Agril. Supervisor
5. Mr. J.S. Sharma, Agril. Supervisor
6. Mr. Gunjan Sharma, Steno
7. Mr. Dhulji, Class-IV

VII. R.A.U., PUSA, SAMASTIPUR

1. Dr. S.K. Jain, Associate Professor & I/C
2. Dr. A.K. Singh, Asstt. Professor (Soil Chemistry)
3. Er. Ravish Chandra, Asstt. Professor (Agril. Engineering)

VIII. I.G.K.V., RAIPUR

1. Dr. M.P. Tripathi, Professor & I/C
2. Er. P. Katre, Asstt. Professor
3. Er. D. Khalkho, Asstt. Professor
4. Mr. Jacob George, Asstt. Gr. II-Steno
5. Mrs. Urmila Yadav, Messenger

IX. J.A.U., JUNAGADH

1. Dr. H. D. Rank, Research Engineer & I/C
2. Shri P. G. Vadher, Assoc. Prof.
3. Er. P. B. Vekariya, Asstt. Prof.
4. Shri Y. H. Hala, Technician/ Mechanic
5. Shri M. R. Paramar, Steno Gr-III
6. Shri G.K. Majethiya, Field Asstt
7. Shri D.M. Parmar, Field Asstt
8. Shri G.T. Sadaniya, Jr. Clerk
9. Shri M. G. Patoliya, Messenger/Peon