*Advances in Applied Sciences*
2024, Vol. 9, No. 2, pp. 31-36
https://doi.org/10.11648/j.aas.20240902.12

Research Article

# Qualitative Assessment of Water Sources in Pench Tiger Reserve, Maharashtra

**Gajanan Khadse*, Sandip Narnaware**

CSIR-National Environmental Engineering Research Institute, Nagpur, India

## Abstract

To ascertain the quality of water used for drinking purpose, by the consumers and wildlife, water quality monitoring of the groundwater and surface water sources was conducted in Pench Tiger Reserve area in Maharashtra. The fecal streptococci (FS) and fecal coliforms (FC) ranged from 0-5 CFU/100ml and 0-62 CFU/100ml respectively. The bacterial contamination in groundwater may be because of improper source protection and possibility of enroute contamination. Geogenic background has major impact on groundwater quality in Pench with gneisses and basaltic type of formation which reflect on the physicochemical water quality parameters. Water quality parameters like turbidity, fluoride, iron and bacterial counts are above the permissible limit in some water sources making the water unsuitable for drinking purpose. The high turbidity in the groundwater samples is attributed to the presence of iron precipitates. Study area is covered with red ferruginous soils which are rich in iron and contributes to iron content in groundwater. Appropriate treatment is required to reduce down the iron and fluoride concentrations followed by disinfection so that the water quality parameters fulfill BIS guidelines for potability of water. The correlation and regression analysis among different water quality parameters helps in establishing relationships among water quality parameters drawing inferences about them. Water quality monitoring at regular interval with suitable treatment measures is very much essential to provide safe drinking water to the consumers.

## Keywords

Iron, Fluoride, Fecal Streptococci, Fecal Coliform, Disinfection

## 1. Introduction

Water conservation and its purification are very much essential for betterment of the life [1]. The quality and quantity are important issues pertaining to water, since in recent years, the quality of the water deteriorated due to industrialization, urbanization, intensive agriculture and allied developmental activities [2] which render the water unsuitable for intended beneficial uses on day to day basis [3-5]. Quality of groundwater is mainly based on the physicochemical constituents due to rock weathering and human activities [6]. Therefore it is required to protect and manage the groundwater quality because if it is contaminated it is difficult to regain its quality [7-9].

The water quality is defined by a set of physicochemical and biological characteristics [10]. These characteristics need to be organized into guidelines pertaining to suitability of water for designated use [11]. The study is undertaken to understand the quality of available water sources in Pench Tiger Reserve, Nagpur, Maharashtra state, India. Pench Tiger

*Corresponding author: gk_khadse@neeri.res.in (Gajanan Khadse), gkkhadse2007@rediffmail.com (Gajanan Khadse)

**Received:** 1 April 2024; **Accepted:** 24 April 2024; **Published:** 2 July 2024

Reserve is wildlife destinations of central India which is an ideal destination for its rich variety of flora and fauna and also one of the major tourist attractions [12]. Nine villages are situated on the periphery of Pench tiger reserve and only one village named Fulzari is located inside the forest boundary. About 4000 people and 4097 cattle depend on the available resources including existing water sources in the study area. People use water from the available water sources in the area that face water quality issues. In order to provide safe drinking water to the consumers, assessment of water quality was carried out in Pench tiger reserve area in Maharashtra.

## 2. Materials and Methodology

Study Area: Pench tiger reserve is located at the southernmost side of the Satpura hill range at the border of Maharashtra and Madhya Pradesh, at about 67 Km from Nagpur on NH-7. It is contiguous on the south with the 257.23 sq. km. area. Pench Tiger Reserve (Maharashtra) belongs to Level-1, Tiger Conservation Unit-31 [13]. Geogenic background has major impact on groundwater quality in Pench with gneisses and basaltic type of formation. The study area is drained by a number of seasonal streams, several water pools, locally known as *dohs*, acts as water holes for the wild life and local people [14].

### 2.1. Sampling and Analyses

For monitoring of water quality at Pench tiger reserve area in Maharashtra twenty water sources, comprised of eighteen India Mark II (IM2) hand pumps, one dug well and one lake, were selected for water quality assessment. The representative water samples were collected from the selected sources with standard procedure [15]. Sampling location details are given in Table 1. Mogra lake is situated within the forest area where most of the animals come to quench their thirst. The water sample of Mogra lake was really helpful to obtain an idea about quality of water consumed by domestic and wild animals. The water quality parameters viz. turbidity, pH, conductivity, DO and COD was analyzed to assess the water quality of Mogra lake. The preservation and testing of the water samples was performed with standard methods [16-18] and results are depicted in Table 2.

### 2.2. Statistical Analysis

Statistical approach is helpful for promoting research, knowledge studies and new exposure to reduce the level of uncertainty in decision making. Correlation analysis provides a mechanism for prediction or forecasting by making attempts to understand the relationship between the variables [7, 19, 20]. The relationship among various water quality parameters was determined by correlation coefficient (r) [1, 19, 21] and measured by the formula (1) given below and r values are provided in Table 2.

$$r = \frac{N\sum(XiYi) - (\sum Xi)\times(\sum Yi)}{\sqrt{[N\sum Xi^2 - (\sum Xi)^2)][N\sum Yi^2 - (\sum Yi)^2]}} \quad (1)$$

Where, X & Y: water quality parameters. N: No. of observations.

## 3. Results and Discussions

### 3.1. Water Quality of Studied Sources

Water quality data (Table 1) showed that all the parameters except turbidity, fluoride and iron in few water samples are below permissible limit as per BIS standards. The water quality data reveals that turbidity is exceeding permissible limit except four samples (10, 15, 19 & 20). The high turbidity in the groundwater samples is attributed to the presence of iron precipitates, general management practices and possibility of enroute contamination. Higher turbidity in drinking water is aesthetically not acceptable as it may provide food and shelter to the pathogens and also having a strong relationship with protozoa [22].

The fluoride concentration in water, except sample Nos. 15 and 20 are below permissible limit [23]. High fluoride in water is a result of geogenic contamination and the samples which exceeded the acceptable limit for fluoride are not recommended for consumption without treatment. Fluoride stimulates birth-rate of osteoblasts, but at higher dose reduces the activity [24]. Animals can ingest some fluorides in their diet without adverse effect but high fluoride can be harmful to animals [25].

The iron concentration in water exceeded the permissible limit [23] except for sample 10 and 15. The high iron concentration is due to processes involved during rock formation and the geological stratum. Study area is covered with red and lateritic soils which are rich in iron [26] and contributes to iron content in groundwater. Groundwater do not show discoloration or turbidity due to iron under reduced condition, but upon exposure to atmosphere the ferrous form of iron oxidizes to ferric form, imparting an undesirable reddish-brown colour to the water and also promotes “iron bacteria” [27].

Microbiological testing of water samples shows the existence of FC and FS in some water samples, indicating microbiological contamination, thus making the water unsuitable for drinking purpose. Generally microorganisms do not found in groundwater, still some water samples showed bacterial contamination. The presence of bacterial contamination may be attributed to factors such as low water level, breakage, leakage of hand pumps etc. Hand pumps located in low lying areas can be affected by rainwater drainage, storm water discharge and seepage water, which in turn may lead to bacterial contamination.

***Table 1.*** *Sample location details.*

| S. N. | Location | S. N. | Location | S. N. | Location |
|---|---|---|---|---|---|
| 1 | Ghotigate HP | 8 | Hattigota protection hut HP | 15 | Salama gate (Dugwell) |
| 2 | Tuyapar protectin hut HP | 9 | Bhimsen HP | 16 | Bakhari protection HP |
| 3 | Kirrangi sarra protection hut HP | 10 | Saddle dam protection hut HP | 17 | Sillari cheaking gate HP |
| 4 | Kirrangi sarra cheaking gate HP | 11 | Nagdev pahadi Tippat HP | 18 | Sillary colony HP |
| 5 | Research centre Ranidhoh HP | 12 | Pivathali protection hut HP | 19 | Pipariya forest colony HP |
| 6 | Hattigota HP | 13 | Dugout Pond (surface water) | 20 | Pauni gate HP |
| 7 | Sadisarra HP | 14 | Chikhaldari HP | | |

***Table 2.*** *Water quality parameters of study area.*

| Parameters | BIS: 10500 2012 | WHO: 1996 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 6.5-8.5 | 6.5-8.5 | 6.9 | 7 | 7.2 | 6.7 | 7 | 7.5 | 7.4 | 6.8 | 7.1 | 7.1 |
| Turbidity (NTU) | 5-10 | | 161 | 25 | 484 | 10 | 33 | 67 | 102 | 292 | 61 | 1 |
| EC (µS/cm) | | | 475 | 760 | 460 | 522 | 448 | 437 | 647 | 573 | 750 | 875 |
| TDS | 500-2000 | | 285 | 456 | 276 | 313 | 269 | 262 | 388 | 344 | 450 | 525 |
| TH | 300-600 | | 204 | 400 | 164 | 212 | 172 | 184 | 248 | 232 | 192 | 452 |
| Ca (meq/L) | 75-200 | | 2.72 | 4.8 | 1.84 | 1.92 | 2 | 2.4 | 4.32 | 2.8 | 3.36 | 4.16 |
| Mg (meq/L) | 30-100 | | 1.36 | 3.2 | 1.44 | 2.32 | 1.44 | 1.28 | 0.64 | 1.84 | 0.48 | 4.88 |
| Na | | | 38.8 | 74.2 | 37 | 33.9 | 32.2 | 26.1 | 43.5 | 32.5 | 71.5 | 4.7 |
| K | | | 2.9 | 3.7 | 3.2 | 2.8 | 3.5 | 2.9 | 1.6 | 0.6 | 3.8 | 3.6 |
| $HCO_3$ | 244-732 | | 132 | 142 | 132 | 84 | 134 | 118 | 197 | 168 | 194 | 259 |
| Alkalinity | 200-600 | 120 | 220 | 236 | 220 | 140 | 224 | 196 | 328 | 280 | 324 | 432 |
| Cl | 250 | 250 | 20 | 28 | 16 | 46 | 12 | 12 | 14 | 14 | 16 | 16 |
| $SO_4$ | 200-400 | 200-400 | 1 | 195 | 1.3 | 17.9 | 1.8 | 2.1 | 2.8 | 1.1 | 1.6 | 2.6 |
| $NO_3$ | 45 | 50 | 0.6 | 7.5 | 0.8 | 25 | 1 | 1.3 | 0.7 | 0.3 | 0.5 | 8.8 |
| F | 1.0-1.5 | 1.0-1.5 | 0.3 | 1.2 | 0.8 | 0.3 | 0.3 | 0.8 | 1.1 | 0.8 | 0.4 | 0.2 |
| Fe | 0.3-1.0 | 0.3-1.0 | 4 | 0.4 | 4.1 | 3 | 3.7 | 3.9 | 3.4 | 3.3 | 3.8 | 0.2 |
| FC (CFU/ 100 ml) | 0 | 0 | 32 | ND | 2 | ND | ND | TNTC | 2 | ND | ND | ND |
| FS (CFU/ 100 ml) | 0 | 0 | ND | ND | ND | 1 | ND | 4 | 5 | ND | ND | ND |

| Parameters | BIS: 10500 2012 | WHO: 1996 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 6.5-8.5 | 6.5-8.5 | 8 | 6.9 | 7.3 | 6.9 | 7.4 | 6.9 | 6.7 | 6.9 | 7.2 | 7.4 |
| Turbidity (NTU) | 5-10 | | 25 | 17 | 95 | 86 | 1 | 263 | 407 | 361 | 1 | 1 |
| EC (µS/cm) | | | 393 | 649 | 117 | 962 | 1033 | 723 | 700 | 1060 | 609 | 1063 |
| TDS | 500-2000 | | 236 | 389 | 70 | 577 | 620 | 434 | 420 | 636 | 365 | 638 |

| Parameters | BIS: 10500 2012 | WHO: 1996 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TH | 300-600 | | 132 | 248 | 52 | 340 | 288 | 280 | 296 | 476 | 236 | 188 |
| Ca (meq/L) | 75-200 | | 1.92 | 3.12 | 0.4 | 5.04 | 4.32 | 4 | 4 | 6.72 | 3.44 | 1.68 |
| Mg (meq/L) | 30-100 | | 0.72 | 1.84 | 0.64 | 1.76 | 1.44 | 1.6 | 1.92 | 2.8 | 1.28 | 2.08 |
| Na | | | 43.9 | 42.4 | 6.3 | 77 | 81.6 | 40.8 | 34.5 | 27.1 | 7.4 | 141 |
| K | | | 2.6 | 7.2 | 5.5 | 6.3 | 1.9 | 2.3 | 1.9 | 0.7 | 0.4 | 3.9 |
| $HCO_3$ | 244-732 | | 103 | 173 | 31 | 250 | 240 | 180 | 204 | 204 | 144 | 266 |
| Alkalinity | 200-600 | 120 | 172 | 288 | 52 | 416 | 400 | 300 | 340 | 340 | 240 | 444 |
| Cl | 250 | 250 | 12 | 16 | 8 | 62 | 32 | 14 | 18 | 92 | 14 | 50 |
| $SO_4$ | 200-400 | 200-400 | 0.4 | 1.3 | 22.5 | 5.6 | 18 | 2.3 | 2.3 | 38.9 | 3.3 | 11 |
| $NO_3$ | 45 | 50 | 1 | 0.8 | 1.7 | 0.8 | 14.9 | 0.4 | 0.6 | 0.4 | 18 | 19.2 |
| F | 1.0-1.5 | 1.0-1.5 | 0.7 | 0.5 | 0.1 | 0.5 | 1.7 | 0.6 | 0.9 | 1 | 0.4 | 1.8 |
| Fe | 0.3-1.0 | 0.3-1.0 | 2.1 | 3.7 | 4.1 | 3.7 | 0.1 | 3.5 | 3.9 | 3.6 | 0.5 | 0.4 |
| FC (CFU/ 100 ml) | 0 | 0 | TNTC | 62 | TNTC | ND | ND | ND | ND | ND | ND | ND |
| FS (CFU/ 100 ml) | 0 | 0 | 1 | 1 | 8 | ND | ND | ND | ND | ND | ND | ND |

*all parameters are in mg/l except pH; *ND – Not Detected; *TNTC – Too Numerous to Count

## 3.2. Correlation Matrix for the Water Quality Parameters

Correlation coefficient represents the degree of relationship existing between two variables where one of them is dependent variable. The regression variables are appropriate and more suitable if regression coefficient value is greater [19]. The matrix of correlation for various water quality parameters is provided in Table 3.

***Table 3.*** *Correlation matrix for water quality parameters.*

| | pH | EC | Turb. | TDS | Fe | TH | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | Cl | $NO_3^-$ | $SO_4^{2-}$ | Alk. | $F^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1.00 | | | | | | | | | | | | | | |
| EC | -0.21 | 1.00 | | | | | | | | | | | | | |
| Turb. | -0.33 | -0.04 | 1.00 | | | | | | | | | | | | |
| TDS | -0.21 | 1.00 | -0.04 | 1.00 | | | | | | | | | | | |
| Fe | -0.25 | -0.47 | 0.53 | -0.47 | 1.00 | | | | | | | | | | |
| TH | -0.44 | 0.74 | 0.11 | 0.74 | -0.34 | 1.00 | | | | | | | | | |
| $Ca^{2+}$ | -0.34 | 0.73 | 0.18 | 0.73 | -0.17 | 0.90 | 1.00 | | | | | | | | |
| $Mg^{2+}$ | -0.41 | 0.47 | -0.03 | 0.47 | -0.46 | 0.77 | 0.41 | 1.00 | | | | | | | |
| $Na^+$ | 0.15 | 0.57 | -0.22 | 0.57 | -0.32 | 0.01 | 0.06 | -0.07 | 1.00 | | | | | | |
| $K^+$ | -0.02 | -0.10 | -0.34 | -0.10 | 0.19 | -0.18 | -0.26 | 0.01 | 0.23 | 1.00 | | | | | |
| $Cl^-$ | -0.26 | 0.66 | 0.11 | 0.66 | -0.07 | 0.54 | 0.54 | 0.34 | 0.35 | -0.04 | 1.00 | | | | |
| $NO_3^-$ | -0.02 | 0.27 | -0.49 | 0.27 | -0.68 | 0.03 | -0.14 | 0.27 | 0.26 | -0.15 | 0.23 | 1.00 | | | |
| $SO_4^{2-}$ | -0.12 | 0.15 | -0.13 | 0.15 | -0.37 | 0.39 | 0.30 | 0.37 | 0.21 | 0.05 | 0.19 | 0.13 | 1.00 | | |

| | pH | EC | Turb. | TDS | Fe | TH | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | Cl | $NO_3^-$ | $SO_4^{2-}$ | Alk. | $F^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alk | -0.16 | 0.90 | 0.00 | 0.90 | -0.38 | 0.62 | 0.61 | 0.40 | 0.51 | -0.03 | 0.39 | 0.08 | -0.11 | 1.00 | |
| $F^-$ | 0.27 | 0.57 | 0.06 | 0.57 | -0.43 | 0.18 | 0.25 | 0.02 | 0.71 | -0.25 | 0.30 | 0.23 | 0.29 | 0.48 | 1.00 |

Very poor positive correlation was observed between pH and sodium (r = 0.15), turbidity and hardness (r = 0.11), turbidity and calcium (r = 0.18), turbidity and chlorides ( r = 0.11) turbidity and fluoride (r = 0.06), TDS and sulphate (r = 0.15), hardness and sodium (0.01), hardness and nitrate (r = 0.03), sodium and calcium (r = 0.06), magnesium and potassium (r = 0.01), potassium and sulphate (r = 0.05), nitrate and alkalinity (r = 0.08) while there is no correlation seen between turbidity and alkalinity. The negative correlation was found between iron and nitrate (r = -0.68).

Significant positive correlations were found between EC and TDS (0.996), hardness and EC (0.737), calcium and EC (0.728), calcium and hardness (0.890), magnesium and hardness (0.771), alkalinity and EC (0.903), alkalinity and TDS (0.903), alkalinity and hardness (0.620), chloride and TDS (0.66). The examination of the integrated samples indicates a reciprocal relationship between iron and fluoride (-0.43), iron and nitrate (-0.68). Turbidity, pH, iron, and potassium are having negative correlation with many water quality parameters which is in conformity with findings by Patil and Patil [21]. It is concluded that correlation among water quality parameters are very much important in water quality [1].

### 3.3. Water Quality of Mogra Lake

Field observations and laboratory findings revealed copious growth of aquatic plants in Mogra lake water. Species of blue-green algae appear in thick mats on the surface of the lake water. The lake water has green colouration imparting turbidity of 332 NTU and sulphidic smell due to putrefaction of organic matter. It was also found that some fishes present in the lake were dead and floating on the surface of water body. The DO content of lake water is estimated to be 1.2 mg/L as $O_2$ and the COD was found to be 290 mg/l. The pH and electrical conductivity were found to be 7.5 and 699 µS/cm respectively during water analysis.

As per CPCB [28] standards, the DO requirement for propagation of wild life and fisheries is 4 mg/L. Hence, lake water is not suitable for propagation of wild life at present and provision of safe water is very much essential, which can be done by refilling the lake with fresh water and by cleaning the lake with suitable remedial measures. DO in water can be improved with installation of fountains for aeration of water.

## 4. Conclusion

The findings from the study indicates that quality of the water sources exceeds the acceptable range as per BIS standards for drinking purpose and hence proper treatment is to be given to the water before using it for drinking purpose. The correlation and regression analysis for water quality parameters helps in establishing relationships among water quality parameters drawing inferences about them. The linear correlation is helpful to obtain an appropriate idea of the groundwater quality by determining limited parameters. The TDS and EC are very well correlated with most of the water parameters indicating the significance of these parameters in water quality. A linear regression analysis has good accuracy and acts as an important tool for monitoring drinking water quality. In future, more number of waterholes should be developed for the animals in the area to protect the wildlife of Pench Tiger Reserve from water scarcity, and to evade the hazards found in Mogra lake. Water quality monitoring at regular interval with suitable treatment measures is very much essential to provide safe drinking water to the consumers.

## Abbreviations

| | |
|---|---|
| WHO | World Health Organization |
| BIS | Bureau of Indian Standards |
| CPCB | Central Pollution Control Board |
| DO | Dissolved Oxygen |
| BOD | Biochemical Oxygen Demand |
| COD | Chemical Oxygen Demand |
| NTU | Nephelometric Turbidity Unit |
| EC | Electrical Conductivity |
| TDS | Total Dissolved Salts |
| FC | Fecal Coliforms |
| FS | Fecal Streptococci |

## Author Contributions

**Gajanan Khadse:** Formal Analysis, Investigation, Supervision, Writing - original draft, Writing - review & editing

**Sandip Narnaware:** Formal Analysis, Methodology

## Conflicts of Interest

The authors declare no conflicts of interest.

## References


[1] Jothivenkatachalam, K., Nithya, A. & Chandra Mohan, S. Correlation analysis of drinking water quality in and around Perur block of Coimbatore District, Tamil Nadu, India. *Rasayan Journal Chemistry*, 3(4), 2010, pp. 649-654.

[2] Champidi, P., Stamatis, G. &. Zangana, E., Groundwater quality assessment and geogenic and anthropogenic effect estimation in Erasinos basin (E. Attica). *Europian water*, 33, 2011, pp. 11-27.

[3] Biswas, S. P. & Boruah, S., Ecology of the river Dolphin (Platanista Gangetica) in the upper Brahmaputra. *Hydrbiologia*, 430, 2000, pp. 97-101.

[4] Wesley Godwin, S. Bioaccumulation of heavy metals by industrial mollusks of Kanyakumari *water. Poll. Res.*, 23(1), 2000, pp. 37- 40.

[5] Khan, N., Mathur, A. and Mathur, R., A study on drinking water quality in Laskhar (Gwalior). *Indian J. Env. Prot.*, 25(3), 2004, pp. 222-224.

[6] Akinbile, C. O. & Yusoff, M. S., Environmental impact of leachate pollution on groundwater supplies in Akure, Nigeria. *International Journal of Environmental Science and Development*, 2(1), 2011, pp. 81-89.

[7] Daraigan, S. G., Wahdain Ahmed, A. S., Ba-Mosa, S., Obid-Manal, H., Linear correlation analysis study of drinking water quality data for Al-Mukalla City, Hadhramout. *Yemen International Journal of Environmental Sciences*, 1(7), 2011.

[8] Gajendaran, C. & Thamarai, P. Study on statistical relationship between groundwater quality parameters in Nambiyar river basin, Tamil Nadu, India. *Poll. Res.*, 27(4), 2008, pp. 679-683.

[9] Khan, M. A., Umar, R., Baten, M. A., Lateh, H. and Kamil, A. A., Seasonal variations in groundwater quality: A statistical approach. *International Journal of the Physical Sciences*, 7(25), 2012, pp. 4026-4035. Available at http://www.academicjournals.org/IJPS

[10] FAO, Water quality for agriculture. FAO Irrigation and Drainage Papers. 1994, Available at http://www.fao.org/docrep/003/T0234E/T0234E01.htm

[11] Khadse, G. K., Patni P. M., Kelkar P. S. & Devotta S., Qualitative evaluation of Kanhan River and its tributaries flowing over central Indian plateau. *Environ. Monit. Assess.*, 147, 2008, pp. 83-92.

[12] Save Tigers: Available at endangered-tiger. blogspot.com/2010/03/tiger-reserves-in-india.html accessed on 10.07.2012

[13] Wikramanayake, E. D., Dinerstein, E., Robinson, G., Karanth, U., Rabinowitz, A., Olson, D., Mathew, T., Hedao, P., Conner, M. Hemley, G. & Bolze, D. An ecology-based method for defining priorities for large mammal conservation: The Tiger as case study. *Conservation Biology*, 12, 1998, pp. 865–878.

[14] Pench Jungle Camp. About Pench Tiger Reserve. Available at http://www.wildlife-camp-india.com/about-pench-tiger-reserve.html accessed on: 10.07.2012.

[15] CPCB., Groundwater Quality Series: GWQS/09/2006-2007. *Status of groundwater quality in India, part -I*. Central Pollution Control Board, (Ministry of Environment & Forests).

[16] APHA., *Standard Methods for Examination of Water and Waste water*, (20th ed.). Washington, D.C., 1999: APHA.

[17] APHA, AWWA, & WEF., *Standard Methods for the Examination of Water and Wastewater*, ($21^{st}$ ed.). Washington, D.C., 2005: APHA.

[18] Greenberg, A. E., Connors, J. J., Jenkins, D. & Franson, M. A., *Standard Methods for the Examination of Water and Wastewater*, ($15^{th}$ ed.). Washington, D. C., 1995: APHA.

[19] Kumar, N. & Sinha, D. K.,. Drinking water quality management through correlation studies among various physicochemical parameters: a case study. *International Journal of Environmental Sciences*, 1(2), 2010, pp. 253-259.

[20] Mehta, K. V., Physicochemical characteristics and statistical study of groundwater of some places of Vadgamtaluka in Banaskantha district of Gujarat state (India), *Journal of Chemical Pharmaceutical Research*, 2(4), 2010, pp. 663-670.

[21] Patil, V. T., & Patil, P. R., Physicochemical analysis of selected groundwater samples of Amalner town in Jalgaon district, Maharashtra, India. *Electronic Journal of Chemistry*, 7(1), 2010, pp. 111-116.

[22] EPA, *Guidance Manual Turbidity Provisions 7-10 April, 1999*. Web Address: http://www.epa.gov/ogwdw/mdbp/pdf/turbidity/chap_07.pdf on dated: 1.05.2012.

[23] BIS, *Specifications for Drinking Water, IS: 10500: 2012, Bureau of Indian Standards*, New Delhi.

[24] Chavassieux, P., Bone effects of fluoride in animal models in vivo: a review and a recent study. *Journal of Bone and Mineral Research*, 5(S1), 1990, S95–S99.

[25] Sutie J. W., Effects of fluoride on livestock. *J. Occup. Med.* (1). 1977, 40-8.

[26] Jain, S. K., Agarwal, P. K. & Singh, V. P., Krishna and Godavari basins, *Hydrology and water resources of India*, vol. 57, 2007, pp. 641-699.

[27] WHO. *Guidelines for drinking-water quality* (3rd ed.) incorporating $1^{st}$ and $2^{nd}$ addenda, Recommendations. Geneva, (1), 2008, 216.

[28] CPCB. The Gazette of India. Extraordinary, Part II, 1993. Ministry of Environment and Forest and Central Pollution Control Board, Ministry of Environment and Forest.