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# Seasonal and Spatial Variation of Water Quality Index of Bassi Tehsil of District Jaipur, Rajasthan, India

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*Keywords: groundwater quality, physico-chemical parameters, water quality index, bassi tehsil and rajasthan.*

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# Seasonal and Spatial Variation of Water Quality Index of Bassi Tehsil of District Jaipur, Rajasthan, India

Swati Saxena [α], Umesh Saxena [σ] & A. K. Sinha [ρ]

*Abstract-* The present study was intended to calculate the water quality index (WQI) of Bassi Tehsil of district Jaipur, Rajasthan, India in order to assess its suitability for drinking purpose. For this ground water samples from 71 sampling sites of 50 villages of study area were collected from tube wells and hand pumps of varying depths in pre and post monsoon seasons and analyzed for ten physico-chemical parameters namely pH, Total Alkalinity, Total Hardness, Calcium, Magnesium, Chloride, Nitrate, Fluoride, Total Dissolved Solid and Electrical Conductivity. Analysis of results showed that almost all parameters were exceeding the permissible limits prescribed by BIS, ICMR and WHO. Assessment of water quality index (WQI) showed remarkable variation of water quality as WQI values ranged from 13.53 to 1052.2 in pre-monsoon and 25.72 to 1024.6 in post monsoon season. The study also revealed that drinking water of Bassi tehsil is not potable and there is an instant need to take ameliorative steps in this region to prevent the population from adverse health effects as 61.97% and 63.38% ground water samples were classified under "unsuitable for drinking" category in accordance with their WQI values in pre and post monsoon seasons, respectively.

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## I. Introduction

*"Jalam Jeevamrutham"* Water is one of the five elements described in "shastra" to life. It is also one of the most important commodities which Man has exploited than any other resource for sustenance of his life. Potable safe water is absolutely essential and is the basic need of all human beings on the earth. Due to modern civilization, rapid urbanization, and industrialization, subsequent contamination of surface and ground water sources, water conservation and water quality management has now a day's assumed a very complex shape. Attention on contamination and its management has become a need of the hour, because of its far reaching impact on human health.

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In India so many factors contribute to pollution of ground water such as; scarcity of water resources, uncontrolled population, urbanization, poverty, lack of education, lack of political commitment etc. Groundwater quality is highly dependent on the nature of the aquifers and on the surrounding climatic conditions (Chand, 2013; Dhok et al., 2011).

Assessment of the groundwater quality has always been important in the field of environmental quality management. One of the most effective tools for the assessment and management of the water quality is Water quality index; it offers a simple, stable, reproducible unit of measure and communicates information of water quality to the concerned citizens and policy makers (Chauhan and Singh, 2010). The water quality is difficult to evaluate from a large number of samples, each containing concentrations of many parameters. WQI is a mathematical instrument used to transform large quantities of water quality data into a single number which represents the water quality level while eliminating the subjective assessments of water quality and biases of individual water quality experts (Yogendra and Puttaaiah, 2008; Chowdhury et al., 2012; Khwakaram et al., 2012; Hussain et al., 2014).

## II. Study Area

Rajasthan is known as "the land of king" and it is the largest state of the republic of India in terms of geographical spread. It is situated in the North- Western part of India having total area is around 3,42,239 Sq. Km. Which represents 10.41 % of total area of the country and population of 6.86 Crores spread over in 44,672 villages, which is 5.67 % of nations population but being just available 1% of the total water resources of the country. The state has extreme climatic and geographical condition and it suffers both the problems of quantity and quality of water (Bhalla and Bhalla, 2013; Yadav et al., 2010).

Jaipur, the capital of Rajasthan, has a total area of 11,117 sq. Km covering the 3.23% of the total area of the state, administered by 13 tehsils or sub-divisions. Our focused area of study is Bassi tehsil, out of the 13 tehsils of Jaipur district. The area of tehsil is 654.69 sq.km, located at $26^{0}96'$ N latitude and $75^{0}62'$E longitude. In Bassi Tehsil there are 210 villages (famous for their



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leather footwear and Embroidery beading). In the study area there are no major surface water sources however; main sources of drinking water are open wells, hand pumps and bore wells (Singh et al., 2012; CGWB, 2007; JDA, 2012).

In Bassi Tehsil 84 villages are reported having fluoride concentration more than 1.5 ppm, 78 villages are exhibiting nitrate concentration more than 45 ppm and 30 villages are having Electrical conductivity more than 3000 micromhos/cm (CGWB, 2007; Mathur, 2007).

Review of literature reveals that no studies have been made to scientifically investigate the ground water contamination of the study area. The present study aims to calculate the Water Quality Index (WQI) in most rural habitations of Bassi Tehsil of Jaipur, Rajasthan, India in order to assess the suitability of ground water for human uses and it also deals with the necessity of restoring the water quality.

## III. Materials and Methods

*a) Sample Collection*

Ground water samples from a total of 71sampling sites of 50 villages of Bassi Tehsil were collected in pre-cleaned and rinsed polyethene bottles of two litre capacity with necessary precautions (Brown et al. 1974). The total water collection in the year of 2013 is divided in to two seasons, one is pre monsoon and another one is post monsoon. The sampling is carried out, during April 2013 for pre monsoon season and in September-October 2013 for post monsoon season from manually operated tube wells and hand pumps of varying depth.

*b) Physico-chemical Analysis*

All the samples were analyzed for the following Physico-chemical parameters; pH, Total Alkalinity (TA), Total Hardness (TH), Calcium hardness (Ca H), Magnesium hardness (Mg H), Chloride, Nitrate, Fluoride, Total Dissolved Solid (TDS) and Electrical Conductivity (EC). The analysis of water samples were out carried in accordance to standard analytical methods (APHA, 2005). All the chemicals used were of AR grade and double distilled water used for preparation of solutions. Details of the analysis methods are summarized in Table 1.

*Table 1 :* Parameters and methods employed in the physicochemical examination of water samples

| S.No. | Parameters | Unit | Method Employed |
|---|---|---|---|
| 1. | pH | - | Digital pH-meter |
| 2. | Total Alkalinity | Mg/L | Titrimetric method (With $H_2SO_4$) |
| 3. | Total Hardness (as $CaCO_3$) | Mg/L | Titrimetric method (with EDTA) |
| 4. | Calcium Hardness (as $CaCO_3$) | Mg/L | Titrimetric method |
| 5. | Magnesium Hardness (as $CaCO_3$) | Mg/L | Titrimetric method |
| 6. | Chloride (as $Cl^-$) | Mg/L | Titrimetric method (With $AgNO_3$) |
| 7. | Nitrate (as $NO_3^-$) | Mg/L | Spectrophotometric method |
| 8. | Fluoride (as $F^-$) | Mg/L | Ion Selective Electrode |
| 9. | Total Dissolved Solids | Mg/L | Digital TDS-meter |
| 10. | Electrical Conductivity | $\mu$mhos/cm | Digital Conductivity-meter |

*c) Water Quality Index (WQI) Calculation*

The calculation of WQI was made using weighed arithmetic index method (Brown et al., 1972) in the following steps-

*Step I- Calculation of sub index of quality rating (qn)*- Let there be n water quality parameters where the quality rating or sub index (*qn*) corresponding to the nth parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value. The value of *qn* is calculated using the following expression.

$$qn = 100[(Vn - Vio) / (Sn - Vio)]$$

where,

*qn* = quality rating for the nth water quality parameter.

*Vn* = estimated value of the nth parameter at a given sampling station.

*Sn* = standard permissible value of nth parameter

*Vio* = ideal value of *n*th parameter in pure water.

All the ideal values (*Vio*) are taken as zero for drinking water except for pH=7.0 and dissolved oxygen=14.6mg/L.

*Calculation of quality rating for pH*

For pH the ideal value is 7.0 (for natural water) and a permissible value is 8.5 (for polluted water). Therefore, the quality rating for pH is calculated from the following relation:

$$qpH = 100\ [(VpH - 7.0)/(8.5 - 7.0)]$$

where

*VpH* = observed value of pH during the study period.

*Calculation of quality rating for dissolved oxygen*

The ideal value (*VDO*) for dissolved oxygen is 14.6 mg/L and standard permitted value for drinking water is 5 mg/L. Therefore, quality rating is calculated from following relation:

$$qDO = 100\ [(VDO - 14.6)/(5 - 14.6)]$$

Where,

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*VDO* = measured value of dissolved oxygen

*Step II- Calculation of unit weight (Wn)*

Calculation of unit weight (*Wn*) for various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

$$Wn = K/Sn$$

Where,

*Wn* = unit weight for nth parameters

*Sn* = standard value for nth parameters

*K* = constant for proportionality

The value of 'K' can be determined by-

$$K = \frac{1}{\frac{1}{S1}+\frac{1}{S2}+\cdots\ldots\frac{1}{Sn}} = \frac{1}{\frac{1}{\sum Sn}}$$

*Step III-Calculation of WQI*

WQI is calculated from the following equation-

$$WQI = \Sigma\, q_n Wn \,/\, \Sigma\, Wn$$

*Table 2 :* Water Quality Index (WQI) range and Quality Status of Water

| Water Quality Index | Description |
|---|---|
| 0-25 | Excellent Water Quality |
| 26-50 | Good |
| 51-75 | Poor |
| 76-100 | Very poor |
| >100 | Unsuitable for drinking |

*(Brown et al., 1972; Hariharan, 2007; Yogendra and Puttaiah, 2008; Chowdhury et al., 2012; Eugene et al., 2014; Sisodia and Moundiotiya, 2006; Rao et al., 2010)*

## IV. Result and Discussion

*a) Physico-chemical Parameters*

The respective values of all observed water quality parameters of groundwater samples in pre and post monsoon seasons are illustrated in Table 3 and 5 respectively. Statistical Parameters of groundwater samples of study area in both seasons are summarized in Table 4 and 6.

*b) Quality Assessment using WQI*

Water quality parameters mentioned in Table 3 and 5 are considered for calculating the WQI values using the above mentioned method. The water quality weightings used in the formula are mentioned in Table 7.

i. *Seasonal Variation of WQI*

Lower WQI values indicate that water is free from impurities at the sampling site, while WQI values more than 100 represents the polluted nature of water and its unsuitability for drinking purpose. Water Quality Index values for pre and post monsoon seasons are calculated and presented in Table 8. Developed Pie-diagrams (Figure 1 and 3) states the percentage variations of different qualities of waters in pre and post monsoon seasons, while Figure 2 and 4 represents the number of sampling sites classified on the basis of WQI values. From the results, it is seen that the WQI values in pre and post monsoon seasons are in the range of 13.53 to 1052.2 and 25.72 to 1024.6 respectively. The graphical representation of WQI values of ground water samples in Pre and Post monsoon seasons depicts that there is not any significant change in WQI values with respect to water quality.



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*Table 3 :* Physico Chemical Characteristics of Groundwater Samples– Pre Monsoon Season

| S.No. | Village | Source | Sample No. | Colour | Odour | pH | Alkalinity | TH | CaH | $Ca^{+2}$ ions | MgH | $Mg^{+2}$ ions | $Cl^-$ | $NO_3^-$ | $F^-$ | TDS | EC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Akhepura | HP | S1 | UO | UO | 7.9 | 411 | 529 | 237 | 94.8 | 292 | 70.95 | 400 | 56 | 0.71 | 2216 | 3165 |
| | | TW | S2 | UO | UO | 8.4 | 305 | 115 | 43 | 17.2 | 72 | 17.49 | 31 | 15 | 1.44 | 778 | 1111 |
| 2 | Anantpura | HP | S3 | UO | UO | 7.9 | 748 | 360 | 151 | 60.4 | 209 | 50.78 | 278 | 22 | 0.37 | 2100 | 3000 |
| | | TW | S4 | UO | UO | 8.3 | 462 | 161 | 67 | 26.8 | 94 | 22.84 | 176 | 18 | 1.8 | 1470 | 2100 |
| 3 | Banskho | HP | S5 | UO | UO | 7.5 | 651 | 516 | 172 | 68.8 | 344 | 83.59 | 137 | 28 | 2.12 | 1696 | 2422 |
| | | TW | S6 | UO | UO | 8.4 | 396 | 105 | 40 | 16 | 65 | 15.79 | 123 | 12 | 1.99 | 1298 | 1855 |
| 4 | Barala | HP | S7 | UO | UO | 7.5 | 586 | 192 | 78 | 31.2 | 114 | 27.7 | 333 | 78 | 2.05 | 2146 | 3065 |
| 5 | Bassi | HP | S8 | UO | UO | 8.4 | 258 | 158 | 64 | 25.6 | 94 | 22.84 | 202 | 86 | 1.14 | 1590 | 2271 |
| | | TW | S9 | UO | UO | 7.8 | 333 | 156 | 67 | 26.8 | 89 | 21.62 | 163 | 44 | 0.79 | 1191 | 1701 |
| 6 | Benada | HP | S10 | UO | UO | 7.6 | 435 | 732 | 336 | 134.4 | 396 | 96.22 | 315 | 131 | 0.93 | 1740 | 2486 |
| 7 | Bharampur | HP | S11 | UO | UO | 7.7 | 368 | 188 | 78 | 31.2 | 110 | 26.73 | 176 | 20 | 0.42 | 920 | 1314 |
| 8 | Chainpuriya | HP | S12 | UO | UO | 7.7 | 562 | 115 | 46 | 18.4 | 69 | 16.76 | 80 | 12 | 1.3 | 1034 | 1477 |
| 9 | Chapariya | HP | S13 | UO | UO | 7.7 | 426 | 163 | 70 | 28 | 93 | 22.59 | 60 | 70 | 1.13 | 760 | 1085 |
| 10 | Charangarh | HP | S14 | UO | UO | 7.4 | 243 | 264 | 121 | 48.4 | 143 | 34.74 | 33 | 29 | 0.71 | 792 | 1131 |
| 11 | Chatarpura | HP | S15 | UO | UO | 7.6 | 707 | 112 | 45 | 18 | 67 | 16.28 | 65 | 19 | 4.67 | 1200 | 1714 |
| 12 | Danau Kalan | HP | S16 | UO | UO | 8.2 | 582 | 46 | 22 | 8.8 | 24 | 5.83 | 20 | 22 | 1.4 | 1055 | 1507 |
| 13 | Danau Khurd | HP | S17 | UO | UO | 7.7 | 409 | 568 | 206 | 82.4 | 362 | 87.96 | 484 | 8 | 0.9 | 2644 | 3777 |
| | | TW | S18 | UO | UO | 8.2 | 458 | 284 | 121 | 48.4 | 163 | 39.6 | 140 | 22 | 2.9 | 1680 | 2400 |
| 14 | Garh | HP | S19 | UO | UO | 8.1 | 651 | 108 | 44 | 17.6 | 64 | 15.55 | 361 | 118 | 1 | 1962 | 2803 |
| 15 | Ghasipura | HP | S20 | UO | UO | 8.4 | 344 | 88 | 32 | 12.8 | 56 | 13.6 | 20 | 38 | 0.03 | 847 | 1210 |
| | | TW | S21 | UO | UO | 8.3 | 766 | 74 | 33 | 13.2 | 41 | 9.96 | 51 | 26 | 11.4 | 1613 | 2304 |
| 16 | Ghata | HP | S22 | UO | UO | 7.1 | 402 | 437 | 198 | 79.2 | 239 | 58.07 | 601 | 11 | 0.86 | 2593 | 3704 |
| | | TW | S23 | UO | UO | 7.3 | 467 | 632 | 297 | 118.8 | 335 | 81.4 | 468 | 14 | 0.7 | 2171 | 3101 |
| 17 | Gudha Meena | HP | S24 | UO | UO | 7.8 | 423 | 160 | 66 | 26.4 | 94 | 22.84 | 23 | 18 | 0.27 | 980 | 1400 |
| 18 | Gumanpura | HP | S25 | UO | UO | 7.8 | 460 | 317 | 128 | 51.2 | 189 | 45.92 | 380 | 16 | 0.88 | 2310 | 3300 |
| | | TW | S26 | UO | UO | 7.9 | 595 | 528 | 238 | 95.2 | 290 | 70.47 | 259 | 72 | 1.4 | 1764 | 2520 |
| 19 | Gwalini | HP | S27 | UO | UO | 7.9 | 520 | 374 | 171 | 68.4 | 203 | 49.32 | 22 | 8 | 1.8 | 1333 | 1904 |
| 20 | Hans Mahal | HP | S28 | UO | UO | 7.6 | 157 | 424 | 187 | 74.8 | 237 | 57.59 | 220 | 7 | 0.32 | 1182 | 1688 |
| 21 | Hanumanpura | HP | S29 | UO | UO | 7.7 | 552 | 123 | 51 | 20.4 | 72 | 17.49 | 83 | 27 | 0.8 | 967 | 1381 |
| | | TW | S30 | UO | UO | 8.2 | 784 | 67 | 23 | 9.2 | 44 | 10.69 | 95 | 24 | 12.5 | 1473 | 2104 |
| 22 | Jhajhwar | HP | S31 | UO | UO | 7.4 | 523 | 668 | 283 | 113.2 | 385 | 93.55 | 1430 | 58 | 0.41 | 4235 | 6050 |
| | | TW | S32 | UO | UO | 8.4 | 254 | 109 | 45 | 18 | 64 | 15.55 | 107 | 45 | 0.8 | 980 | 1400 |
| 23 | Jhar | HP | S33 | UO | UO | 7.9 | 412 | 233 | 102 | 40.8 | 131 | 31.83 | 44 | 37 | 0.65 | 960 | 1371 |
| 24 | Kalyanpura | HP | S34 | UO | UO | 8.5 | 527 | 89 | 36 | 14.4 | 53 | 12.87 | 28 | 34 | 1.3 | 1122 | 1603 |
| | | TW | S35 | UO | UO | 8.2 | 530 | 65 | 22 | 8.8 | 43 | 10.44 | 41 | 16 | 1.8 | 1190 | 1700 |
| 25 | Kaneta | HP | S36 | UO | UO | 7.8 | 286 | 364 | 144 | 57.6 | 220 | 53.46 | 1424 | 6 | 0.11 | 4762 | 6802 |
| | | TW | S37 | UO | UO | 8.4 | 564 | 77 | 34 | 13.6 | 43 | 10.44 | 40 | 14 | 0.7 | 1050 | 1500 |
| 26 | Kaneti | HP | S38 | UO | UO | 7.5 | 586 | 867 | 322 | 128.8 | 545 | 132.43 | 1075 | 236 | 1.06 | 4890 | 6985 |
| 27 | Kanota | HP | S39 | UO | UO | 8.3 | 409 | 203 | 90 | 36 | 113 | 27.45 | 296 | 33 | 0.62 | 1835 | 2621 |
| | | TW | S40 | UO | UO | 8.4 | 741 | 91 | 36 | 14.4 | 55 | 13.36 | 225 | 8 | 1.7 | 1983 | 2833 |
| 28 | Kashipura | HP | S41 | UO | UO | 7.5 | 695 | 105 | 40 | 16 | 65 | 15.79 | 90 | 21 | 3.2 | 1305 | 1864 |
| 29 | Keshopura | HP | S42 | UO | UO | 7.6 | 555 | 350 | 140 | 56 | 210 | 51.03 | 644 | 5 | 0.75 | 2520 | 3600 |
| 30 | Kuthada Kalan | HP | S43 | UO | UO | 7.1 | 233 | 66 | 25 | 10 | 41 | 9.96 | 20 | 22 | 0.77 | 709 | 1013 |
| 31 | Lalgarh | HP | S44 | UO | UO | 7.6 | 510 | 284 | 122 | 48.8 | 162 | 39.36 | 230 | 15 | 1.42 | 1240 | 1771 |
| 32 | Mundali | HP | S45 | UO | UO | 7.7 | 482 | 117 | 46 | 18.4 | 71 | 17.25 | 55 | 12 | 4.2 | 1321 | 1887 |
| | | TW | S46 | UO | UO | 8.2 | 734 | 90 | 34 | 13.6 | 56 | 13.6 | 152 | 26 | 3.38 | 1682 | 2404 |
| 33 | Nagal Karna | HP | S47 | UO | UO | 7.4 | 371 | 154 | 57 | 22.8 | 97 | 23.57 | 60 | 11 | 4.35 | 1295 | 1850 |
| | | TW | S48 | UO | UO | 8.1 | 795 | 73 | 32 | 12.8 | 41 | 9.96 | 80 | 26 | 5.9 | 1610 | 2300 |
| 34 | Parasoli | HP | S49 | UO | UO | 7.7 | 412 | 774 | 397 | 158.8 | 377 | 91.61 | 320 | 2 | 1.17 | 2146 | 3065 |
| | | TW | S50 | UO | UO | 8.4 | 464 | 78 | 35 | 14 | 43 | 10.44 | 60 | 23 | 2.2 | 1050 | 1500 |
| 35 | Parempura | HP | S51 | UO | UO | 7.8 | 431 | 641 | 283 | 113.2 | 358 | 86.99 | 444 | 18 | 1.15 | 3474 | 4963 |
| 36 | Patan | HP | S52 | UO | UO | 7.1 | 655 | 622 | 264 | 105.6 | 358 | 86.99 | 885 | 10 | 0.52 | 3535 | 5050 |
| 37 | Peepalabai | HP | S53 | UO | UO | 7.2 | 160 | 374 | 209 | 83.6 | 165 | 40.09 | 266 | 82 | 1.84 | 1680 | 2400 |
| | | TW | S54 | UO | UO | 8.2 | 435 | 400 | 185 | 74 | 215 | 52.24 | 65 | 26 | 8.95 | 1505 | 2150 |
| 38 | Peipura | HP | S55 | UO | UO | 7.8 | 532 | 267 | 118 | 47.2 | 149 | 36.2 | 250 | 11 | 1.35 | 1750 | 2500 |
| | | TW | S56 | UO | UO | 8.4 | 435 | 110 | 40 | 16 | 70 | 17.01 | 35 | 28 | 1.5 | 875 | 1250 |
| 39 | Rajwas | HP | S57 | UO | UO | 7.6 | 648 | 463 | 205 | 82 | 258 | 62.69 | 551 | 52 | 1.33 | 2306 | 3295 |
| 40 | Ramser | HP | S58 | UO | UO | 7.3 | 520 | 254 | 103 | 41.2 | 151 | 36.69 | 60 | 18 | 3.8 | 1050 | 1500 |
| | | TW | S59 | UO | UO | 8.4 | 464 | 118 | 44 | 17.6 | 74 | 17.98 | 50 | 25 | 2 | 1053 | 1504 |
| 41 | Ratanpura | HP | S60 | UO | UO | 7.9 | 532 | 299 | 135 | 54 | 164 | 39.85 | 80 | 32 | 1.02 | 1435 | 2050 |



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| S.No. | Village | Source | Sample No. | Colour | Odour | pH | Alkalinity | TH | CaH | $Ca^{+2}$ ions | MgH | $Mg^{+2}$ ions | $Cl^-$ | $NO_3^-$ | $F^-$ | TDS | EC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | TW | S61 | UO | UO | 8.4 | 552 | 88 | 35 | 14 | 53 | 12.87 | 60 | 19 | 1.07 | 1129 | 1613 |
| 42 | Roopura | HP | S62 | UO | UO | 7.5 | 263 | 107 | 42 | 16.8 | 65 | 15.79 | 130 | 24 | 1.44 | 1113 | 1590 |
| | | TW | S63 | UO | UO | 8.1 | 415 | 430 | 200 | 80 | 230 | 55.89 | 81 | 25 | 8.75 | 1610 | 2300 |
| 43 | Sambhariya | HP | S64 | UO | UO | 7.4 | 314 | 232 | 96 | 38.4 | 136 | 33.04 | 58 | 14 | 0.07 | 356 | 508 |
| 44 | Shankarpura | HP | S65 | UO | UO | 7.6 | 588 | 134 | 53 | 21.2 | 81 | 19.68 | 58 | 6 | 4.2 | 1028 | 1469 |
| 45 | Siya Ka Bas | HP | S66 | UO | UO | 7.7 | 235 | 234 | 98 | 39.2 | 136 | 33.04 | 62 | 91 | 0.85 | 1225 | 1750 |
| 46 | Tehda | HP | S67 | UO | UO | 8.2 | 276 | 145 | 62 | 24.8 | 83 | 20.16 | 221 | 20 | 1.4 | 1478 | 2111 |
| 47 | Tekchandpura | HP | S68 | UO | UO | 7.8 | 328 | 306 | 133 | 53.2 | 173 | 42.03 | 40 | 14 | 0.2 | 563 | 804 |
| 48 | Tilpatti | HP | S69 | UO | UO | 7.8 | 642 | 194 | 81 | 32.4 | 113 | 27.45 | 80 | 14 | 0.9 | 1280 | 1828 |
| 49 | Todabhata | HP | S70 | UO | UO | 8.5 | 328 | 65 | 22 | 8.8 | 43 | 10.44 | 52 | 24 | 2 | 984 | 1405 |
| 50 | Tunga | HP | S71 | UO | UO | 7.6 | 36 | 38 | 16 | 6.4 | 22 | 5.34 | 15 | 10 | 0.1 | 63 | 86 |

*Where- TA = Total Alkalinity, TH = Total Hardness, CaH = Calcium Hardness, MgH = Magnesium Hardness, Cl = Chloride, $NO_3$ = Nitrate, $F^-$ = Fluoride, TDS = Total Dissolved Solids, EC = Electrical Conductivity.*

*All parameters are expressed in mg/L except pH and EC. EC is expressed in µmhos/cm.*

*$Ca^{+2}$ = Ca mg/L (as $CaCO_3$), $Mg^{+2}$ = Mg mg/L (as $CaCO_3$).*

*UO = Unobjectionable, HP = Hand Pump, TW = Tube Well.*

*Table 4 :* Minimum, Maximum and Average Characteristics of Groundwater Sampling Stations – Pre Monsoon Season

| S.No. | Parameter | Minimum | Maximum | Average | Standard Deviation |
|---|---|---|---|---|---|
| 1. | pH | 7.1 | 8.5 | 7.86 | 0.39 |
| 2. | Total Alkalinity (mg/L) | 36 | 795 | 469.47 | 162.55 |
| 3. | Total Harness (mg/L) | 38 | 867 | 260.19 | 201.90 |
| 4. | Calcium Hardness (mg/L) | 16 | 397 | 111.23 | 90.30 |
| 5. | $Ca^{+2}$ Ions (mg/L) | 6.4 | 158.8 | 44.49 | 36.12 |
| 6. | Magnesium Hardness (mg/L) | 22 | 545 | 148.95 | 113.86 |
| 7. | $Mg^{+2}$ Ions (mg/L) | 5.34 | 132.43 | 36.19 | 27.66 |
| 8. | Chloride (mg/L) | 15 | 1430 | 222.01 | 290.48 |
| 9. | Nitrate (mg/L) | 2 | 236 | 32.16 | 35.64 |
| 10. | Fluoride (mg/L) | 0.03 | 12.5 | 1.96 | 2.41 |
| 11. | TDS (mg/L) | 63 | 4890 | 1589.88 | 899.48 |
| 12. | EC (µmhos/cm) | 86 | 6985 | 2271.05 | 1285.04 |

*Table 5 :* Physico-Chemical Characteristics of Groundwater Samples – Post Monsoon Season

| S. No. | Village | Source | Sample No. | Colour | Odour | pH | Alkalinity | TH | CaH | $Ca^{+2}$ ions | MgH | $Mg^{+2}$ ions | $Cl^-$ | $NO_3^-$ | $F^-$ | TDS | EC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Akhepura | HP | S1 | UO | UO | 8.1 | 410 | 406 | 180 | 72 | 226 | 54.91 | 306 | 102 | 1.36 | 1581 | 2259 |
| | | TW | S2 | UO | UO | 8.6 | 294 | 82 | 32 | 12.8 | 50 | 12.15 | 22 | 21 | 1.94 | 616 | 880 |
| 2 | Anantpura | HP | S3 | UO | UO | 7.7 | 607 | 284 | 122 | 48.8 | 162 | 39.36 | 194 | 15 | 0.85 | 1493 | 2132 |
| | | TW | S4 | UO | UO | 7.7 | 517 | 540 | 245 | 98 | 295 | 71.68 | 417 | 29 | 0.73 | 2074 | 2962 |
| 3 | Banskho | HP | S5 | UO | UO | 7.8 | 580 | 478 | 173 | 69.2 | 305 | 74.11 | 193 | 31 | 0.92 | 1630 | 2328 |
| | | TW | S6 | UO | UO | 8.5 | 363 | 98 | 41 | 16.4 | 57 | 13.85 | 98 | 14 | 1.54 | 1207 | 1724 |
| 4 | Barala | HP | S7 | UO | UO | 7.7 | 484 | 110 | 45 | 18 | 65 | 15.79 | 118 | 7 | 1.8 | 668 | 954 |
| 5 | Bassi | HP | S8 | UO | UO | 7.6 | 459 | 161 | 68 | 27.2 | 93 | 22.59 | 171 | 94 | 0.81 | 1274 | 1820 |
| | | TW | S9 | UO | UO | 7.4 | 255 | 187 | 80 | 32 | 107 | 26 | 113 | 56 | 0.51 | 1356 | 1937 |
| 6 | Benada | HP | S10 | UO | UO | 8.5 | 838 | 254 | 111 | 44.4 | 143 | 34.74 | 107 | 59 | 0.98 | 1612 | 2303 |
| 7 | Bharampur | HP | S11 | UO | UO | 7.8 | 482 | 364 | 163 | 65.2 | 201 | 48.84 | 146 | 21 | 0.6 | 1044 | 1491 |
| 8 | Chainpuriya | HP | S12 | UO | UO | 7.7 | 703 | 261 | 113 | 45.2 | 148 | 35.96 | 118 | 11 | 1 | 1206 | 1723 |
| 9 | Chapariya | HP | S13 | UO | UO | 7.7 | 282 | 211 | 88 | 35.2 | 123 | 29.88 | 28 | 27 | 0.9 | 424 | 605 |
| 10 | Charangarh | HP | S14 | UO | UO | 7.7 | 168 | 220 | 92 | 36.8 | 128 | 31.1 | 40 | 27 | 0.32 | 432 | 617 |
| 11 | Chatarpura | HP | S15 | UO | UO | 7.6 | 698 | 147 | 63 | 25.2 | 84 | 20.41 | 60 | 18 | 2.6 | 956 | 1365 |
| 12 | Danau Kalan | HP | S16 | UO | UO | 7.6 | 454 | 159 | 66 | 26.4 | 93 | 22.59 | 34 | 24 | 1.17 | 712 | 1018 |



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| S. No. | Village | Source | Sample No. | Colour | Odour | pH | Alkalinity | TH | CaH | $Ca^{+2}$ ions | MgH | $Mg^{+2}$ ions | $Cl^-$ | $NO_3^-$ | $F^-$ | TDS | EC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | Danau Khurd | HP | S17 | UO | UO | 7.2 | 312 | 660 | 237 | 94.8 | 423 | 102.8 | 103 | 106 | 0.45 | 910 | 1300 |
| | | TW | S18 | UO | UO | 7.8 | 382 | 337 | 151 | 60.4 | 186 | 45.19 | 84 | 29 | 2.6 | 1478 | 2111 |
| 14 | Garh | HP | S19 | UO | UO | 7.8 | 422 | 777 | 392 | 156.8 | 385 | 93.55 | 355 | 94 | 1.02 | 1685 | 2407 |
| 15 | Ghasipura | HP | S20 | UO | UO | 7.7 | 365 | 127 | 51 | 20.4 | 76 | 18.46 | 21 | 13 | 0.55 | 640 | 914 |
| | | TW | S21 | UO | UO | 7.9 | 817 | 92 | 37 | 14.8 | 55 | 13.36 | 54 | 19 | 11.9 | 1271 | 1816 |
| 16 | Ghata | HP | S22 | UO | UO | 7.9 | 443 | 313 | 140 | 56 | 173 | 42.03 | 246 | 14 | 1.43 | 1414 | 2020 |
| | | TW | S23 | UO | UO | 7.7 | 514 | 501 | 217 | 86.8 | 284 | 69.01 | 367 | 17 | 0.96 | 1669 | 2384 |
| 17 | Gudha Meena | HP | S24 | UO | UO | 7.6 | 403 | 199 | 88 | 35.2 | 111 | 26.97 | 20 | 19 | 0.4 | 642 | 917 |
| 18 | Gumanpura | HP | S25 | UO | UO | 7.7 | 384 | 208 | 89 | 35.6 | 119 | 28.91 | 103 | 8 | 2 | 808 | 1154 |
| | | TW | S26 | UO | UO | 7.8 | 509 | 404 | 181 | 72.4 | 223 | 54.18 | 183 | 53 | 2.5 | 1205 | 1721 |
| 19 | Gwalini | HP | S27 | UO | UO | 7.7 | 510 | 270 | 125 | 50 | 145 | 35.23 | 80 | 6 | 1.4 | 891 | 1273 |
| 20 | Hans Mahal | HP | S28 | UO | UO | 7.6 | 476 | 1100 | 423 | 169.2 | 677 | 164.5 | 1455 | 20 | 2.08 | 5434 | 7763 |
| 21 | Hanumanpura | HP | S29 | UO | UO | 7.1 | 560 | 316 | 144 | 57.6 | 172 | 41.79 | 507 | 95 | 1.6 | 2196 | 3137 |
| | | TW | S30 | UO | UO | 7.5 | 812 | 92 | 33 | 13.2 | 59 | 14.33 | 148 | 37 | 12.2 | 1837 | 2624 |
| 22 | Jhajhwar | HP | S31 | UO | UO | 7.9 | 575 | 440 | 190 | 76 | 250 | 60.75 | 436 | 41 | 1.1 | 2204 | 3149 |
| | | TW | S32 | UO | UO | 8.6 | 278 | 76 | 31 | 12.4 | 45 | 10.93 | 154 | 38 | 1.08 | 647 | 924 |
| 23 | Jhar | HP | S33 | UO | UO | 7.8 | 488 | 271 | 118 | 47.2 | 153 | 37.17 | 63 | 32 | 0.41 | 926 | 1322 |
| 24 | Kalyanpura | HP | S34 | UO | UO | 7.8 | 256 | 307 | 134 | 53.6 | 173 | 42.03 | 30 | 18 | 0.8 | 487 | 696 |
| | | TW | S35 | UO | UO | 7.8 | 318 | 83 | 29 | 11.6 | 54 | 13.12 | 52 | 13 | 1.2 | 607 | 867 |
| 25 | Kaneta | HP | S36 | UO | UO | 7.7 | 223 | 268 | 105 | 42 | 163 | 39.6 | 57 | 14 | 0.5 | 804 | 1148 |
| | | TW | S37 | UO | UO | 8.2 | 459 | 56 | 26 | 10.4 | 30 | 7.29 | 34 | 21 | 0.39 | 651 | 930 |
| 26 | Kaneti | HP | S38 | UO | UO | 7.4 | 674 | 347 | 129 | 51.6 | 218 | 52.97 | 80 | 2 | 0.14 | 918 | 1312 |
| 27 | Kanota | HP | S39 | UO | UO | 7.5 | 415 | 361 | 148 | 59.2 | 213 | 51.75 | 342 | 40 | 1.3 | 1436 | 2051 |
| | | TW | S40 | UO | UO | 7.8 | 689 | 134 | 61 | 24.4 | 73 | 17.73 | 266 | 11 | 2.3 | 1606 | 2294 |
| 28 | Kashipura | HP | S41 | UO | UO | 7.6 | 411 | 161 | 64 | 25.6 | 97 | 23.57 | 86 | 19 | 1.35 | 910 | 1301 |
| 29 | Keshopura | HP | S42 | UO | UO | 7.6 | 330 | 227 | 92 | 36.8 | 135 | 32.8 | 80 | 26 | 0.49 | 1333 | 1904 |
| 30 | Kuthada Kalan | HP | S43 | UO | UO | 7.6 | 785 | 262 | 110 | 44 | 152 | 36.93 | 42 | 21 | 0.5 | 800 | 1142 |
| 31 | Lalgarh | HP | S44 | UO | UO | 7.7 | 505 | 185 | 80 | 32 | 105 | 25.51 | 105 | 49 | 0.9 | 1042 | 1488 |
| 32 | Mundali | HP | S45 | UO | UO | 7.8 | 600 | 106 | 42 | 16.8 | 64 | 15.55 | 92 | 21 | 5.6 | 1131 | 1616 |
| | | TW | S46 | UO | UO | 8.3 | 822 | 77 | 31 | 12.4 | 46 | 11.17 | 206 | 32 | 4.02 | 1951 | 2787 |
| 33 | Nagal Karna | HP | S47 | UO | UO | 7.7 | 389 | 119 | 43 | 17.2 | 76 | 18.46 | 148 | 2 | 1.9 | 608 | 869 |
| | | TW | S48 | UO | UO | 8.5 | 859 | 53 | 21 | 8.4 | 32 | 7.77 | 112 | 19 | 3.25 | 822 | 1174 |
| 34 | Parasoli | HP | S49 | UO | UO | 7.8 | 440 | 553 | 280 | 112 | 273 | 66.33 | 326 | 15 | 1.43 | 1322 | 1889 |
| | | TW | S50 | UO | UO | 8.5 | 516 | 48 | 22 | 8.8 | 26 | 6.31 | 56 | 34 | 1.8 | 693 | 990 |
| 35 | Parempura | HP | S51 | UO | UO | 7.8 | 403 | 520 | 200 | 80 | 320 | 77.76 | 475 | 13 | 0.8 | 2880 | 4114 |
| 36 | Patan | HP | S52 | UO | UO | 7.7 | 535 | 479 | 199 | 79.6 | 280 | 68.04 | 652 | 18 | 1.22 | 2468 | 3526 |
| 37 | Peepalabai | HP | S53 | UO | UO | 7.8 | 206 | 228 | 123 | 49.2 | 105 | 25.51 | 58 | 25 | 0.5 | 408 | 583 |
| | | TW | S54 | UO | UO | 7.7 | 513 | 248 | 99 | 39.6 | 149 | 36.2 | 38 | 16 | 5.3 | 723 | 1033 |
| 38 | Peipura | HP | S55 | UO | UO | 7.7 | 700 | 242 | 106 | 42.4 | 136 | 33.04 | 446 | 24 | 1.23 | 1946 | 2780 |
| | | TW | S56 | UO | UO | 8.2 | 504 | 97 | 34 | 13.6 | 63 | 15.3 | 47 | 41 | 1.3 | 1016 | 1451 |
| 39 | Rajwas | HP | S57 | UO | UO | 7.6 | 704 | 428 | 183 | 73.2 | 245 | 59.53 | 320 | 27 | 1.3 | 2883 | 4118 |
| 40 | Ramser | HP | S58 | UO | UO | 7.3 | 540 | 210 | 85 | 34 | 125 | 30.37 | 100 | 13 | 1.3 | 1040 | 1485 |
| | | TW | S59 | UO | UO | 8.3 | 483 | 89 | 27 | 10.8 | 62 | 15.06 | 66 | 21 | 1.06 | 924 | 1320 |
| 41 | Ratanpura | HP | S60 | UO | UO | 7.8 | 860 | 260 | 113 | 45.2 | 147 | 35.72 | 193 | 8 | 1.13 | 1600 | 2286 |
| | | TW | S61 | UO | UO | 7.9 | 871 | 190 | 75 | 30 | 115 | 27.94 | 130 | 19 | 2.65 | 1440 | 2057 |
| 42 | Roopura | HP | S62 | UO | UO | 7.8 | 353 | 243 | 110 | 44 | 133 | 32.31 | 60 | 30 | 1.4 | 722 | 1031 |
| | | TW | S63 | UO | UO | 8.4 | 511 | 627 | 283 | 113.2 | 344 | 83.59 | 58 | 28 | 8.49 | 1159 | 1656 |
| 43 | Sambhariya | HP | S64 | UO | UO | 7.6 | 425 | 145 | 60 | 24 | 85 | 20.65 | 30 | 30 | 2.25 | 920 | 1314 |
| 44 | Shankarpura | HP | S65 | UO | UO | 7.8 | 540 | 197 | 85 | 34 | 112 | 27.21 | 80 | 2 | 3.6 | 1125 | 1607 |
| 45 | Siya Ka Bas | HP | S66 | UO | UO | 7.6 | 313 | 179 | 73 | 29.2 | 106 | 25.75 | 56 | 71 | 1.13 | 773 | 1104 |
| 46 | Tehda | HP | S67 | UO | UO | 7.7 | 425 | 174 | 72 | 28.8 | 102 | 24.78 | 172 | 24 | 1.55 | 1140 | 1629 |
| 47 | Tekchandpura | HP | S68 | UO | UO | 7.8 | 254 | 292 | 130 | 52 | 162 | 39.36 | 40 | 12 | 0.25 | 529 | 756 |
| 48 | Tilpatti | HP | S69 | UO | UO | 7.8 | 633 | 366 | 153 | 61.2 | 213 | 51.75 | 114 | 22 | 0.76 | 1306 | 1867 |



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| S. No. | Village | Source | Sample No. | Colour | Odour | pH | Alkalinity | TH | CaH | $Ca^{+2}$ ions | MgH | $Mg^{+2}$ ions | $Cl^-$ | $NO_3^-$ | $F^-$ | TDS | EC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 49 | Todabhata | HP | S70 | UO | UO | 7.8 | 550 | 129 | 54 | 21.6 | 75 | 18.22 | 63 | 20 | 1.8 | 1043 | 1490 |
| 50 | Tunga | HP | S71 | UO | UO | 7.8 | 290 | 780 | 395 | 158 | 385 | 93.55 | 288 | 309 | 0.65 | 1604 | 2291 |

*Table 6 :* Minimum, Maximum and Average Characteristics of Groundwater Sampling Stations – Post Monsoon Season

| S.No. | Parameter | Minimum | Maximum | Average | Standard Deviation |
|---|---|---|---|---|---|
| 1. | pH | 7.1 | 8.6 | 7.80 | 0.31 |
| 2. | Total Alkalinity (mg/L) | 168 | 871 | 495.04 | 174.15 |
| 3. | Total Harness (mg/L) | 48 | 1100 | 276.26 | 195.79 |
| 4. | Calcium Hardness (mg/L) | 21 | 423 | 118.38 | 87.05 |
| 5. | $Ca^{+2}$ Ions (mg/L) | 8.4 | 169.2 | 47.35 | 34.82 |
| 6. | MagnesiumHardness (mg/L) | 26 | 677 | 157.88 | 111.31 |
| 7. | $Mg^{+2}$ Ions (mg/L) | 6.31 | 164.51 | 38.36 | 27.05 |
| 8. | Chloride (mg/L) | 20 | 1455 | 171.04 | 206.72 |
| 9. | Nitrate (mg/L) | 2 | 309 | 32.77 | 40.60 |
| 10. | Fluoride (mg/L) | 0.14 | 12.2 | 1.82 | 2.20 |
| 11. | TDS (mg/L) | 408 | 5434 | 1252.28 | 746.36 |
| 12. | EC ($\mu$mhos/cm) | 583 | 7763 | 1788.87 | 1066.23 |

*Table 7 :* Unit Weightage of parameters for Drinking Water based on standard values

| S.No. | Parameter | Standard Value (Sn) | Recommending Agency | Ideal Value ($V_{id}$) | Unit Weight (Wn= K/Sn) |
|---|---|---|---|---|---|
| 1. | pH | 8.5 | BIS/ICMR/WHO | 7.0 | 0.097427 |
| 2. | Total Alkalinity | 120 | ICMR/WHO | 0 | 0.006901 |
| 3. | Total Hardness | 300 | BIS/ICMR | 0 | 0.002760 |
| 4. | Calcium | 75 | BIS/ICMR/WHO | 0 | 0.011042 |
| 5. | Magnesium | 30 | BIS/ICMR/WHO | 0 | 0.027604 |
| 6. | Chloride | 250 | BIS/ICMR | 0 | 0.003313 |
| 7. | Nitrate | 45 | BIS/ICMR/WHO | 0 | 0.018403 |
| 8. | Fluoride | 1.0 | BIS/ICMR/WHO | 0 | 0.828133 |
| 9. | Total Dissolved Solids | 500 | BIS/ICMR/WHO | 0 | 0.001656 |
| 10. | Electrical Conductivity | 300 | ICMR/WHO | 0 | 0.002760 |

*(All values are in mg/l except pH and EC)*

*Table 8 :* Calculated WQI values and quality rating of water in the study area in Pre and Post Monsoon Seasons

| S. No. | Village | Source | Sample No. | Pre- Monsoon | | Post- Monsoon | |
|---|---|---|---|---|---|---|---|
| | | | | WQI Value | Quality Rating | WQI Value | Quality Rating |
| 1 | Akhepura | HP | S1 | 81.883 | VP | 135.79 | Unsuitable |
| | | TW | S2 | 134.0011 | Unsuitable | 176.02 | Unsuitable |
| 2 | Anantpura | HP | S3 | 51.405 | Poor | 86.357 | VP |
| | | TW | S4 | 166.1971 | Unsuitable | 81.65 | VP |
| 3 | Banskho | HP | S5 | 195.8513 | Unsuitable | 97.203 | VP |
| | | TW | S6 | 180.74 | Unsuitable | 143.66 | Unsuitable |
| 4 | Barala | HP | S7 | 186.73 | Unsuitable | 159.75 | Unsuitable |
| 5 | Bassi | HP | S8 | 114.01 | Unsuitable | 82.41 | VP |
| | | TW | S9 | 79.036 | VP | 54.006 | Poor |
| 6 | Benada | HP | S10 | 103.56 | Unsuitable | 105.01 | Unsuitable |
| 7 | Bharampur | HP | S11 | 47.101 | Good | 66.214 | Poor |



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| S. No. | Village | Source | Sample No. | Pre- Monsoon | | Post- Monsoon | |
|---|---|---|---|---|---|---|---|
| | | | | WQI Value | Quality Rating | WQI Value | Quality Rating |
| 8 | Chainpuriya | HP | S12 | 119.65 | Unsuitable | 98.208 | VP |
| 9 | Chapariya | HP | S13 | 107.41 | Unsuitable | 86 | Poor |
| 10 | Charangarh | HP | S14 | 69.478 | Poor | 37.48 | Good |
| 11 | Chatarpura | HP | S15 | 399.4 | Unsuitable | 228 | Unsuitable |
| 12 | Danau Kalan | HP | S16 | 130.45 | Unsuitable | 108.21 | Unsuitable |
| 13 | Danau Khurd | HP | S17 | 96.57 | VP | 57.788 | Poor |
| | | TW | S18 | 259.05 | Unsuitable | 231.79 | Unsuitable |
| 14 | Garh | HP | S19 | 104.02 | Unsuitable | 110.81 | Unsuitable |
| 15 | Ghasipura | HP | S20 | 18.051 | Ex | 55.921 | Poor |
| | | TW | S21 | 961.89 | Unsuitable | 1000.5 | Unsuitable |
| 16 | Ghata | HP | S22 | 86.605 | VP | 135.02 | Unsuitable |
| | | TW | S23 | 77.189 | VP | 99.02 | VP |
| 17 | Gudha Meena | HP | S24 | 35.005 | Good | 44.383 | Good |
| 18 | Gumanpura | HP | S25 | 90.947 | VP | 177.55 | Unsuitable |
| | | TW | S26 | 139.77 | Unsuitable | 225.97 | Unsuitable |
| 19 | Gwalini | HP | S27 | 166.34 | Unsuitable | 129.46 | Unsuitable |
| 20 | Hans Mahal | HP | S28 | 40.613 | Good | 209.21 | Unsuitable |
| 21 | Hanumanpura | HP | S29 | 78.8 | VP | 149.53 | Unsuitable |
| | | TW | S30 | 1052.2 | Unsuitable | 1024.6 | Unsuitable |
| 22 | Jhajhwar | HP | S31 | 61.684 | Poor | 113.24 | Unsuitable |
| | | TW | S32 | 82.195 | VP | 105.51 | Unsuitable |
| 23 | Jhar | HP | S33 | 68.938 | Poor | 49.235 | Good |
| 24 | Kalyanpura | HP | S34 | 125.18 | Unsuitable | 79.435 | VP |
| | | TW | S35 | 163.72 | Unsuitable | 109.45 | Unsuitable |
| 25 | Kaneta | HP | S36 | 32.02 | Good | 53.715 | Poor |
| | | TW | S37 | 73.891 | Poor | 45.58 | Good |
| 26 | Kaneti | HP | S38 | 128.4 | Unsuitable | 25.72 | Good |
| 27 | Kanota | HP | S39 | 70.143 | Poor | 123.71 | Unsuitable |
| | | TW | S40 | 159.55 | Unsuitable | 205.19 | Unsuitable |
| 28 | Kashipura | HP | S41 | 277.16 | Unsuitable | 123.14 | Unsuitable |
| 29 | Keshopura | HP | S42 | 80.245 | VP | 53.505 | Poor |
| 30 | Kuthada Kalan | HP | S43 | 68.973 | Poor | 56.335 | Poor |
| 31 | Lalgarh | HP | S44 | 131.98 | Unsuitable | 88.828 | VP |
| 32 | Mundali | HP | S45 | 359.84 | Unsuitable | 477.01 | Unsuitable |
| | | TW | S46 | 297.49 | Unsuitable | 352.15 | Unsuitable |
| 33 | Nagal Karna | HP | S47 | 370.28 | Unsuitable | 167.46 | Unsuitable |
| | | TW | S48 | 505.31 | Unsuitable | 286.99 | Unsuitable |
| 34 | Parasoli | HP | S49 | 119.32 | Unsuitable | 137.63 | Unsuitable |
| | | TW | S50 | 197.94 | Unsuitable | 165.13 | Unsuitable |
| 35 | Parempura | HP | S51 | 120.21 | Unsuitable | 88.47 | VP |
| 36 | Patan | HP | S52 | 65.009 | Poor | 122.19 | Unsuitable |
| 37 | Peepalabai | HP | S53 | 166.33 | Unsuitable | 52.83 | Poor |
| | | TW | S54 | 761.36 | Unsuitable | 452.44 | Unsuitable |
| 38 | Peipura | HP | S55 | 127.99 | Unsuitable | 119.09 | Unsuitable |
| | | TW | S56 | 140.35 | Unsuitable | 123.45 | Unsuitable |
| 39 | Rajwas | HP | S57 | 131.82 | Unsuitable | 128.82 | Unsuitable |
| 40 | Ramser | HP | S58 | 326.39 | Unsuitable | 118.57 | Unsuitable |
| | | TW | S59 | 182.23 | Unsuitable | 103.09 | Unsuitable |
| 41 | Ratanpura | HP | S60 | 101.89 | Unsuitable | 111.12 | Unsuitable |
| | | TW | S61 | 105.06 | Unsuitable | 236.81 | Unsuitable |
| 42 | Roopura | HP | S62 | 128.8 | Unsuitable | 129.5 | Unsuitable |
| | | TW | S63 | 744.64 | Unsuitable | 728.18 | Unsuitable |
| 43 | Sambhariya | HP | S64 | 15.25 | Ex | 197.83 | Unsuitable |
| 44 | Shankarpura | HP | S65 | 359.35 | Unsuitable | 311.65 | Unsuitable |
| 45 | Siya Ka Bas | HP | S66 | 85.941 | VP | 106.48 | Unsuitable |
| 46 | Tehda | HP | S67 | 131.22 | Unsuitable | 141.3 | Unsuitable |
| 47 | Tekchandpura | HP | S68 | 30.129 | Good | 33.43 | Good |



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| S. No. | Village | Source | Sample No. | Pre- Monsoon | | Post- Monsoon | |
|---|---|---|---|---|---|---|---|
| | | | | WQI Value | Quality Rating | WQI Value | Quality Rating |
| 48 | Tilpatti | HP | S69 | 89.386 | VP | 80.97 | VP |
| 49 | Todabhata | HP | S70 | 181.07 | Unsuitable | 162.15 | Unsuitable |
| 50 | Tunga | HP | S71 | 13.535 | Ex | 88.001 | VP |

*Where- VP = Very Poor, Ex = Excellent*

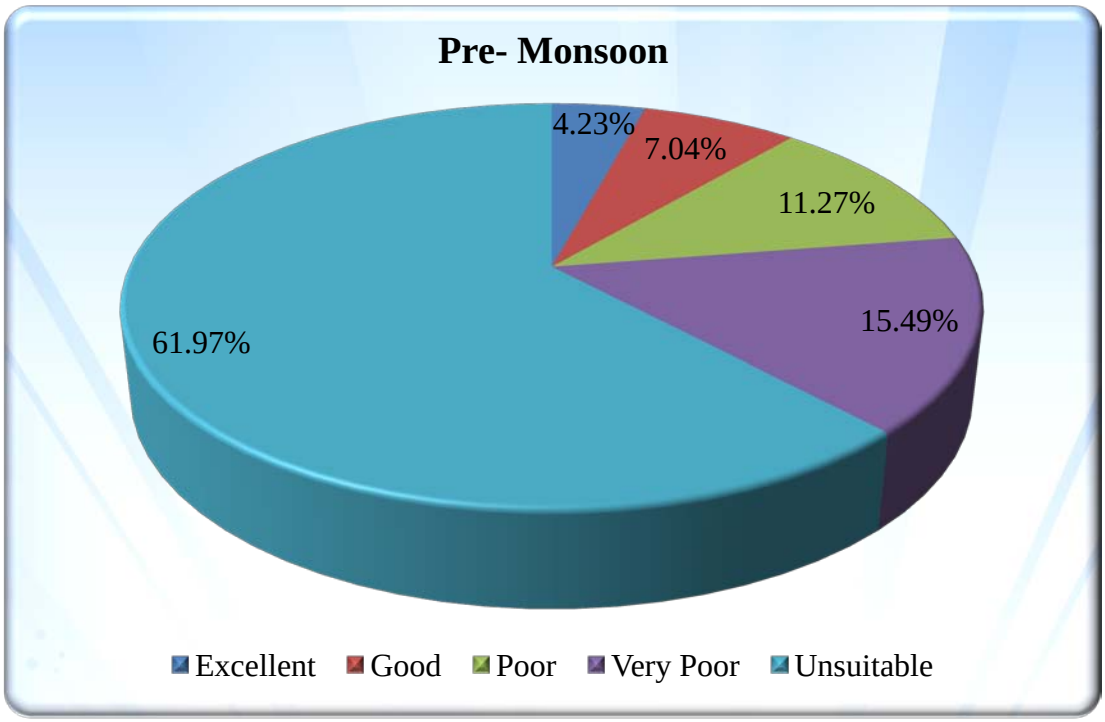


*Figure 1 :* Percentage representation of WQI classification in Pre monsoon season

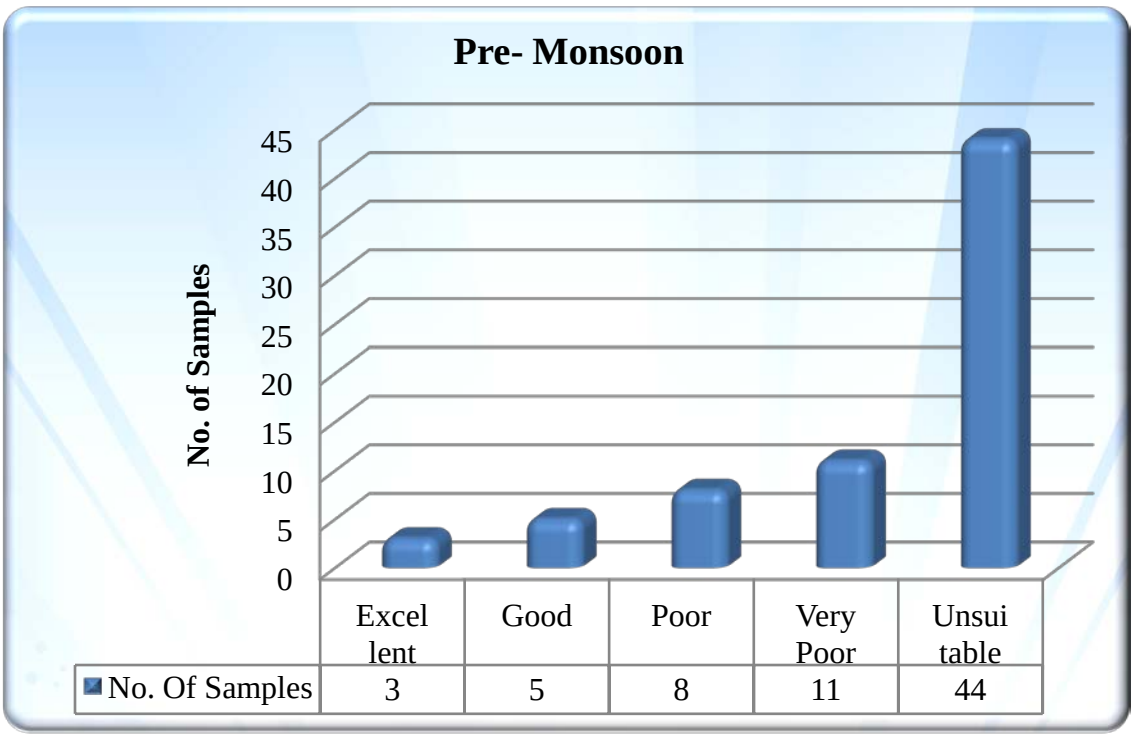


*Figure 2 :* Number of Villages classified on the basis of WQI values in Pre monsoon season



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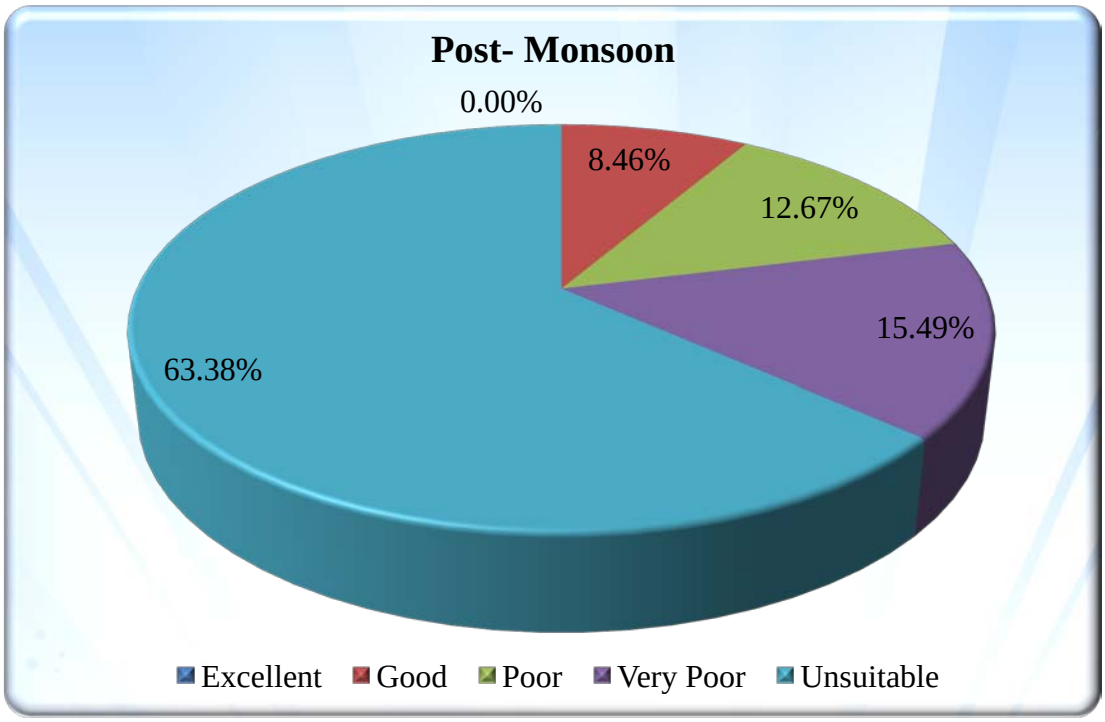


*Figure 3 :* Percentage representation of WQI classification in Post monsoon season

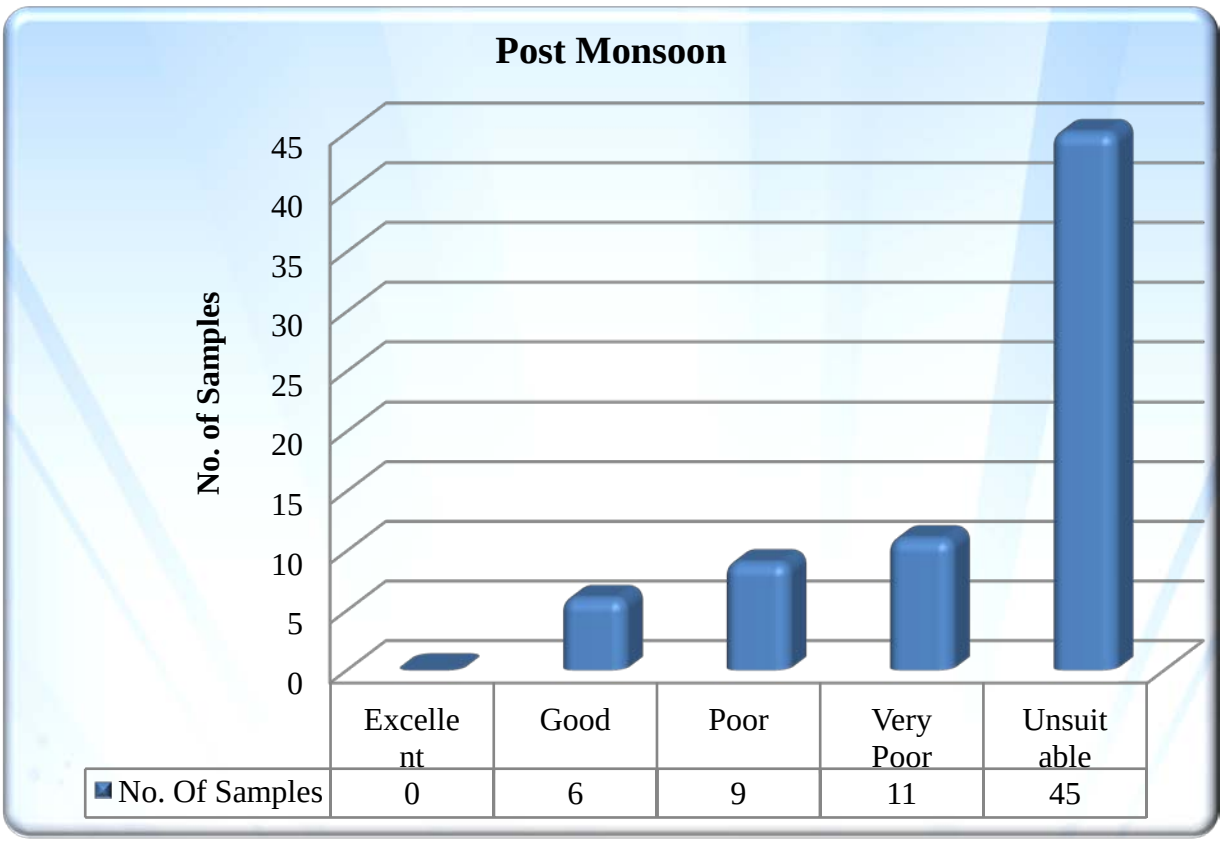


*Figure 4 :* Number of Villages classified on the basis of WQI values in Post monsoon season



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ii. *Spatial Variation of WQI*

According to the results, it is revealed that in pre-monsoon season only three sampling sites namely *Ghasipura* (HP), *Sambhariya* and *Tunga* exhibit excellent groundwater quality for drinking, and five sampling sites namely *Bharampuri, Gudha Meena, Hans Mahal, Kaneta (HP)* and *Tekchandpura* indicate good ground water quality for drinking. The remaining 63 sampling sites are not directly suitable for potability because they are classified as poor, very poor and unfit categories as per the WQI ranges.

In post monsoon season there is not even a single sampling site under the excellent category and only six sampling sites namely *Charangarh, Gudha Meena, Jhar, Kaneta (TW), Kaneti,* and *Tekchandpura* fall in the category good for drinking. The rest 65 sampling sites are not suitable for potability as according to their WQI ranges they are classified as poor, very poor and unfit for drinking purposes. Graph (Figure 5) depicts the spatial variation of the WQI in the study area for the pre and post monsoon seasons both.

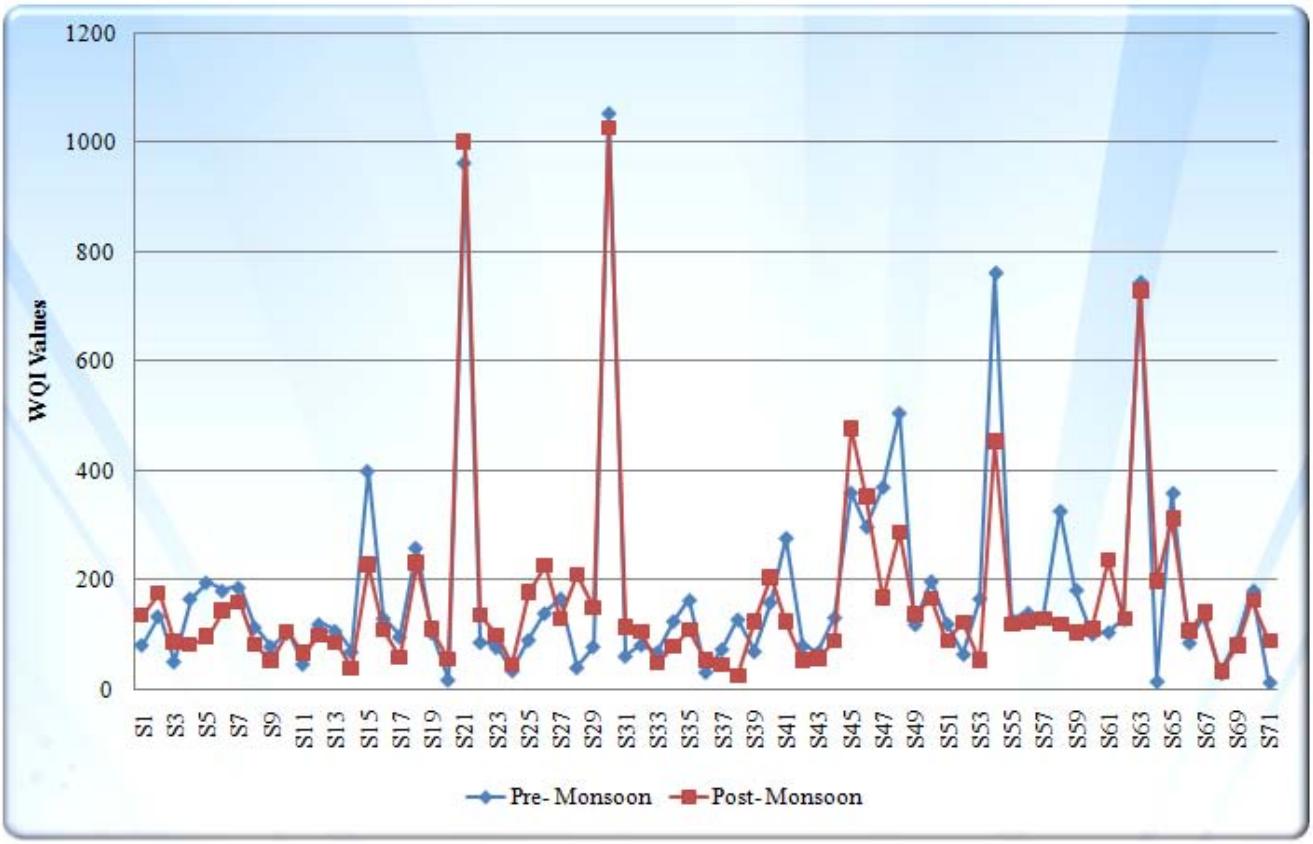


*Figure 5 :* Comparative graphical representation of WQI of groundwater at different Locations in the study area in pre and post monsoon seasons

Most of the stations are having groundwater of very poor and unsuitable categories with water quality ranging from 75 to 100 and >100 respectively. Table 9 and 10 contains the information about the various sampling sites in the study area with varying values of WQI in pre and post monsoon season respectively. These tables provide the appropriate information to take necessary steps in treatment of groundwater in the study area.



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*Table 9 :* Classifications of groundwater in the Study area with respect to WQI in Pre Monsoon Season

| Name of the Sampling Site | No. of Samples | WQI Range | Quality Category |
|---|---|---|---|
| Ghasipura (HP), Sambhariya, Tunga. | 03 | 0-25 | Excellent |
| Bharampuri, Gudha Meena, Hans Mahal, Kaneta (HP), Tekchandpura. | 05 | 26-50 | Good |
| Anantpura (HP), Charangarh, Jhajhwar (HP), Jhar, Kaneta (TW), Kanota (HP), Kuthada Kalan, Patan. | 08 | 51-75 | Poor |
| Akhepura (HP), Bassi (TW), Danau Khurd (HP), Ghata (both), Gumanpura (HP), Hanumanpura (HP), Jhajhwar (TW), Keshopura, Siya Ka Bas, Tilpatti. | 11 | 76-100 | Very Poor |
| Akhepura (TW), Anantpura (TW), Banskho (HP and TW), Barala, Bassi (HP), Benada, Chainpuriya, Chapariya, Chatarpura, Danau Kalan, Danau Khurd (TW), Garh, Ghasipura (TW), Gumanpura (TW), Gwalini, Hanumanpura (TW), Kalyanpura (HP and TW), Kaneti, Kanota (TW), Kashipura, Lalgarh, Mundali (HP and TW), Nagal Karna (HP and TW), Parasoli (HP and TW), Parempura, Peepalabai (HP and TW), Peipura (HP and TW), Rajwas, Ramser (HP and TW), Ratanpura (HP and TW), Roopura (HP and TW), Shankarpura, Tehda, Todabhata. | 44 | Above 100 | Unsuitable for Drinking |

*Table 10 :* Classifications of groundwater in the Study area with respect to WQI in Post Monsoon Season

| Name of the Sampling Site | No. of Samples | WQI Range | Quality Category |
|---|---|---|---|
| Nil | 00 | 0-25 | Excellent |
| Charangarh, Gudha Meena, Jhar, Kaneta (TW), Kaneti, Tekchandpura. | 06 | 26-50 | Good |
| Bassi (TW), Bharampuri, Chapariya, Danau Khurd (HP), Ghasipura (HP), Kaneta (HP), Keshopura, Kuthada Kalan, Peepalabai (HP). | 09 | 51-75 | Poor |
| Anantpura (HP and TW), Banskho (HP), Bassi (HP), Chainpuriya, Ghata (TW), Kalyanpura (HP), Lalgarh, Parempura, Tilpatti, Tunga. | 11 | 76-100 | Very Poor |
| Akhepura (HP and TW), Banskho (TW), Barala, Benada, Chatarpura, Danau Kalan, Danau Khurd (TW), Garh, Ghasipura (TW), Ghata (HP), Gumanpura (HP and TW), Gwalini, Hans Mahal, Hanumanpura (HP and TW), Jhajhwar (HP and TW), Kalyanpura (TW), Kanota (HP and TW), Kashipura, Mundali (HP and TW), Nagal Karna (HP and TW), Parasoli (HP and TW), Patan, Peepalabai (TW), Peipura (HP and TW), Rajwas, Ramser (HP and TW), Ratanpura (HP and TW), Roopura (HP and TW), Sambhariya, Shankarpura, Siya Ka Bas, Tehda, Todabhata. | 45 | Above 100 | Unsuitable for Drinking |

## V. Conclsions

WQI values of groundwater samples analyzed for pre and post monsoon seasons depict that there exists an uncertain and narrow change in the WQI values which is not very significant with reference to potability and groundwater quality.

The results of current study revealed that ground water, used by the people residing in villages of Bassi Tehsil, is not suitable for drinking purpose. So, there is a need of continuous monitoring of water quality and proper environment management plan must be adopted to control drinking water pollution immediately. Based on these results and analysis of water samples, it is also recommended to use water only after boiling and filtering or by Reverse Osmosis treatment for drinking purpose by the individuals to prevent adverse health effects.

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