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WATER QUALITY ASSESSMENT OF GROUND WATER IN UPPER TONS BASIN

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ABSTRACT

The quality of water is most important compared to quantity of water. The quality of groundwater varies depending on location and the level of the water table and is the outcome of all the activities that take place on the water. The Tons is also known as Tamas River, which originates from NFPI and meets the Ganga River in Allahabad district of Uttar Pradesh. The physic-chemical data have been collected for Amdara, Chorhata, Uchehara, Kakra, Amarpataan1, Naruara, Maihar New, Kusendi, Sabhaganj and Jhukehi in upper tons basin. Physical and chemical properties of groundwater have been done according to standard methods. Water quality indexing method used to analyses the water quality of groundwater in catchment. The parameters such as Chloride, Fluorides, Nitrates, Total Dissolved Solids and Electrical Conductivity etc. are having good state in groundwater in upper tons basin. The level of physico-chemical parameters in groundwater in upper tons basin have found within the permissible level which shows that the water is useful for various purpose.the Amdara, chorhata, Uchehara, Amarpatan and Jhukehi have excellent quality of ground water in the catchment and Kakra, Narura, Maihar new, Kusendi and Sabhaganj have good quality of ground water found in the catchment.

Keywords: Upper Tons, Physico-Chemical, Groundwater, Water Quality Index.

INTRODUCTION

Water is one of the most abundant resource available on earth for survival of living being. The plants, animal and other species are directly or indirectly depend on water for their survival on earth. The processes and reactions that have affected the water since it condensed in the atmosphere until it was released by a well determine the quality of groundwater (CPCB, 2008). The quality of water is most important compared to quantity of water. The primary aspects of groundwater and its utility are its chemical, physical, and biological features. Most places in the world, ground water is used for industrial, agricultural, and domestic purposes (Karunakaran *et al.,* 2009). The most prevalent problems related to drinking water include direct or indirect contamination by chemicals, human and animal waste and waste discharge from houses, businesses and municipalities (Deepak and Singh, 2013). In comparison to surface water, ground water is thought to be cleaner and pollution-free (Agrawal, 2010). Due to population growth, urbanization, industry, the failure of the monsoon, and inefficient rainwater management, the ground water potential and quality level in major cities and urban centers are deteriorating (karunakaran *et al.,* 2009).

The quality of groundwater varies depending on location and the level of the water table and is the outcome of all the activities that take place on the water (Shyamala *et al.,* 2008). Aquifer types, evapotranspiration, precipitation, topography, climate, and pumping rates are some of the variables that affect groundwater. Combinations of these elements result in a variety of water types that alter the composition of groundwater throughout time and space (Praveena *et al.,* 2011). Examining the chemical budget of key ions is becoming more significant as it clarifies where the ions come from in groundwater (Rao, 2006). Therefore, it becomes essential to continuously monitor ground water in order to reduce pollution and control the agents that cause it. Continuous ground water monitoring could be made simpler using the creation of a quick technique for measuring water quality without significantly sacrificing the precision of assessment.

STUDY AREA

The Tons is also known as Tamas River, which originates from NFPI and meets the Ganga River in Allahabad district of Uttar Pradesh (Figure 1.1). It has divided the whole Tons basin into two parts: first, the Upper Tons basin (Hilly and plateau region) and second, the Lower Tons basin (plain region). Tons river origin is at Tama-kund in the Kaimur Range. The origin is at the height of 610 metres (2,000 ft) from mean sea level. Tons River passes through Satna and Rewa district of Madhya Pradesh. Tons forms many waterfalls in Rewa district. Total flow length of the Tons river is 264 kilometres. It has a total drainage area of 16,860 square kilometres. The axis of Tons river flow is from south-west to north-east, Vindhyan range makes the boundary of water divider of this basin from south-west to north direction and Kaimur range completes this boundary from south-east to north-east.

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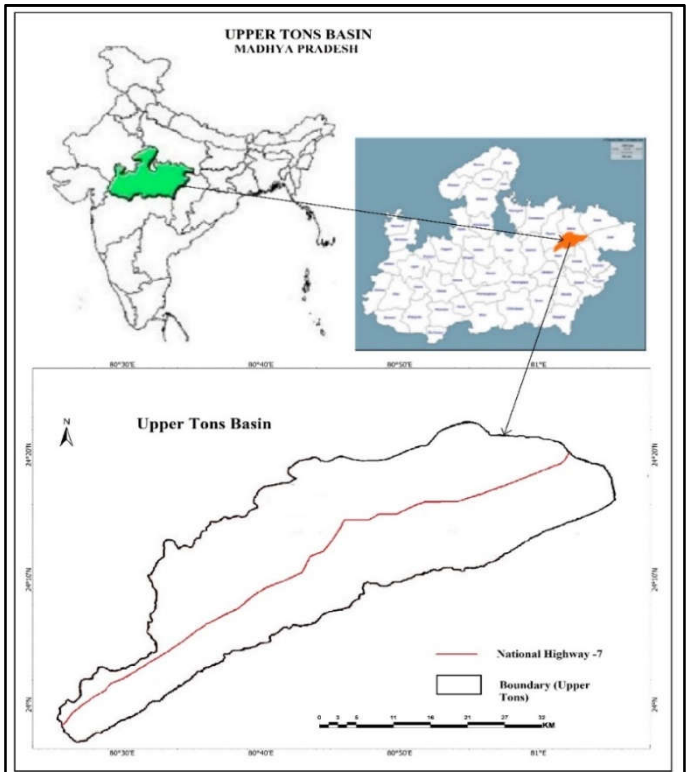


Figure 1: Location of Upper tons in Madhya Pradesh

The border high lands grade down towards the middle. The Tons which follows a highly rugged path treading in a south-west to north-east direction bisects the study region in almost two equal halves.

RESEARCH METHODOLOGY

The groundwater data upper tons basin has been collected from central ground water commission for the month of May. There eight physico-chemical parameter such as chloride, fluoride electrical conductivity, total hardness, bicarbonate, phosphorus, ortho-phosphate, total dissolved oxygen and water table data were selected for the collection of data. The physic-chemical data have been collected for Amdara, Chorhata, Uchehara, Kakra, Amarpataan1, Naruara, Maihar New, Kusendi, Sabhaganj and Jhukehi in upper tons basin. Physical and chemical properties of groundwater have been done according to standard methods (APHA,2005) and Hi- Media (WT-023) kit and their specific range for water analysis.

Water Quality Index (WQI)

The water quality index represents water quality by calculating a scoring rate. WQI helps in defining the overall water quality. Hortan (1965) describes the water quality index as a complex relationship of water parameters. Individual parameter influences water's overall quality (Desai B. and Desai H., 2012). The Water Quality Index (WQI) is being used to assess water quality developments for management purposes. The selection of boundaries in water is extremely useful in determining the WQI. The variety of several parameters broadens the water quality index, as well as the importance of several parameters varies depending on the presented use. The water quality standard is used by ICMR and BIS to standardize the water quality in Upper tons basin (Table 1).

Table 1: Water Standards Recommended by ICMR and BIS

S.No.	Parameters	Standards
1	pH	6.5-8.5
2	Magnesium(mg/l)	30
3	Calcium(mg/l)	75
4	Sulphate(mg/l)	150
5	Chloride(mg/l)	250
6	Nitrate(mg/l)	45
7	Electrical Conductivity(ECμS/cmat 25°C)	300

Source: *Central Pollution Control Board, 2023*

Thirteen physico-chemical parameters are taken into account in this assessment. Parameters are pH, Total Hardness (TH), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sulphate ($SO2-$), Chlorides ($Cl-$), Fluoride ($F-$), nitrate ($NO-$), Sodium ($Na+$), calcium ($Ca2+$), magnesium ($Mg2+$), Potassium ($K+$) were used to calculate WQI. However, chromium concentrations are excluded in the calculation of the WQI as it was found at only one location, i.e., at Nawabganj. These indices transform a large data set into a much condensed and informative form and help to extract the fundamental facts about the characteristics of the samples. In the present study Weighted Arithmetic Index and Nemerow's Pollution Index have been adopted to assess the status of existing water quality and to identify the physico-chemical parameters causing pollution respectively.

Calculation of Water Quality Index

The calculation of WQI was made using weighed arithmetic index method (Brown*et al*., 1972) in the following steps-(Rao *et al.,* 2010).

Determination of Water Quality Index

To know the portability of groundwater (quality), the Water Quality Index calculated by using equation 1:

$$WQI = \left(\sum_{i=1}^{n} W_i q_i \Big/ \sum_{i=1}^{n} W_i\right) \quad (1)$$

Where,

Wi is weight age factor it can be calculated by using equation 3.2:

$$W_i = \frac{K}{S_i} \quad (2)$$

Where,

K is a proportionality constant value is taken 1.0,

Si is the expected value of the ith quality of water parameter, and *n* is the matrix of water quality parameter.

qi is the quality estimation for the ith water variable calculated using equation

$$q_i = \left[\left\{\frac{(V_a - V_i)}{(S_i - V_i)}\right\} \times 100\right] \quad (3)$$

Where,

Va is the real value of the ith quality parameter obtained from laboratory analysis,

Vi is the optimum value of the ith water parameter acquired from standard tables,

Vi is equal to 0 for pH 7, and other parameters are equal to zero.

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.

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

Where,

qn = Quality rating for the n^{th} water quality parameter.

Vn = Estimated (calculated) value of the n^{th} parameter at a given sampling station.

Sn =Standard permissible value of n^{th} parameter.

Vi = Ideal value of n^{th} parameter in pure water.

All the ideal values(*Vi*) are taken as zero for drinking water except for pH=7.0and 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 14.6mg/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,

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 n^{th} parameters

Sn = standard value for n^{th} parameters

K=constant for proportionality

The value of 'K' can be determined by-

Step III - Calculation of WQI

WQI is calculated from the following equation-

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

Nemerow's Pollution Index (NPI)

Nemerow's Pollution Index (NPI) is a simplified pollution index introduced by Neme (Saeedi *et al.,* 2010) which is also known as Raw's pollution index (RPI). It is given as-

$$NPI = CCC\text{-}LCC$$

Where,

Ci Observed value of ith parameter

Li Permissible limit of ith parameter

Each value of NPI shows the relative pollution contributed by single parameter, It should be less than or equal to one. NPI values exceeding 1.0 indicate the presence of impurity in water (Saeedi *et al.,* 2010).

RESULT AND DISCUSSION

Groundwater level in Upper Tons Basin

Considering groundwater as a dynamic and replenish able resource, is typically calculated using the yearly recharge, which might be developed with the use of appropriate groundwater infrastructure. The groundwater status in upper tons basin varies according to their location. It shows that the depth of groundwater level varies in the different place within the basin. Table 1.1 is showing the depth or level of groundwater in the upper tons basin. The areas such as Jhukehi and Kakra have depth of groundwater level 67 feet and 72 feet respectively, which also describe the low potential of groundwater use and extraction.

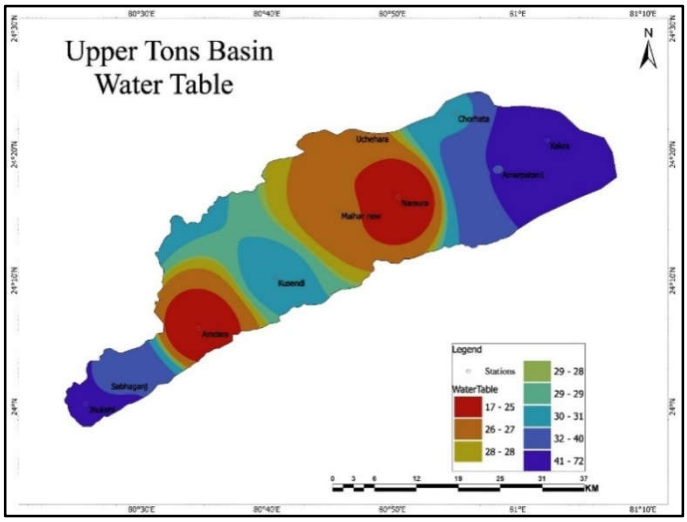


Figure 2: Status of Groundwater level in Upper Tons Basin

The areas such as Naruara, Amdara, Uchehara, Maihar new and Chorhata have groundwater level within 30 feet depth from surface. These locations in the upper tons basin have reflected the high potential use of groundwater and also a good state of groundwater presence in the basin.

Physico-Chemical Components of Water Quality in Upper Tons pH

pH is regarded as a significant ecological aspect and a valuable piece of information (Shyamala *et al.,* 2008). The pH ideal value is 6.5 to 7.2 and pH permissible value is 8.5 as per BIS and ICMR. The

highest pH value in the upper tons basin is observed from Amdara with 8.16 pH value in groundwater followed by Maihar new with 8.01. The Sabhaganj has most ideal pH level in the basin followed by amarpatan1 and Kusendi with 7.4 pH and 7.41 pH level of groundwater in the basin. The Jhukehi and Naraura have pH level around 7.5 which shows that groundwater is also in a good condition in these two location in the basin.

Chloride (mg/L)

The chloride (mg/L) has various forms such as NaCl, CaCl2 and MgCl ans it found in all water throughout the earth's water. According to Shaikh and Mandre (2009 the ideal chloride is 250 mg/L and permissible is 1000 mg/L but in upper tons basin the chloride level is very low. Amdara has lowest level of chloride level with 19.99 mg/L in the upper Tons basin followed by Uchehara with 22.49 mg/L, Naruara and Maihar new with 29.99 mg/L for each location. The light brown zone has concentration of chloride range between 53 mg/L to 65 mg/L(Fig. 1.3). The dark brown zone has chloride concentration range between 66 mg/L to 87 mg/L. the pink zone in basin has showing the chloride concentration range more than 88 gm/L.

Electric Conductivity

Electric conductivity is an index which denotes the total concentration of soluble salts in water (Purandara *et al.,* 2003). The ideal electric conductivity of water is 400 µS/cm and the permissible electric conductivity is 1000 µS/cm. The location such as Jhukehi and Amdara have highest electric conductivity with 1305 µS/cm and 1000 µS/cm respectively. The Sabhaganj and Uchehara have lowest level of electric conductivity in groundwater in upper tons basin with the value of 84 µS/cm and 334 µS/cm respectively (Fig. 1.4). The Chorhata, Amrpatan1 and Kakra have electric conductivity twice the ideal level 721 µS/cm, 735 µS/cm and 832 µS/cm respectively.

Table 1.2 Physico-Chemical Characteristics of Groundwater in Upper Tons Basin

Point /Area	Chloride (mg/L)	Electrical Conductivity (µS/cm) at 25°C)	Fluoride (mg/L)	Total Hardness (mg/L)	Bicarbonate (mg/L)	Phosphorus, ortho-phosphate (mg/L)	Total Dissolved Solids (mg/L)	pH	Sodium (mg/L)
Amdara	19.9994	1000	0.26	250	305	0.08	417.3	8.16	36
Chorhata	77.4978	721	1.25	180	262.3	0.07	468.65	7.55	83
Uchehara	22.4994	334	0.16	85	122	0.08	217.1	7.61	38
Kakra	114.997	832	0.99	360	193.248	0.09	540.8	7.48	30
Amarpatan1	52.4985	735	0.37	300	344.223	0.08	477.75	7.4	45
Naraura	29.9992	617	0.58	220	274.5	0.08	401.05	7.56	35
Maihar new	29.9992	484	0.48	170	189.1	0.05	314.6	8.01	32
Kusendi	57.4822	608	0.35	190	213.5	0.06	395.2	7.41	48
Sabhaganj	37.1135	84	0.36	328.28	392.53	0.07	546	7.26	41
Jhukehi	189.995	1305	0.39	275	317.2	0.08	848.25	7.58	164
Permissible standard	1000	1000	1.5	600	400	0.1	2000	8.5	60
Ideal Standard	250	400	0.6-1.2	200	200	0.08	500	6.5-7.2	30

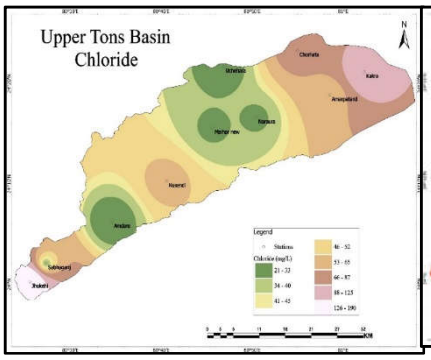
Source: CGWC, 2023

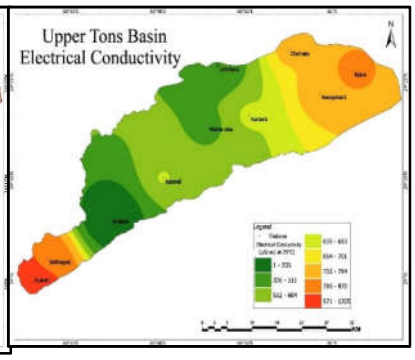
Fluoride (mg/L)

Fluoride (mg/L) is mineral is white and colorless and it is mainly found in groundwater. The ideal level is 0.6-1.2 mg/L and the permissible level is 1.5 mg/L. The Chorhata has highest level of fluoride in upper Ton basin with 1.25 mg/L. Uchehara and Amdara have lowest level of fluoride in the basin with 0.16 and 0.26 respectively. Naruara has fluoride level of 0.58 mg/L which is nearby the ideal level of fluoride in groundwater. The green zones has low concentration of Fluoride with range between 0.161 mg/L to 0.263 mg/L (Fig. 1.5). it is followed by light green zone with range of fluoride concentration between 0.264 mg/L to 0.332 mg/L.

Total Hardness

Total hardness is property of water which prevents the lather formation with soap and it also increase the boiling point of water (Trivedy and Goel, 1986). The ideal level of hardness in groundwater is 200 mg/L and permissible level of total hardness is 600 mg/L in the basin. Uchehara has lowest level of total hardness in the upper tons basin with value of 85 mg/L. the amarpatan1, Sabhaganj and Kakra have highest level of hardness in the upper tons basin with the value of 300 mg/L, 328mg/L and 360 mg/L respectively (Fig. 1.6). The location such as Kusendi and Chorhata in upper tons basin has hardness nearby ideal level of total hardness of water.





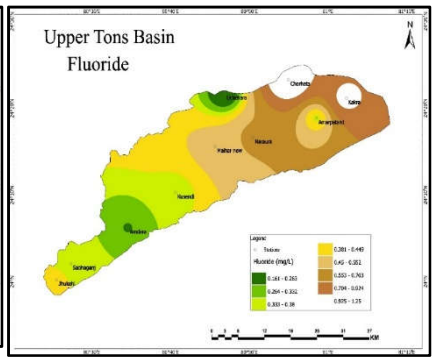
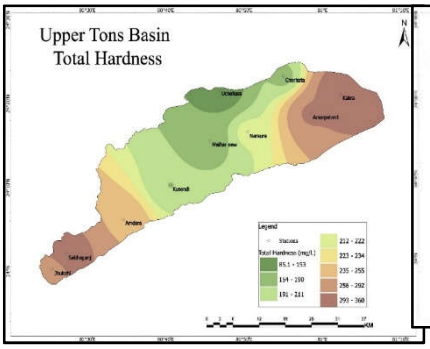
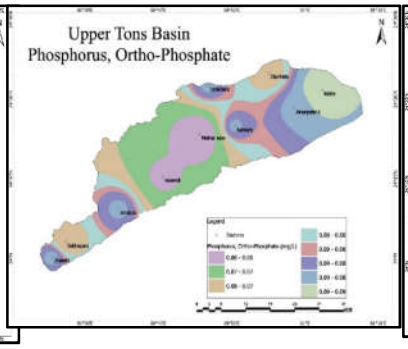


Figure 1.3 Chloride Figure 1.4 Electronic Conductivity Figure 1.5 Fluoride





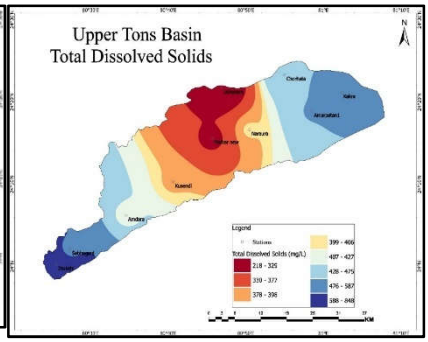


Figure 1.6 Total Hardness Figure 1.7 Bicarbonate Figure 1.9 TDS

Bicarbonate

The bicarbonate in water represents the alkalinity of water. It also represents the buffer against the acidic effect of such water (Dawodu and Ipeaiyeda, 2008). The ideal level of carbonate presence in groundwater is 200 mg/L and permissible level is 400 mg/L. the highest level of bicarbonate is found in Sabhaganj 392.53 mg/L followed by Amarpatan with 344.22 mg/L and Jhukehi with 317.2 mg/L. The lowest level of Bicarbonate is found in Uchehara and Maihar new with 122 mg/L and 189.1 mg/L respectively (Fig. 1.7). Kusendi has ideal level of bicarbonate in the basin with 213.5 mg/L.

Phosphorus

Phosphorus is one of the contaminants of groundwater and it is found in both natural and anthropogenic elements. The ideal level of phosphorus in groundwater is 0.08 mg/L and permissible level of Phosphorus in groundwater is 0.1 mg/L. The lowest level of phosphurs in upper tons basin is found in the Maihar new with 0.05 mg/L. The Location such as Amdara, Uchehara, Amarpatan1, Naraura, and Jhukehi have ideal level of Phosphorus in the upper tons basin with the value of 0.08 mg/L for each locations. There is only Kakra has highest phosphurs level with 0.09 mg/l in the basin.

Total Dissolved Oxygen (TDS)

The permissible level is 2000 mg/L of TDS is allowed for various non-drinking purpose. The Jhukehi has highest level of TDS found in the basin with 848.25 mg/L. Uchehara has lowest level of YDS in basin with 217.1 mg/L value in groundwater. Other locations such as Chorhata and Amarpatan have TDS level nearby the ideal level of TDS into the water with 468 mg/L and 477 mg/L respectively (Fig. 1.9). The TDS concentration over the map has represented by different color zone. The red zone has TDS concentration range between 219 mg/L to 328 mg/L.

Sodium

Sodium is sodium chloride which is common salt found in groundwater. The ideal level of sodium in water is 30 mg/L and permissible level is 60 mg/L. The Kakra has lowest of sodium 30 in the upper tons basin and Jhukehi has highest level of sodium with 164 mg/L. The locations such as Maiher new, Naruara and Uchehara have sodium level more than nearby ideal level with 32 mg/L, 35mg/L and 38 mg/L.

Water Quality Index (WQI)

It is a single number value which is able to describe the overall water quality at a certain location and time based on several water quality parameters. WQI is the simplest form of index which is knowable and used by the public. WQI values comprises various important physico-chemical parameters of drinking water presented in a Table 1.3. The Water Quality Index are represented from 0 to 100 and above 100 show water quality unfit for drinking. The excellent water quality has found between 0-25 and very poor quality found from 76-100.

Table 1.3: Water Quality Status based on WQI.

S. No.	Water Quality Index	Status of Water Quality
1	0 – 25	Excellent Water Quality
2	26 – 50	Good Water Quality
3	51 – 75	Poor Water Quality
4	76 – 100	Very Poor Water Quality
5	> 100	Unfit for Drinking

Source: *WHO, 2004*

Calculation of WQI

The water quality index has been calculate on the basis of seven parameters. These parameters are pH, Magnesium, Calcium, Sulphate, Chloride, Nitrate, and Electrical Conductivity, etc. these parameters samples has been used to study the water quality index of Upper Tons basin. The following table comprises the calculated value of one of the sample station in the study area (Table 1.4).

Table 1.4: Water Quality Status based on WQI.

S.No.	Parameters	Observed Value	Standard Value (Sn)	Quality Rating (Qn)	Unit Weight (Wn)	Qn*Wn
1	Potential of Hydrogen (pH)	7.3	6.5-8.5	20	0.2941	5.882
2	Magnesium (Mg)	19.456	30	64.8533	0.0834	5.4087
3	Calcium (Ca)	80.16	75	106.88	0.0334	3.5697
4	Sulphate (SO4)	22	150	14.6667	0.0167	0. 2449
5	Chloride (Cl)	21.276	250	8.5104	0.01	0.0851
6	Nitrate (NO3)	39	45	86.6667	0.5004	43.368
7	Electrical Conductivity (EC µS/cm at 25°C)	780	300	260	0.0208	5.408
				∑Qn =561.5771	∑Wn =0.9588	∑Qn*Wn =63.7215
Water Quality Index (WQI) = ∑Qn Wn / ∑Wn WQI = 63.7215 / 0.9588= 66.4596						

Source: *Calculated by Author based on CGWB, 2023*

The water quality index has been calculate on the basis of seven parameters. These parameters are TDS, flouride, Chloride, Hardness, and Elecrical Conductivity, Bicarbonate, etc. these parameters samples has been used to study the water quality index of upper tons catchment. The following table 1.5 comprises the calculated value of one of the sample station in the study area. the Amdara, chorhata, Uchehara, Amarpatan and Jhukehi have excellent quality of ground water in the catchment and Kakra, Narura, Maihar new, Kusendi and Sabhaganj have good quality of ground water found in the catchment.

Table 1.5 Water Quality Index Values of different location of Upper Tons Catchment.

S.No	Sampling Location	Water Quality Index	Status
1	Amdara	15	Excellent
2	Chorhata	14	Excellent
3	Uchehara	17	Excellent
4	Kakra	32	Good
5	Amarpatan1	18	Excellent
6	Naraura	28	Good
7	Maihar new	40	Good
8	Kusendi	27	Good
9	Sabhaganj	28	Good
10	Jhukehi	22	Excellent

Source: *Calculated by Author based on CGWC data, 2023*

Correlation between Physico-Chemical Parameters for Water Quality in Upper Tons Basin

Water quality is assessed with the help of physico-chemical parameter of groundwater upper tons basin and their relations show with each other also reflect the level of water quality. Higher salinity was also noted in regions where groundwater levels were only a short distance below the surface by Hu *et al.,* (2005). Chloride has strong relationship high positive correlation with fluoride and total dissolved oxygen and showed a moderate association with electric conductivity and total hardness. The following table 1.6 show the correlation between the components of water quality. The chloride has strong positive correlation between the fluoride (0.822) and Total dissolved oxygen (0.868) and moderate relationship with electric conductivity (0.307) and total hardness (0.401). There is low level of correlation of fluoride with bicarbonate (0.134) and almost no correlation (0.31) with phosphorus is found. The fluoride has strong relationship with total dissolved oxygen (0.808) and moderate relationship with total hardness (0.407). Fluoride has low correlation with phosphorus

Table 1.6 Correlation between the Physico-Chemical Parameters

	Chloride (mg/L)	Fluoride (mg/L)	Electrical Conductivity (µS/cm) at 25°C)	Total Hardness (mg/L)	Bicarbonate (mg/L)	Water table	Phosphorus, ortho-phosphate (mg/L)	Total Dissolved Solids (mg/L)
Chloride (mg/L)	1	0.822	0.307	0.401	0.134	0.846	0.31	0.868
Fluoride (mg/L)	0.822	1	0.287	0.462	0.336	0.719	0.134	0.808
Electrical Conductivity (µS/cm) at 25°C)	0.307	0.287	1	0.188	0.084	0.283	0.098	0.172
Total Hardness (mg/L)	0.401	0.462	0.188	1	0.641	0.617	0.428	0.661
Bicarbonate (mg/L)	0.134	0.336	-0.084	0.641	1	0.041	0.129	0.592
Water table	0.846	0.719	0.283	0.617	0.041	1	0.433	0.708
Phosphorus, ortho-phosphate (mg/L)	0.31	0.134	0.098	0.428	0.129	0.433	1	0.319
Total Dissolved Solids (mg/L)	0.868	0.808	0.172	0.661	0.592	0.708	0.319	1

Source: Calculated by Author based on CGWC data, 2023

(0.134) and electric conductivity (0.287). The electric conductivity has low relationship with all parameters such as total dissolved oxygen (0.172), phosphorus (0.098), total hardness (0.188), and there is no relation found between the electric conductivity and bicarbonate (-0.084). The bicarbonate has strong relationship between total dissolved oxygen (0.592) and low relationship between bicarbonate with phosphorus (0.129). The phosphorus has moderate relationship with total dissolved oxygen (0.319).

CONCLUSION

The Physico-chemical parameters of groundwater in upper tons basin has large portion which does support the water quality level given by BIS. The depth of groundwater level is good and can be used for human purpose. The parameters such as Chloride, Fluorides, Nitrates, Total Dissolved Solids and Electrical Conductivity etc. are having good state in groundwater in upper tons basin. The level of physico-chemical parameters in groundwater in upper tons basin have found within the permissible level which shows that the water is useful for various purpose. The study's findings unequivocally showed that the groundwater is fit for human consumption.

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