Drinking Water Quality by Water Quality Index Method in Pre and Post Monsoon in Araku Valley Region, Visakhapatnam District, Andhra Pradesh, India

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Abstract: ***Drinking water samples from different sources like bore well, open wells, springs and taps were collected from different villages of Araku valley Mandal and analysed for physicochemical characteristics. The samples were collected and studied during pre and post monsoon seasons in 2014 in 12 locations across the tribal villages of Araku Valley Mandal. The present study was intended to calculate the water quality index (WQI) for drinking water by using eleven water quality parameters pH, Chloride (Cl), Calcium Hardness(CH), Magnesium hardness(Mgh),Total hardness (TH),Total dissolved solids(TDS),turbidity(T), Sulphate(SO_4), nitrates (NO_3), Fluoride (F), Total Alkalinity (TA). Each parameter was compared with the standard permissible limit prescribed by World Health Organization (WHO) and ISO(100500). The Water Quality Index (WQI) of the samples assessed from different sources in two seasons, pre and post monsoon period. It reflected that almost all the 12 water samples were in the range of very poor quality, (69.065) in pre monsoon and ranged to be in unsuitable for drinking range (178.50) in post-monsoon. Hence it was resulted that, water is found to be poor in quality and unsuitable for drinking needed to treat before it is consumed by Tribal community.***

Keywords: Physico chemical, water quality index (WQI), Parameters.

1. Introduction

Environmental pollution,especially the contamination of water sources is a problem facing society today. The increasing urbanization, industrialization, the modernization of agriculture, the increase in traffic contribute to global pollution, which requires accurate monitoring and information about the quality of water resources. India possesses a vast and rich diversity of natural resources, water being one of them. It is universal solvent that has been, and being utilised by mankind and all the living organisms since time immemorial. In our country a large section of population is dependent on ground water without any treatment. The ground water is generally believed to be free from contamination and thus considered safe. Contamination of drinking water may occur by percolation of toxic through the soil to ground water (**Sargaonkar et al., 2003**).

The World Health Organization (WHO) estimated that in developing countries about 80% of water pollution is a result of domestic waste. More ever the inadequate management of water systems can cause serious problems in the availability and quality of water **(Krishnan et al.,).**

It is well known that clean water is absolutely essential for several purposes for healthy living (Mandalam et al., 2009). Ground water is highly valued because of certain properties not possessed by surface water. (**Rajankar et al., 2011**

Spring water is vital to man's existence. Early human civilization entered on spring and streams. When ground water appears at the surface, springs are formed. Springs are a good surface of water supply for small towns, especially near hills or bases of hills. Spring water is also likely to contain minerals dissolved from sub soil layers. Spring water from shallow strata is more likely to be affected by surface pollution. The most common source of pollution is due to contamination by human and animal wastes, directly/ indirectly from latrines, septic tanks or farm manure.

It has been estimated that 30% of mortality and 50% of morbidity to infectious diseases in Indians are responsible for major types of water borne diseases (**Naidu, 1998**). Water of good drinking quality is of basic importance to human physiology and man's continued existence depends very much on its availability (**Lamikanra, 1999; FAO, 1997**). The provision of portable water to the rural and urban population is necessary to prevent health hazards **(Lemo, 2002**). Before water can be described as potable, it has to comply with certain physical, chemical and microbiological standards, which are designed to ensure that the water is potable and safe for drinking (**Tebutt, 1983**). About80% of all the diseases in human being are caused by contaminated water, and the ground water is polluted, its quality cannot be renovated by stopping the pollutantnt from the source. **(Tyagi, et al.,2002).** Hence it is very important to analyze the physico-chemical properties to assess the quality of ground/ surface water in rural or urban areas that influence the suitability of water for domestic,irrigation and industrial needs (**Shivayogimath, .,et al., 2012**) . Monitoring of drinking water quality is an important component of water management, while data analysis is necessary for the identification and characterization of water quality problems. The levels of detected contaminants are used to determine compliance with a Maximum Contaminant Level (MCL).Therefore, water quality monitoring of various water variables through Water Quality Index (WQI) forms the foundation of water quality management **(Bartram. et al.,1996)**

The general WQI was developed by **Brown et al. (1970)** and improved by Deininger for the Scottish Development Department (1975). **Horton (1965)** suggested that the various water quality data could be aggregated into an overall index. Water quality index is well-known method as well as one of the most effective tools to expressing water quality that offers a simple, stable, reproducible unit of measure and communicate information of water quality to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of surface water. The standards for drinking purposes as recommended by WHO [1993] and IS 10500 [ISO,1992] have been considered for the calculation of WQI. Water quality class is defined depending on the values of the physical, chemical and biological parameters and the establishment of the quality before the usage (**Cude, C., 2001**)

In Araku valley Mandal, majority of the tribal people do not have access to public water supply and therefore they depend on Openwell, spring and borewell waters for drinking and domestic use. Thus there is a need to look for some useful indicators, both chemical and physical that can be used to monitor both drinking water operation and performance.

The main objectives of the study include:

- To assess the quality of drinking water consumed by Tribal Community by Physical, Chemical parameters.
- To determine the water quality index in pre and post monsoon period.

2. Materials and Methods

Study Area:

The study area is located in Araku valley region which is on the north-eastern part of of Visakhapatnam district, Andhra Pradesh India. The Araku division consist of the hilly regions covered by Eastern Ghats with an altitude of about 900 meters dotted by several peaks exceeding 1200 meters above the sea level. The area lies between longitude of E 18^o 10' 0" N and latitude E 83^o 0' 0" E. The climatic conditions are cool in this area on an account of green vegetation, elevation and thick forest. The temperature gets down on the onset of the south west monsoons and its tumbles to a mean minimum of 4^{o}c by January of every year, after which there is a reversal trend till the temperature reaches to mean maximum of 34^{o}C by the end of May, that is April to June are the warmest months. The area receives an average rainfall is 178.1cm on every year.

Sample Collection and Analysis:

Water samples were collected from Open wells, bore wells , springs and tap from different villages of Araku valley Mandal, Visakhapatnam district Andhra Pradesh, India in pre and post monsoon seasons 2014. The sampling sites are represented in Table 3 . The samples are obtained according to the consumption of local tribal community. Samples were collected in a clean plastic cans of 2 lit capacity for physico chemical analysis. The collected samples were transferred to the laboratory of Department of Environmental Sciences Andhra university, by following the precautions laid by standard methods (APHA ,1995). PH, DO were determined within the felid of collection, the other parameters like TDS, Ca, Mg ,NO_3, SO_4 ,chlorides, fluorides etc, were analyzed in the laboratory within the stipulated period. Physical and Chemical parameters are analyzed as per the standard method of Ground water quality prescribed in standard method for the examination of water and waste water American public health association (APHA 1995). Each of the water samples was analyzed for 10 parameters in three replicates *viz.*, pH, TDS, TH, CH, Cl , SO_4 , NO_3 and F^{-1} [Table 03]. The experimental values were compared with standard values recommended by the WHO. The calculation of WQI was done by Weighted Arithmetic Index (WAI) method. Eleven water quality parameter were considered for calculation of water quality index.

Calculation of water quality index:(WQI)

WQI is defined as a rating reflecting the composite influence of different water quality parameters **(Ramakrishnalah et al., 2009)** Water quality index (WQI) is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water**.**

In study for the calculation of water quality index(WQI) , ten important parameters were chosen. The WQI has been calculated by using the standards of the drinking water quality recommended by the WHO. The WAI method has been incorporated for the calculation of WQI of the water resource. Further quality rating or the sub index (q_n) was calculated by using the following expression.

$$\mathbf{q_n = 100\ (V_n - V_{io}) / (S_n - V_{io})} \quad \mathbf{(1)}$$

(Let there be n water quality parameters and quality rating or sub-index (q) corresponding to n the parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standards permissible value).

q_n = Quality rating for the n Water quality parameter

V_n = Estimated value of the n parameter at a given sampling station

S_n = Standard permissible value of the nth parameter

V_{io} = Ideal value of n parameter in pure water (i.e., 0 for all other parameters except the parameter pH, where it is 7.0).

Unit weight was calculated by a value inversely proportional to the recommended standard value S_n of the corresponding parameter

$$\mathbf{W_n = K/S_n} \quad \mathbf{(2)}$$

W_n = Unit weight for the nth parameters.

S_n= Standard value for nth parameter.

K = Constant for proportionality.

The overall water quality index was calculated by aggregating the quality rating with unit weight linearly.

$$\mathbf{WQI = \sum qn\ Wn / \sum Wn} \quad \mathbf{(3)}$$

The maximum weight of 5 has been assigned to the parameters like NO3-, TDS, Cl-, F- and SO_{-4} due to their major importance in water quality assessment **Srinivasamoorthy, K. et., al (2007)**. In the second step, the relative weight (Wi) is computed from the following equation, where, Wi is the relative weight and Wi is the weight of each parameter and n is the number of parameters.

Table 1: Analytical methods and equipment used in the study:

S.No.	*Parameter*	*Method*	*Instruments/Equipment*
A.	**Physico-chemical**		
1.	pH	Electrometric	pH Meter
2.	TDS	Electrometric	Conductivity/TDS Meter
3.	Hardness	Titration by EDTA	-
4.	Chloride	Titration by $AgNO_3$	-
5.	Sulphate	Turbidimetric	Turbidity Meter
6.	Nitrate	Phenol disulphinic Method	UV-VIS Spectrophotometer
7.	Fluoride	SPADNS	UV-VIS Spectrophotometer
8.	Turbidity	Nephlometric method	Turbidity Nephlometer
9.	Sulphates	Vanadomolybdophosphoric Acid Colourimetric Method)	colourimeter
10.	Calcium	Titration by EDTA	-
11.	Magnesium	Titration by EDTA	-
12.	DO	Titration by Sodium thiosulphate solution	-
13.	BOD	5 days incubation at 20^oC followed by titration	BOD Incubator

Table 2: Water Quality Index (WQI) and status of water quality (Chatterji and Raziuddin 2002)

Water quality index level	Water quality status
0 - 25	Excellent water quality
16 -50	Good water quality
51 -75	Poor water quality
76 - 100	Very poor water quality
≥ 100	Un suitable for drinking

Table 3: Physicochemical parameters of water samples in the pre-monsoon season

S.no	Sampling site	source	pH	Turbidity	TDS (mg/L^{-1})	Cl (mg/L^{-1})	CaH (mg/L^{-1})	TH (mg/L^{-1})	SO_2^{-4} (mg/L^{-1})	NO^{3-} (mg/L^{-1})	F^- (mg/l^{-1})	TA mg/L	DO mg/L
1.	Ravalaguda	Tap	5.8	12.0	110	15.6	72	240	14	4.43	0.9	13.3	1.6
2.	Panirangini	Tap	7.23	11.8	200	27.3	78	322	22	BDL	0.88	16.6	2.36
3.	Karasaliguda	spring	7.6	8.8	240	13.6	72	144	14	2.21	0.67	13.3	1.62
4.	Sarabaguda	Bore	5.9	8.0	220	18.3	184	288	19	2.21	0.92	12.0	4.3
5.	Tangulaguda	well	5.6	7.2	180	11.7	72	288	13	13.29	0.82	16.6	4.2
6.	B- coloney	Bore	5.8	7.2	352	22.23	62	93	24	1.10	0.11	89	3.2
7.	Bosubeda	Bore	6.82	4.7	194	39.2	48	82	20	12.15	0.86	68	4.8
8.	Madagada	spring	6.52	18.5	250	42.3	61	160	24	26.5	0.28	36	5.6
9.	Balluguda	Bore	5.8	8.3	390	16.9	116	174	14	22.45	0.71	6.6	5.9
10	M.Hattaguda	Well	5.62	7.4	240	20.1	68	144	0.8	6.0	0.79	10.0	4.0
11.	Kinangguda	spring	6.9	9.3	1560	10.9	20	92	0.54	0.5	0.8	82	6.2
12	Sunkarametta	well	7.89	15	1119	12.6	84	285	11	7	0.90	40	4.9
13.	Janamguda	spring	7.4	7.5	129	14.5	24	64	1.9	BDL	0.70	35	5.4
Mean value			7.52	9.66	398.76	20.40	73.92	182.76	13.71	8.89	0.91	33.72	4.16

Table 4: Physicochemical parameters of water samples in the post-monsoon season

S.no	Sampling site	source	pH	Turbidity (NTU)	TDS (mg/L^{-1})	Cl (mg/L^{-1})	CaH (mg/L^{-1})	TH (mg/L^{-1})	SO_2^{-4} (mg/L^{-1})	NO^{3-} (mg/L^{-1})	F^- (mg/l^{-1})	TA mg/L	DO mg/L
1.	Ravalaguda	Tap	8.01	12.1	745	85	65	340	16.3	0.9	0.3	200	2.3
2.	Panirangini	Tap	8.26	14.1	141	21	65	135	14.6	0.5	0.4	30	2.1
3.	Karasaliguda	spring	7.67	18.5	2199	36	80	110	16.21	5.5	0.3	50	3.4
4.	Sarabaguda	Bore	8.54	8.5	84	127	75	160	12	7.8	0.2	40	1.9
5.	Tangulaguda	well	8.68	6.5	1248	36	70	195	19	7.6	0.4	70	0.8
6.	B- coloney	Bore	9.05	8.6	745	45	55	110	15	7.5	0.3	70	2.4
7.	Bosubeda	Bore	8.68	7.6	141	52	65	125	19	8.2	0.2	130	2.1
8.	Madagada	spring	8.75	48.2	2199	36	80	90	18	9.7	0.2	40	3.3
9.	Balluguda	Bore	8.66	8.5	84	34	50	100	15	6.4	0.1	30	2.2
10	M.Hattaguda	Well	8.02	10.9	1248	122	105	150	13	5.5	0.2	40	1.8
11.	Kinangguda	spring	8.57	13.2	745	85	170	265	18	8.2	0.3	90	1.2
12	Sunkarametta	well	7.86	12.9	122	98	135	290	17	0.9	0.2	60	2.2
13.	Janamguda	spring	8.22	18.2	213	71	78	175	19	5.1	0.1	38	0.2
Mean value			8.38	14.44	762.6	65.23	84.07	192.6	16.31	5.67	0.24	68.30	1.43

Table 5: Calculation of Water Quality Index during Pre monsoon season

S.no	Parameter	Observed value	Standard value (Sn) WHO,ISO 100500:04	Unit Weight (Wn)	Quality rating (qn)	qn* Wn
1	pH	7.52	6.5-8.5	0.2190	34.66	7.590
2	TDS mg/L	398.76	500 mg/L	0.0037	79.75	0.2950
3	Chlorides mg/L	20.4	250 mg/l	0.0074	8.16	0.0603
4	Total hardness mg/L	182.76	300 mg/L	0.0062	60.92	0.3777
5	Turbidity , NTU	9.66	05 NTU	0.08	193.2	15.45
6	Calcium mg/L	73.92	75 mg/l	0.066	98.56	0.6110
7	Total alkalinity mg/L	33.72	120 mg/L	0.0155	28.1	0.4355
8	Sulphates mg/L	13.71	250 mg/L	0.01236	5.484	0.6778
9	Nitrates mg/L	8.89	45mg/L	0.0412	19.75	0.813
10	Fluorides mg/L	0.71	01 mg/L	0.166	71	11.78
11	Dissolved oxygen mg/L	4.16	5.0 mg/L	0.3723	83.2	30.975
				∑Wn=0.989	**∑ = 682.784**	**∑Wn*qn= 69.0653**
Water quality index =∑ Wn qn / ∑ Wn= 69.786						

Table No:06 Calculation of Water Quality Index during Post monsoon season

S.no	Parameter	Observed value	Standard value (Sn) WHO,ISO 100500:04	Unit Weight (Wn)	Quality rating (qn)	qn* Wn
1	pH	8.38	6.5-8.5	0.2190	92	20.148
2	TDS mg/L	762.61	500 mg/L	0.0037	152.52	0.5643
3	Chlorides mg/L	65.23	250 mg/l	0.0074	26.092	0.19308
4	Total hardness mg/L	172.69	300 mg/L	0.0062	57.56	0.3568
5	Turbidity , NTU	14.4	05 NTU	0.08	288	23.04
6	Calcium mg/L	84.07	75 mg/l	0.066	112.093	112.093
7	Total alkalinity mg/L	68.30	120 mg/L	0.0155	56.91	0.8821
8	Sulphates mg/L	16.31	250 mg/L	0.01236	6.524	0.08064
9	Nitrates mg/L	5.67	45mg/L	0.0412	12.6	0.5192
10	Fluorides mg/L	0.24	01 mg/L	0.166	24	3.984
11	Dissolved oxygen mg/L	1.43	5.0 mg/L	0.3723	28.6	10.647
				∑ = 0.989	**∑= 682.784**	**∑Wn*qn =172.5081**
Water quality index =∑ Wn qn / ∑ Wn= 174.310						

3. Result and Discussion

Groundwater being an important resource for human water supply, on which about one billion people are directly dependent, alone in Asia, needs to be regularly evaluated to reduce its further deterioration (**Foster, S.S.D., 1995, Saleem, R., 2007.**).In addition to the above, India supports more than 16% of the world's population with only 4% of the world's fresh water resources (**Singh, A.K., 2003**.)

The potable nature of groundwater is mainly based on the physico-chemical characteristics of the water sample for which season-wise analysis of 13 water samples of tribal areas of Araku region was done for both pre and post monsoon and is presented in (Table 3 and Table4).

pH:
The mean pH value in the water samples for pre-monsoon and post-monsoon seasons were 7.52 and 8.38 respectively. This approves that the nature of groundwater samples vary from slightly acidic to slightly alkaline. This may be due to the presence if high concentration of dissolved carbon dioxide and organic acids (fulvic and humic acids), which are derived from the decay and subsequent leaching of plant materials [**Langmuir, D., 1987.].** However, all the 15 samples were registered with the mean pH values between 5.6 and 9.05 were slightly above the permissible limit as per the WHO standard, respectively. A value of 5.6 was observed in well water sample in pre monsoon season and the value of 9.05 was observes in bore water sample in post monsoon season, the increase in pH in post monsoon may be due agricultural practices in nearby water sources.

Turbidity:
Turbidity indicates clarity of water and is caused by living and nonliving suspended matter and colour producing substances. The mean turbidity readings of the samples were in the range 9.66 to 14.4NTU, respectively in pre and post monsoon. A value of 18.5 and 48.2 were recorded in Madagada sample in pre and post monsoon respectively, were above the WHO and BIS standards. The presence of suspended particles and other materials are usually responsible for high turbidity values, similarly higher turbidity values were reported by **medudhula et al., 2012**. The soil particles may have found their way into the waters from the unstable sides thereby increasing turbidity of the water .**GARG ET AL., [2006].**

Total Dissolved Solids:
The Mean Total dissolved solids (TDS) were 398.7mg/L, 762mg/L were recorded in pre and post monsoon . According to WHO & BSI standards Total dissolved solids(TDS) value below in level indicates that the recharging of underground water through either rain water or by the water from nearby canals (**Gupta 2009**). 60% of sample founded to be above the permissible limit of WHO in pre and post monsoon respectively. The TDS values of water samples were found higher than the desirable limit of WHO (i.e.) 500 mg/L. The high level of dissolved solids adversely affects the quality of water (**Smedley et, al.2003).** The values for

post monsoon season are higher than the pre monsoon season i.e. 1560 mg /L and 2199.1 mg/ L. High value maybe due to contaminants, such as iron, manganese, sulphate and bromide.

Total Hardness:

Total Hardness (TH) which being an important parameter in deciding the usage of water either for drinking or other domestic and industrial purposes, was observed with the mean values of 182.7.00 mg/ L and 192.6 mg/ L for the pre-monsoon and post-monsoon seasons respectively. The mean values of the water samples in the pre-monsoon and post-monsoon seasons were 73.92 mg L and 84.07mg L respectively. The mean values of hardness in the water samples at all the locations have been shown in Fig. 7. It can be seen in the figure that hardness at all the sources were less than the WHO guideline value of 500 mg/L as CaCO3 (**Tiwari, T.N, et al.,1985).** The CH and TH concentrations showed an increased trend during post-monsoon when compared to the pre-monsoon. The total hardness of water sample varied between 64 mg/L to 322 mg/L in pre monsoon and 90 mg/l to 340 mg/l in post monsoon periods, Although, the concentration of CH and TH was within the prescribed limit set by WHO, which is 100 mg L 1 for drinking water. Water hardness above 500 mg/L needs excess use of soap to achieve cleaning. Another important observation from Fig. 4 is that hardness increased after the monsoon at almost all the sampling locations. This may be due to the dilution effect on the aquifer after the monsoon season.

Chloride (Cl-):

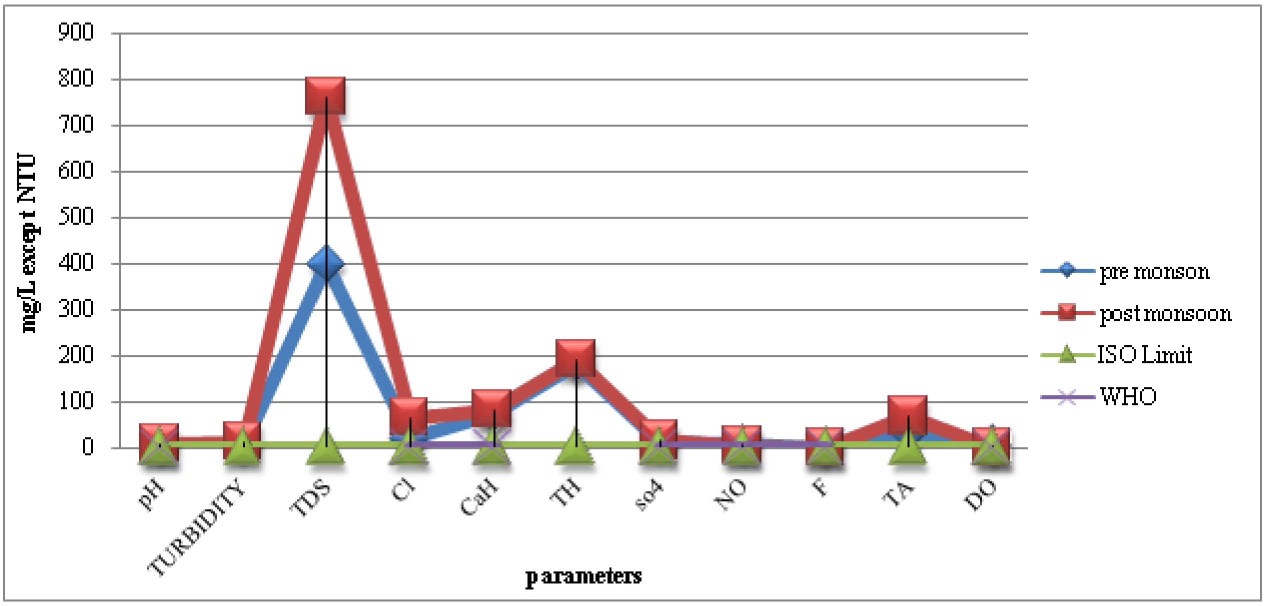
The chloride concentration serves as an indicator of pollution by sewage. People accustomed to higher chloride in water are subjected to laxative effects. In the present analysis, mean concentration was found to be of 20.40 mg/L and 65.23 mg/L respectively in pre and post monsoon. The values are within the limit except water sample collected from sites Sarabaguda and Hattaguda. Higher chloride concentration in samples from this sites may be due to chlorination of open wells in rainy season.

Nitrates:

Nitrates generally occur in trace quantities in surface waters but may attain high levels in some ground waters. The main sources of nitrate in water are human and animal waste, industrial effluent, use of fertilizers and chemicals, silage through drainage system (**Singh and Mathur, 2005**). In excessive limits of nitrates (above 40 mg/L), it contributes to the illness known as methenoglobinemia or "blue baby" in infants. The nitrate values of the samples were found to be in range 0.10 – 0.92 mg/L and 0.5 – 9.7 mg/L in pre and post monsoon, Nitrates were found to be within the permissible limits.

Flouride:

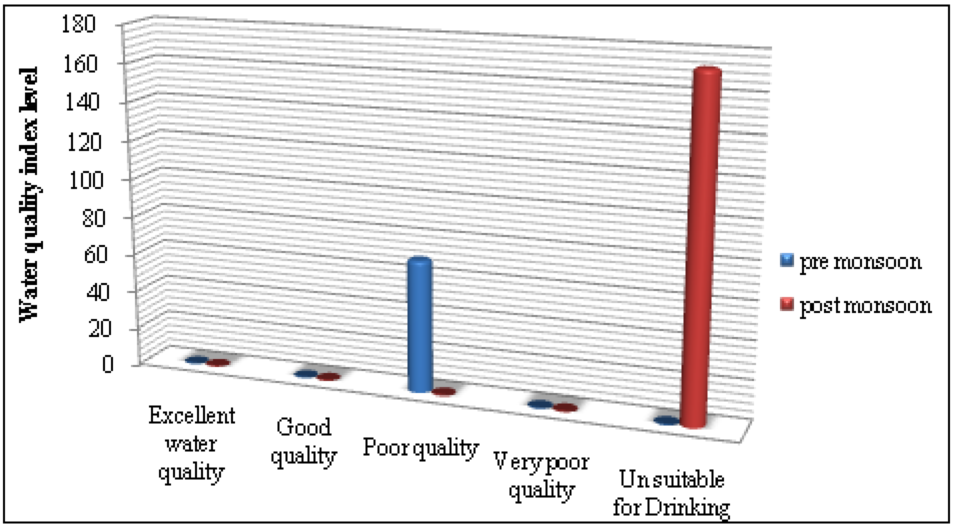
The Fluoride content of the samples varied from 0.1 mg/ L to .00.92 mg L and 0.1 mg L to 0.41 mg L in the pre-monsoon and post-monsoon respectively. It occurs mainly as simple fluoride ion, in groundwater and is capable of forming complexes with silicon and aluminium and is believed to exist at a pH <7. In the pre and post-monsoon season the fluoride concentration was below the permissible limit of 1.5 mg L (WHO). As reported earlier **(Ramachandramoorthy *et al.*, 2010),** the dissolution of F bearing minerals may be contributing the high - percentage of F in water samples. Fluoride is beneficial when present in small concentrations (0.8 to 1.0 mg L 1) in drinking water for calcification of dental enamel. However, it causes dental and skeletal fluorisis if high. Higher concentration of fluoride in drinking water is also linked with cancer (Smedley et, al.2003).



Graph 7: Comparison of physic-chemical parameters with ISO-100500 & WHO standards

Water Quality Index (WQI)

Water quality index(WQI) was also assesd based on the WQI Level by (Chatterji and Raziuddin 2002) (Table 5&6). WQI was registered to be 69.786 in the very poor category (WQI-76-100) in pre monsoon period and 174.310 under the category (≥ 100) of unsuitable for drinking range for post-monsoon . The study shows very poor quality of water sample from all 13 locations across. Araku region for drinking purpose as per the water quality index. The water quality index of post monsoon found to be more worse than the pre monsoon water quality index this may be due to mixing of silt and rain water in to open wells and springs. However, this water can be used for drinking purpose after purification treatment followed by disinfection before consumption and is also need to be protected from the perils and contaminations. A very poor category of water quality index (WQI) was recorded during post monsoon season may be due to excessive flow of agricultural and domestic waste) into ground water. Therefore, the ITDA (Integrated Tribal Development Agency) should take effective measures and urgent monitoring programmes are required for this tribal areas for a quality management plan. Thus, high priority should be given to water quality monitoring and advanced technologies should be adopted to make water fit for , domestic and drinking purpose after treatment as such condition if prevails would make water unfit causing various health hazards, in this tribal areas.



Graph 8: Water Quality Index (WQI) and status of water quality (Chatterji and Raziuddin 2002) in pre and post monsoon

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