Poll Res. 40 (3) : 1041-1051 (2021)

ISSN 0257–8050

ASSESSMENT OF GROUNDWATER QUALITY AND STATISTICAL ANALYSIS OF HYDRO CHEMICAL PARAMETERS IN CUTTACK CITY, ODISHA, INDIA

SANJAYA KUMAR MUDULI[1], NARASIMHAM MANGALAMPALLI[2] AND PRAKASH CHANDRA MISHRA[3]

[1,2] *Centurion University of Technology & Management (CUTM), Paralakhemundi, Odisha, India*
[3] *PG Department of Environmental Science, Fakir Mohan University, Balasore, Odisha, India*

(Received 27 April, 2021; Accepted 22 June, 2021)

ABSTRACT

In this study, a total of 25 number of groundwater samples were collected from different parts of the Silver City Cuttack, Odisha to analyze the hydro geochemical parameters. The water quality parameters such as pH, Turbidity, Electrical Conductivity, Total Dissolved Solids, BOD, Fluoride, Chloride, Nitrate, Sulphate, Total Alkalinity, Calcium, Magnesium, Iron, Sodium, Potassium, Lead, Copper, Cadmium, Nickel, Chromium and Fecal Coli form were analyzed. Out of the total 25 sampling locations, the WQI of 10 locations were found to be poor and 2 locations were found to be unsafe for drinking. Turbidity of 24.6 NTU was found at location S-10 (Haripur road) and TDS value of 688 mg/l was found at the location S-20 (Buxibazar).The iron concentration of 8237.3 µg/l was found at the site S-16 (Dolamundei), Lead concentration of 6.6 µg/l was found at the site S-S-16 (Dolamundei) and Cr concentration of 42.2µg/l was found at the site S-4 (Khan Nagar industrial area). The maximum MPN value counted 58.7 in each 100 ml sample at the location site S-12 (Chhatra bazaar). The seasonal parameter variation was found higher in summer which indicates depletion of groundwater level which leads to enhance the level of contamination. The anthropogenic activates, i.e. discharging of industrial waste to the surface body and flows of untreated sewage effluent by unprotected drainage throughout the city accelerate the deterioration of ground water. The Fecal Coliform present in bore well both in summer and rainy season indicates that water logging and poor sanitary sealing of ground drinking water sources. The day by day increasing of NO_3 concentration in ground water indicated the influence of sewage in the ground water quality. Increasing in concentration of metals such as Pb, Ni, Cr in the ground water in summer season creates an alarming situation for the consumption of drinking water.

KEY WORDS : Water quality, Groundwater, Water Quality Index, Sodium Adsorption Ratio.

INTRODUCTION

Water is an essential commodity, nature gifted resources available in the earth crust. The water has been reserved at ground, surface and in the form of glacier throughout world. Ground water is the most essential source for drinking purpose to maintain a healthy life and productivity of crops. Probably 90% of whole population in the world depend upon the fresh water collecting from ground by digging of bore wells for fulfill their basic necessity (Ramachandraich, 2004). The groundwater quality is affected by local topography and sewage system (Vasanthavigar *et al.*, 2010). The hydro chemical composition of groundwater in an area basically depends on some factor such as wet and dry deposition of atmospheric salts, rack- water and oxidation and reduction during percolation (Krishnakumar, 2015). The soil- water interaction, evaporation, temperature and anthropogenic activities lead to the change in the purity of ground water. Spatial change of ground water depends on atmospheric precipitation and quality of water in lands surface. Contamination of ground water are higher in small area with dense populated which are covered by more industries discharging untreated effluent. It was also observed that surface water contamination plays a vital role and put enormous pressure on groundwater resources which is leading to exploitation. High population growth has led to both over exploitation and scattered dumping of waste disposal. Deterioration of water quality and rapid shortfall of fresh water is the major cause for 80% of human disease & 1/3 death of world population (Das and Nag, 2015). Contamination of water affect the water quality and impact on human health, poor economic and social prosperity (Milovanovic, 2007). The people of Cuttack city basically depend upon the groundwater. More than 200 groundwater supply through pipe line sources and more than five thousand shallow, deep bore well fulfills the basic necessity of urban people. Land filling of solid waste leads to contamination of aquifer as leachate which contain dissolve, suspended and microbial toxic content (Acharya *et al*., 2014). Groundwater quality degrade rapidly by presence of toxic heavy metal such as Fe, Pb, Ni, Hg, Mn, Cr, Cu, derived from geogenic process (Ramesh and Purvaja, 1995).

In the present work a step has been taken to study the quality of groundwater in and around Cuttack city with respect to the rapid growth of population, development of industrialization, functioning a number of commercial markets and old sewage system.

Study Area

Cuttack is the business capital and traditional city of Odisha. The geographical co-ordinate of the city is 20.4338°N to 20.4986°N and 85.8055°E to 85.9416°E. The delta city is surrounded by river Mahanadi and Kathajodi river and more than 6.5 lakh people spread across of 192.5 km^2 area. The Municipal Corporation of the city is divided in to 59 wards for good governance. The climate condition is hot and humid most of the year. Both Mahanadi and Kathjodi rivers are recharging the ground water level and impact on the concentration of water quality parameters during monsoon period. In the present study, water samples were collected from different locations of Cuttack city throughout the year 2019-20 as pre, post and during monsoon period. The site of sampling is selected randomly by considering the population, location and source. The sampling stations are depicted in Table 1 and the geographical representation is depicted in Figure 1.

Table 1. Sampling stations for physico-chemical parameters

Sl. No.	Sampling Station
S1	Jagatpur Market
S2	Jagatpur Industrial area
S3	Govt.ITI Centre
S4	Khan Nagar industrial area
S5	Khannagar bus station
S6	Khapuria
S7	CDA-9
S8	Nuabazar
S9	OMP chowk
S10	Haripur road
S11	Cantanment road
S12	Chatra bazaar
S13	Ranihat,
S14	SCB Medical
S15	Badam badi
S16	Dolamundei
S17	Nandi Sahi
S18	Chandini chowk
S19	Choudhury Bazar
S20	Buxibazar
S21	Arundeomarket
S22	Bidyadhapur
S23	Ranihat sweeper colony
S24	Ganesh ghat
S25	Tulasipur

METHODOLOGY

Water Sampling Procedures and Analysis

The water samples were analyzed for various parameters in the State water testing laboratory (NABL), Bhubaneswar, Odisha. Various physico-chemical parameters like pH, Turbidity, Electrical Conductivity (EC), Total Dissolved Solids (TDS), potassium, Bio-chemical Oxygen Demand (BOD), Total Alkalinity (TA), Chloride, Fluoride, Sulphate, Nitrate, Sodium, Calcium, Magnesium, Iron, Copper, Nickel, Lead, Cadmium, Chromium and Fecal coliform have been monitored.

Polythene bottles of five litre capacity with stopper were used for sample collection. Each bottle was washed with 2% Nitric acid and then rinsed with distilled water. The bottles were then preserved in a clean and dry place. The bottles were filled leaving no air space, and then the bottle was sealed to prevent any leakage. For the Bacteriological parameter the samples were taken in the pre sterilize

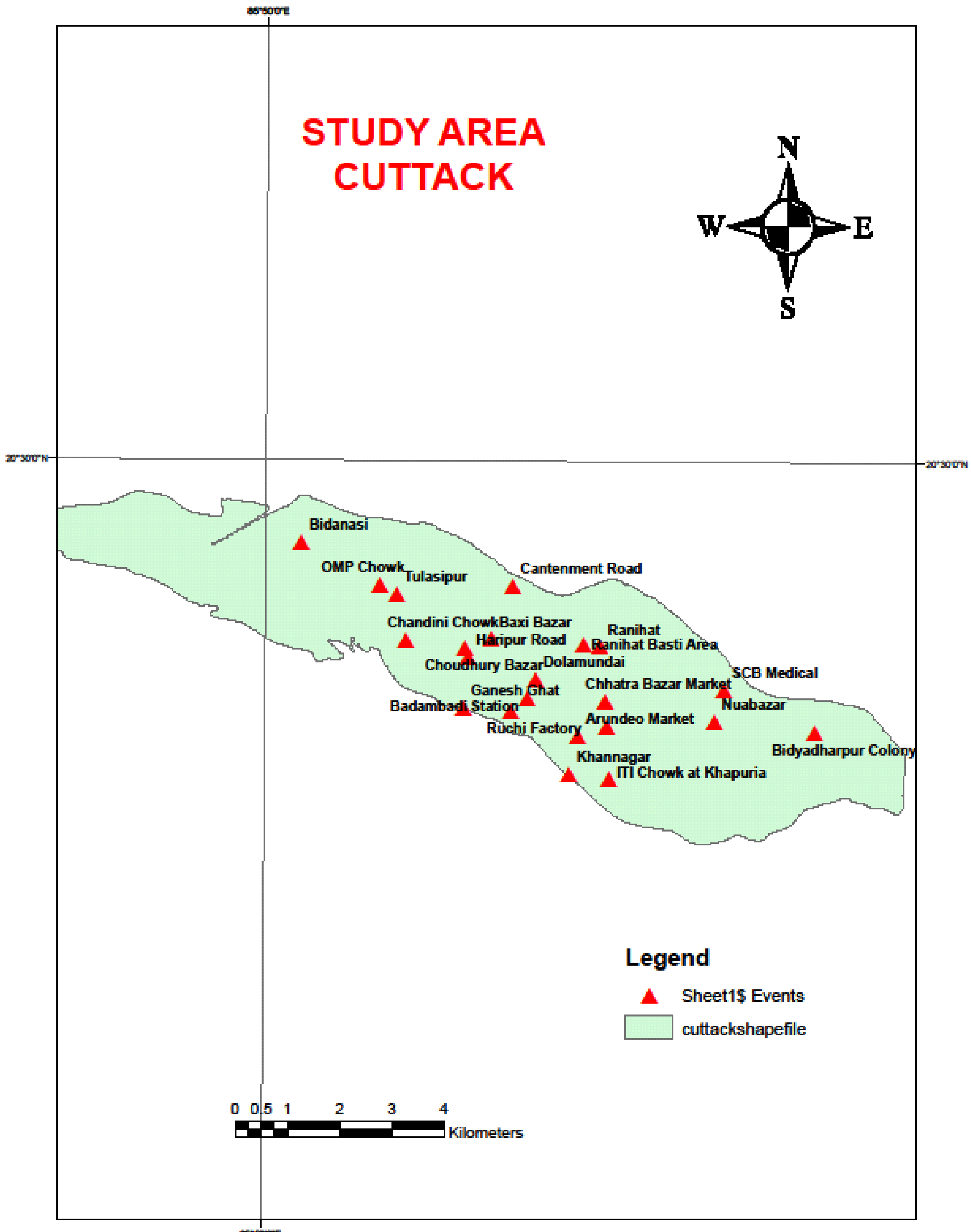

Fig. 1. Geographical representation of the sampling stations.

300 ml capacity container adding with antichlor keeping with ¼ air space. Samples for heavy metal were collected by separate bottle with adding nitric acid.

Analysis of Physico-chemical Parameters of Water Samples

In general, the standard methods recommended by APHA, AWWA, WPCF (2012), Trivedy and Goel (1984) and NEERI (1986) were adopted for determination of various physico-chemical parameters. A brief description is given below.

Physico-chemical parameters like pH, Electrical conductivity were analyzed at the location site using by Portable Field Test Instrument (WTW, Germany). Turbidity was calibrated with standard solution of 400 N.T.U. using Hydrazine Sulphate and Hexamethylenetetramine.

The concentration of Fe, Cu, Ni, Pb, Cd and Cr were analyzed by using Atomic Absorption Spectrophotometer [Perkin Elmer (PINAACLE 900H)] instrument with different EDL and HDL lamp with proper calibration and standardization.

RESULTS AND DISCUSSION

The results of the analyzed parameters of groundwater of the different locations of Cuttack are depicted in Table 2 and compared with the related standards for drinking water prescribed by ISI, USPHS, ICMR and WHO. The drinking water standard of various organizations is given in Table 3.

The pH is a measure the concentration of hydrogen ions in water and also measure the intensity of acidity or alkalinity. It has no direct adverse effect on health, however, a low value, below 4.0 will produce sour taste and higher value above 8.5 shows alkaline taste. A pH range of 6.5 – 8.5 is normally acceptable as per guidelines suggested by ISI. In the present study, the fluctuation of pH in the samples was from 6.39 to 7.96. The pH below 7 indicates that the sample water was slightly acidic may be due to the presence of minerals in the groundwater. From the study, the pH values of all the samples are within the prescribed limit.

Measurement of Turbidity reflects the transparency in water. It is caused by the substances present in water in suspension. In natural waters it is caused by clay, silt, organic matter, phytoplankton and other microscopic organisms. It ranged from 0.8 to 24.6 NTU. However, the prescribed limit of Turbidity for drinking water is 10 NTU (ISI). Turbidity was found within the prescribed limit in all the water samples except in the samples of Haripur Road (S10), Dolamundai (S16) and Nandi Sahi (S17).

Total Dissolved Solids may be considered as salinity indicator for classification of groundwater. The TDS in groundwater is due to the presence of Calcium, Magnesium, Sodium, Potassium, Bicarbonate, Chloride and Sulphate ions. In the study area TDS varied from 119 to 688 mg/l. As prescribed limit of TDS for drinking water is 500 mg/l, all the water samples have TDS concentration well below the prescribed limit except the samples of Khannagar industrial area, Khapuria, Chandini Chawk and Buxibazar. However, the TDS concentration of fresh groundwater generally ranges between 192-1280 mg/l. Water samples of Kalunga Industrial Estate showed high TDS value may be due to the dust fall in the well and leaching of industrial waste.

The concentration of Calcium and Magnesium varied from 8.6 to 93.1 mg/l and 5.03 to 61.2 mg/l respectively. All the samples were within the permissible limit, i.e. 75 mg/l for Calcium (ICMR) except the sample of Jagatpur Markeet, Jagatpur Industrial area, Khan nagar industrial area and Khapuria. The high concentrations of Ca, Mg in ground water indicate the waste material percolating the aquifer (Adebole *et al*., 2013). Similarly all the samples were within the permissible limit, i.e. 50 mg/l for Magnesium (ICMR) except the samples of Jagatpur Markeet and Jagatpur Industrial area.

BOD gives a quantitative index of the degradable organic substances in water and is used as a measure of waste strength. The low BOD value in all groundwater samples showed good sanitary condition of the water. It varied from 0.1 to 1.5 mg/l during the study period where as the permissible limit for BOD is 5 mg/l prescribed by WHO. As in case of groundwater soil matrix acts as a biological filter consequently BOD is quite low.

Electrical Conductivity is the measure of capacity of a substance or solution to conduct electric current. It is an excellent indicator of TDS which is a measure of salinity that affects the taste of potable water (WHO, 1984). The variation in Electrical Conductivity is based on sedimentary structure and composition of rock. Chemically pure water does not conduct electricity. Any rise in the Electrical Conductivity of water indicates pollution. It is a good and rapid measure of the Total Dissolved Solids. The higher values are obviously due to the contamination of groundwater may be due to the ions like OH^-, CO_3^{2-}, Cl^-, Ca^{+2} etc. The groundwater samples showed variation in EC in different seasons of the year. It was varied from 183 μS/cm to 1059 μS/cm during the study period, whereas the permissible limit is 1500 μS/cm prescribed by USPHS.

Chloride occurs naturally in all types of water with a very low concentration. Chlorides are important in detecting the contamination of groundwater by wastewater. In general, high evaporation tends to increase the Chloride and Salinity at the root zone of irrigated plants, making it difficult for crops to take up water due to osmotic pressure difference between the water outside the plants and within the plant cells. For this reason, Chloride and Total Salinity concentration at or below the drinking water standards are normally specified for waters used to irrigate salt sensitive crops. However, in the study area there is no

Table 2. Physico-chemical parameters the ground water samples of 25 sampling points of Cuttack City

Sample code 1	pH 2	Tub. NTU 3	EC μs/cm 4	TDS mg/l 5	K mg/l 6	BOD mg/l 7	TA mg/l 8	Cl mg/l 9	CO_3^{2-} mg/l 10	HCO_3^- mg/l 11	F mg/l 12	SO4 mg/l 13	NO3 mg/l 14	Na mg/l 15	Ca mg/l 16	Mg mg/l 17	Fe μg/l 18	Cu μg/l 19	Ni μg/l 20	Pb μg/l 21	Cd μg/l 22	Cr μg/l 23	FC MPN/ 100 ml 24
S1	6.63	6.7	619	402	17.5	1.2	152	89.3	124	28	0.37	57.9	23.3	59.2	83.5	58.2	1243	6	17.8	4.2	0.84	28.8	0
S2	6.61	0.8	667	433	15.5	0.3	100	98.7	80	20	0.25	62.5	23.8	54.8	93.1	61.2	461	6.43	10.7	4.43	0.82	28.6	0
S3	7.37	1.9	453	294	8.63	1.3	92	44	76	16	0.28	38.3	38.3	33.9	18.4	10.4	1932	6.53	8.43	5.8	0.56	35.3	0
S4	6.46	5.0	809	526	9.8	1.1	176	101	140	36	0.37	37	42.4	39.5	70.8	47.7	1280	4.5	10.3	4.77	0.64	42.3	0
S5	6.77	2.7	927	602	8.67	0.3	184	139	140	44	0.47	22	44.1	44.6	92.3	52.9	1319	4.1	10.4	4.8	0.56	37.5	32.5
S6	6.78	2.0	1039	675	7.47	0.4	212	144	162	50	0.32	21	38.6	31.9	92.7	53.7	1701	5.7	4.4	3.9	0.45	35.6	0
S7	7.05	2.5	183	119	3.37	0.5	152	18.4	126	26	0.33	15.6	5.53	8.37	10.9	9.2	271	3.91	4.17	4.23	0.51	33.6	33.3
S8	7.03	3.9	600	390	4.4	1.5	143	68.7	119	24	0.42	21	8.3	11.8	45	37.5	372	2.79	6.9	3.53	0.76	20.6	0
S9	6.83	3.2	404	263	4.33	0.4	204	23	156	48	0.39	22.8	13.3	13.3	16	10.2	692	2.19	8.93	3.07	0.49	22.2	0
S10	7.01	24.6	577	375	2.4	0.1	208	54	158	50	0.27	30.4	6.37	10.9	33.1	19.2	7113	3.23	7.4	4	0.5	24.6	14.7
S11	6.39	4.8	204	133	2.33	0.4	147	14.6	119	28	0.37	18.9	6.73	7.57	8.6	5.03	732	2.0	6.87	2.1	0.79	26.4	0
S12	7.38	0.9	413	269	10.4	0.3	165	29	129	36	0.41	33.6	46.8	33.8	16.3	9.57	724	4.2	8	1.77	0.65	33.1	58.7
S13	6.93	3.7	443	288	8.23	0.1	160	34	126	34	0.23	13.3	36.7	36.3	18.4	10.6	2132	2.90	9.1	1.7	0.40	19.2	45.3
S14	7.52	1.0	421	274	4.17	0.2	138	52	112	26	0.23	22.5	5.4	10.1	19.6	11.7	292	2.60	12.1	4.9	0.65	28.7	0
S15	7.14	1.5	559	363	14.3	0.1	159	60	129	30	0.28	31	9.0	43.1	83.1	58.6	135	3.40	10.7	4.9	0.72	31.3	0
S16	7.01	17.1	520	338	6.43	0.2	221	48	169	52	0.30	15.9	5.5	24	16.3	10.7	8237	7.00	6.6	6.6	0.91	32.4	0
S17	6.82	13.0	853	555	5.83	0.1	353	108	285	68	0.35	21.5	23.3	23.8	73.3	53.6	6927	8.40	9.3	6.5	0.46	34.2	0
S18	6.86	3.9	932	606	6.1	0.2	317	132	261	56	0.42	14.8	30.3	21.8	76.4	59.6	1892	6.83	9.1	2.2	0.75	29.3	0
S19	6.68	3.0	865	562	7.9	0.2	336	124	276	60	0.50	15.8	7.2	23.4	77.5	53.9	1535	4.83	10.1	1.8	0.59	31.0	0
S20	6.85	3.9	1059	688	3.7	0.5	293	153	235	58	0.57	15.2	6.4	20.9	73.5	33.6	1239	3.73	8.8	1.0	0.42	31.6	0
S21	7.21	4.5	592	385	3.6	0.1	255	61	199	56	0.42	20.8	6.4	16.2	49.8	26.7	1463	3.17	8.1	2.6	0.87	36.2	5.47
S22	7.20	3.8	608	395	4.0	0.3	232	85	180	52	0.29	22.6	10.2	11.5	61.7	41.5	1068	1.93	5.8	2.0	1.05	27.3	0
S23	7.80	4.2	499	324	11.2	0.2	165	40	133	32	0.32	39.1	36.9	33.5	20.7	13.1	1391	3.44	15.5	4.7	0.70	22.3	32.2
S24	6.59	2.8	659	428	2.4	0.4	196	72	156	40	0.49	24.2	5.5	8.8	43.6	34.3	1488	3.67	10.9	5.2	0.65	33.1	48.3
S25	7.96	2.0	221	144	5.4	0.3	81.3	216	69.3	12	0.37	19.8	9.8	19.1	49.9	20.1	319	3.20	8.9	2.4	0.55	28.7	28.3
									124	28													

significant change in Chloride concentration and it ranged from 18.4 to 216 mg/l. Chloride which have been associated with pollution as an index are found below the permissible value set at 250 mg/l in most of the study area.

According to WHO, the maximum permissible and allowable concentration of Sulphate in drinking water is 200 and 400 mg/l, respectively. The concentration of Sulphate ranged between 14.8 mg/l to 62.5 mg/l in the groundwater of the study area.

Nitrate – Nitrogen ranges from 5.4 mg/l to 46.8 mg/l whereas the permissible limit for Nitrate – Nitrogen is 45 mg/l. The highest Nitrate-N value of 46.8 mg/l was found in the well water of Chatra bazar.

The Alkalinity of water is a measure of its capacity to neutralize acids. The Concentration of Alkalinity provide guidance in applying proper doses of chemicals in water and wastewater treatment processes particularly in coagulation, softening and operational control of anaerobic digestion. The Alkalinity in natural water is caused by Bicarbonates, Carbonates and Hydroxides and can be ranked in order of their association with high pH values. However, Bicarbonates represent the major form since they are formed in considerable amounts due to the action of Carbonates with the basic materials in the soil. In the present study Phenolphthalein Alkalinity was absent in all samples and Methyl Orange Alkalinity was ranged from 81.3 mg/l to 353 mg/l, this indicates the absence of Hydroxyl and Carbonate Alkalinity and presence of Bicarbonate. However, the prescribed limit for Total Alkalinity is 120 mg/l (USPHS). The value of Total Alkalinity exceeded the limit in the water samples of all the sampling stations except Jagatpur industrial area, Govt. ITI Centre, and Tulasipur.

In all samples, the Fluoride is very less i.e. < 0.6 mg/l, whereas the ICMR prescribed limit is 1.5 mg/l. Enquiries with dental practitioners in the Cuttack City also testify that there are no cases of fluorosis of teeth reported from the patients.

Because of dumping of various solid waste materials, which contain some heavy metals, there is possibility of leaching of heavy metals into the soil and thereby contaminating the groundwater. The iron concentration of the study area varies from 135 µg/l to 8237 µg/l. Iron was relatively high incase of all the samples except CDA – 9, SCB medical and Badam Badi. All these water samples indicated alarming figure of iron.

The concentration of Copper, Nickel, Lead, Cadmium and Chromium of all the samples are well below the permissible limit.

The bacteriological Parameter such as Fecal coliform detected 9 sampling stations out of 25 sampling stations which were critical condition of health issue. Presence of fecal coliform in groundwater indicates the leaching of sewage in the ground water reservoirs.

Table 3. Drinking water standards

Parameters	ISI(MPL)	USPHS	ICMR		WHO	
			HDL	MPL	HDL	MPL
pH	6.5-8.5	6.0-8.5	6.5-9.2	7.0-8.5	7.0-8.5	6.5-9.2
Turbidity	10 NTU		25 JTU	5 JTU	-	-
TDS	500	500	1500-3000	500	-	-
BOD		5.0			5.0	5.0
EC 300 µmho/cm						
Chloride	250	250	1000	200	200	400
Sulphate	150	250	400	200	200	400
Total Alkalinity						
Fluoride	0.6-1.2		1.5	1.0	-	1.5
Iron	0.3	0.3	1.0	0.1		
Calcium	75	100	200	75	75	200
Magnesium	30	30	-	50	50	150
Lead	0.10		0.05	-		
Chromium	0.05	0.05	-	-	0.05	-
NO_3-N	45	10	100	20	45	45
E. coli (MPN/ml)		100/100ml	1/100 ml			10/100ml

(Except pH and *E. coli* other parameters are in mg/l)

Table 4. Correlation co-efficient between water quality parameters

	pH	Tub	EC	TDS	K	BOD	TA	Cl	F	SO4	NO3	Na	Ca	Mg	Fe	Cu	Ni	Pb	Cd	Cr	FC
pH	1.000	-.114	-.431	-.431	-.049	-.164	-.317	.022	-.280	-.065	-.007	-.152	-.368	-.440	-.099	-.220	.051	-.010	.011	-.209	.279
Tub	-.114	1.000	.054	.054	-.232	-.171	.306	-.121	-.177	-.060	-.238	-.182	-.135	-.111	.903	.227	-.111	.309	-.004	-.097	-.150
EC	-.431	.054	1.000	1.000	.134	-.003	.641	.571	.445	-.029	.269	.290	.781	.746	.176	.438	.083	.007	-.142	.378	-.309
TDS	-.431	.054	1.000	1.000	.134	-.003	.641	.571	.445	-.029	.269	.290	.781	.746	.176	.438	.083	.007	-.142	.378	-.309
K	-.049	-.232	.134	.134	1.000	.183	-.287	.071	-.239	.761	.510	.944	.432	.459	-.185	.395	.611	.217	.178	.089	-.035
BOD	-.164	-.171	-.003	-.003	.183	1.000	-.373	-.026	.118	.343	.169	.178	.018	.069	-.261	.084	.106	.147	.080	.085	-.238
TA	-.317	.306	.641	.641	-.287	-.373	1.000	.239	.478	-.456	-.137	-.231	.330	.364	.423	.301	-.120	-.170	-.088	.175	-.255
Cl	.022	-.121	.571	.571	.071	-.026	.239	1.000	.396	-.082	.080	.193	.725	.591	-.057	.273	.060	-.164	-.171	.302	-.161
F	-.280	-.177	.445	.445	-.239	.118	.478	.396	1.000	-.302	-.099	-.162	.280	.230	-.180	-.032	.035	-.367	-.138	.268	.099
SO4	-.065	-.060	-.029	-.029	.761	.343	-.456	-.082	-.302	1.000	.326	.691	.249	.278	-.147	.265	.584	.314	.288	.044	-.088
NO3	-.007	-.238	.269	.269	.510	.169	-.137	.080	-.099	.326	1.000	.637	.176	.158	-.081	.343	.196	.087	-.231	.251	.299
Na	-.152	-.182	.290	.290	.944	.178	-.231	.193	-.162	.691	.637	1.000	.518	.493	-.098	.459	.541	.216	.043	.215	-.003
Ca	-.368	-.135	.781	.781	.432	.018	.330	.725	.280	.249	.176	.518	1.000	.960	-.095	.385	.212	.006	.056	.376	-.352
Mg	-.440	-.111	.746	.746	.459	.069	.364	.591	.230	.278	.158	.493	.960	1.000	-.068	.439	.247	.088	.151	.317	-.375
Fe	-.099	.903	.176	.176	-.185	-.261	.423	-.057	-.180	-.147	-.081	-.098	-.095	-.068	1.000	.489	-.158	.439	-.063	.057	-.121
Cu	-.220	.227	.438	.438	.395	.084	.301	.273	-.032	.265	.343	.459	.385	.439	.489	1.000	.107	.495	-.037	.434	-.240
Ni	.051	-.111	.083	.083	.611	.106	-.120	.060	.035	.584	.196	.541	.212	.247	-.158	.107	1.000	.199	.113	-.118	.036
Pb	-.010	.309	.007	.007	.217	.147	-.170	-.164	-.367	.314	.087	.216	.006	.088	.439	.495	.199	1.000	.044	.330	-.128
Cd	.011	-.004	-.142	-.142	.178	.080	-.088	-.171	-.138	.288	-.231	.043	.056	.151	-.063	-.037	.113	.044	1.000	-.032	-.285
Cr	-.209	-.097	.378	.378	.089	.085	.175	.302	.268	.044	.251	.215	.376	.317	.057	.434	-.118	.330	-.032	1.000	-.067
FC	.279	-.150	-.309	-.309	-.035	-.238	-.255	-.161	.099	-.088	.299	-.003	-.352	-.375	-.121	-.240	.036	-.128	-.285	-.067	1.000

Correlation between water quality parameters

The dependability of water quality parameters on each other in the samples of water collected from the Cuttack town was determined with regression analysis by determining correlation co-efficient. The results of regression are summarized in Table 4 which indicates the correlation co-efficient of the various parameters investigated. The study of the Table 4 gives an idea of the bearing a single parameter determined has relation on other parameters. These correlation co-efficient values are helpful in calculating the concentration of the water quality of the parameters of the water samples of the particular area under study without analyzing them with the help of equation representing linearity:

$$Y = AX + B$$

The relation is valid between the parameters when their correlation co-efficient is real equal to one. Such dependency between the parameters was found to exist between a numbers of parameters determined as is obvious from the correlation co-efficient values given in the Table 4.

Regression Analysis

Regression analysis is the statistical technique to measure the average relationship among the variable in the form original unit of data. Mathematically, the linear regression is expressed as Y= a + bx; where x is the independent variable, Y is dependent variable and a and b are the intercept and slop of the line. The higher R^2 value indicates a good relationship as compared with calculated dependent variable. From Figure 2, it was evident that the R^2 value between Fe Vs Turbidity (R^2=0.8), E. C. Vs TDS (R^2=1.0), Ca Vs Mg (R^2=0.92), Ni and K (R^2=0.4) show strong relationship due to identical anthropogenic source. The relationship established between Pb Vs Fluoride ((R^2= 0.13) & BOD & Total Alkalinity (R^2= 0.12) indicate no impact of these parameters on the ground water.

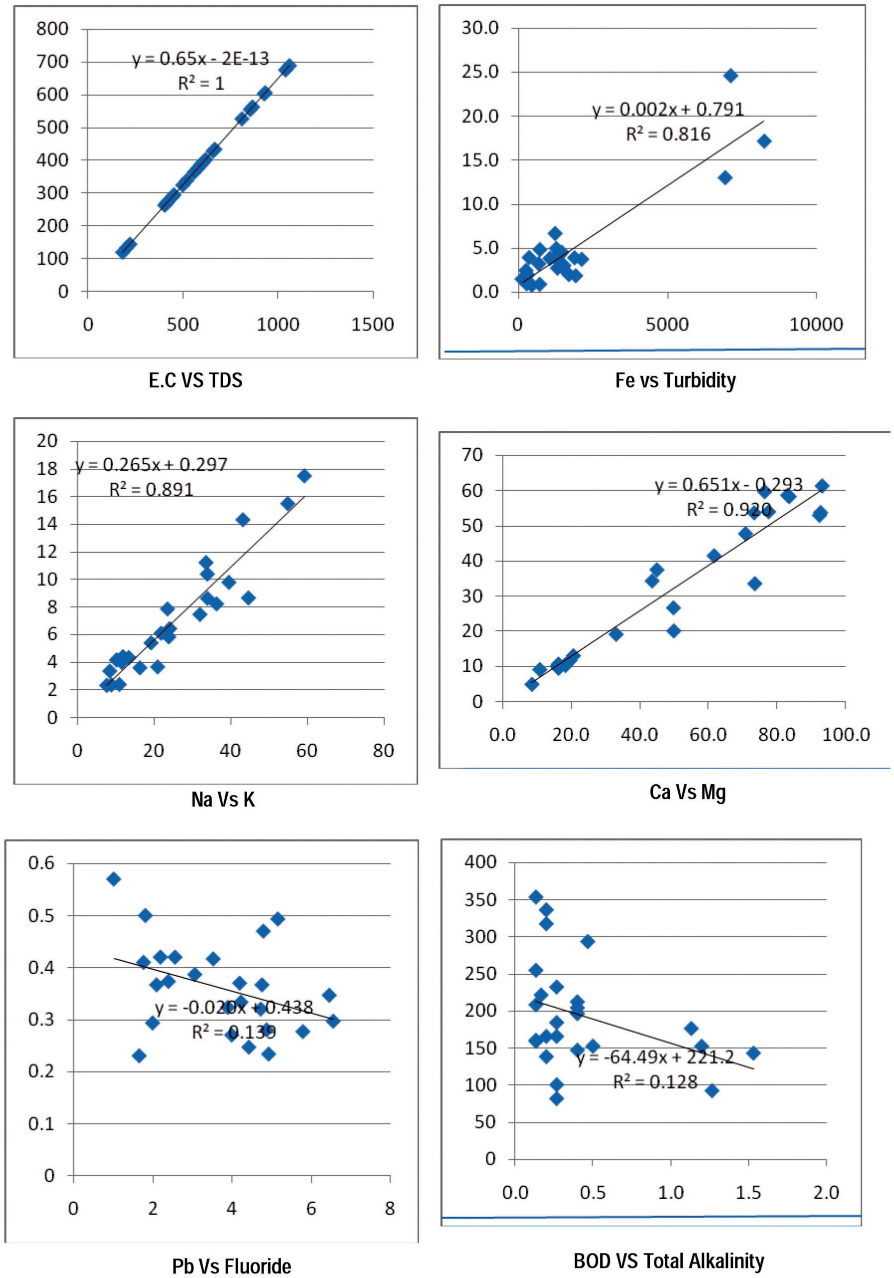

Fig. 2. Linear Regression data of some water quality parameter

Agricultural water quality

The suitability of a given body of water for agriculture is judged from the following characteristics (Mishra *et al*., 2007):

a) Total Dissolved Solids (TDS): If the concentration of salts in the agriculture water increase, it becomes difficult for the plants to extract water. Regarding the salt contents in agriculture water, it is customary to judge the suitability of water by simplified approach is hardly adequate. As a matter of fact, it is the nature and concentration of various salts in the soil solution, rather than in the agriculture waters, the effect changes in the soil and influence the plant growth.

b) Relative proportion of sodium to other cations: While a high concentration of salts in water leads to formation of a saline soil, a high concentration of sodium leads to the development of an alkali soil. United States

Department of Agriculture (USDA) has defined an alkali soil as that having pH of 8.5 or more, with Sodium concentration of 15% or more. An alkali soil produces easily and restricts the aeration. High sodium saturation, more over causes Calcium deficiency.

c) Residual Carbonates: This parameter is useful in describing the quality of agriculture water, since if the sum of carbonates and bicarbonates is in excess of calcium and magnesium (all expressed in meq/l) there is almost complete precipitation of the later.

d) Chlorides and sulphates: Excessive chlorides may directly prove to be toxic to fruit crops by causing the scorching of leaves and severe injury, although no definite limits for these ions have been established so far. Chloride concentration of less than 150 mg/l is generally considered to be safe for agriculture water. A number of crops show sensitivity to very high concentrations of sulphates in the irrigation water. No definite limits have yet been established for the concentration of sulphates in irrigation water.

Calculation of some parameters related to agriculture

Some parameters were calculated (Raghunath, 1987) which are useful for describing the quality of agriculture water (Table 5). Salt concentration of agriculture water can be determined directly by measuring Total Dissolved Solids (TDS) present in it. The salt concentration can also be obtained indirectly by measuring the electrical conductivity (EC) of agriculture water and using the empirical relation (Tiwari *et al.*, 1988).

TDS (mg/l) = 0.64 X EC (μ mho/cm) .. (1)

The sodium hazard of agriculture water is described by two parameters namely sodium adsorption ration (SAR) and sodium percentage (Na%). These are given by

$$SAR = \frac{Na}{\sqrt{(Ca+Mg)/2}} \quad .. (2)$$

$$\& \ Na\% = \frac{Na+K}{Ca+Mg+Na+K} \times 100 \quad .. (3)$$

All parameters are expressed in (meq/l).

Residual Carbonate can be estimated by using the formula

Table 5. Calculated parameters related to agriculture.

Sl. No.	Sampling Station	TDS (Calculated)	SAR	Na%	RC	PI	OP	SI
S1	Jagatpur Market	396.2	7.03	35.1	10.3	32.1	0.223	3739
S2	Jagatpur Industrial area	426.9	6.24	31.3	-54.3	28.3	0.240	3554
S3	Govt. ITI Centre	289.9	8.93	59.6	63.2	60.4	0.163	126
S4	Khan Nagar industrial area	517.8	5.13	29.4	57.5	28.8	0.291	1078
S5	Khannagar bus station	593.3	5.23	26.8	38.8	27.0	0.334	2111
S6	Khapuria	665.0	3.73	21.2	65.6	21.9	0.374	355
S7	CDA-9	117.1	2.64	36.9	131.9	47.3	0.066	-343
S8	Nuabazar	384.0	1.84	16.4	60.5	17.7	0.216	-1185
S9	OMP chowk	258.6	3.67	40.2	177.8	51.2	0.145	-385
S10	Haripur road	369.3	2.13	20.3	155.7	28.4	0.208	-916
S11	Cantanment road	130.6	2.90	42.1	133.37	60.7	0.073	-281
S12	Chatra bazaar	264.3	9.40	63.1	139.13	66.7	0.149	109
S13	Ranihat,	283.5	9.53	60.6	131	64.5	0.159	192
S14	SCB Medical	269.4	2.55	31.3	106.7	36.7	0.152	-566
S15	Badam badi	357.8	5.12	28.8	17.3	26.3	0.201	1714
S16	Dolamundei	332.8	6.53	53.0	194	61.2	0.187	-131
S17	Nandi Sahi	545.9	2.99	18.9	226.1	21.3	0.307	-610
S18	Chandini chowk	596.5	2.64	17.0	181	18.6	0.336	-865
S19	Choudhury Bazar	553.6	2.89	19.2	204.6	20.1	0.311	-692
S20	Buxibazar	677.8	2.86	18.7	185.9	22.3	0.381	-932
S21	Arundeomarket	378.9	2.62	20.6	178.5	25.5	0.213	-982
S22	Bidyadhapur	389.1	1.60	13.1	128.8	16.3	0.219	-1652
S23	Ranihat sweeper colony	319.4	8.15	56.9	131.2	58.2	0.180	129
S24	Ganesh ghat	421.8	1.41	12.6	118.1	17.4	0.237	-1344
S25	Tulasipur	141.4	3.23	25.9	11.3	25.3	0.080	-767

$RC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$ .. (4)

Where, CO_3^{2-} and HCO_3^{-} are the concentration of carbonates and bicarbonates. All parameters are expressed in (meq/l).

The Permeability Index can be calculated by using the formula

$$PI(\%) = \frac{Na + \sqrt{HCO3}}{Ca + Mg + Na} \times 100 \quad .. (5)$$

All parameters are expressed in (meq/l).

Osmotic Pressure can be evaluated by the empirical relation

$$OP\ (atm) = 0.00036X\ E.C(\ \mu\ mho/cm) \quad .. (6)$$

Salt Index (SI) is calculated by using the mathematical expression.

SI= Total Na-24.5 -4.85 (Total Ca-Ca as $CaCO_3$) .. (7),

when all the quantities expressed in parts per million of agriculture water.

$$WQI = \Sigma QnWn\ /\ \Sigma Wn \quad .. (8)$$

Where, Qn=quality rating of nth water quality parameter

Wn=unit weight of nth water quality parameter

The water quality as per the grade of Water Quality Index is represented in Table 6. This indicates that out of 25 sampling stations the water of only 12 sampling stations are safe for drinking and other samples need treatment before consumption.

Table 6. Grade of water quality with respect to Water Quality Index (WQI)

Water Quality	WQI	Grade of water	No of samples
Excellent water	0-25	A	0
Good water	26-50	B	12
Poor Water	51-75	C	10
Very poor water	76-100	D	1
Unfit for drinking	Above 100	E	2

CONCLUSION

From the data it is concluded that though the some water quality parameters are well within the prescribed limit still the overall quality of water for drinking purposes are in the range of good to poor quality and also few samples are very poor and unfit for drinking. It is concluded that the groundwater quality is mainly affected by seepage of sewage, wastewater and urban runoff into the groundwater due to the lack of proper sewerage facilities. Also open drains are prevalent in the study area. This indicates the present steps, which are being taken, are not adequate. More over the load of pollutant are increasing day by day. Keeping all the above in view of long terms, steps may be adopted so that safe drinking water will be available. The water is almost suitable for agriculture purposes. However, conventional water treatment processes is proposed to get better quality of drinking water.

REFERENCES

Adebola, A., Oketola., Seun, M., Adekolurejo and Oladele, O. 2013. Water Quality Assessment of River Ogun using Multivariate Statistical Techniques. *Journal of Environment Protection.* 4 : 466-479.

APHA-AWWA-WPCF. 2012. *Standard Methods for the Examination of Water and Wastewater*. 22nd Edition, American Public Health Association, Washington.

Acharya, G.S., Mohanty, S. K. and Sahoo, R. 2014. Status of ground water quality over the year of Cuttack city, Odisha, India. *Journal of Chemical & Pharmaceutical Research.* 6 : 541-550.

A, Papaioannou., Mavridou, C., Hadjichristodoulou, P., Papastergiou., Pappa, E. and Dovriki, I. 2010. Application of multivariate statistical methods for groundwater physicochemical and biological quality assessment in the context of public health. *Environ. Monit. Assess.* 170 : 87-97.

Barik, S.R. and Ratha, B.K. 2014. Hydro chemical analysis and evaluation of ground water quality of Hial area, Bolangir district, Odisha, India. *Journal of Geosciences and Geometrics.* 1-2 : 22-28.

Borah, J. 2011, Monitoring Fluoride Concentration and Some Other Physico-Chemical Properties of Groundwater of Tinsukia District, Assam, India. *International Journal of Chem Tech Research.* 3 : 1339-1342.

Das, S. and Nag, S.K. 2015. Deciphering ground water quality for irrigation and domestic purpose- a case study in Suri I & II block Birbhumi District west B, India. *J Earth Syst. Sci.* 5 : 965 922.

ISI, 1983. *Indian Standard Specification for Drinking Water.* IS: 10500.

ICMR, 1975. *Manual of Standards of Quality of Drinking Water Supplied* (2nd edition). Special report series no 44. Indian Council of Medical Research, New Delhi.

Jamuna, M. 2018, Stastical analysis of ground water quality parameter in Eroda District, Tamilnadu, India *International Journal of Recent Technology and Engineering.* 7 : 84-89.

Jhariya, D. C., Shandilya, A. K. and Dewangan, R. 2012, Nitrate pollution in the ground water Around Sagar town Madhyapradesh India. *International conference on Chemical, Ecology and Environmental Science (ICEES 2012)* Bangkok, pp 151-154.

Khan, R. and Jaharia, D. C. 2017. Ground water quality assessment for Drinking purpose in Raipur City, Chatishgarh using water quality Index and geographic information System. *Journal of Geographical Society of India.* 90 : 69-76.

Krishnakumar, 2015. Assessment of ground water quality and hydro geochemistry of Mainmukhi River basin Tamilnadu, India. *Environment.* 159 : 341-351.

Lamas, M.R., Martinez and Santos, P. 2005. Intensive ground water use: Silent revaluation and potential sources of social conflict. *Journal of Water Resources Panning and Management*. ASCE/ Sept-Oct pp 337-342.

Milvanovic, M. 2007. Water quality assessment and determination of pollution sources along the axial/ Vander river southeastern Europe. *Desalination.* 213 : 159-173.

Mishra, P. C. and Ptel, R.K. 2007. Status of water quality in and around an industrial city- a case study. *Indian Journal of Environmental Protection.* 27 (2) : 114-124.

Mishra, K. and Nayak, P. L. 2014. A Study on Water Pollution Two Major Rivers of Odisha-Mahanadi and Bramhani. *Middle-East Journal of Scientific Research.* 22 : 1760-1770.

Nandi, D., Mishra, S.R., Sahoo, K.C. and Sahu, S.K. 2015. Ground water quality n industrial belt of Balasore town, Odisha : *International Journal of Earth and Atmosphere Science.* 2 : 16-19.

NEERI, 1986. *Manual on Water and Waste Water Analysis.* National Environmental Engineering Research Institute (NEERI), Nagpur.

NEERI, 2010. *Guidance Manual for Drinking Water Quality Monitoring and Assessment.* 2nd Edition, Nagpur, India.

Panigrahi, S. and Patra, A.K. 2013. Water quality analysis of River Mahanadiin Cuttack Odisha, India. *Indian J.L Science.* 2 : 27-33.

Ramachandraaiah, C. 2004. Right to Drinking water India, centre for economic and social study. Hydrabad.pp 1-28.

Ramesh, R. and Purvaja, G.R. 1995. The problem of ground water pollution a case study. *Proceeding of Boulder Symposium, IAHS, No-230.*

Raghunath, H. M. 1987. *Ground Water* (2nd edition), Wiley Eastern Ltd., New elhi. pp -350-361.

Sawyer, C.N., Mccarty, L.P. and Parkin, G.F. 2003. *Chemistry for Environmental Engineering and Science.* 5th Edition, Tata Mcgraw-Hill. pp 625-630.

Singaraja, C., Chidambaram, S., Anandhan, P., Prasanna, M.V., Thivya, C., Thilagavathi, R. and Sarathidasan, J. 2014. Geochemical Evaluation of Fluoride Contamination of Groundwater in the Thoothukudi District of Tamilnadu, India. *Applied Water Science.* 4 : 241-250.

Sundaray, S. K. 2010. Application of Multivariate Statistical Techniques in Hydro geochemical Studies- A Case Study: Bramani-Koel River, India. *Environ Monit Assess.* 164 : 297-310.

Tiwari, T.N. and Ali, M. 1988. River pollution in Kathamandu Valley (Nepal) : suitability of river water for irrigation. *Indian Journal of Environmental Protection.* 8 (7) : 269-274.

Trivedy, R.K. and Goel, P.K. 1984. *Chemcial and biological methods for water pollution studies. Env. Publ. India*, pp- 215.

Vasnthavigar, M., Srinivasmoorthy, K., Gantth, R., R., Hidambaram, S., Anandhan, P., Manivannan, R., Vaudevan, S. 2010. Application of water quality index for ground water quality assessment: Thirumanimuttar sub basin Tamilnadu, India. *Environ.* 171 : 595-609.

Todd, D.K. 1976. *Ground Water Hydrology.* John Wiley and sons Inc Newyork.

WHO. 1984a. *International Drinking Water Supply and Sanitation Decade-Review of National Baseline Data*. WHO off set publication No. 85, World Health Organisation, Geneva.

WHO. 1984, b. *Guidelines for Drinking Water Quality Vol. 1: Recommendations.* World Health Organization. Geneva, pp-1-130.

WHO. 1984, c. *Guidelines for Drinking Water Quality. Vol. 2. Health Criteria and other Supporting Information.* World Health Organization. Geneva.

Yogendra, K. and Puttaiah, E.T. 2008. Determination of water quality and Suitability of an urban water body in Shimoga Town, Karnatak; *Proceeding of Taal 2007,12 th world lake conference.* pp 342-346.