CHAPTER III

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STUDY OF PHYSICO-CHEMICAL PARAMETERS

3.1 Introduction

Water is an excellent solvent and transport medium for all body fluids of every living organism and hence a vital resource to human beings. It assists in carrying nutrients to desired organs in the body and during return journey, it carries waste products for disposal through lungs and kidney. A list of characteristics of good water would indeed be exhaustive. (Meyer, 1984). It would be a futile academic exercise to list out its dissolved constituents and their acceptability would certainly depend upon the end use, such as drinking, industrial, agricultural, institutional etc.

There is increasingly greater evidence of the progressive deterioration of the water quality not only in India but all over the world. In India, in particular, rural and urban areas present two contrast situations. In rural areas, a water body is normally used for all kinds of human requirements, such as bathing, washing, swimming, waste disposal and often for drinking too. There are many studies made on surface and ground water quality. But no attempt has yet been made in south Maharashtra to document the quality of ground water situated in rural areas on the boundary of a growing city, where large population depends on diverse sources for drinking water requirements. This scenario is very common through out the country.

The dissolved organic and inorganic chemicals in water persist over a long period in nature and have the potential of creating toxicity problems of unimagined dimensions (Cormpton, 1985). The increasing pollution in natural water has intensified detection, frequency and persistence of pathogenic micro-organisms (Barge and Pagano, 1970). Also, contaminated water may harbour several bacteria capable of causing diseases such as typhoid, dysentery, diarrhoea and cholera in human beings.

As the water seeps through the earth it is often filtered quite effectively so that at some depth there are few bacteria remaining. If this water is brought to the surface by

properly constructed well, there is little likelihood of any harmful bacteria being present. There is general belief that the ground water is cleaner and therefore safer for drinking purpose. However, that may not always be true, particularly in the present times of heavy pollution.

Water sampling and analysis form an important part of any water pollution control programme because the identification of the pollutants and pinpointing their concentrations are vital to the selection of the quality of water body. Thus considering all these facts water analysis was carried out during course of study.

Ground water samples were collected from fourteen different sites (depth roughly 50 to 200 fit) located in various parts of these four villages around Kolhapur city. Three tap water samples from KMC water supply and two from Grampanchayat water supply were collected for the sake of comparison. Attempts were made to monitor seasonal changes in their values and study correlation if any. The actual values of all physico-chemical parameters at each sampling site are given in Table-5 (Hand pumps), Table-6 (bore wells), Table-7 (Open wells), Table-8 (KMC taps) and Table-9 (Grampanchayat water supply). The overall average vales of fourteen physico-chemical parameters for the five potable water categories are given in Table-10.

Also the correlation analysis of the water quality data has been carried out and the correlation coefficient (r) between 14 physicochemical parameters have been computed. The correlation coefficient (r) for various correlations are presented in Table 11 in the form of Correlation Matrix. Except few, many correlations are found to be good to excellent.

3.2 Physico- chemical Parameters:

3.2.1 pH

pH of the solution is referred to its hydrogen ion activity. It is defined as the negative logarithm of concentration of hydrogen ion. pH is the measure of the intensity of

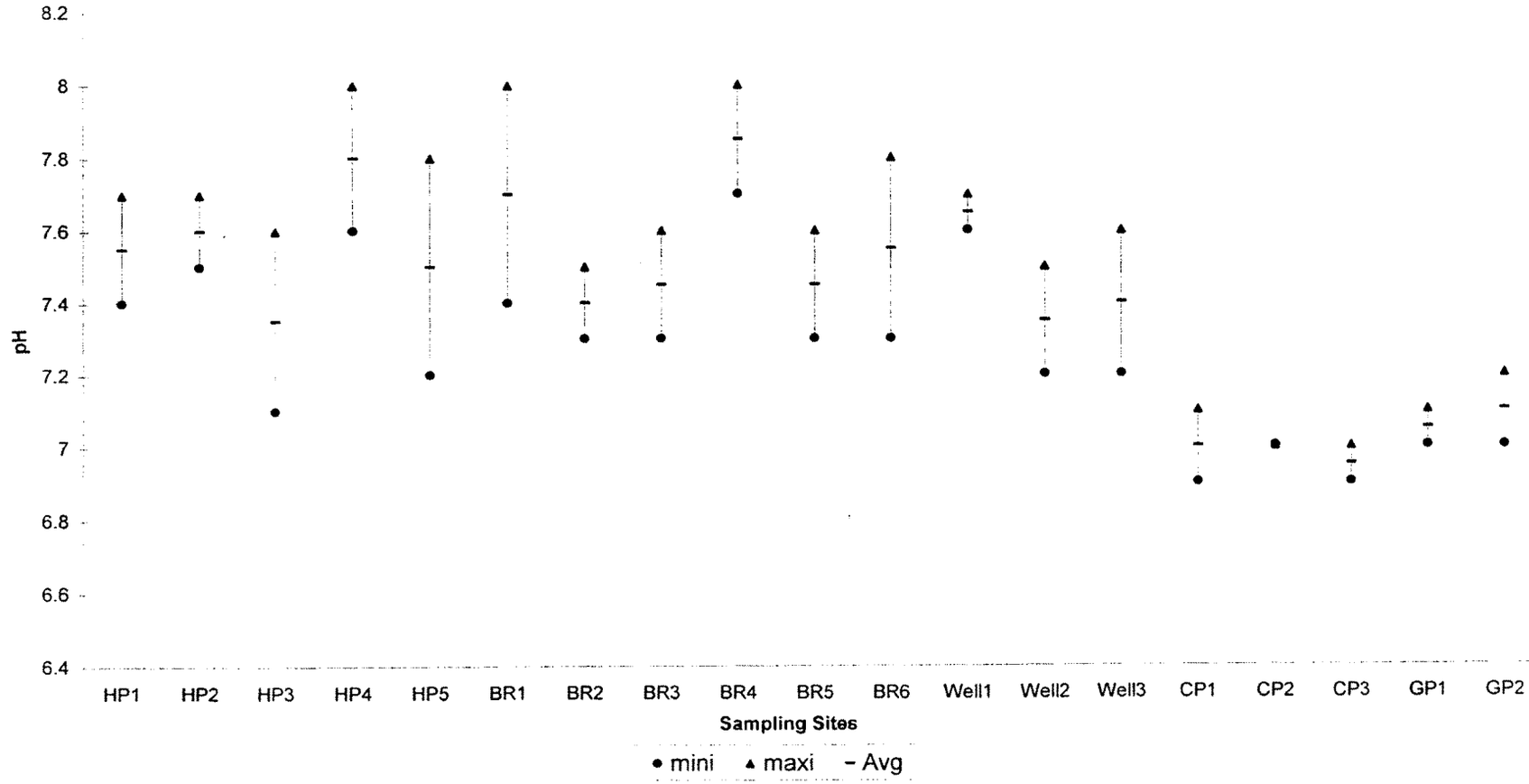


Figure 2: Minimum, maximum and average values of pH at 19 sites during three seasons.

Table 5. Seasonal values of the physico-chemical parameters from Hand Pumps in the study area.

Hand Pumps			Parameters													
Village	Site No.	Season	pH	Temp 0c	E.C. (uMhos/cm)	Turbidity (NTU)	Hardness (Mg/L)	Ca++ (Mg/L)	Mg++ (Mg/L)	CO2 (Mg/L)	D.O. (Mg/L)	T.S. (Mg/L	TDS (Mg/L)	Alkalinity (Mg/L)	Chloride (Mg/L)	Nitrate (Mg/L)
Morewadi	HP 1	Winter	7.6	26.0	539.0	28.8	264.0	71.3	46.8	35.2	3.2	820.0	320.0	320.0	53.9	4.3
		Summer	7.4	28.0	646.0	29.2	368.0	96.1	66.0	50.6	1.6	490.0	280.0	214.0	84.2	8.8
		Rainy	7.7	28.0	660.0	24.8	388.0.	96.1	70.1	44.0	4.2	980.0	740.0	430.0	72.4	10.2
Kasaba	HP 2	Winter	7.5	27.0	305.0	15.6	190.0	39.2	36.6	33.0	2.0	510.0	240.0	185.0	41.8	10.1
Bawada		Summer	7.5	28.0	427.0	28.8	236.0	61.7	42.3	48.4	2.4	370.0	290.0	210.0	38.3	14
		Rainy	7.7	29.0	465.0	28.4	176.0	44.8	31.8	17.6	1.0	830.0	280.0	200.0	41.1	15.8
	HP 3	Winter	7.3	27.0	359.0	16.0	170.0	44.0	30.5	30.8	2.0	830.0	330.0	160.0	34.08	8.6
		Summer	7.1	28.0	332.0	28.8	196.0	52.9	34.7	33.0	1.6	330.0	160.0	185.0	188.8	10.2
		Rainy	7.6	28.0	370.0	34.8	190.0	51.3	33.7	13.2	1.6	710.0	240.0	190.0	41.1	12.8
	HP 4	Winter	7.9	27.0	740.0	20.8	398.0	126.6	65.9	33.0	1.6	870.0	420.0	365.0	180.3	5.6
		Summer	7.6	28.0	997.0	32.4	502.0	155.5	84.3	33.0	1.6	330.0	160.0	185.0	188.8	10.2
		Rainy	8.0	29.0	420.0	33.6	464.0	160.0	73.8	13.2	2.4	1570.0	510.0	390.0	194.5	8.6
Nagdev-wadi	HP 5	Winter	7.8	25.0	194.0	24.4	104.0	24.8	19.2	26.4	2.4	350.0	230.0	105.0	22.7	5.8
		Summer	7.2	28.0	232.0	28.8	112.0	27.2	20.5	39.8	1.6	410.0	230.0	125.0	25.5	8.6
		Rainy	7.2	28.0	256.0	29.6	118.0	29.6	24.4	13.2	3.6	510.0	190.0	140.0	28.4	8.4

Table 6. Seasonal values of the physico-chemical parameters from Bore wells in the study area.

Bore well			Parameters													
Village	Site No.	Season	pH	Temp 0C	E.C. (uMhos/cm)	Turbidity (NTU)	Hardness (Mg/L)	Ca++ (Mg/L)	Mg++ (Mg/L)	CO2 (Mg/L)	D.O. (Mg/L)	T.S. (Mg/L)	TDS (Mg/L)	Alkalinity (Mg/L)	Chloride (Mg/L)	Nitrate (Mg/L)
Morewadi	BR 1	Winter	7.6	26.0	785.0	23.2	366.0	98.5	64.9	57.2	2.4	830	600.0	321.0	79.5	5.6
		Summer	7.4	28.0	750.0	27.6	416.0	105.0	75.5	77.0	1.6	610	310.0	270.0	112.8	8.4
		Rainy	8.0	29.0	734.0	26.0	398.0	100.2	72.3	64.2	3.7	1070	760.0	460.0	90.8	6.2
	BR 2	Winter	7.4	27.0	397.0	24.8	314.0	76.9	75.5	50.6	6.10	740.0	610.0	252.0	66.7	8.2
		Summer	7.3	29.0	659.0	28.0	384.0	91.3	71.1	70.4	5.6	560.0	520.0	212.0	86.0	15.8
		Rainy	7.5	28.0	522.0	23.6	344.0	87.3	62.3	58.1	6.1	850.0	680.0	360.0	73.8	14.0
	BR 3	Winter	7.3	26.0	400.0	23.6	272.0	103.4	40.9	26.4	5.7	680.0	560.0	212.0	72.4	5.2
		Summer	7.3	27.0	511.0	28.4	314.0	76.9	75.5	55.0	5.6	480.0	220.0	250.0	93.5	6.8
		Rainy	7.6	29.0	632.0	23.6	374.0	92.9	68.2	33.5	6.2	870.0	660.0	400.0	79.5	5.6
Nagdev-wadi	BR 4	Winter	8.0	25.0	451.0	20.8	320.0	82.5	57.6	35.2	2.8	410.0	270.0	300.0	63.9	26.2
		Summer	7.7	28.0	600.0	28.0	159.0	52.0	26.0	24.2	3.6	480.0	370.0	275.0	79.5	28.8
		Rainy	7.9	29.0	585.0	30.8	198.0	64.1	32.8	8.8	2.0	650.0	240.0	290.0	73.8	30.4
	BR 5	Winter	7.4	26.0	232.0	22.8	120.0	29.6	21.9	13.2	1.6	320.0	250.0	120.0	22.7	5.8
		Summer	7.3	28.0	264.0	28.4	108.0	26.4	19.0	19.8	1.1	280.0	170.0	145.0	26.9	8.5
		Rainy	7.6	28.0	275.0	30.0	134.0	28.8	25.5	8.8	2.4	600.0	180.0	175.0	29.8	8.2
Tamgoan	BR 6	Winter	7.5	25.0	938.0	27.2	574.0	179.5	95.8	15.4	5.2	890.0	680.0	135.0	211.5	25.8
		Summer	7.3	29.0	1122.0	28.4	950.0	244.0	171.0	48.0	5.6	1610.0	1120.0	155.0	224.3	28.4
		Rainy	7.8	28.0	1320.0	22.8	754.0	186.7	137.8	17.6	6.0	1580.0	1310.0	165.0	232.0	29.0

Table 7. Seasonal values of the physico-chemical parameters from Open wells in the study area

Open well			Parameters													
Village	Site No.	Season	pH	Temp °C	E.C. (uMhos/cm)	Turbidity (NTU)	Hardness (Mg/L)	Ca++ (Mg/L)	Mg++ (Mg/L)	CO2 (Mg/L)	D.O. (Mg/L)	T.S. (Mg/L)	TDS (Mg/L)	Alkalinity(Mg/L)	Chloride(Mg/L)	Nitrate (Mg/L)
Kasaba Bawada	Well1	Winter	7.6	28.0	308.0	24.4	242.0	49.6	46.7	26.4	3.2	650.0	300.0	285.0	44.0	4.2
		Summer	7.6	30.0	432.0	32.4	240.0	60.1	43.7	37.4	2.0	410.0	260.0	310.0	188.8	8.7
		Rainy	7.7	28.0	513.0	29.2	264.0	71.3	46.3	19.8	3.2	1040.0	300.0	320.0	56.8	9.0
Tamgoan	Well 2	Winter	7.5	23.0	717.0	26.8	398.0	125.0	66.3	19.8	2.8	620.0	450.0	135.0	249.9	5.0
		Summer	7.2	28.0	829.0	30.0	450.0	108.2	83.0	59.4	2.0	670.0	580.0	150.0	269.8	6.5
		Rainy	7.4	27.0	1241.0	22.8	650.0	173.9	115.9	13.2	7.7	1580.0	1190.0	155.0	286.8	5.8
	Well 3	Winter	7.3	24.0	771.0	27.2	144.0	52.9	22.1	4.4	6.8	680.0	530.0	120.0	245.6	26.6
		Summer	7.2	29.0	869.0	30.4	198.0	60.9	33.1	6.6	6.8	710.0	650.0	140.0	264.1	27.0
		Rainy	7.6	27.0	1406.0	22.4	272.0	103.4	40.9	6.6	4.6	1310.0	440.0	180.0	276.9	28.0

Table 8. Seasonal values of the physico-chemical parameters from KMC water supply in the study area.

KMC taps		Parameters														
Village	Site No.	Season	pH	Temp ^{0}C	E.C. (uMhos/cm)	Turbidity (NTU)	Hardness (Mg/L)	Ca++ (Mg/L)	Mg++ (Mg/L)	CO2 (Mg/L)	D.O. (Mg/L)	T.S. (Mg/L)	TDS (Mg/L)	Alkalinity (Mg/L)	Chloride(Mg/L)	Nitrate (Mg/L)
Morewadi	KMC tap1	Winter	7.1	25.0	46.0	19.6	100.0	42.0	14.0	11.0	6.8	150.0	80.0	140.0	9.9	3.7
		Summer	7.0	28.0	133.0	28.4	34.0	9.6	5.9	4.4	6.8	70.0	20.0	190.0	19.0	4.0
		Rainy	6.9	29.0	130.0	24.8	64.0	18.4	11.7	4.2	6.7	160.0	80.0	180.0	17.0	4.6
Bawada	KMC tap2	Winter	7.0	27.0	57.0	14.8	64.0	16.0	11.6	6.6	6.0	110.0	70.0	50.0	9.9	3.6
		Summer	7.0	28.0	54.0	28.8	40.0	12.0	6.7	2.2	7.2	100.0	40.0	65.0	14.2	4.0
		Rainy	7.0	28.0	57.0	28.4	36.0	11.2	6.0	4.4	6.4	170.0	90.0	70.0	11.3	4.2
Nagdev wadi	KMC tap3	Winter	7.0	27.0	29.0	14.8	24.0	5.6	4.4	4.4	6.4	100.0	70.0	40.0	8.5	4.1
		Summer	7.0	27.0	41.0	28.8	26.0	7.2	4.5	4.4	7.7	110.0	100.0	45.0	9.9	4.6
		Rainy	6.9	28.0	48.0	30.8	20.0	4.8	0.8	2.2	6.8	150.0	80.0	45.0	9.9	4.2

Table 9. Seasonal values of physico-chemical parameters from Grampanchayat supply in the study area.

Grampanchayat			Parameters													
Village	Site No.	Season	pH	Temp ^{0}C	E.C. (uMhos/cm)	Turbidity (NTU)	Hardness (Mg/L)	Ca++ (Mg/L)	Mg++ (Mg/L)	CO2 (Mg/L)	D.O. (Mg/L)	T.S. (Mg/L)	TDS (Mg/L)	Alkalinity (Mg/L)	Chloride (Mg/L)	Nitrate (Mg/L)
Nagdev Wadi	G.P.1	Winter	7.1	26.0	80.0	15.6	36.0	8.8	6.6	6.6	6.0	140.0	90.0	50.0	12.7	4.2
		Summer	7.0	28.0	118.0	30.4	32.0	8.0	5.8	2.2	7.3	190.0	120.0	40.0	15.6	5.8
		Rainy	7.1	28.0	114.0	29.2	84.0	18.4	15.9	4.4	5.6	190.0	110.0	60.0	18.4	6.2
Tamgoan	G.P.2	Winter	7.2	24.0	540.0	26.4	76.0	24.0	12.6	8.8	4.8	110.0	80.0	85.0	34.0	4.2
		Summer	7.0	29.0	539.0	28.0	62.0	23.2	9.4	11.0	3.6	420.0	320.0	100.0	65.3	4.6
		Rainy	7.2	28.0	655.0	22.0	90.0	32.8	13.8	2.2	3.6	140.0	70.0	120.0	139.7	4.1

Table 10. Average values of fourteen physico-chemical parameters studied for the five categories of fresh water sources

Parameters	Categories					
	HP1-HP5	BR1- BR6	W1-W3	CP1-CP3	GP1-GP2	Final Average
pH	7.5	7.6	7.5	7.0	7.1	7.3
Temp(0C)	27.6	27.5	27.1	27.0	27.0	27.2
E.C.(uMhos/cm)	438.0	621.0	787.0	66.0	341.0	451.0
Turbidity(NTU)	26.9	26.0	27.2	24.3	25.2	25.9
Total Hardness(Mg/L)	258.4	361.1	317.6	45.3	63.3	209.2
Calcium (Mg/L)	72.1	95.9	89.5	14.1	19.2	58.1
Magnesium (Mg/L)	45.4	66.3	55.3	7.34	10.7	37.0
Free CO_2 (Mg/L)	31.0	38.0	21.5	4.9	5.9	20.2
Dissolved Oxygen (mg/L)	2.2	4.1	4.3	6.8	5.1	4.5
T.S. (Mg/L)	660.7	750.6	852.2	124.4	198.3	517.2
T.D.S. (Mg/L)	308.0	528.3	522.2	70.0	131.7	312.0
Alkalinity(Mg/L)	226.9	249.8	199.4	91.6	75.8	168.7
Chlorides (Mg/L)	82.4	95.5	209.2	12.2	47.6	89.4
Nitrate (Mg/L)	9.4	14.8	13.4	4.1	4.8	9.3

Table 11 Correlation Coefficient between fourteen physicochemical parameters observed during the study

	pH	Temp	EC	Turbidity	Hardness	Ca++	Mg++	CO2	DO	TS	TDS	Alkalinity	Chlorides	Nitrate
pH	1	0.003	0.470	0.072	0.503	0.517	0.484	0.361	-0.528	0.610	0.425	0.748	0.287	0.396
Temp		1	0.010	0.387	0.074	0.009	0.090	0.149	-0.086	0.144	0.068	0.259	-0.034	0.062
EC			1	0.083	0.796	0.818	0.767	0.331	-0.109	0.745	0.765	0.340	0.830	0.569
Turbidity				1	0.083	0.099	0.076	0.046	-0.176	0.057	-0.032	0.101	0.159	0.138
Hardness					1	0.977	0.991	0.526	-0.102	0.806	0.844	0.443	0.660	0.412
Ca++						1	0.949	0.438	-0.099	0.811	0.811	0.432	0.736	0.435
Mg++							1	0.572	-0.067	0.787	0.840	0.447	0.641	0.387
CO2								1	-0.365	0.299	0.378	0.590	0.153	0.041
DO									1	-0.096	0.130	-0.343	-0.043	-0.031
TS										1	0.861	0.525	0.617	0.448
TDS											1	0.391	0.640	0.452
Alkalinity												1	0.171	0.136
Chlorides													1	0.471
Nitrate														1

acidity or alkalinity and measure the concentration of hydrogen ions present in water. It does not measure total acidity or alkalinity.

The pH of most natural waters falls within the range of 4 to 9. The majority of waters are slightly basic because of the presence of carbonates and bicarbonates. The practical pH scale extends from 0, very acidic to 14, very alkaline, with 7 corresponding to exact neutrality at 25^0C. The pH is important in almost every phase of environmental monitoring practice. In the field of drinking water supplies, it is factor that must be considered in chemical coagulation, disinfecting, water softening and corrosion control.

Every water body shows the seasonal and diurnal variation in pH values. In the present study pH of all the sites ranged between 6.9 at (KMC tap_1) and (KMC tap_2) in rainy season to 8.0 at (HP_4), (BR_1) in rainy season and at (BR_4) in winter season. In case of only groundwater sample the lowest pH value recorded was 7.1 at (HP_3) in summer. The overall average pH value recorded was 7.3.

The Figure-2 shows the minimum, maximum and average values of pH at each sampling site during three seasons. Correlation coefficient between pH and other water quality parameters are given in Table-11, which is found to be negative (-0.528) for dissolved oxygen and positive for other parameters having highest r (0.748) value for alkalinity.

HP1 - HP5: Hand pump water samples showed the maximum and minimum pH values of 8.0 (HP_4) in rainy season and 7.1 (HP_3) in summer with average of 7.5 pH value. pH values recorded in different seasons from hand pumps in the study area are given in Table-5.

BR1 - BR6: The average pH recorded for bore wells was 7.6. The highest pH estimated was 8.0 at (BR_1) in rainy season and at (BR_4) in winter season with lowest of 7.3 at (BR_3) in winter and at (BR_2), (BR_5), (BR_6) in summer season respectively. pH

values recorded in different seasons from bore wells in the study area are given in Table-6.

W1 – W3: pH of well water ranged between 7.2 (W_2), (W_3) in summer and 7.7 at (W_1) in rainy season with an average pH value of 7.5. pH values recorded in different seasons from open wells in the study area are given in Table-7.

KMC tap1- KMC tap3: KMC tap water samples showed average pH value 7.0 with minimum and maximum of 6.9 (KMC tap_1), (KMC tap_3) in rainy season and 7.19 (KMC tap_1) in winter season respectively.

GP1 – GP2: Grampanchayat water samples showed highest and lowest pH values of 7.2 (GP_2) in rainy season and 7.0 (GP_1), (GP_2) in summer respectively. The average pH value recorded was 7.1.

pH values recorded in different seasons from KMC tap water and Grampanchyat ware samples are given in Table-8 and Table-9 respectively. The water samples collected from all the sampling sites were within the prescribed limit provided by WHO and ICMR.

3.2.2. Temperature (^{0}C) :

The temperature of water depends on the season and temperature of the ground with which it is in contact. Temperature is basically important parameter for its effects on the chemistry and biological reactions in water. Temperature is also very important in the determination of various other parameters such as pH, conductivity, alkalinity etc.

The optimum temperature of water is supposed to be between 11^{0}C and 7^{0}C. However, in the tropical conditions the water temperature is always on higher side. Water in cooler temperature range has a pleasant taste and is refreshing.

The overall average value of temperature recorded during the investigation was 27.24^{0}C. The seasonal variation was in the range of 23^0 C to 30^{0}C in the groundwater

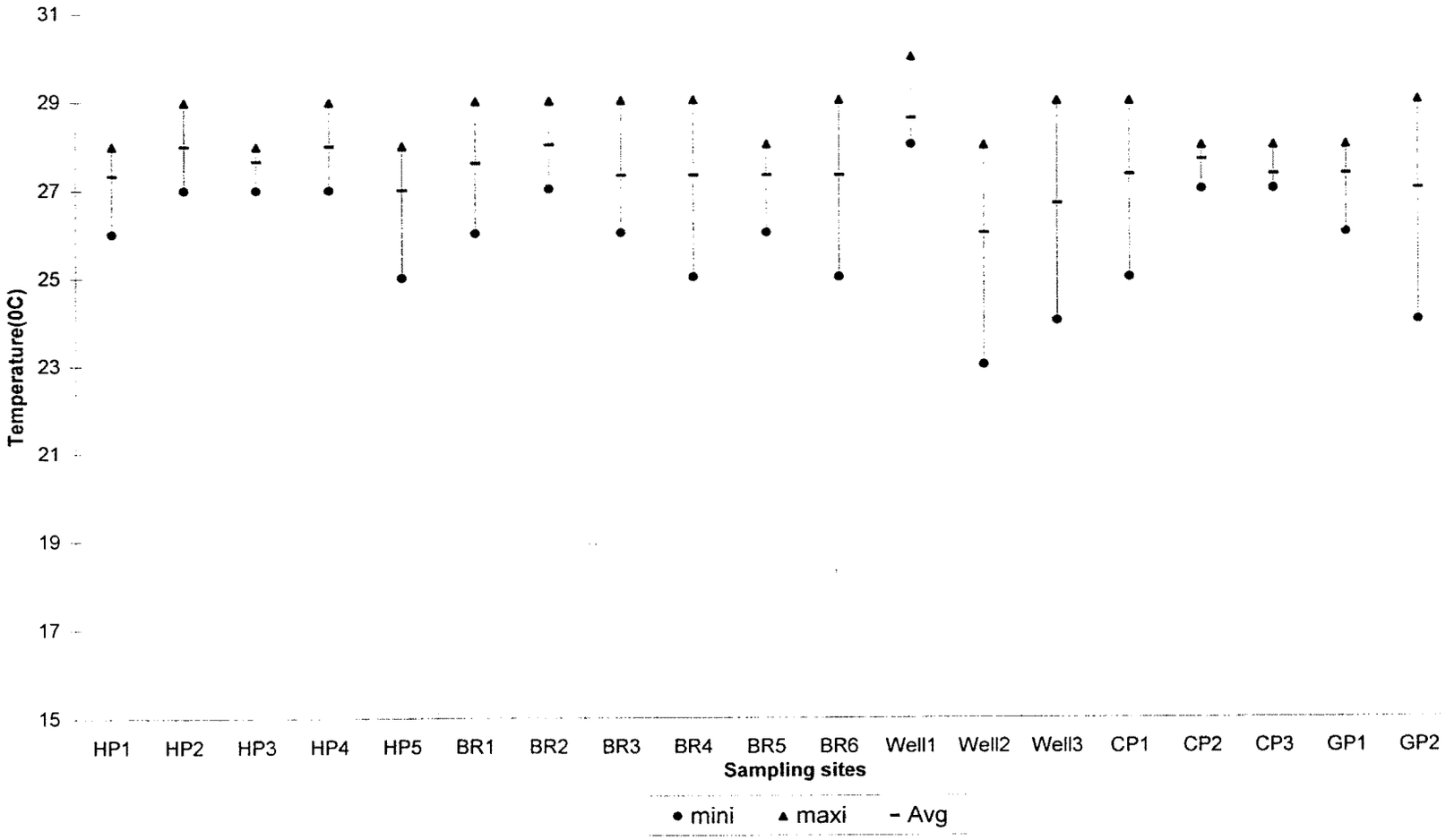


Figure 3 Minimum, minimum average values of temperature (^{0}C) at 19 sites during three season.

during all seasons. Temperature recorded during summer and rainy seasons were found to be some what similar and were comparatively higher than temperature values recorded during winter season. The maximum temperature of 30^0C was recorded in summer season (W_1) and the minimum of 23^0C in winter (W_2).

The Figure-3 shows the minimum, maximum and average values of temperature at each sampling site during the three seasons. Correlation coefficient between temperature and other water quality parameters are given in Table-11, which is found to be negative for dissolved oxygen and chlorides and slightly positive correlation with other parameters.

HP1 - HP5: In case of hand pumps the maximum temperature recorded was 29^0C (HP_2 , HP_4) in rainy season and minimum was 25^0C (HP_5) in winter. 27.6^0C was the average value for the hand pump water samples.

BR1 - BR6: The highest temperature recorded in case of bore wells was 29^0C (BR_1, BR_3, BR_4) in rainy season and (BR_2. BR_6) in summer season. Lowest temperature observed was 25^0C (BR_4, BR_6) in winter season. The average value recorded in case of bore well was 25.5^0C.

W1 – W3: The average values recorded for wells were 27.1C. The overall maximum and minimum values considering all ground water samples collected were recorded from well. The highest temperature recorded at (W_1) in summer season with lowest temperature value 23^0C (W_2) in winter season. It is interesting to note that the highest and lowest temperature in the study was recorded from well water samples. Perhaps this is because of the contact of water with the air at surface level.

KMC tap_1-KMC tap_3: The minimum and maximum temperature was recorded form same site i.e. (KMC tap_1) as 25^0C in winter season and 29^0C in rainy season respectively. The average value recorded was 27^0C.

GP1 – GP2: In case of Grampanchayat water samples, the average temperature value was 27^0C. The minimum and maximum temperature recorded was 24^0C and 29^0C respectively for the same sites (GP_2).

3.2.3 Electrical Conductivity (uMhos/cm) :

Electrical conductance is the ability of substance to conduct the electric current. in water. It is the property caused by the presence of various ionic species. Conductivity of water varies directly with the temperature and is proportional to its dissolved mineral matter content. It is an important indicator to check the purity of distilled water and determining the suitability of drinking water and wastewater for irrigation. Chemically pure water does not conduct electricity. Any rise in the electrical conductivity of water indicates pollution with electrolytes. According to U.S.P.A.(1974) ground waters with conductivity values are grouped as .

- less than 500 micro mohos/cm- Low conductivity.
- 500 to 1000 micro mhos/cm- Medium conductivity.
- Greater than 1000 micro mhos/cm – High conductivity.

Electrical conductivity of water samples collected from the four villages at different sites ranged between 29 umhos/cm to 1406 umhos/cm. The overall average electrical conductance was 451 umhos/cm. In most of the samples conductivity values decreased in the winter season and most of the samples electrical conductivity increased in rainy season. Due to increase in dissolved material content.

The Figure-4 shows the minimum, maximum and average values of electrical conductivity at each sampling site during three seasons. Correlation coefficient between electrical conductivity and other parameters are given in Table-11, which is found to be negative for dissolved oxygen. It shows excellent to good correlation between hardness, Ca^{++}, Mg^{++}, total solids, total dissolved solids, and nitrates.

The ground water samples collected from (HP_4) and (BR_5) were within the std limit (ICMR) of 300 umhos/cm in all season, remaining all sampling site exceeds the

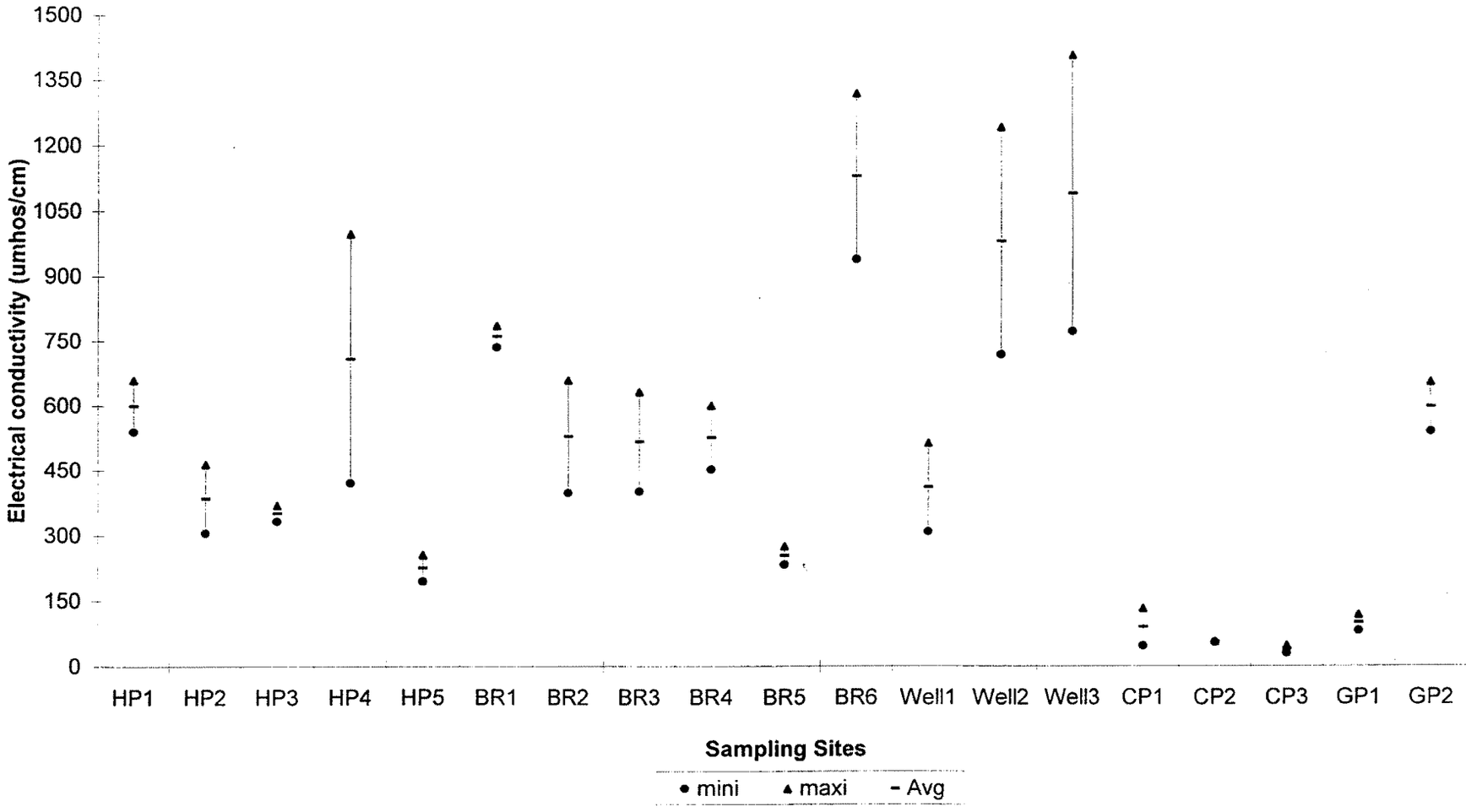


Figure 4. Minimum,maximum and average values of Electrical Conductivity (umhos/cm) at 19 sites during three seasons.

standard limit of 300umhos/cm. The KMC water samples showed electrical conductivity within the standard limit. Grampanchayat water samples collected from (GP_1) site were within limit and from (GP_2) it exceeded.

HP1 – HP5: The average value of electrical conductivity recorded for hand pumps was 438 umhos/cm. The highest and lowest electrical conductivity recorded was 997.0 umhos/cm (HP_4) in summer and 194.0 umhos/cm (HP_5) in winter season from same site that is HP_4.

BR_1 – BR_6 The highest values recorded for bore wells was 1320 umhos/cm (BR_6) in rainy season where as lowest value was 230 umhos/cm (BR_5)in winter season. The average value was 621 umhos/cm.

W_1 – W_3 In case of open wells the electrical conductivity ranged between minimum of 308-umhos/cm (W_1) in winter season to maximum of 1406 umhos/cm (W_3) in rainy season which is the highest record of electrical conductivity in all samples. Well water shows average EC value was 787 umhos/cm.

KMC tap1-KMC tap3: KMC tap water sample showed 66.0 umhos/cm average electrical conductivity value. Maximum was 133.0 umhos/cm (KMC tap_1) in summer where as 29.0 umhos/cm (KMC tap_3) was the minimum value recorded in winter season, which was the lowest record considering all the samples.

GP_1– GP_2 Grampanchayat water samples shows electrical conductivity in the range of minimum of 80.0 umhos/cm (GP_1) to maximum 655.0 umhos/cm (GP_2) recorded in winter and rainy season respectively. The average value recorded at the sites was 341.0 umhos/cm.

3.2.3 Turbidity (NTU)

The turbidity of the sample is measured from the amount of light scattered by the sample taking reference with standard turbidity suspension. Turbidity in water is due to

colloidal and extremely fine dispersions. Suspended matter such as clay, silt, finely divided organic and inorganic matter and micro-organisms also contribute to turbidity. The light, which absorbed or scattered by suspended material in the water body, is termed as turbidity. Because absorption and scattering are influenced by size and surface characteristics of suspended material, turbidity can not be measured in terms of quantitative measurement of suspended solids.

The degree of turbidity of water course may be used as measure of the intensity of pollution. Turbidity makes the water unfit for domestic purposes, food and beverage industries and many other industrial uses. The reduction in turbidity is associated with reduction in suspended matter and microbial growth.

The Figure-5 shows the minimum, maximum and average values of turbidity at each sampling site during three seasons. Correlation coefficient between turbidity and other water quality parameters are given in Table-11, which is found to be negative for dissolved oxygen and total dissolved solids. It showed slight positive correlation with other water quality parameters.

According to WHO and ICMR 5 NTU and 25 NTU are the highest desirable and maximum permissible concentrations for turbidity. During the period of investigations the average value for turbidity was 25.97. NTU. At KMC tap_3 14.8 NTU was the lowest and 34.8 NTU (HP_3) was the highest values recorded during the study. In case of ground water samples, 15.6 NTU was the lowest turbidity recorded for HP_2 in winter season and highest turbidity 34.8 NTU (HP_3) in rainy season.

HP_1 – HP_5: The average turbidity recorded for hand pumps was 26.98 NTU. The maximum and minimum turbidity estimated was 34.8 NTU (HP_3) and 15.6 NTU (HP_2) respectively. All hand pump water samples from (HP_2) to (HP_5), except in winter season and at (HP_1) in winter and summer, exceed the max permissible limit of 25 NTU.

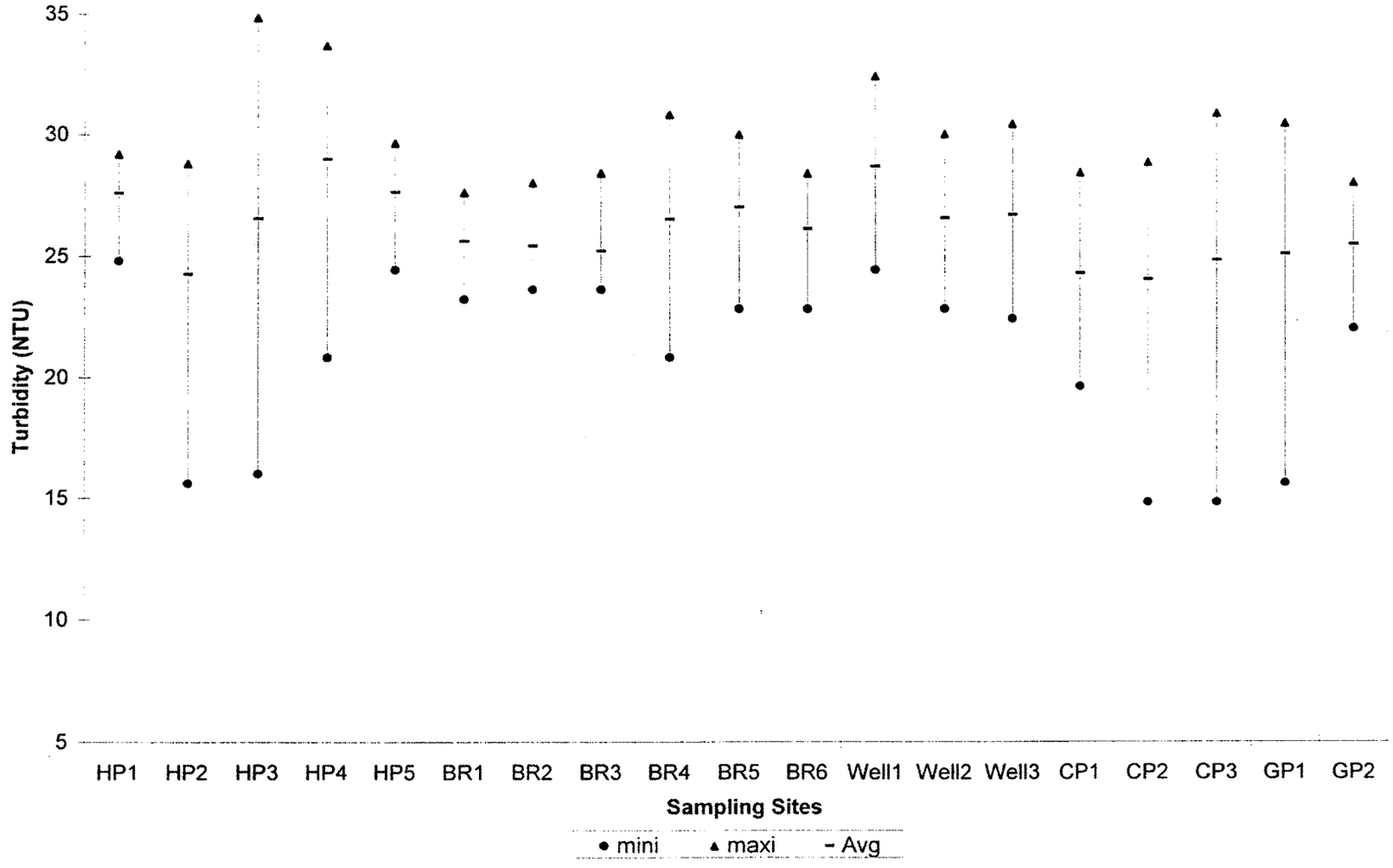


Figure 5. Minimum, maximum and average values of Turbidity (NTU) at 19 sites during three seasons.

$BR_1 - BR_6$: In case of bore wells the average value recorded was 26.0 NTU. It was interesting to note that the highest and lowest turbidity values were 30.8 NTU and 20.8 NTU in rainy and winter season respectively from the same sampling site (BR_4). In case of bore wells, water samples were within maximum permissible limit from (BR1), (BR_4) and (BR_5) in winter season and from (BR_6) only in rainy season. At (BR_2) and (BR_3) in summer only exceed the limit.

$W_1 - W_3$: Water samples collected from wells showed average turbidity of 27.2 NTU with maximum and minimum of 32.4 NTU (W_1) in summer and 22.4 NTU (W1-winter), (W_3- rainy season) respectively. It is interesting to note that (W_2) and (W_3) showed turbidity values within limit in rainy season and exceeds the limit in the season from (W_1) site.

KMC tap1-KMC tap3: The amount of turbidity estimated in KMC tap water samples varied as lowest recorded was 14.8 NTU (KMC tap_2) and (KMC tap_3) in winter season and 30.8 NTU (KMC tap_3) in rainy season respectively with average turbidity of 24.356 NTU. Water samples from (KMC tap_1) and (KMC tap_3) only in winter were within the limit and for (KMC tap_1) in summer it exceeded the maximum permissible limit.

GP_1– GP_3: Grampanchayat water samples showed maximum of 30.4 NTU in summer and minimum of 15.6 NTU in winter season respectively from sampling site (GP_1). The site (GP_1) showed turbidity within limit in winter and for (GP_2) in the rainy season. All water samples from 19 sites exceeds the highest desirable limit of 5 NTU.

3.2.5 Total Hardness (mg/lit)

Hardness is the property of water, which prevents the lather formation with soap and increases the boiling point of water. Hardness is defined as the concentration of multivalent metallic cations in solution.

At super-saturated condition, the hardness cations react with anions in the water to form a solid precipitate. The hardness is classified as carbonate hardness (equivalent to alkalinity) and non-carbonate hardness (remaining hardness). Generally estimation of hardness is important for ground water, which is generally more than surface water.

Principle cations imparting hardness are calcium and magnesium. However other cations such as strontium, iron, manganese also contribute to the hardness. The anions responsible for hardness are mainly bicarbonates, carbonates, sulphates, chlorites, nitrates and silicates etc. hardness is called temporary if it is caused by bicarbonate and carbonate salts of the cations, since it can be removed simply by boiling the water. Mainly sulphates and chlorides of metals cause permanent hardness.

Classification of ground water based on hardness (Sawer and McCorty, 1967)

Hardness range (mg/lit)	**Water class**
0 – 75	Soft
75 – 150	Moderate hard
150 – 300	Hard
> 300	Very hard

The Figure-6 showed the minimum, maximum and average values of total hardness at each sampling site during three seasons. Correlation coefficient between total hardness and other water quality parameters are given in Table-11, which is found to be negative for dissolved oxygen. It showed excellent to good correlation with Ca^{++}, Mg^{++}, total solids, total dissolved solids, chloride and free CO_2 respectively.

According to ICMR, BIS and MWH 300 mg/lit and 600 mg/lit are highest desirable and maximum permissible concentrations for total hardness. All the samples except at BR6 (summer and rainy season) and W2 (rainy season) were within the maximum permissible limit of 600 mg/lit.

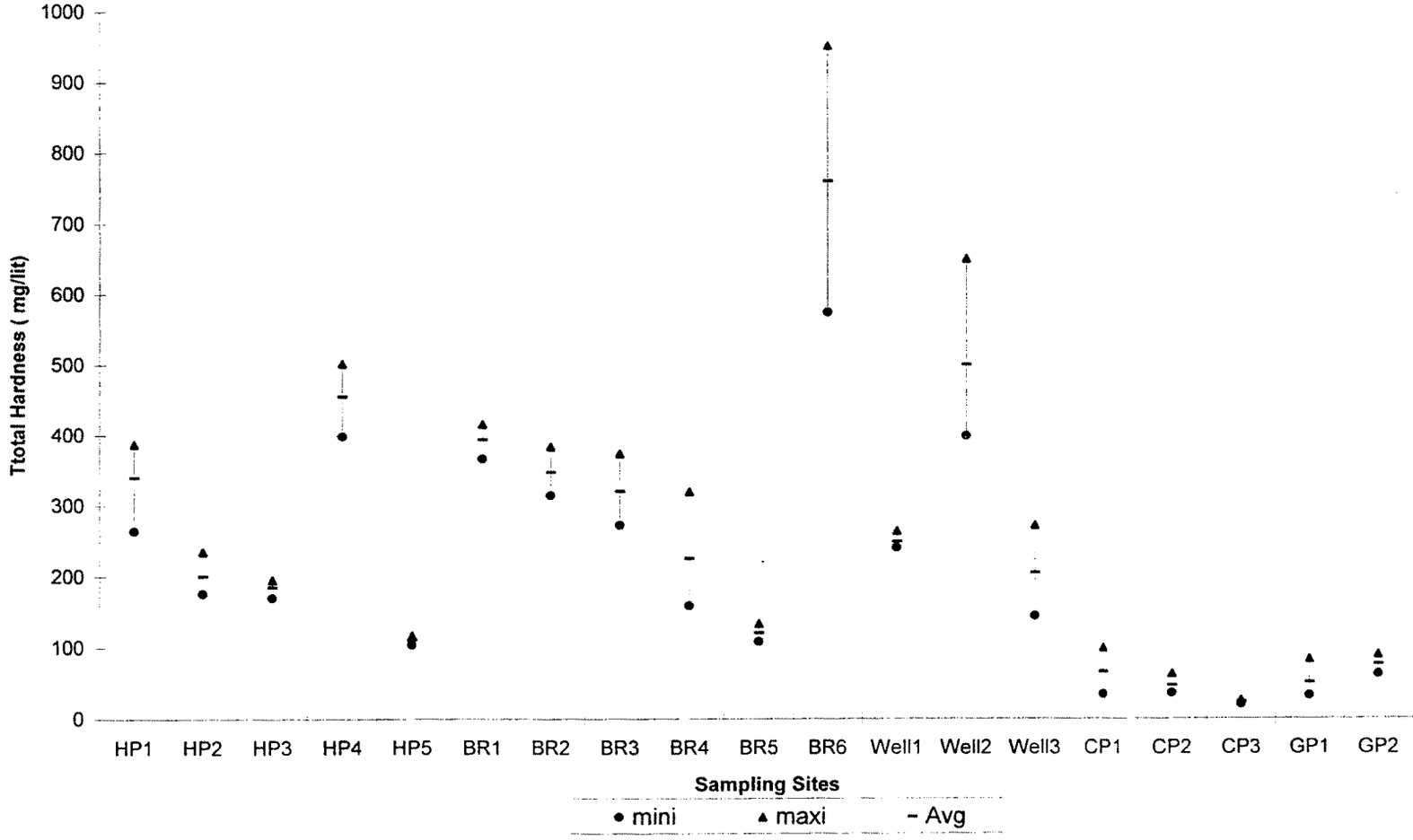


Figure 6 Minimum, maximum and average values of total hardness (mg/lit) at 19 sites during three seasons.

The total hardness values ranged from 20.0 to 950 mg/lit. Minimum hardness estimated as 20.0 mg/lit. (KMC tap_3), maximums was 950.0 mg/lit (BR6) in summer season. Average value calculated from all samples was 209.2 mg/lit.

HP_1 – HP_5: In case of hand pumps minimum hardness was 104.0 mg/lit. (HP_5) in winter season and maximum as 502 mg/lit. The average value calculated was 258.4 mg/lit. Total hardness of hand pump samples from (HP_2), (HP_3) and (HP_5) sites were within the limit (300.0 mg/lit) in all seasons. The ground water samples collected from (HP_1) and (HP_4) sites crossed the standard limit, but for (HP_1) in winter it was within limit of 300 mg/lit.

BR_1 – BR_6: For bore well water samples the average value calculated was 361.1 which was the highest value recorded from averages of all water samples. The minimum hardness estimated was 108 mg/lit. (BR_5) and maximum as 950 mg/lit. (BR_6) in summer season; it was the highest hardness value recorded during the period of investigation considering all water samples. Water samples collected from BR1, BR2 and BR6 exceeded the highest desirable limit of 300 mg/lit in all seasons, but from BR5 it was within limit. In case of BR4 it exceeded the limit in winter and at BR3 only during winter it was within limit.

W_1 – W_3: Wide range of hardness was estimated for open well water samples as minimum 144 mg/lit (W_3) in winter season and maximum 650.0 mg/lit.(W_2) in rainy season. The average hardness for well water samples was 317.6 mg/lit. and the maximum hardness recorded during rainy season. The seasonal and overall average value exceeded the maximum permissible limit.

KMC tap1-KMC tap3 : The KMC water samples showed highest value of hardness of 100.0 mg/lit. (KMC tap_1) and lowest as 20 mg/lit. (KMC tap_3) in winter season. Average value was 45.33 mg/lit.

GP_1– GP_3: The average value recorded for Grampanchayat water samples was 63.33 mg/lit. The water samples from these sites showed minimum hardness as 32.0 mg/lit. and maximum 90.0 mg/lit. Corporation and for Grampanchayat water samples showed total hardness values within the prescribed limit.

3.2.6 Calcium (mg/lit):

Calcium occurs in water mainly due to the presence of lime stone, gypsum, dolomite etc. material. Calcium and magnesium are the major scale forming constituents in raw waters. The quantities in natural waters generally vary from 10 to 100 mg/lit depending upon the types of the rocks. Disposal of sewage and industrial waste is also important sources of calcium. There are disadvantages in household and industrial uses, as high concentrations of calcium are not desirable in washing, laundering and bathing owing to its suppression of formation of lather with soap. Scale formation in boilers takes place by high calcium along with magnesium.

The Figure-7 showed the minimum, maximum and average values of calcium at each sampling site during three seasons. Correlation coefficient between Ca^{++} and other water quality parameters are given in Table-11, which is found to be negative for dissolved oxygen. But it showed significant r-values for Mg^{++}, total solids, total dissolved solids, and Chlorides respectively.

According to WHO and ICMR 75 and 200 mg/lit are the highest desirable and maximum permissible limits respectively. All water samples were within the maximum permissible limit except at (BR_6) in summer but few samples crossed the highest desirable limit.

The average value of calcium calculated from averages of all samples was 58.17 mg/lit. In general 4.8 mg/lit (KMC tap_3) is the lowest and 244.0 mg/lit. (BR_6) was the highest value of calcium recorded during the period of investigation. The concentration of calcium and magnesium vary in proportion with concentration of total hardness.

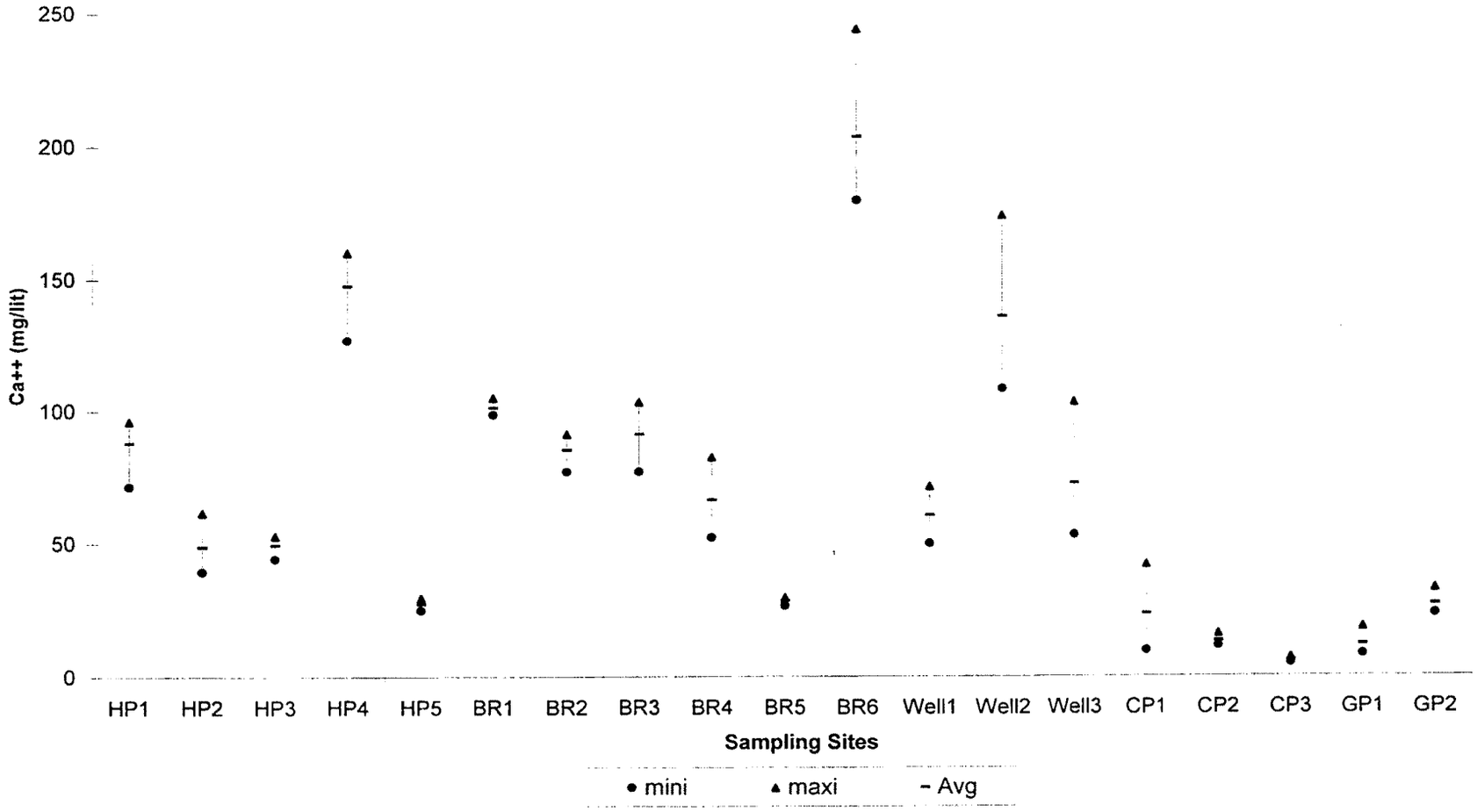


Figure 7: Minimum, maximum and average values of Calcium (mg/lit) at 19 sites during the three seasons.

$HP_1 - HP_5$: Water samples collected from hand pumps showed maximum 160mg/lit (HP_4) in rainy season and minimum value of 24.84 mg/lit (HP_5) in winter season. The average calcium value recorded was 72.12 mg/lit. The ground water samples collected from (HP_2) (HP_3) and (HP_5) sites were with in limit of 75 mg/lit in all seasons and for (HP_1) in winter it was within limit. Water samples from (HP_4) cross the standard limit in all seasons.

$BR_1 - BR_6$: The wide range of calcium concentration was estimated as lowest value of 26.4 mg/lit (BR_5) and highest of 244.0 mg/lit (BR_6) in summer season. The average value recorded from bore well was 95.93 mg/lit, which is the highest average value of all types of sampling stations. The calcium estimated from bore well samples for (BR_1), (BR_2), (BR_3) and (BR_6) crossed the limit of 75 mg/lit. for (BR_4) it exceeds only in winter and for only (BR_5) BR_5 it was within limit for all seasons.

$W_1 - W_3$: The average value recorded for well water samples was 89.5 mg/lit. The lowest calcium concentration recorded was 49.9 mg/lit (W_1) in winter season and highest was 173 mg/lit (W_3) in rainy season. Here all water samples from (W_1) were within limit and for (W_2) all water samples exceeds the limit for calcium only in rainy season.

KMC tap1-KMC tap3: KMC tap water samples showed maximum value of 42 mg/lit (KMC tap_1) and minimum 4.8 mg/lit (KMC tap_3) of calcium with average value of 14.1 mg/lit.

$GP_1 - GP_3$: The maximum amount of calcium estimated was 32.8 mg/lit (GP_2) in rainy season and minimum of 8.01 mg/lit (GP_2) in summer season. The average value of Grampanchayat water sample was 19.2 mg/lit. The calcium concentration of KMC tap and Grampanchayat water samples was within the standard limit during the period of investigation.

2.3.7 Magnesium

Magnesium also occurs in all kinds of natural waters with calcium, but its concentration remains generally lower than the calcium. Its principal sources in the natural waters are various kinds of rocks, sewage and industrial waste are also important contributors of magnesium. High concentrations may be cathartic and diuretic for the initial users but tolerance is developed in short time (Lehr et.al, 1980). High concentration combined with sulphate acts as laxative to human beings. The Figure-8 shows the minimum, maximum and average values of magnesium at each sampling site during three seasons.

In general 0.89 mg/lit (KMC tap_3) was the lowest and 84.33 mg/lit (HP_4) was highest value of magnesium recorded, averages of all samples was 37.04 mg/lit. According to WHO and MWH 30 and 150 mg/lit are the highest desirable and maximum permissible concentrations for magnesium. All water samples except (BR_6) in summer were within the maximum permissible limit of 150 mg/lit.

Correlation coefficient between Mg^{++} and other water quality parameters are given in Table-11. It shows positive r- values between 0.387 (nitrate) to 0.840 (total solids). It showed positive correlation with all water quality parameters except dissolved oxygen.

HP_1 – HP_5: The average value of hand pump water samples was 45.42 mg/lit. The highest magnesium concentration estimated was 84.33 mg/lit (HP_4) in summer season and lowest of 19.23mg/lit (HP_5) in winter season. The hand pump water samples except from (HP_5) all other hand pump sites crossed the highest desirable limit in all seasons.

BR_1 – BR_6: The maximum and minimum values estimated for bore well water sample were 171.0 mg/lit (BR_6) and 19.0 mg/lit (BR_5) both in summer season respectively. The average value calculated was 66.36 mg/lit, which was the highest value, recorded for calcium considering the average values. All bore well water samples from

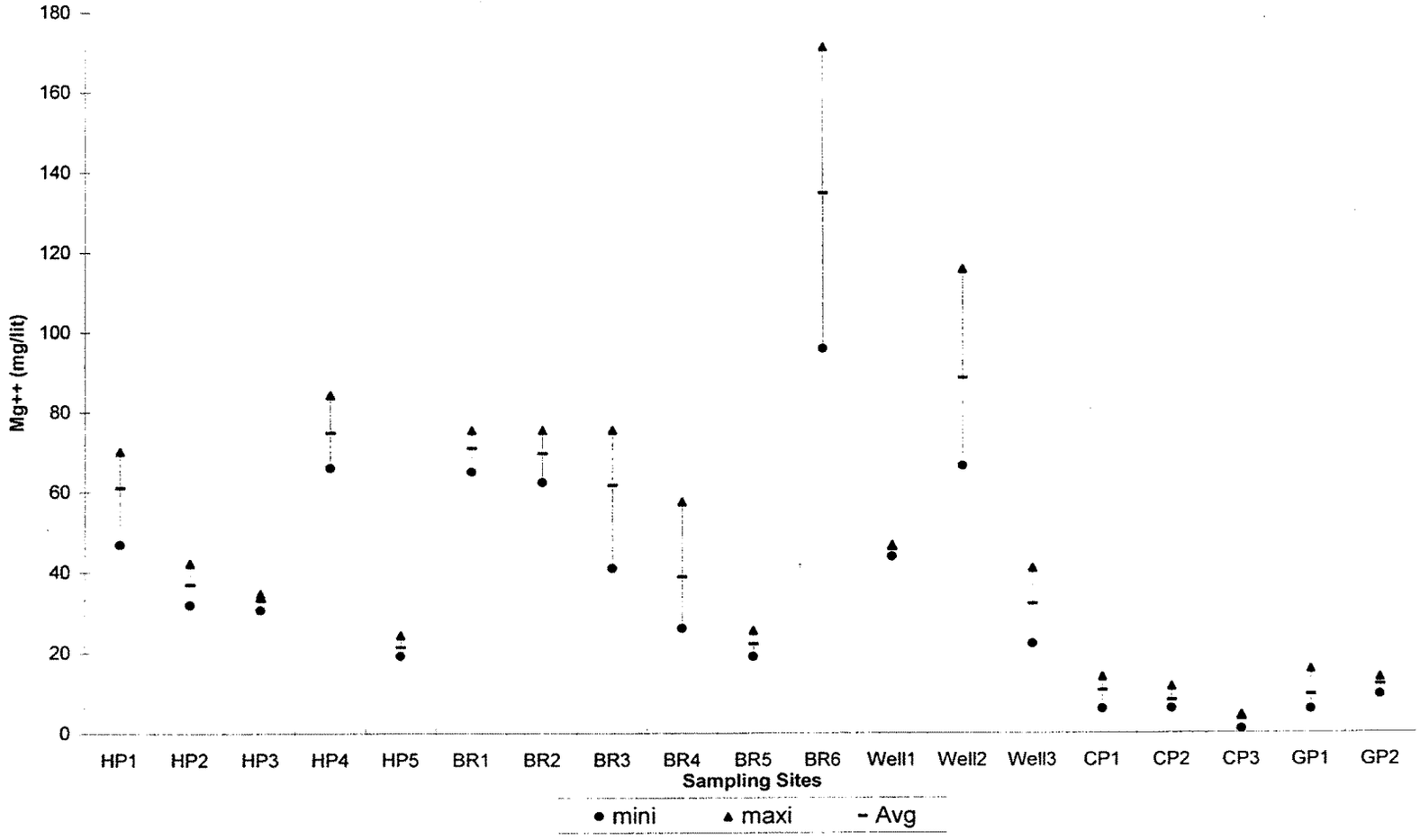


Figure 8 : Minimum, maximum and average values of Magnesium (mg/lit) at 19 sites during three seasons.

(BR_1) (BR_3) and (BR_6) cross the limit of 30 mg/lit where as for (BR_5) it was in limit for all seasons and for (BR_4) it was in limit in summer only.

W_1 – W_3: In case of well water samples the lowest concentration of magnesium estimated was 22.13mg/lit (W_3) in winter season and 115.9mg/lit (W_2) was the highest concentration with an average of 55.36 mg/lit. All open well water samples, except (W_3) in winter season , crossed the limit of 30 mg/lit.

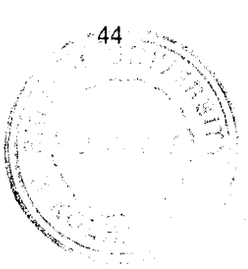
KMC tap1-KMC tap3: The estimated values of magnesium showed minimum of 0.89 mg/lit (KMC tap_3) and maximum 14.09 mg/lit (KMC tap_1) with an average 7.34 mg/lit.

GP_1– GP_3: Grampanchayat water samples showed average value of 10.71 mg/lit. The minimum value was 5.8 mg/lit. and maximum of 15.93 mg/lit from same site W_1 in summer and rainy season respectively. All water samples from KMC taps waters and Grampanchayat water samples were within the limit.

2.3.8 Free CO_2

Carbon dioxide is normal constituent of natural waters. In polluted water, it is formed by biological oxidation of organic matter. Surface waters normally contain lesser than 10-mg/lit free carbon dioxide, while some ground waters may easily exceed that concentration. The carbon dioxide content of water may contribute significantly to corrosion. The recarbonation of a supply during the last stages of water softening is a recognised treatment process. The amount of carbon dioxide depends on the decomposition of the topsoil and chemical nature of the underlying rocks.

Surface water normally contains less than 10mg/lit free carbon dioxide, while ground water may easily exceed that concentration up to 30-50 mg/lit. The carbon dioxide content of water may contribute significantly to corrosion. It combines chemically with water to form carbonic acid, which affects pH of water.



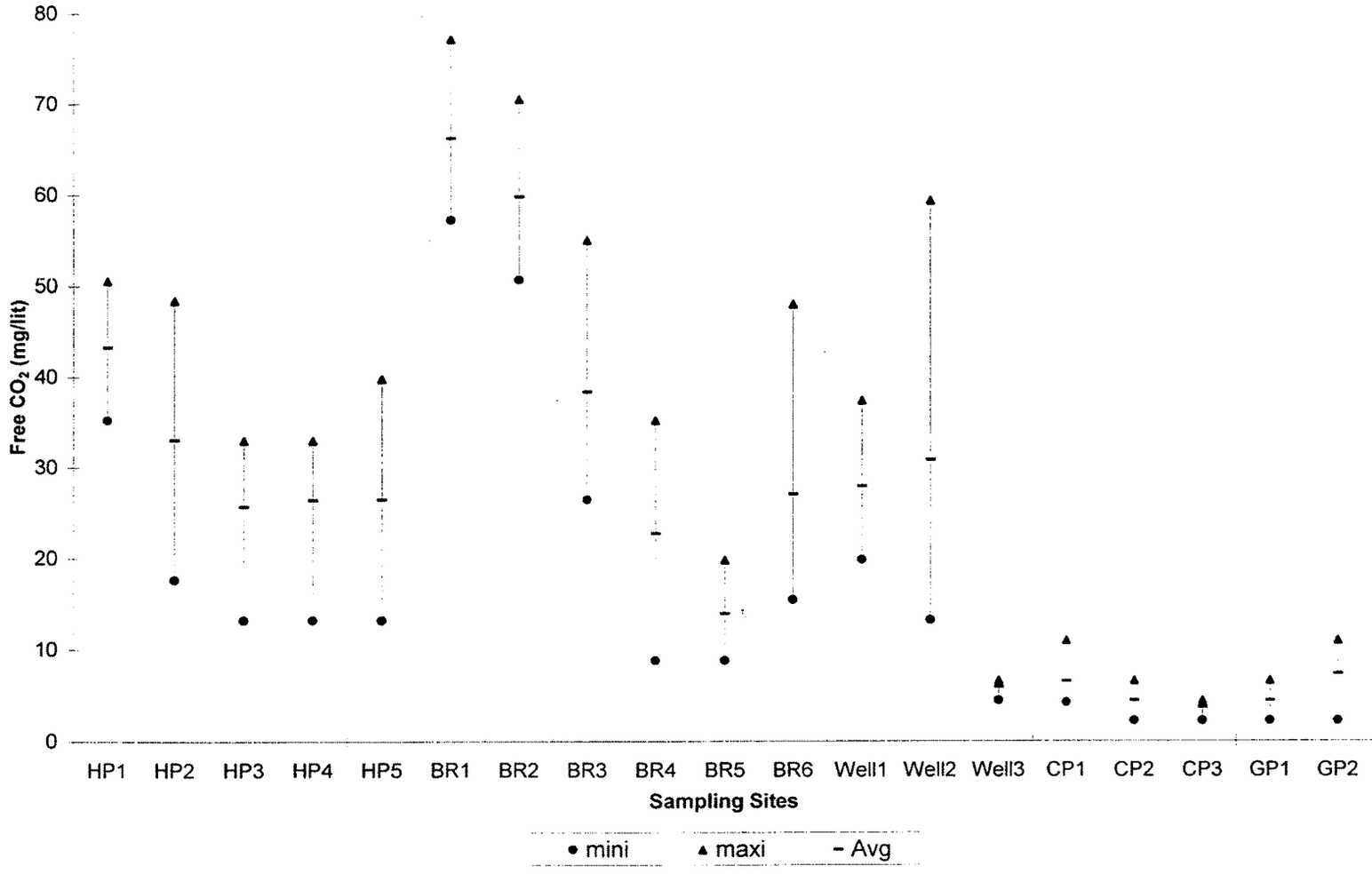


Figure 9 : Minimum, maximum and average values of free CO_2 (mg/lit) at 19sites during the three seasons.

The Figure-9 shows the minimum, maximum and average values of free CO_2 at each sampling site during three seasons. Correlation coefficient between free CO_2 and other water quality parameters are given in Table-11. Free CO_2 showed slight positive correlation with all water quality parameters. It showed significant r- value (0.590) for alkalinity except for dissolved oxygen where it is negatively correlated.

Free CO_2 values ranges from 2.2 mg/lit (KMC tap_1), (KMC tap_2), (GP_1) and (GP_2) to 77 mg/lit (BR_1). The overall average value recorded was 20.26 mg/lit. In case of only ground water samples the lowest value recorded was 4.4mg/lit (W_3) in winter season and highest was 77 mg/lit (BR_1) in summer season.

HP1 - HP5: The average values of free CO_2 for a hand pump was 31mg/lit. The minimum amount of free CO_2 estimated was 13.2 mg/lit (HP_4) in rainy season and maximum of 50.6 mg/lit (HP_1) in summer.

BR_1 – BR_6: In case of bore wells the minimum free CO_2 estimated was 8.8 mg/lit (BR_5) in rainy season and maximum of 77.0 mg/lit (BR_1) in summer with an average of 38 mg/lit. Which was the highest average Free CO_2 value from all averages of samples collected from different sampling station.

W_1 – W_3: Well water samples showed the average free CO_2 of 21.5 mg/lit. The maximum and minimum concentration of free CO_2 estimated was 59.4 mg/lit (W_2) in summer and 4.4 mg/lit (W_3) in winter season respectively.

KMC tap1-KMC tap3: KMC tap water sample showed maximum of 11.0 mg/lit (KMC tap_1) in winter and minimum 2.2 mg/lit (KMC tap_2), (KMC tap_3) in summer and rainy season respectively. The average amount of free CO_2 estimated was 4.9 mg/lit.

GP_1– GP_2: In case of Grampanchayat maximum and minimum amount of free CO_2 estimated was 11.0 mg/lit and 2.2 mg/lit from same sampling site (GP_2). The lowest of 2.2 mg/lit observed also at (GP_1) in summer.

2.3.9 Dissolved Oxygen:

The dissolved oxygen values provide information about the biological and biochemical reactions undergoing in the water body. Dissolved oxygen play a vital role in supporting aquatic life. Dissolved oxygen level in natural and waste waters are dependent on the physical, chemical and biochemical activities prevailing in the water body. In case of ground waters the average O_2 content is less than 1 mg/lit approximately two meters below the water table (Steenvoordan, 1976). Low oxygen concentrations are generally associated with heavy contamination by organic matter. The analysis for DO is a key test in water pollution control activities and wastewater treatment process control.

The Figure-10 shows the minimum, maximum and average values of dissolved oxygen at each sampling site during three seasons. Correlation coefficient between dissolved oxygen and other water quality parameters are given in Table-11. Dissolved oxygen showed negative correlation with all water quality parameters except for Total Dissolved Solids, which also sowed slight positive correlation with dissolved oxygen.

The over all average of dissolved oxygen recorded during whole period of investigation was 4.54 mg/lit. The seasonal variation in dissolved oxygen was in the range of 1.03 mg/lit (HP_2) to 7.7 mg/lit ($well_2$), (KMC tap_3) in the water samples collected from different sites. The permissible limit of dissolved oxygen for drinking water is 4.0 mg/lit to 6.0 mg/lit (WHO, ISO, 1989).

HP1 - HP5: Minimum dissolved oxygen estimated for hand pump water samples was 1.03 mg/lit recorded for (HP_2) which is the lowest dissolved oxygen considering among all samples during period of investigation. Maximum and average concentrations, were 4.2 mg/lit (HP_1) and 2.20 mg/lit respectively. Average value of hand pumps was the lowest average of dissolved oxygen among averages of all other sampling stations. All the hand pump water samples except (HP_1) sites were below the permissible limit.

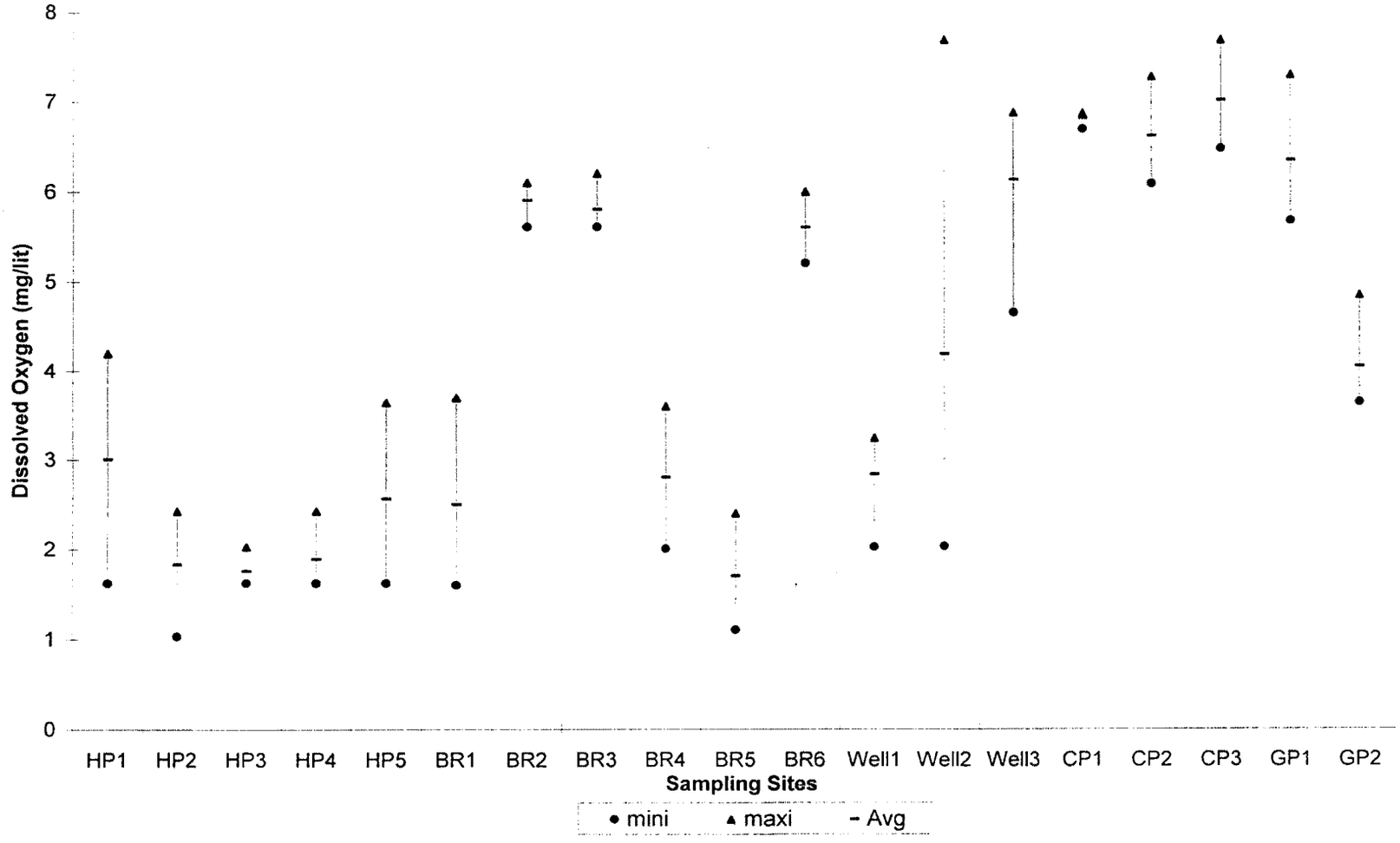


Figure 10 : Minimum, maximum and average values of Dissolved Oxygen (mg/lit) at 19 sites during the three seasons.

BR_1 – BR_6: The average dissolved oxygen for bore wells was 4.10 mg/lit. The highest dissolved oxygen estimated was 6.2 mg/lit (BR_3) in rainy season and lowest of 1.12 mg/lit (BR_5) in summer. Most of the samples showed decrease in dissolved oxygen level in summer season. In the water samples from BR_1, BR_4, and BR_5, dissolved oxygen concentration was below the permissible limit.

W_1 – W_3: In case of open well water samples lowest dissolved oxygen recorded was 2.02 mg/lit (W_1) in summer and highest of 7.7 mg/lit (W_2) in rainy season. The average value recorded for well water samples was 4.38 mg/lit. Water sample from (W_1) and (W_2) showed dissolved oxygen below permissible limit, except at (W_2) in rainy season, DO level below prescribed limit in winter and summer limit and exceeds in rainy season.

KMC tap_1-KMC tap_3: The average dissolved oxygen calculated for KMC tap water sample was 6.82 mg/lit that is the highest record of dissolved oxygen from averages of all sampling stations. The increase in dissolved oxygen level was due to aeration during water treatment and water forcefully coming from taps. The minimum dissolved oxygen was 6.08 mg/lit (KMC tap_2) in winter season and maximum 7.7 mg/lit (KMC tap_3) in summer recorded during the period of investigation.

GP_1– GP_3: The amount of dissolved oxygen estimated in Grampanchayat water samples varies as lowest 3.64 mg/lit (GP_2) and highest 7.3 mg/lit (GP_1). The average dissolved oxygen was 5.19 mg/lit. GP_1 site exceeded the limit in winter and summer season and at GP2 it was below permissible limit in summer and rainy season.

2.3.10 Total Solids:

Solids are present in water in both suspended and dissolved forms. Solids suspended in water may consist of inorganic material like clay, slit, other soil constituent etc. and organic particles such as plant material, fibbers, biological material etc. or immissible liquids. The solids may affect water quality adversely in number of ways. Water with higher amount of solids generally are of inferior palatability and may induce

an unfavourable physiological reaction in transient consumer. Highly mineralised waters also are unsuitable for many industrial applications. Suspended material may objectionable in water for several reasons. It is aesthetically displeasing and provides sites for chemical and biological agents. Suspended organic solids may degrade biologically, resulting in objectionable by-products.

Wide range of total solids was observed at each sampling site during the course of study. Figure-11 shows the minimum, maximum and average values of total solids at each sampling site during three seasons. Correlation coefficient between Total Solids and other water quality parameters are given in Table-11. Total solids showed excellent to good positive correlation with total dissolved solids, chlorides, alkalinity and nitrates respectively.

The average value for total solids recorded was 517.2 mg/lit. It is quite interesting to note that the lowest and highest concentration of total solids was recorded for bore well samples in rainy season. The over all lowest concentration observed was 70 mg/lit (KMC tap_1) and for ground water samples it was 280 mg/lit (BR_5). The highest amount of total solids estimated was 1610 mg/lit (BR_6). The value of total solids was increased in rainy season.

According to WHO and MWH 500 mg/lit and 1500 mg/lit are the highest desirable and maximum permissible concentrations respectively. All the samples except at (HP_4) in rainy season and (BR_6) in summer and rainy season respectively showed the higher value than the maximum permissible concentration of 1500 mg/lit. In case of ground water samples seasonal averages of total solids showed that only (HP_5) and (BR_5) sites were within the highest permissible limit.

HP_1 - HP_5: Samples collected from (HP_3) and (HP_4) sites show lowest concentration as 330 mg/lit and 1570mg/lit was the highest concentration recorded at HP_4 in rainy season. The average concentration of total solids for hand pumps was 660.7 mg/lit. Hand pump water samples from (HP_1) to (HP_4) cross the highest desirable limit of

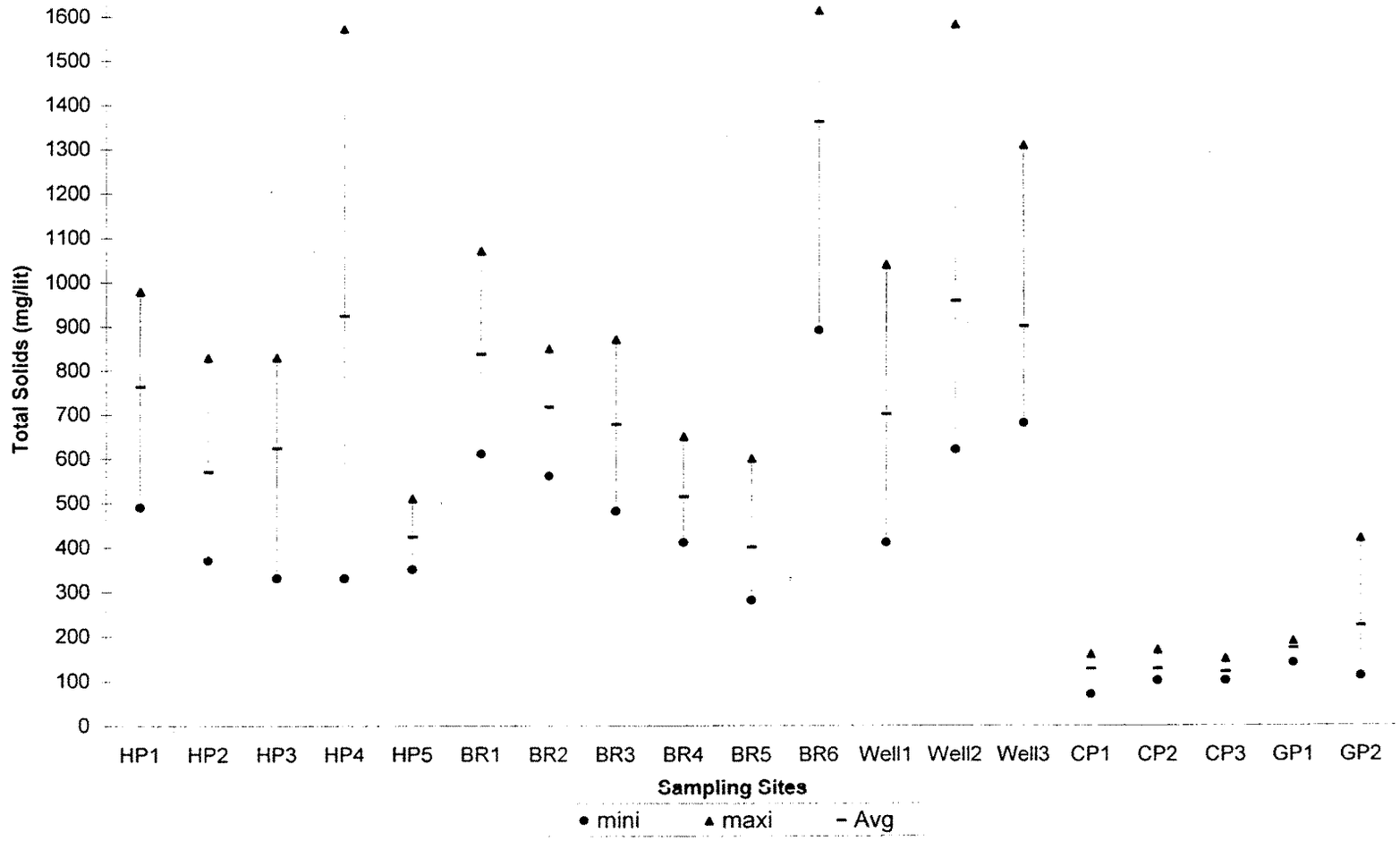


Figure 11 : Minimum, maximum and average values of Total Solids (mg/lit) at 19 sites during the three seasons.

500 mg/lit except in winter season at all sampling sites. But at (HP_5) it crosses the limit only in rainy season.

$BR_1 - BR_6$: The average value of total solids recorded for bore well samples was 750 mg/lit. The maximum and minimum concentration of total solids recorded from (BR_5) and (BR_6) sites respectively in summer season. Water samples from (BR_1), (BR_2) and (BR_6) cross the limit of 500 mg/lit during all season. But in case of (BR_4) and (BR_5) only in winter and at (BR_3) in both winter and rainy season respectively.

$W_1 - W_3$: In case of well water samples the average value of total solids was 852.2 mg/lit, which was the highest average of total solids recorded among the averages of total solids in water sample, collected from other sampling stations. 410mg/lit (W_1) was the lowest concentration of total solids recorded in summer and 1580mg/lit (W_2) was the highest concentration recorded in rainy season. All open well water samples except (W_1) in summer exceeded the limit of 500 mg/lit.

KMC tap_1-KMC tap_3: For KMC tap water samples minimum total solids recorded was 70 mg/lit (KMC tap_1) in summer and 170 mg/lit (KMC tap_2) in rainy season respectively. The total solids recorded for corporation was 124.4 mg/lit.

GP_1– GP_2: The water samples collected from (GP_2) site shows both maximum and minimum concentration of 420 mg/lit and 110 mg/lit respectively, with the average of 198.3 mg/lit. All water samples from KMC tap and Grampanchayat were within the limit.

2.3. 11 Total Dissolved Solids:

Many dissolved substances are undesirable in water. Dissolved minerals, gases and organic constituents may produce aesthetically displeasing colour, taste and odour. Conductivity measurements are roughly proportional to the filterable residue i.e. total dissolved solids. It may be used to advantage selecting the proper size of sample for residue determination.

Total dissolved solids indicate the general quality of water. The bulk of TDS includes bicarbonate, sulphates and chlorides of calcium, magnesium, sodium, potassium, silica, nitrate and boron from a minor part of the dissolved solids in ground water. Groundwater contains dissolved salts in such concentrations so as to make them unusable for ordinary water supply purposes. Ground water containing more than 1000 mg/lit of TDS is considers as saline waters. Actually an important aspect of TDS with respect to drinking water quality is the effect on taste. The portability of water with TDS level less than 600 mg/lit is generally consider to be good, at TDS level greater than 1200 mg/lit, drinking water becomes increasingly non potable.

The Figure-12 shows the minimum, maximum and average values of total dissolved solids at each sampling site during three seasons. Correlation coefficient between Total Dissolved Solids and other water quality parameters are given in Table-5. Total dissolved solids showed positive correlation with alkalinity, chlorides and nitrates.

The whole period of investigation showed the over all average value of total dissolved solids was 312.0 mg/lit. 20 mg/lit (KMC tap_1) recorded in summer and 1310mg/lit (BR_6) in rainy season, was the lowest and highest concentrations of total dissolved solids. Except Grampanchayat and KMC water samples 160 mg/lit at (HP_3), (HP_4) both recorded in summer season was the lowest total dissolved solids concentration for ground water samples.

According to WHO and MWH 500 mg/lit and 1500 mg/lit are the highest desirable and maximum permissible concentrations respectively. All water samples were within maximum permissible limit.

HP_1 - HP_5: The average total dissolved solids calculated for hand pumps was 308.0 mg/lit. The highest total dissolved solids estimated was 740 mg/lit (HP_1) in rainy season and lowest of 160 mg/lit at (HP_3) (HP_4) both in summer season. All hand pump water samples except (HP_1) and (HP_4) in rainy season were within the limit of 500 mg/lit.

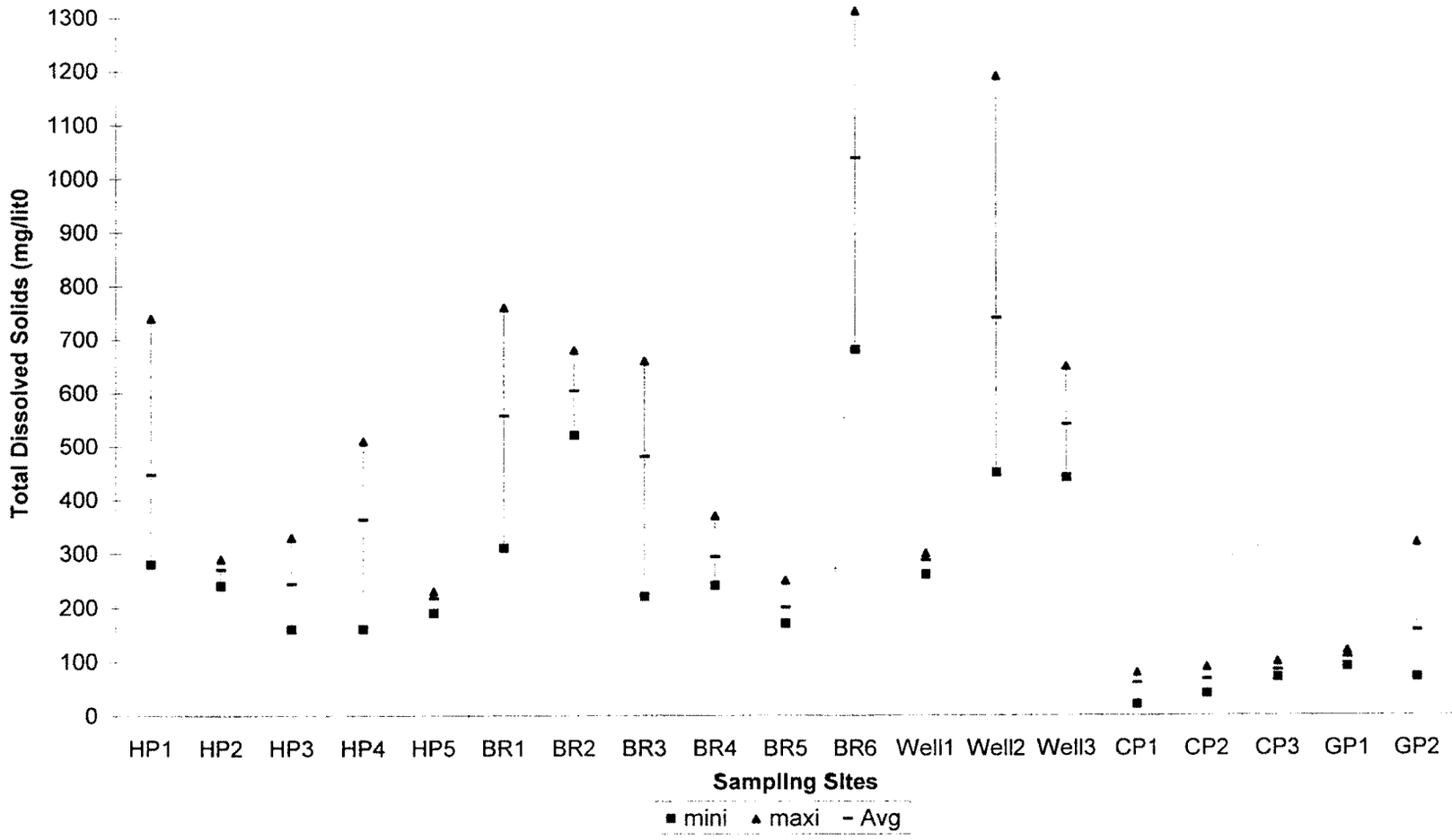


Figure 12 : Minimum, maximum and average values of Total Dissolved Solids (TDS) at 19 sites during the three seasons.

$BR_1 - BR_6$: In case of bore wells the maximum concentration of total dissolved solids was1310 mg/lit (BR_6) in rainy season and minimum was 170 mg/lit (BR_5) in summer. The average total dissolved solids value was 528.9 mg/lit which was the highest average value considering all sampling stations. All water samples from (BR_1) and (BR_6) cross the highest desirable limit. But from (BR_4) and (BR_5) were within limit. Also from (BR_1) and (BR_3) only in summer TDS values were within limit.

$W_1 - W_3$: The amount of total dissolved solids estimated in well water samples varies as lowest 260 mg/lit (W_1) in summer and highest 1190 mg/lit (W_2) in rainy season. The average total dissolved solid was 522.2 mg/lit. All water samples collected from (W_2) and (W_3) cross the limit except at (W_2) in winter and at (W_1) in in all the three seasons TDS values were with in limit.

KMC tap_1-KMC tap_3: The maximum and minimum amount of total dissolved solids estimated from KMC tap water samples was 100 mg/lit (KMC tap_3) and 20 mg/lit (KMC tap_1) respectively both in summer with an average of 70 mg/lit.

$GP_1 - GP_2$: Grampanchayat water samples showed maximum 320 mg/lit in summer and minimum of 70 mg/lit in rainy season from same sampling site (GP_2) with an average of 131.7 mg/lit. The KMC tap and Grampanchayat water samples where within the prescribed limit.

3.2.12 Alkalinity

Total alkalinity is the measure of the capacity of the water to neutralise a strong acid and is characterised by the presence of all hydroxyl ions capable of combing with the hydrogen ion. A number of bases such as carbonates, bicarbonates, silicates, borate etc. contribute to the alkalinity. In natural water most of the alkalinity is caused due to free carbon dioxide.

From the results obtained in the present study, it was observed that the overall average concentration of total alkalinity was 168.7 mg/lit. The seasonal variation was in the wide range of 40.0 mg/lit (KMC tap_3) to 460.0 mg/lit. (BR_1).

In case of only ground water samples 105.0 mg/lit was the lowest total alkalinity recorded in winter season and highest of 460 mg/lit (BR_1) in rainy season. Most of the samples showed increased alkalinity in rainy season this should be due to the weathering and leaching of basaltic rocks. All ground water samples showed alkalinity due to the presence of bicarbonate ions only where carbonate or phenolphthalein alkalinity was zero. Almost all ground water samples showed total alkalinity less than total hardness indicating the presence of calcium and magnesium.

The Figure-13 showed the minimum, maximum and average values of alkalinity at each sampling site during three seasons. Correlation coefficient between alkalinity and other water quality parameters are given in Table-11. Alkalinity showed slight positive correlation with chlorides and nitrates.

HP_1 - HP_5: In case of hand pumps the maximum total alkalinity estimated was 430 mg/lit (HP_1) in rainy season and minimum was to be 105.0 mg/lit (HP_5) in winter season which was the lowest total alkalinity considering all ground water samples. The average total alkalinity was 226.3 mg/lit. The water samples from (HP_3) and (HP_5) sites showed alkalinity within the standard limit of 200 mg/lit.

BR_1 – BR_6: The average value of total alkalinity for bore well samples was 249.83 mg/lit. Minimum alkalinity estimated recorded was 120.0 mg/lit (BR_5) in winter season and maximum of 460 mg/lit (BR_1) in rainy season, which was the highest total alkalinity, estimated during the course of study. The ground water samples from (BR_1) (BR_2) (BR_3) and (BR_4) exceeds the standard limit except water samples from (BR_5) and (BR_6) sites.

W_1 – W_3: The well water samples showed maximum total alkalinity of 320mg/lit (W_1) in rainy season and minimum of 120mg/lit (W_3) in winter season. Well water collected from (W_1) site exceed the standard limit other (W_2), (W_3) showed the total alkalinity within the prescribed limit.

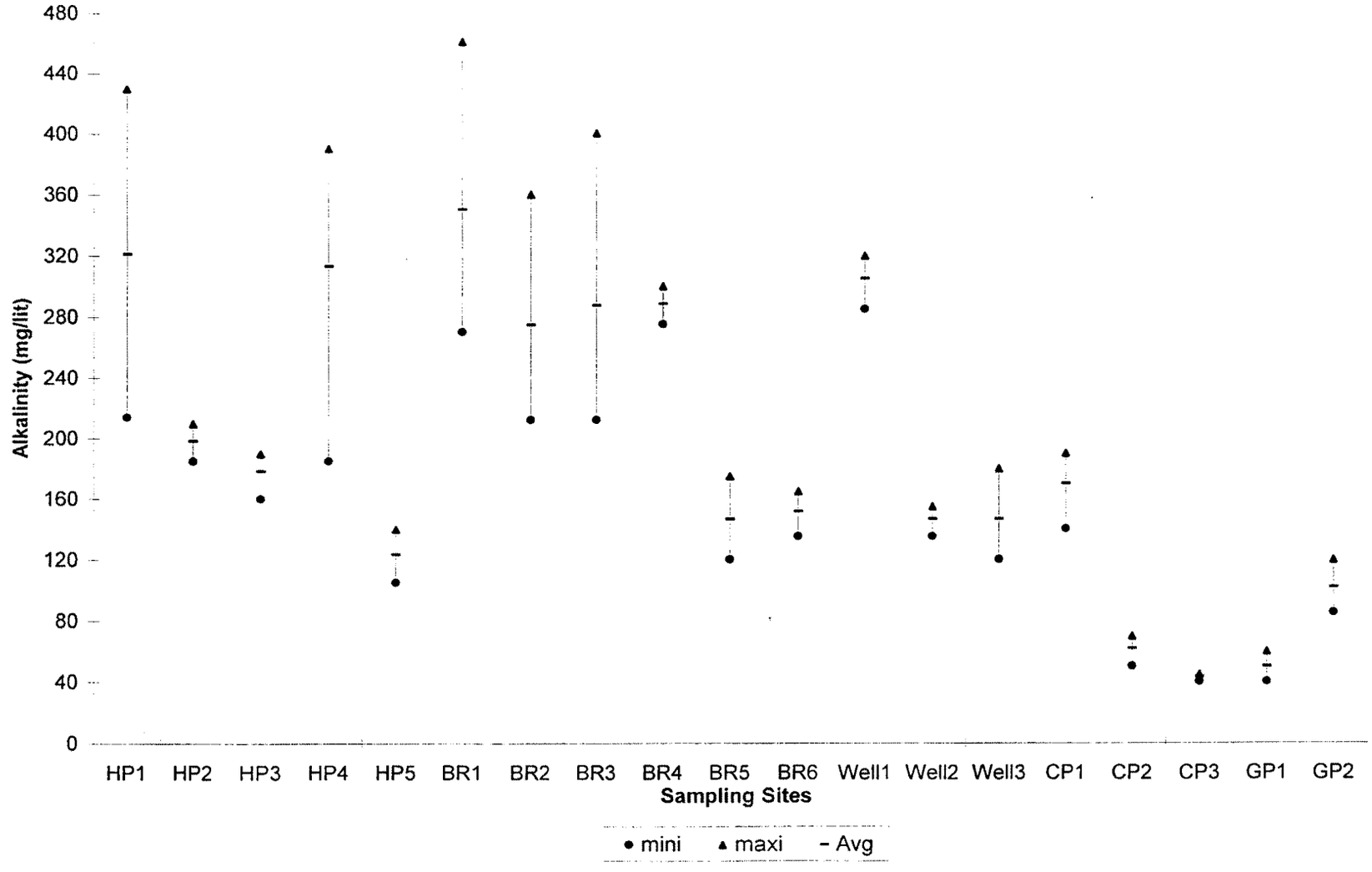


Figure 13 : Minimum, maximum and average values of Alkalinity (mg/lit) at 19 sites during the three seasons.

KMC tap_1-KMC tap_3: KMC tap water samples showed maximum of 190 mg/lit (KMC tap_1) in summer and minimum of 40 mg/lit (KMC tap_3) in winter season with an average total alkalinity of 91.67 mg/lit.

GP_1– GP_2: For Grampanchayat water samples the minimum and maximum total alkalinity recorded was 40 mg/lit (GP_1) in summer and 120 mg/lit (GP_2) in rainy season respectively. The average value of total alkalinity was 75.83 mg/lit. Grampanchayat and KMC tap water samples showed total alkalinity with in the standard limit.

3.2.13 Chlorides:

The large content of chlorides in water is indication of organic pollution. (Thrash et. al. 1944). Chlorides occur naturally in all types of waters. In natural freshwaters, its concentration remains quite low and is generally less than that of sulphates and bicarbonates. The most important source of chlorides in the water is discharge of domestic sewage. In natural freshwater high concentration of chlorides is consider to be an indicator of pollution due to organic wastes of animal origin. Man and other animals excrete very high quantities of chlorides together with nitrogenous compounds. Industries are also important sources of chlorides.

The figure-14 shows the minimum, maximum and average values of chlorides at each sampling site during study period. Correlation coefficient between chlorides and other water quality parameters are given in Table-11. Chlorides showed positive r- value of 0.471 with nitrate.The average value of chloride of all sampling stations during the total period of investigation was 89.41mg/lit. The highest and lowest chlorides that estimated during the study course were 286.8mg/lit (W_2) in rainy season and 8.2 mg/lit (KMC tap_3) in winter season.

According to WHO 200 mg/lit and 600 mg/lit are the highest desirable and maximum permissible limits for chlorides. All water samples were with in maximum permissible limit.

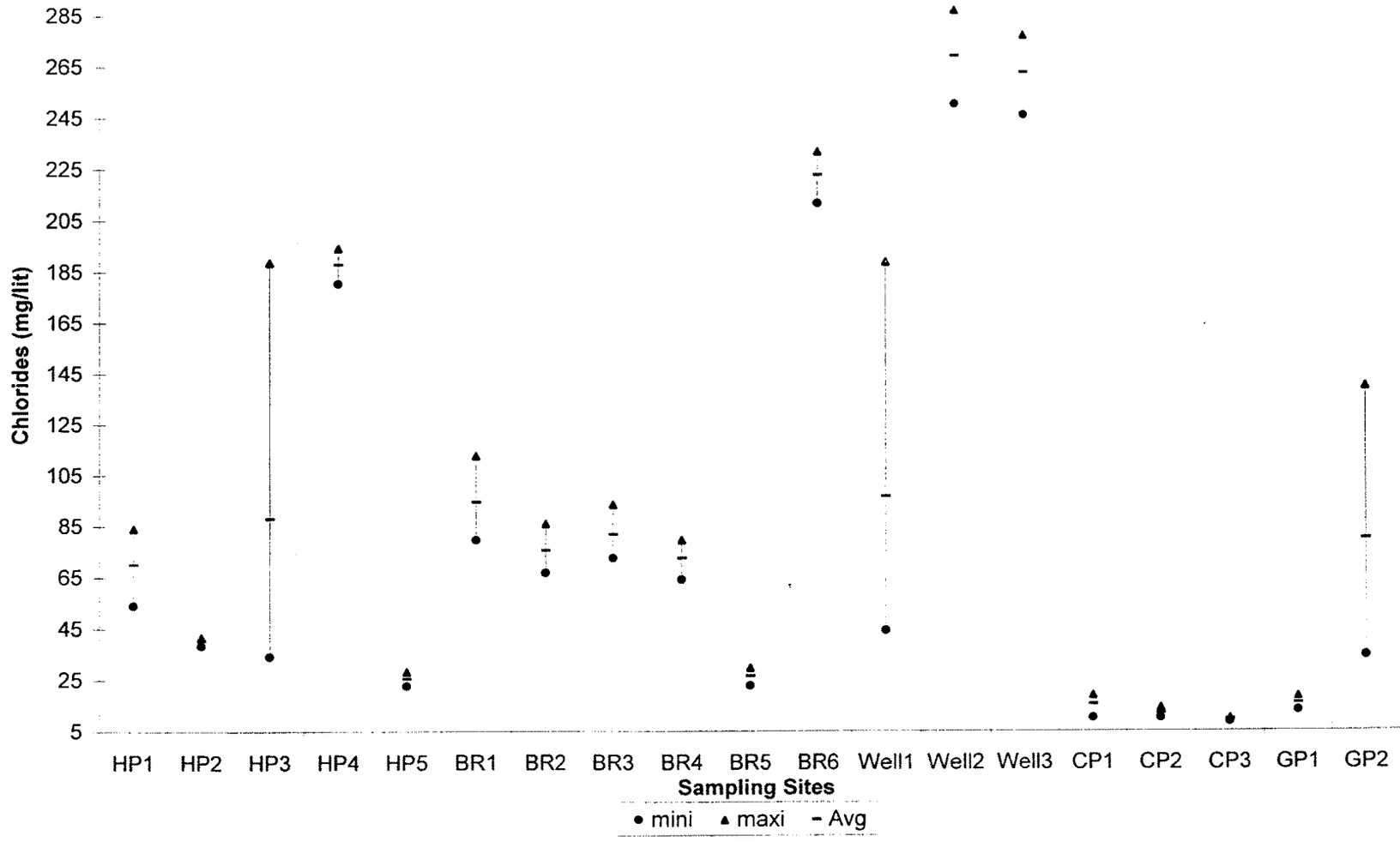


Figure 14: Minimum, maximum and average values of Chlorides (mg/lit) at 19 sites during the three seasons.

HP_1 - HP_5: The average concentration of chlorides for hand pumps was 82.41 mg/lit. The maximum chloride concentration estimated was 194.5 mg/lit (HP_4) in rainy season and lowest of 22.72 mg/lit (HP_5) in winter season. All hand pumps water samples showed chloride concentration with in the limit (200.0 mg/lit.).

BR_1 – BR_6: In case of bore wells minimum chlorides estimated was 22.72 mg/lit. at (BR_5) in winter season and maximum of 232.0 mg/lit. (BR_6) in rainy season. The average value of chlorides was 95.5 mg/lit. All bore well water samples were within limit of 200 mg/lit except for (BR_6) site during all the three seasons.

W_1 – W_3: The average value of chlorides in case of open well water was 209.2 mg/lit. Which was the highest average chloride concentration among all sampling stations. The highest and lowest value recorded was 286.8 mg/lit. (W_2) in rainy season and 44.07 mg/lit (W_1) respectively. Water samples collected from W_2 and W_3 exceeded the standard limit.

KMC tap_1-KMC tap_3: KMC tap water samples showed maximum 19.02 mg/lit (KMC tap_1) and minimum 8.52 mg/lit (KMC tap_3) of chlorides with an average of 12.21 mg/lit.

GP_1– GP_2: The maximum concentration of chlorides estimated was 139.7 mg/lit (GP_2) in rainy season and minimum of 12.78 mg/lit. (GP_1) in winter season. The average value of chlorides for Grampanchayat water samples was 47.66 mg/lit. The chloride concentrations of corporation and Grampanchayat water samples were within the standard limit during the course of study.

3.2.14 Nitrate (Mg/lit)

Nitrates are generally present only in trace amount in water. The most important source of the nitrate is biological oxidation of organic nitrogenous substances, which come in sewage and industrial waste or are produced indigenously in water. Domestic

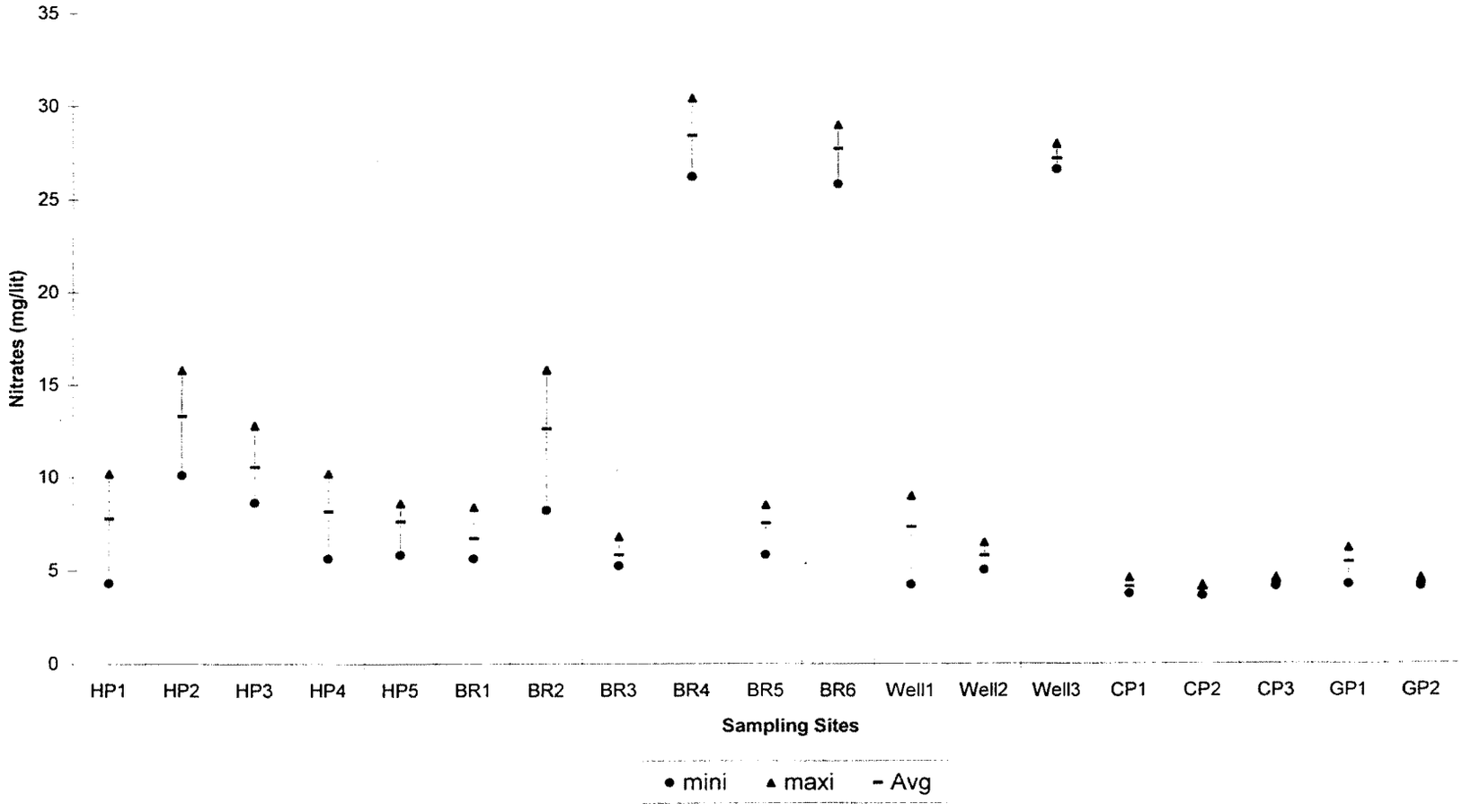


Figure 15: Minimum, maximum and average values of nitrates (mg/lit) at 19 sites during three seasons.

sewage, run-off from agricultural fields contain high amount of nitrate. This high amount of nitrates in water is generally indicative of pollution.

The Figure-15 shows the minimum, maximum and average values of nitrates at each sampling site during study. The average value of 9.33 mg/lit of nitrate was recorded during the study period. The seasonal variation in the nitrate ranged between 3.6 mg/lit (KMC tap_2) to 30.4 mg/lit (BR_4). In case of ground water samples the highest amount of nitrate estimated was 30.4 mg/lit at (BR_4) site in rainy season and lowest of 4.2 mg/lit at (W_1) in winter season. During the entire period of investigation water samples collected at all sampling stations showed nitrate levels within the standard limit of 45 mg/lit.

HP_1 - HP_5: The average value of nitrates for water samples collected from hand pumps was 9.46 mg/lit. The highest value of nitrate estimated was 15.8 mg/lit (HP_2) in rainy season and lowest of 4.3 mg/lit (HP_1) in winter season.

BR_1 – BR_6: In case of bore wells the lowest concentration of nitrate estimated was 5.2 mg/lit (BR_3) in winter season and highest concentration was 30.4 mg/lit (BR_4) in rainy season. The average value was 14.83 mg/lit which was the highest average value of nitrate in overall averages during the course of study.

W_1 – W_3: The amount of nitrate estimated in open well waters varied as lowest of 4.2mg/lit (W_1) in winter season and highest of 28.0 mg/lit (W_3) in rainy season was observed. The average value of nitrate recorded was 13.42 mg/lit.

KMC tap_1-KMC tap_3: The maximum nitrates estimated from KMC tap water samples was recorded as 4.6 mg/lit at (KMC tap_1) and (KMC tap_3) in rainy and summer season respectively with minimum of 3.6 mg/lit (KMC tap_2) in winter season and average of 4.11 mg/lit.

GP_1– GP_2: The Grampanchayat water sample showed highest of 6.2 mg/lit (GP_1) in rainy season and lowest of 4.1 mg/lit (GP_2) in rainy season. The average value was 4.85 mg/lit.
