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CHARACTERIZATION OF WATERS

Part II. Chemical Composition of Hub Dam Water and its Variations

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Continuous monitoring of the composition of Hub dam water has been carried out for the last eight years, since 1978. Seasonal variations leading to an overall change in the composition have been described by noting the number of rainy days per year and measuring the concentration of chemical constituents viz. calcium, magnesium, sodium, potassium, chloride, sulphate, carbonate and bicarbonate. It has been found that each annual rain in August and February decreases the total salt concentration and that the later has been reduced from an initial value of approximately 1300 mg/litre in 1978 to 350 in 1985. Other factors affecting the composition and quality of dam water like leaching of building materials and quality of soil have also been identified and discussed. Its cationic composition in 1978 was that of ground water having cationic and anionic composition viz. Na > Ca > Mg > K and HCO_3 > Cl > SO_4 respectively which is unlike the Pakistani river water which have their corresponding composition Ca > Na K Mg and HCO_3 > SO_4 > Cl. The water as such can be classified as good quality raw water and may be used for industrial and agricultural purposes and human consumption after simple treatment.

Keywords: Hub dam, Chemical composition of water, Seasonal variations.

INTRODUCTION

The processes of rapid industrialization and urbanization have created problems of water scarcity in the city of Karachi for the last several years. A dam has recently been constructed on Hub river to deal partially with the situation. This 46 metre high and 6400 m wide earthen dam has been constructed by WAPDA, across Hub river, at the junction of Sovein Nala 56 km North of Karachi [1]. The dam reservoir is spread over an area of 98 Km^2 and has a gross storage capacity of 114 km^3 with a live storage capacity of 102 km^3 and a withdrawal rate of 27 km^3 per annum. The estimated life of the reservoir is about 75 years. The reservoir is filled by the annual rainfall over the catchment area comprising 8500 km^2. The average rainfall of the area is about 175 mm ranging from a minimum of 37 mm to a maximum of 550 mm.

A 100 MGD pumping station has been commissioned by Karachi Development Authority in the first phase, while in the second phase, a 100 MGD filter plant would be constructed to supply filtered water to the consumers. Raw water has been supplied to the Karachi city at an average rate of 50 MGD and the agricultural and industrial demand in Lasbella district has also been met from Hub dam since its commissioning in 1982. One of the canals drawn off the dam, irrigates 20,000 hectacre of land in Lasbella District. A spillway is under construction to ensure perennial supply of water for increased industrial and agricultural consumption in Lasbella District. Karachi city would eventually receive 89 MGD water from Hub dam for its municipal needs.

Since rainfall in this region has a 4-5 years cycle, the dam has a storage capacity to meet the requirements for four years of continued drought. The four years storage target can be achieved when the level of the lake rises to 103 metres.

The present work describes the changes in composition and quality of the Hub dam water by monitoring the concentration of chemical ingredients viz. calcium, magnesium, sodium potassium, chloride, sulphate, carbonate and bicarbonate ions regularly since 1978.

EXPERIMENTAL

Sampling and methodology. The first water sample from the dam reservoir was collected in the month of April 1978; and regularly onwards upto December, 1985. From 1978 to 1979 the frequency of sample collection was three to four samples per month, but from 1980 to 1985, it was reduced to two samples per month. The samples were collected in polyethylene 5 litre screw cap containers, which were cleaned sequentially with detergent wash, tap water rinse, 24 hour soak in 1% HNO_3 and several distilled water rinses [2]. The containers were then dried at 100°

for 1 hour, cooled to room temperature, capped and labelled. Each container was filled to the brim with the water sample to avoid any space. The samples were transported to the laboratory as soon as they were collected and were refrigerated at 4^{o} immediatley, and analysed by standard methods [3,4].

Grab water samples were also collected from the wells/ tube wells located at or near the Hub river and analysed. Locations of the wells are listed in Table 12.

Samples of top soil from the beds of Hub and Malir rivers were collected and analysed by standard methods [4,5]. Physical and chemical characteristics of the soil samples are listed in Table 11.

RESULTS AND DISCUSSION

Variation in chemical composition of Hub dam water during the 1978 to 1985 period is listed in Table 1-8. Table 1 shows the monthly average ionic concentration of chloride, sulphate, bicarbonate, sodium, potassium, calcium and magnesium of the water samples collected from April to December 1978. Table 2-8 list the monthly average ionic concentrations from January 1979 to December 1985.

It would be noted from Table 1 that there is no significant change in the overall composition of the dam water during the year 1978 except slight temporary dilution after the monsoon rains. A decrease in chloride, sulphate, sodium and magnesium content during the months of July and August may be attributed to dilution due to heavy rains spread over 13 rainy days, the longest during the period under observation as shown in Table 10. Total dissolved solids decreased during the rainy months and their minimum content 824 mg/litre, was noted in the month of July 1978, which increased subsequently. The maximum concentration of total dissolved solids and of other constituents was observed in the month of June, which was hottest month of the year. It would appear that total salts content started rising soon after July which was the first year of live storage and withdrawal of water had just started. There was a combined action of leaching of dam soil and of the sediment brought along by flood water responsible for the rise in ionic concentration.

Table 1. Monthly mean composition of Hub water - 1978 (mg/litre)

	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Chloride	410	453	478	245	283	291	310	333	396
Sulphate	358	371	389	212	285	337	346	387	313
Bicarbonate	128	134	128	136	138	129	186	212	195
Sodium	270	323	340	194	212	241	265	270	320
Potassium	7.5	8	8	6.5	7	8	8	9	7
Calcium	63	71	68	49	66	67	66	65	67
Magnesium	54	51	55	30	38	36	38	52	46
Total dissolved Solids	1232	1350	1400	824	979	1065	1168	1274	1295

Table 2. Monthly mean composition of Hub dam water - 1979 (mg/litre)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Chloride	314	300	265	297	236	267	288	176	130	141	148	149
Sulphate	332	355	300	354	267	278	292	180	158	152	155	161
Sodium	261	250	220	230	185	205	222	130	88	118	120	122
Potassium	9	8	8	9	8	7.5	8	6	5	6	6	6
Calcium	72	73	70	72	60	51	63	43	38	45	45	47
Magnesium	45	48	43	49	34	41	42	25	25	18	20	20
Bicarbonate	219	198	206	160	188	150	169	110	108	146	140	146
Total dissolved solids	1200	1182	1066	1150	925	951	1038	642	510	592	595	610

Table 3. Monthly mean composition of Hub dam water - 1980

	Jan.	Feb.	Mar.	Apr.	May	Jun:	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Chloride	139	164	178	192	196	162	212	221	223	234	199	180
Sulphate	168	185	198	194	203	206	211	196	235	238	234	245
Sodium	113	130	140	148	148	125	150	158	164	175	155	140
Potassium	5	5	5	5	5	3	5	7	6	6	5	5
Calcium	50	52	53	50	50	51	54	54	55	55	53	50
Magnesium	20	23	25	25	27	26	29	25	30	32	31	33
Bicarbonate	137	135	140	134	142	122	110	111	114	120	121	110
Total dissolved solids	590	648	690	698	725	654	725	728	779	810	755	722

Table 4. Monthly mean composition of Hub dam water - 1981

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Chloride	182	190	190	204	210	208	214	205	194	208	206	206
Sulphate	210	240	185	210	212	216	214	192	195	215	209	207
Sodium	138	140	140	156	160	160	170	161	145	160	160	160
Potassium	5	6	6	7	6	7	7	6	6	6	7	7
Calcium	51	48	53	54	54	58	51	53	58	58	54	53
Magnesium	26	33	25	26	28	27	27	25	21	27	27	26
Bicarbonate	122	136	122	122	122	122	122	134	105	120	126	106
Total dissolved solids	694	747	183	734	753	756	762	730	684	750	746	744

Table 5. Monthly mean composition of Hub dam water - 1982

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Chloride	215	222	215	224	226	234	243	225	149	154	152	139
Sulphate	228	230	232	238	249	256	216	212	175	184	178	190
Sodium	165	165	165	170	180	190	180	185	130	136	135	125
Potassium	6	6	6	6	6	6	6	6	5	5	5	6
Calcium	54	53	52	50	50	50	50	49	49	50	50	50
Magnesium	29	29	29	30	32	33	26	25	20	21	20	22
Bicarbonate	113	94	96	107	97	104	110	104	98	102	104	122
Total dissolved solids	765	755	750	779	792	823	794	760	586	611	602	612

Table 6. Monthly mean composition of Hub dam water - 1983 (mg/litre)

	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul	Aug.	Sep.	Oct.	Nov.	Dec.
Chloride	141	144	158	163	159	166	133	50	80	78	83	90
Sulphate	184	186	155	169	165	171	140	69	86	84	88	88
Sodium	122	124	125	130	125	130	110	45	57	65	65	74

(Continued.....)

(Table 6, continue)

Potassium	6	6	5	4	4	5	5	4	4	4	4	4
Calcium	52	53	56	51	49	48	43	34	38	39	40	42
Magnesium	20	21	22	23	22	21	19	7	10	12	12	13
Bicarbonate	110	122	128	122	110	100	98	97	115	103	115	115
Total dissolved solids	595	610	605	618	594	600	513	276	355	352	376	394

Table 7. Monthly mean composition of Hub dam water - 1984 (mg/litre)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Chloride	97	98	98	100	104	102	99	46	57	64	64	63
Sulphate	91	93	94	92	94	95	100	48	60	68	64	82
Sodium	70	70	71	72	75	73	71	30	40	50	46	46
Potassium	4	4	4	4	5	5	5	3	4	4	4	3.5
Calcium	46	47	46	44	45	45	44	30	32	36	34	40
Magnesium	13	13	14	13	14	14	14	6	8	10	9	11
Bicarbonate	114	116	116	110	116	116	116	85	90	116	110	10
Total dissolved solids	401	404	408	400	413	410	408	210	250	310	302	325

Table 8. Monthly mean composition of Hub dam water - 1985 (mg/litre)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Chloride	64	64	66	74	64	79	82	78	76	76	80	83
Sulphate	86	85	86	89	84	89	90	88	88	96	92	95
Sodium	46	46	48	50	57	55	58	54	56	55	56	58
Potassium	3.5	4	3.5	3.5	3.5	4	4.5	4	4	4	4	4
Calcium	40	40	39	40	36	38	37	38	37	37	36	35
Magnesium	11	11	10	11	12	11	11	11	10	12	12	13
Bicarbonate	110	110	105	98	97	110	98	88	86	98	90	85
Total dissolved solids	339	330	328	326	334	356	355	334	332	338	336	340

Decrease in the various constituents noted from Table 2 showing analysis of samples collected during 1979. The overall composition of water markedly changed during this year, and the concentration of almost all the constituents was reduced to half of 1978. Total dissolved solids found to be 1200 mg/lit. in January 1979, and slowly decreased to 610 mg/lit in December. The concentration of other constituents reduced correspondingly. The minimum total dissolved solids were (510 mg/lit) in the month of September.

Table 10 shows two rainy periods in February and August and the concentration of salt recorded decreased each time Table 2. Leaching of soil and sediment brought in by flood is a continuous process and raises the concentration of salts during subsequent months. After the August rains the water seems to have sufficiently diluted and to be stabilized to half the concentration of that observed in the earlier months of the same year.

Table 3 shows the variations in the chemical constituents of the Hub dam water during the year 1980. It would be noted that unlike the preceding years, the concentrations of various constituents recorded an increase though slight from the month of January to December of 1980. All constituents excepting potassium, calcium, and bicarbonate showed an increase in the earlier months particularly upto May whereafter there was rain during two rainy days and in June a slight dilution is noticeable. Maximum concentration of salts was observed during October which

decreased again due to precipitation in November and December.

Analytical results for the samples collected during 1981 listed in Table 4, show significant changes in the amount of total dissolved solids, as well as of calcium, magnesium, potassium, bicarbonate and sulphate, from January to December. The only significant increase would be noted in the contents of sodium from 138 to 160 mg/lit. and chloride from 182 to 206 mg/lit. The rains in the months of March and September (Table 10) slightly diluted the dam water, consequently the concentration of total dissolved solids became the minimum (684 mg/lit) during these months. All in all the dam water during 1981 became slightly more concentrated than it was in 1980.

Chemical constituents of the Hub dam water samples, collected and analysed during the months of 1982 are listed in Table 5. During the first three months, there does not appear any change in the composition of water, the salts content is thereafter found to slightly increase subsequently from April to August. A sudden decrease in concentration of the constituents may be noted for the month of September which could be attributed to dilution caused by the rains in the months of July and August which together recorded five rainy days. Total dissolved salts and all anions

Table 9. Cations and anions in Hub dam water (mg/litre) (Yearly mean)

	1978	1979	1980	1981	1982	1983	1984	1985
Chloride	355	255	192	201	200	120	83	74
Sulphate	333	249	210	209	215	132	82	81
Sodium	270	179	145	154	161	98	60	52
Potassium	7.6	7.2	5	6	6	4.6	4	4
Calcium	65	57	52	54	51	45	41	38
Magnesium	44	35	25	26.5	26	17	12	11
Bicarbonate	154	162	125	123	104	111	110	98
Total dissolved solids.	1176	872	705	732	719	491	353	309

Table 10. Number of rainy days (2.5 mm and above)

No. of Rainy days 2.5 & above		No. of Rainy days 2.5 & above		No. of Rainy days 2.5 & above		No. of Rainy days 2.5 & above		No. of Rainy days 2.5 & above		No. of Rainy days 2.5 & above		No. of Rainy days 2.5 & above	
1978	1978	1979	1979	1980	1980	1981	1981	1982	1982	1983	1983	1984	1984
Airport	Maripur	Airport	Maripur	Airport	Maripur	Airport	Maripur	Airport	Maripur	Airport	Maripur	Airport	Maripur
Jan. 1	–	–	–	–	–	–	–	–	–	–	–	–	–
Feb. 1	1	1	4	–	–	1	1	2	2	–	1	–	–
Mar. –	–	–	–	–	–	2	2	–	–	–	–	–	–
Apr. –	–	–	–	–	–	1	–	–	–	3	2	–	–
May –	–	–	–	–	–	–	–	–	–	–	–	–	–
Jun. 1	–	1	–	2	2	–	–	–	–	–	–	–	–
Jul. 8	10	–	–	1	2	2	2	3	1	4	4	–	–
Aug. 5	5	5	4	–	–	–	2	2	3	6	7	–	–
Sep. –	–	–	–	–	–	–	–	–	–	2	3	–	–
Oct. –	–	1	–	1	1	–	–	–	–	–	–	–	–
Nov. 1	–	–	–	1	2	–	–	–	–	–	–	–	–
Dec. –	–	1	–	2	2	–	–	–	1	–	–	–	–

were maximum and minimum in the months of June and September respectively. The average composition of water in 1982 was comparable with the composition in 1981 upto August.

Monthly mean composition of the Hub dam water during the year 1983 listed in Table 6, indicates no significant change from the September-December 1982 composition of water for the first six months but there is considerable decrease thereafter. Decrease in the total dissolved solids content from 513 to 276 mg/lit., of the chloride from 133 to 50 mg/lit. and of sulphate from 140 to 69 mg/lit. is quite significant for the month of August. From August to December the concentration of various constituents recorded a slight but significant increase. The sudden but considerable decrease in the salt content may again be attributed to dilution due to heavy rains in the months of July, August and September 1983 which comprised a total of 14 rainy days widespread over the province of Sind [6]. The increase in salt concentration in the post-rainy period may be due to leaching of salts from the soil of the Dam and of the sediments on the one hand and evaporation on the other.

Table 7 showing the monthly mean chemical composi tion of the dam water during the year 1984, suggests a slight but significant rise in the concentration of various constituents observed for the September-November 1983 period (Table 6). For the first seven months their content is almost constant but a sharp decrease is noted thereafter due mainly to rains during the rainy days from July to September. A steady increase in composition again is a characteristic feature of the analyses recorded for the last four months of the year.

The analytical data for samples collected in 1985, listed in Table 8 indicate that the compositon of the dam water remained almost constant throughout the year excepting June and July when it rose slightly due perhaps to intensive heat and evaporation. It decreased in August due to slight rains and had almost stabilized. This is suggested by the minimum amount of total dissolved solids 326 mg/lit in April and the maximum of 356 mg/lit. in June. It may be mentioned here that 1985 did not record heavy rains and the only rainy days which occurred were in March and August when the concentration of salts was also lower than in the preceding months.

The above results indicate that starting with slightly brackish water in 1978, the salt content has lowered with each rainfall occurring every February and August. The variations, however, has not been consistent. The total salts, as it would appear from Fig. 1 first decreased in June 1978 and started increasing again. With rains in February

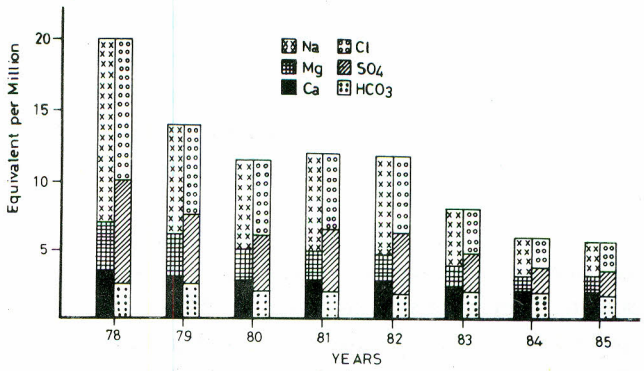

Fig. 1. Yearly composition of Hub dam water (average)

1979 it decreased slightly but in August it was about 600 ppm, almost half of 1978. With a slight but consistent increase it levelled off in 1980 and remained stable at over 725 ppm upto August 1982. With a heavy rainfall at this stage the concentration was again 600 ppm and remained stable at this level until the next rains in July and August 1983. With a level of 350 ppm in September, it started increasing to 400 ppm, only to become stable at 325 ppm after the rains in August 1984.

Table 9 shows the yearly mean concentration of the major cations and anions viz. Na^+, K^+, Ca^{++}, Mg^{++}, Cl^-, SO_4^- and HCO_3^- expressed in mg/lit. in the Hub dam water from 1978 to 1985. Values of yearly mean cations and anions were also converted into meq/lit. and plotted against time (years) as shown in Fig. 2.

It may be seen from Table 9 that sodium is the major constituent of the dissolved salts of water. It was a maximum of 340 ppm in June 1978 which decreased to 194 in July and then sharply to 130 mg/lit. in August 1979.

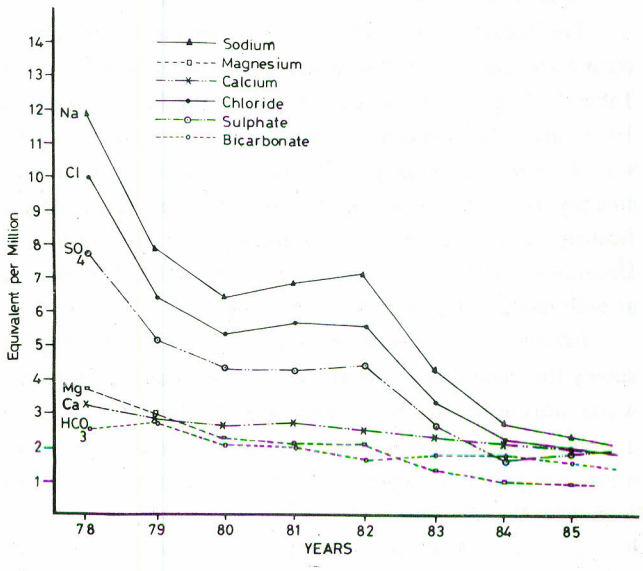

Fig. 2. Yearly ionic changes in Hub dam water.

It rose sightly and fluctuated between 140 and 180 mg/lit. from 1980 to 1982. There was again a sharp decline to 130 in September 1982 and to 45 mg/lit. in August 1983. It rose again to 74 mg/lit in December, 1983. This value remained stable upto July 1984 and after August 85 it was stable at 50 mg/lit.

The pattern of variation of the other major cations viz. calcium and magnesium may be seen to follow that of sodium. They are maximum in June 1978 and with a subsequent rise to their original level towards January, 1979 they remain levelled upto April 1979. They decrease in May 1979 and the values of 50 mg/lit. calcium, 25 mg/lit. magnesium and 6 mg/lit. potassium attained hereafter keep fluctuating at this level upto August 1982. With another rain in August 1983 they decrease further and seem to level off at calcium 35 mg/lit. mangesium 10 mg/lit. and potassium 4 mg/lit. The yearly mean variation pattern of all the major cations viz. Na^+, Ca^{++} and Mg^{++} has been illustrated in Fig. 2.

Anions content in the Hub dam water had a trend of variation similar to that of the cations on live storage of water. Chloride and sulphate concentration decreased from a maximum of 478 and 389 in June 1978 to 245 and 212 mg/lit. in July the same year. With a gradual increase to 400 and 300 respectively they came down to 290 mg/lit. each in July 1979. A sharp decrease in August marked a lowering of their level to 140 and 170 in January 1980 whereafter there was an increase to a level of 200-225 and 210-250 mg/lit. respectively upto August 1982. For another twelve months the values kept fluctuating between 150, 160, 180 and 170 respectively. During the next two cycles of 12 months the level was reduced first to 100 mg/lit. and then to 80 and 90 mg/lit. respectively.

The bicarbonate content did not change considerably during the period of this study as would be evident from Table 9. Slight increase was noted in the later months of 1978 and the maximum concentration of 219 mg/lit. was recorded in January 1979. Its concentration decreased steadily till 1982, rose slightly in 1983, decreased insignificantly and reached its minimum of 85 mg/lit. in December, 1985. The variation trend records lowering at each rainfall stage e.g. for every August.

Factors influenceing chemical composition. Fig. 1 shows the chemical composition (yearly mean) of Hub dam water during the 1978 to 1985 period. The water in 1978 contained larger quantities of chemical constituents. Its ionic composition expressed in meq-/-l terms follows the sequence $Na^+ > Mg^{++} > Ca^{++} > K^+$ and $Cl^- > SO_4^{--} > HCO_3$. This is a typical tionic composition of ground spring water noted for Karachi and its neighbourhood [7]. The sequence of ionic composition of Pakistani rivers viz. Indus, Kabul, Jehlum, Chenab, Ravi and Sutlej is $Ca^{++} > Na^+ > Mg^{++}$ and $HCO_3^{--} > SO_4^{--} > Cl^-$. The descending order of the amounts of salts in the Hub dam water in 1978 was: $NaCl > MgSO_4 > Na_2SO_4 > Na_2SO_4 > Ca(HCO_3)_2$.

Fig. 1 suggests that the dam water was more concentrated in 1978 than in the subsequent years. It contained large quantities of almost all the major cations and anions so much so that the water could be classed as ground water.

The most likely explanation for the initially high concentration of salts could be (a) leaching of top soil and building material like cement, mortar, etc. used in the construction of the dam, (b) turnover of soil during construction of the dam and its leaching during live storage and (c) presence of sedimentary rocks and minerals of marine origin, so that leaching of excessive soluble salts is possible with impounded water.

Analytical data on top soil samples, collected from the beds of Hub and Malir rivers and presented in Table 11 suggest that Hub soil is calcareous in nature, its pH ranges between 6.7 and 6.8 and organic matter between 0.05 and 0.12% and it also contains excessive quantities of aqueous soluble salts, ranging between 0.164 and 0.267% which, however, is lower than that of Malir. Hub is a perennial river, which runs through a broad alluvial plain lying in the valley between Cape Monze range and the Baluchistan Hills extending over the north-west into the Pab region.

Table 11. Analysis of top soils

Parameters	Hub river			Malir river	
	I	II	III	IV	V
pH	6.75	6.8	6.7	6.8	6.8
Moisture	0.63%	0.43%	0.55%	0.58%	0.98%
Loss on ignition	13.6%	15.3	12.4%	11.72%	12.3%
Organic matter	0.12%	0.05%	0.03%	0.15%	0.09%
Silt and clay	10.0%	5.0%	9.0%	14.75%	15.5%
Water soluble salts					
Calcium	0.027%	0.020%	0.020%	0.035%	0.019%
Magnesium	0.0015%	0.006%	0.006%	0.015%	0.007%
Sodium	0.026%	0.002%	0.002%	0.17%	0.069%
Potassium	0.0035%	0.001%	0.004%	0.007%	0.004%
Carbonate	–	–	–	–	–
Bicarbonate	0.112%	0.097%	0.085%	0.079%	0.068%
Chloride	0.046%	0.007%	0.007%	0.030%	0.119%
Sulphate	0.49%	0.031%	0.041%	0.066%	0.057%
Total soluble salts.	0.267%	0.164%	0.162%	0.67%	0.343%

Table 12. Analytical data of the well waters

Well No.	(mg/lit.)								
	pH	Na	K	Ca	Mg	Cl	HCO_3	SO_4	TDS*
1.	7.3	1087	7	224	149	1617	171	839	4128
2.	7.8	258	10	174	47	340	146	520	1554
3.	7.9	1145	14	120	117	1347	342	1045	4070
4.	7.24	1057	35	196	153	1347	349	874	5250
5.	7.36	1225	31	200	165	1489	415	756	4366
6.	7.6	775	17	228	153	1284	220	1240	3990
7.	7.75	1057	18	150	195	1241	475	975	4150
8.	7.31	1145	20	301	233	1766	256	1230	5218
9.	7.24	1112	17	457	221	2127	268	1145	5464
10.	7.16	850	75	685	215	2468	256	786	4432
11.	7.91	248	41	80	63	277	378	248	1386

* Total dissolved solids.

Hub river drains the western side of the Kirthar range and does not receive any water from the vicinity of Karachi because of the intervening Jhil hills. As such the Hub water is likely to conform to the soil of the catchment area only.

The catchment area extending over 8,500 km^2 comprises mainly sedimentary rocks which have a higher solubility in water than igneous rocks. Sedimentary rocks, it may be added, are the main source of mineral matter present in the ground water [8]. The catchment area of the river and the dam both are located in a region where sandstone, shale, limestone and conglomoerates are the main rocks while calcite and gypsum are the associated minerals.

Ground waters normally contain higher TDS levels than do river waters from the same region. The TDS in river water are usually 10 to 20 times greater than those present in precipitation of the region [9]. This is borne out from the analysis of the well/tube wells located at or near the Hub river and dam. Analytical data are presented in Table 12, while the location of wells is given in Table 13. It would be noted that out of 11 wells anlaysed, 9 have total dissolved solid levels ranging between 3990 and 5464 mg/lit. suggesting their highly brackish nature and accumulation of salt in the lower strata of the soil of the region. The analytical data listed in Table 12 suggest that the major portion of the chemical constituents of these waters originate from rocks and minerals i.e. limestone, sand, gypsum calcite etc. The higher content of sodium chloride also suggests that the sedimentary rocks of the region under reference are of marine origin and that the aqueous soluble salts from the soils, rocks and minerals have influenced the salt content in the Hub water.

Table 13

Well No.	Location
1.	Tubewell, Ata Faiz Farm, about 8 km from Hub Dam.
2.	Tubewell, Village Bun Murad, 6 km away from Dam.
3.	Well, Akram Colony near Hub Chowki.
4.	Well River Bed, near Hub Chowki Bridge.
5.	Well River Bed close to Well 5.
6.	Tubewell River Bed about 1 km from Well 5.
7.	Tubewell, near Hub Chowki.
8.	Tubewell, Poultry Farm near Hub Chowki.
9.	Tubewell, near Poultry Farm about 1 km from Well 9.
10.	Well, Haji Sheikh Mohammad Goth near Hub Chowki.
11.	Well, Farm near Haji Sheikh Mohammad Goth.

The initially high concentration of salts and fluctuations leading to an increase in total salts content may also be due to evaporation resulting from high heat, low humidity and wind speed. However, subsoil water draining from bordering lands of marine origin perhaps contributed more to the observed increase in total chemical constituents.

The composition of water started changing with storage time and it may be seen that the 1979 cationic

Table 14. Characteristics of water available in Karachi.

Parameters	Dumloti wells	Haleji lake	Kinnjher lake	Hub dam
Colour (Hazen Scale)	2 – 6	35 – 53	5 – 75	3 – 6
pH	7.9 – 8.6	7.9 – 9.1	8.0 – 9.0	7.2 – 8.0
Turbidity	1 – 5	8 – 46	3.5 – 100	2 – 6
Chloride (ppm)	146 – 320	44 – 78	26 – 60	65 – 85
Alkalinity (ppm)	100 – 162	413 – 148	88 – 116	60 – 90
Total solids (ppm)	270 – 560	196 – 340	140 – 250	325 – 365
Bacteriological (mpn)	150 – 1800/100 ml.	1800/100 ml.	250 – 1800/100 ml.	25 – 250/100 ml.

composition viz. Na^+ K $Mg^{++} > Ca^{++}$ changed over to $Na^+ > Ca^{++} > Mg^{++}$ in 1980 (Fig. 1). This could possibly be due to leaching of the marine salts by water draining calcareous soil. Since sea water has magnesium content about 5 times higher than that of calcium on a molecular equivalent basis, the magnesium level exceeded that of calcium changing the ionic composition to : $Na^{++} > Mg^{++} > Ca^{++}$. It would be noted from Table 2 that in the later months of the year 1979, magnesium content declined till it became lower than calcium in 1980 (Fig. 1).

A direct consequence of the sharp decline in the concentration of sodium, calcium and magnesium ions in the 1984 analysis has been noted in an overall change in the ionic composition of anions: $HCO_3^- > Cl^- > SO_4^{--}$. Bicarbonate exceeded chloride perhaps, on account of dilution with abundant river water. Bicarbonate constitutes more than 70% anions in Pakistani rivers followed by sulphates and chlorides: $HCO_3^- > SO_4^{--} > Cl^-$ [10].

It can be concluded from the present study that the quality of water has considerably improved after 1983 and all its major chemical constituents are now within the acceptable limits as per WHO drinking water guidelines [11]. A comparison of Hub dam water with other waters drawn from the various sources in Karachi is presented in Table 14 [12].

The composition of water in 1984 and 1985 does suggest that with the present trend of precipitation in the area, no major changes are likely to take place. However, the composition of the dam water would be affected to a great extent by rainfall, temperature, conditions of evaporation and seasonal changes in the river flow.

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