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Assessment of water quality index of groundwater in Madhurawada, Visakhapatnam, Andhra Pradesh, India

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Abstract
The present paper aims at determining the water quality of Groundwater by analyzingthe physico-chemical characteristics and assessment of Water quality index (WQI) of Madhurawada region, Visakhapatnam city. Total of 30 samples were collected during the year 2018 and 2019 in pre and post monsoon respectively. The physico-chemical parameters include pH, Conductivity, Total Dissolved Solids, Total Suspended Solids, Alkalinity, Turbidity, Total Hardness, Calcium, Magnesium, Chlorides, DO and BOD. Results showed that most of the parameters were exceeded the recommended ground water quality levels of Bureau of Indian Standards (BIS).
The computed WaterQuality Index (WQI) values ranges from 62.92 to 123.97 and thereforecan be categorized into “Poor water” to “water unsuitable for drinking.” Of the all groundwater samples collected and calculated 7% of samples fall under “poor water quality”, 54% samples fall under “very poor water quality” andunfortunately, 40% of the samples represent water “unsuitable for drinking purposes. Results obtained from the analyses showed that, pH are slightly alkaline in nature with ranges from 6.84–7.99 and Total hardness ranges from 235–585mg/l. pH is observed high at Chandrampalem ZPH School, APHB Kommadi and Carpenters Colony.Total Hardness values are above the permissible limits at Shilparamam, VambayColony and Dmart area. Total Dissolved Solids ranges from 350 to 1060 mg/l. TDS values are above the permissible limits in at DMart Area, NGO Layout and APHB Kommadi. Chlorides and Electrical Conductivity values are also above permissible limits. Chloride values are above the permissible limits at Chandrampalem ZPH School.Results revealed that ground water is getting polluted day by day due to Urbanization and Industrialization activities and treatment of groundwater is recommended before consumption.

Keywords: groundwater quality, physico-chemical parameters, water quality index

Introduction

Water is a finite source. Water never leaves the Earth. It is constantly being cycled through the atmosphere, oceans and lands in liquid, gas or solid forms. This process, known as the water cycle, is driven by energy from the sun. The water cycle is crucial to the existence of life on our planet. Man-kind can stay without food for a longer time than without water.

Water is universal solvent. It is useful for domestic, agricultural and industrial purpose. It comes from many sources like streams, rivers, lakes, ponds, springs, wells and rain. A huge surface of Earth (71%) is covered with water, only a meagre (0.014%) amount of it usable by humans; causing frequent water famines/crisis and water wars. Amount of salty water on earth is 97.2% and that of fresh water which is usable by humans being 2.8% has to be managed quite carefully to meet our ever increasing needs.

Urbanization increased the need for domestic water and the sewage, municipal waste generated is causing a myriad of problems leading to non-availability of usable safe water. Groundwater is highly valued because of certain properties not possessed by surface water (Rajankar *et al*., 2011) [19]. The demand for groundwater is increasing rapidly due to over population. Groundwater quality has become an important water resources issue due to rapid increase of population, rapid industrialization, unplanned urbanization and too much use of fertilizers and pesticides in agriculture (Joarder *et al*., 2008) [11]. Unexpected population growth is related to water quality degradation and is causing large increase in nutrients and microbial loads (Ghosh *et al*., 2014 and Maillard & Santos, 2008) [8, 15]. Industrialization is the index of modernism which leads to alternation in the physical and chemical properties of environment (S.P.Bhalme *et al*., 2012) [4].

In 1965, the concept of WQI to clarify gradation the water quality was first proposed by Horten (R.K.Horten *et al*., 1965) [9]. Gradually, the general WQI has been developed by Brown in 1970 which were based on weights to individualparameter (Brown *et al*. 1970) [5]. WQI is one of the most effective tools to express water qualitythat depicts the composite influence of different water quality parameters andcommunicates water quality information to the public and legislative decisionmakers. Water pollution not only affects water quality, but also threatens human health, economic development, and social prosperity (M.Milovanovic *et al*., 2007) [14].

It is an important technique for evaluating water quality and its suitability water for drinking purposes (T.N.Tiwari and M.A. Mishra 1985) [26]. WQI reflects composite influence of contributing factors on the water quality for any water system (S.S.Kakati and H.P. Sarma, 2007) [12].

The present situation of water quality management is far from satisfactory due to the pressure of increasing population and developing economy all over the world. To enhance the sustainability of water quality management systems, in depth research of related barriers and relevant mitigation methods should be implemented.

2. Study area

The present study deals with the assessment of the quality ofwater quality index in Madhurawada area, Visakhapatnam. Madhurawada is one of the fastest growing sub-urban area in the Visakhapatnam. Due to the Urbanization, Industrialization and Population size it became like second Vizag. Places of importance in the study area Dr.YSR International Cricket stadium, Shilparamam, near to IT Hub i.e., ITSEZ, proposed five star hotel, convention center etc.

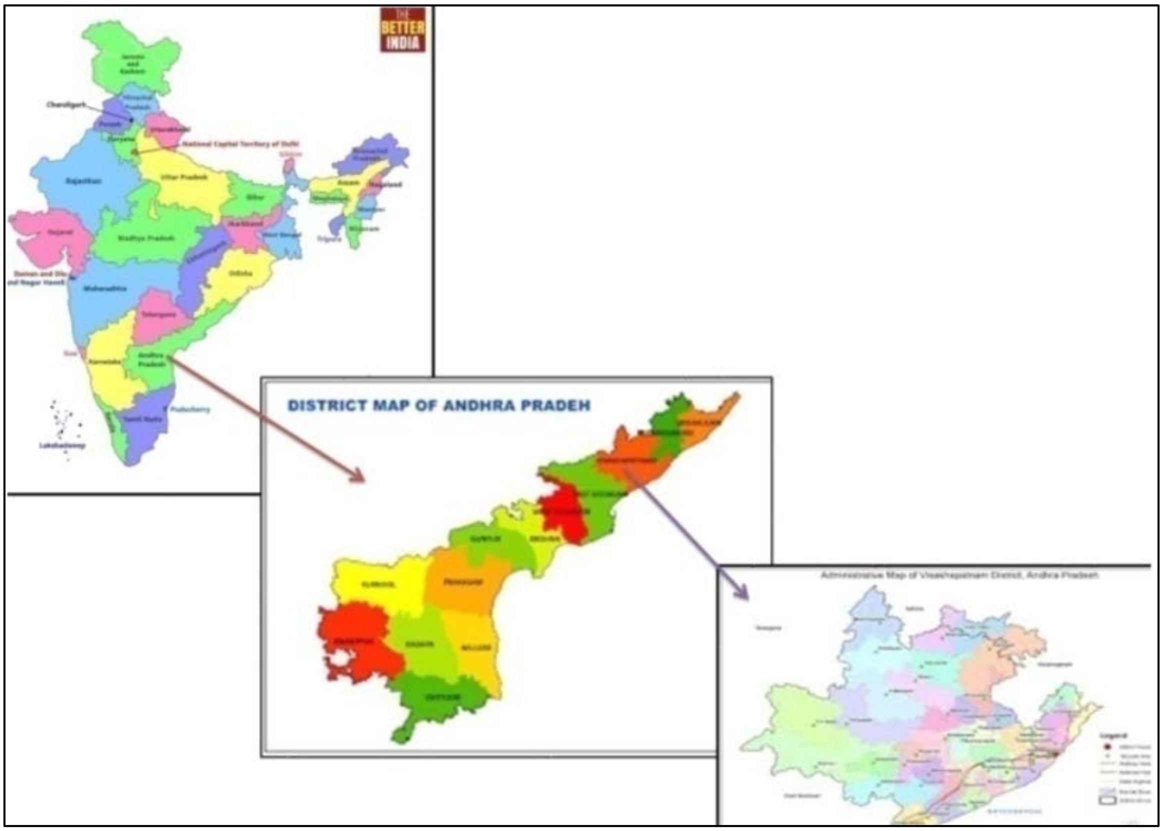

Fig 1: Location map of Visakhapatnam District

Fig 2: Study area with sampling stations extracted from Google earth

Materials and Methodology

a. Pre field activity

Before going to field, a survey was carried out, and marked the sampling stations as per the utilization of ground water for government schools, urbanization, commercial and residential activities using Google earth and field survey in person. 2 liter water cans were purchased, washed, rinsedthoroughly with distilled water and labeled accordingly. Reagentsrequired for analysis were freshly prepared andinstruments to be used at sampling sites were properly calibrated and checked.

b. Sampling Procedure

A total of 30 samples were collected in two seasons (pre and post monsoon period) in the morning hours (between 8am to 10pm) during September 2018 to March 2019. Water was collected in sterilized 2 litre cans labelled with the sample code and transported to the laboratory in an ice box and stored at 4°C.The samples were processed and analysed in the laboratory. The time between sampling and analysis was kept minimum. PH and DO tests were carried out immediately after sampling at the location as they may change during the storage and transport.

Table 1

Code	Sampling stations	Source	Latitude	Longitude
S1	Shilparamam	Borewell	17º 48′ 19″ N	83º 21′ 11″ E
S2	Sambuvanipalem government school	Hand Pump	17º 47′ 54″ N	83º 18′ 35″ E
S3	Rajiv Gruhahousing board	Borewell	17º 48′ 35″ N	83º 19′ 58″ E
S4	Bakkannapalem government high school	Borewell	17º 48′ 58″ N	83º 20′ 25″ E
S5	Navodaya government school	Borewell	17º 49′ 15″ N	83º 20′ 14″ E
S6	DMart area	Borewell	17º 48′ 57″ N	83º 21′ 23″ E
S7	Chandrampalem ZPHS	Hand Pump	17º 49′ 06″ N	83º 21′ 20″ E
S8	APHB Kommadi	Hand Pump	17º 49′ 42″ N	83º 20′ 49″ E
S9	Carpenters colony	Borewell	17º 49′ 26″ N	83º21′ 27″ E
S10	NGO layout	Borewell	17º 48′ 17″ N	83º 22′ 10″ E
S11	RTC colony	Borewell	17º 48′ 45″ N	83º 22′ 27″ E
S12	Srinivas nagar	Borewell	17º 48′ 48″ N	83º 21′ 29″ E
S13	Revenue layout	Borewell	17º 47′ 60″ N	83º22′ 01″ E
S14	Vambay colony	Hand Pump	17º 48′ 46″ N	83º 21′ 50″ E
S15	Mithilapuri VUDA colony	Borewell	17º 48′ 19″ N	83º 21′ 34″ E

c. Methodology for Laboratory Analysis

Each of thegroundwater sample collected are analyzed for 12 different parameters such as pH, EC,Turbidity, TDS, TSS, Total alkalinity, Total hardness as $CaCO_3$, calcium hardness, magnesium hardness, chlorides, DO and BOD. All the analyses have been carried out as per theAmerican Public Health Association standard methods.

d. Procedure for Calculation of Water Quality Index

The water quality index also called weightedarithmetic index method was used for thecalculation of WQI (Shweta Tyagi *et al.*, 2013) [27]. was made by using the following equation:

$WQI = \Sigma QiWi/\Sigma Wi$

The quality rating scale (Qi) for each parameter is calculated by using this expression:

$Qi = 100[(VI – VO) / (Si – VO)$

Where,

VI is estimated concentration of i^{th} parameter in the analysed water
VO is the ideal value of this parameter in pure water
VO = 0 (except pH =7.0 and DO = 14.6 mg/l)
Si is recommended standard value of i^{th} parameter

The unit weight (WI) for each water quality parameter is calculated by using the following formula:

$WI = K / Si$

Where,

K = proportionality constant and can also be calculated by using the following equation

$$K = \frac{1}{\sum (1/Si)}$$

Table 2: The rating of water quality according to this WQI is

WQI Value	Rating of Water Quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
Above 100	Unsuitable for drinking purpose	E

Results and discussion:

PH mean value ranges from 6.84 to 7.67 with a mean of 7.28 in post-monsoon and values ranges from 7.21 to 7.99 with mean of 7.63 in pre-monsoon during the years 2018 and 2019. PH is an indicator of acidity and basicity. Low pH values in water results in water corrosionwhereas very high pH values have adverse effect on the taste of water, dermal and eye health (Rao and Rao 2010 [21]. Ravikumar *et al*. 2013).If pH increases the permissible level it may promote corrosion of plumbing systems and fixtures (N.V.Srikanth, 2012) [24].

Electrical Conductivity (EC) is a vital factor for representing the quality of groundwater and it indicates a salinity risk. Highconductivity might arise from anthropogenic sources and natural weathering (V.Dhilleswara Rao *et al*., 2019) [7].

EC values of the samples ranged from 525 -1250 µS/cm with a mean of 939.53 in Post monsoon season values ranges from 540 -1280 µS/cm with a mean of 933.2µS/cm in Pre-monsoon during the year 2018 and 2019.

Turbidity mean value ranges from 0.28 to 2.3 mg/l with a mean of 0.871 mg/l in post-monsoon and values ranges from 0.31 to 2.1 mg/l with mean of 0.862 mg/l in pre-monsoonduring the years 2018 and 2019. There is a risk that pathogenic organisms could be shielded by the turbidity particles and hence escapes the action of the disinfectant (Behailu TW 2017) [3]. Total Dissolved Solids mean value ranges from 350 to 1060 mg/l with a mean of 746 mg/l in post-monsoon and values ranges from 285 to 1050 mg/l with mean of 696.1 mg/l in pre-monsoon during the years 2018 and 2019. The high TDS may be due to the percolation of channel water containing solids, agricultural wastes, and industrial seepages. The country rocks are also the most important sources of increasing dissolved solids in the groundwater (S. Selvakumar *et al*., 2017) [23]. Total Suspended Solids (TSS) mean value ranges from 0.11 to 2.22 mg/l with a mean of 0.92 mg/l in post-monsoon and values ranges from 0.19 to 2.82 mg/l with mean of 1.18 mg/l in pre-monsoon during the years 2018 and 2019. TSS, which are closely related to turbidity, are substances that mixed withwater in various ways and form turbidity in water and do not precipitateover time. Turbidity of natural waters increases during periodsof runoff, terrestrial flow, erosion and landslides (Olyaie *et al*., 2015) [18]. Alkalinity mean value ranges from 63 to 145 mg/l with a mean of 88.2 mg/l in post-monsoon and values ranges from 58 to 148 mg/l with mean of 86.53 mg/l in pre-monsoon during the years 2018 and 2019. Alkalinity is a measure of the capacity of water to neutralize acids or hydrogen ions.Most alkalinity insurface water comes from calcium carbonate ($CaCO_3$) that comes from rocks and soil (). Alkalinity above the permissible limits imparts unpleasant perception to water and can be harmful to humans in presence of high pH, hardness and TDS (Kamaldeep *et al*., 2011) [13]. Total hardness mean value ranges from 235 to 585 mg/l with a mean of 386 mg/l in post-monsoon and values ranges from 243 to 600 mg/l with mean of 398.6 mg/l in pre-monsoon during the years 2018 and 2019. The principal hardness causing cations are calcium, magnesium, strontium, ferrous and manganese ions. (Byragi Reddy *et al*., 2013) [6]. Calcium mean value ranges from 64 to 168 mg/l with a mean of 114.93 mg/l in post-monsoon and values ranges from 70 to 178 mg/l with mean of 122.87 mg/l in pre-monsoon during the years 2018 and 2019. Excessive calcium in drinking water is linked to the formations of concretions in the body and may cause gastro intestinal diseases and stone formations (SwarnaLatha.P. *et al*., 2010) [25].

Magnesium mean value ranges from 129 to 521 mg/l with a mean of 271.1 mg/l in post-monsoon and values ranges from 128 to 530 mg/l with mean of 275.73 mg/l in pre-monsoon during the years 2018 and 2019.Magnesium >125 mg/l may show laxative affects (Mohd Saleem *et al*., 2016) [16].

Chlorides mean value ranges from 29.9 to 260 mg/l with a mean of 153.86 mg/l in post-monsoon and values ranges from 33 to 269 mg/l with mean of 156.93 mg/l in pre-monsoon during the years 2018 and 2019. Chloride is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), $NaCO_2$ andadded through industrial waste, sewage, sea water etc. Surface water bodies often have low concentration ofchlorides as compare to ground water. It has key importance for metabolism activity in human body and othermain physiological processes. High chloride concentration damage metallic pipes and structure as well as harmsgrowing plants (Muhammad Mohsin *et al*., 2013). The higher chloride content in groundwater may be attributed to the presence of soluble chloride from rocks and saline intrusion (Swarna Latha P. *et al*., 2010) [25]. Lowlevels of dissolved oxygen (DO) in water could beattributed to discharge of effluents rich in organic matter, whereas an increase in DO levels in water could be influenced by frequent rainfall as at the time ofsampling (I.R. Allison *et al*., 2020) [1]. DO mean value ranges from 1.37 to 5.22 mg/l with a mean of 2.514 mg/l in post-monsoon and values ranges from 1.18 to 3.14 mg/l with mean of 2.383 mg/l in pre-monsoon during the years 2018 and 2019. The Biological Dissolved Oxygen (BOD) is considered as most important indicator of water pollution to sewage and industrial waste discharge. BOD mean value ranges from 0.23 to 3.14 mg/l with a mean of 1.43 mg/l in post-monsoon and values ranges from 0.1 to 2.52 mg/l with mean of 1.52 mg/l in pre-monsoon during the years 2018 and 2019.

Water Quality Index

In the present study, the computed WQI values ranges from 62.92 to 123.97. Water unsuitable for drinking has been observed in samplesS1, S10, S11, S12, S13 and S15 respectively. Very Poor water quality has been observed in samples S2, S3, S4. S5, S6, S8, S9 and S14. Poor quality of waterquality has been observed in sample S7. It has been observed that most of thesamples indicate a very poor water quality to water unsuitable for drinking around the study area. Analysis of results reveals the factthat WQI pertaining to the groundwater of the area needs degree of treatment before consumption.

The computed WQI values range from 67 to 588and therefore can be categorized into four categories: "goodwater" to "water unsuitable for drinking."Overall, 36% of groundwater sites sampled in the studyarea had good water quality, while 53% were poor. Themajority had fair quality. Unfortunately, 6% of the samplesindicate "very poor water quality" and 5% represent "waterunsuitable for drinking purposes"

Table 4: Wqi Index of sampling stations

Sampling Station	WQI	Water Quality rating	Range
S1	102.52	Unsuitable for drinking	0-25 Excellent water quality 26-50 Good water quality 51-75 Poor water quality 76-100 Very poor water quality Above 100 Unsuitable for drinking
S2	84.36	Very poor	
S3	84.57	Very poor	
S4	73.98	Very poor	
S5	99.73	Very poor	
S6	96.66	Very poor	
S7	62.92	Poor	
S8	88.49	Very poor	
S9	90.54	Very poor	

S10	105.58	Unsuitable for drinking	
S11	122.35	Unsuitable for drinking	
S12	112.33	Unsuitable for drinking	
S13	102.95	Unsuitable for drinking	
S14	75.68	Very poor	
S15	123.97	Unsuitable for drinking	

Summary and Conclusion

Due to multiple sources of pollution and based on this study, it can be concluded that ground water situation in Madhurawada area is not good. The situation has been deteriorating over the time and water quality is degrading in the years 2018 and 2019. Our results reveal that Urbanization and anthropogenic operations carried out in the surrounding and nearby areas affected the ground water quality and the samples did not meet the drinking water specifications in most of the cases. Hardness is above the permissible limits in Station S4, Chloride values are above the permissible limits in S7. Electrical Conductivity, Total dissolved solids and Total Hardness were above the permissible limits in S6, S10 and S13. Results revealed that groundwater is getting polluted day by day and treatment of groundwater is recommended before consumption. Most of the results of the physico-chemical parameters are complying with maximum standards proposed in BIS. And finally the WQI calculation states that most of the water samples are unsuitable for drinking and maximum WQI values were recorded due to the high EC, TDS, Total hardness, calcium and magnesium hardness in the water samples. No one sample has achieved the class excellent and good. The result analysis from the present studyreveals the fact that the water quality of the study area has deteriorated and needs a thorough degreeof treatment before being utilized for drinking purpose and human consumption.

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