QUALITY OF WATER RESOURCES IN INDIA

by K. V. PALIWAL, *Senior Irrigationist, Water Technology Centre, Indian Agricultural Research Institute, New Delhi-110012*

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Consolidated information on the chemical composition of major water resources of India viz., rivers, canals and wells is presented. The fluorine content of waters and their possible hazards on human health are discussed. Seasonal variations in the total salt concentration of some important rivers and well waters are discussed. Emphasis has been laid for developing suitable standards of rating water quality for irrigation both with respect to the total salt concentration and proportion of individual ions. Suitable standards for minor elements in drinking waters which may be hazardous to human health may be developed.

INTRODUCTION

Water is essential for life. It is used for irrigation, drinking, industrial and other various daily necessities. If the quality of water happens to be below the standard prescribed, for drinking purposes, from time to time, with respect to its different chemical constituents, it is likely to affect human health and life span. The main factors responsible for deterioration in water quality are excess of soluble salts, disproportion of dissolved ions, industrial effluents and bacterial contamination.

Whatever may be the source of water i.e., river, canal, well and tank etc., some soluble salts of sodium, potassium, calcium, magnesium, ferrous, copper, zinc, manganese, chloride, fluoride, lithium, silicon, sulphate and phosphate etc. are dissolved therein, depending upon the nature of the source, geological surroundings and climatological conditions. This determines the quality of water as far as the salinity is concerned.

Excess of soluble salts adversely affects human health, and in case of some constituents even amount in excess of a few ppm causes serious diseases. According to the recent census of 1971, about 438 million of Indian population i.e., 80 per cent of the total, lives in villages, and they mostly depend on dug-well and nearby perennial river waters. Moreover, the well water if saline and is used for irrigation purposes, it not only adversely affects the soil properties and crop productivity, but also the quality of produce and indirectly it affects the health of the consumers.

With the industrial development in the country, the water quality is further deteriorated by industrial effluents especially near the industrial towns.

Bacterial contamination is another factor which determines the quality of water used for human consumption. Improper disposal of sewage water is responsible for breeding in various diseases like Filariasis and some virus diseases. In India, large number of deaths occur every year due to water borne diseases as cholera, typhoid, infectious hepatitis and polio etc. caused by organic contamination.

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Of the several factors affecting water quality enumerated above, attempt is made here to review the quality of important Indian water resources in relation to its total salt concentration and chemical characteristics so that problematic areas could be demarcated and a systematic research could be planned and undertaken for their remedial measures.

Water Quality

River water—The water quality of Indian rivers viz., Ganga, Gandak, Kosi, Beas and Brahmaputra is quite good both for drinking and irrigation purposes, showing electrical conductivity (EC) less than 275 micromhos/cm (Deb and Chadha 1964). However, the EC of South Indian rivers along with Yamuna is slightly more ranging from 300 to 1400 micromhos/cm. Of the ions, normally calcium, magnesium and bicarbonate form the main constituents while in more saline waters of Godavari, Krishna and Yamuna, sodium is present in quite an appreciable amount. The seasonal variation in water quality of rivers was such that it slightly improved during August and September due to monsoon rains and slightly deteriorated in summer especially in arid areas. However, the overall water quality is not so deteriorated which may create health hazard. But this does not overrule the possibility of pollution from industrial waste and bacterial contamination.

Canal water—Water quality of canals generally reflects that of the river from which it originates, until and unless it is contaminated by salts, if passing over a salt-infested area. Hence the canals originating from North Indian rivers have good quality water, but indirectly by way of seepage and increasing watertable they have been responsible for the development of saline soils. This is true to a large extent of areas in U.P., Delhi, Punjab and Chambal commanded area of Rajasthan and Punjab.

Drain waters of Godavari and Pavara are of medium salinity (Kulkarni 1961). Quality of canal waters arising from perennial rivers is quite good in Mysore while those flowing over arid areas show relatively poor quality. Recently Mehta *et al.* (1969) concluded that tank and canal waters of Rajasthan are of good quality.

Well water—In an attempt to find out quality and potentiality of water resources in the country, surveys were conducted in different states by several organizations as Geological Survey of India, Exploratory Tubewells Organisation (now Central Ground Water Board), State Dept. of Agriculture, Universities and other Research Institutions. Their statewise consolidated data are summarised here.

Rajasthan—This State by virtue of aridity and low rainfall has got very low water potential especially in the arid and semi-arid regions of the central and western Rajasthan and in some areas water potential is so low that it is insufficient for the villagers even for their daily consumptions, and several families, from generations together are engaged in transporting water from miles together on camels to meet their daily requirements. However, this situation is slowly improving now.

Moreover, unfortunately, in some areas whatever water is available, it is highly saline. Consolidated representative data on the quality of well waters of Ajmer, Bharatpur, Bhilwara, Barmer, Bikaner, Jaipur, Jalore, Jodhpur, Nagaur, Pali and Sawai Madhopur districts show (Table I) that more than 95 per cent waters have salt content above the permissible limits for human consumption, and even for

irrigation purposes, more than 30 per cent waters show electrical conductivity beyond 5,000 micromhos/cm and are unsuitable according to U.S.S.L.Classification (Richards 1954). In the whole of Rajasthan, the above districts are more affected with this problem. On further classifying the waters on district basis, the waters of the eastern region, comprising of Alwar, Bharatpur, Sawai Madhopur, Bundi and Kota districts getting relatively more rainfall (700 mm) than the west (150-200 mm) are less saline. However, there are wide variations in the nature and amount of salt content from well to well and village to village, even in the same district.

TABLE I

*Frequency distribution of well water quality of some districts of Rajasthan**
(Expressed as per cent in each class)

District	No. of Sample	0–250	251–750	751–2250	2251–6750	Above 6750
		micromhos/cm				
Ajmer	19	–	10.5	42.3	15.7	31.5
Barmer	389	0.3	5.5	23.9	38.5	31.8
Bharatpur	280	–	12.5	46.4	27.2	13.9
Bhilwara	216	1.4	1.4	18.5	44.5	34.2
Bikaner	286	0	1.6	24.5	35.4	38.5
Udaipur	161	0	5.0	18.0	55.9	21.1
Jaisalmer	339	0.6	9.7	31.5	34.9	23.3
Jodhpur	314	0.5	5.3	34.2	36.7	23.3
Nagaur	74	–	–	1.4	32.4	66.2
Pali	34	–	–	5.8	50.0	44.2
Sawai Madhopur	545	–	18.3	52.3	20.9	8.5

*Paliwal (1969)

Regarding the chemical composition these highly saline well waters are mostly dominated by sodium and chloride ions but those of moderate salinity i.e., (EC=2 to 3 mmhos/cm) are predominant with calcium, magnesium and bicarbonate ions (Table II). Generally waters rich in bicarbonate content are of low electrical conductivity and a negative correlation was observed between EC and bicarbonate ion content (Paliwal and Gandhi 1969). Another specific characteristics of these waters is that out of 4162 well waters, 73 per cent have more magnesium than calcium and Mg/Ca ratio ranges from 1 to 16 and even more, but most of the samples fall in the range of 1 to 4. On classifying them on Mg/Ca ratio basis, samples falling upto the range of 1, 2, 4, 6, 8 and above are 27.0, 33.3, 21.3, 6.5, 4.2 and 7.7 per cent respectively of the total. Such waters may have their specific effect on physiological system of human health as it does so on plant growth. In general, these waters can be classified as Na-Mg-Ca and Cl-SO_4-HCO_3 type.

A very systematic study on the quantity and quality of well waters of western regions comprising of the districts of Bikaner, Barmer, Jaisalmer and Jodhpur has been undertaken by the Defence Science Organisation Laboratory, Jodhpur in

TABLE II

Consolidated data on average chemical composition of well waters of some districts of Rajasthan

District	No. of samples	pH	EC micromhos/cm.	Na^+	K^+	Ca^{++}	Mg^{++} meq/l	Cl^-	$SO_4^=$	$CO_3^=$	HCO_3^-
Ajmer	19	8.7	5500	37.7	0.28	4.86	5.50	10.20	24.76	0.80	9.70
Barmer	389	7.9	5180	38.80	1.60	4.73	7.13	38.30	6.18	—	6.40
Bharatpur	276	8.3	3090	20.20	—	3.70	8.70	16.501	8.2	0.5	8.401
Bhilwara	216	8.1	6040	42.20	0.88	5.10	5.60	44.90	12.10	0.3	8.801
Bikaner	249	7.78	6250	45.50	0.98	8.101	9.20	46.201	12.20	—	6.901
Jaipur	161	8.3	2986	35.12	0.32	3.61	11.40	29.74	11.10	3.74	8.34
Jaisalmer	339	7.23	4748	32.21	1.00	5.50	7.23	29.77	6.67	—	6.23
Jalore	50	7.78	8270	65.85	0.99	7.52	8.96	60.70	14.22	—	7.03
Jodhpur	314	7.7	6800	50.55	1.45	6.71	7.67	45.70	17.20	0.261	6.55
Kota and Bundi	100	7.8	2120	11.10	—	6.60	4.20	4.001	7.501	—	9.30
Nagaur	74	7.9	9100	71.80	0.37	4.36	10.5	51.80	16.80	3.40	7.80
Pali	178	8.0	7432	59.90	0.45	6.65	8.03	45.93	20.69	0.73	8.55

Paliwal (1969)

relation to the amount and nature of the salt present, hardness, microbiological contamination and water potentiality (Chaudhary *et al.* 1966). According to the health standards of U.S.A. only 4 per cent groundwaters of Barmer, 21 per cent from Jaiselmer, 10 per cent from Jodhpur and 1.2 per cent from Bikaner districts are potable (Bhargawa *et al.*, 1967). But villages in these areas are using these so-called unpotable waters without any visible harmful effect. Hence the potable limits of U.S.A. are not applicable. And the cattles were found to tolerate salts from 6000 to 12000 ppm in drinking water. Bacterial contamination was not a problem in these deep waters.

Uttar Pradesh—This state is very rich in its water resources and fifty per cent of the irrigated area is covered by wells and tube-wells. Most of the well waters are of low to medium salinity (Table III) with predominance of calium, magnesium, and bicarbonate ions (Mehrotra 1969). Well water of North and Hilly regions is quite good. However, waters of Mathura, Agra and Unnao districts are quite saline with predominance of sodium and chloride, and sometimes sulphate ions (Mehrotra 1969; and Tripathi *et al.* 1969).

TABLE III

Mean chemical composition of well waters of some districts of U.P.

District	No. of samples	pH	EC micromhos/cm.	SAR
Nainital	8	8.3	420	0.99
Moradabad	59	7.9	460	1.19
Rampur	14	7.3	580	0.82
Badaun	20	8.1	450	1.24
Aligarh	53	7.9	970	3.28
Bulandshahar	17	8.2	660	2.04
Etah	50	8.1	912	3.7
Lucknow	85	7.6	860	4.41
Raibareley	12	7.7	1110	1.81
Barabanki	8	7.3	59	0.48
Fatehpur	35	7.6	1350	1.57
Kanpur	29	8.6	1470	8.66
Farrukhabad	108	8.1	1600	4.15
Varanasi	44	7.6	920	1.98
Jhansi	47	8.5	860	2.12
Hamirpur	26	8.7	2060	2.75
Banda	18	8.5	2140	7.21
Mathura	51	7.7	3100	7.10
Unnao	63	7.9	2213	6.84

Consolidated from the data of Mehrotra (1969) and Gupta and Prasad (1967).

Punjab—In this state about 31 per cent of the total irrigated area is covered by wells. According to Bhumbla (1969) salinity of well waters decreases as the rainfall increases and on average basis, waters of Ferozepur and Bhatinda districts are most saline (2000 to 2500 micromhos/cm), and of Kapurthala, Jullundhur,

TABLE IV

Average chemical composition of well waters of some districts of Punjab

District	No. of samples	E.C. (micro-mhos/cm)	SAR	Na^+	$(Ca^{++}+Mg^{++})$ meq/l	Cl^-	HCO^-_3	SO^-_4
Ferozepur	1702	2062	8.7	14.8	5.8	5.8	8.5	5.8
Bhatinda	1151	2668	9.1	18.5	8.2	10.7	10.2	5.0
Kapurthala	45	899	2.4	5.3	3.7	2.2	5.6	1.2
Sangrur	400	1521	8.1	11.7	3.5	13.8	11.2	10.6
Amritsar	533	1014	4.6	6.4	3.8	1.7	8.5	0.5
Patiala	76	1006	3.1	5.1	5.1	2.2	6.0	1.1
Jullundur	143	768	1.7	3.1	4.6	2.5	6.6	1.7
Ropar	31	770	1.7	2.7	5.0	1.1	6.7	0.1
Ludhiana	642	810	2.0	3.2	4.9	1.4	6.9	0.1
Hoshiarpur	91	856	3.3	4.9	3.7	1.9	6.6	0.1
Gurdaspur	66	794	2.4	3.5	4.4	2.5	5.5	0.1

Bhumbla (1969).

TABLE V

Frequency distribution of well water quality in different classes of electrical conductivity (expressed as per cent)

District	0–250	251–750	751–2250	2251–5000	Above 5000
			(micromhos/cm)		
Amritsar (2672)	–	48.9	48.9	2.2	–
Kapurthala (565)	–	89.7	10.3	–	–

Uppal (1964). No. of samples in brackets.

Ropar, Hoshiarpur, Ludhiana and Gurdaspur are of low value in the range of 700 to 900 micromhos/cm and the rest in the intermediate range (Table IV).

The frequency distribution data (Table V) on well waters with respect to EC show that most of the waters of Kapurthala district are of low salinity (250–750 micromhos/cm) while those of Amritsar are of low as well as medium (751 to 2250 micromhos/cm) salinity levels.

In general, the north-western part of Punjab has good water while that of south-east is quite brackish.

Haryana—Wells form an important source of water in this state (Table VI), but in most of the part of the state the well waters are quite saline (Uppal and Khanna 1966; Bhumbla 1969).

TABLE VI

Frequency distribution of well waters with respect to E.C. of some districts of Haryana Tehsilwise

(expressed as per cent of the total)

E.C. classes* (micromhos/cm)	Rewari Gurgaon District	Jhajjar Rohtak District	Bhiwani Hissar District	Mohendra-garh	Narnaul Mohendragrah District	Dadri
250	Nil	Nil	Nil	Nil	Nil	Nil
251–750	6.0	Nil	Nil	6.4	4.7	5.6
751–2250	35.3	38.9	31.0	50.3	54.6	31.9
225–5000	28.0	30.3	48.3	28.8	30.0	33.2
Above–5000	30.7	30.8	20.7	14.5	10.7	29.3

*Uppal and Khanna (1966)

TABLE VII

*Frequency distribution of well waters of Delhi State with respect to E.C.**

(Expressed as per cent of 153 total samples)

Range	0–250	250–750	751–2250 micromhos/cm	2250–6750	Above 6750
Percentage	Nil	4.6	37.9	37.2	20.3

*Consolidated by the author from Chemistry Division, IARI New Delhi.

TABLE VIII

*Average chemical composition of well waters of Delhi**

pH	EC micromhos/cm	Na^+	K^+	Ca^{++}	Mg^{++} meq/l	Cl^-	$SO_4^=$	$CO_3^=$	HCO_3^-
7.7	3.64	22.5	0.9	5.4	9.8	19.8	7.5	0.9	7.7

*Consolidated by the author from Chemistry Division IARI, New Delhi.

Delhi—Frequency data on well water quality with respect to EC show (Table VII) that most of these waters are highly saline showing Na-Mg-Ca and Cl-HCO_3-SO_4 type (Table VIII). Here the water quality is highly influenced by high underground water table as a result of seepage from canals and poor drainage conditions.

Mysore—The water quality of this state is influenced more by the soil type and climatological conditions. Well waters of Bellari, Raichur, Colar Gulberga, Bijapur Chitradurga and Bidar are more saline than those areas having heavy rainfall. Seventy per cent water of Bangalore District are of medium to high salinity

(Puttuswamy Gowda *et al.* 1968). Well and stream waters of Tunghbhadra water shed in Hadagalli Taluk of Bellari district are of medium to high salinity (Landey and Murty 1967). Recently Dharanendran and Nagaraja (1969) taking representative samples from the districts of Bangalore, Belgaum, Bellari, Chickmagalur, Dharwar, Kolar and Tumkur districts with a total of 107 concluded that most of the waters are of good quality both for domestic and agricultural purposes.

Gujarat—In this state 76 per cent of cultivated area is irrigated with well, and water quality is more influenced by the aridity and salinity of the area. Waters of northern and eastern regions of Mehsana, Kaira and Baroda districts are of quite a good quality while those of western regions are saline. Most of the waters of Rann of Kutch are of high salinity, and sodium chloride is the main constituent. In Saurashtra region tube well waters are highly saline due to marine nature of formation (Raghav Rao *et al.* 1967). Analysis of 607 tube well waters from the districts of Banaskantha, Mehsana, Sabarkantha, Ahmedabad, Baroda, Kaira, Broach and Kutch shows (Table IX) that 70 per cent of samples have moderate salinity and 60 per cent show residual sodium carbonate. Acquifers between 100′ and 400′ are less than the deep acquifers (Talati 1969). Tanwar (1971) discussed major trends of salinity and zoning of groundwaters in North Gujarat and concluded that quality of nearly subsurface waters changes abruptly in the Central Banaskantha and North-Eastern and eastern Mehsana and the salinity in the deep confined ground waters progressively increases at different rates towards the boundary of the Rann of Kutch.

Tamilnadu—Waters of poor quality have been found in the districts of North and South Arcot, Chengelput, Tirunelveli, Coimbatore, Salem, Dharamapuri and Madurai (Ahmed *et al.* 1967).

In the rest of the States of the country, water quality is not of alarming nature except in some localised conditions.

Toxicity of Fluorine

Fluorine is essential in very small amount for animals and men, but it becomes toxic beyond certain limits. The maximum permissible limit of fluorine in drinking water is 1 to 1.5 ppm, and all waters containing fluorine above it, are considered as unsuitable for drinking purposes and are likely to develop physiological disorders in the body. Symptoms of dental fluorises and sketal diseases have been observed in Bhatinda district of Punjab (Singh *et al.* 1962) and Kurnool district of Andhra Pradesh (Ramamohan Rao & Bhaskaran 1964). Inspite of the magnitude and severity of the problem, not much systematic work appears to have been done on the fluoride content of well waters except a few here and there.

Kanwar and Mehta (1968) reported toxic concentration of fluorine in well waters of Hissar (Haryana) and Sangrur (Punjab) districts. It ranges from 0.11 to 13.64 ppm and in most of the samples fluorine was found more than the permissible limits. A systematic survey of well waters of Bhilwara, Nagaur and Jaipur districts (Paliwal *et al.* 1969; Somani *et al.* 1971) shows that in all the waters examined fluorine content was found quite toxic and need immediate attention (Table X). Several cases of enamel mottling and bone deformations have been observed in these areas.

TABLE IX

Mean chemical composition of tube-well waters of Northern Gujarat

Saliniry classes EC micromhos/ cm	No. of samples	pH	EC microm mmhos/cm.	Cations				Anions				Residual sodium carbonate meq/l
				SAR	Na^+	Ca^{++}	Mg^{++}	Cl^-	$SO_4^=$	CO_3	HCO_3^-	
						meq/l			meq/l			
Samples without RSC (231)												
<1000	36	7.8	6 49	1.4	2.3	3.5	2.0	3.2	0.8	3.6	0.4	Nil
1000—2000	133	7.6	1298	3.1	6.2	4.9	3.5	6.1	1.8	5.4	0.6	,,
2000—4000	34	8 0	2764	7 6	19 2	7.0	5.3	18.0	5.4	6.8	0.6	,,
4000—6000	20	7.3	4525	12.9	35.2	7.1	9.5	37.9	7.6	4.6	1.5	,,
Above 6000	8	7.9	9635	23.4	74.3	7.9	15.2	74.5	12.3	4.4	4.8	,,
Samples with RSC (376)												
<1000	28	8.0	661	2.4	3.3	2.2	1.9	1.6	0.7	3.7	1.6	0.7
1000—2000	277	7.7	1451	4.8	9.5	2.8	2.4	5.4	1.5	4.8	3.2	2.6
2000—4000	57	7.9	2658	12.0	21.2	3.2	3.7	14.8	3.0	5.1	4.9	3.2
4000—6000	3	8.2	4933	22.6	38.2	1.9	7.2	26.4	7.7	3.2	9.6	3.8
Above 6000	11	8.4	7644	35.7	74.7	2.9	5.8	57.0	9.1	3.0	13.8	8.3

Total Samples 607

Talati (1969).

TABLE X

Fluorine content of well waters of some districts of Rajasthan

Districts	No. of samples	Min. ppm	Max. ppm	Mean ppm
Bhilwara[1]	118	2.10	24.01	6.01
Nagaur[2]	74	1.48	13.32	5.46
Jaipur[2]	92	4.44	23.09	12.18

1. Paliwal *et al.* (1969); 2. Somani *et al.* (1971).

Keeping in view the severity of the problem, Geological Surveys of India conducted a systematic survey of entire Rajasthan and Gujarat. Fluorine content above 8 ppm was observed in the groundwaters of South-western portion of Ganganagar, North-western and eastern part of Jodhpur, eastern part of Nagaur and northern part of Sirohi districts in Rajasthan and South-eastern part of Kutch district of Gujarat (Nautiyal and Pathak, 1971).

The above comprehensive review gives a clear picture of water quality of the entire water resources of the country. It draws the attention to the fact that there is need to set suitable standards of rating water quality both for irrigation and drinking purposes with respect to total salt concentration, proportion of individual ions alongwith fluorine and any other such minor element found in water.

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