Assessment of Seasonal Variation of Water Quality in Bhubaneswar Urban Catchment Using Water Quality Index Method

Kshyana Prava Samal[1], Asish Kumar Pradhan[2] and Ashok Tarai[2]

[1] Associate Professor, School of Civil Engineering, KIIT DU, Bhubaneswar, Odisha, India
[2] Research Assistant, KIIT DU, Bhubaneswar, Odisha, India
[3] Research Scholar, School of Civil Engineering, KIIT DU, Bhubaneswar, Odisha, India
kshyanaprava.samalfce@kiit.ac.in

Abstract. The scientific community is very concerned about groundwater contamination since it directly affects human health and also to achieve SDG6. Since fast pace of urbanization have been ascertained in Bhubaneswar- a smart city of eastern India and mostly dependent on ground water so the quality of ground water must be rigorously examined. This research has taken an initiative to focus the ground water contamination and quality declination through different seasons in Bhubaneswar. Most likely high population density areas, industrial areas and landfills nearby areas have been considered for sample collection and testing. The groundwater samples were collected from deep bore-well i.e., 150-200ft and were tested for summer season and rainy season of the year 2023. Twelve different water quality parameters like pH, dissolved oxygen (DO), total hardness, electrical conductivity (EC), total dissolved solids (TDS), chloride, iron, alkalinity, nitrate, fluoride, sulphate, were examined in order to determine the city's water quality for the given year using weighted arithmetic water quality index method. The parameters like pH have got varied in 73.3% in Summer and 93.3% in rainy season in all the above areas. Whereas Mancheswar has got a high variation in the parameters like electrical conductivity and nitrate in summer and rainy respectively beyond permissible limit as per IS10500(2012). Also, water quality index indicates 33.3% and 40% areas in summer and rainy are unsuitable for drinking. It shows that care must be taken for all the above parameters to stop further contamination of groundwater.

Keywords: Groundwater, Deep-borewell, Water Quality Index, Water Contamination, Bhubaneswar, Parameters.

1 Introduction

Contamination of groundwater with various pollutants has grown day by day and has become a major environmental issue worldwide. To achieve SDG6 the quality management is one of the major challenges. Ensuring the quality and safety of groundwater is pivotal for fostering social and human sustainable development (Gao et al. 2020). Around 20% of the fresh water supply on Earth comes from groundwater,

The original version of this chapter was revised: The article title has been updated and the repetitive word "The" has been removed. The correction is available at https://doi.org/10.2991/978-2-38476-192-0_22

T. Pradhan et al. (eds.), *Proceedings of the World Anthropology Congress 2023 (WAC 2023)*, Advances in Social Science, Education and Humanities Research 821,
https://doi.org/10.2991/978-2-38476-192-0_9

which accounts for 0.61% of all water on earth (including oceans and ice sheets). The overall amount of freshwater held in the snow and ice pack, including the north and south poles, is about equivalent to the amount of groundwater retained globally. This makes it a valuable resource that can serve as a natural reservoir to protect against surface water shortages, such as those that occur during droughts (Lathamani, Janardhana, Mahalingam & Suresha 2015, 1031-1038).

Currently, groundwater supplies are used to meet around 50% and 43% respectively of the world's drinking as well as irrigation needs (FAO, 2010). However, due to dwindling water levels, there is a global shortage of fresh and potable groundwater (Tiwari et al. 2009; van der Gun, 2012; Richey et al. 2015; De Graaf et al. 2017; Bierkens and Wada, 2018). Groundwater resource is continuing to decline due to deterioration in quality (Vörösmarty, Green, Salisbury, Lammers 2000, 284-288; van der Gun, 2012). According to Ramesh, Purvaja & Raveendraet (1995, 147) anthropogenic activities like the discharge of sewage waste and industrial effluents are the reason for the uneven distribution of major and trace elements in groundwater. Due to the rapid pace of urbanization and the rising volume of waste being released, the deterioration of groundwater quality has emerged as a global concern. This is attributed to its extensive prevalence and the potential implications it holds for human health (Abelson, 1984, Bulut et al. 2020, Kaur and Garg, 2019, Liu et al. 2019a, Grimmeisen et al. 2017). Water contamination is to blame for over 80% of the diseases affecting the global population and for more than one-third of mortality in underdeveloped nations (Earth summit 1992).

Overuse, over abstraction, or overdraft of ground water however can have serious negative effects on both the environment and human users. The lowering of the water table beyond the capacity of current wells is the most obvious issue. According to experts, India is quickly approaching a catastrophe of contaminated and overused ground water because both rural and urban

India relies on groundwater for its domestic water needs India depends on the ground water for domestic use as well as for drinking use (Singhal et al. 2002). When the average rate of extraction from aquifers exceeds the average rate of recharge over time, this is referred to as overusing or over exploiting ground water. The Central Water Commission, Central Ground Water, Central Ground Water Authority, and Central Pollution Control Board are the four organizations in charge of managing groundwater regulation in India. It is a crucial supply of drinking water and a major source of domestic water in India, both in the cities and the countryside (Singhal et al. 2002).

The protection of groundwater quality, crucial for providing cleaner and safer drinking water, necessitates collaborative efforts from various stakeholders, including water resource managers, legislators, water suppliers, and the general public (Abtahi et al. 2015). As the public comprises individuals with diverse professional backgrounds, conveying information about groundwater quality requires a concise approach (Nasirian, 2007, 2977-2987). In this regard, traditional methods like individual parameter assessment have given way to the adoption of the water quality index (WQI), originally formulated by Horton in 1965, (300-306). The WQI serves as a comprehensive tool, amalgamating numerous groundwater chemical components into an easily understandable format—a single score. This is achieved by selectively weighting water quality parameters and applying an aggregation function (Abtahi et al. 2015). Furthermore, the WQI has proven to be an effective means of communicating water quality information to decision-makers, finding widespread application in various water quality assessment studies (Batabyal; Chen et al. 2019; Das Kangabam et al. 2017; Molekoa et al. 2019; Nath et al. 2018; Vasanthavigar et al. 2010).

Researchers and governmental organizations have put forth and used a number of WQIs over the years. The Index of River Water Quality (Liou, Lo&Wang2004, 25-32) the Scatter score Index (Kim&Cardon2005, 277-295), the Canadian Council of Ministers of Environment Water Quality Index (CCMEWQI) (Lumb, Halliwell & Sharma 2006, 411-429, Damo & Icka 2013) the National Sanitation Foundation Water Quality Index (NSFWQI) (Brown, McClelland, Deininger & Tozer 1970, 339-343, Kumar & Alappat 2009, 75-79) the Oregon Water Quality Index (OWQI) (Dunnette 1979, 53-61, Dinius 1987, 833-843) and the Weighted Arithmetic Water Quality Index Method (WAWQIM) (Chauhan & Singh 2010 53-61, Rao, Rao, Hariharan & Bharathi 2010, 79-86, Manju, George & Rekha 2014, 53-58) are some of these measures. The most widely used of these are WAWQIM, OWQI, NSFWQI, and CCMEWQI (Bharti & Katyal 2011, 154-164, Tyagi, S., Sharma, Singh & Dobhal 2013, 34-38).

The Water Quality Index (WQI), frequently employed by researchers in developing nations, utilizes the Weighted Arithmetic Index Method (WAWQIM). This approach is particularly prevalent in regions where the infrastructure for extensive data collection is limited (Yogendra & Puttaiah 2008, 342-346, Amadi, Olasehinde, Okosun, E. A. & Yisa 2010, 116-123, Yisa & Jimoh 2010, 453-458, Akoteyon, Omotayo, Soladoye & Olaoye 2011, 263-271, Boah, Twum & Pelig-Ba 2015, 11-16, Aktar et al. 2016). It is particularly valuable for assessing water quality at locations where data has been systematically gathered over time for the explicit purpose of evaluation. Earlier few studies have been done in Bhubaneswar using water quality index method by (Acharya et al. 2017 7). The ground water quality study of the areas like high population density, industrial estate and landfill using weighted arithmetic water quality index has not been addressed by any of the researcher so far. For which this study will be helpful for proper quality study of groundwater in Bhubaneswar urban catchment. In this study the WQI has been used as a tool to analyze the water quality condition and the variation of water quality parameters during summer and rainy season.

2 Scope and Objectives

The principal objective of the present study is to understand the hydrochemistry of ground water and seasonal variation in the quality of ground water due to geogenic and anthropogenic activities using weighted arithmetic water quality index.

3 Methodology

3.1 A description of the study area

Bhubaneswar, the capital of the Indian state of Odisha, is situated between latitudes 20º12’ and 20º25’N and 85º44’ and 85º45’E. It is 40–45 meters above mean sea level (msl), is a part of the Gondwana landmass, and its rocks range in age from Archean to more recent creation. It is supported by Athagarh sandstones, which are compact and hard in the city's south-west but worn and friable in its north-west. The phreatic aquifer zone was created by these laterally altered, cracked, and worn Athagarh sandstones (Das 1988, 26). In shallow aquifers, groundwater occurs both below the water table and in semi-confined circumstances in deeper aquifers. Alluvium and laterite soils from the quaternary period cover the majority of the city. In Odisha, the oldest Precambrian rocks cover 72.5% of the state's total territory, with younger rocks from the Phanerozoic and Cenozoic eras covering 8% and 19.5% of that area, respectively (Madhav et al. 2020). The unconsolidated formations are found to the east of the city and are the older and younger alluviums. In laterites and worn sandstones, the depth to the water table is only 5–12 meters, but in fractured and friable sandstones under semi-restricted to confined circumstances, the depth can reach 40–150 meters. By developing more roads, improving connection, and erecting high-rise structures, the city has quickly advanced, which has increasingly worsened the behavior of the soil mass. As a result, the risk of groundwater quality degradation and dangerous groundwater is at its highest. Researchers have recently become quite concerned about groundwater management in order to prevent any unforeseen occurrences, such as drought, a lack of access to drinking water, inappropriate irrigation, etc.

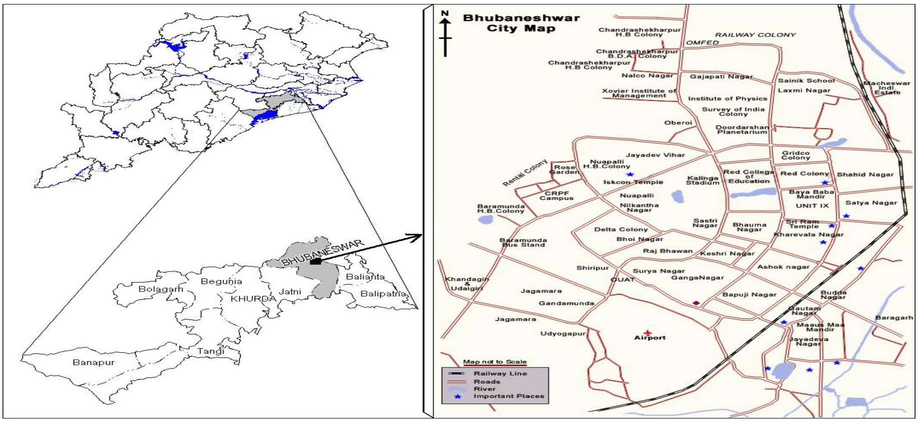

Fig. 1. Bhubaneswar City Map (Source- Central Ground Water Board, South Eastern Region, Bhubaneswar, Odisha)

The experiment was conducted in locations where drinking and domestic uses of ground water predominated. To cover the entire of the capital city- Bhubaneswar, fifteen locations were selected for sample collection on the basis of high population density area, industrial area and landfill nearby area. The samples were collected in the physical space using a global positioning system which will help for the further sample collection in the same locations.

For the study nearly 30 ground water sample collected from different areas of Bhubaneswar during summer and rainy for the year 2023. The location that has been chosen comes under National Hydrograph Network Station which is basically ground water observation points by Central Ground Water Board (CGWB).

3.2 Sample collection and testing

The sample collection has been done at a distance of within 500m to 1km of the vulnerable areas like high population density area, industrial area and landfill nearby area.

One-liter transparent plastic bottles were used to collect water samples from deep bore well. Pre-washed sample bottles with dilute acid, rinsed with distilled water, then dried by air. Each sample was taken in three different containers for analysis of F-, Fe, SO42-, and NO3- (100 ml water in 2 ml of ultra-pure H2SO4); and 1 liter of water for the estimation of other pertinent parameters. By utilizing the accepted techniques, the samples were examined for pH, dissolved oxygen, total hardness, electrical conductivity (EC), total dissolved solids (TDS), chloride, iron, alkalinity, nitrate, fluoride, sulphate. After the samples were collected, the EC and pH were immediately assessed.

The pH, electrical conductivity, dissolved oxygen was analyzed using Hach multimeter (model-hq40d). pH was assessed right away at each location following sampling, whereas DO and EC were assessed right away in the field laboratory. Following the sampling, further parameters were examined in the institute laboratory. The other physico-chemical parameters were calculated as per standard APHA (2019) methods. Alkalinity, total hardness calculated by titrimetric method. Chlorine (Cl) was calculated using argentometric method (Mohr's method). Sulphate (SO42-) was determined by turbidity method with the help of a UV-VIS spectrophotometer at 420nm. The total dissolved solids have been derived from the electrical conductivity value by incorporating a factor 0.65of EC. Ion-selective electrode method have been used to determine the fluoride level in ground water. The estimation of iron (Fe) content was done with the help of flame emission spectrophotometer. Nitrate (NO3–) estimation was done by UV-spectrophotometer at 220nm & 275nm.

The Water Quality Index (WQI) is an effective tool that simplifies informing the public, particularly policymakers, about the quality of water. It is an unambiguous tool that makes it possible to integrate water parameters that are deemed significant for the water's quality. In this study, the WQI, which is calculated using the weighted arithmetic index method (Brown, McClelland, Deininger & Tozer 1970, 339-343) is used to determine the effect of anthropogenic and geogenic activity on ground water.

The WQI is given as:

$$WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i}$$

where
qi=quality rating (sub index) of ith water quality parameter
wi= unit weight of ith water quality parameter; = 1
Also, qi , which relates the value of the parameter in polluted water to the standard permissible value is obtained as follows:

$$q_i = 100\left(\frac{v_i - v_{i0}}{s_i - v_{i0}}\right) \quad k = \frac{1}{\sum_{i=1}^{n} 1/s_i}$$

Where
vi= estimated value of the ith parameter
vio= ideal value of the ith parameter
si= standard permissible value of the ith parameter as per IS 10500
In most cases, vio=0 except for pH and DO
For pH, vio=7; For DO, vio=14.6mg/L
The unit weight (wi), which is inversely proportional to the values of the recommended standards is obtained as:

$wi = \frac{k}{si}$, Where $k = \frac{1}{\sum_{i=1}^{n} 1/si}$

The rating of the water quality using the above method is shown in Table.1

Table 1. Standard of Water Quality Index (Sinha, Kumar&Singh2014, 567)

Water Quality Index Level	Water Quality Status
0-25	Excellent Water Quality
26-50	Good Water Quality
51-75	Poor Water Quality
76-100	Very Poor Water Quality
>100	Unsuitable for Drinking

4 Result and discussion

4.1 A Subsection Analysis using Box plot

The major ground water parameters and the variation in phreatic aquifer in Bhubaneswar have been produced in the Box and whisker plot. The box plots show the variation of the parameters from minimum range to maximum range with mean, median, quartile data and outlier. The dotted mark above the maximum limit represented as outlier.

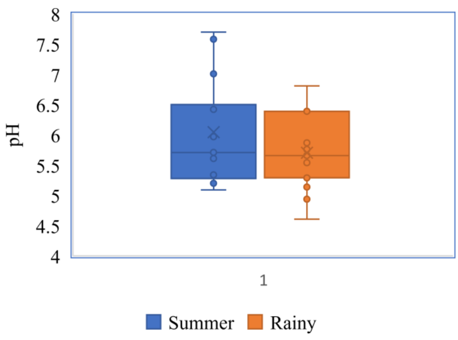

Figure 2. Seasonal variation of pH

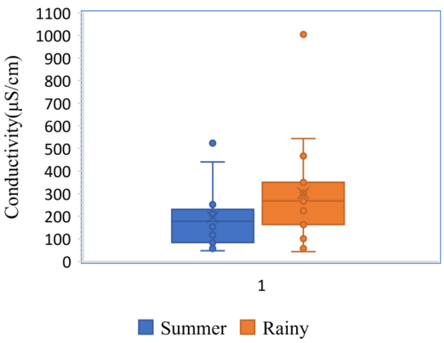

Figure 3. Seasonal variation of Conductivity

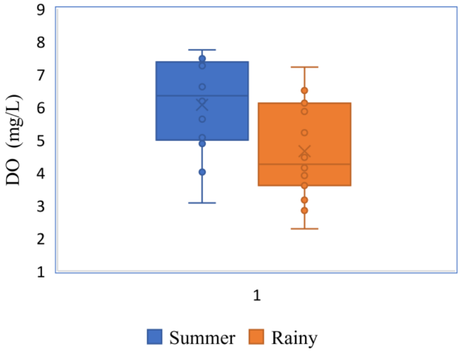

Figure 4. Seasonal variation of DO

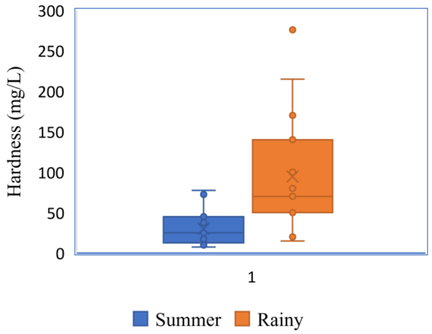

Figure 5. Seasonal variation of Hardness

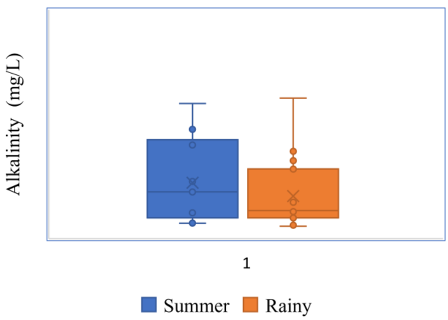

Figure 6. Seasonal variation of Alkalinity

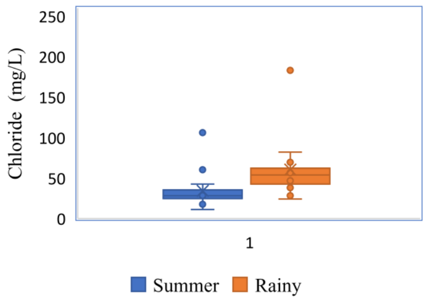

Figure 7. Seasonal variation of Chloride

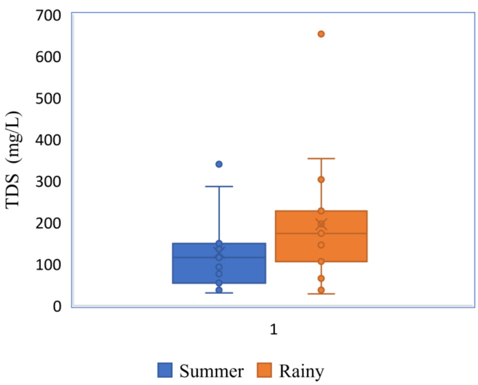

Figure 8. Seasonal variation of TDS

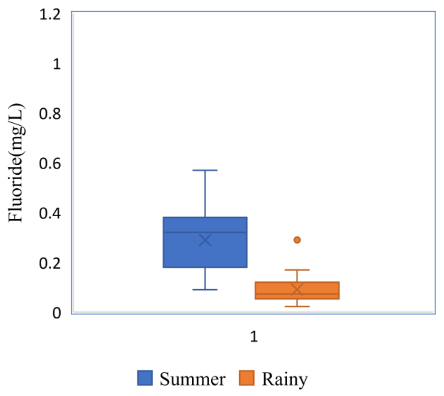

Figure 9. Seasonal variation of Fluoride

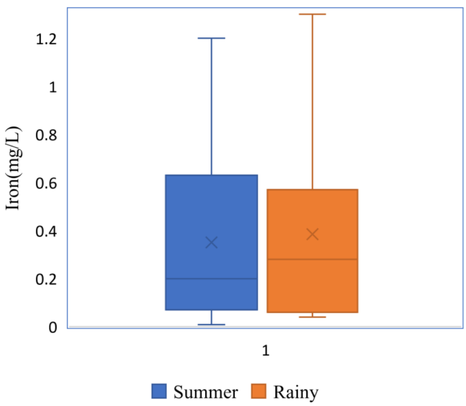

Figure 10. Seasonal variation of graph of Iron

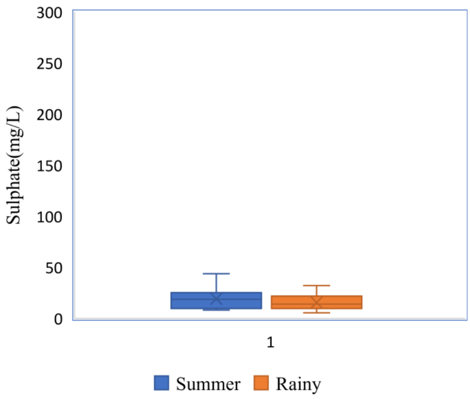

Figure 11. Seasonal variation of graph of Sulphate

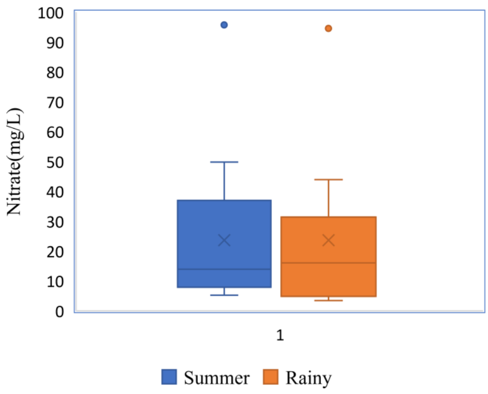

Figure 12. Seasonal variation of graph of Nitrate

4.1.1 pH

The data set represented in Graphical form with the help of box and whisker plot graph. The first quartile (Q1) is the median of the lower half of the data set. Median is the middle value of the data set, which divides the given data set into two equal parts. The median is considered as the second quartile (Q2), third quartile (Q3) is the median of the upper half of the data. Summer season pH values in Fig. 2 range from a maximum of 7.7 to a minimum of 5.09. The first quartile (Q1) is 5.28, the median is 5.71, and the third (Q3) is 6.5.

In rainy season the pH ranges from 4.61 to a maximum of 6.81. The first quartile, or Q1 is 5.21, the median is 5.66, and the third quartile or Q3 is 6.39. This reveals that the pH value for the maximal area is 5.71. As per the results, it shows that in case of pH value it was observed 73.3% areas in summer and 93.3% areas in rainy shows pH acidic in nature. Low pH of water may be found near industries, landfills, power plants etc. pH generally lower in the warmest month due to rise in temperature. Seasonal fluctuation that can be seen in the above data are not unusual.

The above changes in pH are due to mostly the leaching of organic matter, bacterial activity, and some cases due to the application of fertilizers in gardens. The acidity may have been due to high concentration of CO2 from eutrophication processes of organic matter, adsorption of metal anions and presence of some non-metallic compounds such as F-.

4.1.2 Electrical conductivity

The electrical conductivity values of the water samples show how solid waste at this location affects groundwater quality through leachate production and inorganic pollution. As per our result electrical conductivity varies from 46.8-523 µs/cm in summer season while it is 43.4-1004 µs/cm in rainy season. The Area like Old Town

(High Density population), Lingaraj Railway Station (landfill site) and Mancheswar Industrial Estate (Industrial Area) have shown higher values of conductivity. Enrichment of salt is the reason of high electrical conductivity. Mancheswar Industrial Estate showed 440 µs/cm in summer season and 1004 in winter season. During the summer season, water evaporates and ion concentration rises, increasing electrical conductivity. Since Mancheswar is an industrial area the leachates of industrial waste from the industrial waste could be the reason of the high value in rainy season. However, all the rest water samples are within the permissible limits.

4.1.3 Dissolved Oxygen

DO is an important geochemical oxidant. It is the amount of O2 molecules, that are dissolved in water. Low dissolved oxygen value is a sign of contamination.
In Saileshree vihar (4.89 mg/L and 3.17 mg/L) and OMFED square (3.08 mg/L and 3.91 mg/L) the dissolved oxygen value is found to be very much low in both summer and rainy season. In Summer the DO levels were found to be slightly lower than rainy. The reason could be that when solar radiation increased, surface water temperatures rose and oxygen's ability to dissolve in water reduced. Gadakana road records the lowest dissolve oxygen value in rainy season which is 65.4% lower as compare to summer season and Linagarj railway station area showed 51.73% low dissolve oxygen in rainy as compared to summer season. Since both Gadakana and Lingaraj railway station have the lowest distance from the landfill site (500 meters) which results organic pollution in the water due to percolation of effluent containing soluble organic compounds in rainy season.

4.1.4 Total hardness

The total hardness of the ground water samples varied from 7.5 to 77.5 mg/L in summer season, 20 to 276mg/L in rainy season. Total hardness is typically categorized as (1) soft: 0–75 mg/L; (2) moderate: 75–150 mg/L; (3) hard: 150–300 mg/L; and very hard >300 mg/L(Wurts,1993). The permissible limit of hardness in drinking water is 200-600mg/L. In the groundwater samples, TH values in all the location are comes under soft category. All the locations are in the permissible range in summer season. However, groundwater from Mancheswar industrial estate and Lingaraj railway station showed hardness value above 200mg/L which is the permissible range as suggested by IS 10500. This was due to effluent discharge at the start of the rainy season. Besides, there was increased sewage, domestic waste, and animal excreta, during the rainy season.

4.1.5 Alkalinity

In Fig. 6, during the summer season, the Alkalinity values range from a maximum of 130 mg/L to a minimum of 15 mg/L. The 1st Quartile (Q1) is 20 mg/L, the median is 45 mg/L, and the 3rd Quartile (Q3) is 95 mg/L, with a mean value of 53.66. In the rainy season, the Alkalinity values range from a maximum of 135 mg/L to a minimum of 12 mg/L. The 1st Quartile (Q1) is 20 mg/L, the median is 27 mg/L, and the 3rd Quartile (Q3) is 67 mg/L, with a mean value of 41.06.

According to IS-10500-2012, the permissible limit for alkalinity in drinking water is 200-600 mg/L. In all 15 locations, the alkalinity is found to be within the acceptable limit. The graph indicates that the average alkalinity is higher in the summer season compared to the rainy season. The increase in alkalinity from the rainy to the summer season is attributed to the presence of more carbonates and bicarbonates. The dissolution of carbonate minerals primarily regulates water alkalinity under conditions of lower pH, as evidenced by the acidic pH during the post-monsoon season.

4.1.6 Chloride

From the above study area, it has been found that chloride in summer ranges from 11.34 to106.35 mg/L and in rainy it ranges from 24.1-183.18mg/L. As per IS-10500-2012, the limit for chloride is 250mg/L. The natural chloride concentrations in groundwater derived from rainwater are typically below 10 mg/L. However, chloride levels in groundwater can increase to 20 or 30 mg/L or even higher due to the discharge of wastewater onto the land surface or leaching from chemical fertilizers applied to agricultural soils. In all the study area the Chloride level found to be with in the permissible limit as per IS-10500-2012 both in summer, rainy season. Though the range of Chloride is within the permissible limit but old town Bhubaneswar i.e. high population density area and Mancheswar i.e. industrial estate, the alkalinity level found to be increased in a striking manner as compared to other areas. Mancheswar showed a variation of 67.1% in rainy season as compared to summer season. Chloride presence in groundwater can stem from diverse factors, such as soil weathering, salt-bearing geological formations, salt spray deposition, road de-icing salt usage, contributions from wastewater, and, in coastal areas, the intrusion of saline ocean water into freshwater sources. As Mancheswar is an industrial area the landfill leachate in rainy season percolate to ground water causes increase in chloride content. Chloride helps the body to maintain its fluid balance. It helps make the digestive enzymes to help the body metabolize food. When chloride levels are moderately high, it causes many symptoms like long-term hyperchloremia, muscle weakness, high blood pressures, spasms, twitches, dehydration or kidney disease.

4.1.7 Total Dissolved Solids

According to IS-10500-2012, the acceptable range for total dissolved solids in drinking water is 500-2000 mg/L. As per the results, it shows that in case of TDS value it is under the permissible limit in most of the cases. But in Mancheswar industrial estate TDS value is beyond the permissible limit in rainy season which is almost double the summer season. The elevated concentrations of TDS are found in rainy season due to salt inputs from the industrial effluents. It is possible to relate the presence of natural solutes from soil dissolution and weathering to the higher TDS value in water samples.

4.1.8 Total Fluoride

The Fluoride ranges from 0.1-0.57 mg/L in summer and 0.03-0.17 mg/L in rainy season. Several variables influence the concentration of fluoride in natural groundwater, including temperature, pH, the solubility of fluoride-bearing minerals, anion exchange capacity of aquifer materials (OH^- for F^-), the geological formation type, and the duration of water contact with a specific formation.

4.1.9 Nitrate

The distribution of nitrate-N concentrations in the 15 locations is shown in Figure 10. It is clear that the nitrate concentration varied greatly from season to season. Gadakana road area have shown little bit rise above the permissible limit in both but in case of Mancheswar there is a high increase in nitrate value in both summer and rainy season which is represented in the graph as outlier. The high rates of precipitation that promote fertilizer infiltration are responsible for the high NO_3^- values observed during the rainy season.

4.1.10 Sulphate

As per IS-10500-2012, the range for Sulphate is 200-400 mg/L. Sulphate in groundwater originates from various sources, including mineral dissolution, atmospheric deposition, and anthropogenic activities such as mining and fertilizer use. Gypsum, in particular, plays a significant role as a contributor to elevated sulphate levels in numerous aquifers globally. The reason may be due to the industrial activity. All the targeted locations show sulphate very much under the permissible limit. In summer the sulphate ranges from 8.1-43.7 mg/L and in rainy the sulphate ranges from 5.4-32.1 mg/L. Rainwater appears to contain more sulphates than water from wells and boreholes, which explains the notable difference in sulphate concentrations. This could be the result of high-level emissions of hydrocarbons containing sulphur burning in the study area, particularly close to the industrial area. The breakdown of organic materials in surface soil and fertilizers containing SO_4^{2-} are the other sources of SO_4^{2-} (Brindha and Elango 2014).

4.1.11 Iron

The As per IS-10500-2012, the limit of Iron for consumption is 0.3 mg/L- No Relaxation. From the Figure. 12 it has been found that 46.66% areas both in summer and rainy season. Higher levels of Iron may be due to the influence of activities in biosphere. The Iron concentration in the ground water of the area where the landfill site is within the range of <500m found to be high as compared to industrial area and high population density area. The elevated concentration of groundwater iron in the summer season is attributed to the depletion of the groundwater table, increased levels of heavy metals in water samples, and the additional flushing or dissolution of both lithogenic and non-lithogenic materials by infiltrating water. Because of the heavy rainfall during the rainy season, groundwater is more mobile, and because rainwater naturally contains acid, this causes it to react with minerals found in the crust of the earth which results in presence of iron content of ground water.

4.2 A Water Quality Index

The Water Quality Index (WQI) serves as a numerical representation of water quality, indicating the overall suitability for consumption. A lower WQI value suggests minimal deviation from recommended parameter values, signifying better water quality for human consumption, and vice versa. Table 2 presents the measured values of groundwater quality parameters at Acharya Vihar, while Table 2 also includes the World Health Organization (WHO) guidelines, widely recognized as acceptable values for water quality parameters.

Table 2. Water Quality Index Calculation of Acharya Vihar

Sr. No.	Parameters	si	1/si	Unit Weight (wi=k/si)	original values	qi	wiqi
1	pH	8.5	0.1176	0.026941176	7.58	38.66666667	1.04172549
2	Conductivity	300	0.0033	0.000763333	209.8	69.93333333	0.053382444
3	DO	5	0.2000	0.0458	7.38	75.20833333	3.444541667
4	Hardness	200	0.0050	0.001145	40	20	0.0229
5	Alkalinity	200	0.0050	0.001145	95	47.5	0.0543875
6	Chloride	250	0.0040	0.000916	28.36	11.344	0.010391104
7	TDS	500	0.0020	0.000458	136.37	27.274	0.012491492
8	Fluoride	1.5	0.6667	0.152666667	0.22	14.66666667	2.239111111
9	Nitrate	45	0.0222	0.005088889	6.47	14.37777778	0.073166914
10	Sulphate	150	0.0067	0.001526667	32.57	21.71333333	0.033149022
11	Iron	0.3	3.3333	0.763333333	0.128	42.66666667	32.56888889
		Σ(1/si) = 4.3659		0.999784065			39.55413563
		K= 1/(Σ(1/si) = 0.2290		Σwi= 0.999784065 ≃ 1.0			
WQI= 39.5							

Water quality Index of all the 15 locations of Bhubaneswar have been calculated in both summer and rainy season which is represented in Figure. 13. The graph summarizes represents that in summer season water quality index ranges from 6-311.4 while in rainy season it ranges from 13.1-226.5. The water quality status is given in Table 3.

Table 3. Water quality status in summer and rainy season (Sinha et al. 2014)

Water Quality Status	Summer	Rainy
Excellent Water Quality	26.6%	33.3%
Good Water Quality	20%	6.6%
Poor Water Quality	6.6%	13.3%
Very Poor Water Quality	13.3%	6.6%
Unsuitable for Drinking	33.3%	40%

From Table 3. it can be seen that water quality is of excellent condition in rainy season (33.3%) as compared to summer season (26.6%). Some of the areas like OMFED Square, Mancheswar Industrial Estate, OMFED Industries, BMC Micro Composting, Gadakan Road in summer season and in rainy season Acharya Vihar, OMFED Square, Lingaraj railway station area, BMC Micro Composting and Gadakan Road have water that is unsuitable for drinking.

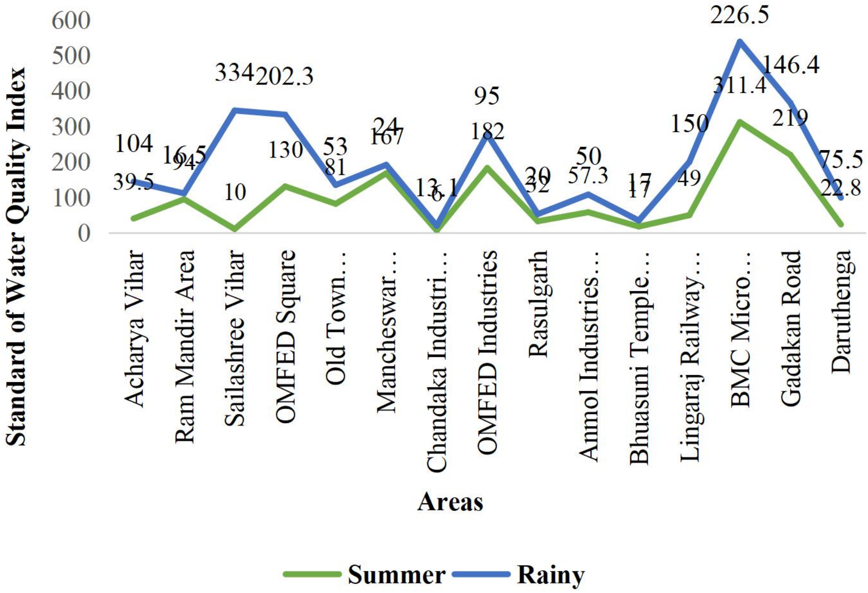

Fig. 13. Comparison graph of Water Quality Index of Bhubaneswar in summer and rainy season.

From the Figure 13. it can be observed that areas of Bhubaneswar show a drastic variation in Water Quality Index. The Reason is due to the increasing in atmospheric temperature during summer season. In rainy season it can be predicted that the leachate from landfill site, industrial site and household waste percolate to the aquifer which results in the water quality index out of standard range.

5. Conclusion

The above study indicates that the Groundwater in Bhubaneswar, Odisha, is more deviated from the permissible limit values. Around 73.3% of areas in summer and 93.3% of areas in the rainy season show acidic pH. Similarly, 46.66% areas both in summer and rainy season have iron higher than the permissible range. The value of Nitrate shows high variation in Mancheswar Industrial Estate in both the seasons beyond the permissible limit. Other parameters like hardness, electrical conductivity also found to be higher than the permissible range in Mancheswar. After analyzing by WQI method the Mancheswar Industrial Estate WQI is found to be >100 where as in rainy the WQI is found very low i.e., in the range of 0 to 25. It indicates Mancheswar Industrial Estate water is at threat and further study can be done to know the cause of the pollution and also more frequent testing is needed to monitor the water quality deterioration of Mancheswar industrial Estate.

6. Acknowledgment

The above research work is in reference to the ICSSR Project titled 'Anthropogenic and Geogenic contamination of ground water in Bhubaneswar urban catchment-A systematic Investigation'. (F.No. 02/147 /2021-22/ICSSR/MJ/RP). In gratitude, the authors wish to express their appreciation to ICSSR for providing the opportunity to investigate water quality of Bhubaneswar Supply water and Ground water with a comparison of result.

References

1. A.S. Richey, B.F. Thomas, M. Lo, J.T. Reager, J.S. Famiglietti, K. Voss, S. Swenon,M. Ro dell Quantifying renewable groundwater stress with GRACE Water Resour. Res., 51 (2015), pp. 5217-5238. https://doi.org/10.1002/2015WR017349
2. Abelson, P.H., 1984. Groundwater contamination. Science, 224(4650), pp.673-673. DOI: 10.1126/science.224.4650.673.
3. Abtahi, M., Golchinpour, N., Yaghmaeian, K., Rafiee, M., Jahangiri-rad, M., Keyani, A. and Saeedi, R., 2015. A modified drinking water quality index (DWQI) for assessing drinking source water quality in rural communities of Khuzestan Province, Iran. Ecological indicators, 53, pp.283-291. https://doi.org/10.1016/j.ecolind.2015.02.009
4. Achary, G.S., 2014. Studies on ground water pollution due to iron content in Bhubaneswar, Odisha, India. International Journal of Current Engineering and Technology, 4(1), pp.88-93.
5. Akoteyon, I.S., Omotayo, A.O., Soladoye, O. and Olaoye, H.O., 2011. Determination of water quality index and suitability of urban river for municipal water supply in Lagos-

Nigeria. European Journal of Scientific Research, 54(2), pp.263-271. http://www.eurojournals.com/ejsr.htm
6. Akter, T., Jhohura, F.T., Akter, F., Chowdhury, T.R., Mistry, S.K., Dey, D., Barua, M.K., Islam, M.A. and Rahman, M., 2016. Water Quality Index for measuring drinking water quality in rural Bangladesh: a cross-sectional study. Journal of Health, Population and Nutrition, 35, pp.1-12. https://doi.org/10.1186/s41043-016-0041-5.
7. Amadi, A.N., Olasehinde, P.I., Okosun, E.A. and Yisa, J., 2010. Assessment of the water quality index of Otamiri and Oramiriukwa Rivers.
8. Batabyal, A.K. and Chakraborty, S., 2015. Hydro geochemistry and water quality index in the assessment of groundwater quality for drinking uses. Water Environment Research, 87(7), pp.607-617. https://doi.org/10.2175/106143015X14212658613956
9. Boah, D.K., Twum, S.B. and Pelig-Ba, K.B., 2015. Mathematical computation of water quality index of Vea dam in upper east region of Ghana. Environ Sci, 3(1), pp.11-16. http://dx.doi.org/10.12988/es.2015.4116
10. Brown, R.M., McClelland, N.I., Deininger, R.A. and Tozer, R.G., 1970. A water quality index-do we dare. Water and sewage works, 117(10).
11. Bulut, O.F., Duru, B., Çakmak, Ö., Günhan, Ö., Dilek, F.B. and Yetis, U., 2020. Determination of groundwater threshold values: A methodological approach. Journal of Cleaner Production, 253, p.120001. https://doi.org/10.1016/j.jclepro.2020.120001.
12. C.J. Vörösmarty, P. Green, J. Salisbury, R.B. Lammers Global water resources: vulnerability from climate change and population growth Science, 289 (5477) (2000), pp. 284-288. https://doi.org/10.1126/science.289.5477.284.
13. Chauhan, A. and Singh, S., 2010. Evaluation of Ganga water for drinking purpose by water quality index at Rishikesh, Uttarakhand, India. Report and opinion, 2(9), pp.53-61.
14. Chen, J., Huang, Q., Lin, Y., Fang, Y., Qian, H., Liu, R. and Ma, H., 2019.
15. Hydrogeochemical characteristics and quality assessment of groundwater in an irrigated region, Northwest China. Water, 11(1), p.96. https://doi.org/10.3390/w11010096.
16. Damo, R. and Icka, P., 2013. Evaluation of Water Quality Index for Drinking Water. Polish Journal of Environmental Studies, 22(4). https://www.researchgate.net/profile/PirroIcka/publication/287957321_Evaluation_of_Water_Quality_Index_for_Drinking_Water/links/5923fd63aca27295a8aad7c1/Evaluation-of-Water-Quality-Index-for-Drinking-Water.pdf.
17. Das Kangabam, R., Bhoominathan, S.D., Kanagaraj, S. and Govindaraju, M., 2017. Development of a water quality index (WQI) for the Loktak Lake in India. Applied Water Science, 7, pp.2907-2918. https://doi.org/10.1007/s13201-017-0579-4.
18. Das, S. 1988. High discharge well at Chandrasekharpur, Bhubaneswar city, Orissa, Bhujal News. 3(4) : 26.
19. Dinius, S.H., 1987. Design of an index of water quality 1. JAWRA Journal of the American Water Resources Association, 23(5), pp.833-843. https://doi.org/10.1111/j.1752-1688.1987.tb02959.x.
20. Dunnette, D.A., 1979. A geographically variable water quality index used in Oregon. Journal (Water Pollution Control Federation), pp.53-61. https://www.jstor.org/stable/25040240.
21. FAO, A., 2010. FAO's global information system on water and agriculture, FAO, Rome, Italy.
22. Gao, Y., Qian, H., Ren, W., Wang, H., Liu, F. and Yang, F., 2020. Hydrogeochemical characterization and quality assessment of groundwater based on integrated-weight water quality index in a concentrated urban area. Journal of cleaner production, 260, p.121006. https://doi.org/10.1016/j.jclepro.2020.121006.

23. Horton, R.K., 1965. An index number system for rating water quality. J Water Pollut Control Fed, 37(3), pp.300-306.
24. I.E.M. Dem Graaf, L.P.H. vanBeek, T. Gleeson, N. Moosdorf, O. Schmitz, E.H. Sutanudja ja, M.F.P. Bierkens A global-scale two-layer transient groundwater model: development and application to groundwater depletion Adv. Water Resour., 102 (2017), pp. 53-67. https://doi.org/10.1016/j.advwatres.2017.01.011.
25. J. Van der Gun Groundwater and Global Change: Trends, Opportunities and Challenges.
26. United Nations World Water Assessment Programmes UNESCO, France (2012). https://www.circleofblue.org/wp-content/uploads/2015/03/UNESCO_groundwater-and-global-change.pdf.
27. Katyal, D., 2011. Water quality indices used for surface water vulnerability assessment. International journal of environmental sciences, 2(1). https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2160726.
28. Kaur, H. and Garg, P., 2019. Urban sustainability assessment tools: A review. Journal of cleaner production, 210, pp.146-158. https://doi.org/10.1016/j.jclepro.2018.11.009.
29. Kim, A.G. and Cardone, C.R., 2005. Scatterscore: a reconnaissance method to evaluate changes in water quality. Environmental Monitoring and Assessment, 111, pp.277-295. https://doi.org/10.1007/s10661-005-8225-2
30. Kumar, A. A. and Alappat, B. (2009). NSF-Water Quality Index: Does it represent the Experts" Opinion? Pract. Period. Hazard. Toxic. Radioact. Waste Manage. 13(1), pp 75-79. https://doi.org/10.1061/(ASCE)1090-025X(2009)13:1(75).
31. Lathamani, R., Janardhana, M.R., Mahalingam, B. and Suresha, S., 2015. Evaluation of aquifer vulnerability using drastic model and GIS: a case study of Mysore city, Karnataka, India. Aquatic Procedia, 4, pp.1031-1038. https://doi.org/10.1016/j.aqpro.2015.02.130.
32. Liou, S.M., Lo, S.L. and Wang, S.H., 2004. A generalized water quality index for Taiwan. Environmental monitoring and assessment, 96, pp.35-52. https://doi.org/10.1023/B:EMAS.0000031715.83752.a1.
33. Liu, D., Qi, X., Li, M., Zhu, W., Zhang, L., Faiz, M.A., Khan, M.I., Li, T. and Cui, S., 2019. A resilience evaluation method for a combined regional agricultural water and soil resource system based on Weighted Mahalanobis distance and a Gray-TOPSIS model. Journal of Cleaner Production, 229, pp.667-679. https://doi.org/10.1016/j.jclepro.2019.04.406.
34. Lumb, A., Halliwell, D. and Sharma, T., 2006. Application of CCME Water Quality Index to monitor water quality: A case study of the Mackenzie River basin, Canada. Environmental Monitoring and assessment, 113, pp.411-429. https://doi.org/10.1007/s10661-005-9092-6
35. M.P.F. Bierkens, Y. Wada Non-renewable groundwater use and groundwater depletion: a review Environ. Res. Lett., 14 (2019) (2018), Article 063002. DOI 10.1088/1748-9326/ab1a5f.
36. Madhav, S., Kumar, A., Kushawaha, J., Ahamad, A., Singh, P. and Dwivedi, S.B., 2020.
37. Geochemical assessment of groundwater quality in Keonjhar City, Odisha, India. Sustainable Water Resources Management, 6, pp.1-11. https://doi.org/10.1007/s40899-020-00395-7
38. Manju, E.K., George, A.V. and Rekha, V.B., 2014. A comparative study of water quality index (Wqi) of Vagamon and peermade sub-watersheds of Meenachil and Pamba River basins of Western Ghats, Kerala, South India. IOSR Journal of Environmental Science, Toxilogy and Food Technology, 8(1), pp.53-58.
39. Molekoa, M.D., Avtar, R., Kumar, P., Minh, H.V.T. and Kurniawan, T.A., 2019.

40. Hydrogeochemical assessment of groundwater quality of Mokopane area, Limpopo, South Africa using statistical approach. Water, 11(9), p.1891. https://doi.org/10.3390/w11091891.
41. Nasirian, M., 2007. A new water quality index for environmental contamination contributed by mineral processing: a case study of Amang (Tin Tailing) processing activity. Journal of applied sciences, 7(20), pp.2977-2987. https://ui.adsabs.harvard.edu/link_gateway/2007JApSc...7.2977N/doi:10.3923/jas.2007.2977.2987.
42. Nath, B.K., Chaliha, C., Bhuyan, B., Kalita, E., Baruah, D.C. and Bhagabati, A.K., 2018.
43. GIS mapping-based impact assessment of groundwater contamination by arsenic and other heavy metal contaminants in the Brahmaputra River valley: a water quality assessment study. Journal of Cleaner Production, 201, pp.1001-1011. https://doi.org/10.1016/j.jclepro.2018.08.084.
44. New public health policy statements adopted at APHA 2019.Date: Nov 06 2019. https://www.apha.org/news-and-media/news-releases/apha-newsreleases/2019/policy-statements-adopted-at-apha-2019.
45. Ramesh R, Purvaja GR, Raveendra VI (1995). Man's Influence on Freshwater Ecosystems and Water Use, The problem of groundwater pollution: a case study from Madras city India. Proceedings of a Boulder Symposium. Inter. Asso. Hyd. Sci. 230: 147. http://www.iomenvis.in/rramesh/publications/1995-1.pdf.
46. Rao, C.S., Rao, B.S., Hariharan, A.V.L.N.S.H. and Bharathi, N.M., 2010. Determination of water quality index of some areas in Guntur District Andhra Pradesh. https://pesquisa.bvsalud.org/portal/resource/pt/sea-157641.
47. Selvakumar, S., Chandrasekar, N. and Kumar, G. (2017) Hydrogeochemical Characteristics and Groundwater Contamination in the Rapid Urban Development Areas of Coimbatore, India. Water Resources and Industry, 17, 26-33. https://doi.org/10.1016/j.wri.2017.02.002
48. Singhal, B.B.S. (2002) Groundwater Resource of India, International Association of Hydro geologists Australian National Chapter’s International Groundwater Conference Proceeding, Balancing the Groundwater Budget, Darwin, Northern Territory, Australia, 12–17 May. https://doi.org/10.1504/IJW.2018.093668
49. Singhal, R.K., Joshi, S., Gurg, R.P., Shenoy, N.S., Ferandes, N., Gopale, R.S. and Jhaveri, A.S., 2002. Uptake of uranium from underground drinking water by chlorella (Chlorella pyrendoidosa). https://www.osti.gov/etdeweb/biblio/20260990
50. Sinha, A., Kumar, B. and Singh, T., 2014. Water quality assessment of two ponds of Samastipur District (India). International Journal of Environmental Sciences, 4(4), p.567. doi: 10.6088/ijes.2014040400012.
51. Tyagi, S., Sharma, B., Singh, P. and Dobhal, R., 2013. Water quality assessment in terms of water quality index. American Journal of water resources, 1(3), pp.34-38. DOI:10.12691/ajwr-1-3-3. United Nations Conference on Environment and Development, Rio de Janeiro, Brazil, 3-14 June 1992
52. V.M. Tiwari, J. Wahr, S. Swenson Dwindling groundwater resources in northern India, from satellite gravity observations Geophys. Res. Lett., 36 (18) (2009), pp. 1-5. https://doi.org/10.1029/2009GL039401.
53. Vasanthavigar, M., Srinivasamoorthy, K., Vijayaragavan, K., Ganthi, R.R., Chidambaram,
54. S., Anandhan, P., Manivannan, R. and Vasudevan, S., 2010. Application of water quality index for groundwater quality assessment: Thirumanimuttar sub-basin, Tamilnadu, India. Envi ronmental Monitoring and Assessment, 171 (1), 595–609. https://doi.org/10.1007/s10661-009-1302-1.

55. Yisa, J. and Tijani, J.O., 2010. Analytical studies on water quality index of river Landzu.
56. Yogendra, K. and Puttaiah, E.T., 2008. Determination of water quality index and suitability of an urban waterbody in Shimoga Town, Karnataka. In Proceedings of Taal2007: The 12th world lake conference (Vol. 342, p. 346).