SWMP Pub. No. 21

Management of Water Resources in Gujarat

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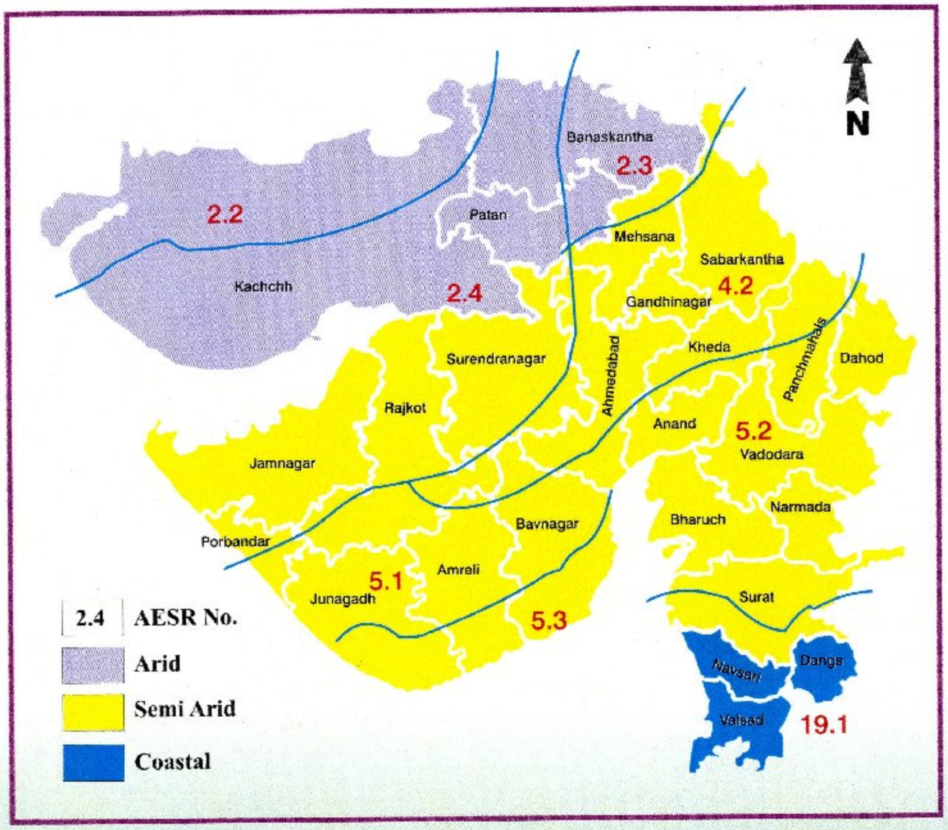

AICRP on Water Management

Soil and Water Management Research Unit
Navsari Agricultural University,
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Gujarat
2009

Management of Water Resources in Gujarat

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Preface

Soil and water are the most important two natural resources gifted by the nature for sustainability of civilization. Gujarat has unique advantage of possessing these resources with ample diversities. Misuse of these resources will lead to the disastrous effect on the existence of mankind. In this state, 31 per cent of the cultivated area is under irrigation, 80 per cent of which is irrigated through ground water and around 18 per cent through surface water. Even after full commissioning of Sardar Sarovar Project, agriculture in more than 50 per cent of cultivated area in the state will remain rainfed. Thus, soil-water management is the prime concern of the state. While water logging and secondary salinization are the constraints in the South and middle Gujarat, receding water table in North and poor quality of ground water in other parts of the state are the bottle necks of irrigated agriculture. To resolve these complex problems, large numbers of location specific soil and water management technologies have been developed by Soil and Water Management Research Unit, as a lead centre of erstwhile Gujarat Agricultural University and presently under Navsari Agricultural University, Navsari in collaboration with substations of the university. Gujarat is not only water scarce state, but also has tremendous spatial heterogeneity with respect to availability of water resources. The information related to district wise variations in availability and quality of irrigation water, efforts of government towards augmentation of water resources, efficient utilization of available water, use of effluent as alternative water resources along with sound strategy for drinking water in state have been compiled in this publication. In my opinion, this information will be of immensely helpful to researchers, academicians and planners. I congratulate the team of scientists of Soil and Water Management Research Unit, NAU, Navsari for bringing out this publication.

Navsari
09-09-2009

(H. C. Pathak)
Vice Chancellor
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Water Resources and Their Development in Gujarat- An Overview

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Profile of the state

The Gujarat state is situated on the western part of India. It is surrounded by Arabian sea in the West, state of Rajasthan in the North-East, international boundary with Pakistan on the North, Madhya Pradesh in the East and Maharashtra in the South-East and South. It has the longest sea coast in India with a length of about 1600 km. It is located between $20^0\ 01^{'}$and $24^0 07^{'}$North latitudes and $68^0 04^{'}$and$74^0 04^{'}$East longitudes. It covers an area of 19.6 mha (1.958 lakhs km^2) contributing to 6 per cent of the total geographical area (TGA) of the country. The state had 19 districts earlier, which subsequently has been sub divided to 25 during 1998 and 26 during 2007.

The population of the state according to 2001 census is 50.67 million accounting nearly 5 per cent of the country. The density of population is 258 persons per km^2 and it is lower than all India value of 324 persons. Urban population accounts for 37.36 per cent as against 27.78 per cent for the country and ranks 5^{th} among the states of India.

Gujarat is endowed with many rivers some of which are perennial while many are seasonal. The perennial large rivers like Narmada, Tapi, Mahi and small ones like Daman Ganga are flowing in the South and middle Gujarat. On the other hand, in North Gujarat, the rivers are not only very few but also seasonal in flow. Sabarmati, Banas, Rupen and Saraswati are the important ones.

Sectorwise water demand

During the year 2000, the total water requirement was estimated to be around 29.4 thousand MCM and it is estimated to rise to 36.5 thousand MCM during 2010 and 46.8 thousand MCM during 2020 and 53.1 thousand MCM during 2025 registering an increase of 80 per cent (Table 1). At the state level, the maximum contribution for the per cent increase is from industry which is estimated to draw 736 per cent more water than that during 2000. This is followed by the demand for domestic use with a percentage increase of 165.

The water requirement form agriculture which was 93 per cent during 2000 will be going down steadily and it will contribute to 80 per cent of the total water requirement by 2025. This reduction is mainly due to the more demand by other sectors and not due to reduction in the quantity of water required in this sector. In fact by 2025, the state needs 16 thousand MCM more of water for agriculture as compared to the year 2000.

Table 1: Trend of water requirements by different sectors

Sector	Water requirement(MCM)				
	1997	**2000**	**2010**	**2020**	**2025**
Domestic	1374	1545	2288	3618	4103 (165)
Industrial	448	644	1505	3522	5386 (736)
Livestock	224	230	239	263	284 (23)
Agriculture	25672	27013	325151	39352	43306 (60)
Total	**27718**	**29432**	**36547**	**46755**	**53079 (80)**
%Agriculture	93	93	90	84	82
%Domestic	5	5	6	8	8
%Industry	2	2	4	8	10

( ) Variation over 2000 in % *Source:* Anon. (2000)

Water resources

Water resources of Gujarat are extremely limited. Enough steps have already been taken to harness the river waters from major rivers like Tapi (Ukai-Kakrapar), Mahi (Mahi-Kadana), Sabarmati (Dharoi) *etc*. Efforts are in full swing to harness the water resources from Narmada. Due to low rainfall in major parts of the state and predominantly alluvial nature of the soils, the potential from other small rivers not only is limited but also poses problems.

River Basins of Gujarat

There are three distinct river basins in Gujarat *viz*., (i) river basin of Gujarat region (ii) river basin of Saurashtra and (iii) river basin of Kutch (Table 2).

Table 2: Details of different river basins in Gujarat

Basin / Region	No. of river basins*	Name of major rivers	Total catchment area	Annual yield liabilities (%)
Gujarat	17	Rel, Banas, Saraswati, Rupen,Sabarmati, Mahi, Narmada, Tapi, Damanganga	168530	75
Saurashtra	71	Shetrunji, Bhadar	6016	60
Kutch	97	Luni	43750	50

*Includes small rivers and rivulets. Source: Anon (1971)

Surface and groundwater potentials

For working out the potential and utilization from these basins, they have been categorized as (i) Cambay composite, (ii) Kutch and Saurashtra composite, (iii) Narmada and (iv) Tapi. The details of these basins are given in table 3.

Table 3: Basin wise groundwater potential, net draft and percentage development (km^3/year)

Basin	Total repleni-shable GW resources	Provision for domestic, industrial and other uses	Available GW resources	Net draft	Balance	Level of GW development (%)
Cambay composite	7.19	1.08	6.11	2.45	3.66	40.09
Kutch & Saurashtra composite	11.23	1.74	9.49	4.85	4.64	1.14
Narmada composite	10.83	1.65	9.10	1.99	7.18	1.74
Tapi composite	8.27	2.34	5.93	1.96	3.97	33.05

GW= Groundwater *Source:* Anon. (2005)

The total surface water potential of the state is 38.5 thousands MCM of which 32.3 thousands MCM is contributed by South and central Gujarat (Table 4). The contribution from North Gujarat is only of the order of 2 thousand MCM. As against this, the ground water potential is only 16 thousands MCM. Though, the combined contribution of South and central Gujarat is the maximum, yet unlike the surface water potential wherein the contribution from this region is 84 per cent, in the ground water potential the contribution is only 35 per cent. Thus, out of the total water potential of 54.5 thousands MCM about 38 thousands MCM is contributed by the South and central Gujarat working out to a percentage of 70. The corresponding percentages for North Gujarat, Saurashtra and Kutch are 11.2, 16.9 and 2.2.

Table 4: Surface and ground water potentials of Gujarat ('000 MCM)

Region	Surface water	Ground water	Total
South and central	32.3	5.7	38.0 (69.7)
North Gujarat	2.0	4.1	6.1 (11.2)
Saurashtra	3.6	5.6	9.2 (16.9)
Kutch	0.6	0.6	1.2 (2.2)
Total	**38.5**	**16.0**	**54.5**

( ) = % of total water *Source:* Anon. (2000)

Out of the 54.5 MCM /y of available water 19.1 MCM is being utilized working out to 35 per cent of the availability (Table 5). Among the different regions, the utilization was minimum in South and central Gujarat with a percentage of 18 though the actual usage is 7.0 MCM/yr. On the other hand, in North Gujarat, where the availability is 6.1MCM/yr the utilization is 6.0 MCM amounting to 98 per cent. In other words, all the available waters are almost fully utilized in this region. The percentage utilization in Saurashtra and Kutch are 59 and 58, respectively.

Table 5: Water utilization pattern in Gujarat ('000 MCM)

Region	Available	Utilization	% Utilization of total available
South and Central	38.0	7.0	18
North Gujarat	6.1	6.0	98
Saurashtra	9.2	5.4	59
Kutch	1.2	0.7	58
Total	**54.5**	**19.1**	**35**

Source: Srinivas (2004)

Per capita availability

The per capita availability of water at the state level as per the 2001 census has been reported to be 1121 m^3 per year (Table 6). Falkenmark, suggested 1700 m^3 per person as the critical level for assessing the sufficiency of per capita availability of water. If we go by this standard, then the state is in the shortage category.

Table 6: Per capita availability of water

Particulars	South and Central Gujarat	North Gujarat	Saurashtra	Kutch	Gujarat
Water availability (MCM/yr)	11697	2733	3910	570	18910
Population (million)	20.89	14.74	13.44	1.58	50.65
Per capita availability(m^3/yr)	1885	359	540	719	980

Source: Patel (2007)

Ground water resources and development

During 2003, out of the 16000 MCM of ground water recharge at the state level, it was estimated that about 13000 MCM was estimated to be utilizable and 9700 MCM was estimated to be the draft leaving around 3100 MCM as ground water balance. The level of ground water development was 76 per cent and the state was categorized as grey. But, at the districts levels there were wide variations ranging from white to over exploited categories (Table 7).

Table 7: Ground water development (MCM/yr)

District	Utilizable recharge	Net draft	Balance	Development (%)
Ahmedabad	452	481	-29	106
Amreli	677	453	224	67
Anand	603	328	275	54
Banaskantha	859	1001	-141	117
Bharuch	268	150	118	56
Bhavnagar	731	461	270	63
The Dangs	50	10	40	20
Dohad	256	154	102	60
Gandhinagar	344	623	-279	181
Jamnagar	863	500	363	58
Junagadh	1140	804	336	70
Kutch	687	612	75	89
Kheda	649	426	223	66
Mehsana	785	1168	-383	149
Narmada	204	64	140	31
Navsari	484	225	259	46
Panchmahals	480	281	199	58
Patan	222	296	-76	133
Porbandar	143	122	21	85
Rajkot	1140	796	344	70
Sabarkantha	894	737	157	82
Surat	1290	467	823	36
Surendranagar	518	330	188	64
Vadodara	1000	676	324	54
Valsad	338	145	193	43
Total	**12849**	**9709**	**3140**	**76**

<70% White; 71-90 Grey; 91-100 dark; >100 OE

Source: Anon. (2002)

Out of the 5 North Gujarat districts, four, namely Mehsana, Patan, Gandhinagar and Banaskantha as well as Ahmedabad of middle Gujarat were falling under over exploited category. On the other hand, the utilization of ground water in the southern districts was very poor. In Surat district which has got the maximum balance of ground water with a value of 823 MCM/year is utilizing only 36 per cent of it.

There has been a steady increase in the ground water exploitation over the years. While during 1984, all districts were falling under "white" category three districts during 1997 and 5 during 2002 were falling under over exploited category (Table 8).

Table 8: District and talukas level ground water development trend

Category	**Districts**			**Talukas**		
	1984	**1997**	**2002**	**1984**	**1997**	**2002**
White	19	9	15	163	96	104
Grey	Nil	6	4	13	43	63
Dark	Nil	1	1	1	7	12
OE	Nil	3	5	5	31	30
Saline	-	-	-	2	7	14
Total	**19**	**19**	**25**	**184**	**184**	**223**

OE= over exploited *Source:* Anon. (2002)

Out of the 184 talukas, during 1984, 163 talukas were falling under white category which decreased to 96 talukas during 1997, while out of 223 talukas 104 were under white category during 2002.Simultaneously, the talukas under over exploited category during 1984 were only 5 and during 2002 they rose to 30.

Groundwater extraction structures for irrigation

The total numbers of groundwater extraction structures are 6.6 lakhs of which 5.06 lakhs are electrified and 1.54 lakhs are diesel pump sets (Table 9). Out of the electrified pump sets the maximum (65013) was recorded in Sabarkantha district and minimum in Dangs. On the other hand, the diesel pump sets are maximum in Junagadh which closely followed by Rajkot. In Patan there are no diesel sets recorded.

Table 9: District wise water extraction structures for irrigation

District	Electrified sets	Diesel sets	Total
Ahmedabad	6656	4736	11393
Amreli	24930	16965	41895
Anand	8060	715	8775
Banaskantha	48066	5950	54016
Bharuch	5735	235	5970
Bhavnagar	28978	13351	42329
The Dangs	136	320	456
Dohad	3918	12341	16259
Gandhinagar	8494	15	8509
Jamnagar	35614	9774	45388
Junagadh	57002	23483	80485
Kutch	13477	6727	20204
Kheda	13438	2630	16068
Mehsana	18439	1172	19611
Narmada	2191	423	2614
Navsari	16812	75	16887
Panchmahals	15296	10675	25971
Patan	4299	0	4299
Porbandar	8303	3353	11656
Rajkot	49890	20096	69986
Sabarkantha	65013	6158	71171
Surat	29511	225	29370
Surendranagar	18597	7650	26247
Vadodara	13845	7186	21031
Valsad	9648	380	10028
Total	**506348**	**154636**	**660482**

Source: Anon. (2002)

Ground water quality

The ground water quality in the state is subjected to three major constituents. They are mainly salt concentration, nitrate and fluoride. From the salt concentration point of view, the waters of the eastern belt districts from Dangs to Sabarkantha are generally good while salinity/ sodicity is observed in the waters of coastal belt of Gujarat and in the inland areas adjoining the coastal tract. The nitrate problem are encountered more in the districts of Amreli and Bhavnagar districts of Saurashtra region and the North Gujarat region faces the maximum of fluoride problem.

Irrigation status

Out of the 196 thousand km^2 of TGA of the state, 124 thousand km^2 is culturable. With all the available water resources, it is estimated that the state has an ultimate irrigation potential of 64.88 lakh ha (Table 10).

Table 10: Irrigation potential (lakh ha) in Gujarat (2007)

Source	Ultimate	Potential created	Maximum utilization
A) Surface Water			
Major and medium schemes	18.00	14.92	13.32
Sardar Sarovar (including conjunctive use)	17.92	3.56	1.53
Minor irrigation	3.48	3.44	2.14
Sub total (A)	39.40	21.91	16.99
B) Ground water (including private resources)	25.48	20.35	20.34
Total(A+B)	64.88	37.34	35.13
C) Indirect benefits through water harvesting structures	-	4.8	4.2
Grand Total (A+B+C)	**124.0**	**39.84**	**37.63**

Source: Source: Anon. (2008)

Out of the 124 lakh hectares of culturable area, the gross irrigated area in the state as reported for the year 98-99 was 38.4 lakh ha working out to a percentage of 31. The corresponding net irrigated area was 30.8 lakh ha with a percentage of 24.8 (Table 11).

Table 11: Sourcewise net and gross irrigated area of Gujarat ('00 ha)

Tank		Canal		Tube well		Other wells		Others		Total	
Net	**Gross**	**Net**	**Gross**	**Net**	**Gross**	**Net**	**Gross**	**Net**	**Gross**	**Net**	**Gross**
253	305	6021	7109	8897	11133	15428	19553	245	306	30824	38406

Source: Anon. (1998-99)

The area under gross canal irrigated area with a hectarage of 7 lakhs contributes to 19 per cent of the gross irrigated area in the state leaving around 81 per cent as ground water irrigated area. The tank command in the state is less than 1 per cent.

As per the 1998-99 statistics, the state had nearing 50,000 tube wells and 8 lakh open wells. The respective intensities, as measured by the number of wells per unit area, were 0.25 and 4.0 .Thus, the intensity of open well in the state was 16 times the tube well intensity. While, the tube wells are concentrated only in North Gujarat and very little portion of middle Gujarat, the open wells are distributed through out the state. But the concentration was more in Saurashtra followed by middle Gujarat.

Though, tube well is minimum or absent in Saurashtra, ironically the second maximum intensity of this is reported in Surendranagar followed by Mehsana. The highest intensity was observed in Gandhinagar with a value of 2.4 tube wells per km^2 and in Surendranagar and Mehsana the figures were 1.64 and 1.26, respectively corresponding to nearly ten, seven and five times more intensity than the state average The ill effect of high intensity of tube well in the North Gujarat with special reference to Mehsana is reflected in the receding water table conditions and the over exploitation of ground water in Mehsana, Gandhinagar and Banaskantha districts .

District and sourcewise irrigated area

Out of the 112 lakh ha GSA in the state, 41 lakh ha is irrigated working out to 37 per cent. While Anand is having the highest irrigated area (78%), Panchmahals, Porbandar and Surendranagar districts have the lowest (17-19%). In North Gujarat and Saurashtra, ground water is the major source of irrigation water, that in South Gujarat, surface water is the predominant source. At state level, the contribution of surface and ground water is 19 and 81 per cent, respectively (Table 12).

Table 12: District and source wise irrigated area in Gujarat

District	Net irrigated area (‘ 00ha)	Gross irrigated area (ha)	Surface Source (%)	Ground source (%)	Gross irrigated area (%)
Ahmedabad	1669	2100	25	75	38
Amreli	1024	1188	5	95	21
Anand	1794	2314	42	58	79
Banaskantha	3732	4721	8	92	46
Bharuch	980	1086	43	57	32
Bhavnagar	1977	2158	5	95	35
Dahod	531	749	18	82	25
Dangs	4	5	0	100	-

District	Net irrigated area (‘ 00ha)	Gross irrigated area (ha)	Surface Source (%)	Ground source (%)	Gross irrigated area (%)
Gandhinagar	970	1132	0	100	57
Jamnagar	1242	1527	6	94	22
Junagadh	1776	2193	6	94	32
Kheda	1951	2556	28	72	63
Kutch	1781	2223	14	86	31
Mahesana	1990	2436	5	95	55
Narmada	256	299	35	65	25
Navsari	905	1002	56	44	59
Panchmahals	421	515	30	70	17
Patan	1037	1253	2	98	30
Porbandar	192	223	7	93	17
Rajkot	2094	2626	10	90	30
Sabarkantha	1415	1773	14	86	33
Surat	2420	2718	67	33	59
Surendranagar	1145	1302	5	95	18
Vadodara	2008	2498	10	90	44
Valsad	420	515	13	87	29
State	**33734**	**41112**	**19**	**81**	**36**

Source: (2003-04)

In addition, about 18 lakhs hectares are to be brought under irrigation through Sardar Sarovar Project and the district wise projected area are given in table 13.

Table 13: District wise projected area under irrigation through Sardar Sarovar Project

Districts	Area (lakh ha)
Ahmedabad	3.30
Banaskantha	3.13
Baroda	3.40
Bharuch	0.98
Bhavnagar	0.48
Gandhinagar	0.10
Kheda	1.16
Kutch	0.37
Mehsana	1.50
Panchmahals	0.10
Rajkot	0.34
Surendranagar	3.04
Total	**18.00**

Source: Anon. (1994-95)

Rise in water table

Irrigation projects play pivotal role in enhancing the crop productivity and bringing prosperity to the area. However, if the created irrigation facility is not properly utilized, then the natural resources *viz.,* soils and crops/vegetation are deteriorated to such an extent that they become unproductive. This is the case in most of the major and medium irrigation projects in different states of India and Gujarat is not an exception. In Gujarat, the ill effects like water logging, salinity and sodicity *etc.* are apparent in both the major projects *viz*. Ukai-Kakrapar (UKC) on river Tapi in South Gujarat and Mahi-Kadana (MKC) on river Mahi in middle Gujarat. The severity of these problems is more in South Gujarat due to higher rainfall and heavy texture of the soils than middle Gujarat.

Further, the rate at which water table is rising in Surat branch of UKC suggest that about 40 per cent of the command area will become water logged with in a period of 10 years (Patel *et al*., 2000). The salinity and sodicity are the associated problems of the water logging situation. The major causes of water logging and its associated problems are due to adoption of faulty irrigation methods (flooding, field to field *etc*.) by ignoring the land irrigability classification, inclination towards high water consuming crops like paddy, sugarcane, banana *etc*. by neglecting suggested cropping pattern and heavy rainfall (1400 mm). This is also true for MKC, but with relatively less severity owing to loamy soils and lower rainfall (Raman *et al*., 1999). Based on these experiences, adequate care has been taken in partly commissioned Narmada project, wherein limited quantity of water will be supplied for low water consuming crops during r*abi* season only. Not only this, farmers are being encouraged for conjunctive use of surface and ground water. Narmada water is also made available for drinking purpose in water scarce areas of Saurashtra and North Gujarat through release of water in rivers and reservoirs in the respective areas.

Receding water table

In Contrast to South and middle Gujarat, receding water table is matter of serious concern in North Gujarat. As a result of this, as on today all the districts of North Gujarat (Banaskantha, Sabarkantha, Mehsana and Gandhinagar), Ahmedabad district of middle Gujarat including Kutch are either in dark or over exploited zone. Not only this, along with receding water table @ 0.3 m/year, ground water quality is also deteriorating at an alarming rate. Consequently, most of the ground waters in North Gujarat are becoming unfit for irrigation as well as for drinking. About 28 per cent villages are affected by the problem of high fluoride content in drinking water and more so in Mehsana district (50 %). Though, fluoride content in ground water is above permissible limit, yet people are drinking such waters in absence of other options (Anon., 2004). So with in the state both rising and receding water table situations are encountered because of human interventions. This is high time to stop further deterioration of natural resources through formulating and implementing the appropriate water management strategy in the state of Gujarat.

Remedial measures

In order to counteract the multiplexed problems of water management in the state, concerted efforts have been done by Gujarat Agricultural University and are being done by the State Agricultural University with the financial help from ICAR, other agencies, state government and foreign agencies (Raman, 2002). The remedial measures based on the research findings are briefly mentioned here.

Pressurized methods of irrigation and mulching technologies

For restricting rise in water table in South and middle Gujarat, large volume of work has been done on various aspects of water saving techniques and improving irrigation use efficiency both including surface as well as modern methods of irrigation and mulching. Further, identification of alternate crops having less water requirement but equally remunerative to that of existing high water consuming crops like summer paddy have also been done. The results of drip alone or drip + mulch or mulch alone in major crops of the state have shown that water saving to the tune of 9 to 54 per cent can be achieved along with increase in yield by about 17 to 60 per cent. The beneficial effects of drip alone are further magnified in presence of mulch and more so if fertigation is done. This implies that if modern methods of irrigation are adopted on large scale, it will certainly increase the area under irrigation and also mitigate the problems of rise in water table and subsequent salinization.

Provision of drainage

With the collaboration of ILRI, Netherlands, sub surface drainage technology has been developed which is found to be techno economically viable in the canal command areas of the state. Seeing the advantages of this sub surface drainage, many farmers are installing this type of field drainage in their fields to have better returns from their sugarcane crops as well as to prevent the deterioration of the health of their soils.

Government's efforts for development of water resources

Some of the important activities carried out by the state government for the development of water resources are:

- *Sardar Patel Participatory Water Conservation Scheme (SPWCS):* Under this scheme farmers are given 80 per cent subsidy for creating water harvesting structures in their fields. During 2007, more than 4700 check dams are constructed and 3046 ponds are deepened
- *Sujalam Sufalam Yojna*: Under this scheme
  - Works of 332 km long *Sujalam Sufalam* Spreading Canal work is in progress
  - To utilize the flood waters of Narmada and to fill reservoirs and enroute ponds in North Gujarat, works on 7 lift irrigation pipelines are completed and 1 is in progress
  - It is planned to divert flood waters of Narmada to 17 rivers by constructing 107 check dams in Surendranagar district. Works on 100 check dams are completed
  - To prevent salinity ingress 12 *bandharas* are constructed in Kutch
- *Participatory Irrigation Management:* Under this scheme
  - So far 1.73 lakhs ha command area is transferred to cooperative Water Users Association (WUA)
  - Enacted law on "Gujarat Water Users Participatory Irrigation Management Act
  - Cleaning of 15000 km length of drains has been done
- *Sardar Sarovar Project :* This multipurpose project envisages:
  - Provision of irrigation to 17.92 lakhs ha spread over 75 talukas and 15 districts
  - Provision of water for domestic and industrial uses to 8215 villages and 1345 townships
- *Establishment of Gujarat Green Revolution Company:* Gujarat Green Revolution Company has been established as the single nodal agency for implementing all the central and state government schemes pertaining to micro irrigation. During last three years, nearing 1 lakhs ha have been brought under micro irrigation in the state

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Augmentation of Water Resources of Gujarat

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Introduction

The Gujarat state has an area of 1,96,024 km^2 consisting of 25 districts. It is the seventh largest state in India situated on the West coast of country between 20-6' to 24-42' North latitude and 68-10' to 74-28' East longitude. Gujarat is bounded by the Arabian sea in the West, Rajasthan in North and North-East, Madhya Pradesh in the East and Maharashtra in South and South-East. The total population of the state is 505.97 lakhs with an average population density of 258 persons per km^2. The rural population of the state is 63 % (316.98 lakhs) of total population of the state. The literacy rate of the state is about 70 % with 50 % literacy rate in the rural area.

The natural resources in the state show tremendous variations. The rainfall ranges from < 500 mm in Kutch and parts of North Gujarat to > 2000 mm in South Gujarat. The climatic variation is evident from arid in Kutch and North Gujarat to subhumid in the southern parts of the state. Similarly, sandy soils in North and North-West of Gujarat and clay soils in South are predominant. The physiography of the state is having all the types *i.e.*, undulating and hilly terrain in East, plain in middle and coastal belt all along the western side.

The reporting area of Gujarat state is 19.01 m ha for which land use statistic is available. Per capita land availability in Gujarat is about 43 per cent higher than the national value. The detail land use statistics of the state is given in table 1.

Table 1: Land use pattern of Gujarat state

Land use	Area* ('000 ha)	% of total reported area
Forest	1854	9.75
Not available for cultivation	3753	19.75
Permanent pastures and other grazing lands	850	4.47
Land under misc. tree crops and groves	4	0.02
Culturable wasteland	1985	10.44
Fallow land other than current fallows	11	0.06
Current fallows	930	4.89
Area under cultivation	9622	50.62
Total reported area	**19009**	100.00

**Estimated*

[1] Joint Director
[2] Managing Director

The major crops in the state are rice, wheat, sorghum, pearl millet, maize, pigeon pea, gram, groundnut, cotton and tobacco. Of the total cropped area, food crops like cereals and pulses account for about 50 per cent, while the remaining area is under oilseed, fiber and fodder crops.

Extent of waste land

An area of 81.33 lakh ha has been reported as degraded in Gujarat state due to various problems (41.5 % of TGA). Among the various factors, water erosion contributes to the maximum extent *i.e.*, 64. A wide range of physiographic features are displayed within relief variations from sea level to 1000 m elevation. The vast stretch of wastelands under different categories is the major constraint. The recent status of wastelands in different districts of the state under various categories of waste land is reported in table 2. Among the various degraded lands, land with/ without scrub ranked first (21787 km^2) followed by salt affected soils (7637 km^2) and degraded notified forest (5443 km^2). Similarly, among the districts, the maximum degraded area is in Kutch (19120 km^2) and the next in order is Junagadh (3141 km^2) and Jamnagar (2884 km^2).

Delineation of watersheds

In order to plan the soil and water conservation work on scientific basis, the whole status has been delineated into different units of watershed. Accordingly, entire area of the state has been demarcated in region, basin catchment, sub catchments, watershed and sub, mini and micro watershed by the Bhaskaracharya Institute of Space Application and Geo-Informatics (BISAIG), Gandhinagar (Table 3).

Table 3: Classification of watershed in Gujarat

SN	Particular	No.
1	Region	2
2	Basin	8
3	Catchments	18
4	Sub-Catchments	40
5	Watershed	217
6	Sub - Watershed	773
7	Mini - Watershed	1896
8	Micro - Watershed	9716

Table 2: District-wise status of wastelands in Gujarat

District	Categorized wastelands area (km^2)												
	GR	S	WLM	SA	DNF	DPG	DPC	SIC	MIW	BR	SS	TW	% to TGA
Ahmedabad	65	107	0	865	1	53	0	5	0	3	0	1100	13
Amreli	3	372	6	12	73	0	0	0	0	33	0	500	7
Banaskantha	80	1237	54	552	547	9	1	47	4	53	160	2743	22
Bharuch	76	144	292	109	110	0	2	0	7	3	0	742	8
Bhavnagar	26	1265	0	574	34	8	0	7	0	47	0	1962	18
Dangs	0	0	0	0	113	0	0	0	0	0	0	113	6
Gandhinagar	24	1	0	0	0	2	0	0	0	0	0	27	4
Jamnagar	0	2536	0	1	35	0	0	0	0	311	0	2884	20
Junagadh	0	2329	0	0	487	0	0	0	0	325	0	3141	30
Kheda	153	73	0	147	27	19	4	9	2	93	0	527	7
Kutch	108	8860	1619	4462	1765	161	1	107	14	1876	148	19120	42
Mehsana	80	330	0	116	0	90	0	4	0	0	0	619	7
Panchmahals	33	272	0	0	985	0	0	0	3	63	0	1356	15
Rajkot	57	1592	23	49	100	24	24	0	1	125	1	1996	18
Sabarkantha	181	600	0	3	432	2	2	4	0	135	163	1522	21
Surat	20	133	250	30	251	17	16	0	8	1	0	724	9
Surendranagar	35	1514	82	710	56	2	0	0	0	214	0	2614	25
Vadodara	61	218	8	0	304	0	2	0	0	10	3	605	8
Valsad	12	205	324	8	123	0	26	6	10	2	12	728	14
Total	**1013**	**21787**	**2656**	**7637**	**5443**	**388**	**78**	**188**	**50**	**3293**	**487**	**43021**	**22 (avg.)**

Notes: **GR:** Gullied / Ravine land, **S:** Land with / without scrub, **WLM:** Waterlogged / Marshy land, **SA:** Saline/Alkaline land, **DNF:** Degraded Notified Forest land, **DPG:** Degraded Pasture/Grazing land, **DPC:** Degraded land under plantation crops, **SIC:** Sands-Inland/Costal, **MIW:** Mining / Industrial Wastelands, **BR:** Barren Rocky Area, **SS:** Steep Sloping land, **TW:** Total Wastelands, **TGA**: Total Geographical Area

Major programme implementing agencies

In view of the facts described so far, Govt. of Gujarat realized the significance of soil and water conservation in the state and established GLDC to implement this program more efficiently, in addition to the other departments. Gujarat state Land Development Corporation Limited (GLDC) is one of the leading implementing agencies for watershed development works in the state. It was established in March 1978, with the main objective of executing land reclamation and soil conservation schemes in the state. It acts as a wholly Government and implement Watershed Development Programme in the state, such as (1) Soil Conservation Schemes in normal areas (2) Soil Conservation Schemes in tribal area (3) Farm Pond and Village Ponds Scheme (4) Macro Management Schemes (5) Flood Relief Scheme (6) Water Harvesting Structure Scheme and other such schemes. Similarly, State Rural Development is another agency which is also implementing these programs.

GLDC is implementing soil and moisture conservation schemes in 3330 watersheds. So far, about 945 watersheds are completed and 2385 watershed are under implementation. Similarly, Rural Development Department of the state is also implementing various schemes like DPAP, DDP, EAS, IWDP, State Watershed *etc*. Scheme wise status of the watershed is given in table 4. State Rural Development has treated 31.96 lakh ha up to March 2005. They have completed 1662 watersheds and 4724 watersheds are under implementation.

Table 4: Schemes wise status of watersheds

Schemes	No. of watersheds	Completed watershed	Watershed under implementation
GLDC	3330	945	2385
DPAP	2149	449	1700
DDP	2642	445	2197
EAS	546	546	0
IWDP	851	24	827
State Watershed	198	198	0
Total	**9716**	**2607**	**7109**

So far, GLDC has treated 23.98 lakh ha area since its inception. Through this activity, there is an increase in irrigated area per year is around 1.33 lakh ha (Table 5).

Table 5: Work done by GLDC (up to July - 2009)

1.	Area covered under watershed (lakh ha)	:	23.98
2.	Desilting work of village ponds (Nos.)	:	6440
3.	Water harvesting structure constructed (Nos.)	:	12445
4.	Farm ponds (Nos.)	:	48449
5.	*Sim talavadi* (Nos.)	:	3923
6.	Beneficiaries covered (lakh person)	:	9.35
7.	Estimated water harvesting per year (MCM)	:	200
8.	Estimated increased irrigated area (ha per year)	:	133000

Physical and financial achievement

The total area treated in the state up to march, 2007 is 47,31,422 ha involving expenditure of Rs. 1,23,813.64 lakhs under different watershed programme. The details of programme wise achievement up to March, 2007 are given in table 6.

Table 6: Physical and financial achievements under different watershed development programmes in Gujarat (Up to March, 2007)

SN	Name of the programme	Physical achievement (ha.)	Financial Achievement (Rs in lakh)
A) Major Watershed Programmes			
1	NWDPRA	6,44,444	16,085.68
2	DPAP	12,22,000	22,202.00
3	DDP	15,31,000	34,964.00
4	IWDP	5,50,669	12,219.94
5	RVP/FPR	1,99,153	11,006.91
6	NAP (NAEB)	35,455	9,074.00
7	RAS	48,820	1,911.08
	Sub total (A)	42,31,541	1,07,463.61
B) Other Watershed Programmes			
1	EAS	2,47,881	4,230.03
2	State Schemes	2,52,000	15,120.00
	Sub total (B)	4,99,881	19,350.03
	Grand total (A + B)	**47,31,422**	**1,26,813.64**

Status of rainwater storage

Information regarding water harvesting bodies constructed, water storage by GLDC is given in table 6 indicated that total 74,461 water harvesting bodies are constructed which stored about 4946 lakh m^3 water which can irrigate 629118 ha areas including supplementary irrigation (Table 7).

Table 7: Statement showing information on rainwater storage

SN	Year	Village pond		Farm pond/ *Sim talav*		Water harvesting structures		Total		
		Nos.	Water storage (lakh m^3)	Nos.	Water storage (lakh m^3)	Nos.	Water storage (lakh m^3)	Nos.	Water storage (lakh m^3)	Estimated increase in irrigated area (ha)
1	1996-97	0	0	6910	391	0	0	6910	391	78264
2	1997-98	0	0	5853	46	62	4	5915	50	10064
3	1998-99	20	5	6425	59	380	27	6825	91	17644
4	1999-00	616	154	1536	13	575	40	2727	207	29140
5	2000-01	1156	289	4682	37	1295	91	7133	417	60118
6	2001-02	755	189	5055	41	672	47	6482	277	40218
7	2002-03	66	17	546	4	139	10	751	31	4790
8	2003-04	319	80	1824	14	375	26	2518	119	17530
9	2004-05	165	41	29	0	1499	118	1693	160	28630
10	2005-06	302	76	0	0	1592	121	1894	197	33416
11	2006-07	412	103	2342	95	2305	168	5059	366	64946
12	2007-08	1081	270	5497	271	1764	123	8342	664	111440
13	2008-09	2118	508	13269	1327	2825	141	18212	1976	132918
	TOTAL	**7010**	**1731**	**53968**	**2297**	**13483**	**917**	**74461**	**4946**	**629118**

The total water requirement of the state is 30,000 MCM which constitute 2,000 MCM for drinking and domestic, 22,400 MCM for irrigation and 5,600 MCM for industrial and other purposes. Considering the rainfall and runoff pattern, about 27,000 to 30,000 MCM water can be used. The capacity of reservoir is about 32,000 MCM, of which about 20,000 to 22,000 MCM water remains in the reservoir and 18,000 to 19,000 MCM water is available from the reservoir as against the requirement of 30,000 MCM per annum. So, there is a gap of 11,000 to 12,000 MCM water which is to be met from the ground water. As far as ground water quantity in the state is concerned, it is about 12,800 MCM and we have to draw about

11,000 MCM water which comes to about 85 per cent of the ground water source. As per the international standard those states which draw more than 75 per cent of ground water storage are categorized as severe water scarce state.

Benefits of rainwater storage achieved

Gujarat state has archived 10.4% GDP during 10th five year plan which was higher than allocated target to the state (10.2%). This was due to runoff water harvesting in rainfed areas. Due to intensive water harvesting work during last 10 years *viz.*, no. of village ponds, farm ponds and water harvesting structure has been constructed and ultimately resulted in:

- rise in ground water table,
- well irrigated area in the state increased from 19,30,100 to 27,36,400 ha,
- cultivation of cash crops / value added crops has been increased as compared to cereals crops,
- cultivation of summer and winter crops has been increased,
- quality of under ground water has been improved and more employment has been generated,
- production of fruits, vegetable, medicinal, and spices crops has been increased,
- expenditures on water harvesting may be recovered within one year, if the rainfall is normal and
- in the year 2004-05 at state level, an increase in irrigated area by 35 per cent over the base year of 1990-91 (29,10,500 ha)

Impact assessment

The work carried out by GLDC and other agencies in state is evaluated by professional agencies *viz*.,

1. Agriculture Finance Corporation
2. Gujarat Institute of Development Research
3. Director Evaluation, Govt. of Gujarat, Gandhinagar
4. The Energy and Resource Institute (TERI), Bangalore
5. Sadguru Foundation, Dahod
6. Sardar Patel Agro Economics Research Center, Vallabh Vidhyanagar

Based on the evaluation survey they, the agency reported 10 to 30 per cent rise in agriculture production, 25 to 30 per cent agriculture income, 3 to 15 m rise in groundwater table, 20 per cent additional irrigation potential and 20 to 30 per cent milk production due to implementation of watershed management schemes.

The Energy Resource Institute, New Delhi in its Mid Term Evaluation of 10th Plan Watersheds of NWDPRA Gujarat State, revealed that there is a tangible increase in agriculture income of the project beneficiaries, which varied from Rs. 14,000 to Rs. 25,880. Along with these, the project has yielded 2,200 to 18,000 man days of employment opportunities. Family income per year varies from Rs. 3,500 to 25,880. Decrease in migration of rural labourers from 65 to 25 per cent was also observed.

Ground water level rise by 6 to 8 m. Crop productivity has definitely and substantially enhanced during project implementation. The increase has been in the range of 25 to 200 per cent in these watersheds, depending on the crop. There was increase in green cover / biomass by 40 to 45 per cent in these watersheds.

Financial analysis of the watershed at 10 per cent discount rate gives Cost-Benefit Ratio (CBR) ranging from 0.05-0.2 and Internal Rate of Return (IRR) for the project varies from 45-132.2 per cent.

Performance evaluation of State Government Schemes for water harvesting implemented by GLDC was conducted by Directorate of Evaluation, Government of Gujarat, Gandhinagar covering **400 beneficiaries** selected randomly. From the survey, following facts were emerged.

- 371 had got more than one benefits *viz.*, increase in production of crops as well as irrigation, increase in ground water table i.e. increase in water level in their wells, increase in fertility of land *etc*.
- The area under *kharif* crops had increased from 851.6 ha to 925.0 ha and *rabi* crops from 35.70 ha to 92.25 ha (158.40%), which shows an increase of 8.62 and 158.40 per cent, respectively, in *kharif* and *rabi* seasons.
- The increase in irrigated area under *kharif* crop was 37.5 per cent & that in *rabi* crop was 275.5 per cent.

- In *kharif* and *rabi* seasons agriculture production of different crops had increased by 29.1 and 26.9 per cent, respectively after the implementation of the scheme. The overall agriculture production increased by 34.1 per cent after the implementation of the scheme.
- 371 (92.8 %) were using improved seeds, 347 (86.8 %) were using chemical fertilizers, 314 (78.5 %) were using pesticides and 214 (53.5 %) beneficiaries were using improved agriculture implements.
- 310 (77.5 %) had made change in the cropping pattern after the implementation of the scheme (within 1999-2000 to 2001-02).
- 201 (50.3 %) had well in their farm and ground water table rised in their well. The remaining 199 (49.8 %) beneficiaries had no well in their farm.
- 308 (77.0 %) were taking responsibility of repairing and maintenance work of structure regularly and remaining 92 (23.00%) beneficiaries were not doing any maintenance.
- The average annual income from all sources was Rs. 63,914 prior to scheme which increased to Rs. 86,966 after the implementation of the scheme which shows 36.07 per cent increase in the average annual income of sample beneficiaries.
- 378 (94.50 %) beneficiaries felt that after the implementation of the scheme, their agriculture production of crops had increased, hence their economic conditions have also improved.
- 324 (81.00 %) beneficiaries opined that their social conditions improved after the implementation of the scheme.
- 373 (93.25 %) samples beneficiaries opined that their living standard of life also improved.
- The surveyed beneficiaries' possessed 2076 different livestock *viz.*, cows, buffaloes, bullock's, sheep and goats *etc.*, before the implementation of the scheme. After the implementation of the scheme the no. of livestock increased from 2076 to 2195 which shows 5.73 per cent increase in total live stocks.

Conclusions

Soil, water and air pollution are hampering crop production, human and animal health and eroding biodiversity. Concentrated efforts are needed to protect the natural resources from pollution to sustain agriculture productivity through establishing appropriate vegetative cover and by installing gadgets, which will reduce pollution from industrial activities. Our farming practices

need to be oriented towards eco-friendly direction to save our natural resources and mother earth.

At state level, 70 per cent water for irrigation and 80 per cent water for domestic use is from the ground water. The storage of ground water is decreasing and more number of wells are drying. In spite of such a severe situation, there is no policy to restrict the withdrawal of ground water more than recharge.

Following are the suggestions for promoting conservations of natural resources for sustainable development and environmental protection.

1. Creation of natural resources data base using modern techniques.
2. Inter - basin water transfer to minimize water scarcity and regional imbalances in the supply and demand.
3. Shift in emphasis from an expensive supply management approach to a more efficient approach promoting soil and water conservation and demand management.
4. Legislative measure to promote removal of water from areas affected by degradation, higher entitlement for those using water more efficiently.
5. Afforestation, policy measures to arrest soil erosion through watershed approach.
6. Effective utilization of water resources.
7. Judicious use of water for irrigation and gypsum application to alkali land.
8. Application of bio-mass, afforestation, balanced fertilization, proper cropping practices.
9. Appropriate tillage, irrigation, manure and fertilization practices.

Quality of Ground Water Used for Irrigation in Gujarat

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Introduction

Gujarat is situated on the western part of India and has the longest coast line in the country (1,600 km). The climate is basically arid to semi arid except in down South where it is sub humid. The agriculture is predominantly a rainfed one with a net irrigated area of less than 40 per cent. Out of the total irrigated area, 80 per cent is through wells and tube wells. Over exploitation of ground water in the North Gujarat resulting in fast receding water table and excessive withdrawal from the wells in Saurashtra and Kutch resulting in sea water intrusion are the characteristics of lift irrigation command in the state. Both the above factors result into the deterioration of ground water quality. So far no systematic survey of ground water quality has been made, though some works have reported the quality of ground water for some specific location /district of North Gujarat/Kutch and Saurashtra like for Bhiloda area of Sabarkantha district of North Gujarat (Acharya *et al*.,2008) *etc*. or for river basin like Sabarmati basin *etc*. So far no attempt has been made to characterize the ground water used for irrigation at the state level. Hence is the present attempt.

Methodology

The Gujarat Green Revolution Company, the nodal agency for implementing the Micro Irrigation Scheme of the government has made it mandatory that any farmer who is opting for adoption of micro irrigation must get his soil and water tests done and report attached with the application form. Between 2005 and 2008, about 56,000 samples have been collected and analyzed at the Soil and Water Testing Laboratory of the Gujarat State Fertilizer and Chemicals Ltd., Vadodara.

The samples were taken as per standard procedure by adopting all the prescribed precautions before sending them to the laboratory. These samples were analyzed for pH, EC,

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TSS, cations *viz*., Ca, Mg, Na and soluble anions *viz*., CO_3, HCO_3, SO_4 and Cl by following standard procedures. The derived parameters are SAR, RSC and SSP.

Results

pH: Though, the reaction (pH) values per se may not indicate the salinity or sodicity extent except when it is very high, nevertheless it gives some idea about the quality of the water. Normally, the water with pH value between 6.5 and 8.5 may not create any problems for soil and crop.

The 56000 samples analysis showed that the minimum pH was 6 and maximum 11.9 with an average of 7.8 (Table 1). Thus the state level mean pH value does not suggest any problem with special reference to alkalinity. But, a more detailed analysis showed that only 20 per cent of the samples were having a pH value of less than 7.5 and which can be categorized as "Good" water. On other hand, as high as 1/3rd of the waters analyzed were having a pH value of 8 and above. That means around 20000 samples indicate a possibility of sodicity problem in the waters used for irrigation. Among the different districts, nearly 50 per cent of the waters analyzed were having a pH value of 8 and above in the districts of Bharuch, Bhavnagar and Narmada.

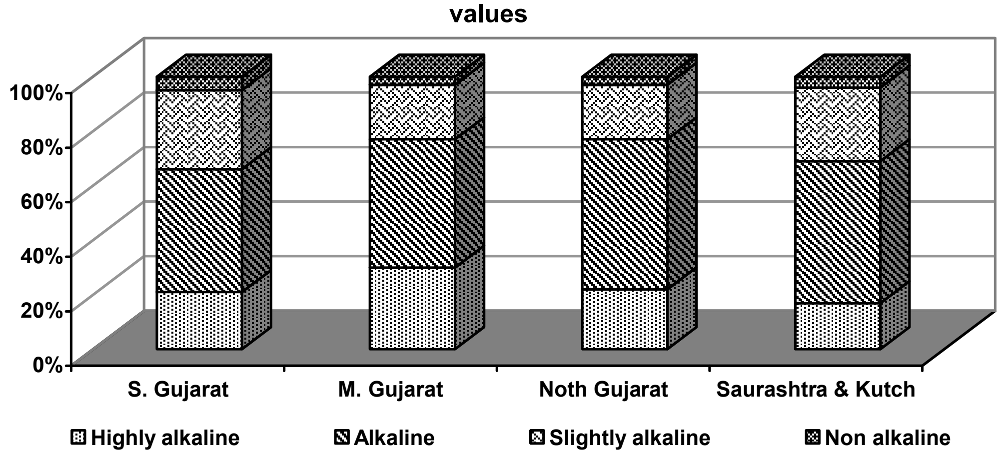
Table 1: Reaction (pH) values of ground waters used for irrigation in Gujarat

District	No. of samples	pH range		Average	pH class (% samples)			
		Min	Max		<7.5	7.5-8	8-8.5	>8.5
Ahmedabad	557	6.8	9.2	7.9	13	52	31	4
Amreli	5333	6.3	9.3	7.8	14	56	26	4
Anand	1139	6	8.9	7.7	26	46	26	2
Banaskantha	6168	6.1	9.3	7.8	14	60	24	2
Bharuch	553	6.7	8.9	7.9	13	40	42	5
Bhavnagar	2791	6.4	9.1	7.9	10	48	35	7
Dahod	713	6.3	8.6	7.5	44	46	10	0
Gandhinagar	614	6.8	9.4	7.8	18	56	23	3
Jamnagar	4415	6.2	8.9	7.8	20	54	26	0
Junagadh	6404	6.2	11.9	7.8	18	57	24	1
Kutch	1714	6.2	9.9	7.7	27	46	24	3
Kheda	781	6.6	9	7.7	32	49	17	2
Mehsana	613	6.7	8.9	7.7	26	57	16	1

District	No. of samples	pH range		Average	pH class (% samples)			
		Min	Max		<7.5	7.5-8	8-8.5	>8.5
Narmada	628	6.4	8.9	7.9	11	41	41	7
Navsari	1642	6.5	9.9	7.7	27	53	14	6
Panchmahals	554	6.1	8.8	7.6	32	50	17	1
Patan	468	6.2	8.6	7.6	30	53	16	1
Porbandar	1482	6.2	8.7	7.8	12	55	32	1
Rajkot	5230	6.4	9	7.8	14	53	31	2
Sabarkantha	5813	6.3	9.4	7.7	32	47	19	2
Surat	504	7	8.9	7.8	20	45	33	2
Surendranagar	2148	6	11.2	7.8	21	46	32	1
Vadodara	5299	6.3	10.6	7.8	21	40	36	3
Valsad	913	6.4	9	7.7	35	41	20	4
State	**55987**	**6**	**11.9**	**7.8**	**20**	**51**	**26**	**3**

Among the different regions of the state, 31 per cent of the waters were neutral in reaction in middle Gujarat while in Saurashtra and Kutch only 17 per cent of the samples had a pH value of less than 7.5. In the other two zones, the percentages were around 20. On the other hand, the slightly alkaline pH varied from 44 per cent in South Gujarat to 54 per cent in North Gujarat. The highly alkaline condition varied very narrowly from 2 to 5 per cent (Fig. 1).

Fig. 1: Regionwise per cent distribution of water samples based on pH values



Electrical conductivity: The salt concentration in the water is expressed in terms of electrical conductivity. As the salt concentration increases, the conductivity value will increase. The

United States Soil Survey Laboratory (USDA) classifies the waters based on the electrical conductivity (Table 2).

Table 2: Water quality rating based on the total salt concentration as per USDA

EC of irrigation water (dS/m) at 25° C	Saline water class	Suitability
0 – 0.25	Low (C_1)	Can be used in most of the soils for most of the crops. Only in soils with very low permeability some leaching is required.
0.25 – 0.75	Medium (C_2)	Can be used with moderate leaching and growing moderately salt tolerant plants.
0.75 – 2.25	High (C_3)	Can not be used where drainage is poor. Salt tolerant plant and appropriate management practice should be followed
2.25 – 5.00	Very high (C_4)	Not suitable for irrigation. Can be used under special circumstances occasionally. The soil must be very permeable and very high salt tolerant crops only can be grown

Note: Though, the waters having 0.25 or less electrical conductivity are classified as most suitable for irrigation by USDA, yet these waters can create permeability problems due to very low electrolyte concentration.

As per the above standard, the district wise distribution of the water samples is presented in table 3. The minimum EC varied narrowly from 0 .19 to 0.29 dS/m in different districts with an average of 0.19. On the other hand, the maximum EC varied from 3 dS/m in the districts of Navsari and Surat to as high as 30 dS/m in Porbandar.

In the state, the low saline water is very little as less than 1 per cent of the samples analyzed had an EC up to 0.25 dS/m. But there is a sudden jump in the medium saline water which contributed to 31 per cent. But, in the districts of Anand, Bharuch, Dahod, Narmada, Porbandar and Surat, around 50 per cent of the samples were of medium salinity. The medium salinity status was 10 per cent and less in the districts of Ahmedabad and Gandhinagar.

The maximum percentage of samples analyzed fall in the high salinity group with a value of 52 at the state level. The percentage was highest in Gandhinagar with a value of 83 followed by Navsari with a value of 73. In the districts of Banaskantha, Sabarkantha, Mehsana and Kheda, the per cent samples falling in this group are between 60 and 70.

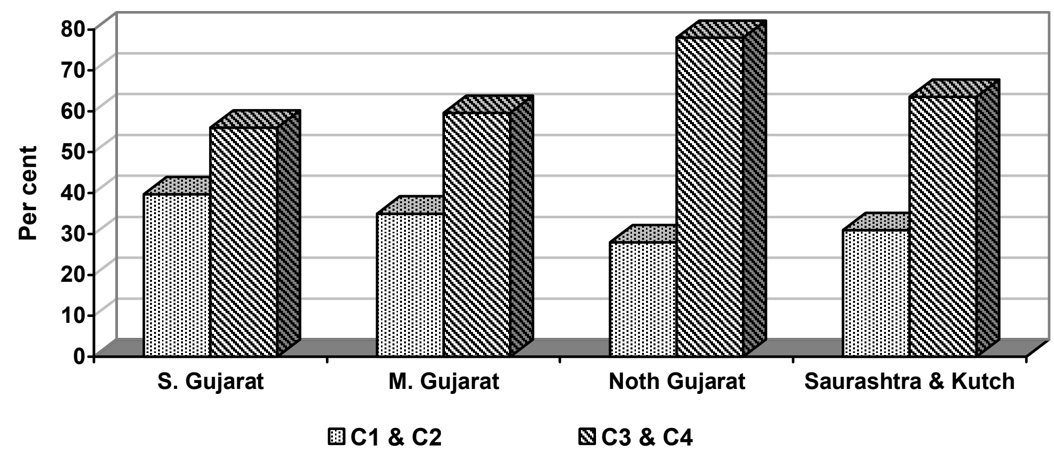
Anand, Jamnagar, Bharuch, Dahod, and Surendranagar the percentages are between 40 and 50, while in the districts of Narmada and Patan it is 34 per cent. The minimum value was observed in Porbandar with a percentage of 29. The percentage of high saline water is 16 at the state level. But, in the district of Patan, it is as high as 43, followed by Ahmedabad with a percentage of 33 and Kutch with 30.Gandhinagr, Dahod and Surat registered a percentage of less than 5 each.

Table 3: Distribution of water samples into different classes of salinity (as per USDA)

	EC range (dS/m)			Salinity class (% samples)			
District	**Min**	**Max**	**Average**	**C_1 (0.25)**	**C_2 (0.25-0.75)**	**C_3 (0.75-2.25)**	**C_4 >2.25**
Ahmedabad	0.19	15.1	2.2	2.0	10	55	33
Amreli	0.19	10.5	1.8	0.2	25	50	25
Anand	0.19	16.3	1.2	0.6	46	45	8
Banaskantha	0.21	7.5	1.4	0.3	26	63	11
Bharuch	0.19	14.9	1.3	1.3	47	43	9
Bhavnagar	0.20	11.6	1.4	3.2	34	50	13
Dahod	0.19	8.0	0.9	0.3	53	43	4
Gandhinagar	0.29	4.9	1.6	0.0	5	83	2
Jamnagar	0.20	17.6	1.4	0.0	39	44	16
Junagadh	0.19	10.9	1.7	0.1	24	52	24
Kutch	0.20	10.4	2.0	1.2	18	51	30
Kheda	0.19	7.2	1.8	1.0	13	61	25
Mehsana	0.25	16.2	1.7	0.0	14	67	19
Narmada	0.21	22.0	1.0	3.0	57	34	6
Navsari	0.19	3.4	1.4	1.0	14	73	12
Panchmahals	0.19	6.2	1.2	1.0	34	55	10
Patan	0.25	16.9	2.5	0.0	23	34	43
Porbandar	0.23	30.3	1.3	0.0	51	29	20
Rajkot	0.19	14.0	1.4	0.2	44	36	20
Sabarkantha	0.19	8.3	1.2	4.0	26	64	6
Surat	0.19	3.45	1.1	0.0	46	51	3
Surendranagar	0.19	12.1	1.7	0.6	27	49	23
Vadodara	0.19	16.5	1.3	0.3	38	53	9
Valsad	0.19	7.0	1.1	0.8	40	53	6
State	**0.19**	**30.3**	**1.5**	**0.8**	**31**	**52**	**16**

In all the regions, the low saline water contributes to the minimum. In North Gujarat, the medium saline water contributes only around 17 per cent, but the high saline water contributes to as high as 61 per cent. South and middle Gujarat zones registered medium and high saline waters in the range of 40 to 50 per cent (Fig. 2).

Fig. 2: Region wise salinity classes of water (as per USSSL)



Sodium adsorption ratio (SAR): The suitability of water is always considered in association with SAR. The SAR gives an indication of relative predominance of Na over Ca and Mg. The USDA has made four categories with regard to SAR values as below.

Class	Range of SAR	Suitability
S_1	0-10	Can be used in all soils. Sodium sensitive crops may accumulate Na in leaves
S_2	10-18	Moderate problems in fine textured soils. Needs application of gypsum. Can be used in coarse textured soils
S_3	18-26	High Na water. May create problem in all soils. Need special management practices like drainage, leaching addition of organic matter *etc*.
S_4	>26	Unsatisfactory for irrigation. Can be used with C1 type of water along with gypsum.

At the state level, category indicating fewer problems for its usage except in very fine textured soils. But, in the districts of Ahmedabad and Patan the percentages of S_1 category waters are only 69 and 63 indicating that in these districts 30 per cent of the waters are having Na problems and the usage of such waters in these districts need special attention. In fact, 332 samples of the total samples analyzed fall in S_3 and 111 samples in S_4 categories distributed in different districts (Table 4).

Table 4: Distribution of water samples in different categories of SAR

District	S_1	S_2	S_3	S_4
	0-10	**10-18**	**18-26**	**>26**
Ahmedabad	69	19	6	6
Amreli	99	1	0	0
Anand	92	6	2	0
Banaskantha	94	5	1	0
Bharuch	96	3	1	0
Bhavnagar	97	2	1	0
Dahod	99	1	0	0
Gandhinagar	87	13	0	0
Jamnagar	99	1	0	0
Junagadh	98	2	0	0
Kutch	83	13	0	0
Kheda	81	18	1	0
Mehsana	88	11	1	0
Narmada	99	1	0	0
Navsari	94	6	0	0
Panchmahals	97	3	0	0
Patan	63	24	7	6
Porbandar	98	2	0	0
Rajkot	99	1	0	0
Sabarkantha	99	1	0	0
Surat	97	3	0	0
Surendranagar	89	8	3	0
Vadodara	94	6	0	0
Valsad	97	3	0	0
State	**95**	**4**	**1**	**0**

The USDA recommends the use of combination of the salinity (C) and sodicity (SAR) values to determine the scope of actual usage of the water for irrigation. But, this approach is being debated by many especially for Indian conditions (Gupta and Gupta, 1987). Ramamurthy (1964) also modified the USDA classification by considering the factors of soil and crops simultaneously in addition to salinity. Subsequently, Gupta (1979) suggested a modification for salinity classification of irrigation waters.

Salinity criteria for classification of waters (Gupta, 1979)

Salinity water class	**Code**	**Salinity range (dS/m)**	**Suitability**
Normal	C_1	0.2-1.5	No restriction for irrigation
Low	C_2	1.5-3.0	No restriction for light and medium soils. But in heavy soils, only semi tolerant crops should be grown.
Medium	C_3	3.0-5.0	Semi tolerant crop in medium and light textured soils and tolerant crop in fine textured soil. Soil drainage should be good
High	C_4	5.0-10.0	Tolerant crops in light and medium textured soils with good drainage. In heavy soils this will create problems
Very high	C_5	>10.0	To be used for irrigation only under special conditions in all types of soils

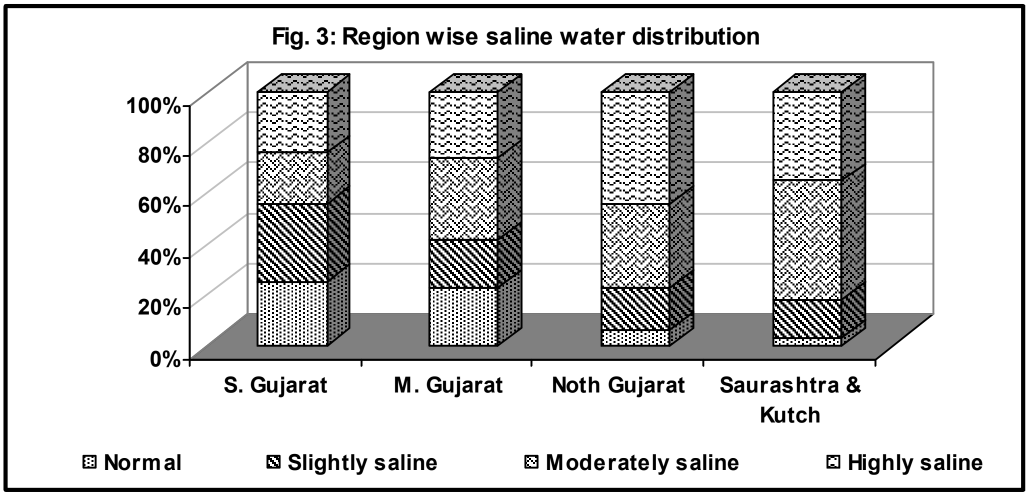
As per this classification though, 61 per cent of the waters in the state fall under normal group with regard to salinity followed by 30 per cent as low saline yet, in the districts of Ahmedabad and Patan only 30 and 36 per cent of the waters are falling under normal category (Table 5). Nearing 10 per cent of the samples (around 5600) in the state can be categorized as having medium to high salinity. In Patan district, 23 per cent of the waters fall under medium to high salinity category. This is followed by around 15 per cent in the districts of Ahmedabad (17%), Amreli (16%), Kutch (16%), Surendranagar (15%), Junagadh (12%), Kheda (12%) and Jamnagar (11%).

Table 5: Distribution of water samples in different categories of salinity

District	Normal	Low saline	Medium saline	High saline
Ahmedabad	30	53	14	3
Amreli	50	34	13	3
Anand	82	13	3	2
Banaskantha	61	34	4	5
Bharuch	58	39	2	1
Bhavnagar	58	37	3	2
Dahod	87	11	2	0
Gandhinagar	55	40	5	0
Jamnagar	64	25	10	1
Junagadh	48	40	10	2
Kutch	34	50	12	4
Kheda	52	36	10	2
Mehsana	50	42	5	3
Narmada	76	23	1	0
Navsari	54	44	2	0
Panchmahals	77	21	2	0
Patan	36	41	16	7
Porbandar	65	26	7	2
Rajkot	68	18	13	1
Sabarkantha	74	24	2	0
Surat	70	30	0	0
Surendranagar	53	32	12	3
Vadodara	69	27	3	1
Valsad	81	16	3	0
State	**61**	**30**	**7**	**2**

Source: Gupta (1979)

The above two classifications are not in line. While according to USDA classification and also with the modification done by Ramamurthy and others, at least 68 per cent of the samples in Gujarat have got medium to high level of salinity. But on the other hand, Gupta's classification suggests (Fig. 3) that around 60 per cent of the water samples are in normal range and another 30 per cent low saline leaving only 10 per cent of the sample with medium to high salinity level. Some concerted efforts should be made at the university levels to examine both the type of classifications and arrive at a suitable classification for the waters of the state, considering the different soil types.



Total soluble salts (TSS): Another way of expressing the salinity hazard of the water is in terms of its TSS content. The water is categorized as saline if the TSS exceeds 2100 ppm.

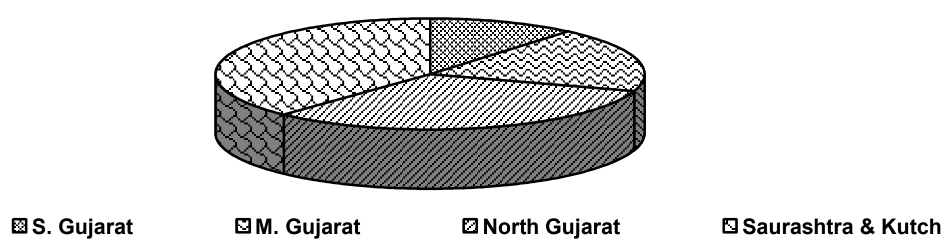
It is observed that 8 per cent out of the 56000 samples analyzed has a TSS content of more than 2100 ppm (Table 6). In the districts of Surat, Panchmahals, Dahod, Bharuch, Gandhinagar, Navsari, Vadodara, Valsad and Sabarkantha less than 5 per cent of the waters contain more than 2100 ppm. On the other hand, in Patan 22 per cent of the waters analyzed more than 2100 ppm of salts. This is followed by Ahmedabad and Amreli districts with a percentage of 15. The region wise distribution of the samples having more than 2100 ppm is depicted in fig.4.

Table 6: District wise distribution of water samples into different classes of TSS (%)

District	Up to 2100 (ppm)	> 2100 (ppm)
Ahmedabad	85	15
Amreli	85	15
Anand	22	6
Banaskantha	95	5
Bharuch	97	3
Bhavnagar	96	4
Dahod	98	2
Gandhinagar	97	3

District	Up to 2100 (ppm)	> 2100 (ppm)
Jamnagar	90	10
Junagadh	89	11
Kutch	88	12
Kheda	88	12
Mehsana	94	6
Narmada	98	2
Navsari	96	4
Panchmahals	98	2
Patan	78	22
Porbandar	92	8
Rajkot	86	14
Sabarkantha	98	2
Surat	99	1
Surendranagar	89	11
Vadodara	96	4
Valsad	96	4
State	**92**	**8**

Fig. 4: Region wise percentage of samples having TSS values of > 2100 ppm



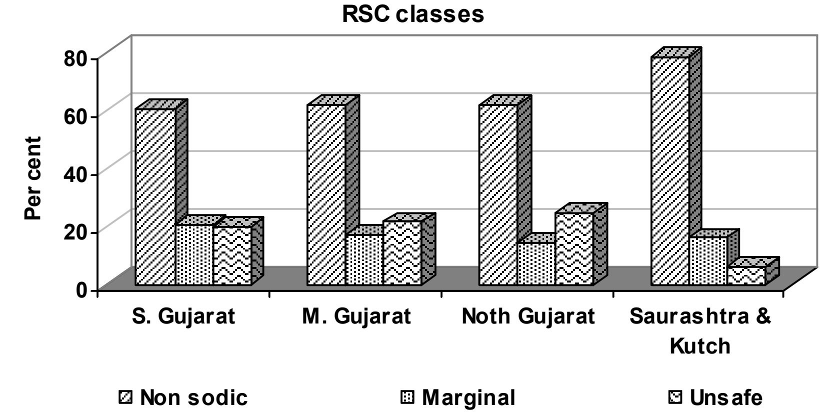
Residual sodium carbonate (RSC): As per USDA and other workers, the RSC is the most standard expression of assessing the sodic nature of the water. The RSC calculated as the difference between CO_3 + HCO_3 and Ca + Mg. If the value is less than 1.25 the water is considered safe, 1.25 to 2.5 as marginal and > 2.5 me/l as unsafe. The RSC values obtained are detailed in table 7. The average RSC value for the state has been found to be negative (-2 me/l). But the average values for Gandhinagar and Navsari are around 2 indicating that these waters are marginal to unsafe from irrigation point of view. It has been observed that 74 per cent of the water analyzed are in the safe range leaving 26 per cent as marginal (15%) and unsafe (11%). But, the waters of Navsari district showed that only 40 per cent is safe and 48 per cent are unsafe with RSC values of > 2.5. Similarly, in Gandhinagar district also around 50 per cent of the samples are unsafe for irrigation. Ahmedabad is another district where considerable percentage of waters are either marginal (11%) or unsafe (37%).

Table 7: Distribution of water samples into different classes of RSC

District	**Average (me/l)**	**RSC class (% samples)**		
		<1.25	**1.25-2.5**	**>2.5**
Ahmedabad	1.0	52	11	37
Amreli	-6.0	83	11	6
Anand	1.3	58	22	20
Banaskantha	1.5	76	12	12
Bharuch	-0.7	73	21	6
Bhavnagar	-1.7	72	17	11
Dahod	0.7	71	17	12
Gandhinagar	2.6	38	13	49
Jamnagar	-3.8	80	18	2
Junagadh	-4.6	81	13	6
Kutch	-1.9	81	10	9
Kheda	1.7	46	19	35
Mehsana	-0.4	69	13	18
Narmada	-0.6	71	22	7
Navsari	2.1	40	12	48
Panchmahals	-0.2	71	11	18
Patan	0.3	56	21	33
Porbandar	-2.5	73	23	4
Rajkot	-4.0	78	18	4
Sabarkantha	-0.4	81	12	7
Surat	0.3	63	20	17
Surendranagar	-0.6	79	14	7
Vadodara	0.9	62	16	22
Valsad	0.8	56	24	20
State	**-2.0**	**74**	**15**	**11**

Among the different regions, the Saurashtra region has more percentage of safe water from RSC point of view as against the other three zones (Fig. 5). In this zone, the waters having RSC value of less than 1.25 is around 80 per cent while in other zones they are around 60 per cent. Thus, in Saurashtra zone 20 per cent of the waters need gypsum treatment while in other zones 40 per cent of the waters need gypsum treatment, in case if we want to use these waters for irrigation purpose.

Fig. 5: Distribution of water samples of different regions of Gujarat in RSC classes



Residual sodium bicarbonate (RSBC): Based on experiments conducted in 1950s, Wilcox *et al*. (1954) suggested the HCO_3 and Ca only for calculating the RSC. Though, some later some experiments are supported it, during late 1960s Mg and CO_3 were also added. But, subsequently, it was suggested that as it is only the Ca that is getting precipitated in the presence of HCO_3, another parameter RSBC may be worked out as HCO_3 - Ca (Gupta, 1983). It is further suggested that a RSBC values of <5, 5-10 and >10 me/l may be considered as satisfactory, marginal and unsatisfactory, respectively.

According to the above, the mean RSBC at the state level is around 2 (Table 8). At state level most of the samples are in satisfactory class (81%) followed by marginal class (17%) and unsatisfactory (3%). In Kheda and Navsari districts about 62 per cent samples are beyond marginal quality.

Table 8: District wise percentage of RSBC in waters of different districts of Gujarat

District	Satisfactory <5	Marginal 5 to 10	Unsatisfactory >10
Ahmedabad	52	39	9
Amreli	88	10	2
Anand	59	34	7
Banaskantha	81	17	2
Bharuch	85	12	3
Bhavnagar	80	16	3
Dahod	90	10	1
Gandhinagar	34	59	7
Jamnagar	94	5	0
Junagadh	87	10	2
Kutch	88	10	2
Kheda	38	47	15
Mehsana	71	26	3
Narmada	85	13	2
Navsari	38	52	10
Panchmahals	69	27	4
Patan	73	25	2
Porbandar	92	8	0
Rajkot	93	6	0
Sabarkantha	86	13	1
Surat	75	20	5
Surendranagar	82	17	1
Vadodara	66	27	7
Valsad	69	28	3
State	**81**	**17**	**3**

Soluble sodium percentage (SSP): Soluble sodium content is an important parameter which will directly affect the soil permeability. As per the BIS, if the SSP in irrigation water exceeds 60 per cent, then it will deteriorate the soil physical conditions.

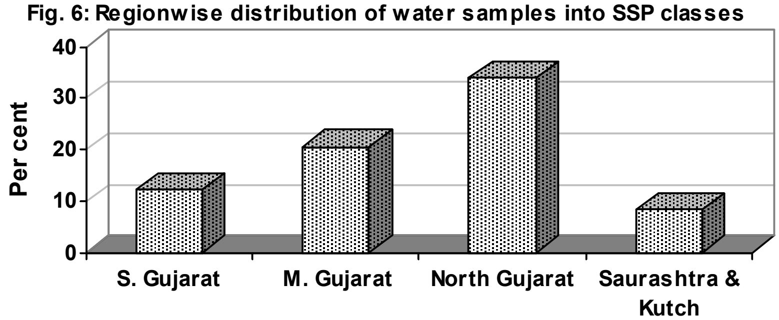
In 87 per cent of the waters analyzed, the SSP is below 60 per cent (Table 9). Though, at the state level, only 13 per cent of the samples have a value of more than 60, yet in different districts it varied widely. In the districts of Patan and Ahmedabad the trend is reverse and 66 per cent and 54 per cent of the samples analyzed more than 60 per cent SSP. Gandhinagar, Kutch, Navsari and Surendranagar districts are some of the districts any where between 25 to 44 per cent of the samples analyzed high SSP.

Table 9: Soluble sodium per cent in irrigation water of different districts of Gujarat

District	Up to 60 %	> 60 %
Ahmedabad	46	54
Amreli	95	5
Anand	85	15
Banaskantha	82	18
Bharuch	91	9
Bhavnagar	90	10
Dahod	96	4
Gandhinagar	56	44
Jamnagar	96	4
Junagadh	95	5
Kutch	70	30
Kheda	59	41
Mehsana	69	31
Narmada	96	4
Navsari	66	34
Panchmahals	91	9
Patan	34	66
Porbandar	95	5
Rajkot	96	4
Sabarkantha	96	4
Surat	87	13
Surendranagar	75	25
Vadodara	81	19
Valsad	87	13
State	**87**	**13**

Among the different regions (Fig. 6), the waters of North Gujarat analyzed as high as 33 per cent high SSP while it is very low in the Saurashtra and Kutch waters.

Fig. 6: Regionwise distribution of water samples into SSP classes



Specific ion effects: The chloride concentration is another important parameter to assess the water quality for irrigation. Plants differ in their characteristics. Considering 15 me/l as the limit for chloride concentration, it has been observed that 89 per cent of the water samples had chloride at non toxic level (Table 10).

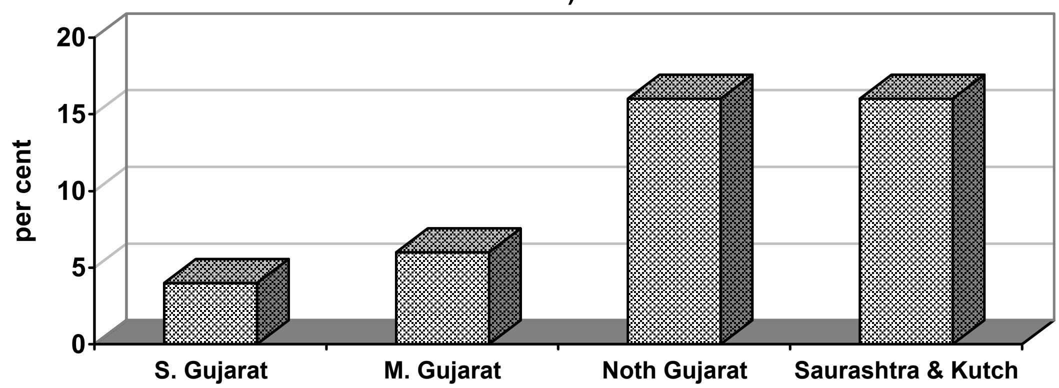
Table 10: Chloride content in irrigation water of different districts of Gujarat

District	**Chloride class (%)**	
	Up to 15 me/l	**>15 me/l**
Ahmedabad	76	24
Amreli	81	19
Anand	95	5
Banaskantha	93	7
Bharuch	95	5
Bhavnagar	93	7
Dahod	98	2
Gandhinagar	91	9
Jamnagar	86	14
Junagadh	85	15
Kutch	75	25
Kheda	86	14
Mehsana	88	12
Narmada	97	3
Navsari	94	6
Panchmahals	96	4
Patan	63	37
Porbandar	88	12
Rajkot	84	16
Sabarkantha	96	4
Surat	98	2
Surendranagar	81	19
Vadodara	95	5
Valsad	96	4
State	**89**	**11**

As against the value of 11 per cent at the state level, in Patan as high as 37 per cent of the waters have got the chloride toxicity. This is followed by Ahmedabad and Kutch districts where almost every fourth sample exhibits the chloride problem. The tribal districts of Narmada, Dahod and Surat pose minimum chloride problem.

Among the different regions, the waters of South and middle Gujarat the per cent waters having more than 15 me/l are as low as 4 and 6 respectively. Contrarily, 16 per cent of the waters of North Gujarat and Saurashtra and Kutch exhibit chloride toxicity. This may be due to the ingress of sea water in the coastal districts of Saurashtra and reducing water table due to excess withdrawal of water in North Gujarat (Fig. 7).

Fig. 7: Regionwise per cent water samples with high chloride content (> 15 me/l)



Conclusions

A perusal of the irrigation water analysis of the 56,000 samples reveals the following points:

- Nearly 30 per cent of the water have pH value of 8 or more
- Based on USDA classification, about 68 per cent of the water samples fall in C_3 and C_4 (saline to high saline) categories. But, as per the classification suggested by Gupta (1979) only 10 per cent of the samples fall under saline to highly saline category and remaining 90 per cent under normal to slight saline one
- The TSS analysis is in close conformity with the Gupta's classification as 9 per cent of the samples had a TSS value of more than critical value of 2100 ppm
- Based on TSS analysis, among the different districts, the water salinity has been observed to be more in the districts of Patan, Ahmedabad, Amreli, Rajkot, Jamnagar, Junagadh, Kutch, Kheda and Surendranagar. Among the different zones, the ground

water salinity is around 10 per cent in North Gujarat and Saurashtra, while it is only around 5 per cent in South and middle Gujarat.

- The RSC data indicated that sodic waters are more widespread than saline waters.
- In the districts of Navsari and Gandhinagar, the marginal and sodic waters are more than non sodic water. Patan and Ahmedabad are other districts where nearly 50 per cent of the waters are marginal or sodic.
- The RSC also followed almost a similar trend.
- Based on the RSC value, contrary to the salinity trend, only 22 per cent of the water samples fall in marginal to unsafe level in Saurashtra and Kutch regions, while it is around 40 per cent in the other three zones.
- The SSP is also more in the North Gujarat than Saurashtra and Kutch waters
- Gypsum application based on irrigation water quality especially in the South, middle and North Gujarat need more popularization.
- The per cent water samples analyzing high chloride contents in Saurashtra, Kutch and North Gujarat is three to four times more than those in middle and South Gujarat.

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Research on Enhancing Water Use Efficiency in Different Crops of Gujarat

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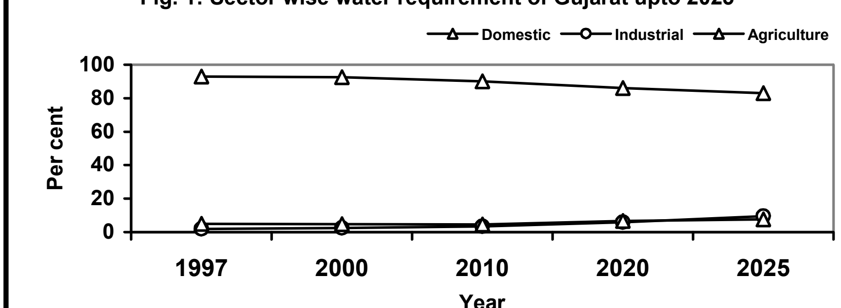
Introduction

The state of Gujarat is blessed with diversified natural resources with tremendous spatial variations. The climatic variation ranges from arid in Kutch and part of North Gujarat to sub humid in southern parts of the state. The central Gujarat and Saurashtra regions fall-under semi-arid class. The rainfall varies from less than 500 mm in Kutch to more than 2000 mm in the Dangs district. The soil heterogeneity in the state is so high that the soil map of Gujarat exhibit mosaic appearance *i.e.*, sandy soils in North Gujarat to high clay containing soils in South Gujarat. Such variations are also encountered in spatial distribution of the water resources as evident from the receding ground water table situation in North Gujarat to rise in ground water table situation in South Gujarat. This has been amply reflected on the district and source wise irrigated area as well as on per capita availability of water per annum. By any standard, Gujarat is categorised as water scarce state (980 m^3/y/capita). The situation is further aggravated by the sectoral competition being posed for allocation of water resources. Presently, about 93 per cent of water resources are being used for irrigation which will be decreased to 82 per cent by 2025 for meeting the industrial as well as domestic demands (Fig. 1). In view of considerable heterogeneity with respect to rainfall, water availability, development of water resources, quality of ground water, soil type *etc.,* it is rather imperative to use the available water resources in most efficient ways. In this paper, some of the available technologies for improving the water use efficiency (WUE) are discussed.

Fig. 1: Sector wise water requirement of Gujarat upto 2025



Source: Anon. (2002)

Technologies for improving WUE

In order to resolve the multiplexed problems of water management in the state, concerted efforts have been done by erstwhile Gujarat Agricultural University and are being done by all the four university *viz.,* Navsari Agricultural University, Navsari, Anand Agricultural University, Anand, S. D. Agricultural University, Sardar Krushi Nagar and Junagadh Agricultural University, Junagadh with the financial help from ICAR, other agencies, state and centre government and foreign agencies. Some of the research based technologies available for efficient utilization of irrigation water are discussed under surface irrigation technologies, pressurized method of irrigation, mulching, selection of crop, utilization of ground water directly for meeting ET demand of the crop and drainage from improving WUE subtitles.

Surface irrigation technologies

Normally, the irrigation efficiency of surface methods is very poor owing to conveyance losses, unleveled fields, adoption of inappropriate schedule, faulty design of system, non-adherence to suggested crops and cropping patterns in command area, unassured water supply *etc*. However, there are technologies through which efficient use of irrigation water can be achieved.

Paddy: Paddy is high water consuming crop. One of the major sources through which the water losses occur from the paddy fields is through percolation. This loss can be effectively controlled by adopting soil based appropriate method of puddling. Generally, puddling using power tiller with cage wheels is recommended. Another major way of water losses in paddy is continuous submergence. It has been established through field experiments that continuous submergence is not required for paddy crop. Similarly, the depth of ponding water maintained by the farmers is invariably more than recommended level of 5cm +/- 2 cm which is actually not essential. The grain yield of paddy can be increased significantly by following alternate wetting and drying cycles along with saving in water to tune at 30 to 50 per cent. This has been demonstrated on farmers' fields on large scale also (Table 1). The results clearly indicate that WUE is increased from 3.5 kg/ha-mm with conventional water management practices in paddy to 5.5 kg/ha-mm with improved practices. Apart from water saving and increase in grain yield of paddy, adoption of improved water management practices will also help in mitigating the water logging and salinity problems in Ukai - Kakrapar commands (UKC). For further improvement in efficient use of water, the research on aerobic rice and system of rice intensification (SRI) is in progress in the state.

Table 1: Response of paddy to water management practices (Mean of 3 years)

SN	Particulars	Study block	Control block
1.	Total paddy area (ha)	29.4	10.4
2.	Total irrigation water applied (ha mm)*	1197	1686
3.	Yield of paddy (kg/ha)	6627	6007
4.	WUE of applied water (kg/ha-mm)	5.5	3.5
5.	Water saving percentage over control	29.0	---
6.	WUE improved over control	55.3	---

Source: Raman and Desai (1995)

* *Irrigation applied was excluding the water requirement for seedling raising and puddling the field.*

Arable crop: For the crops grown during *rabi* or summer seasons, lot of work related to scheduling of irrigation on scientific basis has been done. Though, the schedules of irrigation in different crops have been adopted by the farmers, but depth of irrigation to be applied is generally more than the recommended depth. This is one of the major factors for poor WUE at field level. By adopting appropriate land configuration in surface method of irrigation particularly in widely spaced crops like cotton, sugarcane, castor, *etc.*, considerable water saving was achieved (Table 2). In crops like cotton, sugarcane and castor, simply by adopting alternate furrow irrigation technique, water saving to the extent of 50 per cent was achieved which ultimately improves the WUE.

Table 2: WUE in all and alternate furrow irrigation in different crops

Crop	All furrow		Alternate furrow		WUE (kg/ha-mm)	
	Water applied (mm)	Yield (t/ha)	Water applied (mm)	Yield (t/ha)	All furrow	Alternate furrow
Cotton	420	0.730	210	0.736	1.73	3.50
Sugarcane	1140	102	570	97	89.39	169.8
Castor	300	2.97	250	3.12	9.9	12.5

Source: Anon. (1986-87and 1994-95)

In all the transplanted paddy based cropping sequences, the yields of *rabi* or summer crops are generally low because of deterioration in soil physical properties caused by pudding in paddy. If raised bed technique is followed for *rabi* and summer crops, it is possible to save about 20 to 30 per cent water along with increase in crop yield by 10 to 25 per cent. Under Farmers' Participatory Action Research Programme, raised bed land configuration has been demonstrated on large scale in farmers' fields. Irrespective of crops, the extent of water saving of 35-39 per cent and yield increase of 8.6-23.1 per cent were recorded (Table 3).

Table 3: Effect of land configuration on yield and WUE of different crops in various talukas of South Gujarat

Crop (No. of demonstrations)	Taluka	FP/ LC	Total water applied (mm)	Av. yield (q/ha)	Yield increase (%)	WUE (kg/ha-mm)	Increase in WUE over FP (%)
Wheat (12)	Jalalpore, Kamrej	FP	234	27.6	---	11.8	---
	Olpad	LC	172	32.3	17.3	18.8	60
Cabbage (1)	Jalalpore	FP	420	138	---	32.9	---
		LC	300	151	9.7	50.5	53
Cauliflower (2)	Kamrej	FP	450	150	---	33.4	---
		LC	340	185	23.1	54.4	63
Onion (12)	Jalalpore, Kamrej	FP	420	152	---	36.1	---
	Olpad	LC	313	182	19.9	58.1	61
Castor (5)	Jalalpore, Kamrej	FP	313	16.3	---	5.2	---
	Olpad	LC	229	18.9	16.0	8.3	60
Brinjal (2)	Jalalpore	FP	480	139	---	29.0	---
	Olpad	LC	340	151	8.6	44.4	53

FP= Farmers' practice, LC= Land configuration *Source:* Anon. (2008- 09)

Pressurized methods of irrigation

Selection of appropriate method of irrigation is one of the important factors in increasing WUE. Generally, the efficiency of surface methods of irrigation seldom exceeds 40 per cent *i.e*., we are not only wasting more than half of the irrigation water, but also inviting the problems like water logging, secondary salinization *etc*. particularly in canal command areas. The pressurized methods of irrigation with higher efficiency are the most effective tools for counteracting the receding and rising ground water table situations. As both these situations are encountered in Gujarat, large volume of works related to pressurized methods of irrigation have been done across the state. Because of this, location specific techno-economically viable technologies have been generated and are being popularized among the farmers by Agricultural Universities, GGRC, State Departments, NGOs, Sugar and Fruit Co-operatives *etc.* The comparative WUE recorded with drip and surface methods of irrigation in different crops reported in table 4 indicate that in crops like sugarcane, cotton, chillies, tomato *etc.,* the WUE is more than double with drip method as compared to surface method of irrigation. This is due to yield increase as well as application of less water through drip than surface method of irrigation. As drip irrigation facilitates fertigation, it not only increases yield, save water and improve WUE, but also saves fertilizers up to 60 per cent in certain crops (Table 5).

As like drip, sprinkler method of irrigation is more efficient than surface method. This method is recommended particularly for the close grown crops where drip irrigation is not economical. In close grown crops like onion, cabbage, lucerne *etc.* invariably higher WUE was recorded with sprinkler method in comparison to surface method of irrigation (Tables 6 and 7). The WUE achieved with sprinkler is comparable with that of drip method of irrigation. At the same time, sprinkler is less costly than drip system. Looking to the advantages in terms of water saving of pressurized methods of irrigation, more and more areas need to be brought under these methods in Gujarat, a water scare state.

Table 4: WUE of different crops under drip and surface methods of irrigation

Crop	Yield (t/ha)		Water applied (mm)		WUE (kg/ha-mm)		% increase in WUE over surface
	Drip	Surface	Drip	Surface	Drip	Surface	
Banana	68	66	1132	1720	60	38	58
Sugarcane	10	117	710	1170	194	100	94
Cotton	1.77	1.70	489	988	3.6	1.7	112
Castor	2.64	2.15	400	480	6.57	3.65	80
Cabbage	28	19	358	543	46	36	28
Brinjal	35	29	1072	1170	33	25	32
Chillies	6.31	5.42	522	1000	12.0	5.4	122
Tomato	66	48	466	700	143	69	107

Source: Savani *et al.* (2005)

Table 5: WUE and fertilizer saving in different crops under drip and surface methods of irrigation

Crop	Yield (t/ha)		Water applied (mm)		WUE (kg/ha-mm)		Fertilizer saving (%)
	Drip + fertigation	Surface	Drip + fertigation	Surface	Drip + fertigation	Surface	
Banana	65	56	1154	1653	50	34	40
Papaya	61	48.6	786	1105	77.9	44	20
Castor	7.2	5.5	421	680	17	8	60
Cotton	1.77	1.70	489	988	3.6	1.7	25
Chillies	6.3	5.4	522	1000	12	5.4	20
Bhindi	11	10	350	730	30	14	20
Brinjal	34	31	743	1155	46	27	20
Potato	29.7	24	238	420	125	57	40
Tomato	66	48	466	700	143	69	40

Source: Savani *et al.* (2005)

Table 6: WUE of different crops under macro sprinkler and surface methods of irrigation

Crop	Yield (t/ha)		Water applied (mm)		WUE (kg/ha-mm)		% increase in WUE over surface
	Sprinkler	Surface	Sprinkler	Surface	Sprinkler	Surface	
G' nut (S)	2.15	1.89	600	680	3.58	3.06	16
Lucern	67.5	62.6	1020	1410	66.00	44	50
Gram	1.67	1.14	200	320	8.35	3.56	134
Fenugreek	1.17	0.87	312	440	3.80	2.0	90
Potato	20.5	19.8	440	820	46.70	24.1	94
Cabbage	27.0	25.0	240	360	115.00	70	64
Cauliflower	21.0	18.8	450	688	47.00	27	74

Source: Savani *et al.* (2005)

Table 7: WUE of different crops under mini sprinkler and surface methods of irrigation

Crop	Yield (t/ha)		Water applied (mm)		WUE (kg/ha-mm)		% increase in WUE over surface
	Mini sprinkler	Surface	Mini sprinkler	Surface	Mini sprinkler	Surface	
G' nut (S)	3	2.4	680	825	4.5	2.96	50
Onion	31.7	25.7	225	390	141	66	114
Potato	30	24	520	800	58	31	87
Cabbage	21	20	313	523	66	38	85
Garlic	4.8	3.5	500	630	9.6	5.6	71

Source: Savani *et al.* (2005)

Mulching

Organic or plastic mulches have been found to reduce the irrigation requirement, conserve soil moisture, restrict upward movement of soluble salts, induces early maturity and control weeds. Because of these advantages, mulching plays vital role in irrigation management. Large numbers of experiments on different crops under varying agro-climatic conditions were conducted and recommendations have been made for the farmers of the state. Mulching is beneficial in both surface as well as drip methods of irrigation. In surface method, irrigation with mulching could enhance WUE by 16 per cent in brinjal to as high as 145 per cent in banana (Table 8). The beneficial effect of mulching are further enhanced if used in combination with drip method of irrigation. The WUE of 122 kg/ha-mm was recorded with drip + mulch in tomato which is 273 per cent more than surface method of irrigation. Similarly, an increase in WUE was more than 100 per cent in crops like banana, brinjal, chillies, okra, *etc.* (Table 9). It is our observation that black plastic mulching induces early maturity in crop like banana by 30-35 days. Looking to the advantages of mulching in irrigated agriculture, there is needed to popularize this technology on large scale in farmers' fields. In this direction, black plastic mulching demonstrations on farmers' fields in about 20 ha area under banana crop have been laid through Precision Farming Development Centre (Anon., 2008-09). Further, use of black plastic mulch in drip irrigated brinjal also enabled to use the saline water (EC 6 dS/m) without deteriorating soil health and crop yield (Anon., 2008-09).

Table 8: Mulching effect on WUE of different crops under surface method of irrigation

Crop	Yield (t/ha)		Water applied (mm)		WUE (kg/ha-mm)		% increase in WUE over surface
	Surface + mulch	Surface	Surface + mulch	Surface	Surface + mulch	Surface	
Banana	62	45	740	1360	84	33	154
Sugarcane	95	104	768	1251	123	83	48
G' nut (S)	2.7	1.8	420	420	6.4	4.3	49
Brinjal	41	36	420	420	99	85	16
Chillies	15	13	320	400	48	33	45

Source: Savani *et al.* (2005)

Table 9: Drip + mulch effect on WUE of different crops

Crop	Yield (t/ha)		Water applied (mm)		WUE (kg/ha-mm)		% increase in WUE over surface
	Drip + mulch	Surface	Drip + mulch	Surface	Drip + mulch	Surface	
Banana	84	56	1154	1653	73	34	115
Bitter gourd	25.4	21.6	479	802	53	27	96
Brinjal	46	34	570	960	80	35	128
Chillies	12.5	7.9	928	1250	13.5	6.3	114
Okra	13.0	8.5	351	462	37	18	106
Tomato	43	27	380	880	112	30	273
Rose	7.50*	4.9*	1276	1540	592	318	86

*Lakh flowers/ha *Source:* Savani *et al.* (2005)

Selection of crop

This is the basic factor in achieving the higher WUE under canal as well as lift commands. In most of the commands, this factor is neglected which leads to aberration in suggested cropping pattern and consequently, the water logging and soil salinity problems have arised. In UKC, only 10 per cent area of the command was earmarked for sugarcane, but presently this crop occupies about 40 per cent area of the command. Similarly, considering the soil types of UKC, summer paddy was not at all included in suggested cropping pattern, but summer paddy is being grown in about 30,000 ha area of the UKC. In this context, using crop suitability criteria, the suitability of existing and some new crops was assessed for coastal areas of South Gujarat. It is interesting to note that sugarcane which is not suitable for coastal area of the command is the major crop of this area. Because of wrong selection of crop that too high water consuming crop like sugarcane, the desired level of productivity is not achieved even with best management practices. This is evident from the productivity of sugarcane grown in coastal area is only 52.0 t/ha as against the state average of 72 t/ha (Anon., 2009). Further, summer paddy which require about 1200-1500 mm water can realize the net profit of Rs. 13000/ha (gross income: 5000 kg/ha x 7 Rs./kg = 35000 Rs./ha - cost of cultivation Rs 22000/ha). Contrary to this, if castor (*rabi*) crop is grown which needs only 350 mm water can fetch net profit of Rs.47500 ha with an average productivity of 2500 kg/ha (gross income 2500 x 25 Rs/kg = 62500 Rs/ha - cost of cultivation 15000 Rs/ha). So, for achieving higher WUE and net return, it is essential to select highly suitable and water use efficient crops (Table 10).

Table 10: Crop suitability classification of existing and some new crops for sub watershed

Crop	Climate	Landform	Soil		Overall
			Physical	Chemical	
Paddy	S_1	S_1	S_1	S_1	S_1
Sorghum	S_1	S_1	S_1	S_2	S_1
Wheat	S_5	S_1	S_1	S_1	S_3
Pigeon pea	S_1	S_1	S_2	S_2	S_2
Soybean	S_1	S_1	S_1	S_1	S_1
Oil palm	S_2	S_1	S_1	S_3	S_2
Sugarcane	$\mathbf{S_2}$	$\mathbf{S_1}$	$\mathbf{S_1}$	$\mathbf{S_3}$	$\mathbf{S_3}$
Cotton	S_1	S_1	S_1	S_1	S_1
Castor (*rabi*)	$\mathbf{S_1}$	$\mathbf{S_1}$	$\mathbf{S_2}$	$\mathbf{S_1}$	$\mathbf{S_1}$
Mango	S_1	S_1	S_2	S_2	S_2
Sapota	S_1	S_2	S_1	S_1	S_1
Guava	S_2	S_1	S_1	S_2	S_2
Brinjal	S_1	S_1	S_1	S_1	S_1
Okra	S_1	S_1	S_2	S_1	S_1
Onion	S_2	S_1	S_1	S_2	S_2
Marigold	S_1	S_1	S_1	S_2	S_1
Tuberose	S_1	S_1	S_1	S_2	S_1

Utilization of ground water directly for meeting ET demand of crop

Rise in water table and development of water logging situation in root zone of crop are very common phenomenon in most of the canal command area in Gujarat. Under these conditions, considerable amount of ground water may enter in root zone through capillary action and there by meet part of the ET demand of the crop. Of course, this contribution will depend upon soil type, depth of ground water table, rooting depth of crop etc. Thus, under shallow water table conditions, there is a definite possibility for reducing the irrigation water to be applied to the crop. Under high rainfall and clay soil condition of South Gujarat, when the ground water table fluctuates from surface to 1.5 m during the year, the irrigation requirement of sugarcane was only around 10 irrigations as against the normal requirement of 14-16 irrigations (Anon., 1994). This suggests that irrigation water can be saved up to 40 per cent without adversely affecting the cane yield and thereby improving the WUE.

Drainage for improving WUE

In UKC, about 15 per cent area has gone out of cultivation due to twin problems of water logging and salinity. Under such situations, the WUE is very poor as crop yield are extremely low. In order to increase the crop yield under water logged and salt affected soil situation, subsurface drainage technology has been perfected and demonstrated on farmers' fields (IDNP team, 2003). The sugarcane yield obtained in closed subsurface drainage block was 105 t/ha as against the 48 t/ha recorded in undrained block. This means that with same amount of irrigation water in undrained block, the yield is almost half which ultimately reduces the WUE. Seeing the advantages of closed subsurface drainage, farmers are adopting drainage technology by bearing cent per cent cost of the drainage system under the guidance of Soil and Water Management Research Unit, NAU, Navsari. This empathetically proves the cost effectiveness of the drainage technology.

Considering the heterogeneous spatial distribution of water resources, diversified climatic conditions and varying soil types in the state, it is essential to enhance the WUE through adopting recommended practices *viz.,* appropriate surface method of irrigation, pressurized methods of irrigation, mulching and selection of suitable crop. The WUE can also be improved by reducing application of irrigation water under high water table conditions and adopting drainage technology for reclaiming water logged and salt affected soils.

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Status and Potential of Micro Irrigation in Gujarat

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Introduction

In Gujarat, contribution of ground water to the total water resources of the state is hardly 30 per cent. But, the contribution exhibits a skewed nature. In South and middle Gujarat, where the canal system predominates the contribution of ground water to the total water resources is only around 11 per cent. On the other hand, in the North Gujarat and Saurashtra, where the underground water is the major source, it contributes 62 and 54 per cent, respectively to the total resources. In Kutch, it is 38 per cent.

Presently, the ground water contributes to 80 per cent of the irrigated area inspite of its low potential (16,000 MCM as against 39,000 MCM of surface water potential). In South and middle Gujarat, surface water is the major source of irrigation, whereas in the North Gujarat, Saurashtra and Kutch regions, the ground water contribution as source of irrigation water is more than 90 per cent.

As per 2002 values, the annual ground water recharge in the state is 18000 MCM per year of which 14400 MCM is calculated as utilizable recharge. The gross ground water draft is estimated to be 11400 MCM leaving a ground water balance as 3000 MCM. Thus, with the over all development of about 80 per cent, the state falls under the "Grey" category. During 1984, the state was under "White" category. Though, at the state level it is under "Grey" category, there is lot of inter districts variations. While, the South Gujarat districts are still falling under "White" category, majority of the North Gujarat districts are falling under "Over Exploited" category. During 1984, 95 per cent of the talukas were under "White" and "Grey" categories and rest 5 per cent were either "Dark" or "Over Exploited" or "Saline". But, during 2002, only 74 per cent of the talukas were falling under either "White" or "Grey" category. As high as 19 per cent of the talukas fall under "Over Exploited " category and 5 per cent of the talukas exhibit complete "Saline" water conditions.

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As a result of the excess draft conditions, especially in North Gujarat, the water table is receding at a very faster rate of 5-6 m per year. During 1960s and 1970s, the depths of the tube wells in North Gujarat were ranging between 80 and 120 m. But, of late, the tube wells have to be drilled to a depth of even more than 300 m. This tube well deepening trend had necessitated the farmers to go in for lifting devices of very high HP.

Apart from receding water table, the mining of ground water as is being done in North Gujarat has resulted in water pollution with special reference to fluoride. It is reported that at least 15 per cent of wells in the state are exhibiting high fluoride content. In North Gujarat, every third well is having fluoride problem and in Mehsana district of North Gujarat, every alternate well is fluoride polluted. The over draft of ground water has also resulted in intrusion of sea water especially in the coastal areas of Saurashtra and Kutch.

Technology which will bring improvement in irrigation efficiency will go a long way to reduce the over drafting and other problems. Micro irrigation is such a technology which increases the irrigation efficiency apart from other benefits to the farmers. During 1990's micro irrigation scheme (MIS) was started in Gujarat with an objective to save water and energy along with increase cop production.

Factors which favour micro irrigation in Gujarat are as under

- Predominant arid and semi arid conditions
- Water scarcity situation in major parts of the state
- Rapid development horticulture since last decade
- Longest coastline resulting in soil and water salinity conditions demanding micro irrigation for proper management.
- Hilly and undulating terrain on the eastern border
- Dominance of drip responsive non food grain crops over food grain
- Marginally saline water in many parts of the state which if used by traditional methods of irrigation will adversely affect soil health
- Poor irritability nature of the soils in many places

Government effort to popularize adoption of MIS in Gujarat

In order to inspire the farmers of the state by maximizing agriculture production at minimum cost and increasing their income by adopting scientific management of water and to bring in revolutionary transformation of the agriculture scenario, the state Government has embarked upon *Jal Sanchay Abhiyan* (drive for storage of water).

As a major initiative, Honourable Chief Minister of Gujarat announced formation of **Gujarat Green Revolution Company Limited (GGRC)**, a Special Purpose Vehicle (SPV) promoted by Gujarat State Fertilizers and Chemicals Ltd. (GSFC), Gujarat Narmada Valley Fertilizers Company Ltd. (GNFC) and Gujarat Agro Industries Corporation Ltd. (GAIC) as the implementing agency appointed for implementation of MIS in the state of Gujarat and in this regard Government of Gujarat issued Govt. Resolution (GR No. PRCH-102005-497-N, dated 09.05.2005).

Rationale for establishment of GGRC

Before formation of GGRC, the MIS had been implemented by different government departments such as Department of Horticulture, Department of Agriculture *etc.*, and subsidy was available under different schemes and sub-schemes having varying subsidy assistance norms. It was experienced that, farmers were getting confused due to the fact that the procedure for granting assistance, norms for assistance, terms and conditions *etc*., vary from one government department to another departments who were implementing the scheme. As a result, some administrative difficulties were also experienced in implementing the schemes through different departments.

It was therefore, considered by the government to put all the efforts into an integrated approach in such a way that provisions under various schemes are uniform and their inequalities and anomalies should be removed and available funds under different scheme and sub scheme heads should be utilized efficiently and benefits will be extended to more and more farmers of the state effectively. This led to the formation of a SPV, GGRC.

Special features of the MI scheme implemented by GGRC

- Any individual/group of farmer can avail subsidy of Rs.60,000/ha or 50 % of the MIS cost whichever is less for any areas and for any crops.
- Looking to suitability of different MIS system with crops, various kinds of MIS *i.e.*, Drip, sprinkler, mini sprinkler, porous pipe, rain gun & drip tape has been included in the scheme. (Some of these MI system are even not added in centrally sponsored scheme of the Govt. of India)
- The MIS system is tailor made and farmer has freedom to choose MI System as per his cropping pattern.
- Government of Gujarat has placed the subsidy at the disposal of GGRC for onward disbursement to the beneficiaries as per the scheme norms.
- Subsidy is directly released by GGRC after scrutinizing the MIS applications whereas in other states subsidy is released through government.
- GGRC facilitate the farmers to avail loan for MIS from banks on lower interest rate.
- Compulsory provision of agronomic and post sales services after installation of MI system at farmers' fields. While in other schemes, such facility is partially or not available.
- Maintenance and repairs of MIS support by the supplier for at least five years.
- MI System as well the Beneficiary farmer (except natural death) is insured equivalent to cost of MIS for a period of five years.
- Farmer can install his MI system after submission of his part of contribution of MIS cost to GGRC.
- The subsidy and farmers' contribution is only released after satisfactory report by the farmer and independent professional third party inspection agency (TPIA).
- More than 200 depots of promoter companies' *i.e.*, GSFC/GNFC are working as coordination centres of GGRC at all taluka places for implementation of MIS scheme.
- Credible NGOs have been appointed in all districts of the state to assess changes in socio-economic conditions of the farmers and feedback report of the project.

- "Agricultural Finance Corporation Limited" a well known agency has been appointed to evaluate the impact of MIS on the farm economics on yearly basis.
- Development of independent formula for revision of MIS unit cost based on the contents of raw material in the components.

Convergence of the MIS with other departmental and major irrigation projects

To increase the existing scope of micro irrigation project, general MIS is converged with other departmental scheme or major irrigation projects which are as under.

i. Agricultural electricity connection has been provided by *Gujarat Urja Vikas Nigam Limited* (GUVNL) on overriding priority basis to those farmers who adopts MIS, (more than 18,000 connections have been released).
ii. Additional subsidy of 25 per cent to the tribal farmers by Tribal Development Department, Govt. of Gujarat.(within one year from the commencement of additional subsidy more than 3,000 farmers have availed the benefit)
iii. MIS in Sardar Sarovar Project (SSP) Canal Command area through Pressurized Irrigation Network System (PINS). The PINS project has been started on pilot basis and work started at 24 sites.
iv. Beneficiary farmers who take water from government owned tube wells are provided PINS and additional subsidy of 25 per cent for MIS. The PINS and MIS project has been started on pilot basis in 12 tube-well sites.
v. Increasing the scope of MIS by implementing the scheme under MIS Partner Model, wherein NGOs, Credit Cooperative Societies, Milk Cooperative Societies, Horticulture Cooperative Society, Corporate bodies *etc.*, can act as MIS partner and provide financial help to economically poor farmers who are even not able to pay the non-subsidy amount for MIS.

Innovative support services to farmers under the MIS

i. *Agronomy support services:* As an innovative support service to farmer, Agronomy Consultancy Services is provided to beneficiaries mandatorily by MIS supplier for two cropping seasons or for a period of one year. MIS supplier will organize training twice in each cropping season (first at the time of start of season and second sometime at the end of the season), *i. e.*, total four times in a year and also invite concerned GGRC/GSFC/GNFC field staffs and other experts from their head office or universities at the time of training programme.

During training programme, guidance on the following areas is provided:

a) Drip irrigation – principles and practices and water management. Irrigation schedules for various crops proposed in the project including management of poor quality water and variable sources of water and drought management.
b) Guidance of introduction of new crop/ varieties / hybrid seed, tissue culture plants, grafts, *etc.*, planting pattern under drip irrigation.
c) Fertigation – methods, fertilizer compatibility, nutrient uptake and fertigation.
d) Operation and maintenance of drip system including aspects of filtration and flushing system, flow monitoring system, acidification, chlorination *etc*.
e) Hazards, caution, safety aspects and limitations involved in commercial intensive farming.
f) Arrange professional's visit to the farmers' fields and utilize training sessions for interaction with the agricultural input manufacturers, bankers, and insurance company and third party inspection agencies.

ii. *System maintenance support services:* MIS supplier shall undertake repair or replacement of any components/ instruments of the system within guarantee period, if they are found to have manufacturing defects or workmanship defects. The authorized representatives of MIS supplier shall carry out the repairs or the replacement of instrument/component within 7 working days on the receipt of the complaints.

iii. *Insurance services to farmer:* As an innovative support service to farmer, insurance coverage is provided for the MI system and life of the beneficiary farmers for a period of five years to the extent of cost of MIS through an insurance company appointed by GGRC. The insurance coverage commences from the date of MIS installed and accepted by the farmer. Insurance coverage to the system is provided against different perils such as, fire, theft, burglary, natural calamities like earth quake, SIFI perils *etc.*, and external physical damage due to any other reasons and also provided to the life of the farmer under *Janta* Personal Accident policy (JPA).

Status of MIS in Gujarat

Before formation of GGRC, various departments of government of Gujarat combined together had achieved 2.20 lakh ha in a time span of 14 years starting from 1991 till 2005 The average per year MIS area coverage is 16,000 ha.

MIS coverage since May 2005 up to till July 2009: In the time span of four years since inception in 2005, GGRC has covered 1,65,990 ha of area under MIS benefiting 1,02,446 numbers of farmers (Table 1). The area covered under drip category of MIS system is 106244 ha (64%) and sprinkler was 59747 ha (36%). During four years GGRC has achieved **Average Annual Growth Rate of 45** % per annum **for area coverage** under MIS**.** Till financial year 2008-09, the numbers of small farmers are 31,686 and marginal farmers are 6502, which is in total of 40.8 per cent of total beneficiaries. The MIS adoption is maximum in cotton groundnut, sugarcane, potato, vegetables and orchard crops across the state (Table 2).

Table 1: Year and MI system wise achievement till July 2009

Years	Drip		Sprinkler		Total		% Growth	
	No. of farmers	Area (ha)	No. of farmers	Area (ha)	No. of farmers	Area (ha)	No. of farmers	Area (ha)
2005-06	5037	13139	2180	2753	7217	15892	-	-
2006-07	7590	18307	6215	8924	13805	27231	91	71
2007-08	13805	26334	18693	23926	32498	50260	135	85
2008-09	27283	37607	12152	20120	39435	57727	21	15
2009-10 (up to July-09)	7089	10856	2402	4024	9491	14880	-	-
Total	**60804**	**106244**	**41642**	**59747**	**102446**	**165990**	**64**	**45**

Table 2: Different crop wise MIS coverage up to 2008-09

Horti / Non-Horti	Crops	MIS coverage	
		No.	Area
Horti.	Potato	4869	8829
	Banana	4957	7914
	Mango	2510	6581
	Papaya	1543	2969
	Vegetable	703	1404
	Lemon	1356	2009
	Sapota	256	715
	Other horticulture crops	7197	11834
Sub total		**23391**	**42254**
Non-Horti.	Groundnut	34844	48729
	Cotton	23218	41143
	Sugarcane	3532	7549
	Castor	1148	1694
	Other Agriculture crops	6822	9741
Sub total		**69564**	**108856**
Grand total		**92955**	**151111**

The area under drip irrigation was maximum in Sabarkantha (11334 ha) and Banaskantha (11032 ha) and that of minimum in the Dangs district (8 ha). In case of sprinkler the highest area was in Junagadh district (19065 ha) and that of minimum in Anand district (18 ha). In general, the area under drip and sprinkler irrigation is equal *i.e.*, 50 per cent each (Table 3).

Table 3: District and system wise MIS coverage in Gujarat

SN	District	Micro irrigation systems					
		Drip		Sprinkler		Total	
		No.	ha	No.	ha	No.	ha
1	Ahmedabad	323	874	175	525	498	1399
2	Amreli	5057	5691	2857	3509	7914	9200
3	Anand	748	1275	9	18	757	1293
4	Banaskantha	5785	11032	3432	7064	9217	18097
5	Bharuch	2555	5681	60	134	2615	5815
6	Bhavnagar	3832	4419	3098	3314	6930	7732
7	Dahod	38	89	189	286	227	376
8	The Dangs	8	8	77	94	85	102

SN	District	Micro irrigation systems					
		Drip		Sprinkler		Total	
		No.	ha	No.	ha	No.	ha
9	Gandhinagar	672	1772	23	42	695	1814
10	Jamnagar	4227	4900	2176	3382	6403	8282
11	Junagadh	3624	5014	14787	19065	18411	24079
12	Kheda	732	2207	69	142	801	2349
13	Kutch	2589	8556	23	104	2612	8660
14	Mehsana	669	1570	432	625	1101	2195
15	Narmada	1349	1931	122	134	1471	2065
16	Navsari	1069	1917	966	1338	2035	3255
17	Panchmahals	145	271	211	321	356	592
18	Patan	367	1040	201	586	568	1626
19	Porbandar	339	403	3954	6028	4293	6431
20	Rajkot	6078	6741	3176	4238	9254	10979
21	Sabarkantha	4671	11334	1270	1617	5941	12951
22	Surat	2699	5221	109	169	2808	5390
23	Surendranagar	2124	5290	357	842	2481	6132
24	Tapi	213	416	151	199	364	614
25	Vadodara	2793	5546	931	1380	3724	6925
26	Valsad	1009	2191	385	568	1394	2759
	Grand total	**53715**	**95387**	**39240**	**55723**	**92955**	**151111**

Benefits of micro irrigation

Impact and benefits resulted out of the micro irrigation project are enormous. Adoption of micro irrigation increases crop productivity and quality of produce. It also saves water, energy, fertilizer and pesticides and expenses on labour and interculturing operations.

The GGRC is conducting a concurrent monitoring and evaluation of the scheme through the Agricultural Finance Corporation (AFC), an independent body under the government of India. The report submitted by the above organization, after making field survey/observations in different districts brings out the fact with the use of MIS, the water savings was around 30 per cent, energy savings around 20 per cent and yield increase around 30 per cent in different major crops where the MIS is being adopted on large scale in the state (Table 4).

Table 4: Water saving, energy saving and yield increase in different crops under MIS

Crop	Water savings (%)	Energy savings (%)	Yield increase (t/ha)	Additional return ('000Rs/ha)
Banana	40	22	15	51
Cotton	31	16	0.8	19
Mango	33	NR	2.5	27
Sugarcane	42	22	30	31
Groundnut	33	NR	0.4	8
Wheat	24	NR	0.8	6
Potato	30	20	8	35

NR – Not reported

Crop wise payback period for the investment made on MIS

Cotton, banana, sugarcane and mango are the four major crops, which together had contributed to more than 75 per cent of area under drip during 2006-07. Based on the cost and benefit accrued due to MIS in these crops, Agricultural Finance Corporation(AFC) worked out the pay back period for the investment made by the government/farmers during 2006-07 (Table 5). The payback period was minimum in banana (1.8 year) and that of maximum in cotton (4-9 year).

Table 5: Pay back period in come crops (No. of crop seasons) under MIS

Crop	System cost (Rs/ha)	Addl. yeld (t/ha)	Price (Rs./t)	Additional returns (Rs./ha)					Pay back period (yrs.)
				Yield	Fertilizer	Energy	Labour	Total	
Cotton	92000	0.8	20000	16000	540	258	1400	18738	4.9
Banana	90000	15	3000	45000	1093	1031	3000	51217	1.8
S' Cane	84000	30	900	27000	352	1096	2000	30800	2.7
Potato	128000	8	4000	32000	490	387	1200	34567	3.7
Mango	43000	2.5	10000	25000	200	385	1000	26585	1.6
Wheat	18000	0.8	8000	6400	-	-	-	6400	2.5
G' nut	18000	0.4	20000	8000	-	-	-	8000	2.0

Potential of MIS in Gujarat

One of the major requirements of drip and sprinkler irrigation system is pressurized irrigation water to the system. Water can be provided to the system in pressurized form mostly by drawing water through electric or diesel pumps. MIS is crop and soil specific and some crops also not suitable for MIS like Paddy. Considering all those parameters, MIS potential for the state estimated at GGRC is around 3.8 million ha. Since, a single system can be used for two or more crop (except orchard crops) on sequence basis, it is estimated that system installation potential is 2.7 m ha (Table 6). Among the districts, the maximum potential exists in Banaskantha and Rajkot districts. Similarly, drip and sprinkler have more potential than minisprinkler.

Table 6: District and MI system wise potential in Gujarat

Sr. No.	District	Micro irrigation systems			
		Sprinkler	Drip	Mini Sprinkler	Total
1	Ahmedabad	66	44	3	**113**
2	Amreli	54	130	3	**187**
3	Anand	31	21	4	**56**
4	Banaskantha	318	104	31	**453**
5	Bharuch	8	60	0	**68**
6	Bhavnagar	73	201	19	**293**
7	Dahod	62	9	3	**74**
8	The Dangs	-	-	-	**-**
9	Gandhinagar	38	52	3	**93**
10	Jamnagar	90	179	19	**288**
11	Junagadh	196	95	24	**315**
12	Kheda	59	25	5	**89**
13	Kutch	62	67	12	**141**
14	Mehsana	109	93	6	**208**
15	Narmada	3	23	3	**29**
16	Navsari	0	20	0	**20**
17	Panchmahals	20	8	1	**29**
18	Patan	49	34	4	**87**
19	Porbandar	22	18	3	**43**
20	Rajkot	129	288	24	**441**
21	Sabarkantha	121	108	12	**241**
22	Surat (Including Tapi district)	7	53	0	**60**
23	Surendranagar	42	184	3	**229**
24	Vadodara	40	163	2	**205**
25	Valsad	2	31	0	**33**
Total		**1601**	**2010**	**184**	**3795**

The district and crop wise potential area under micro irrigation system reported in table 7 clearly suggest that irrespective of districts cotton has the highest potential which is followed by wheat, fruits, vegetables and spices + condiments crops (Table 7).

Conclusion

Micro irrigation technology is boon to the farming community, efficient promotion of MIS and bringing different MI schemes by government brings enormous benefits to the farmers as well as government. After formation of GGRC by Govt. of Gujarat, the MIS adoption level in Gujarat has increased manifolds. Though, the potential of MIS in Gujarat is high, high cost of MIS and poor economic conditions and small land holding size deters many farmers to come forward for MIS.

Table 7: District wise and major crop wise potential

Sr. No.	District	Major agricultural and horticultural Crops												
		Wheat	Cotton	Groun dnut	Sugar cane	Pulses	Bajra	Sorg hum	Must ard	Fruits & Veg.	Castor	Spices & Cond.	Others	Total
1	Ahmedabad	55	20	-	-	6	-	-	-	8	-	16	8	**113**
2	Amreli	26	119	22	-	-	-	-	-	7	-	6	7	**187**
3	Anand	23	-	-	-	-	5	-	-	20	-	6	2	**56**
4	Banaskantha	66	15	-	-	-	46	-	198	38	23	57	10	**453**
5	Bharuch	5	30	-	15	-	-	-	-	12	-	-	6	**68**
6	Bhavnagar	32	181	28	-	-	8	-	-	34	-	5	5	**293**
7	Dahod	49	-	-	-	12	-	-	-	7	-	3	3	**74**
8	The Dangs	-	-	-	-	-	-	-	-	-	-	-	-	**-**
9	Gandhinagar	28	27	-	-	-	4	-	-	13	11	7	3	**93**
10	Jamnagar	47	152	38	-	-	-	-	-	10	-	32	9	**288**
11	Junagadh	134	40	48	14	-	4	-	-	31	-	31	13	**315**
12	Kheda	46	10	-	-	-	8	-	-	15	-	4	6	**89**
13	Kutch	22	27	17	-	-	12	-	10	13	22	16	2	**141**
14	Mehsana	52	33	-	-	-	12	-	41	16	13	37	4	**208**
15	Narmada	14	-	-	3	-	-	-	-	5	-	-	5	**27**
16	Navsari	-	-	-	13	-	-	-	-	7	-	-	-	**20**
17	Panchmahals	15	1	2	-	4	-	-	-	1	-	-	6	**29**
18	Patan	10	8	-	-	-	8	-	28	4	4	19	6	**87**
19	Porbandar	12	10	6	-	4	-	-	-	5	-	6	-	**43**
20	Rajkot	76	255	29	-	-	-	16	-	19	-	36	10	**441**
21	Sabarkantha	91	70	10	-	-	-	6	10	18	13	11	12	**241**
22	Surat (Including Tapi dist.)	2	-	3	39	-	-	-	-	10	-	-	6	**60**
23	Surendranagar	23	130	2	-	-	8	-	-	11	9	38	8	**229**
24	Vadodara	22	119	9	-	-	-	16	-	27	-	7	5	**205**
25	Valsad	-	-	-	14	-	-	-	-	16	-	-	3	**33**
	Total	**850**	**1247**	**214**	**98**	**26**	**115**	**38**	**287**	**347**	**95**	**337**	**139**	**3793**

Case Studies of Subsurface Drainage in Gujarat

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In the quest of achieving self sufficiency in food grain production, Government of India has made concerted efforts in increasing area under irrigated agriculture by spending @ Rs. 1.25 to 1.50 lakh/ha. As a result of these efforts, our country has not only become self sufficient, but also started exporting the food grains. However, along with this success some ill effects like water logging, secondary salinization *etc*., are emerging and acquiring menacing proportion in most of the command areas. The existing command areas in Gujarat are not an exception to this phenomenon. The extent of areas with ground water table depth up to 1.5 m and between 1.5 to 3.0 m indicates the severity of the problems of water logging in the state (Table 1). On an average, 15 per cent of the total command area is water logged and another 24 per cent area is on the verge of water logging.

Table 1: Pre-monsoon water logged area in irrigation projects of Gujarat ('000 ha)

SN	Command	Depth of water table (m)		
		0-1.5	**1.5-3.0**	**0-3.0**
1	Kakarapar	11.46	66.00	77.46
2	Ukai (RBC)	2.15	21.06	23.21
3	Ukai (LBC)	2.04	13.08	15.12
4	Mahi (RBC)	3.94	28.80	32.74
5	Kadana (LBC)	0.80	5.05	5.85
6	Ghed area	69.00	--	69.00
7	Shetrunj (LBC)	0.02	5.54	5.56
	Total	**89.41 (15 %)**	**139.53 (24 %)**	**228.94 (39 %)**

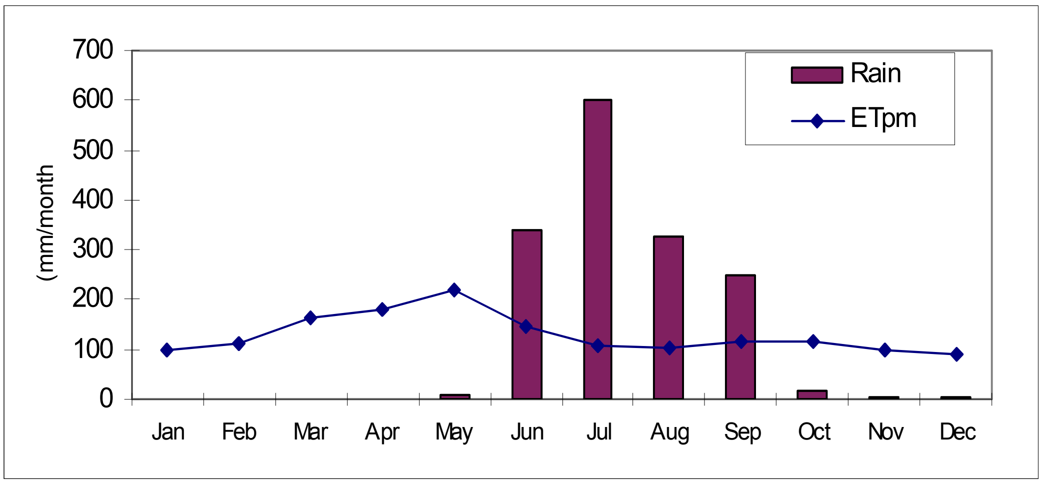
Source: Gupta and Tyagi (1996)

Causes of water logging and salinity

Irrespective of the command area, the major causes of the water logging and secondary salinization with special reference to the South and middle Gujarat are heavy rainfall, aberration in suggested cropping pattern, ignorance of land irrigability classification, inadequate agricultural drainage net work, over irrigation, negligible conjunctive use, release of excess water, poor awareness about irrigated agriculture, mostly unlined canal network, cheaper availability of irrigation water, inclination towards high water consuming crops like paddy and sugarcane, aquatic weeds *etc*.

Among these, the predominant factors are climate and cropping pattern being adopted by the farmers. The monthly rainfall and evaporation values depicted in fig. 1 clearly show that in Ukai-Kakrapar Command (UKC) rainfall is invariably more than evaporation during monsoon season (June to September). The situation of water logging is further aggravated as high clay containing (> 40 %) soils occupying majority of the area of command.

Fig. 1: Average monthly rainfall and evaporation of Bardoli taluka (part of UKC)



Source: IDNP Team (2003)

Another important factor is cropping pattern followed by the farmers of command area. Due to the abundant availability of good quality irrigation water farmers not only tend to over irrigate but also change to the cultivation of water loving crops. In the Surat branch command area, the present cropping is dominated by high-water-consuming crops *viz*., sugarcane (61 %) and paddy (14 %). At UKC level also the same trend can be observed. The main crops those were grown prior to commissioning of the project, *viz*., sorghum, pigeon pea; beans and gram, have been completely disappeared and rain fed rice varieties have been replaced by high yielding varieties that need more water. Apart from this, majority of the soil of command area are not suitable for the flood method of irrigation. However the farmers are not only adopting the flood method of irrigation, but puddling the soil for growing transplanted paddy even during summer season.

Prevalence of high water consuming crops in canal irrigated area not only bring water table up but also add considerable amount of soluble salts. The quantity of soluble salts added to soil at recommended level of irrigation with canal water per crop is varying between 0.5 t/ha in cotton and 3.6 t/ha in banana. The quantity of soluble salts added for soil increases almost 3 fold when slightly saline water (EC 1 dS/m) is used for irrigating the same crops (Table 2).

Table 2: Salts added to the soil through irrigation per season

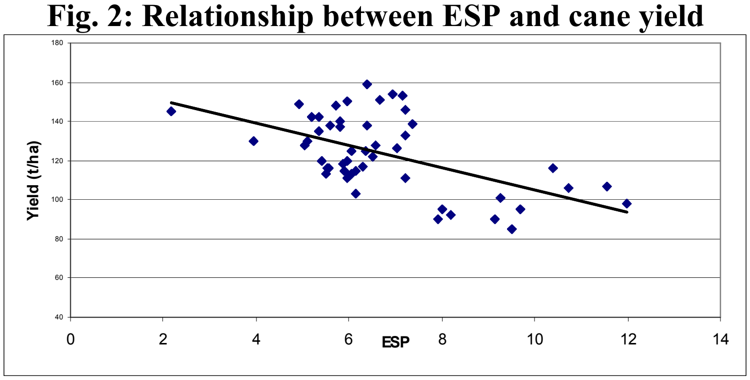
Crops	Recommended irrigation			Salt added (t/ha/crop)		
	No. of irrigation	Depth (mm)	Total (mm/crop)	Canal	Ground water	
				0.3 dS/m	1 dS/m	2 dS/m
Sugarcane	18	80	1500	2.9	9.6	19.2
Paddy (S)	15	80	1200	2.3	7.7	15.4
Banana	24	80	1920	3.6	11.9	23.8
Okra (S)	13	60	780	1.5	5.0	10.0
Cotton	4	70	280	0.5	1.8	3.6

Source: IDNP Team (2003)

Ill effects of water logging and salinity

The cultivation of paddy and sugarcane continuously for years together has caused water logging and salinity problems which adversely affected the productivity of crops in UKC. The values depicted in fig.2 substantiate this statement that when exchangeable sodium percentage (ESP) exceeds 8, there is significant reduction in the cane yield. This is also true for effect of water logging on cane yield (Table 3). Irrespective of varieties, cane yield was tended to decline by about 5 per cent with rise in water table by every 25 cm over 200 cm water table depth.

Fig. 2: Relationship between ESP and cane yield



Patil *et al.* (2004)

Table 3: Estimated cane yield and per cent reduction in cane yield in relation to water table

SN	Water table (cm)	Estimated yield (t/ha)	% decrease in yield over 200 cm deep water table	
			Cumulative	Incremental
1	25	82.5	34.4	7.0
2	50	88.7	29.5	5.8
3	75	94.2	24.6	6.7
4	100	101.0	19.6	5.9
5	125	107.3	14.7	5.5
6	150	113.5	9.8	5.1
7	175	119.6	4.9	4.9
8	200	125.8	--	--

Case studies

1) Considering the severity and extent of water logging and secondary salinization problems in UKC, Soil and Water Management Research Unit, NAU (formerly GAU), Navsari conducted studies on subsurface drainage in 56 ha block at the farmers' fields situated in the jurisdiction of Chalthan Sugar Factory, Chalthan during 1984-85 to 1991-92. After installation of subsurface drainage, paddy and sugarcane yields were higher as compared to pre drainage yields. The pH and EC values also showed a decreasing trend with the progress of time after drainage.

2) Similarly, WALMI, Anand (middle Gujarat) also conducted pilot scale demonstration of subsurface drainage technology in Mahi Right Bank Canal Command during 1990-91. The soils were extremely saline and water logged and the area was almost lying barren. After installation of subsurface drainage, paddy crop was grown and yield level of 2 to 3 t/ ha was achieved.

3) Subsequently, for testing and demonstrating the drainage need on larger scale for controlling water logging and soil salinity, a collaborative project with ILRI, The Netherlands was approved by ICAR, Government of India with Navsari as one of the network centers and CSSRI, Karnal as the coordinating center. Under this project, two pilot areas were selected in UKC. The important characteristics of both the pilot areas are given in table 4. The distinct difference between both the pilot areas was cropping intensity *i.e.,* in Segwa it was 116 per cent and only 48 per cent in Sisodara. This was mainly because of severity of water logging and salinity problems were more in Sisodra than in Segwa. The cropping intensity of 48 per cent in Sisodra suggests presence of barren land in pilot area.

Table 4: Important characteristics of pilot areas

SN	**Particulars**	**Pilot area**	
		Segwa	**Sisodra**
1	Taluka/ district	Kamrej/ Surat	Ankleshwar/Bharuch
2	Climate	Sub humid	Semi arid
3	Branch/ minor	Surat branch/ Segwa minor	Kosamba branch/ Pandvai minor
4	Size of pilot area (ha)	188	169
5	Cropping intensity (%)	116	48
6	Major crops	Sugarcane, paddy	Sugarcane, paddy
7	Major constraints	Water logging and initiation of salinization	Extreme water logging and high salinity/sodicity
8	Source off irrigation water (ha)		
	- Canal	76	76
	- Well alone	37	--
	- Drain	4	--
	- Conjunctive use	26	--

Source: IDNP Team (2003)

Drainage design

After completion of pre project survey and analysis of drainage related parameters of soil, drainage design details were worked out and system installation work was initiated during 1998. The system details are presented in table 5.

At Segwa pilot site, singular and composite closed subsurface drainage (CSSD) systems were installed at 30, 45 and 60 m spacing with and without amendment and envelop. In all, 28.1 ha area was brought under CSSD in phased manner. While at Sisodra, only open subsurface drainage (OSSD) was laid out in16 ha area with 30 and 60 m drain spacing. Both these pilot areas were monitored vigorously for soil, drain water, ground water level and crop yield parameters.

Table 5: Information about drainage system installed

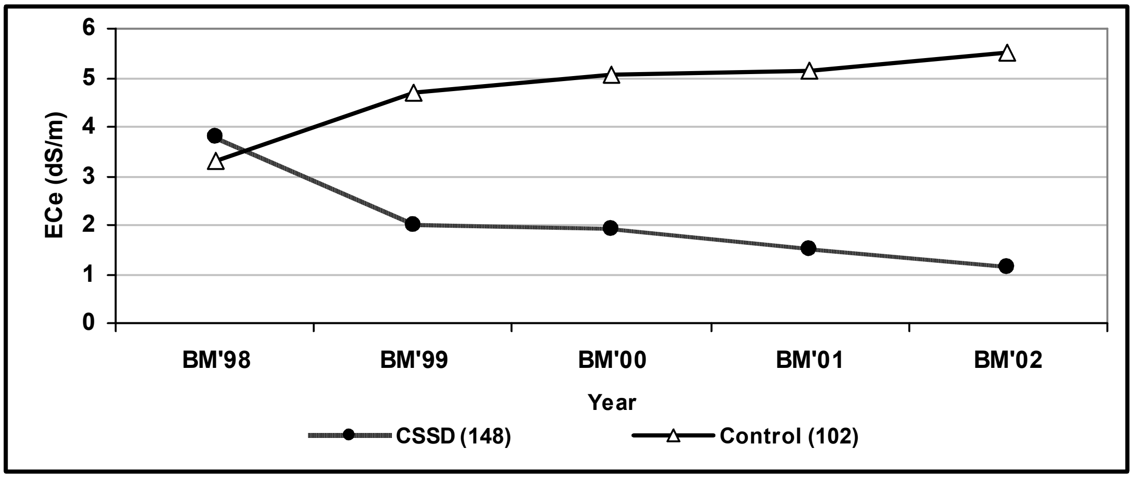
Particulars	**Segwa**				**Sisodara**	
	Singular pipe drains (m)	**Area (ha)**	**Composite pipe drains (m)**	**Area (ha)**	**Open drains (m)**	**Area (ha)**
Drain depth/ spacing	0.9/ 30 0.9/ 45 0.9/ 60	4.2 5.6 5.4	1.2/ 30 1.2/ 45 1.2/ 60	2.6 5.7 4.6	0.8/ 30 0.8/ 60	2.0 14.0
Installation method	M	--	M + E	--	M	--
Envelop	None	--	Some	--	--	--
Amendment	None	--	Some	--	--	--
Total area (ha)		**15.2**		**12.9**		**16.0**

M= Manual, M + E= Manual + excavator *Source*: IDNP Team (2003)

Monitoring

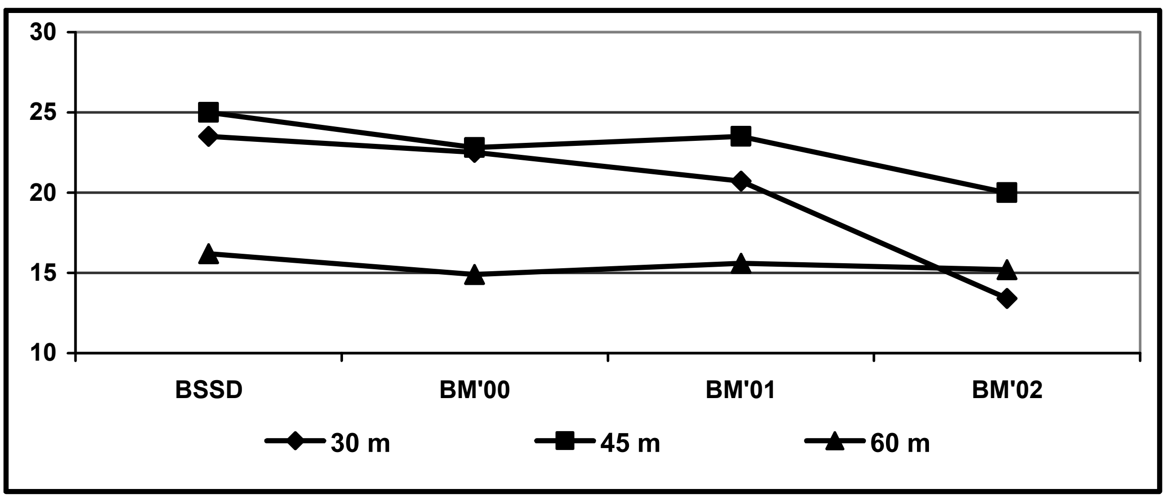
After installation of CSSD in Segwa pilot area, salinity and sodicity parameters of the soil were monitored periodically. The soluble salt content in soil (0 – 90 cm) under CSSD was declined from initial value of about 4.0 dS/m in 1998 to 1.0 dS/m in 2002 (Fig. 3). Similarly by sodicity was also tended to decline after installation of CSSD system at Segwa (Fig.4).

Fig. 3: Periodical changes in soil salinity under CSSD and control blocks



BM = Before Monsoon, CSSD = Closed subsurface drainage

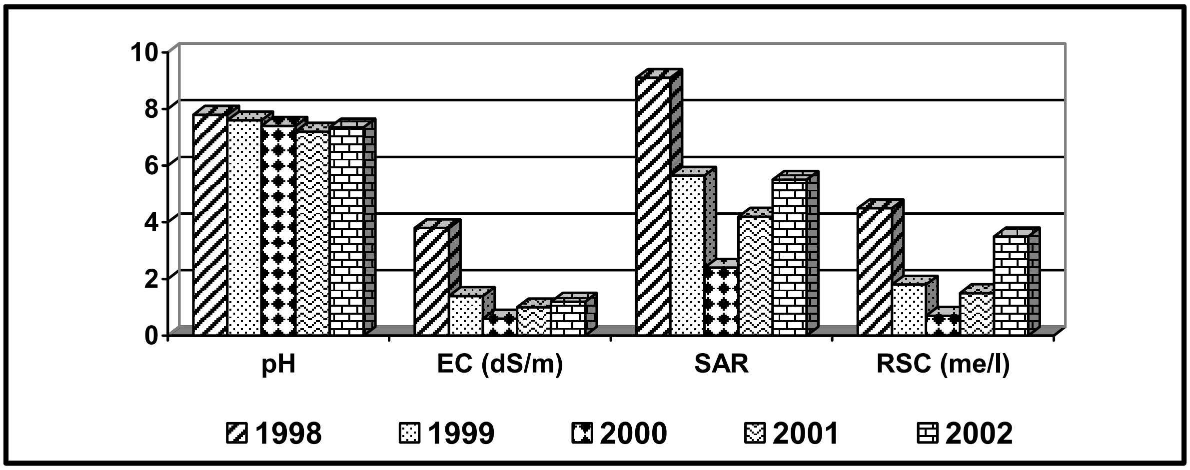
Fig. 4: Periodical changes in soil sodicity under different drain spacing of CSSD (Segwa)



BSSD=Before Sub Surface Drainage, BM=Before *Source*: IDNP Team (2003)

The values of quality parameters of drain water depicted in fig. 5 revealed that with progress of time EC, SAR and RSC showed declining trend. Looking to the reduction in salinity and sodicity parameters of drain water after first year of CSSD installation indicate that drain water can be used safely for irrigation.

Fig. 5: Periodical changes in quality parameters of drain water



Source: IDNP Team (2003)

Apart from decrease in soil salinity and sodicity, on annual basis ground water table level was lowered down by 0.15 to 0.33 m in subsurface drainage blocks (Table 6). This was reflected positively, as the yield of sugarcane was increased by 44, 31 and 5 per cent with 30, 45 and 60 m drain spacing, respectively over control. In case of OSSD, the grain yield of paddy was increased by three folds.

Table 6: Effect of drainage on crop yield and water table

Particulars	Yield (t/ha)	% increase in yield	Water table (m bgl)		
			Pre	Post	Difference
***Sugarcane* (Segwa)**			**CSSD**		
Control	80	-	0.35	0.35	0.00
30 m drain spacing	115	44	0.53	0.74	0.21
45 m drain spacing	105	31	0.32	0.46	0.14
60 m drain spacing	84	05	0.53	0.72	0.19
***Paddy* (Sisodara)**			**OSSD**		
Control	0.6	-	-	-	-
OSSD	1.8	200	0.55	0.88	0.33

bgl = below ground level *Source:* IDNP Team (2003)

Economics

Considering the installation cost of CSSD and OSSD along crop yields, economics was computed for both the type of system at different spacings. In view of economic viability of the system, drain spacing of 45 m for CSSD was recommended and details are given in table 7. The benefit: cost ratio of 1.7, internal rate of return of 58 per cent and pay back period of 2 – 3 years empathetically establishes the techno economical viability of CSSD.

Table 7: Economics of singular system CSSD (45 drain spacing)

Particulars	Control plots	Drained plots
Cost of installation (Rs./ha)	-	20,400.00
Cost of cultivation (Rs./ha)	31,386.00	41,143.00
Yield (t/ha)	78	105
Gross income (Rs./ha)	63,555.00	85,500.00
Benefit : Cost ratio	-	1.7
Internal rate of return	-	58
Pay back period (years)	-	2 - 3

Source: IDNP Team (2003)

Impact of the project

Having been convinced by seeing the perceptible increase in crop yields and improvement in soil physical conditions on large scale in farmers' fields, they have started adopting drainage technology by bearing 100 per cent cost of the system under the technical guidance of Soil and Water Management Research Unit, NAU, Navsari. After completion of Indo-Dutch Network Project in 2003, about 36 farmers have installed CSSD/OSSD system covering about 55 ha area in South Gujarat (Anon., 2007).

These farmers are cultivated variety of crops in CSSD/OSSD field and they observed tremendous increase (40-45 %) in yield. They also experienced that fields are reaching to *vapsa* condition quickly thereby facilitating interculturing which control weeds and provide aeration to growing crop. Though, the area is only 55 ha, yet it shows the impact of drainage pilot area. The reasons for slow pace of adoption of drainage technology are: unavailability of corrugated PVC pipes in small quantity, high initial investment and effluent disposal problem in inter-locked fields.

Table 8: Details of CSSD demonstrations on farmers' fields

SN	Drain spacing (m)	District	No. of farmers	Crop taken	Increase in yield over control (%)
1	30-40	Surat	3	Sugarcane, Cotton	20-50
		Bharuch	1	Sugarcane, Cotton	20
		Navsari	2	Sugarcane, Banana, Mango, Vegetable, Rose	30-40
2	40-50	Surat	15	Sugarcane, Cotton, Wheat, Vegetable	10-40
		Bharuch	1	Sugarcane	50
		Navsari	1	Sugarcane, Vegetable, Rose	30-40
3	50-60	Surat	10	Sugarcane, Cotton, Wheat, Mango, Vegetable, Sapota	20-50
		Bharuch	4	Sugarcane	30-40

Note: 100 per cent cost of the system was borne by the farmers *Source:* Anon. (2007)

Strategy for increasing adoption rate of drainage technology

1. Delineation of severely water logged and salt affected areas in the canal command.
2. Create awareness about subsidy scheme of land reclamation among the farmers.
3. Drainage needs to be adopted on community basis.
4. Participation of sugar co-operative needs to be intensified.
5. Establishment of drainage company at state level *i.e.* on the line of GGRC for micro irrigation.

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Scope of Waste Water Usage in Gujarat

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Introduction

The diverse industries such as dyes, pulp and paper, metal, soda ash, polyester fibers, pharmaceuticals, pesticides, fertilizers, oil and petrochemicals, power generation, refinery etc. are generating large quantities of industrial waste effluents. With liberalization and globalization policy of the Government of India, industrial sector has made a fast progress therefore water demands are likely to be increased by 10-15 per cent. Particularly, in Gujarat, there is rapid industrial development from Vapi at the southern end of Gujarat to Mehsana about 450 km to the North, the so called "The Golden Corridor of Gujarat". These industries generate huge quantity of solid and liquid wastes. The effluents from these industries are either released to channels or disposed off on land and are used for irrigation due to non-availability of good quality water. The agriculturists are much worried about the pollution due to entry of toxic elements into food chain. Among the different polluting elements, the heavy metals create serious problems whenever they get accumulated in the environment. The unwise use of raw sewage water and industrial waste water for irrigation continuously has elevated levels of available heavy metals in the cultivated layer of the soil (Totawat, 1991).

In the industrial development sector, Gujarat ranks first in India followed by Tamil Nadu. About 4000 industrial units in Gujarat need daily a large quantity of fresh good quality water in production units. A survey estimated that liquid hazardous waste effluent discharged by Ankleshwar industrial area is about 300 mld and more than 400 mld in Ahmedabad industrial area. Nandesari industrial estate near Vadodara in Gujarat is a focal point of industrial growth. It includes GSFC, IPCL, Gujarat Refinery, GIDC, microcosm of about 300 industries discharging nearly 200 mld effluent to Mahi besides large quantities of solid wastes and by-products annually. In future, industrialization will require a major share of fresh water and release large quantities of industrial waste effluents either into nearby river streams, drains, *nala* or are being dumped into the open space except few cosmos which have adopted effluent treatment plant effectively as per Central Pollution Control Board or Supreme Court guidelines. Besides these industries, various food and fish processing, sugar factories, distillery and other core sector industries are also using high quantities of fresh water to process the final products.

Although most regulatory effort goes unenforced to treat the waste water for improving its quality, much of the effluents from disposal channel do not reach the estuary. A part of these effluents are intercepted by the farmers for irrigating their crops in agricultural fields, which may pose serious soil environment hazards leading to low or sometimes no crop production later.

The sewage water can be used profitably in agriculture for irrigation or its nutrient supply or for reclamation of problematic soils. The quality of sewage varies with the type or source of urban waste. The sewage water contains undesired substances such as heavy metals, which may result in undesired effects when applied in large quantities. Therefore, any unscientific use of sewage water results in deterioration of soil health and crop production also on long term basis. However, the use of treated waste water reduces the load of toxic elements in soil and thereby restricts their entry into food chain. Hence, with appropriate scientific techniques, the sewage waste water can be utilized beneficially in agriculture.

Heavy metals (broadly defined as a group of toxic metals and metalloids associated with pollution and toxicity) are the ones having density of more than that of 6 Mg/m^3 and atomic weight more than that of iron (Alloway, 1990). Operationally, all the micronutrient cations viz., iron, manganese, copper, zinc and nickel are classed as the heavy metals and depending on levels in the plants/ organisms exhibit both deficiency and toxicity. In addition, lead, cadmium, mercury, selenium and arsenic are the other heavy metals and metalloids which exhibit toxicity to animals including human beings and plants. Heavy metals may build-up in the soil while the crop may take them up, thus resulting in high concentrations of heavy metals in consumable products (Mitra and Gupta, 1999).

Composition of waste water (sewage and effluents)

Nutrient supplying potential of sewage is directly related to its composition. In general, sewage generated in India contains more than 90 per cent water and good amount of N, P, K and micronutrients. Mitra and Gupta (1999) assessed the quality of effluent from sewage canal and ground water from tube well. Both sources of water differed widely in chemical characteristics. Similar observations were also noted for domestic waste water of Varanasi (Tiwari *et al.,* 2003) and different cities (Anon., 2002-03). The important properties of sewage samples from major industrial cities of Gujarat are presented in tables 1 and 2.

The pH was generally alkaline and the EC was below 3 d/Sm in all the cases. The Cl^- content was slightly above the permissible level in samples from Pirana, Lambhwell II and Kapadvanj. The CO_3^{-2} and HCO_3 content was low in almost all the cases. The range for HCO_3 was 3.50-6.80 me/l. The contents of Ca^{+2}, Mg^{+2} and K^+ were also low, while the Na^+ was above 9.0 in all the cases except for Model farm (8.21) in Vadodara.

Apart from lesser pollution hazards, the sugar industry effluent (spent wash) is having highest manurial value as compared to the other effluents Thus, utilization of water resource is crucial in agricultural production due to its ever increasing demand for producing more and more food. Reuse of domestic waste water (sewage) for irrigation has gained importance throughout the world due to limited water resource and costly treatments of waste water for discharge. If and with suitable topography, soil characteristics and drainage is available, sewage water can be put to good use as a source of both irrigation and plant nutrients. The Indian soils have been experiencing on an average a net negative balance of 8-10 Mt of nutrients/ annum (FAI, 1999-2000). Kaul *et al.* (2002) mentioned the 5R concept of waste water management, recycling, reuse and eco-development for better use in agriculture. It is recognized that sewage is just not a pollutant but also a nutrient resource as evidenced by the presence of about 90 t N, 32 t P and 55t K valued at Rs. 61 million, that could be recovered from country's domestic sewage to the tune of 15, 000 millions litres daily (MLD) (CPCB, 1989-90).

The trace elements and heavy metals contents in these sewage samples revealed that the contents of water soluble metals were very low (Table 2). The water soluble Mn was negligible and the Zn content was below 2.0 ppm in all the cases. Similarly, the Cu content was also below 0.2 ppm in all the cases. The water soluble metals were observed in traces only, except for one from Model farm. The content of Co did not exceed the limit in any of the cases. The Cr, Pb and Ni contents were found to be negligible in all the cases as per the limit fixed by FAO, 1992 except in case of Model Farm Vadodara.

Table 1: Chemical composition of sewage water before and after monsoon

Class	City	Site	Sampling month	$pH_{1:2}$	EC dS/m	Cl-	CO_3^{-2}	HCO_3^-	$Ca^{+2}+Mg^{+2}$	Na^+	K^+
						meq/l					
Big	Ahmedabad	Behrampur	June	8.41	1.36	9.00	4.00	4.00	14.00	19.9	7.80
			October	8.15	2.56	13.20	1.50	5.65	6.25	15.40	6.58
		Jespur	June	8.54	1.56	9.00	2.40	6.00	8.00	20.00	6.70
			October	7.42	2.52	13.50	0.00	5.98	4.50	18.30	5.50
		Pirana	June	8.20	1.94	13.52	1.00	3.50	7.20	10.8	5.31
			October	8.08	2.77	12.48	1.00	5.42	5.54	13.50	12.35
		Mean	June		**1.62**	**10.51**	**2.47**	**4.50**	**9.73**	**16.90**	**6.60**
			October		**2.62**	**13.06**	**0.83**	**5.68**	**5.43**	**15.73**	**8.14**
Medium	*Vadodara*	Model farm	June	8.17	1.50	9.00	0.80	4.50	5.40	8.21	3.42
			October	8.40	1.52	8.05	2.65	4.32	5.65	8.07	3.12
		Atladara	June	9.28	1.17	8.50	3.20	6.80	12.00	18.30	7.60
			October	6.75	2.30	9.08	4.25	5.56	7.15	9.20	4.29
		Mean	June		**1.34**	**8.75**	**2.00**	**5.65**	**8.70**	**13.26**	**5.51**
			October		**1.91**	**8.57**	**3.45**	**4.94**	**6.40**	**8.64**	**3.71**
Small	Anand	Lambhwel-I	June	8.25	1.15	9.00	2.40	5.20	16.00	18.5	7.80
			October	7.85	1.51	10.20	2.00	4.42	7.10	6.35	4.18
		Lambhwel-II	June	7.72	1.46	10.50	2.00	3.50	6.00	10.50	5.50
			October	7.42	2.10	8.43	4.20	7.05	6.25	10.15	4.23
	Kapadvanj	Sewage farm	June	7.88	1.53	12.00	3.20	4.00	6.00	20.7	10.8
			October	7.48	2.15	6.25	3.40	6.65	7.70	9.28	5.98
		Mean	June		**1.38**	**10.50**	**2.53**	**4.23**	**9.33**	**16.57**	**8.03**
			October		**1.92**	**8.29**	**3.20**	**6.04**	**7.02**	**8.59**	**4.80**
Toxic limit for irrigation water				**8.40**	**3.0**	**10.00**	**---**	**8.50**	**---**	**9.00 (SAR)**	**---**

Table 2: Water-soluble trace and heavy metals in sewage water before and after monsoon

Class	*City*	Site	Sampling Month	Fe	Mn	Zn	Cu	Cd	Co	Cr	Pb	Ni
				ppm								
Big	**Ahmedabad**	**Behrampur**	June	0.01	Tr	0.01	Tr	Tr	0.01	Tr	Tr	0.00
			October	0.04	0.01	0.01	0.02	0.01	Tr	0.01	Tr	0.01
		Jespur	June	0.01	0.01	0.03	Tr	Tr	0.05	0.07	Tr	0.02
			October	1.28	0.06	3.02	0.12	0.01	0.02	0.10	0.09	0.12
		Pirana	June	0.09	0.13	0.01	Tr	Tr	0.01	Tr	Tr	0.01
			October	0.98	0.04	0.03	0.06	Tr	0.01	0.01	0.02	Tr
Medium	**Vadodara**	**Modal farm**	June	0.08	0.02	0.02	0.01	0.03	0.01	0.20	0.02	Tr
			October	0.07	0.02	0.03	0.01	0.02	0.05	0.01	0.04	0.05
		Atladara	June	Tr	Tr	0.02	Tr	Tr	0.02	Tr	0.13	0.02
			October	0.07	0.02	0.04	0.01	0.01	0.03	0.01	0.04	0.02
Small	**Anand**	**Lambhwel-I**	June	0.01	0.12	0.02	0.03	Tr	0.02	0.04	Tr	Tr
			October	1.50	0.09	0.02	0.01	0.01	0.10	0.01	0.03	0.12
		Lambhwel-II	June	0.02	0.18	0.01	0.01	Tr	0.02	Tr	0.02	0.01
			October	1.23	0.10	0.03	0.01	Tr	0.02	Tr	0.04	0.04
	Kapadvanj	**Sewage farm**	June	0.01	Tr	0.04	Tr	Tr	Tr	Tr	0.03	0.02
			October	2.11	0.09	0.08	0.03	0.01	0.03	0.01	0.05	0.03
Toxic limits (ppm) in irrigation water (FAO, 1992)				**5.00**	**0.20**	**2.00**	**0.20**	**0.01**	**0.05**	**0.10**	**5.00**	**0.20**

Similarly, the analysis after monsoon showed that among the heavy metal concentrations, the water soluble Fe content was very low, ranging from 0.04 to 2.11 ppm (Table 3). The water soluble Mn, Zn and Cu contents were very low in all sites. The water soluble contents of Cd, Co, Cr, Pb and Ni were either below detectable level or within the standards set for these metals.

Suitability as irrigation

Success in using treated waste water for crop production will largely depend on adopting appropriate strategies aimed at optimizing crop yields, quality, maintaining soil productivity and safeguarding the environment (Kaul *et al.,* 2002). Chhabra (1988) estimated that sewage water has a potential to irrigate 2.5, 3.8 and 3.3 lakh ha of vegetables, fodders and cereals equivalent to irrigation worth rupees 75, 113 and 50 million, respectively. The sewage availability is equal to that generated by 65 to 95 thousand tube wells. Sreeramulu (1994) also estimated net profit per year due to marketing of pretreated sewage water for irrigation purpose to dry land farms in urban areas of Tamil Nadu. It has been estimated that sewage water on supply 2023 t/day or 743870 t/year of NPKS equivalent to 2470 million rupees of inorganic fertilizers (Chhabra, 1988). Urban waste is considered to be a good source of micronutrients also. An estimate indicated that the waste could supply about 21 thousand tones of micronutrients annually (Prasad, 1999).

On the basis of classification for quality of irrigation water (Table 3), almost all the effluents can be used in different soil types for different crops with due consideration to the salinity and sodicity sensitiveness of crops. Among the different effluents, paper and sugar industries effluents were comparatively less hazardous (Raman and Zalawadia, 1997).

Table 3: Suitability of different effluent waters for irrigation

Sr. No.	Type of factory	Water quality class	Suitability	RSC (me/l)
1.	Cloth mill – 1	C_4S_1	STC-S, TC-L	- Ve
2.	Cloth mill – 2	C_4S_2	TC-S	17.4
3.	Cloth mill – 3	C_3S_3	TC-S	7.3
4.	Paper mill- 3	C_3S_2	STC-S,TC-L	5.8
5.	Paper mill – 1	$C_{2.5}S_1$	SC-SL, TC-CL, C	- Ve
6.	Sugar factory – 1	C_3S_1	SC-S, STC-L, TC-C	- Ve
7.	Sugar factory – 2	C_5S_1	TC-S	- Ve
8.	Pharmaceutical Industry	C_3S_3	TC-S	10.7
9.	Chemical factory - 1	C_5S_1	TC-S	- Ve

Sr. No.	Type of factory	Water quality class	Suitability	RSC (me/l)
10.	Chemical factory – 2	C_5S_4	Unsuitable for all crops	- Ve
11.	Electroplating industry	C_3S_1	SC-S, STC-L,TC-C	2.7
12.	Rubber industry	C_4S_2	TC-S	9.3
13.	Oil products industry	C_4S_1	STC-S, TC-L	- Ve
14.	Dairy industry	$C_{2.5}^S$	SC-SL, STC-CL,TC-C	1.9
15.	Rice mills	C_4S_1	STC-S,TC-L	9.06
16.	Dying factory	C_4S_2	TC-S	- Ve
17.	Plastic Industry	C_3S_2	STC-S, TC-L	8.1

Note:

Crops -	SC = Sensitive,	STC = Semi tolerant,	TC = Tolerant
Soil texture -	S = Sandy	L = Loamy	SL = Sandy Loam
	CL = Clay Loam	C = Clay	

Source: Raman and Zalawadia (1997)

Effect of urban wastes

Soil properties are affected by addition of organic matter through urban wastes.

Physical: Soil application of waste increased hydraulic conductivity, aggregate stability, water holding capacity and total porosity, while it decreased bulk density (Paulraj and Sree ramulu, 1994). Similar trend was also observed by Jayraman *et al.* (1983) with long term land application of sewage water. Application of sewage sludge at 20 t/ha with mineral fertilizers reduced the bulk density of soil with concomitant increase in hydraulic conductivity, pore space and available macro and micronutrients, besides reducing fertilizer dose by 50% of recommended level for rice in Tamil Nadu (Paulraj, 1989 and Paulraj and SreeRamulu, 1994). Juwarker *et al.* (1991) observed that increase in application of sewage sludge from 0 to 90 t/ha increased organic matter content, decreased bulk density, and increased infiltration rate of soil Jayaraman *et al*. (1983) also reported improved soil physical parameters with application of sewage (Table 4).

Table 4: Effect of long term sewage irrigation on physical properties of soil

Properties	Fresh water	Sewage	
		After 15 years	After 25 years
Bulk density (g/cc)	1.53	1.53	1.06
Aggregate stability	72.43	84.38	83.48
Stability index	62.30	65.80	71.10
Water holding capacity, %	33.20	49.70	59.10
Hydraulic conductivity, cm/hr	19.10	23.60	26.63
Total porosity, %	36.20	49.70	59.78
Organic carbon, %	1.42	2.56	4.63

Source: Jayaraman *et al.* (1983)

Chemical: The surface soil samples collected from different cities after the harvest of the crops showed alkaline reaction in all the cases. The EC ranged from 0.07 to 1.03 dS/m indicating safe level. The OC was in low range except in the soils of Lambhwel-I in Anand region, which showed medium level.

The Fe content was found to range from medium to sufficient (5.52 to 16.38 ppm) while Mn varied from deficient (Jespur and Pirana in Ahmedabad) to sufficient (Lambhvel-I in Anand). The Zn and Cu contents were sufficient ranging from 1.43 to 21.41 and 1.81 to 40.37 ppm respectively and comparatively higher in big class cities. Both the highest values were observed in the soil of Pirana in Ahmedabad. The accumulation of Cd, Co, Cr, Pb and Ni was not high except for Pb in Ahmedabad.

Maliwal (2002-03) observed that there was decrease in total salt concentration with sewage water irrigation while increase in organic carbon, available P and K was observed during irrigation with sewage water to sweet corn–cabbage – okra cropping system.

Irrespective of the depth, the sewage irrigated soils showed alkalinity ranging from 8.11 to 9.23 whereas, the reference soils, except for one (8.61) showed pH ranging from 7.16 to 8.46 (Table 5). The EC was found beyond permissible limit in the case of sewage-irrigated soils of Ahmedabad only. The organic C content was very low in both the types of soils. However, generally the surface soils had higher organic C contents. The P_2O_5 content ranged from 43 to 240 and 28 to 258 kg/ha, respectively in sewage and well water irrigated soils. Similarly, the S content at different depths varied from 6 to 136 ppm in the former and 10 to 142 ppm in latter. However, in both the cases of normal and sewage water irrigated soils, no trend could be observed for the distribution of P_2O_5 and S contents (Table 5).

The data of the comparative study on depth wise distribution of micronutrients in sewage and well water irrigated soils indicated higher accumulation of these nutrients due to sewage irrigation, though not to a toxic level.

Table 5: Depth wise changes in important properties of soils irrigated with normal and sewage water (Jan.-Feb. –2002)

Category	Location	Depth (cm)	EC (dS/m)		pH		OC (%)		P_2O_5 (kg/ha)		S (ppm)	
			Sewage	Reference	Sewage	Reference	Sewage	Reference	Sewage	Reference	Sewage	Reference
Small	*Anand*	0-15	0.23	0.19	8.19	8.15	0.65	0.30	240	107	136	52
		15-30	0.29	0.20	8.36	8.29	0.45	0.20	206	85	76	55
		30-45	0.23	0.18	8.31	8.30	0.33	0.18	143	120	77	52
		45-60	0.40	0.10	8.11	8.23	0.32	0.13	122	51	66	60
		+ 60	0.21	0.09	8.23	8.22	0.30	0.12	141	38	62	42
	Kapdvanj	0-15	1.03	0.21	9.24	8.21	0.01	0.40	118	194	71	47
		15-30	1.98	0.21	9.16	8.24	0.04	0.18	167	94	78	55
		30-45	1.96	0.15	9.23	8.19	0.00	0.18	43	100	71	57
		45-60	1.01	0.16	9.20	8.12	0.04	0.16	43	51	19	41
		+ 60	1.01	0.39	9.22	8.15	0.02	0.16	43	28	34	61
Medium	*Vadodara*	0-15	0.07	0.10	8.54	7.16	0.23	0.63	64	223	23	10
		15-30	0.05	0.07	8.45	7.78	0.19	0.23	58	167	22	10
		30-45	0.05	0.08	8.38	7.71	0.34	0.26	73	165	19	11
		45-60	0.07	0.08	8.18	7.96	0.28	0.27	79	75	8	16
		+ 60	0.08	0.08	8.24	8.06	0.26	0.26	56	45	6	17
Big	*Ahmedabad*	0-15	2.26	0.34	8.80	8.61	0.44	0.60	216	85	24	29
		15-30	2.22	0.72	8.95	8.24	0.36	0.47	227	258	15	142
		30-45	2.21	0.28	9.07	8.46	0.32	0.43	162	59	15	56
		45-60	2.36	0.25	8.80	7.90	0.16	0.38	105	51	36	49
		+ 60	2.36	0.21	9.03	7.67	0.10	0.35	96	42	17	45

The content of pollutant elements in both the soils at all the depths were far below the permissible level especially in case of sewage farms which were under irrigation with sewage water for more than 20 years. However, in general, the sewage irrigated soils exhibited higher accumulation. Patel *et al*. (2003) also observed that the accumulation of the pollutant elements was more in surface (0 – 15 cm) than in lower (15 – 30 cm) depth. Besides, much variation in their contents was not noticed between the two sewage water and normal water irrigated soils (Fig. 1). The maximum value noticed for Cd, Co, Cr, Ni and Pb in the sewage-irrigated soil was 0.12, 0.44, 0.34, 0.54 and 3.84 ppm respectively. The corresponding value for normal water irrigated soil was 0.06, 0.44, 0.32, 0.88 and 1.30 ppm.

Primary treated sewage water increased yield of different crops more favorably than the untreated (Arti Bhatia *et al.,* 2001). The significantly higher yields of oat, barley, sorghum and maize were obtained with treated sewage as compared to tube well water (Singh *et al.,* 1993 & 1995). Tiwari *et al.,* (1996) reported 50 per cent saving of NPK by using treated sewage water in rice.

However, the indiscriminate use of untreated urban waste may cause an accumulation of heavy metals in soils which adversely affect the crop yield (Rechigl, 1995; Singh, 2002). The excess supplementation of Ni (Gupta *et al.,* 1996) and Cd (Sarkunan *et al.*, 1996) showed harmful effects on crop yields and in case of rice straw, Cd crossed the phyto-toxicity limits (Alloway, 1990) when it was applied @ 25 ppm Cd or more. The concentration of heavy metals was higher in grass, urine, blood serum and milk samples collected from milch animals being fed with grasses grown by continuous irrigation of sewage water (Singh, 2002). The composted city waste was found more beneficial than the use of FYM to improve different growth parameters of maize (Nagori and Desai, 2002).

Source of nutrients

The use of domestic waste water (sewage water) in agriculture can add appreciable quantity of nutrients. The content of organic carbon, N, P and K are substantially increased by irrigating soils with sewage water rather than tube well or canal water which finally improved the soil fertility and productivity (Singh and Kansal, 1985). It is estimated that five irrigations of 7.5 cm/ ha with untreated sewage water will add 181, 29, 270 and 130 kg of N, P, K and S, respectively and 0.28, 0.75, 41.86 and 1.37 kg of Zn, Cu, Fe and Mn, respectively (Baddesha *et al.,* 1986).

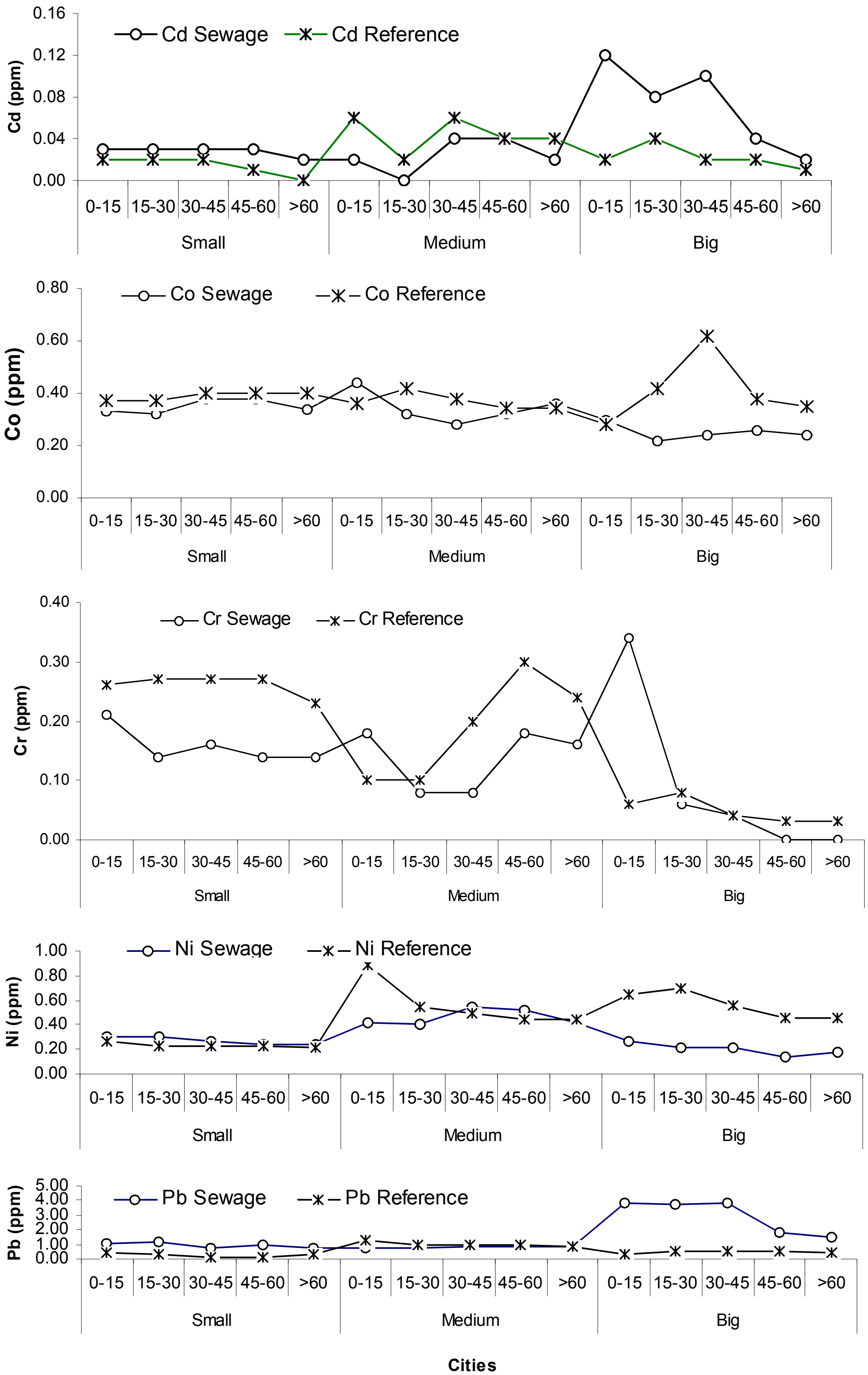

Fig 1: Depth wise (cm) distribution of heavy metal contents (ppm) in the soils irrigated with normal and sewage water

Chhabra (1988) estimated that sewage water has a potential to contribute total nutrients of 7.4 million tones/year equivalent to Rs. 2470 million in terms of nutrients through inorganic fertilizers. Datta *et al.,* (2000) in an experiment confirmed that soils receiving sewage water irrigation for long term had higher organic carbon status than that of tube well irrigated soils. The volume of waste water used for irrigation and nutrient loading through waste water against standard application rate was worked out by Kaul *et al.,* (2002).

Impact on crop production

Several researchers have reported positive effect of sewage on crop yield. Mahida (1981) obtained higher yields of vegetables irrigated with undiluted sewage compared to irrigation with canal water. Singh *et al.* (1991) noticed that dry matter yield of berseem increased significantly with increasing number of irrigations consisting of sewage water and reduction with effluent irrigation water.

Significantly higher yields of oat, barley, sorghum and maize were obtained with treated sewage than well water (Singh *et al.,* 1993 & 1995). Juwarkar *et al.* (1994) revealed that application of primary treated sewage water increased yield of rice by 12% and wheat by 24% over irrigation with well water. Similar increase in yield of pulses and vegetables were also observed. Tiwari *et al.,* (1996) reported 50% saving of NPK by using treated sewage water in rice. At Karnal, treated sewage water improved crop growth and increased yield of rice (11%), wheat (15%), spinach (28%), cauliflower (19%) and sorghum (9%) as compared to tube well water (Anon, 2001-02). The highest gain yield of maize (31.4 q/ha) was obtained in case of alternate irrigation with tube well water and treated sewage and it was closely followed by tube well water irrigation (Anon., 2002-03).

Use of diluted RIL and UPL effluent water along with 100 per cent RDF (320 and 285 g/pot) as a source of irrigation water increased fresh yield of onion bulb by 33.47 and 18.87 per cent over canal water irrigation in conjunction with 100 per cent RDF (239.75 g/ pot). Yield of bulb and leaves was statistically same at 100 per cent recommended dose with normal water and 50 per cent recommended dose with RIL and UPL effluent waters (Table 6).

Table 6: Direct effect of diluted industrial effluents and graded fertilizer levels on fresh and dry weight of onion bulb and leaves

Treatments	Bulb (g/pot)		Leaves (g/pot)	
Effluent + RDF (%)	**Fresh**	**Dry**	**Fresh**	**Dry**
NW + 100	2.39.75	29.66	67.50	8.27
R + 0	202.50	25.12	56.25	6.92
R + 50	241.25	29.94	75.00	9.17
R + 75	295.00	36.69	97.50	11.89
R + 100	320.00	39.40	98.75	11.98
U + 0	185.00	22.92	41.25	5.09
U + 50	218.75	27.14	62.50	7.68
U + 75	227.50	28.26	70.00	8.56
U + 100	285.00	35.49	92.50	11.26
NW + 0	110.00	13.63	28.75	3.62
S. Em ±	11.42	1.45	3.62	0.44
C. D. at 5%	**30.90**	**4.17**	**10.44**	**1.27**

Similarly, the cumulative effect on fodder maize showed that fresh and dry matter of fodder maize produced at RIL effluent plus 50 per cent RDF (675.50 and 95.34 g/pot) and UPL effluents plus 50 per cent RDF (606.50 and 87.94 g/pot) were statistically same as that obtained at 100 per cent RDF and irrigated with canal water (589 and 85.41 g/pot). Fresh yield of fodder maize with RIL and UPL effluent irrigation along with 100 per cent RDF got increased by 29 and 21 per cent, respectively over canal water irrigation along with 100 per cent RDF (Table 7).

In a pot culture experiment where in the possibility of fertilizer reduction at optimum effluent dilution was tried with onion (Direct effect) and fodder maize (Cumulative effect), there was clear cut indication that in both the studies, about 50 per cent fertilizers could be saved. Use of diluted effluent water improved the fertilizer use efficiency and available nutrient status in soil. Thus, the disposal of industrial wastes viz., liquid and solid be made for better crop production and sustaining soil fertility. However, more such studies should be undertaken in future.

Table 7: Cumulative effect of diluted industrial effluents and graded fertilizer levels on fresh and dry yield of fodder maize

Treatments Effluent + RDF (%)	Fresh yield (g /pot)	Dry yield (g/pot)
NW + 100	589.00	85.41
R + 0	446.75	63.89
R + 50	675.50	95.34
R + 75	710.50	104.45
R + 100	758.25	113.74
U + 0	435.25	61.81
U + 50	606.50	87.94
U + 75	681.75	99.83
U + 100	712.00	106.80
NW + 0	151.00	20.99
S. Em ±	24.79	3.63
C. D. at 5%	**71.60**	**10.47**

Management of sewage water as a source of irrigation water and nutrient under cabbage / cauliflower-okra-sweet corn cropping system

In a field experiment carried out during 2000-2004 to evaluate the impact of sewage water use on crop yields and contamination of the soil with heavy metals. It was observed that the use of sewage water alone or its use with tube well water (1:1) was found beneficial in improving the crop yields over only tube well water. The maximum improvement in crop yields due to sewage irrigation was 30.4 q and 8.5 q/ha equivalent to about 8 to 9 per cent in cauliflower and sweet corn, respectively.

The use of sewage showed the significant reduction of N by 25 per cent in the crops viz., cabbage/cauliflower and okra which received direct sewage irrigation as well as in sweet corn (*Kharif*) due to cumulative residual effect of sewage irrigation (Table 8).

The beneficial effect of the sewage could be ascribed to the addition of nutrients as well as organic matter to the soil.

Efficient management of industrial effluents as a source of irrigation

A field experiment conducted on farmers' field at Umaraya (Vadodara District) during 2001–04 to evaluate the impact of mixed industrial effluent of dyes organic and inorganic chemicals and pharmaceuticals on crops of cabbage-sorghum (fodder)-

pearlmillet sequence showed that the sole use of untreated effluent was found more harmful to sorghum (fodder) and pearlmillet as compared to cabbage. However, the toxic effect of the effluents could be reduced by alternate use of tube well water and treated effluent (1:1). The beneficial effect of use of treated effluent and tube well water (1:1) was more pronounced in cabbage as it gave maximum average increase in cabbage head yield by about 42 per cent over sole use of tube well water (Table 8).

Table 8: Effect of sewage water with graded levels of fertilizer on yields (q/ha) of different crops (Average of 2 years)

Treatment Irrigation (I) water	Fertilizer Level (F)	Sequence-I (2000-02)			Sequence-II (2002-04)		
		Cabbage-Okra-Sweet corn			Cauliflower-Okra-Sweet corn		
		Cabbage head	Okra fruit	Sweet corn cobs	Cauliflower Head	Okra fruit	Sweet corn cobs
Tube well (T)	**50%**	216.1	104.1	110.6	255.4	62.6	95.2
	75%	220.3	103.3	114.0	260.9	72.7	99.5
	100%	253.0	100.9	123.4	267.4	64.8	103
	Mean	229.8	102.8	116.0	261.3	66.7	99.2
Sewage Water (S)	**50%**	214.6	103.8	116.3	273.8	63.0	110.5
	75%	247.0	105.2	125.1	281.7	76.6	103.9
	100%	243.5	100.7	127.4	289.7	78.9	108
	Mean	235.0	103.2	122.9	281.7	72.9	107.7
T:S (1:1)	**50%**	211.3	106.0	117.8	259.1	64.1	103.0
	75%	217.3	103.5	121.8	268.5	77.6	105.5
	100%	247.8	104.6	122.5	272.7	71.5	107.4
	Mean	225.5	104.7	120.7	266.8	71.0	105.3
Mean for fert. level	**50%**	214.0	104.6	114.9	262.8	63.2	102.9
	75%	228.2	104.0	120.3	270.4	75.6	103.0
	100%	248.0	102.1	124.4	276.6	71.8	106.4
C. D. @ 5%	**I**	NS	NS	4.8	NS	3.9	5.0
	Y x F	25.4	NS	6.9	13.3	5.5	-
CV%		13.5	9.0	7.0	5.99	9.52	5.75

Minimizing risk of pollution

The risk of heavy metals contamination could be reduced by primary treatment to make the sewage a good source of irrigation (Savithri *et al.,* 1999). Suitable crop selection identified on the basis of sewage treatments may reduce the risk of pollution and helps in harvesting high crop yields (Juwarkar, 1991).

As these waste materials contain macro and micronutrients, their use in crop production can be one of the potent and economic ways of recycling. But along with essential plant nutrients, these waste materials also contain heavy metals *viz.*, Cd, Ni, Pb, Cr, Hg *etc*. which when applied to the soil can cause health problems due to their accumulation in soil and plant.

Although at many instances the use of IWW has favourably influenced crop production, its continuous use for number of years may result in accumulation of heavy metals in soil and plant (Bansal *et al.,* 1992). Pretreatment prior to its disposal and suitable dilution would lessen the deleterious effect (Zalawadia *et al.,* 1997). Dilution of sewage water with tube well water (1:1) was found beneficial to reduce the risk of heavy metals contamination in soil (Mahida, 1991). Maliwal (2002) reported that concentration of heavy metals were more in plant parts than in seeds and fruits in corn and okra plant under sewage irrigated condition. Thus, the judicious use of waste material may help in recycling of waste and increasing crop production without effecting the soil quality, plant nutrition and animal health.

Potential hazards

Potential hazard of soil and water contamination due to land disposal of sewage is a major environmental concern (Bhatia *et al.,* 2001). The presence of enteric pathogens in waste water is the most serious hazard (Chhabra, 1988). The risk of heavy metals contamination could be reduced by primary treatment to make the sewage a good source of irrigation (Savithri *et al.,* 1999). The concentration of heavy metals was higher in grass, urine blood serum and milk samples collected from milch animals being fed with grasses grown on soils irrigated with sewage water (Singh, 2002). Tube well waters nearby waste water channel were found contaminated with heavy metals, which is likely to pollute the soil (Anon., 2000-02; Anon., 2001-02).

Growing of certain crop/crops species on polluted soil absorb high amounts of polluting elements, especially in vegetable crops. Suitable management of solid and liquid wastes would be useful to reduce the contamination of heavy metals in soil.

Conclusions

The industrial and domestic waste waters (sewage) are potential sources of irrigation and plant nutrients. Irrigation with these waste waters during crop growth period can meet the nutrient requirement for major as well as micronutrients. Further, its application favours an increase in yield of many crops over tube well water irrigation. It also improve the chemical and physical properties of soil and enhances the fertility status by increasing total N, P, K and organic carbon status of soil. However, potential hazards due to heavy metal pollution and health risks from pathogens are of great concern. Hence, to reduce the input of high cost fertilizers, waste water can be successfully used as a source of plant nutrients as well as irrigation under scarce availability of water for irrigation purpose.

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Drinking Water Security: Gujarat's Strategy

Water and Sanitation Management Organization, Gandhinagar

An overview of the water situation in Gujarat

The State of Gujarat in the Western part of India has a great diversity of physiography, climate and hydrology. There is a hilly eastern belt with relatively thick forests, particularly in South Gujarat; an arid region in the north and north-west of the state; long sea coast of 1,600 km with two gulfs viz. Gulf of Cambay and Gulf of Kutch, and plains in the central region and some part of the south. Rainfall in the state varies from 350 mm in Kutch to more than 2000 mm in South Gujarat.

A glimpse into Gujarat's past shows that of the last 75 years, almost one third have been drought years. Two thirds of the Sate faces acute water scarcity. The freshwater availability varies across the State (Fig. 1). It was common for the State to supply drinking water to villages and towns even, through tankers and at times trains, as a part of the emergency drought relief measures. In the year 2001, 4054 villages were supplied water by tankers. Data on drinking water scarcity mitigation shows that during 1999-2003 works had to be taken up in over 23,000 villages and the average annual expenditure on scarcity mitigation was Rs. 120.26 crores.

Fig. 1: Freshwater availability in Gujarat

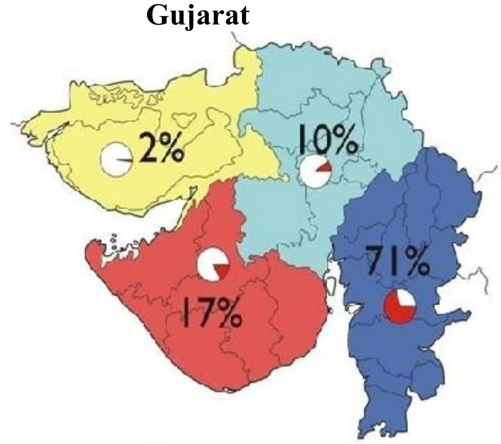
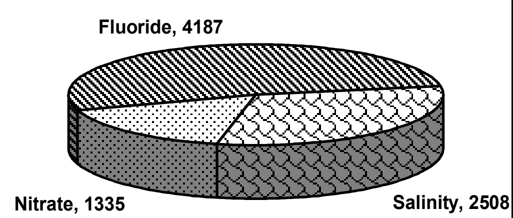


Fig. 2: Quality affteced habitations of Gujarat



The problem in the state is not just that of availability, but also of quality. As a result of recurrent drought and over exploitation of ground water, many parts of the state are experiencing water quality issues and leading to impacts on the health of people. The habitation survey of 2003, showed that almost 7675 habitations of the state were suffering from excessive, salinity, fluoride or nitrate in the ground water (Fig. 2).

Thus more than 50% of the total habitations were either facing water availability issues or water quality problems.

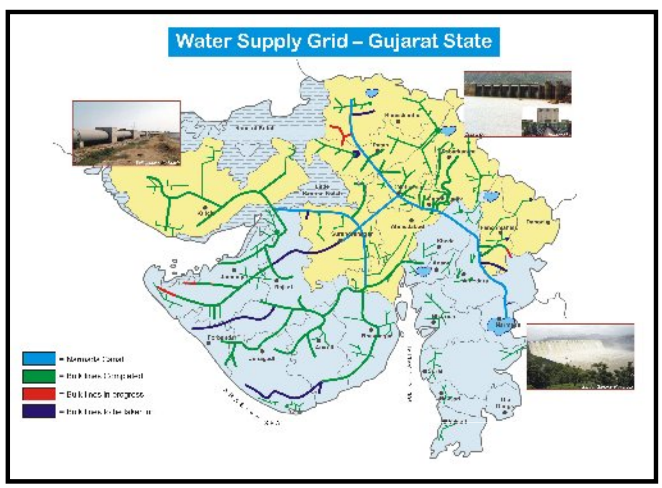
Drinking water security – A holistic approach

The state has addressed the water scarcity issue by bringing in a paradigm shift in the approach to long-term water security. The problem is being looked at in a holistic manner and the State has adopted a multi-pronged strategy:

- Shift from Ground Water to Surface Water
- State wide Drinking Water Grid for Drought Proofing and Sustainability
- Extensive Water Resource Management
- Role of Governance from Provider to Facilitator
- Empowerment of *Panchayati Raj* Institutions by Capacity Building and Constant Facilitation

This shift in approach reiterates the fact that - all sources of water (ground/surface, local or regional) and all stakeholders – the government, the service providers, the user community - are equally important for ensuring water security. None is less important.

1. Bulk water transfer through a state-wide water supply grid



A State wide drinking water supply grid has been planned that will transfer bulk water from the water rich areas of South Gujarat to the water deficient North Gujarat, Saurashtra and Kutch regions. The Grid comprises of three mega infrastructure projects namely the Sardar Sarovar Canal Based Drinking Water Supply Scheme, the Sujalam Sufalam Yojana and the Regional Rural Water Supply Schemes. This grid plans to provide water to 15095 villages of which 10,501 villages have already been covered, while the work is in progress in another 3164 villages. The State is also investing funds in the development of state of the art infrastructure like filtration plants, pumping machinery, head works, intake structures etc. The development of this grid does not in any sense reduce the importance of the local sources and in fact is supposed to serve as a supplementary source, local sources not withstanding. Details of the water supply grid and infrastructure created in the State are given in *Annexure I*.

2. Water resource management: Initiatives for sustainability

An important aspect of drinking water security involves the sustainability of the source. Over-withdrawal of ground water for irrigation, industries and due to the pressures of rising populations, often results into drying of sources. Bearing this in mind the state has taken up several water resource management measures both at the macro and micro levels. Inter-basin water transfer (*e.g.* from Narmada canal to the Sabarmati river), spreading channels, augmentation of major resources, check dams in rivers are some the macro level initiatives. Water resource management at the micro level has also been taken up which includes

- De-silting and deepening of ponds
- Small check dams
- Underground/ Sub-surface check dams
- Filtration wells on ponds
- Recharge/injection wells, bore wells
- *Nala* Plugging
- Roof-top Rain water harvesting
- Linking of ponds and diversion channels
- Hydro-fracturing of sick bore wells
- Bore blasting to develop secondary porosity
- Revival of traditional structures like step wells

Each and every department which has any relation with water resources contributes in conservation of water resources and capturing water wherever possible (Table 1).

Table 1: Information on various departments' contribution to water conservation

Department	Check Dams	Boriband	Khet-talavdi
Water Resources Dept.	61,668	-	-
Rural Development Dept.	26,264	35,130	1,71,400
Tribal Development Dept.	4,525	164	-
Forest Department	3,289	185	-
Agriculture Department	9,620	-	-
Water Supply Department	1,098	-	-
Total	**1,06,464**	**35,479**	**1,71,400**

3. Decentralization – An alternate management approach

In spite of huge investments being made and infrastructure being created, the efforts were not sustainable. Drinking water availability and quality issues continued to plague the sector. This was because of multiple factors such as a supply and engineering driven approach of the service provider, negligible involvement of the rural communities or the users, lack of well designed systems for the management of in-villages water resources and their distribution and over-dependence of the people on the government and a consequent neglect of traditional systems and wisdom.

The need for putting people's initiatives and their demands into planning of the systems was increasingly felt. In fact, piece meal efforts at community managed water supply programmes were being made by the Government of Gujarat and a few NGOs in the State. But the decentralised community managed approach was stabilised only with the creation of the Water and Sanitation Management Organization (WASMO) as a Special Purpose Vehicle to address the issue of engagement of the people residing in villages and strengthening public awareness and capacities to manage water supply systems at the local level. In 2002, when WASMO was formed the State adopted the approach of decentralised community managed in-village water supply systems, the key features of which are:

a. Empowering the community: Formation of Pani Samitis: Realising the need for appropriate and relevant institutions for improving the natural resources and ensuring their equitable use and ownership, the Government of Gujarat passed a resolution for the formation of *Pani Samitis* with representation from marginalised sections and one third reservation for women. Being formed as a sub-committee of the *Gram Panchayat*, the *Pani Samiti* enjoys a Constitutional legitimacy and thus upholds the decentralised democratic process initiated in India with the 73rd Constitutional Amendment. All the three Fs - the fund functions and the functionaries have been transferred to the *Pani Samiti*, and it is empowered to implement the entire village water supply works from planning, construction, financial management, levying the water tariffs, operation and maintenance of the systems, regular testing of drinking water sources to devising mechanisms for ensuring safety and sustainability of drinking water sources.

b. Facilitation - The Fourth 'F': The most important aspect of community management was preparing the rural people to shoulder responsibility of their drinking water systems. This was the single-most important reason for the setting up of WASMO which was to act as a facilitator and provide technical, financial support to the people. Intensive information, education and communication (IEC) activities were carried out to generate awareness on need for collective action, water conservation, the water-health-hygiene connect, quality surveillance, dos and don'ts for ensuring sanitary conditions around sources etc. Capacity building and training constitutes an important aspect of the facilitation process. WASMO conducts trainings for a cross section of the rural community from *Pani Samiti* and *Gram Panchayat* members to women, teachers, school children, *anganwadi* workers etc. In fact it is a continuous part of the project cycle. The *Pani Samiti* in particular is trained on aspects of development of a Village Action Plan, record keeping, construction management and supervision, financial management and book keeping, different techno-economic options, O&M of the system etc. WASMO has generated a wealth of materials for IEC and manuals for training which are meticulously disseminated and used for making the community capable to take on the job as managers of their resources.

c. Facilitating a true-bottom up approach – Adopting new procedures and systems: The functional autonomy provided to WASMO has made it possible to have a flexible approach and develop its own rules and regulations for institutional development of WASMO itself and for facilitating the community level work. It has had the freedom to select suitable personnel and, NGOs as partners as well as adopt several path-breaking measures at the village level such as:

- Reducing the levels of hierarchy and giving the community the direct control over the finances

- A clear time bound project cycle for implementation
- A mandatory time assigned in the project cycle for software activities of mobilising the community so that all sections of the village are included, developing a Village Action Plan in a participatory manner and generating consensus on the project
- Complete O & M responsibility with the community.
- Social audit of the *Pani Samitis* decisions and the handling of the work through *Gram Sabhas* at regular intervals

d. Partnership with NGOs: A strategic partnership has been developed with reputed NGOs and they are involved in the demand driven approach as Implementation Support Agencies (ISAs). The NGOs provide the crucial linkage between the government or programme developers and the people who actually execute the programme. The ISAs with their core competency in a direct contact with the community, especially play a very critical role in the initial phase of the project during which the community is mobilised for collective action and planning for sustainable systems is done. WASMO's partnership with the NGOs and the community (through the *Pani Samiti*) is based on mutual dignity and trust and with appreciation for the strengths and weaknesses of each partner.

e. Adopting a holistic approach at the village level: Even in the community managed programmes at the village level, a comprehensive strategy is being adopted while planning the water supply systems, which includes:

- Creation of alternate, even multiple sources, for better quantity and improved quality of water either seasonally or perennially
- Collection and storage of rainwater within accessible distance of its place of use
- Rainwater harvesting using various innovative techniques for recharging existing sources
- Technical innovations for ensuring year-round water security and improvement in water quality

– Dual water supply, such as the usage of potable water for drinking purposes and inferior quality water for other domestic uses

Protecting life saving natural resources

Godhra village of Mandvi taluka is situated in the coastal belt where salinity in ground water is inherent. Through the community managed water supply and sanitation programme in earthquake affected villages a percolation tank with 250 ha catchment area was constructed. The tank is protected with fencing to restrict entry of cattle and water is used only for drinking purposes. The water is filtered and pumped to village distribution system. Additionally, through a social forestry project plantation of 7 lakh saplings has been taken. The tank has helped in dilution of salinity in water sources in the vicinity. The village is self-reliant for their drinking water and have had assured and safe water availability even in three consecutive drought years.

4. Household tap connectivity - A dream come true

It is well known that tap connections at home can have a great impact on the household hygiene, family health, and school and workforce participation. Another important impact is that on the health of women and girls who are responsible for fetching the water, by reducing their drudgery and the impact of freeing time from water transport duties on leisure, labor supply and educational attainment. To that extent a woman's right to having access to water at the doorstep has been recognized by the State. Similarly round the clock supply can greatly impact the quality of life. Household connections and 24x7 supply at the user level are therefore being aimed at, wherever they are technically and economically feasible. With increased accessibility of drinking water through grid, augmented supply from local water sources, and community-managed water supply system in the villages, it is aimed to cover 75% of the household with tap connectivity by 2010.

5. Technology innovations

a. Installation of reverse osmosis plants in quality affected villages: In spite of the State's effort, to establish a grid of pipelines to reach safe and treated surface water to the villages, it cannot be ensured that the villages switch to the safe pipeline water, due to several reasons like increasing demand, spread of the village (many families live on their farms and access water from their wells/ bores). The fishery community and *agarias* also have temporary camps near sea coast and access to drinking water becomes a problem for such groups. Thus it is difficult to guarantee alternate supply of piped water to each household of the village. In such situations, where local sources do not yield quality water, the strategy of the State is to try out technology options.

In villages where quality of local sources is unsafe and access to potable water for all inhabitants is not possible, a Reverse Osmosis plant is an option which is being tried, so as to ensure availability of safe water. The chemical constituents that make water non-potable are Total Dissolved Solids, Chlorides, Salinity, Fluoride, Nitrate and also bacterial parameters. Establishing an RO plant will bring down the concentration of un-desirable chemical constituents to an acceptable level as well remove the bacteriological impurities. Presently villages with TDS of 2000 and more are being considered for this option with the treated water meeting the demand of drinking and cooking purposes only.

Over the last decade RO technology has improved tremendously and plants of very small to very high capacity are available, which are capable of treating different quality parameters of water. Various models for establishment and O&M of the RO plants are being considered and at present about 150 RO plants have been installed in the State, about 105 through the State initiative and the others through private vendors on a BOOT basis.

b. Use of solar technology: Solar pumps have several advantages over diesel pumps such as, no dependence on electricity, easy to install, reliable, long life, low maintenance, simple repair, no fuel needed, no harmful emissions, environment friendly. By effectively harnessing the power of the sun and using solar water pumps, not only can renewable energy be used to meet the demands of the community, but costs can also be reduced. Being a renewable energy source it offers a sustainable solution.

In the hilly eastern belt of Gujarat, which mainly accounts for the State's tribal population, open wells are one of the important sources of water. But the many of the habitations are very remote making the task of electrification very challenging and capital intensive. Even if electrification is done, the subsequent maintenance of the facilities is very difficult. As a result, accessing water from the local wells and bore wells through appropriate pumping machinery is not feasible. This technology also holds immense potential for application in the district of Kutch where temperatures are soaring and monsoon duration very short.

The option of solar pumps for drawing water from wells is being experimented in such areas by the state. With the help of solar pumps 35,000 – 1,35,000 litres of water can be pumped from heads of 10-50 metres. The solar pumps have been installed after thorough ground research and surveys to study the feasibility of this application. The cost benefit ratio of this technology shows that the O&M cost is much lower than that of systems operating on electricity or diesel pumps.

c. Rooftop rain water harvesting structures (RRWHS): Harvesting rooftop rain water is a method of direct collection of rainwater and storing it in tanks or using it for recharging ground water. It is an efficient technique to take the benefit of high intensity and short duration rains characteristic to hilly and dry areas like tribal pockets of the State, Kutch and parts of Surendranagar located near the Little Rann of Kutch. In coastal areas with water quality problems they also offer an option for harvesting safe and potable water and ensuring water security. The status of the RRWHS works taken up in the State is given in table 2.

Table 2: Status of RRWHS in Gujarat

Area	Total allotted	Completed	Under progress
Tribal areas	7194	2398	1409
Coastal areas	12208	7898	2308
Earthquake Rehabilitation and Reconstruction programme (ERR)	4706	4165	218
Total	**24108**	**14461**	**3935**
RRWHS in Schools in ERR	1153	1057	10

6. Combating the water quality problem

Gujarat is among the three states that experience the most serious problems of water quality. High levels of fluoride, nitrates and salinity are largely responsible for making the ground water unfit for drinking. According to the Bureau of Indian Standards (BIS), the permissible limits for nitrates, fluorides and TDS in drinking water where alternate sources are absent are 100 mg/ L for nitrates, 1.5 mg/L for fluorides, and 2000 mg/L for TDS. However, in pockets of rural Gujarat the extent of contamination has been found in the ranges of 101.89 to 648 mg/L, 1.51 to 11.60 mg/L and 2008 to 24,150 mg/L, respectively.

Excessive contaminants in drinking water take their toll on the body and lead to diseases such as fluorosis, high blood pressure, and kidney stones. The chronic manifestations of excessive fluoride and salinity that brings infirmity at early age especially in women, are often brushed aside as routine aging problems and are seldom attributed to drinking water.

Water quality monitoring and surveillance programme

The National Rural Drinking Water Quality Monitoring and Surveillance Programme (NRDWQM&SP) was launched in Gujarat in March 2006. WASMO is the nodal agency for implementing the programme, while Gujarat Jalseva Training Institute (GJTI) was identified as the State level Referral Institute (SRI).

Programme objectives

- Monitoring and surveillance of all drinking water sources in the State by the community.
- Decentralization of water quality monitoring and surveillance of all rural drinking water sources in the State.
- Institutionalization of community participation and involvement of PRIs for water quality monitoring and surveillance
- Generation of awareness among the rural masses about the water quality issues and the problems related to water borne diseases.
- Building capacity of *Panchayats* to own the field test kits and take up full O&M responsibility for water quality monitoring of all drinking water sources in their respective PRI area.

Information, education and communication

The IEC activities are aimed at making the community aware about safe drinking water, need for maintaining cleanliness of sources and personal hygiene practices, informing them about various contaminants in drinking water and different methods of chlorination and promoting community-based water quality surveillance. A variety of media are put to use and IEC involves door to door contact of villagers and convening mass awareness through *Gram Sabhas*, campaigns and drives.

Apart from the State level IEC activities undertaken through print and audio visual media, various IEC initiatives have been taken up through district and block level functionaries. Some of these are street plays, folk media and door to door awareness campaigns, rallies and drives for chlorination, cleanliness etc. by encouraging involvement of women and school children. In local fairs also, stalls are taken up and messages of safe drinking water, hygiene and sanitation are displayed, whereas water testing is demonstrated with the help of field test kits.

Capacity building and team formation

To initiate the programme, capacity building of all State, district and block level players was done though the State level workshops and subsequent ToTs. For community managed water quality surveillance, the strategy adopted is to form a water quality team in each village. To form this team, around 5 such members from the community are being identified who are ready to shoulder the responsibility of village water testing. These may include village *anganwadi* worker, an active *Pani Samiti* member, school teacher, +7 student, village pump operator, health worker, women from SHG or any such influential person from the village.

Once the team is formed it is trained for testing samples from all village drinking water sources and water quality field testing kits are given to the villages to facilitate the surveillance activities. Under convergence of WASMO with Health department it has been decided to train ASHA workers for testing water quality parameters with the help of field test kit. The status of the programme is as follows:

Particulars	No.
Village level water quality team formation	14,216 (All *panchayats*)
Village level training	15,325 villages (76,931 participants)
	Includes *Anganwadi* worker, active PS member, pump operator, school teacher, *Gram Mitra* (Health) and others
Block level training conducted	1,283 (48,163 participants)
District level trainings conducted	299 (5,843 participants)
State level training conducted	38 (1,460 participants)
Water quality testing kits distribution	14,216
Sanitary survey conducted	26,717
No. of bacteriological testing vials distributed	11,72,500

7. Impact

The multi- pronged strategy is reaping rich dividends to the State and its people. Adopting the three shifts – from ground to surface water, due care and augmentation of local water resources and water resource management and making the sector demand driven instead of supply driven – has yielded significant results. The year-wise supply of water through tankers has reduced from 4054 villages in 2000-01 to 600 in 2003-04 and 112 villages in 2008-09. It has unburdened the State by reducing its O&M responsibilities which now largely lie with the people. Having accepted the principle of community participation, about 14,000 villages of the total 18,600 villages in the State have formed *Pani Samitis* and communities have made a contribution of Rs. 838.3 mn towards the creation of need based, sustainable water supply systems. Work at the village level has been taken up in 7980 villages, has been completed in 4299 villages and in progress in 3136 villages.

A massive pool of human resources has been developed at the grassroots which is aware about the water supply issues, capable to think creatively and managing their resources according to their needs in a sustainable manner. The willingness to pay for water supply services – whether local source based or external source based – has increased. Responsible and responsive leadership has been developed which is confident enough to take on not just management of water resources and dealing with scarcity, but other development activities too.

Annexure I

Sardar Sarovar canal based drinking water supply

Particulars	At a Glance		
	Planning	Achievement	In progress
Bulk Pipeline (kms.)	2700	1896	351
No. of villages	9633	5243	3185
No. of towns	104	89	34

Bulk Pipeline	1896 km
Pipeline	106000
ESR	6415 nos. 65.40 crore litres
Sumps	4689 nos. 110.22 crore litres
Treatment plants	149 nos. 250 crore litres per day

Coverage of habitations under various projects (grid)

Project	Villages/ Habitations planned	Villages/ habitations with water supply commissioned	Villages/ habitations with work in progress
Sardar Sarovar Canal based drinking water supply project	10219	6041	2748
Regional Rural water supply schemes	4876	4460	416
Total	**15095**	**10501**	**3164**