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**Original Article**

# Appraisal of Ground Water Chemical Quality for Drinking and Domestic Use in Thandla Area, Jhabua District, Madhya Pradesh, India

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**ABSTRACT**

*Paper highlights the determination of ground water chemical quality of Thandla area for drinking and domestic uses in Thandla area situated in vicinity of Jhabua district, Madhya Pradesh in India. The selected 30 ground water samples have been subjected to chemical treatment. The analyzed data have been described and interpreted for drinking and domestic applications. Based on determined values of Cations (Ca, Mg, Na, K) and Anions ($Cl^-$, $SO_4^-$, $CO_3^-$, $HCO_3^-$, $NO_3^-$, $F^-$) of ground water plotted on Trilinear Piper's diagram, and compared with the World Health Organization and Indian Standard limits. In general, the ground water is suitable for drinking and domestic purpose.*

**KEYWORDS**: Ground Water, Chemical quality, Thandla, Jhabua, Madhya Pradesh, Appraisal, Drinking - Domestic use, Trilinear Piper's diagram, World Health Organization and Indian Standard.

## 1. INTRODUCTION

### 1.1 Concept of Chemical Quality

Ground water quality determination by chemical analysis constitutes the subject matter of Hydro-geochemistry. Chemical composition of ground water is subjective to soluble product of rock weathering and changes with respect to time space. Concentrations of dissolved elements in water are helpful to estimate suitability of water for diverse applications, such as drinking and domestic. Chemical analysis is to be carried out with accuracy with a view to find out ground water quality. Todd (1980, 2010) recognized that in order to set-up quality criteria, procedures of chemical, physical, biological and

radiological constituents should be precise and standard techniques for reporting and comparing the results of water analysis.

Charlu and Dutt (1982) remarked that physical and chemical exchanges of ground water result into solubility of a majority of minerals of parent rock in ground water system. Mineral content increases in ground water as it moves along until a balanced or equilibrium of the dissolved substances is obtained. According to Karanth (2003) ground water usability is determined by the physical, chemical, and bacteriological properties. Ground water quality envisages field observation regarding the source and environment of ground water occurrence, source, pollution and other related aspects are effecting the ground water quality. Some of the properties such as temperature and $p^H$ are to be recorded in the field.

### 1.2 Characteristics of Study Area

The study area constitutes a part of Thadla in Jhabua district of Madhya Pradesh, India. It is confined to the Latitude $23^0$ 0' to $23^0$ 10' N and Longitude $74^0$ 30' to $74^0$ 40' E, (Survey of India Toposheet No.- 46 I/12), in Thandla area of Jhabua district, Madhya Pradesh (Figure 1).The present study area covers 366.58 sq. km. The research area is accessible by both road and rail throughout the year.

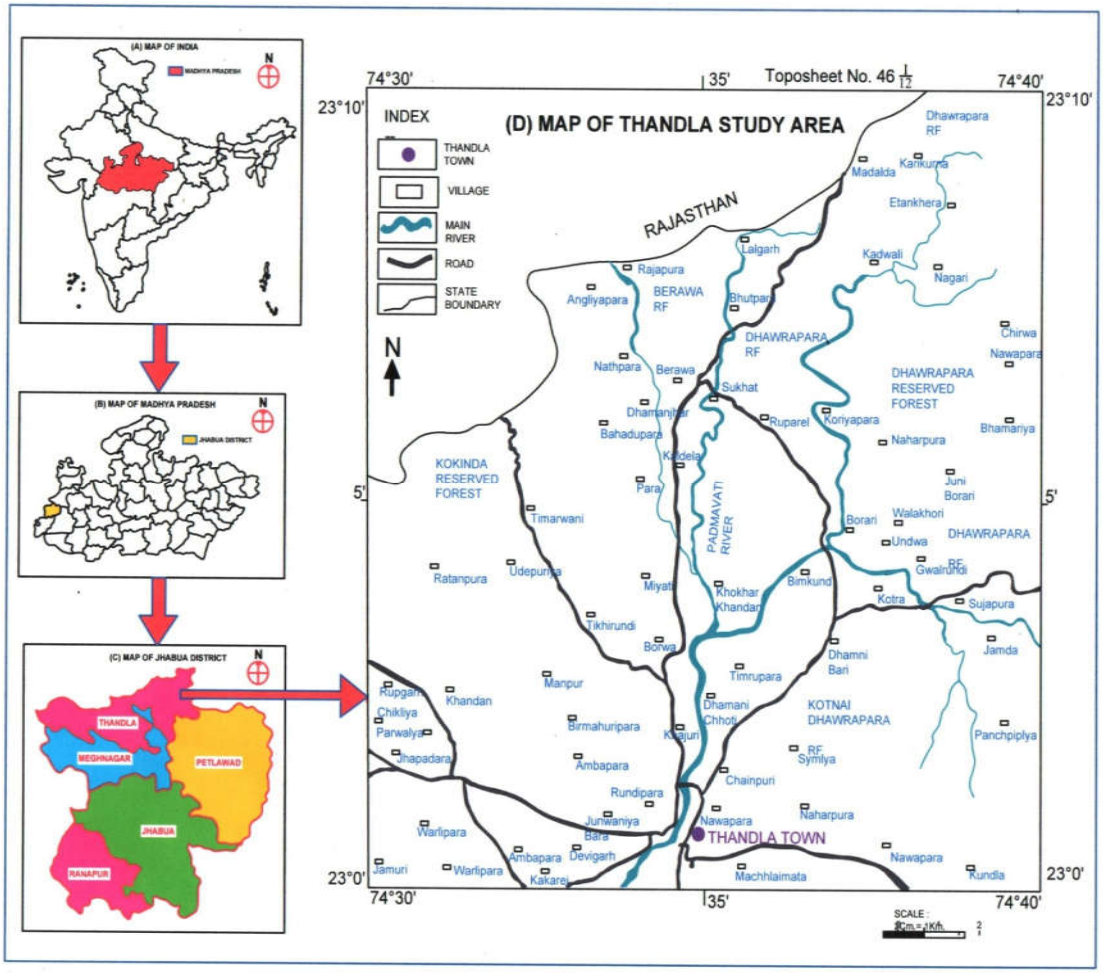


**Figure 1:** Location Map of Thandla area, Jhabua district, Madhya Pradesh, India.

Physio-graphically, study area is urbanized with the denudation brought by water and wind. The climate of Thandla area is tropical - monsoon type. It is separated into three physiographic regions namely, Hilly

Terrain, Undulating country, and Plain country. Temperature variation is within $6^0$ C to $46^0$ C. The annual rainfall varies within 423.00 to 2086.20 mm, and average of 964.324 mm. Relative humidity is observed in the range of 34.4 to 50 %. Rainy season provides enjoyment amongst inhabitants. Thandla area is characterized by the occurrence of Quartzite, and Phyllite, which are exposed in the Padmavati River basin and exhibit similarity with the Aravalli Super group (Archaean) of Rajasthan. The study area is characterized by three Lava flows having joints, fractures, followed by three types of soils as black cotton, lateritic, and alluvial.

## 2. GROUND WATER CHEMICAL ANALYSIS

### 2.1 Chemical Quality Estimation

Chemical quality assessment has been established on the basis of selected 30 ground water samples of Thandla study area. Location and number of samples have been marked on plastic bottles used for collecting ground water from existing dug wells in the study area. Ground water samples have been analyzed.

Determination of physical analysis involves Colour, Odour, Taste, $p^H$ (Hydrogen ion concentration), Turbidity, Total Dissolved Solids (TDS), Electrical Conductivity (EC), Total Hardness (TH), and Alkalinity. Chemical analysis determines Cations (Ca, Mg, Na, K) and Anions ($Cl^-$, $SO_4^-$, $CO_3^-$, $HCO_3^-$, $NO_3^-$, $F^-$) in ground water samples.

### 2.2 Ground Water Samples Collection

Method of ground water samples collection is based on the ground water quality requirements. The general process of water samples collection considered the following: (a) Selection of sampling site, (b) Frequency sampling, (c) Equipment of sampling, and (d) Instruction for sampling.

General method of water sample collection has been followed in the study. The procedure of sample collection proposed by Rainwater and Thatcher (1968) has been favoured on the basis of hydrogeological data and delineation of chemical composition of ground water samples.

The collection of water sample has been conducted by selecting sites in the study area. Representative samples have been taken in plastic bottles of 1 liter capacity. The bottles were rinsed before sampling and tightly sealed after the collection of water. The labels indicating location of sample site, type of well, number of water sample and date of collection have been pasted on the respective bottles. The sampling bottles were placed in a container and transported to the laboratory for chemical analysis. The locations of sampling sites of dug wells have been displayed (Figure 2).

### 2.3 Methods of Chemical Analysis

Chemical analysis data are represented by tabular and graphic methods of data display. Methods adopted by various workers for chemical treatment of quality evaluation have been employed in the present research study. The methods suggested by Todd (1959, 1980, 2010), Rainwater and Thatcher (1968), Wellborn and Skinner (1968), Brown *et.al.* (1970), Walton (1970), Montgomery and Hart (1974), I.C.M.R. (1975), Clark *et. al.* (1977), A.P.H.A. (1980, 1998, 2005), Raghunath (1982, 1985), Wilson (1982), B.I.S. (1983, 1991), W.H.O. (1983, 1984, 1993, 1994, 2004, 2011, 2012), Fetter (1988, 1990), Singhal and Gupta (1999), Karanth (2003), Gupta (2005) and others.

The physical and chemical analysis of 30 ground water samples have been conducted in laboratory by adopting standard chemical analysis. The results of analysis are recorded herein.

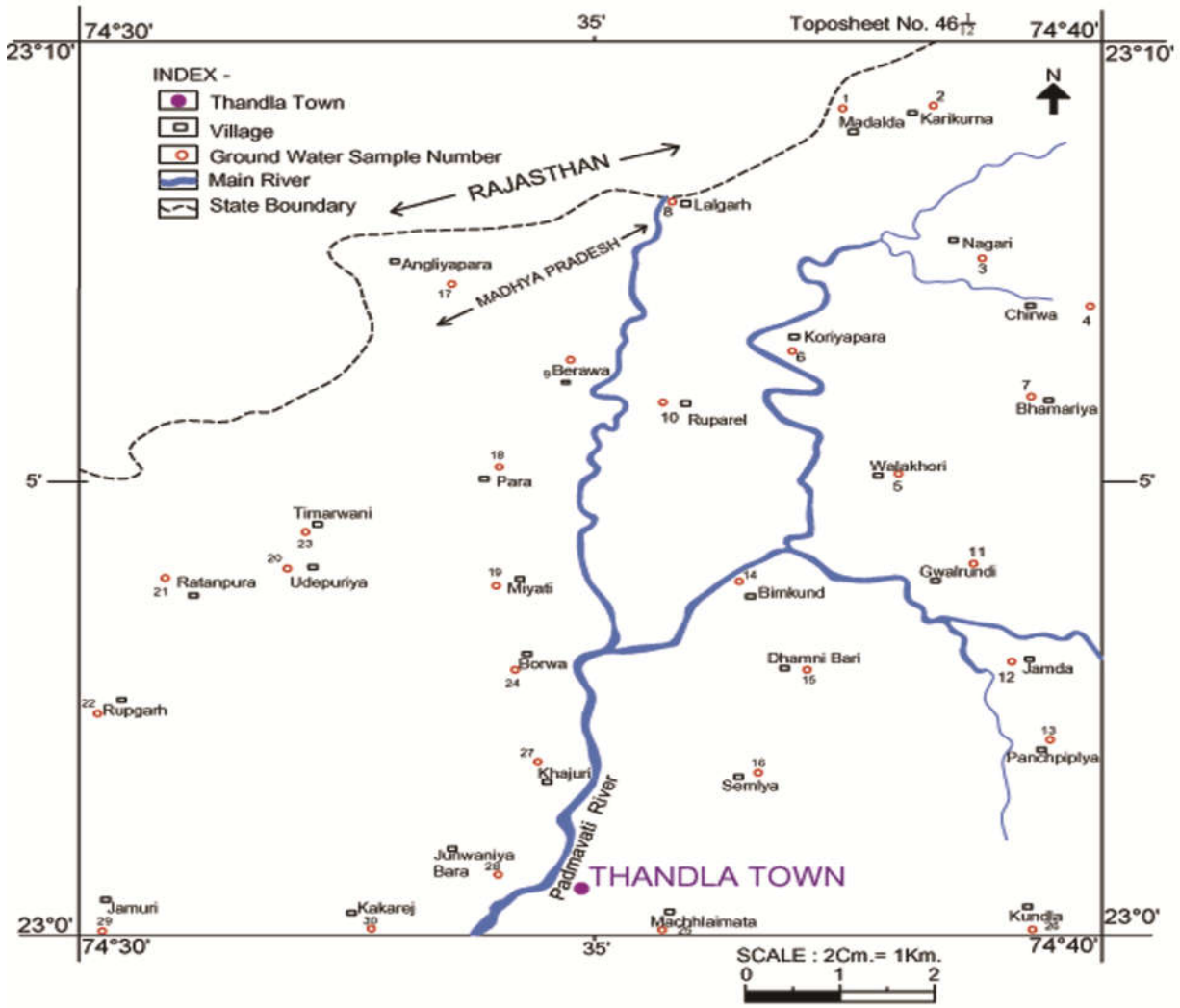


**Figure 2:** Location of ground water samples from Thandla study area, Jhabua.

### 2.3.1 Physical Characteristics of Ground Water

Physical characteristics of ground water samples include detection of Colour, Odour, Taste, Turbidity, Hydrogen ion concentration ($p^H$), Electrical Conductivity (EC), and Total Dissolved Solids (TDS) have been determined and described (Table 1).

- **Colour**

The water is generally colourless. Colour in water may be due to presence of inorganic ions, humus, peat, planktons and industrial wastes. In present study, all ground water samples are colourless (Table 1).

- **Odour**

It is a factor that affects quality suitability of drinking water. A good number of organic and a few inorganic chemicals also affect odour. These chemicals generate from natural, municipal and industrial wastes. All the analyzed ground water samples are odourless (Table 1).

- **Taste**

Taste of ground water samples is due to presence of higher concentration of acidic and alkaline salts, organic and toxic materials. All examined samples of ground water are tasteless (Table 1).

- **Hydrogen ion concentration**

Hydrogen ion concentration ( $p^H$ ) has been referred to effective concentration (activity) of hydrogen ions in water. It is expressed as negative logarithm (base 10) of the $H^+$ activity in mol/l. At a $p^H$ of 7 the $H^+$ activity is $10^{-7}$ mol/l, and the solution is considered natural. When the $p^H$ is less than 7, the solution behaves as an acid, particularly below ($p^{H4}$). Above $p^H$ of 7, the solution reacts like a base. Most of natural waters are within a $p^H$ range from 6 to 8.5 (Hem, 1970, *vide etiam,* Nagabhushaniah, 2001).

In present study area, the $p^H$ value of water samples has been determined. These determined values of $p^H$ record a range of 7.05 (Nagari) and 8.30 (Dhamni Bari) and rest of the water samples $p^H$ are within permissible range of 6.5 to 9.2 (W.H.O., 1993, 2004, 2011, 2012) indicating water is safe for drinking application (Table 1).

- **Turbidity**

Turbidity is measured in laboratory by the Turbidity meter (Garg, 1979). Turbidity of ground water generally expressed in terms of reduced light transmission by the water or as suspended solids contents, is principally caused by clay, silt and other fine materials that enter the well from aquifer (Nagabhushaniah, 2001). In Thandla study area, the turbidity values are ranging from 0.89 (Bhimkund) to 4.91 (Karikurna) and recorded (Table 1).

- **Total Dissolved Solids**

Absorption of total dissolved solids (TDS) in water is expressed by weight of the material on evaporation of water to dryness, which is followed by heating for one hour at $180^0$ C. Desirable limit 500 ppm and permissible limit 1500 ppm of T.D.S. is recommended by World Health Organization (W.H.O.; 1993, 2004, 2011).

Aravindan *et.al.*(2004) remarked that higher content of TDS are attributed to contribution of salts from the thick mantle of soil and weathered media of the rock and there can be some oxidation and reduction processes during winter and summer, thereby also causing enrichment in total dissolved solids. Devis and De Wiest (1966) confirmed that high TDS value has adverse impact on biomass. In Thandla study area, determined values of total dissolved solids have been recorded. Total dissolved solids values reveal a minimum of 275 mg/1 (Angliyapara) and maximum of 481 mg/1 in (Borwa) rest samples are under permissible limits. All samples are having T.D.S. values below the desirable limit of 500 mg/l (Table 1).

- **Electrical Conductivity**

Electrical conductivity (EC) has been described as conductance of a cubic centimeter of water at a standard temperature of $25^0$ C, an increase of $1^0$ C increases conductance by about 2 percent (Todd, 1959, 1980, 2010). Electrical conductivity is also known as Specific conductance and measured in µS/cm (microsiemens/cm).

In Thandla study area, determined Electrical conductivity values range from 307 (Berawa) to 600 (Kakarej) mohos/cm. World Health Organization (W.H.O.,1993, 2004, 2011) has recommended the desirable limit of E.C. as 1400 µS/cm (microsiemens/cm) (Table 1).

- **Total Hardness**

Total Hardness (TH) results from presence of divalent metallic cations - Calcium and Magnesium are most plentiful in ground water. These ions react with soap to form precipitates and with certain anions present in water to form scale. Because of there adverse action with soap, hard water are unsuitable for household cleansing purposes, hence water-softening processes for removal of hardness are essential (Todd, 1959, 1980, 2010). In Thandla study area, the values of hardness are recorded, as minimum 230 ppm (Chirwa) and maximum 340 ppm values (Junwaniya Bara) and rest samples are under the permissible limits (Table 1).

- **Alkalinity**

Alkalinity is capacity of water to neutralize acid. It is produced by carbonate and bicarbonate ions expressed as equivalent concentration of $CaCO_3$ mg/1 (Nagabhushaniah, 2001). In Thandla study area ground water samples indicate a range of alkalinity from 132 (Angliyapara) to 198 ( Koriyapara) (Table 1).

**Table 1:** Determination of physical parameters of ground water samples in study area, Jhabua district, M.P.

| Location | Sample No. | Colour | Odour | Taste | pH | Turbidity | T.D.S. | E.C. | T.H. | Alkalinity |
|---|---|---|---|---|---|---|---|---|---|---|
| Madalda | 1 | CL | OL | TL | 7.31 | 4.50 | 468 | 349 | 295 | 180 |
| Karikurna | 2 | CL | OL | TL | 7.85 | 4.91 | 310 | 418 | 270 | 190 |
| Nagari | 3 | CL | OL | TL | 7.05 | 3.10 | 390 | 340 | 251 | 195 |
| Chirwa | 4 | CL | OL | TL | 7.83 | 4.20 | 480 | 549 | 230 | 197 |
| Walakhori | 5 | CL | OL | TL | 7.92 | 2.05 | 430 | 472 | 286 | 182 |
| Koriyapara | 6 | CL | OL | TL | 7.51 | 3.70 | 395 | 401 | 301 | 198 |
| Bhamariya | 7 | CL | OL | TL | 7.41 | 1.95 | 420 | 429 | 295 | 189 |
| Lalgarh | 8 | CL | OL | TL | 8.02 | 2.80 | 290 | 412 | 275 | 185 |
| Berawa | 9 | CL | OL | TL | 7.81 | 3.40 | 435 | 307 | 261 | 192 |
| Ruparel | 10 | CL | OL | TL | 7.60 | 0.95 | 407 | 449 | 272 | 183 |
| Gwalrundi | 11 | CL | OL | TL | 8.03 | 1.20 | 370 | 420 | 305 | 162 |
| Jamda | 12 | CL | OL | TL | 7.61 | 2.86 | 295 | 517 | 256 | 168 |
| Panchpiplya | 13 | CL | OL | TL | 7.86 | 3.02 | 300 | 430 | 265 | 180 |
| Bhimkund | 14 | CL | OL | TL | 7.83 | 0.89 | 315 | 318 | 285 | 190 |
| Dhamni Bari | 15 | CL | OL | TL | 8.30 | 1.85 | 302 | 338 | 279 | 135 |
| Semlya | 16 | CL | OL | TL | 7.95 | 3.50 | 410 | 362 | 266 | 138 |
| Angliyapara | 17 | CL | OL | TL | 7.21 | 3.30 | 275 | 410 | 286 | 132 |
| Para | 18 | CL | OL | TL | 7.87 | 4.25 | 367 | 540 | 310 | 180 |
| Miyati | 19 | CL | OL | TL | 7.88 | 2.80 | 400 | 590 | 258 | 172 |
| Udepuriya | 20 | CL | OL | TL | 7.62 | 2.40 | 290 | 470 | 320 | 189 |
| Ratanpura | 21 | CL | OL | TL | 7.30 | 3.25 | 325 | 345 | 295 | 132 |
| Rupgarh | 22 | CL | OL | TL | 7.70 | 3.47 | 340 | 420 | 331 | 145 |
| Timarwani | 23 | CL | OL | TL | 7.56 | 2.95 | 460 | 330 | 287 | 148 |
| Borwa | 24 | CL | OL | TL | 7.36 | 2.80 | 481 | 560 | 275 | 190 |
| Machhlaimata | 25 | CL | OL | TL | 8.20 | 3.75 | 376 | 480 | 240 | 197 |
| Kundla | 26 | CL | OL | TL | 7.11 | 4.20 | 285 | 481 | 270 | 198 |
| Khajuri | 27 | CL | OL | TL | 7.90 | 0.90 | 345 | 455 | 290 | 167 |
| Junwaniya Bara | 28 | CL | OL | TL | 8.0 | 2.78 | 363 | 430 | 340 | 161 |
| Jamuri | 29 | CL | OL | TL | 7.15 | 3.05 | 435 | 330 | 295 | 167 |
| Kakarej | 30 | CL | OL | TL | 7.65 | 4.32 | 416 | 600 | 280 | 180 |

***(Abbreviations** - CL = Colourless, OL = Odourless, TL = Tasteless, T.D.S. = Total Dissolved Solids, E.C. = Electrical Conductivity, T.H. = Total Hardness.)*

**2.3.2 Chemical Characteristics of Ground Water**

Ionic parameters such as Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Chloride ($Cl^-$), Sulfate ($SO_4^-$), Carbonate ($CO_3^-$), Bi-carbonate ($HCO_3^-$), Nitrate ($NO_3^-$), and Fluoride ($F^-$) have been determined and the values are recorded (Table 2). The values of different elements measured in part per million (ppm) have been converted to equivalent per million (epm) and displayed (Table 3).

| **Characteristics of Chemical Parameters** |
|---|
| **Calcium (Ca) -** Calcium is most common element in ground water generally due to its large abundance and high soluble nature. Its main source is the presence of some members of silicates mineral groups (plagioclase, pyroxene, and amphibole). Silicate minerals are insoluble in water but due to weathering it gets break down the minerals into soluble calcium products and clay minerals. Carbonates and Sulphates of calcium are soluble in nature and rarely Chloride. Recommended range is 75 to 200 ppm (Nagabhushaniah, 2001). |
| **Magnesium (Mg) -** In general, ground water contains relatively small amounts of Magnesium. In igneous rock, it occurs as dark coloured micas, and amphiboles. In metamorphic and other altered rock it occurs like Chlorite, and Montmorillonite. It occurs in sedimentary rocks as Magnetite. Dolomite contains Calcium and Magnesium (Nagabhushaniah, 2001). Commonly, less than 50 mg / l, ocean water contains more than 1000 mg / l, and brines contain 57, 000 mg / l (Todd, 1980). |
| **Sodium (Na) -** Sodium is derived from igneous rock. Generally, it occurs less than 200 mg / l, about 10,000 mg / l in seawater, and about 25,000 mg / l in brines. |
| **Potassium (K) -** In igneous rocks, **Potassium** is less common than Sodium, and more abundant in sedimentary rocks as Potassium feldspars. In general, less than 10 mg / l to 100 mg / l in hot springs, and 25,000 mg / l in brines (Nagabhushaniah, 2001, Todd, 1980). |
| **Chloride ($Cl^-$) -** Sources of Chloride in ground water are evaporites, salty connate water, and marine water. Igneous rocks add modest Chloride. Ground water containing important amounts of Chloride also tend to have high amounts of Sodium, indicating prospects of contact with water of marine origin. Generally**,** less than 10 mg/l in humid regions, up to 1000 mg / l in arid regions, about 19,300 mg/l in seawater, and up to 200,000 mg/l in brines |
| **Sulfate ($SO_4^-$) -** Sulfate is formed by oxidation of Pyrite and other Sulfides widely distributed in igneous and sedimentary rocks. Most important Sulfate deposits are observed in Evaporite leaching sediments (Gypsum, Anhydrite, Sodium sulfate). Sulfate concentration in drinking water is desirable up to 250 mg / l. Normally less than 300 mg / l Sulfate occurs in wells influenced by acid mine drainage, and 200,000 mg / l in some brines (Nagabhushaniah, 2001). |
| **Carbonate ($CO_3^-$) -** Carbonate and Bi-carbonate sources include $CO_2$ from atmosphere and soil also contributes to some extent. Sodium carbonate may accumulate as Evaporite in closed basins, causing high carbonate levels in ground water. Carbonate concentrations in ground water are usually less than 10 mg / l. Water high in Sodium may contain as much as 50 mg / l of Carbonate. |
| **Bi-carbonate ($HCO_3^-$) -** Bi-carbonate concentration more than 200 mg / l is common in ground water, and higher concentration can occur where $CO_2$ is produced within the aquifer. Generally $HCO_3^-$ - ranges up to less than 500 mg / l, may exceed 1000 mg / l in water highly charged with Carbon dioxide. |
| **Nitrate ($NO_3^-$) -** Nitrogen is a minor constituent of rocks, and is a major constituent of atmosphere. Nitrogen and Oxygen of atmosphere are combined by electrical discharge during lightning, and dissolve in rain water. Average Nitrate content in rain water is reported as 0.2 ppm ( Riffenburg, 1926, *vide etiam*, Karanth, 2003). |
| **Fluoride ($F^-$) -** Sources of Fluoride in ground water is minerals like Calcium fluoride, Apatite, Cryolite (in igneous rocks), Fluoraspar (in sedimentary rocks) and so on. Ground water having more than 1 mg / l of Fluoride are frequently found. High concentrations are likely to be associated with a high $p^H$. Some fluorine in drinking water is beneficial because it reduces tooth decay. At higher levels, however, mottling of the teeth (fluorous) occurs. Hence, fluorine concentration is recommended for drinking water ranges from 1.4 to 2.4 mg/l (Nagabhushaniah, 2001). |

**Table 2:** Chemical parameters determined in ground water samples of Thandla study area (Values expressed in ppm)

| Location | Sample No. | Concentration of Cation | | | | Concentration of Anion | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca | Mg | Na | K | $Cl^-$ | $SO_4^-$ | $CO_3^-$ | $HCO_3^-$ | $NO_3^-$ | $F^-$ |
| Madalda | 1 | 115 | 147 | 28 | 1.10 | 110 | 69 | - | 122 | 28 | 0.70 |
| Karikurna | 2 | 120 | 130 | 37 | 1.70 | 98 | 110 | - | 235 | 21 | 0.20 |
| Nagari | 3 | 95 | 98 | 30 | 2.30 | 170 | 125 | - | 146 | 27 | 0.80 |
| Chirwa | 4 | 170 | 76 | 37 | 1.80 | 120 | 70 | - | 122 | 35 | 0.75 |
| Walakhori | 5 | 195 | 81 | 32 | 3.60 | 165 | 78 | - | 134 | 40 | 0.67 |
| Koriyapara | 6 | 185 | 135 | 22 | 3.40 | 181 | 180 | - | 165 | 45 | 0.81 |
| Bhamariya | 7 | 137 | 122 | 44 | 1.20 | 132 | 178 | - | 170 | 50 | 0.25 |
| Lalgarh | 8 | 200 | 136 | 23 | 0.30 | 192 | 195 | - | 130 | 41 | 0.60 |
| Berawa | 9 | 187 | 120 | 45 | 0.70 | 215 | 138 | - | 146 | 42 | 0.95 |
| Ruparel | 10 | 125 | 67 | 36 | 1.20 | 195 | 169 | - | 207 | 40 | 0.30 |
| Gwalrundi | 11 | 89 | 78 | 47 | 1.35 | 117 | 68 | - | 150 | 30 | 0.40 |
| Jamda | 12 | 175 | 95 | 38 | 2.30 | 138 | 125 | - | 208 | 38 | 0.50 |
| Panchpiplya | 13 | 181 | 137 | 50 | 1.95 | 162 | 126 | - | 190 | 35 | 0.80 |
| Bhimkund | 14 | 198 | 85 | 48 | 1.50 | 186 | 175 | - | 185 | 27 | 0.65 |
| Dhamni Bari | 15 | 177 | 110 | 35 | 1.70 | 230 | 190 | - | 178 | 38 | 0.20 |
| Semlya | 16 | 185 | 127 | 54 | 1.85 | 118 | 150 | - | 145 | 41 | 0.35 |
| Angliyapara | 17 | 155 | 135 | 30 | 1.65 | 120 | 76 | - | 160 | 36 | 0.40 |
| Para | 18 | 187 | 65 | 29 | 3.25 | 181 | 139 | - | 155 | 28 | 0.36 |
| Miyati | 19 | 190 | 69 | 51 | 2.50 | 215 | 128 | - | 205 | 31 | 4.00 |
| Udepuriya | 20 | 170 | 123 | 37 | 1.20 | 220 | 121 | - | 190 | 29 | 1.21 |
| Ratanpura | 21 | 178 | 118 | 30 | 1.15 | 97 | 148 | - | 130 | 26 | 1.13 |
| Rupgarh | 22 | 186 | 139 | 41 | 1.80 | 138 | 136 | - | 195 | 32 | 2.30 |
| Timarwani | 23 | 198 | 63 | 35 | 1.40 | 157 | 117 | - | 210 | 37 | 3.70 |
| Borwa | 24 | 115 | 138 | 55 | 2.05 | 172 | 98 | - | 200 | 40 | 3.60 |
| Machhlaimata | 25 | 135 | 140 | 58 | 2.10 | 235 | 117 | - | 170 | 35 | 0.35 |
| Kundla | 26 | 147 | 147 | 25 | 1.55 | 156 | 68 | - | 120 | 31 | 0.71 |
| Khajuri | 27 | 150 | 95 | 60 | 1.40 | 240 | 182 | - | 135 | 28 | 0.25 |
| Junwaniya Bara | 28 | 181 | 91 | 45 | 1.85 | 198 | 110 | - | 140 | 34 | 0.37 |
| Jamuri | 29 | 195 | 128 | 48 | 1.90 | 170 | 87 | - | 185 | 30 | 0.30 |
| Kakarej | 30 | 180 | 116 | 40 | 1.50 | 150 | 93 | - | 180 | 38 | 0.28 |

(***Abbreviations*** *- Ca = Calcium, Mg = Magnesium, Na = Sodium, K = Potassium,* $Cl^-$ *= Chloride,* $SO_4^-$ *= Sulfate,* $CO_3^-$ *= Carbonate,* $HCO_3^-$ *= Bi-Carbonate,* $NO_3^-$ *= Nitrate,* $F^-$ *= Fluoride.)*

**Table 3:** Determination of chemical parameters in ground water samples of study area (Values expressed in epm).

| Location | Sample No. | Concentration of Cation | | | | Total of Cation | Concentration of Anion | | | | Total of Anion |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca | Mg | Na | K | | $Cl^-$ | $SO_4^-$ | $CO_3^-$ | $HCO_3^-$ | |
| Madalda | 1 | 5.738 | 12.092 | 1.218 | 0.028 | 19.076 | 3.103 | 1.436 | - | 1.999 | 6.538 |
| Karikurna | 2 | 5.988 | 10.693 | 1.609 | 0.043 | 18.333 | 2.764 | 2.290 | - | 3.851 | 8.905 |
| Nagari | 3 | 4.740 | 8.061 | 1.305 | 0.058 | 14.164 | 4.795 | 2.602 | - | 2.392 | 9.789 |
| Chirwa | 4 | 8.483 | 6.251 | 1.609 | 0.046 | 16.389 | 3.385 | 1.457 | - | 1.999 | 6.841 |
| Walakhori | 5 | 9.730 | 6.663 | 1.392 | 0.092 | 17.877 | 4.654 | 1.623 | - | 2.196 | 8.473 |
| Koriyapara | 6 | 9.231 | 11.105 | 0.957 | 0.086 | 21.379 | 5.106 | 3.747 | - | 2.704 | 11.557 |
| Bhamariya | 7 | 6.836 | 10.035 | 1.914 | 0.030 | 18.815 | 3.723 | 3.705 | - | 2.786 | 10.214 |
| Lalgarh | 8 | 9.98 | 11.187 | 1.000 | 0.007 | 22.174 | 5.416 | 4.059 | - | 2.130 | 11.605 |
| Berawa | 9 | 9.331 | 9.871 | 1.957 | 0.017 | 21.176 | 6.065 | 2.873 | - | 2.392 | 11.33 |
| Ruparel | 10 | 6.237 | 5.511 | 1.566 | 0.030 | 13.344 | 5.500 | 3.518 | - | 3.392 | 12.41 |
| Gwalrundi | 11 | 4.441 | 6.416 | 2.044 | 0.034 | 12.935 | 3.300 | 1.415 | - | 2.458 | 7.173 |
| Jamda | 12 | 8.732 | 7.814 | 1.653 | 0.058 | 18.257 | 3.892 | 2.602 | - | 3.409 | 9.903 |
| Panchpiplya | 13 | 9.031 | 11.269 | 2.175 | 0.049 | 22.524 | 4.570 | 2.623 | - | 3.114 | 10.307 |
| Bhimkund | 14 | 9.880 | 6.992 | 2.088 | 0.038 | 18.998 | 5.247 | 3.643 | - | 3.032 | 11.922 |
| Dhamni Bari | 15 | 8.832 | 9.048 | 1.522 | 0.043 | 19.445 | 6.488 | 3.955 | - | 2.917 | 13.36 |
| Semlya | 16 | 9.231 | 10.447 | 2.349 | 0.047 | 22.074 | 3.328 | 3.123 | - | 2.376 | 8.827 |
| Angliyapara | 17 | 7.734 | 11.105 | 1.305 | 0.042 | 20.186 | 3.385 | 1.582 | - | 2.622 | 7.589 |
| Para | 18 | 9.331 | 5.346 | 1.261 | 0.083 | 16.021 | 5.106 | 2.893 | - | 2.540 | 10.539 |
| Miyati | 19 | 9.481 | 5.675 | 2.218 | 0.063 | 17.437 | 6.065 | 2.664 | - | 3.359 | 12.088 |
| Udepuriya | 20 | 8.483 | 10.117 | 1.609 | 0.030 | 20.239 | 6.206 | 2.519 | - | 3.114 | 11.839 |
| Ratanpura | 21 | 8.882 | 9.706 | 1.305 | 0.029 | 19.922 | 2.736 | 3.081 | - | 2.130 | 7.947 |
| Rupgarh | 22 | 9.281 | 11.434 | 1.783 | 0.046 | 22.544 | 3.892 | 2.831 | - | 3.196 | 9.919 |
| Timarwani | 23 | 9.880 | 5.182 | 1.522 | 0.035 | 16.619 | 4.428 | 2.435 | - | 3.441 | 10.304 |
| Borwa | 24 | 5.738 | 11.351 | 2.392 | 0.052 | 19.533 | 4.852 | 2.040 | - | 3.278 | 10.17 |
| Machhlaimata | 25 | 6.736 | 11.516 | 2.523 | 0.053 | 20.828 | 6.629 | 2.435 | - | 2.786 | 11.85 |
| Kundla | 26 | 7.335 | 12.092 | 1.087 | 0.039 | 20.553 | 4.400 | 1.415 | - | 1.966 | 7.781 |
| Khajuri | 27 | 7.485 | 7.814 | 2.61 | 0.035 | 17.944 | 6.770 | 3.789 | - | 2.212 | 12.771 |
| Junwaniya Bara | 28 | 9.031 | 7.485 | 1.957 | 0.047 | 18.52 | 5.585 | 2.290 | - | 2.294 | 10.169 |
| Jamuri | 29 | 9.730 | 10.529 | 2.088 | 0.048 | 22.395 | 4.795 | 1.811 | - | 3.032 | 9.638 |
| Kakarej | 30 | 8.982 | 9.542 | 1.74 | 0.038 | 20.302 | 4.231 | 1.936 | - | 2.950 | 9.117 |

***(Abbreviations** - Ca = Calcium, Mg = Magnesium, Na = Sodium, K = Potassium, $Cl^-$ = Chloride, $SO_4^-$ = Sulfate, $CO_3^-$ = Carbonate, $HCO_3^-$ = Bi-Carbonate.)*

**Table 4:** Determination of chemical parameters of ground water samples of Thandla area, Jhabua district, Madhya Pradesh (Values expressed in percentage (%) epm).

| Location | Sample No. | Concentration of Cation | | | | Concentration of Anion | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Ca | Mg | Na | K | $Cl^-$ | $SO_4^-$ | $CO_3^-$ | $HCO_3^-$ |
| Madalda | 1 | 30.079 | 63.388 | 6.384 | 0.146 | 47.460 | 21.963 | - | 30.575 |
| Karikurna | 2 | 32.662 | 58.326 | 8.776 | 0.234 | 31.038 | 25.715 | - | 43.245 |
| Nagari | 3 | 33.465 | 56.911 | 9.213 | 0.409 | 48.983 | 26.580 | - | 24.435 |
| Chirwa | 4 | 51.760 | 38.141 | 9.817 | 0.280 | 49.481 | 21.298 | - | 29.220 |
| Walakhori | 5 | 54.427 | 37.271 | 7.786 | 0.514 | 54.927 | 19.154 | - | 25.917 |
| Koriyapara | 6 | 43.177 | 51.943 | 4.476 | 0.402 | 44.181 | 32.421 | - | 23.397 |
| Bhamariya | 7 | 36.332 | 53.335 | 10.172 | 0.159 | 36.449 | 36.273 | - | 27.276 |
| Lalgarh | 8 | 45.007 | 50.450 | 4.509 | 0.031 | 46.669 | 34.976 | - | 18.354 |
| Berawa | 9 | 44.064 | 46.614 | 9.241 | 0.080 | 53.530 | 25.357 | - | 21.112 |
| Ruparel | 10 | 46.740 | 41.299 | 11.735 | 0.224 | 44.319 | 28.348 | - | 27.332 |
| Gwalrundi | 11 | 34.333 | 49.601 | 15.802 | 0.262 | 46.005 | 19.726 | - | 34.267 |
| Jamda | 12 | 47.828 | 42.800 | 9.054 | 0.317 | 39.301 | 26.274 | - | 34.423 |
| Panchpiplya | 13 | 40.095 | 50.031 | 9.656 | 0.217 | 44.338 | 25.448 | - | 30.212 |
| Bhimkund | 14 | 52.005 | 36.803 | 10.990 | 0.200 | 44.011 | 30.556 | - | 25.431 |
| Dhamni Bari | 15 | 45.420 | 46.531 | 7.827 | 0.221 | 48.562 | 29.603 | - | 21.833 |
| Semlya | 16 | 41.818 | 47.327 | 10.641 | 0.212 | 37.702 | 35.380 | - | 26.917 |
| Angliyapara | 17 | 38.313 | 55.013 | 6.464 | 0.208 | 44.604 | 20.845 | - | 34.550 |
| Para | 18 | 58.242 | 33.368 | 7.870 | 0.518 | 48.448 | 27.450 | - | 24.100 |
| Miyati | 19 | 54.372 | 32.545 | 12.720 | 0.361 | 50.173 | 22.038 | - | 27.787 |
| Udepuriya | 20 | 41.914 | 49.987 | 7.949 | 0.148 | 52.419 | 21.277 | - | 26.302 |
| Ratanpura | 21 | 44.583 | 48.720 | 6.550 | 0.145 | 34.428 | 38.769 | - | 26.802 |
| Rupgarh | 22 | 41.168 | 50.718 | 7.908 | 0.204 | 39.237 | 28.541 | - | 32.220 |
| Timarwani | 23 | 59.450 | 31.181 | 9.158 | 0.210 | 42.973 | 23.631 | - | 33.394 |
| Borwa | 24 | 29.375 | 58.111 | 12.245 | 0.266 | 47.708 | 20.058 | - | 32.232 |
| Machhlaimata | 25 | 32.341 | 55.290 | 12.113 | 0.254 | 55.940 | 20.548 | - | 23.510 |
| Kundla | 26 | 35.688 | 58.833 | 5.288 | 0.189 | 56.548 | 18.185 | - | 25.266 |
| Khajuri | 27 | 41.713 | 43.546 | 14.545 | 0.195 | 53.010 | 29.668 | - | 17.320 |
| Junwaniya Bara | 28 | 48.763 | 40.415 | 10.566 | 0.253 | 54.921 | 22.519 | - | 22.558 |
| Jamuri | 29 | 43.447 | 47.014 | 9.323 | 0.214 | 49.750 | 18.790 | - | 31.458 |
| Kakarej | 30 | 44.241 | 47.000 | 8.570 | 0.187 | 46.407 | 21.235 | - | 32.357 |

***(Abbreviations** - Ca = Calcium, Mg = Magnesium, Na = Sodium, K = Potassium, $Cl^-$ = Chloride, $SO_4^-$ = Sulfate, $CO_3^-$ = Carbonate, $HCO_3^-$ = Bi-Carbonate.)*

The concentrations of analyzed ground water samples *are* displayed (Table 4) in tabular form and graphic methods such as trilinear diagram *and* others.

### 2.3.3 Evaluation of Chemical Quality Applications

Chemical quality assessment for the drinking and domestic use is described in the text.

❖ **Ground Water Quality Suitability for Drinking and Domestic use**

In general, ground water is free from suspended impurities and pollution. It is having constant temperature that makes ground water as superior in comparison of surface water. Chemical quality of ground water remains nearly constant, except water supply points are located close up to saline zones. The permissible and maximum desirable limits of different ions and physical parameters of water recommended by Piper (1944), B.I.S. (1983), W.H.O. (1993, 2004, and 2011) have been followed. Comparative examination of chemical quality standards with determined values of ground water of study area have been carried out for evaluation of ground water suitability for drinking and domestic uses.

Most useful graphic representation for comparing water quality analysis is the Trillinear diagram proposed by Piper (1944), which expressed as percentage of total cations in milli equivalents per liter, plot as a single point on the left triangle, and anions, similarly expressed as percentage of total anions, plotted as a point in the right triangle. These two points are then projected into the central diamond-shaped figure parallel to the upper edges of the central area. This single point is thus distinctively related to the total ionic distribution (Todd, 1959, 1980, 2010).

- **Representation of Analyzed Data on Trilinear Diagram (Piper's Diagram)**

Trilinear diagram was first used by Hill (1940) for graphic representation of chemical analysis data of water samples. This method has been modified by Piper (1944, 1953) and modified diagram is most commonly used for classifying the natural water (Figure 3). Karanth (2003) described Trillinear methods of plotting Piper's diagram has been extensively used to understand problems concerning with the geochemical evolution of ground water. Diamond shaped field has been subdivided into nine areas. The plots on diamond shaped field represent the type of water.

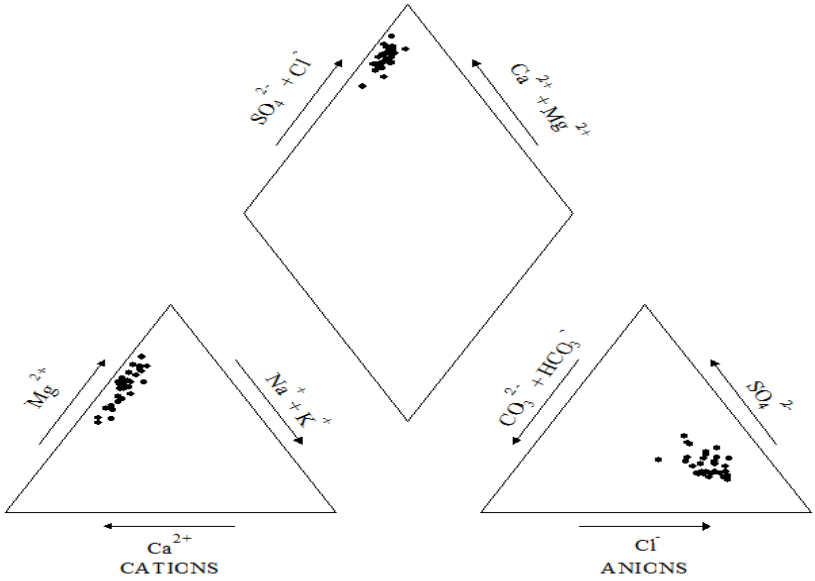


**Figure 3:** Trilinear diagram (Piper's diagram) for water analysis of study area.

(1) Alkaline earth (Ca + Mg) exceed alkalies (Na + K), (2) Alkalies exceeds alkaline earth, (3) Week acids ($CO_3$ + $HCO_3$) exceed Strong acids ( $SO_4$ + Cl), (4) Strong acids exceeds weak acids, (5) Magnesium bicarbonate type, (6) Calcium-Chloride type, (7) Sodium-chloride type, (8) Sodium-Bicarbonate type, and (9) Mixed type (No cation-anion exceed 50%).

The chemical analysis of Thandla ground water samples indicate that all the plots of ground water samples represents category 6 (Calcium-chloride type) classification has been suggested by Karanth (2003).

**Table 5:** Comparison of physical and chemical parameters of ground water samples in Thandla study area with BIS (1983, 1991), and WHO (1983, 1984, 2004, 2012) for drinking use.

| **S. No.** | **Water Quality Constituents** | **Bureau of Indian Standards (BIS, 1983, 1991)** | | **World Health Organization (WHO, 1983, 1984, 2004, 2011, 2012)** | | **Ground water samples in study area, Jhabua district** | |
|---|---|---|---|---|---|---|---|
| | Physical and Chemical Parameters | Highest Desirable | Maximum Permissible | Highest Desirable | Maximum Permissible | Concentration Range in study area (mg/l) | Remark |
| 1 | Colour | - | - | - | - | Colourless | - |
| 2 | Taste | - | - | - | - | Tasteless | - |
| 3 | Odour | - | - | - | - | Odourless | - |
| 4 | TDS | 500 | 1000 | 500 | 1500 | 275 - 481 | Samples are within limits |
| 5 | $p^H$ | 6.5 - 8.5 | 6.5 - 9.2 | 7.0 - 8.5 | 6.5-9.2 | 7.05 - 8.30 | Samples are within limits |
| 6 | TH (mg/lit) | 300 | 600 | 100 | 500 | 230 - 340 | Low values |
| 7 | Ca (mg/lit) | 75 | 200 | 75 | 200 | 89 - 200 | - |
| 8 | Mg (mg/lit) | 30 | 100 | 30 | 150 | 63 - 147 | - |
| 9 | $Na^-$ (mg/lit) | - | 200 | - | 200 | 22 - 60 | Samples are within limits |
| 10 | $SO_4^-$ (mg/lit) | 150 | 1000 | 200 | 400 | 68 - 195 | Samples are within limits |
| 11 | $Cl^-$ (mg/lit) | 250 | 1000 | 45 | 600 | 97 - 240 | - |
| 12 | $NO_3^-$ (mg/lit) | 45 | 45 | - | - | 21 - 50 | 1 Sample indicates high value |
| 13 | $HCO_3^-$ (mg/lit) | - | - | - | - | 120 - 235 | - |
| 14 | $F^-$ (mg/lit) | 0.5 | 1.5 | 1 | 1.5 | 0.20 - 4.00 | 4 Samples have high values |

**3.1 Comparison of Ground Water for Drinking and Domestic Purposes**

The comparative analysis of analyzed values of ground water samples with Bureau of Indian Standards (B.I.S., 1983, 1991) and World Health Organization (W.H.O., 983, 1984, 2004, 2011, 2012) recommended values indicate that the ground water of Thandla study area is, in general, suitable for domestic and drinking applications (Table 5). Except Fluoride, all Cations and Anions are within recommended values as suggested by Bureau of Indian Standards and World Health Organization. In the study area, 4 samples of ground water exhibit higher values of fluoride than the prescribed values of fluoride. People of the area, suffering health problems due to excess concentration of fluoride content. The ground water of *Miyati, Timarwani, Borwa and Rupgarh* villages revealing higher fluoride content needs to be treated for permissible limit of fluoride before supply with a view to reduced the prevailing health problem.

**3.2 Quality Assessment of Ground Water**

Chemical quality of ground water has been determined on the basis of collected 30 samples from Thandla study area located in Jhabua district, Madhya Pradesh. Based on the results of determined physical and chemical parameters of water samples collected from open dug wells. The comparative analysis of determined parameters with recommended values of the Bureau of Indian Standards, and World Health Organizations reveal that the ground water of Thandla study area, in general, is favourable for drinking and domestic purposes.

## CONCLUSION

The paper highlights chemical characteristics of Thandla ground water system of study area by treatment of 30 samples to chemical analysis adopting standard method of water analysis. The chemical analysis indicates ionic concentrations values which help to assess the nature of ground water suitability. The comparison of determined chemical values with the recommended ranges for water quality assessment with the Indian standards and World Health Organization. The comparative study reveals that the Thandla ground water samples except villages of *Miyati, Timarwani, Borwa and Rupgarh,* in general, indicate ground water is suitable for drinking and domestic applications.

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