# WATER QUALITY INDEX AND MULTIVARIATE ANALYSIS FOR GROUNDWATER QUALITY ASSESSMENT OF VILLAGES OF RURAL INDIA

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**ABSTRACT**

Drinking water is an important resource that needs to be protected from pollution and biological contamination. Water borne diseases continue to be a dominant cause of water borne morbidities and mortality all over the world and the open defecation pollute ground water and helps in the spread of enteric diseases. Hence, analyzed the effect of open defecation practices on chemical and bacteriological quality of water in open defecation free (ODF) and open defecation not free (ODNF) village in Amravati district and detected source of contamination by antibiotic resistant analysis. Total 211 drinking water samples from 138 (66 ODF and 72 ODNF) villages, were analyzed for physico-chemical and bacteriological quality from ODF, and ODNF villages of Amravati district. In the present study, the ODNF village's drinking water was 55% contaminated with coliform and 35% with thermotolerant *E.coli* while the water from ODF villages was 38% and 8% respectively. The physico-chemical analysis of drinking water showed that all those samples which have poor WQI were contaminated with thermotolerant coliforms. Hence, the percentage of contamination was more in open defecation not free villages, thus it conclude that open defecation was one of the most responsible factors that to leads more contamination of drinking water samples. Hence, unhygienic practices must be stopped to prevent spread of faeco-oral diseases among human beings due to contaminated water.

**Key words:** Open defecation, Water quality Index, Coliform, *E.coli,* enteric infection)

## INTRODUCTION

Drinking water is an important resource that needs to be protected from pollution and biological contamination. Underground water is clean but it depends upon quality and quantity of materials dispersed and dissolved in it. Water picks up impurities in during its flow, which are harmful to man and vegetation. The reason for contamination and pollution of water in the natural surroundings and in the storage are pesticides, fertilizers, industrial wastes, inorganic and organic salts from top soil and geological strata (Nanoti, 2004). The domestic water bodies are being used for cattle drinking, human bathing, cloths washing and other domestic purposes. The quality of groundwater is highly related with local environmental and geological conditions. The quality of soil and rock and the water table determines the quality of groundwater.

Excess amount of physico-chemical components, cause a certain ecological and physical problems to human. A chloride present in excess imports the salty taste to water and people who are not accustomed to high chlorides are subjected to laxative effect, due to chloride present in excess amount the salinity of water also increases. Turbidity is a measure of cloudiness in water, when water is highly turbid, which can clog fish gill, reduce growth rate and residence of disease (http://www.indiawaterportal.org/sites/indiawater portal.org /files / Know Your Water). The presence of nitrate in water has been associated with methamoglobinemia and also certain disease in animal (Frank and Shannon, 2005). The presence of high amount of nitrate and phosphate caused eutrophication in water. Water with high TDS have salty taste and produce scale on water heaters and cooking utensils. It was harmful for irrigation due to presence of carbonates as it increased salinity of soil (Tambekar *et al*, 2008). Dissolved oxygen present in drinking water was highly fluctuating factor. The physico-chemical properties of ground water clearly explain its geological profile, pollution states as well as human and animal health problems and other perspective.

Millions of people in many states in India are affected by waterborne diseases and a large number of them are in crippling stage and leading vegetative life (Tambekar *et al.*, 2008).

According to the recently released Joint Monitoring Programme by World Health Organisation and UNICEF, about 626 million people or nearly 51 percent of the population in India still defecate in the open hence hygiene and sanitation needs more priority, particularly in rural areas and efforts to curb the habit of open defecation (A Report of UNICEF and WHO, 2008). Hence, Government of India in 2003 has introduced the Nirmal Gram Puraskar (NGP) scheme for fully sanitized and open defecation-free Gram Panchayat (George, 2009). NGP is given to those "Open Defecation Free (ODF)" Nirmal Gram Panchayat, Blocks, and Districts, which have become fully sanitized. A "Nirmal Gram" is an "Open Defecation Free" village where all houses, Schools and Anganwadis having sanitary toilets and awareness amongst community on the importance of maintaining personal and community hygiene and clean environment (Nirmal Gram Puraskar Guideline, 2010). Open defecation deteriorate the quality of drinking water, makes the water unfit for drinking purpose and enhances the chances of water borne diseases. The most important aspect of water quality is its freedom from contamination with faecal matter. The primary objective of bacteriological examination of drinking water is thus the detection of faecal pollution indicated by the presence of bacteria of faecal origin or from open defecation. The common sources of ground water are wells (open/ tube wells) and various routes may contaminate these natural sources of water. To avoid the spread of water borne diseases in the community and to ensure the safety of drinking water, the open defecation should be stopped and the regular water quality monitoring should be performed (Sobsey and Pfaender, 2002; Tambekar *et al.,* 2007).

Water quality is the term use to describe the chemical, physical and biological characteristics of water, and a means to summarize large amounts of water quality data into simple terms for reporting to management and the public in a consistent manner. The advantages of an index include its ability to represent measurements of a variety of variables in a single number, its ability to combine various measurements in a variety of different measurement units in a single metric and its effectiveness as a communication tool (CCME, 2005). The present study was based on the analysis of drinking water samples collected from different sources like open well, tube well, hand pump and water supplied by Gram Panchayat for drinking and domestic use. Thus, attempt was made to analyze the effect of open defecation practices on physico-chemical and bacteriological qualities of water in open defecation free (ODF) and open defecation not free (ODNF) village in Amravati district and its relation to overall hygienic practices of the villagers.

## MATERIALS AND METHODS

**Sample collection and inoculation:** Total 211 drinking water samples from open well, tube well and hand pump from 138 (66 ODF and 72 ODNF) villages, were collected during 2011 to 2012 for physico-chemical and bacteriological quality analysis from the Nirmal Gram Puraskar awarded (ODF), above 60% open defecation free, and open defecation not free villages (ODNF) of Amravati district. The bacteriological examination of water was performed within 24 h of water collection using Manja's Modified $H_2S$ rapid test (Manja, 2001; Tambekar *et al*, 2008a) and standard Multiple Tube Fermentation Technique (MTFT) for determination of Most Probable number (MPN) Index.

**Detection of Thermotolerant coliform:** Both $H_2S$ and MPN positive test broth were further processed for detection of thermotolerant coliform (TTC) or thermotolerant *E. coli* by Eijkman test by inoculating in Brilliant Green Lactose broth and Tryptone broth for indole test at $44.5^0$C. The indole positive and gas formation in BGLB at $44.5^0$C confirmed the TTC.

**Physico-chemical examination of water:** Drinking water samples were analyzed for various water quality parameters as per standard procedures. Colour, odour, taste, turbidity, pH, temperature, conductivity, TDS, Salinity, chloride, dissolved oxygen of water sample were determined on the spot by Kit supplied by Delhi based company NAYANA and Phosphate, Nitrate by standard methods (APHA, 1998). The calculation of Water Quality Index (WQI) carried out using software available on website (*http://www.waterresearch.net/watrqualindex/waterqualityindex.htm*).

Water quality index is calculated to determine the suitability of water for drinking purposes (Srivastava and Sinha, 1994). The statistical analysis performed with the Statistical Package for Social Sciences 15 for Windows (SPSS Inc.; Chicago, IL, USA) software.

**RESULTS AND DISCUSSION**

Total 211 drinking water samples were collected during 2011 to 2012 for physico-chemical and bacteriological analysis from 138 (66 ODF and 72 ODNF) villages. Out of 211 drinking water samples, 104 (45 from OW and 59 from TW/HP) from ODF; whereas 107 (47 from OW and 60 from TW/HP) from ODNF) villages. A physico- chemical analysis and water quality indexing of the collected water samples were performed.

The 49% (2% after 24h, 47% after 48h and 49% after 72h) water samples from OW whereas 30% (0% after 24 h, 14% after 48 h and 30% after 72 h) water samples from TW/HP from ODF Villages were showed contaminated after 72 h by $H_2S$ test. Out of these ODF villages water samples 2% found to be contaminated by thermotolerant coliform. The 77% (6% after 24h, 64% after 48h and 77% after 72h) water samples from OW whereas 37% (2% after 24 h, 23% after 48 h and 37% after 72 h) water samples from TW/HP from ODNF Villages were showed contaminated after 72 h by Manja's Rapid H2S test. Out of these ODNF villages water samples 49% and 23 found to be polluted with thermotolerant coliform from open well and tube well/ hand pump respectively (Table 1).

Out of 211, ground water sample only 22 water samples were turbid and remaining was clear as groundwater is less turbid as compared to surface water. The pH of open well water was more as compared to tube well water. The temperature was well within 25ºC-29ºC range. Chloride concentration observed between 54mg/L - 2295mg/L maximum in Maishpur (open well) and minimum in Shivangaon (tube well). Hence the salty taste of ground water of study area might be due to high chloride content. It was reported that chloride occurred naturally in all types of water the most important source of chloride was due to the discharge of domestic sewage. Out of 211 water samples studied from 138 villages, only 55 water samples were well within permissible limit of 200-600mg/L (WHO, 1994). But 31 water samples were above 600mg/L. Due to high chloride content the salinity of water was also high. The maximum salinity was recorded as 5500mg/L in Maishpur (open well) and minimum salinity was 100mg/L in Devgaon (open well). Out of 211 water samples, salinity was well within the permissible limit of 200-600mg/L (WHO, 1994). The 60 water sample showed salinity more than 600mg/L which means that the water from study area was more saline and unsuitable for drinking, domestic and irrigation purpose. Total dissolve solid (TDS) varied from 200-2666mg/L. The TDS also well within permissible limit during studied. The range of TDS is 200-2666mg/L. Out of 211 samples, only 131 samples are well within permissible limit and 6 samples showed excessive permissible limits, due to high salinity, the chloride is also high and between 100-5500mg/L. Only 84 samples are within permissible limit and 60 samples was excess permissible limit. Phosphate concentration was from the tube well and open well of the study area was much below the permissible limit it indicated the healthy ground water quality with respect to phosphate pollution. The phosphate was above permissible limit and nitrate was below permissible limit.

**Table 1: Quality of Open defecation free (ODF) and Open Defecation Not free (ODNF) village's drinking water by Rapid Manja's $H_2S$ and TTC test**

| Type of villages | Water source | No. of samples | Positive $H_2S$ test | | | TTC positive |
|---|---|---|---|---|---|---|
| | | | 24h | 48h | 72h | |
| ODF (66) | Open well | 45 | 1 (2%) | 21(47%) | 22 (49%) | 7 (15%) |
| | TW/HP | 59 | 0 (0%) | 8 (14%) | 18 (30%) | 1 (2%) |
| | Sub total | 104 | 1 (1%) | 29 (28%) | 40 (38%) | 8 (8%) |
| ODNF (72) | Open well | 47 | 4 (6%) | 30 (64%) | 36 (77%) | 23 (49%) |
| | TW/HP | 60 | 1 (2%) | 14 (23%) | 22 (37%) | 14 (23%) |
| | Sub total | 107 | 5 (4%) | 44 (41%) | 58 (55%) | 37 (35%) |
| Total | | 211 | 6 (2%) | 73 (35%) | 98(47%) | 45 (21%) |

**Table 2: Quality of Open defecation free (ODF) and Open Defecation Not free (ODNF) village's drinking water in Amravati district**

| Parameters | Detail Results | Type of village | | $H_2S$ Test 24h | | $H_2S$ Test 48 h | | $H_2S$ Test 72 h | | Eijkman Test | | MPN Test | | Water quality Index | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ODF | ODNF | Positive | Negative | Positive | Negative | Positive | Negative | Positive | Negative | Positive | Negative | Poor | Marginal | Fair | Good | Excellent |
| Water Sources | OW | 45 | 47 | 5 | 87 | 51 | 41 | 58 | 34 | 30 | 62 | 58 | 34 | 32 | 32 | 25 | 2 | 1 |
| | TW/HP | 59 | 60 | 1 | 118 | 22 | 97 | 40 | 79 | 15 | 104 | 40 | 79 | 16 | 47 | 47 | 8 | 1 |
| Color | Colorless | 91 | 86 | 4 | 173 | 62 | 115 | 85 | 92 | 36 | 141 | 85 | 92 | 38 | 66 | 64 | 8 | 1 |
| | Rusty | 6 | 8 | | 14 | 4 | 10 | 5 | 9 | 3 | 11 | 5 | 9 | 4 | 6 | 3 | 1 | |
| | Yellowish | 7 | 13 | 2 | 18 | 7 | 13 | 8 | 12 | 6 | 14 | 8 | 12 | 6 | 7 | 5 | 1 | 1 |
| Odor | Earthy | 51 | 45 | 4 | 92 | 41 | 55 | 55 | 41 | 20 | 76 | 55 | 41 | 21 | 38 | 36 | 1 | |
| | Musty | 18 | 31 | 2 | 47 | 14 | 35 | 20 | 29 | 11 | 38 | 20 | 29 | 12 | 18 | 13 | 4 | 2 |
| | Odorless | 35 | 31 | | 66 | 18 | 48 | 23 | 43 | 14 | 52 | 23 | 43 | 15 | 23 | 23 | 5 | |
| Taste | Bitter | 8 | 17 | 1 | 24 | 11 | 14 | 14 | 11 | 5 | 20 | 14 | 11 | 5 | 11 | 7 | 2 | |
| | Salty | 10 | 28 | 3 | 35 | 13 | 25 | 17 | 21 | 10 | 28 | 17 | 21 | 12 | 12 | 10 | 2 | 2 |
| | Tasteless | 86 | 62 | 2 | 146 | 49 | 99 | 67 | 81 | 30 | 118 | 67 | 81 | 31 | 56 | 55 | 6 | |
| Turbidity | No turbid | 100 | 89 | 4 | 185 | 67 | 122 | 90 | 99 | 40 | 149 | 90 | 99 | 42 | 68 | 67 | 10 | 2 |
| | Turbid | 4 | 18 | 2 | 20 | 6 | 16 | 8 | 14 | 5 | 17 | 8 | 14 | 6 | 11 | 5 | | |
| pH | 6 to 6.99 | 9 | 19 | | 28 | 14 | 14 | 15 | 13 | 11 | 17 | 15 | 13 | 12 | 9 | 6 | 1 | |
| | 7 to 7.99 | 50 | 34 | | 84 | 34 | 50 | 47 | 37 | 17 | 67 | 47 | 37 | 18 | 35 | 28 | 3 | |
| | 8 to 8.99 | 37 | 45 | 2 | 80 | 20 | 62 | 28 | 54 | 12 | 70 | 28 | 54 | 12 | 31 | 31 | 6 | 2 |
| | 9 to 9.99 | 8 | 9 | 4 | 13 | 5 | 12 | 8 | 9 | 5 | 12 | 8 | 9 | 6 | 4 | 7 | | |
| Temperature | 25 to 25. 9 | 20 | 11 | | 31 | 2 | 29 | 5 | 26 | 2 | 29 | 5 | 26 | 2 | 13 | 15 | 1 | |
| | 26 to 26.9 | 4 | 2 | | 6 | 1 | 5 | 2 | 4 | 1 | 5 | 2 | 4 | 1 | 2 | 3 | | |
| | 27 to 27.9 | 6 | 9 | | 15 | 2 | 13 | 4 | 11 | 2 | 13 | 4 | 11 | 2 | 6 | 6 | 1 | |
| | 28 to 28.9 | 30 | 40 | 4 | 66 | 24 | 46 | 31 | 39 | 17 | 53 | 31 | 39 | 19 | 23 | 25 | 1 | 2 |
| | 29 to 29.9 | 44 | 45 | 2 | 87 | 44 | 45 | 56 | 33 | 23 | 66 | 56 | 33 | 24 | 35 | 23 | 7 | |
| Conductivity | WPL | 47 | 30 | 2 | 75 | 27 | 50 | 31 | 46 | 11 | 66 | 31 | 46 | 12 | 36 | 28 | 1 | |
| | APL | 57 | 77 | 4 | 130 | 46 | 88 | 67 | 67 | 34 | 100 | 67 | 67 | 36 | 43 | 44 | 9 | 2 |
| TDS | BPL | 45 | 29 | 2 | 72 | 26 | 48 | 30 | 44 | 11 | 63 | 30 | 44 | 12 | 34 | 27 | 1 | |
| | WPL | 57 | 74 | 4 | 127 | 46 | 85 | 66 | 65 | 32 | 99 | 66 | 65 | 33 | 43 | 44 | 9 | 2 |
| | APL | 2 | 4 | | 6 | 1 | 5 | 2 | 4 | 2 | 4 | 2 | 4 | 3 | 2 | 1 | | |
| Salinity | BPL | 42 | 25 | 1 | 66 | 25 | 42 | 28 | 39 | 10 | 57 | 28 | 39 | 10 | 31 | 26 | | |
| | WPL | 40 | 44 | 2 | 82 | 30 | 54 | 40 | 44 | 17 | 67 | 40 | 44 | 18 | 27 | 30 | 7 | 2 |
| | APL | 22 | 38 | 3 | 57 | 18 | 42 | 30 | 30 | 18 | 42 | 30 | 30 | 20 | 21 | 16 | 3 | |
| Chloride | BPL | 72 | 53 | 1 | 124 | 43 | 82 | 54 | 71 | 21 | 104 | 54 | 71 | 22 | 53 | 45 | 5 | |
| | WPL | 19 | 36 | 3 | 52 | 22 | 33 | 29 | 26 | 15 | 40 | 29 | 26 | 16 | 13 | 19 | 5 | 2 |
| | APL | 13 | 18 | 2 | 29 | 8 | 23 | 15 | 16 | 9 | 22 | 15 | 16 | 10 | 13 | 8 | | |
| Phosphate | APL | 104 | 107 | 6 | 205 | 73 | 138 | 98 | 113 | 45 | 166 | 98 | 113 | 48 | 79 | 72 | 10 | 2 |
| Nitrate | BPL | 104 | 107 | 6 | 205 | 73 | 138 | 98 | 113 | 45 | 166 | 98 | 113 | 48 | 79 | 72 | 10 | 2 |
| DO | BPL | 104 | 107 | 6 | 205 | 73 | 138 | 98 | 113 | 45 | 166 | 98 | 113 | 48 | 79 | 72 | 10 | 2 |

The phosphate range was between 0.2-0.7 mg/L and nitrate range between 3-16mgandL. Nitrate may arise from the excessive application of fertilizers or from leaching of waste water or other organic wastes. The nitrate content was high in open well water samples as compared with tube well water. Dissolved oxygen (DO) present in drinking water was highly fluctuating factor in water. According to European Economic Community, the permissible level of drinking water for dissolved oxygen was 5mg/L (Indirabai and George, 2002).

In this study the DO contents varied between 3.0-9.0 mg/L. The organic waste contained in drinking water enhances the dissolved oxygen of water. Temperature, pressure and salinity greatly affected the dissolve oxygen in water. The maximum DO value was recorded in (4.2 mg/L) and minimum DO value in (3.1 mg/L). Out of 211 water samples, samples were below the permissible limit of 5-9.5 mg/ and remaining water samples were well within the permissible limit prescribed by WHO (1994).

Water quality index of 211 village water sample from study area showed that only Akhadwada village, showed excellent water quality which is open defecation free village. The water parameter of water samples were well within the permissible limit prescribed by WHO and ISI standard. Water of that village can be useful for domestic and drinking purpose. The percentage wise water quality of Amravati region showed that out of 138, 1% water sample had Excellent quality, 10% water samples showed good quality, 34% water samples showed fair quality, 37% water samples showed marginal quality and 23% water samples showed poor water quality.

**Table 3: Correlation of type of villages , Source of water, Rapid $H_2S$ test, WQI and TTC**

| Type villages | Water source | $H_2S$ Test 72 h | Water quality index | Eijkman test | | Total |
|---|---|---|---|---|---|---|
| | | | | Positive | Negative | |
| Open defecation free Villages (ODF) (104) | Open Well (45) | Positive (22) | Poor | 7 | | 7 |
| | | | Marginal | | 8 | 8 |
| | | | Fair | | 6 | 6 |
| | | | **Excellent** | | **1** | **1** |
| | | | **Total** | **7** | **15** | **22** |
| | | | Marginal | | 11 | 11 |
| | | | Fair | | 11 | 11 |
| | | | Good | | 1 | 1 |
| | | | **Total** | | **23** | **23** |
| | Tube well/ Hand pump (59) | Positive (18) | Poor | 1 | | 1 |
| | | | Marginal | | 8 | 8 |
| | | | Fair | | 9 | 9 |
| | | | **Total** | 1 | 17 | 18 |
| | | | Marginal | | 19 | 19 |
| | | | Fair | | 17 | 17 |
| | | | Good | | 4 | 4 |
| | | | Excellent | | 1 | 1 |
| | | | **Total** | | **41** | **41** |
| Open defecation Not free Villages (ODNF) (107) Total Water Samples (211) | Open Well (47) | Positive (36) | Poor | 23 | 1 | 24 |
| | | | Marginal | | 7 | 7 |
| | | | Fair | | 4 | 4 |
| | | | Good | | 1 | 1 |
| | | | **Total** | **23** | **13** | **36** |
| | | Negative (11) | Poor | | 1 | 1 |
| | | | Marginal | | 6 | 6 |
| | | | Fair | | 4 | 4 |
| | | | **Total** | | **11** | **11** |
| | Tube well/ Hand pump (60) | Positive (22) | Poor | 14 | | 14 |
| | | | Marginal | | 6 | 6 |
| | | | Fair | | 2 | 2 |
| | | | **Total** | **14** | **8** | **22** |
| | | Negative (38) | Poor | | 1 | 1 |
| | | | Marginal | | 14 | 14 |
| | | | Fair | | 19 | 19 |
| | | | Good | | 4 | 4 |
| | | | **Total** | | **38** | **38** |

All the water samples having very poor water quality index (WQI) were TTC positive. It clearly showed significant correlation between WQI and presence of thermotolerant coliform in drinking water. Thermotolerant coliform did not detected in any of the water samples with marginal, fair, good, and excellent quality of drinking water. It clearly showed that samples with good quality. The excess quantity of any parameter in water causes water pollutions and it may become unsafe for drinking and domestic purpose.

The overall water quality of Amravati region showed that out of 211 villages 92% drinking water samples from open defecation free (ODF) villages were suitable for drinking and domestic purpose and 8% village water samples were unsuitable for drinking purposes on the other side 65% drinking water samples from open defecation not free (ODNF) villages were suitable for drinking purposes 35% drinking water samples were unsuitable for drinking purposes and on the basis of physico-chemical parameter study and CCME Water Quality Index for drinking and domestic purpose.

**Table 4: Pearson Correlation coefficient among the various physico-chemical parameters for ground water in Amravati**

| | Type of village | Water Sources | Colour | Odour | Taste | Turbidity | pH | Temperature | Conductivity | TDS | Salinity | Chloride | Phosphate | Nitrate | DO | WQI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of village | 1.000 | -.007 | .102 | .013 | -.238 | .212 | -.007 | .101 | .178 | .171 | .202 | .163 | a | a | a | -.282 |
| Water Source | -.007 | 1.00 | .101 | .220 | -.074 | .144 | .133 | -.004 | .108 | .097 | .147 | .078 | a | a | a | .235 |
| Colour | .102 | .101 | 1.000 | .059 | -.105 | .714 | -.014 | .005 | .171 | .167 | .048 | .022 | a | a | a | -.033 |
| Odour | .013 | .22** | .059 | 1.0 | .194 | .020 | .050 | -.168 | -.182 | -.185 | -.163 | -.204 | a | a | a | .050 |
| Taste | -.238 | -.074 | -.105 | .194** | 1.00 | -.22** | .064 | -.317 | -.272 | -.292 | -.502 | -.513 | a | a | a | .007 |
| Turbidity | .212 | .144 | .714 | .020 | -.220 | 1.000 | .035 | .070 | .130 | .180 | .115 | .164 | a | a | a | -.109 |
| pH | -.007 | .133 | -.014 | .050 | .064 | .035 | 1.000 | -.197 | -.083 | -.073 | -.001 | .049 | a | a | a | .145 |
| Temperature | .101 | -.004 | .005 | -.168* | -.31** | .070 | -.197** | 1.000 | .233 | .249 | .385 | .253 | a | a | a | -.134 |
| Conductivity | .178** | .108 | .171* | -.18** | -.27** | .130 | -.083 | .233 | 1.000 | .923 | .730 | .531 | a | a | a | .003 |
| TDS | .171* | .097 | .167* | -.185** | -.292** | .18** | -.073 | .249 | .923 | 1.000 | .720 | .586 | a | a | a | -.029 |
| Salinity | .202** | .147** | .048 | -.163** | -.502** | .115 | -.001 | .385 | .730 | .720 | 1.000 | .781 | a | a | a | -.085 |
| Chloride | .163** | .078 | .022 | -.204** | -.513** | .164* | .049 | .253 | .531 | .586 | .781 | 1.000 | a | a | a | -.092 |
| Phosphate | a | a | a | a | a | a | a | a | a | a | a | a | a | a | a | a |
| Nitrate | a | a | a | a | a | a | a | a | a | a | a | a | a | a | a | a |
| DO | a | a | a | a | a | a | a | a | a | a | a | a | a | a | a | a |
| WQI | -.282** | .235** | -.033 | .050 | .007 | -.109 | .145* | -.134 | .003 | -.029 | -.085 | -.092 | a | a | a | |

* Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
a Cannot be computed because at least one of the variables is constant

The highest positive correlation was observed between chloride and salinity. The pH was negatively correlated with the temperature and total dissolved solid. Temperature was negatively correlated with water quality index. TDS was negatively correlated with water quality index. TDS was positively correlated with salinity (Table 4). Singh *et al,* (2004) also observed the negative correlation between dissolved oxygen and water temperature. Surve *et al*, (2005) [15] found the highest positive correlation between air temperature and water temperature, while highest negative correlation between water temperature and dissolved oxygen.

All the water samples having very poor water quality index (WQI) were TTC positive. It clearly showed significant correlation between WQI and presence of thermotolerant coliform in drinking water. Thermotolerant coliform did not detected in any of the water samples with marginal, fair, good, and excellent quality of drinking water. It clearly showed that open defecation in rural villages deteriorates the water quality and fecal *E. coli* was detected in water samples with poor water quality. According to CCME Water Quality Index of only one village water was excellent, 10 water samples were good and 197 villages' water samples were unsafe for drinking and domestic purpose.

The physico-chemical analysis of drinking water showed that all those samples which have poor Water Quality Index were contaminated with thermotolerant coliforms. In the present study the open defecation not free villages the drinking water sample were found to be 55% contaminated with coliform associated organism and 35% found to be contaminated with thermotolerant coliform while in the open defecation free villages the drinking water sample were found to be 38% contaminated with coliform associated organism and 8% found to be contaminated with thermotolerant coliform. Hence, the percentage of contamination was more in open defecation not free villages, thus it conclude that open defecation was one of the most responsible factors that to leads more contamination of drinking water samples. Hence, open defecation practices must be stopped to prevent spread of faeco-oral diseases among human beings due to contaminated water.

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