# Quality Of Natural Water Of The Area In And Around Bhopal City, District Bhopal, Madhya Pradesh, With Special Reference To Its Drinking Suitability

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***Abstract – The study area in and around Bhopal lies between latitude 23º 10' – 23º 22' N and longitude 77º 15' – 77º 30' E on the survey of India Toposheet Nos 55- E/7 and 55 E/8 covering an area of about 550km$^2$. In order to assess the quality of surface and sub-surface water of the study area, the physico-chemical characters of 50 water samples were studied.***

***The calcium and magnesium content of the surface and sub-surface waters in pre-monsoon season is higher than their content in post-monsoon season. In the present study at places chloride content in the samples of underground water is higher in comparison to surface water samples in various parts of the city. The important source of chloride in the water is the discharge of domestic sewage. The higher nitrate concentration in the sub-surface water in comparison to surface water is mainly due to unlined drains carrying untreated sewage water.***

***Sulphate and fluoride concentration are within the permissible limit as laid down by the WHO and other Govt. agencies. In order to understand the variation in hydro-chemical facies with space and time the analytical data have been plotted on the Piper trilinear diagram reveals. The physical and chemical characters of surface and sub-surface waters have been utilized and evaluated on the basis of water quality standard proposed by various agencies. As per these standards the natural water of the study area is safe for drinking purpose except samples collected from surface water bodies like Lower lake, Shahpura lake and sample collected from few bore-bells where the $PO_4$ and $NO_3$ values are beyond the permissible limits.***

***Keywords : Bhopal, Natural water, quality, drinking suitability.***

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## 1. INTRODUCTION

The study area in and around Bhopal lies between latitude 23º 10' – 23º 22' N and longitude 77º 15' – 77º 30' E on the survey of India Toposheet Nos 55-E/7 and 55 E/8 covering an area of about 550km$^2$.

The sustainable water supply of desired quality in adequate quantity desired for the growing need is one of the main issues of Bhopal city. The major requirement of drinking water supply is met from surface water sources, namely upper Lake and Kolar reservoir. Besides, More than 1000 tube wells and a few large diameters dug wells and hand pumps also meet the requirement. The present study of hydro-chemistry of water includes the nature and amount of dissolved constituents, the chemical and geological factors that control the concentration of cations and anions carried in solution and the chemical relationship between dissolved constituents of surface and sub-surface water and the composition of the rock through which water circulates.

**Table 1 Physico-chemical Parameters of surface and sub-surface waters from Pre Monsoon Season -2008**

| Sr. No. | Location of Name of Place | Station Code | Source | Date of Collection | PH | EC | TDS | TA | TH | Ca++ | Mg++ | Na+ | K+ | Cl | $SO_4$ | $CO_3$ | $HCO_3$ | $NO_3$ | F | $PO_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Lalghati | PW1 | Bore-well | 02.04.08 | 8.5 | 400 | 256.0 | 80 | 224 | 54.5 | 20.6 | 25 | 1.4 | 60 | 12.5 | 0.0 | 80.0 | 9.0 | 0.5 | ND |
| 2 | Kamlanagar | RW1 | Bore-well | 02.04.08 | 8.6 | 985 | 630.4 | 368 | 218 | 32.1 | 30.0 | 32 | 2.0 | 74 | 16.0 | 0.0 | 284.0 | 3.8 | 0.0 | ND |
| 3 | 40 Qts Piplani | SW2 | Bore-well | 02.04.08 | 8.6 | 840 | 520.0 | 315 | 120 | 62.5 | 47.6 | 4.6 | 21.0 | 84 | 1.2 | 48.0 | 320.0 | 9.6 | 0.2 | ND |
| 4 | Azad Nagar | SW3 | Bore-well | 02.04.08 | 8.0 | 720 | 332.0 | 64 | 280 | 38.0 | 10.3 | 20 | 6.0 | 108 | 2.5 | 0.0 | 64.0 | 1.9 | 0.4 | ND |
| 5 | Shakti Nagar | XW4 | Bore-well | 02.04.08 | 8.6 | 387 | 247.6 | 480 | 348 | 89.8 | 30.0 | 42 | 2.9 | 54 | 3.5 | 0.0 | 480.0 | 2.8 | 0.3 | ND |
| 6 | Sarangpani Lake BHEL | RW3 | Surface water | 03.04.08 | 8.2 | 750 | 480.0 | 244 | 152 | 32.1 | 30.0 | 32 | 2.0 | 74 | 16.0 | 0.0 | 244.0 | 1.2 | 0.0 | 0.03 |
| 7 | Bagsewania | AD1 | Bore-well | 03.04.08 | 7.6 | 655 | 4192.0 | 244 | 192 | 18.6 | 21.9 | 23.4 | 1.0 | 43 | 1.9 | 0.0 | 198.0 | 1.7 | 0.4 | ND |
| 8 | Bhadbhada (Upper Lake) | AA2 | Surface water | 03.04.08 | 7.3 | 1040 | 6656.0 | 172 | 70 | 59.3 | 17.5 | 32.2 | 2.0 | 54 | 3.2 | 0.0 | 172.0 | 7.3 | 0.5 | ND |
| 9 | Baghmugaliya | AD2 | Bore-well | 03.04.08 | 7.3 | 328 | 209.9 | 120 | 224 | 19.2 | 21.4 | 33.3 | 1.8 | 43 | 0.5 | 0.0 | 120.0 | 1.6 | 0.4 | ND |
| 10 | Barkhedi | HW1 | Bore-well | 03.04.08 | 8.3 | 715 | 4576.0 | 136 | 152 | 52.9 | 4.9 | 8.9 | 3.9 | 128 | 5.2 | 0.0 | 136.0 | 3.1 | 1.0 | ND |
| 11 | Jawahar Chowk | PW1 | Bore-well | 04.04.08 | 7.4 | 1360 | 870.4 | 312 | 212 | 75.3 | 24.3 | 52.7 | 2.3 | 82 | 1.5 | 16.0 | 296.0 | 0.1 | 0.6 | ND |
| 12 | Banskhedi | AC1 | Bore-well | 04.04.08 | 7.6 | 1330 | 851.2 | 268 | 144 | 70.5 | 28.2 | 36.7 | 4.5 | 79 | 3.5 | 40.0 | 228.0 | 4.8 | 0.4 | ND |
| 13 | 6 No.-Bus Stop | IW1 | Bore-well | 04.04.08 | 7.5 | 842 | 538.9 | 384 | 220 | 126.6 | 37.9 | 26.6 | 3.1 | 113 | 5.1 | 24.0 | 360.0 | 2.8 | 0.4 | ND |
| 14 | Upper Lake Kamla park | VW2 | Surface water | 04.04.08 | 7.4 | 312 | 199.6 | 144 | 324 | 22.4 | 48.7 | 8.4 | 1.0 | 28 | 8.1 | 0.0 | 144.0 | 6.8 | 0.4 | 0.5 |
| 15 | Lower Lake Dhobi Ghat | VW1 | Surface water | 04.04.08 | 8.3 | 1360 | 851.2 | 268 | 192 | 9.6 | 12.9 | 26.2 | 0.6 | 79 | 7.8 | 24.0 | 56.0 | 5.8 | 0.3 | 9.0 |
| 16 | Kaliyasot Dam | AB1 | Surface water | 05.04.08 | 7.4 | 789 | 268.0 | 139 | 208 | 82.4 | 30.1 | 30.6 | 1.4 | 76 | 1.9 | 18.0 | 175.0 | 2.9 | 0.5 | ND |
| 17 | Tajul Masajid | JW1 | Bore-well | 05.04.09 | 8.4 | 839 | 442.0 | 408 | 212 | 31.9 | 42.2 | 8.8 | 1.0 | 106 | 3.4 | 0.0 | 439.0 | 1.8 | 0.4 | ND |
| 18 | Ram Mandir (Chuna Bhatti) | QW1 | Bore-well | 05.04.08 | 7.5 | 1039 | 8504.0 | 308 | 320 | 80.6 | 22.5 | 36.4 | 2.3 | 86 | 1.9 | 28.0 | 128.0 | 2.5 | 0.5 | ND |
| 19 | Shahpura Lake | RW1 | Surface water | 05.04.08 | 7.5 | 1280 | 850.1 | 260 | 292 | 69.4 | 27.1 | 26 | 4.3 | 79 | 2.8 | 39.0 | 260.0 | 3.9 | 0.4 | ND |
| 20 | Rose Garden | IW1 | Bore-well | 05.04.08 | 8.2 | 1279 | 203.4 | 0 | 238 | 78.4 | 42.6 | 92 | 7.2 | 67 | 4.3 | 0.0 | 520.0 | 3.8 | 0.2 | ND |
| 21 | BSNL Extention | RW2 | Bore-well | 25.05.08 | 7.3 | 1150 | 738.0 | 0 | 560 | 188.0 | 34.0 | 92 | 2.1 | 178 | 378.0 | 0.0 | 224.5 | 19.8 | 1.0 | ND |
| 22 | Chunna Bhatti | AB2 | Bore-well | 25.05.08 | 7.1 | 558 | 367.0 | 0 | 436 | 122.0 | 32.1 | 28 | 0.1 | 40 | 242.0 | 0.3 | 307.7 | 9.2 | 0.3 | ND |
| 23 | Near Kolar Bridge | KW1 | Bore-well | 25.05.08 | 7.8 | 730 | 467.0 | 0 | 400 | 104.0 | 36.0 | 65 | 0.1 | 118 | 209.0 | 0.4 | 167.0 | 10.6 | 0.2 | ND |
| 24 | Kanha Kunj | JW3 | Bore-well | 26.05.08 | 7.2 | 551 | 352.0 | 12 | 378 | 104.0 | 28.2 | 18 | 0.1 | 28 | 113.0 | 0.4 | 291.8 | 8.7 | 0.5 | ND |
| 25 | Loke Nagar | IW1 | Bore-well | 26.05.08 | 8.3 | 367 | 228.0 | 20 | 216 | 44.8 | 36.3 | 25 | 0.2 | 36 | 130.0 | 1.4 | 65.5 | 8.0 | 0.4 | ND |
| 26 | Bairagarh | OW1 | Bore-well | 26.05.08 | 8.4 | 466 | 298.0 | 0 | 280 | 36.8 | 45.7 | 35 | 0.1 | 50 | 73.0 | 6.8 | 261.1 | 2.3 | 0.3 | ND |
| 27 | Harshwardhan Nagar | JW1 | Bore-well | 27.05.08 | 7.8 | 410 | 262.0 | 12 | 100 | 49.6 | 15.6 | 26 | 1.2 | 44 | 58.0 | 0.2 | 127.2 | 2.2 | 0.3 | ND |
| 28 | Kotra Sultanabad | VW3 | Bore-well | 27.05.08 | 7.3 | 889 | 428.0 | 0 | 380 | 98.0 | 29.2 | 41 | 0.4 | 82 | 154.0 | 0.3 | 287.5 | 5.9 | 0.3 | ND |
| 29 | Nehru Nagar | PW2 | Bore-well | 27.05.08 | 7.2 | 447 | 288.0 | 12 | 284 | 80.0 | 15.6 | 30 | 5.2 | 46 | 83.0 | 0.4 | 247.8 | 2.5 | 0.2 | ND |
| 30 | Depo Chauraha | PW3 | Bore-well | 29.05.08 | 8.0 | 586 | 301.0 | 12 | 200 | 84.4 | 12.6 | 47 | 11.0 | 54 | 162.0 | 1.9 | 207.6 | 5.5 | 0.4 | ND |
| 31 | New Market | VW5 | Bore-well | 29.05.08 | 7.7 | 489 | 300.0 | 28 | 184 | 52.8 | 12.6 | 59 | 15.0 | 80 | 79.0 | 0.6 | 230.0 | 4.3 | 0.4 | ND |
| 32 | Professor Colony | PW5 | Bore-well | 29.05.08 | 8.0 | 410 | 262.0 | 8 | 200 | 44.8 | 21.4 | 25 | 4.7 | 44 | 117.0 | 2.2 | 143.4 | 3.8 | 0.4 | ND |
| 33 | Bhapal Talkies | KW1 | Bore-well | 04.06.08 | 8.2 | 705 | 451.0 | 0 | 240 | 75.2 | 12.8 | 53 | 17.0 | 78 | 115.0 | 2.4 | 220.8 | 8.3 | 1.0 | ND |
| 34 | Bhopal Railway Station | QW1 | Bore-well | 04.06.08 | 8.3 | 672 | 430.0 | 0 | 332 | 62.4 | 42.8 | 71 | 0.3 | 110 | 246.0 | 9.8 | 181.5 | 4.3 | 1.0 | ND |
| 35 | Teela jamalpura | PW1 | Bore-well | 04.06.08 | 8.3 | 888 | 468.0 | 12 | 254 | 36.8 | 38.9 | 10 | 3.0 | 114 | 167.0 | 0.0 | 195.2 | 6.2 | 0.2 | ND |
| 36 | Near LIC Factory | SW1 | Bore-well | 06.06.08 | 8.4 | 788 | 504.0 | 12 | 348 | 84.0 | 45.7 | 85 | 0.8 | 118 | 275.0 | 4.8 | 185.4 | 10.2 | 0.5 | ND |
| 37 | Chola Ganesh Mandir | QW4 | Bore-well | 06.06.08 | 7.4 | 660 | 422.0 | 0 | 392 | 81.2 | 37.9 | 66 | 1.0 | 80 | 220.0 | 0.0 | 223.1 | 6.3 | 0.5 | ND |
| 38 | Nishatpura | QW3 | Bore-well | 06.06.08 | 7.8 | 934 | 597.0 | 0 | 520 | 92.8 | 38.9 | 11 | 1.2 | 208 | 180.0 | 14.4 | 92.7 | 9.5 | 0.3 | ND |
| 39 | E-1 Arera Colony | WW1 | Bore-well | 08.06.08 | 8.4 | 864 | 616.0 | 0 | 360 | 148.0 | 60.3 | 78 | 1.2 | 144 | 300.0 | 7.4 | 233.1 | 37.2 | 0.2 | ND |
| 40 | E-3 Arera Colony | WW2 | Bore-well | 08.06.08 | 8.5 | 524 | 335.0 | 0 | 276 | 88.0 | 34.0 | 32 | 1.3 | 48 | 142.0 | 28.0 | 249.5 | 3.7 | 0.1 | ND |
| 41 | E-7 Arera Colony | WW3 | Bore-well | 11.06.08 | 8.3 | 558 | 367.0 | 0 | 312 | 72.0 | 23.3 | 42 | 0.9 | 67 | 174.0 | 4.7 | 149.5 | 12.5 | 0.2 | ND |
| 42 | E-8 Kishna Vihar | WW4 | Bore-well | 11.06.08 | 8.3 | 460 | 294.0 | 0 | 288 | 51.5 | 26.2 | 48 | 1.6 | 55 | 101.0 | 0.7 | 251.2 | 4.4 | 0.4 | ND |
| 43 | Bawadia Kalan Exten. | CW2 | Bore-well | 13.06.08 | 8.3 | 497 | 318.0 | 0 | 392 | 52.8 | 37.9 | 20 | 1.1 | 30 | 98.0 | 6.3 | 251.2 | 8.3 | 0.4 | ND |
| 44 | E-8 Arera Colony Gulmohar | VW4 | Bore-well | 15.06.08 | 7.5 | 96 | 445.0 | 0 | 320 | 57.6 | 60.3 | 33 | 1.1 | 56 | 126.0 | 4.0 | 305.6 | 7.7 | 0.4 | ND |
| 45 | Daulat Indus. Govindpura | QW2 | Bore-well | 15.06.08 | 8.3 | 850 | 418.0 | 0 | 300 | 80.2 | 29.2 | 87 | 3.5 | 120 | 145.0 | 0.0 | 183.9 | 5.0 | 0.3 | ND |
| 46 | E-Sector Govindpura | QW5 | Bore-well | 15.06.08 | 8.4 | 803 | 514.0 | 0 | 340 | 88.2 | 34.0 | 84 | 3.4 | 152 | 189.0 | 0.6 | 283.4 | 4.1 | 0.6 | ND |
| 47 | H-Sector Govindpura | XW1 | Bore-well | 19.06.08 | 7.8 | 1151 | 137.0 | 0 | 400 | 19.2 | 22.4 | 39 | 0.8 | 140 | 162.0 | 0.4 | 893.0 | 4.9 | 0.5 | ND |
| 48 | D-Sector Govindpura | XW2 | Bore-well | 19.06.08 | 8.3 | 582 | 372.0 | 0 | 352 | 107.0 | 32.1 | 70 | 1.0 | 100 | 151.0 | 0.4 | 343.8 | 1.5 | 0.2 | ND |
| 49 | A-Sector Govindpura | RW3 | Bore-well | 21.06.08 | 7.3 | 537 | 344.0 | 0 | 232 | 88.0 | 32.1 | 40 | 1.5 | 74 | 123.0 | 0.2 | 227.6 | 3.7 | 0.6 | ND |
| 50 | Rachana Nagar | XW3 | Bore-well | 21.06.08 | 7.0 | 515 | 329.0 | 0 | 141 | 57.8 | 21.4 | 44 | 4.9 | 74 | 118.0 | 0.2 | 203.8 | 2.4 | 0.6 | ND |

## 2. REVIEW OF LITERATURE :

A review of the available literature reveals that the development and management of safe drinking water is the prime concern for the society. A review of the literature on chemical quality of water and recommended standards in general, has attracted the attention of many workers from time to time, like – Rainwater and Thatcher (1960), Wilcox (1967), Holland (1978), Goel (1983, 1991), GreenBurg, Trussell and Clerceri (1985), Handa (1975, 1979, 1983), Hem (1985), American Water Works Association (1971), I.C.M.r. (1975), I.S.I. (1983), Karanth (1987), Brown, Skaugusted and Fishman (1974), Liod and Heathcote (1985), Raghunath (1987), Studyfzand (1989), Subba Rao *et al.* (2002), Ahmad *et al*. (2002), Bis (1991),Hem (1991), C.G.W.B. (1999), Bechmann, M.E, Berge, D., Eggestad, H.O. and Vandsemb, S.M. (2005), Chakrapani, G.J. (2002).

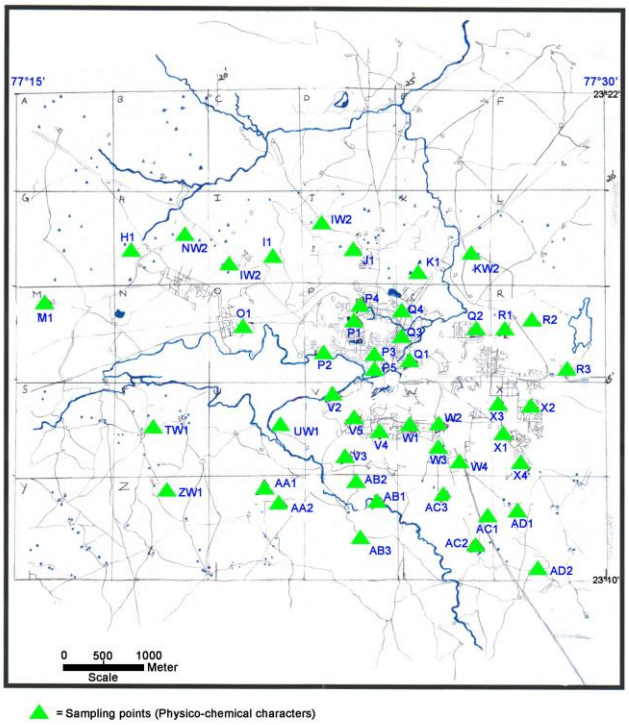


**Fig. 1 : Map showing location of sampling points**

Singh, Omkar, Kumar, V., Rai, S.P. and Choubey, V.K.

(2006), Nigam Neelam, Mehrotra Pooja (2007), Piper, A.M. (1953) Srivastava s.K. (2007) and many other for evaluating the quality of natural water for various purposes.

**Table 2 Physico-chemical Parameters of surface and sub-surface waters from Post-Monsoon Season - 2008**

| Sr. No. | Location of Name of Place | Station Code | Source | Date of Collection | PH | EC | $HCO_3$ | Cl | $SO_4$ | $NO_3$ | TH $CO_3$ | Ca | Mg | Na | K | TDS | $CO_3$ | $PO_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Lalghati | PW1 | Bore-well | 15.09.08 | 8.0 | 240 | 58.0 | 56.0 | 10.1 | 7.1 | 0.0 | 32.4 | 10.8 | 22.0 | 1.2 | 196.0 | 0.12 | ND |
| 2 | Kamlanagar | RW1 | Bore-well | 15.09.08 | 8.2 | 668 | 159.0 | 62.0 | 1.3 | 2.0 | 0.0 | 15.2 | 15.6 | 18.0 | 1.9 | 529.0 | 0.11 | ND |
| 3 | 40 Qts Piplani | SW2 | Bore-well | 15.09.08 | 7.6 | 353 | 258.0 | 32.0 | 1.1 | 9.5 | 0.0 | 42.1 | 25.2 | 32.0 | 8.0 | 420.0 | 0.23 | ND |
| 4 | Azad Nagar | SW3 | Bore-well | 15.09.08 | 7.1 | 402 | 56.0 | 98.0 | 2.3 | 1.5 | 0.0 | 3.8 | 8.6 | 28.0 | 5.0 | 219.0 | 0.55 | ND |
| 5 | Shakti Nagar | XW4 | Bore-well | 16.09.08 | 7.0 | 180 | 261.0 | 53.0 | 2.5 | 2.6 | 0.0 | 56.1 | 15.0 | 56.0 | 2.7 | 150.1 | 0.32 | ND |
| 6 | Sarangpani Lake BHEL | RW3 | Surface water | 16.09.08 | 8.1 | 470 | 170.0 | 49.0 | 1.2 | 0.9 | 0.0 | 30.0 | 16.6 | 30.0 | 2.0 | 340.0 | 0.00 | ND |
| 7 | Bagsewania | AD1 | Bore-well | 19.09.08 | 7.3 | 350 | 89.0 | 40.0 | 1.4 | 1.5 | 0.0 | 14.2 | 15.2 | 21.2 | 1.0 | 307.0 | 0.00 | ND |
| 8 | Bhadbhada (Upper Lake) | AA2 | Surface water | 19.09.08 | 7.0 | 741 | 59.0 | 35.0 | 2.9 | 7.2 | 0.0 | 32.6 | 8.4 | 31.0 | 2.0 | 548.1 | 0.21 | ND |
| 9 | Baghmugaliya | AD2 | Bore-well | 19.09.08 | 7.5 | 129 | 42.0 | 40.0 | 0.2 | 1.2 | 0.0 | 18.2 | 18.2 | 29.6 | 1.2 | 129.0 | 0.00 | ND |
| 10 | Barkhedi | HW1 | Bore-well | 19.09.08 | 8.0 | 430 | 116.0 | 116.0 | 4.9 | 3.6 | 0.0 | 46.1 | 16.2 | 8.4 | 2.6 | 346.1 | 0.00 | ND |
| 11 | Jawahar Chowk | PW1 | Bore-well | 19.09.08 | 7.2 | 170 | 150.0 | 128.0 | 1.2 | 0.1 | 0.0 | 59.8 | 14.6 | 36.1 | 1.9 | 796.0 | 0.00 | ND |
| 12 | Banskhedi | AC1 | Bore-well | 19.09.08 | 7.0 | 540 | 168.0 | 79.0 | 2.9 | 4.5 | 0.0 | 60.0 | 12.3 | 28.5 | 3.8 | 750.1 | 0.22 | ND |
| 13 | 6 No.-Bus Stop | IW1 | Bore-well | 21.09.08 | 7.1 | 219 | 102.0 | 21.0 | 5.9 | 2.6 | 0.0 | 108.8 | 30.2 | 15.9 | 3.0 | 419.0 | 1.30 | ND |
| 14 | Upper Lake Kamla park | VW2 | Surface water | 21.09.08 | 8.0 | 976 | 28.0 | 75.0 | 7.6 | 6.4 | 0.0 | 20.6 | 40.9 | 8.0 | 1.0 | 136.1 | 0.00 | ND |
| 15 | Lower Lake Dhobi Ghat | VW1 | Surface water | 21.09.08 | 7.1 | 740 | 86.0 | 68.0 | 7.2 | 5.5 | 0.0 | 29.0 | 10.6 | 39.0 | 0.4 | 690.2 | 0.24 | 4.8 |
| 16 | Kaliyasot Dam | AB1 | Surface water | 22.09.08 | 7.6 | 239 | 329.0 | 110.0 | 1.8 | 2.7 | 0.0 | 52.1 | 26.2 | 25.7 | 1.4 | 128.0 | 0.12 | ND |
| 17 | Tajul Masajid | JW1 | Bore-well | 22.09.08 | 7.4 | 1046 | 65.0 | 80.0 | 2.8 | 1.8 | 0.0 | 281.2 | 41.6 | 7.9 | 1.0 | 350.0 | 0.00 | ND |
| 18 | Ram Mandir (Chuna Bhatti) | QW1 | Bore-well | 22.09.08 | 7.2 | 185 | 138.0 | 65.0 | 1.6 | 2.3 | 0.0 | 60.2 | 15.0 | 30.5 | 1.5 | 649.1 | 1.10 | ND |
| 19 | Shahpura Lake | RW1 | Surface water | 23.09.08 | 7.5 | 868 | 384.0 | 59.0 | 1.7 | 3.0 | 0.0 | 46.0 | 18.9 | 14.5 | 2.0 | 743.0 | 1.00 | ND |
| 20 | Rose Garden | IW1 | Bore-well | 23.09.08 | 7.6 | 502 | 225.0 | 48.0 | 4.3 | 3.8 | 0.0 | 58.1 | 39.1 | 24.0 | 6.8 | 159.1 | 0.00 | ND |
| 21 | BSNL Extention | RW2 | Bore-well | 14.09.08 | 7.1 | 819 | 158.2 | 40.0 | 20.0 | 9.5 | -0 | 100.0 | 19.2 | 22.0 | 1.9 | 524.0 | 0.00 | ND |
| 22 | Chunna Bhatti | AB2 | Bore-well | 14.09.08 | 7.2 | 455 | 143.8 | 32.0 | 56.0 | 1.3 | 0.0 | 90.0 | 15.5 | 23.0 | 0.1 | 299.0 | 0.11 | ND |
| 23 | Near Kolar Bridge | KW1 | Bore-well | 17.09.08 | 7.3 | 778 | 115.8 | 54.4 | 23.2 | 10.2 | 0.0 | 136.0 | 16.0 | 40.0 | 0.1 | 498.0 | 0.11 | ND |
| 24 | Kanha Kunj | JW3 | Bore-well | 17.09.08 | 7.5 | 447 | 119.6 | 24.0 | 2.8 | 7.1 | 0.4 | 60.0 | 19.4 | 18.0 | 0.1 | 488.0 | 0.37 | ND |
| 25 | Loke Nagar | IW1 | Bore-well | 18.09.08 | 7.1 | 644 | 178.6 | 21.6 | 53.0 | 7.8 | 0.2 | 66.0 | 42.8 | 27.0 | 0.1 | 412.0 | 0.46 | ND |
| 26 | Bairagarh | OW1 | Bore-well | 18.09.08 | 7.0 | 880 | 214.0 | 68.8 | 79.0 | 12.8 | 0.0 | 112.0 | 28.2 | 44.0 | 0.8 | 580.0 | 0.00 | ND |
| 27 | Harshwardhan Nagar | JW1 | Bore-well | 20.09.08 | 7.3 | 182 | 135.0 | 61.2 | 142.0 | 7.6 | -0.3 | 168.0 | 18.4 | 43.0 | 6.0 | 443.0 | 0.23 | ND |
| 28 | Kotra Sultanabad | VW3 | Bore-well | 20.09.08 | 7.2 | 470 | 258.6 | 54.3 | 58.0 | 6.6 | 0.0 | 148.0 | 17.2 | 31.0 | 6.5 | 621.0 | 0.00 | ND |
| 29 | Nehru Nagar | PW2 | Bore-well | 20.09.08 | 8.0 | 679 | 170.5 | 60.6 | 33.0 | 0.3 | 1.1 | 152.0 | 15.6 | 34.0 | 6.5 | 429.0 | 1.10 | ND |
| 30 | Depo Chauraha | PW3 | Bore-well | 24.09.08 | 76.0 | 526 | 160.8 | 56.0 | 51.0 | 1.1 | 1.2 | 140.0 | 19.4 | 32.0 | 6.2 | 361.0 | 1.20 | ND |
| 31 | New Market | VW5 | Bore-well | 24.09.08 | 7.1 | 442 | 123.9 | 40.0 | 59.0 | 1.1 | 0.1 | 100.0 | 9.7 | 33.0 | 4.0 | 283.0 | 0.24 | ND |
| 32 | Professor Colony | PW5 | Bore-well | 24.09.08 | 8.1 | 297 | 110.8 | 32.0 | 27.0 | 0.1 | 1.2 | 60.0 | 8.7 | 14.0 | 2.6 | 164.0 | 1.30 | ND |
| 33 | Bhapal Talkies | KW1 | Bore-well | 27.09.08 | 7.4 | 240 | 59.8 | 21.2 | 70.0 | 0.7 | 0.2 | 68.0 | 7.8 | 10.0 | 2.8 | 154.0 | 0.22 | ND |
| 34 | Bhopal Railway Station | QW1 | Bore-well | 27.09.08 | 7.3 | 868 | 165.8 | 51.6 | 132.0 | 4.3 | 0.0 | 144.0 | 43.7 | 52.0 | 0.6 | 818.0 | 0.00 | ND |
| 35 | Teela jamalpura | PW1 | Bore-well | 28.09.08 | 7.6 | 871 | 302.6 | 75.1 | 121.0 | 10.2 | 0.0 | 164.0 | 36.0 | 30.0 | 6.3 | 677.0 | 0.00 | ND |
| 36 | Near LIC Factory | SW1 | Bore-well | 03.10.08 | 7.5 | 831 | 122.0 | 38.2 | 128.0 | 3.9 | 0.0 | 98.0 | 15.0 | 74.0 | 0.8 | 532.0 | 0.00 | ND |
| 37 | Chola Ganesh Mandir | QW4 | Bore-well | 03.10.08 | 7.2 | 794 | 165.1 | 60.1 | 36.0 | 2.0 | 0.0 | 152.0 | 41.1 | 42.0 | 5.7 | 508.0 | 0.00 | ND |
| 38 | Nishatpura | QW3 | Bore-well | 06.10.08 | 7.6 | 1006 | 263.0 | 56.1 | 123.0 | 0.2 | 0.0 | 140.0 | 58.3 | 44.0 | 1.0 | 643.0 | 0.00 | ND |
| 39 | E-1 Arera Colony | WW1 | Bore-well | 06.10.08 | 7.1 | 531 | 107.8 | 28.1 | 56.0 | 2.8 | 0.0 | 12.0 | 18.4 | 24.0 | 0.4 | 340.0 | 0.41 | ND |
| 40 | E-3 Arera Colony | WW2 | Bore-well | 06.10.08 | 8.3 | 490 | 121.6 | 24.1 | 53.0 | 4.8 | 2.3 | 60.0 | 32.1 | 28.0 | 0.4 | 307.0 | 2.30 | ND |
| 41 | E-7 Arera Colony | WW3 | Bore-well | 11.10.08 | 7.2 | 797 | 89.9 | 48.2 | 137.0 | 16.8 | 0.0 | 108.0 | 28.2 | 52.0 | 2.2 | 452.0 | 0.11 | ND |
| 42 | E-8 Kishna Vihar | WW4 | Bore-well | 11.10.08 | 7.7 | 572 | 29.0 | 12.0 | 154.0 | 0.7 | 0.0 | 30.0 | 11.7 | 30.0 | 0.3 | 306.0 | 0.12 | ND |
| 43 | Bawadia Kalan Exten. | CW2 | Bore-well | 16.10.08 | 8.3 | 806 | 165.9 | 36.3 | 158.0 | 13.1 | 19.3 | 83.0 | 59.3 | 31.0 | 0.1 | 516.0 | 19.20 | ND |
| 44 | E-8 Arera Colony Gulmohar | VW4 | Bore-well | 18.10.08 | 8.4 | 600 | 261.1 | 14.4 | 43.0 | 4.1 | 5.2 | 36.0 | 60.5 | 26.0 | 0.1 | 384.0 | 6.20 | ND |
| 45 | Daulat Indus. Govindpura | QW2 | Bore-well | 18.10.08 | 7.7 | 868 | 167.3 | 43.2 | 38.0 | 0.8 | 0.1 | 108.0 | 14.3 | 28.0 | 3.8 | 322.0 | 0.70 | ND |
| 46 | E-Sector Govindpura | QW5 | Bore-well | 23.10.08 | 7.6 | 1000 | 239.1 | 76.0 | 39.0 | 0.3 | 0.0 | 132.0 | 36.0 | 66.0 | 2.2 | 640.0 | 0.00 | ND |
| 47 | H-Sector Govindpura | XW1 | Bore-well | 23.10.08 | 6.5 | 480 | 418.2 | 11.2 | 53.0 | 10.3 | 60.1 | 26.0 | 10.7 | 28.0 | 0.8 | 854.0 | 1.30 | ND |
| 48 | D-Sector Govindpura | XW2 | Bore-well | 23.10.08 | 7.8 | 924 | 219.8 | 51.3 | 120.0 | 8.3 | 0.0 | 128.0 | 18.2 | 34.0 | 2.3 | 691.0 | 0.00 | ND |
| 49 | A-Sector Govindpura | RW3 | Bore-well | 24.10.08 | 7.6 | 746 | 176.9 | 22.4 | 37.0 | 2.1 | 1.1 | 96.0 | 17.9 | 60.0 | 2.6 | 479.0 | 1.40 | ND |
| 50 | Rachana Nagar | XW3 | Bore-well | 24.10.08 | 7.7 | 834 | 216.3 | 68.6 | 41.0 | 2.2 | 1.0 | 112.0 | 15.6 | 13.0 | 4.9 | 406.0 | 1.00 | ND |

## 3. METHODS AND MATERIAL

In order to assess the quality of surface and sub-surface waters of the study area. Base map of the study area has been prepared using Survey of India Toposheet Nos. 55-E/7 and 55-E/8 to show the locations of collected water samples (Map Fig. 1). In all 50 water samples have been collected from various parts of the area, by dividing the area into rectangular grid system. All the samples were taken from surface and sub-surface water bodies, both for pre and post-monsoon

spells .

Each grid has been assigned alphabets A to Z and water samples have been collected from dug wells, tube wells, etc. falling in the respective grids. They were prefixed with the block No. as $A_1$, $B_1$, $C_1$ etc. The water samples were collected in air tight polythene bottles.

The physical and chemical characters of collected water samples were determined by using pH meter, conductivity meter, flame photometer, spectrophotometer etc. The major cations and anions concentration have been determined by using analytical techniques laid down by Rainwater and Thatcher (1960) and Greenburg *et al*. (1985).

**Table 3 : Drinking water standards of WHO and MWH**

| Characteristics | World Health Organization (W.H.O.) (1987) | | Ministry of Works and Housing (MWH) (1975) | | IS 10500:1991 | | Surface water | | Sub-surface water | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Highest desirable | Maximum permissible | Acceptable | Cause of rejection | Requirement (desirable limit) | Permissible limit | Pre-monsoon | Post-monsoon | Pre-monsoon | Post-monsoon |
| Turbidity (J.T.U.) | 5 | 25 | 2.5 | 10 | 5 | 10 | Unobjectionable | Turbid | Unobjectionable | Turbid |
| Colour (pt. scale) | 5 | 50 | 5 | 25 | 5 | 25 | Colourless | Colourless | Colourless | Colourless |
| Taste and Odour | Nothing | Disagreeable | Unobjectionable | Unobjectionable | Agreeable | - | Agreeable | Agreeable | Agreeable | Agreeable |
| pH | 7.0-8.5 | 6.5-9.2 | 7.0-8.5 | 6.5-9.2 | 6.5 to 8.5 | No relaxation | 7.3-8.3 | 7.1-8.1 | 7.0-8.6 | 7.0-8.4 |
| Total solids (ppm) | 500 | 1500 | 500 | 1500 | | | 199.6-6656.0 | 128.0-743.0 | 137.0-8504.0 | 129.0-796.0 |
| Total Hardness | 100 | 500 | 200 | 6000 | 300 | 600 | 70-324 | 0.0-0.0 | 100-560 | 0.0-60.1 |
| Chlorides | 200 | 600 | 200 | 1000 | 250 | 1000 | 28-79 | 35.0-110.0 | 28-208 | 11.2-128.0 |
| Sulphates | 200 | 400 | 200 | 400 | 200 | 400 | 1.9-16.0 | 1.2-7.6 | 0.5-378 | 1.1-158.0 |
| Fluorides | 1 | 1.5 | 1 | 1.5 | 1 | 1.5 | 0.0-0.5 | - | 0.0-1.0 | - |
| Nitrates | 4.5 | 4.5 | 4.5 | 4.5 | 45 | 100 | 1.2-7.3 | 0.9-7.2 | 0.1-37.2 | 0.1-12.8 |
| Calcium | 75 | 200 | 75 | 200 | 75 | 200 | 82.4 | 20.6-52.1 | 18.6-188.0 | 3.8-281.2 |
| Magnesium | 30 | 150 | 30 | 150 | | | 17.5-48.7 | 8.4-40.9 | 4.9-60.3 | 8.4-43.7 |
| Iron | 0.1 | 1 | 0.1 | 1 | 0.3 | 1 | - | - | - | - |
| Manganese | 0.05 | 0.5 | 0.05 | 0.5 | 0.1 | 0.3 | - | - | - | - |
| Copper | 0.05 | 1 | 0.05 | 1 | 0.75 | 1.5 | - | - | - | - |
| Zinc | 5 | 15 | 5 | 15 | 5 | 15 | - | - | - | - |
| Phenolic Compounds | 0.001 | 0.002 | 0.001 | 0.002 | | | - | - | - | - |
| Arsenic | 0.05 | 0.05 | 0.05 | 0.05 | | | - | - | - | - |
| Cyanide | - | 0.05 | 0.05 | 0.05 | | | - | - | - | - |
| Lead | - | 0.1 | 0.1 | 0.1 | 0.05 | No relaxation | - | - | - | - |
| Selenium | - | 0.1 | 0.1 | 0.1 | | | - | - | - | - |
| Cadmium | - | 0.01 | 0.01 | 0.01 | | | - | - | - | - |
| Mercury | - | 0.001 | 0.001 | 0.001 | | | - | - | - | - |
| PCB. (µg/1) µ | - | 0.2 | 0.2 | 0.2 | | | - | - | - | - |
| Bacteriological standards MPN in 100 ml | Zero | Zero | Zero | Zero | | | - | - | - | - |

## 4. RESULTS AND DATA INTERPRETATION

### a) Physico – Chemical Characteristics

All water samples collected from the study area are colourless as observed by naked eye. The pH value of water samples from study area varies from 6.5 to 8.4 ppm in post-monsoon and from 7.0 to 8.62 in pre-monsoon period. These values of pH show that the water is slightly alkaline in its nature. The pH value are slightly higher than the upper limit recommended by WHO (1971) has recommended maximum permissible limit of pH from 6.5 to 8.2. The electrical conductivity of the water samples of the study area was found to vary from 129 mmho/cm to 1480 mmho/cm in post-monsoon and 96 mmho/cm to 1151 mmho/cm in pre-monsoon periods.

In the present study, alkalinity was found to range from 40 mg/lit to 528 mg/lit in post monsoon, and 68 mg/lit to 584 mg/lit in pre-monsoon periods in study area. Alkaline water may decrease the solubility of metals. The alkalinity varies in accordance with the fluctuation in the pollution load. It is observed that as the TDS increases, the specific conductivity also increases. The determined values of TDS of water samples of the study area ranges from 128 mg / lit to 854 mg / lit in post-monsoon and 137 mg / lit to 870.4 mg / lit in pre-monsoon periods. In some areas of the study area the hardness is very high and is beyond permissible limit. It may be due to slow and sluggish circulation of water through calcium and magnesium rich rocks. Bis has prescribed desirable limit of total hardness as 300 mg./ lit and permissible limit in the absence of alternate source as 600 mg. / lit. In the present study the BOD value is within limit (Upper lake 2.6 and 4.1 mg/l) while COD values varies between 13.0 - 36.0 mg/l (Upper lake). The higher values of BOD indicate presence of more biodegradable organic material accordingly (ICMR, 1975).

**b) Major Cations**

In the present study calcium content in water samples ranges from 8 ppm to 281.2 ppm in post-monsoon and 8.02 ppm to 188 ppm in pre-monsoon periods. In the present study the magnesium content in water samples of study area ranges from 8.4 ppm to 60.5 ppm in post-monsoon and 49.9 ppm to 60.3 ppm in pre-monsoon periods. In the study area the sodium content in water samples ranges from 7.9 mg/l. to 287 mg/l. in post-monsoon and 4.6 mg/l. to 395 mg/l. in pre-monsoon periods. Sodium content is found within limit in both post and pre-monsoon periods BIS has laid down the permissible limit of sodium between 60 to 120 mg/lit. The potassium is slightly less abundant then sodium and its behaviour is similar to that of sodium. The potassium content in water samples of the study area ranges from 0.1 ppm to 8 ppm in post-monsoon and 0.1 ppm to 7.2 ppm in pre-monsoon periods.

**c) Major Anions**

The important source of chloride in the water is the discharge of domestic sewage. Man and other animals excrete carry very high quantities of chloride. Therefore, the chloride concentration serves as an indicator of pollution by sewage. In the present study area chloride content in water samples ranges from 12 ppm to 128 ppm in post-monsoon and 28 ppm to 208 ppm in pre-monsoon periods. Nitrate is a powerful oxidizing agent and converts iron in the hemoglobin from ferrous to ferric form and due to this hemoglobin loses its property to carry oxygen. In the present study area the nitrate content in water samples ranges from 0.1 mg/lit. to 16.8 mg/lit. in post-monsoon and 0.12 to 37.2 mg/lit in pre-monsoon periods. Increase in sulphate ions concentration may be related to the pollution of the water body. In the present study sulphates content in water samples ranges from 1.1 mg/lit. to 158 mg/lit. in post-monsoon and 1.2 mg/lit. to 378 mg/lit. in pre-monsoon periods. The amphiboles and Micas may contain fluorine by the substitution of hydroxyl group. Fluorine forms F ions in water which may form strongly soluble complexes with aluminum, beryllium and ferric iron. In the presence of boron it forms mixed fluoride-hydroxide complexes. In present study the fluoride content in water samples ranges from 0.1 ppm to 1.4 ppm in post-monsoon and 0 ppm to 1 ppm in pre-monsoon periods. A concentration of 0.02 mg/l of phosphate has been suggested by Mc. Neeley, *et al*. (1979) as the acceptable limit in potable water. Six representatives water samples of surface water bodies have been selected for determination of phosphate concentration. Concentration of phosphate observed in Lower lake during pre-monsoon period was 9 mg/l and in post-monsoon period it has been found to be 4.80 mg/l, while in other water samples the value is less than 0.08 mg/l. The critical limit ranges from (0.06 to 0.08 mg/l). Excessive growth of aquatic plants has taken place in Lower lake water which has led to hyper-eutropic conditions in the Lower lake and thereby making it highly polluted The values of carbonate alkalinity in the water samples ranges from 0 ppm to 2.3 ppm in post-monsoon and 0 ppm to 48 ppm in pre-monsoon periods. Bicarbonate is the predominant anion in the water samples of the study area. Its concentration varies from 28 ppm to 418.2 ppm in post-monsoon and 56 ppm to 480 ppm in pre-monsoon periods.

**d) Graphical Representation of Chemical Analysis**

To represent chemical data of water, several graphical methods are available for immediate characterization of water for a particular purpose. H.A. Stiff (Jr.) (1951) has proposed the ionic concentration diagram for representing the chemical analysis of water. In order to understand the variation in hydro-chemical facies with space and time the data has been plotted on the pipers trilinear diagram (Fig. 2 and Fig. 3). The data in part per million (ppm) was converted into equivalent per million (epm).

It is seen from the Fig. 2 that out of fifty (50) samples of post-monsoon season, 33 samples (66%) represent Ca + Mg (alkaline earths), 17 samples (34%) belong to Ca + Mg > Na + K (alkaline earths exceeds alkalies) hydro-chemical facies. Similarly, 34 samples (68%) represent Cl + $SO_4$ > $HCO_3$ + $CO_3$ (strong acid exceeds weak acids) hydro-chemical facies. 16 samples (32%) represent $HCO_3$ + $CO_3$ > Cl + $SO_4$ (weak acid exceeds strong acids) (Table 4). 17 samples (34%) represent to Ca + Mg (alkaline earths) and 33 samples (66%) belong to Ca + Mg > Na + K (alkaline earths exceeds alkalies) hydrochemical facies. Similarly 30 samples (60%) represent Cl + $SO_4$ > $HCO_3$ + $CO_3$ (strong acid exceeds weak acid) and 20 samples (40%) belong to $HCO_3$ + $CO_3$ > Cl + $SO_4$ (weak acid exceeds strong acid) hydrochemical facies (Table 4).

**Table 4 : Distribution of surface and sub-surface water samples according to water types based on Pipers trilinear diagram**

| S. No. | Type of Facies | Post Monsoon | Pre Mon soon |
|---|---|---|---|
| 1. | Ca + Mg | 33 | 17 |
| 2. | Ca + Mg > $N_a$ + K | 17 | 33 |
| 3. | Cl + $So_4$ > $Hco_3$ + $Co_3$ | 34 | 30 |
| 4. | $CHO_3$ + $CO_3$ > Cl + $So_4$ | 16 | 20 |

## 5. DISCUSSION AND CONCLUSIONS :

In order to assess the quality of surface and sub-surface waters of the area physico-chemical characteristics, major cations and anions have been determined (Table 1 and 2) besides the drinking water standards as suggested by IS10500 : 1991 (Table 3). To understand the variation in hydro-chemical facies with space and time the chemical data has been plotted on the pipers trilinear diagrams which clearly show the types of facies exists in (Table 4) the surface and sub-surface water samples of the study area as mentioned earlier.

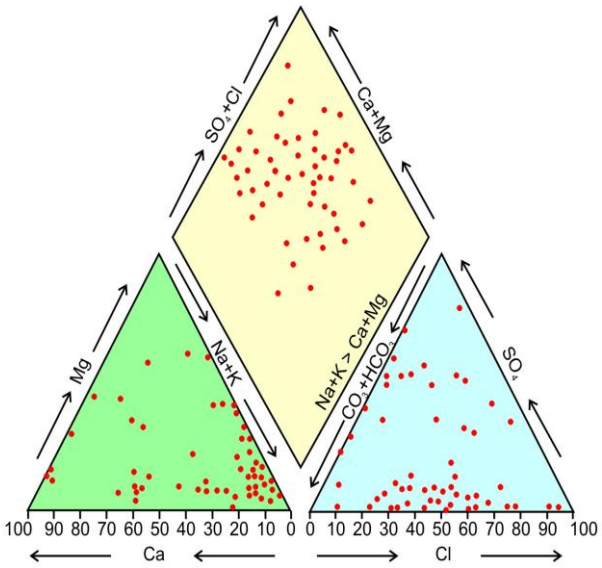


**Fig. 2**
**Piper (trilinear) classification of hydrochemical facies of the study area (Surface and sub-surface water samples) - Post-monsoon**

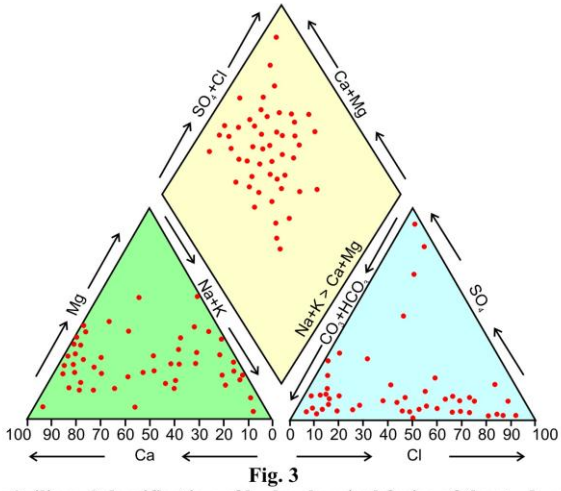


**Fig. 3**
**Piper (trilinear)classification of hydrochemical facies of the study area (Surface and sub-surface water samples) - Pre-monsoon**

Colour, temperature, taste, odour and turbidity of the collected water samples, in case, where water is used for drinking purposes is not objectionable while in other parts like Lower lake, Shahpura lake, Rachna Nagar, Shantinagar and M.P. Nagar areas objectionable taste, odour and turbidity can be observed, which makes water unsuitable for drinking use. pH values of water samples from the study area shows that the water is slightly alkaline in its nature. The higher electrical conductivity of the water samples during post-monsoon spells observed in comparison to pre-monsoon spells. The value of conductivity and dissolved solids are directly proportional to each other. The important part of urban development sanitary system that in being given least priority, this can be achieved by designing better sewage system for the entire city with provision of sewage treatment plants.

It is expected that if implemented would shape up the water scenario of Bhopal in an eco-friendly direction and scale down the overall exploitation there by maintaining the equilibrium between the recharge and discharge.

As mentioned earlier alkalinity is produced by anions or molecular species of week acids mainly carbonates, bicarbonates and hydroxyl ions. The alkalinity varies in accordance with the fluctuation in the pollution load. It is worthy to mention here that as the TDS increases, the specific conductivity also increases. In case of present study area, in some parts the hardness is very high and is beyond permissible limit. It may be due to slow and sluggish circulation of water through calcium and magnesium rich rocks. The higher values of the BOD have direct correlation with the increase in nutrient level of the lake due to various activities including immersion of idols etc. The COD test is helpful in indicating toxic conditions and the presence of biologically resistant organic substances. Higher COD has been noticed during post monsoon period in the study area.

In the study area magnesium is in the permissible limit. Sodium and potassium also found in the permissible limits in the water samples of the study area.

The higher concentration of chloride is the prime concern in some parts of the study area. In these parts, the discharge of domestic waste mixed into water bodies and pollutes the natural source of potable water.

Sulphate and fluoride concentrations in the water samples of the study area are well within limits. The concentration of phosphate in surface water bodies like Lower lake & Shahpura lake was exceptionally higher in comparison to other parts of the study area. A significant variation in the concentration of nitrate and phosphate in pre-monsoon and post-monsoon season was observed in the Upper lake water which may be attributed to the different agricultural activities in the field surrounding the lake. In the study area mainly in Rachna Nagar and Shanti Nagar there is the high concentration of nitrate in due to disposal of untreated sewage through open and unlined drain

nallas and indiscriminately dumping of solids.

Excessive growth of aquatic plants has taken place in the lakes which has led to hyper-eutropic conditions and thereby making it highly polluted.

In the present study the physical and chemical character of Natural water has been utilized and evaluated on the basis of water quality standard proposed by Indian Council Medical Research (1983), World Health organization (1987) and ISI (1991). As per these standards the natural water used for drinking purpose should have no visible suspended material, colour, Turbidity, odour and any objectionable toxic constituents.

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