INTRODUCTION

The water covers 71% of the earth's surface and is vital for all known forms of life. On earth, 96.5% of the planet's water is found in seas and oceans, 1.7% in surface and underground, 1.7% in glaciers and ice caps of Antarctica and Greenland, and 0.001% in the air as vapour (clouds). Less than 0.3% of available freshwater is in rivers, lakes and the atmosphere, and an even smaller amount as earth's fresh water (0.003%) is contained within biological systems and manufactured products (Gleick, 1993; Water Vapor Climate System, 2007). Groundwater is the water that is found in the aquifer, deep in empty spaces in soils and cracks of rocks under the ground. A layer of rock that is sufficiently porous to store water and permeable enough to transmit water in quantities that can be economically exploited is called an aquifer. The groundwater resources are being utilized for drinking, irrigation and industrial purposes. In addition to this, groundwater contains a variety of dissolved inorganic chemical constituents in various concentrations resulting from chemical and biochemical interactions between water and geological material. The inorganic contaminants including salinity, chloride, fluoride, nitrate, iron are important in determining the suitability of groundwater for drinking purpose. Due to increase in population, industrialization, use of fertilizers in the agriculture and man-made activity, the quality of the groundwater may be deteriorated. Keeping this view, the present study was aimed to evaluate the water quality in order to assess the suitability of groundwater for drinking and domestic usages of the local inhabitants.

Madhya Pradesh is located in central region of India. It has year round tropical climate characterized by warm days and cooler evenings. The climate of Dindori district is fairly pleasant except later part of summer season, including a seasonal rhythm of weather. The climatic year consists of five distinct seasons, viz., spring (February-March), summer (April-15th June), rainy (16th June-15th September), autumn (16th September –November), and winter (December-January). December and January are the coldest month having minimum mean temperature of 10.4°C. May is the hottest month with mean daily maximum temperature of 43°C. The annual average total rainfall of the district 704.7mm.

Dindori district of Madhya Pradesh state was created on 22th May, 1998 with a total of 924 villages. It is 142 kms away from Jabalpur and is part of Jabalpur division. The district covers an area of 7470sq. km. and is located at an average height of 1100m above mean sea level in the Maikal mountain ranges in the eastern part of Madhya Pradesh, bordering the state of Chhattisgarh in south. The district is situated between the latitudes 22°.27’ and 23°.22’ north, and longitude 80°.30’ and

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MATERIAL AND METHODS

The study was conducted at 28 villages belonging to seven community development blocks namely Dindori, Shahpura, Mehadwani, Amarpur, Bajag, Karanjiya and Samnapur of Dindori district of Madhya Pradesh state. The handpumps, borewells and dugwells which were functional and continuously in use for the drinking and domestic purposes were selected for this study. The other criteria which were kept in mind for the selection of water source of the present study, include (i) wells closure to polluting sources like waste water drains, garbage dump sites, and (ii) wells suspected for natural contaminants like fluoride, iron etc. A total of 28 samples of groundwater were collected during each period, i.e., pre-monsoon (April, May, June, 2018) and post-monsoon (September, October, November, 2018). The water samples were collected after pumping for 10-15 minutes in order to remove stagnant water. One liter of groundwater was collected in pre-cleaned plastic bottle and 300 ml in BOD bottle from each water source. The collection bottles were pre-cleaned by soaking them in dilute HCl, washing with tape water and finally rinsing with double distilled water.

The colour and odour of the water sample were recorded during the sampling. The pH, temperature and total dissolved solid were measured at the site by using portable Water Analyzer-371 (Systronics India Ltd.). The instrument automatically analyses the TDS by using the relation i.e. TDS = electrical conductivity × 0.64. Samples for chemical analysis were processed according to the methods of APHA (2005). The BOD (bottle incubation for 5 days at 20°C, dissolved oxygen by Winkler method), calcium hardness (EDTA titrametric method), iron (spectrophotometric method: Visiscan 167, Systronics), fluoride (SPADNS method), chloride (argentometric titration), sulphate (turbidimetric method), nitrate (UV Spectrophotometric method) were analyzed within 24 hrs of sampling at Public Health Engineering Laboratory, Shahpura /Jabalpur and also at the Department of P.G. Studies & Research in Biological Science, Rani Durgavati University, Jabalpur (M.P.). Mean, standard deviation and analysis of variance were performed by using Statistical Package Social Sciences(IBM).

RESULTS AND DISCUSSION

The physico-chemical parameters, viz., pH, temperature, total dissolved solids, calcium hardness, chloride, fluorides, nitrate, sulphate, dissolved oxygen, biochemical oxygen demand and iron of the groundwater collected during pre–monsoon and post-monsoon periods are presented in Table 1&2, respectively. The data revealed considerable variation in the water samples with respect to location and period of collection. The groundwater temperature of different sources ranges from 27.2 to 27.5°C with an average of 27.4±0.1°C in pre-monsoon and from 27.7 to 30.5°C (mean 29.2±0.7°C) during post-monsoon period. The data indicate insignificant difference in the groundwater temperature of pre and post-monsoon periods. The temperature of the earth below 30 feet is relatively constant throughout the year. The high specific heat capacity of water and the insulating effect of soil and rock can mitigate the effect of climate and maintain groundwater at a relatively steady temperature. On contrary to this, Ansari and Salahuddin (2013) reported minimum temperature of ground water during January (17.1°C) and maximum during June (30.8°C) at Ghazipur district of Uttar Pradesh. The increase in temperature decreases the potability of water because carbon dioxide and other volatile gases which impart test are expelled at elevated temperature (Karunakaran et al., 2009). It is desirable to have the temperature of drinking water not exceeding 15°C as the palatability of water is enhanced by its coolness.

The pH value ranged from 6.2 to 8.5 with a mean of 7.4± in pre-monsoon period and from 6.3 to 8.8 with a mean of 7.0±0.74 in post-monsoon period. This indicates that groundwater of the study area is acidic to alkaline in nature. The lower value of pH in post-monsoon period as compared to pre-monsoon period might be due to the mixing of rain water to groundwater.

The total dissolved solids is a measure of the combined content of all organic and inorganic substances contained in water in molecular, ionized or micro - granular suspended forms. The total dissolved solids (TDS) content fluctuated from 210 to 363.9 mg/liter during pre-monsoon and from 205 to 2650 mg/liter with a mean of 361.1±442.2 mg/liter during post-monsoon period. The TDS contents of all the sampling stations except of Pre-metric Aadiwashi Boys Hostel, Chanda were within the desirable limit prescribed by BIS (2012). Data indicate that groundwater of Chanda exceeded the permissible limits of TDS in both the periods. It is, therefore, not suitable for drinking and domestic usage. Slightly lower values of TDS in post-monsoon season as compared to pre-monsoon season have also been reported by other scientists (Mishra and Shukla, 2016; Chandra et al., 2017).

The water hardness refers to the total concentration of polyvalent cations present in water. The divalent cations like calcium and magnesium are main cause of hardness. The iron, manganese, strontium etc. also contribute to hardness of water.

Fig 1 Map of Dindori district showing sites of ground water sampling
### Table 1: Physico-Chemical parameters of groundwater of Dindori district during pre-monsoon period (April-June, 2018)

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Blocks/ Villages</th>
<th>Location of water source</th>
<th>Source type</th>
<th>Temperature (°C)</th>
<th>pH values</th>
<th>T.D.S. (mg/l)</th>
<th>Calcium hardness (mg/l)</th>
<th>Chloride (mg/l)</th>
<th>Fluoride (mg/l)</th>
<th>Iron (mg/l)</th>
<th>Nitrate (mg/l)</th>
<th>Sulphate (mg/l)</th>
<th>B.O.D (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i)</td>
<td>Amarapur</td>
<td>Govt. Hospital</td>
<td>Borewell</td>
<td>27.2</td>
<td>8.5</td>
<td>290</td>
<td>132.0</td>
<td>200.0</td>
<td>0.10</td>
<td>0.80</td>
<td>15.0</td>
<td>496.0</td>
<td>1.31</td>
</tr>
<tr>
<td>(ii)</td>
<td>Bajaj</td>
<td>Govt. Excellence Higher Sec. School</td>
<td>Hand pump</td>
<td>27.5</td>
<td>6.5</td>
<td>290</td>
<td>124.0</td>
<td>140.0</td>
<td>1.04</td>
<td>0.10</td>
<td>26.0</td>
<td>120.0</td>
<td>1.27</td>
</tr>
<tr>
<td>(iii)</td>
<td>Dindori</td>
<td>Satish Sharma</td>
<td>Dugwell</td>
<td>27.3</td>
<td>6.7</td>
<td>365</td>
<td>196.0</td>
<td>250.0</td>
<td>1.00</td>
<td>0.80</td>
<td>10.0</td>
<td>252.0</td>
<td>1.30</td>
</tr>
<tr>
<td>(iv)</td>
<td>Karanjya</td>
<td>Amarpali</td>
<td>Dugwell</td>
<td>27.4</td>
<td>7.0</td>
<td>225</td>
<td>216.0</td>
<td>300.0</td>
<td>1.00</td>
<td>0.10</td>
<td>12.0</td>
<td>215.0</td>
<td>1.23</td>
</tr>
<tr>
<td>(v)</td>
<td>Mehadwani</td>
<td>M.P. Online Centre</td>
<td>Dugwell</td>
<td>27.3</td>
<td>6.5</td>
<td>355</td>
<td>200.0</td>
<td>190.0</td>
<td>1.01</td>
<td>0.60</td>
<td>24.0</td>
<td>233.0</td>
<td>1.22</td>
</tr>
<tr>
<td>(vi)</td>
<td>Shahpura</td>
<td>Govt. Hospital</td>
<td>Borewell</td>
<td>27.5</td>
<td>6.4</td>
<td>320</td>
<td>272.0</td>
<td>100.0</td>
<td>1.00</td>
<td>0.10</td>
<td>15.0</td>
<td>244.0</td>
<td>1.25</td>
</tr>
<tr>
<td>(vii)</td>
<td>Devrikala</td>
<td>Anujitha Mihan</td>
<td>Hand pump</td>
<td>27.3</td>
<td>6.9</td>
<td>455</td>
<td>160.0</td>
<td>160.0</td>
<td>0.97</td>
<td>0.88</td>
<td>30.0</td>
<td>240.0</td>
<td>1.13</td>
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<tr>
<td>(viii)</td>
<td>Rahuri</td>
<td>Shrimukhari Kishorilal Jhariya</td>
<td>Hand pump</td>
<td>27.4</td>
<td>7.0</td>
<td>330</td>
<td>192.0</td>
<td>125.0</td>
<td>0.98</td>
<td>0.85</td>
<td>19.0</td>
<td>223.0</td>
<td>1.10</td>
</tr>
</tbody>
</table>

### Table 2: Physico-Chemical parameters of groundwater of Dindori district during post-monsoon period (September-November, 2018)

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Blocks/ Villages</th>
<th>Location of water source</th>
<th>Source Type</th>
<th>Temperature (°C)</th>
<th>pH values</th>
<th>T.D.S. (mg/l)</th>
<th>Calcium hardness (mg/l)</th>
<th>Chloride (mg/l)</th>
<th>Fluoride (mg/l)</th>
<th>Iron (mg/l)</th>
<th>Nitrate (mg/l)</th>
<th>Sulphate (mg/l)</th>
<th>B.O.D (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i)</td>
<td>Amarapur</td>
<td>Govt. Hospital</td>
<td>Borewell</td>
<td>28.0</td>
<td>8.0</td>
<td>300</td>
<td>150.0</td>
<td>180.0</td>
<td>0.10</td>
<td>0.70</td>
<td>12.0</td>
<td>480.0</td>
<td>1.35</td>
</tr>
<tr>
<td>(ii)</td>
<td>Bajaj</td>
<td>Govt. Excellence Higher Sec. School</td>
<td>Hand pump</td>
<td>27.8</td>
<td>6.2</td>
<td>285</td>
<td>175.0</td>
<td>135.0</td>
<td>1.00</td>
<td>0.10</td>
<td>25.0</td>
<td>110.0</td>
<td>1.30</td>
</tr>
<tr>
<td>(iii)</td>
<td>Dindori</td>
<td>Satish Sharma</td>
<td>Dugwell</td>
<td>29.5</td>
<td>6.6</td>
<td>360</td>
<td>196.0</td>
<td>210.0</td>
<td>0.10</td>
<td>0.75</td>
<td>10.0</td>
<td>250.0</td>
<td>1.35</td>
</tr>
<tr>
<td>(iv)</td>
<td>Karanjya</td>
<td>Gaganwadi Centre</td>
<td>Hand pump</td>
<td>29.0</td>
<td>7.5</td>
<td>370</td>
<td>185.0</td>
<td>430.0</td>
<td>1.00</td>
<td>0.45</td>
<td>24.0</td>
<td>175.0</td>
<td>1.45</td>
</tr>
<tr>
<td>(v)</td>
<td>Mehadwani</td>
<td>M.P. State Rural Livelyhood</td>
<td>Hand pump</td>
<td>28.5</td>
<td>6.4</td>
<td>315</td>
<td>292.0</td>
<td>90.0</td>
<td>0.90</td>
<td>0.10</td>
<td>12.0</td>
<td>240.0</td>
<td>1.30</td>
</tr>
</tbody>
</table>

* Note: All water samples were colourless (except of Chanda) and odorless. Chanda hand pump water was turbid and odorous.
carbonate (mg/l). In the present study, it ranged from 105 to 540 mg/l with a mean of 187.9±95.0mg/l during pre-monsoon and 120 to 544 mg/l with a mean 212.3±86.4mg/l during post-monsoon period. A total of 9 samples exceeded desirable limit but all the samples come within the permissible limit of BIS.

Chloride is usually present as NaCl, CaCl₂ and MgCl₂ in all types of water in varying concentration. These molecules enter in water by solvent action of water on salts present in soil, from polluting material like sewage and trade wastes (Shaikh and Mandre, 2009). The maximum value of chloride, i.e., 510 and 430mg/l were recorded in village Nevsa during the pre and post-monsoon periods, respectively. All the samples except of Chanda has lower values of nitrate content as compared to BIS standard, i.e., 45mg/l.

The possible sources of sulphate in the groundwater include pyrite (FeS₂)/gypsum, percolated fertilizer and sewage. The elevated concentration of sulphate may cause laxative effects. The average values of sulphate content i.e. 246.3 and 238.9 mg/l of the pre and post-monsoon periods exceed desirable limit (200mg/l) of BIS. The samples of Amarpur and Chanda exceed the permissible limit of BIS.

Biochemical oxygen demand is a measure of oxygen required by microbes to degrade organic matter under aerobic condition. BOD indicates the nature and extent of pollution and also about the water quality. Average BODs of the pre and post-monsoon period of the present study were 1.23mg/l and 1.33mg/l, respectively.

One way analysis of variance indicate that there was a significant difference in the pre-monsoon and post-monsoon values of temperature, pH and total dissolved solids at $\alpha = 0.05$. The rest of the parameters of both the periods do not differ significantly.

CONCLUSIONS

An analysis of standard indicates that temperature, pH, BOD, iron and fluoride values of both the period show less variation as compared to other parameters. ANOVA (at $\alpha = 0.05$) indicates no significant difference in pre and post – monsoon values of calcium hardness, chloride, fluoride, iron, nitrate, nitrite.
sulphate and BOD. On the basis of concentration, the chemical parameters may be ordered as An analysis of standard deviation indicates that temperature, pH, BOD, iron and fluoride values of TDS > sulphate > chloride > calcium hardness > nitrate > fluoride > iron in pre - monsoon and TDS > sulphate > calcium hardness > chloride > nitrate > fluoride > iron S in post - monsoon period . Approximately, 35% of total samples have slightly higher values of one or more parameter than the desirable limit but below the permissible limit prescribed by the Bureau of Indian Standard. The groundwater of Chanda village showed turbidity and exceeded the permissible limit of total dissolved solid in both periods. This water is, therefore, not suitable for drinking and domestic purposes.

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