

**FINAL PROJECT REPORT**  
**ON**  
Assessment of Ground Water Quality of the First Industrial-Residential  
Confluence Area of Visakhapatnam

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*By*

**Dr. P. SARADA**

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Lecturer in Chemistry, St. Joseph's College for Women (Aut.)

Visakhapatnam, 530004



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Dr. P. Sarada

# **Assessment of Ground Water Quality of the first industrial-residential confluence area of Visakhapatnam.**

(Final Report)

## **Introduction**

Gnanapuram (latitude 83°17'N and longitude 17°65'E) and its surrounding areas in Visakhapatnam are situated on reclaimed marshy land. This area is the confluence point of industrial and residential belts of Visakhapatnam. It is located in close proximity to several industrial establishments including Visakhapatnam Port Trust. Also several BPL residential colonies namely Sebastian colony, Sevanagar, Kobbarithota, Babu Colony and Allipuram exist in and around this locality. St. Joseph's College for Women (Autonomous) is also situated in Gnanapuram. This college, being a non-profit oriented missionary institution with low fee structure, draws 20 to 30% of its students from this area and its neighbourhood. This area also forms the terminal point of city sewage disposal. Two huge sewage drains Errigedda and Gangula gedda (fresh water nalas / storm water outlets once) flow in close proximity to this area. Gnanapuram area has rich groundwater abundance (Groundwater Table is shallow and perennial - open and tube wells never dry up) but its quality is doubtful. Despite rich ground water supply people in these areas almost entirely depend on Municipal Corporation supplied water not only for their drinking needs but for their domestic chores as well. Women folk waiting in long serpentine queues for their turn to collect municipal corporation supplied water is a common sight here.

### **Ground water tribulations**

On enquiry it emerged that groundwater in Gnanapuram and its neighbourhood is 1.foul smelling, 2.foaming, 3.unfit for bathing and washing (as it forms no lather with soap) 4.scale forming and 5.harmful to health (can lead to gastroenteritis and skin diseases).

## Significance of the proposed study

Several investigators have studied groundwater quality parameters in selected points of rural, sub urban and urban areas of Visakhapatnam district. But **none have exclusively studied the confluence zone**. In this backdrop the investigator of this project has proposed to undertake this study **with UGC support** which is locally relevant and has lab to land orientation as well. Since the levels of certain physico-chemical parameters like pH, alkalinity, BOD, COD, total hardness(Ca,Mg,Chlorides, $\text{HCO}_3^-$ , $\text{CO}_3^{2-}$ ),  $\text{NO}_3^-$ ,  $\text{PO}_4^{3-}$ , Na, K and total dissolved solids found in ground water determine its behaviour as well as quality, it has been proposed to analyse ground water in the five slum areas separately so as to find reasons for the ground water problems in the said area.

## Methodology: Materials & Methods for Analysis

### Sample Collection and Preservation

Sample collection was done in the pre-monsoon, monsoon and post-monsoon periods in the two year study period. Manual sampling with a plastic container in compliance with established standard norms was adopted. Labels were used to prevent sample misidentification. Sample preservation was done in tune with Ground Water Board guidelines with minimum possible time lapse between collection and analysis.

### Details of Sampling Locations

Sampling stations are situated in and around Gnanapuram. Their details are given below.

**Table: 1-** Details of Sample Sources

Sample No.	Sample Station	Type of Source	Depth in feet	Latitude N	Longitude E
1	Kobbarithota	Open Well	28	17 <sup>0</sup> 713 <sup>1</sup>	83 <sup>0</sup> 295 <sup>1</sup>
2	Allipuram	Bore Well	65	17 <sup>0</sup> 715 <sup>1</sup>	83 <sup>0</sup> 295 <sup>1</sup>
3	Convent Jn.	Bore Well	68	17 <sup>0</sup> 719 <sup>1</sup>	83 <sup>0</sup> 289 <sup>1</sup>

4	Convent Jn.	Open Well	32	17 <sup>0</sup> 719 <sup>1</sup>	83 <sup>0</sup> 289 <sup>1</sup>
5	Gnanapuram	Bore Well	68	17 <sup>0</sup> 718 <sup>1</sup>	83 <sup>0</sup> 287 <sup>1</sup>
6	Nicholas Street	Open Well	31	17 <sup>0</sup> 722 <sup>1</sup>	83 <sup>0</sup> 286 <sup>1</sup>
7	Port Main Rd.	Open Well	35	17 <sup>0</sup> 718 <sup>1</sup>	83 <sup>0</sup> 283 <sup>1</sup>
8	Sebastian Clny.	Open Well	34	17 <sup>0</sup> 718 <sup>1</sup>	83 <sup>0</sup> 283 <sup>1</sup>
9	Kancharapalem	Bore Well	65	17 <sup>0</sup> 725 <sup>1</sup>	83 <sup>0</sup> 285 <sup>1</sup>
10	Sakilgadda	Open Well	27	17 <sup>0</sup> 729 <sup>1</sup>	83 <sup>0</sup> 281 <sup>1</sup>
11	MSN Colony	Bore Well	69	17 <sup>0</sup> 724 <sup>1</sup>	83 <sup>0</sup> 286 <sup>1</sup>
12	SJCW(A)	Open Well	30	17 <sup>0</sup> 721 <sup>1</sup>	83 <sup>0</sup> 291 <sup>1</sup>

### Analysis of Samples

Analysis of the collected ground water samples was done in accordance with the procedures suggested in the Standard Analytical Procedure Manual for water samples which is based on ‘Standard Methods for the Examination of Water and Wastewater’ 19<sup>th</sup> edition, APHA, AWWA, wef 1995 (alkalinity-titrimetrically, pH-potentiometrically, HCO<sub>3</sub><sup>-</sup> + CO<sub>3</sub><sup>2-</sup>-calculation from pH and alkalinity, DO-Iodometrically, BOD- bottle incubation for 5days at 20°C, COD-open reflux, Ca and total hardness-EDTA titrimetric, Mg- calculation from total hardness and Ca, NO<sub>3</sub><sup>-</sup>&PO<sub>4</sub><sup>3-</sup>spectrophotometric, Cl<sup>-</sup>-argentometric titrimetric, total dissolved solids- calculation from conductivity).

**Table: 2-** Methods of Analysis

S.NO.	Parameter	Method	Instrument/Equipment
1	Temperature	Laboratory method	0.1 <sup>0</sup> c scale thermometer
2	pH	Electrometric	pH meter
3	Conductivity	Electrometric	Conductivity meter
4	DO, BOD	Iodometric (Titrimetric)	
5	Hardness, Ca	Titration with EDTA	
8	Alkalinity	Titration with Sulphuric acid	

9	<b>Chloride</b>	Titration with Silver nitrate	
10	<b>Na, K</b>	Flame Photometric	Flame photometer
11	<b>Nitrate, Phosphate</b>	Spectrophotometric abs. UV, Vis.	UV-Vis. Spectrophotometre

**Table: 3** - Details of solutions and reagents used in analysis

<b>PARAMETER STUDIED</b>	<b>REQUIRED SOLUTIONS</b>	<b>MANUFACTURER</b>
<b>Dissolved Oxygen, BOD</b>	1. 0.025 M Hypo solution 2. Alkali- iodide- azide reagent 3. MnSO <sub>4</sub> solution 4. Starch Indicator	Merck (India) limited Merck (India) limited Loba chemicals Pvt. Ltd Merck (India) limited
<b>COD</b>	1.0.025N K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> + Sulphamic acid solution 2. 0.025N FAS 3. Conc. H <sub>2</sub> SO <sub>4</sub> +AgSO <sub>4</sub> reagent 4. Ferroin indicator 5.Hg SO <sub>4</sub>	Merck (India) limited Merck (India) limited Loba chemicals Pvt. Ltd Merck (India) limited Merck (India) limited Merck (India) limited
<b>Alkalinity</b>	1. 0.1 N Standard sulphuric acid 2. methyl orange indicator 3. 0.5 N Sodium carbonate solution	Merck (India) limited Finar chemicals Reachem laboratory chemicals Pvt. Ltd
<b>Hardness</b>	1.0.01M standard EDTA solution 2.Ammomium chloride and ammonium hydroxide buffer solution 3. E.B.T. indicator	Finar chemicals SV fine chemicals Merck (India) limited
<b>Nitrate</b>	1.Standard Potassium Nitrate solutions 2.1.0N HCL solution	Merck (India) limited Finar reagent

<b>Phosphate</b>	1. Standard $\text{KH}_2\text{PO}_4$ solutions 2. Potassium antimony tartrate + ammonium molybdate + ascorbic acid combined reagent	Merck (India) limited Finar reagent SV fine chemicals
<b>Calcium</b>	1.0.01M standard EDTA solution 2. NaOH buffer solution 3.E.B.T. solution	Finar chemicals Finar chemicals Merck (India) limited
<b>Chloride</b>	1.0.141 M standard Silver Nitrate solution 2.Standard NaCl solution 3. $\text{K}_2\text{CrO}_4$ solution	S.d. fine chemicals Ltd  Merck (India) limited SV fine chemicals
<b>Potassium</b>	Standard KCl solutions	Merck (India) limited
<b>Sodium</b>	Standard NaCl solutions	Merck (India) limited

### Experimental Procedures

- **Temperature** was measured at the time of sample collection with a good mercury filled Celsius thermometer, having a scale marked for every  $0.1^\circ\text{C}$ .
- **pH** was measured within 2 hr of sample collection because the pH of the sample can change due to carbon dioxide from the air dissolving in the sample water. A Systronics pH meter of 0.01 readability was used for the measurement of pH.
- **Eelectrical conductivity(EC)** was measured with Systronics conductivity meter. 0.01M KCl solution was used as the standard reference solution.
- In the **total hardness** determination, the water samples were first buffered to a pH of 10.0 with ammonia buffer and 2 or 3 drops EBT indicator was added. The indicator reacts with calcium and magnesium ions to yield a wine red coloured complex. As EDTA is added, it combines with free calcium and magnesium ions in the sample to produce



EDTA – calcium and EDTA – magnesium complexes. When all free ions are used up, EDTA begins to break the red metal–indicator complex and combines with the free calcium and magnesium ions. Then the colour of the solution changes from wine red to pale blue.

Hardness as mg CaCO<sub>3</sub> = A x B x mol.wt. of CaCO<sub>3</sub> x 1000/vol. of sample

where A = Volume of EDTA consumed (ml) ; mol.wt. of CaCO<sub>3</sub>=100 ;

B = concentration of EDTA

Two titration method was adopted to determine the concentration of calcium and magnesium ions in water. One method measures the concentration of calcium ions alone and the second measures the total hardness. The concentration of magnesium ions was calculated as the difference between the two test results .

- **Calcium-** Water samples were buffered to a pH of 12-13 with sodium hydroxide buffer for the determination of calcium hardness. At a pH of 12.0, magnesium precipitates out so that it will not interfere in the titration. Eriochrome Black T indicator was added to the solution and EDTA was then added as a titrant. Disodium EDTA combines with the free calcium ions to produce an EDTA – calcium complex.

Calculation :

Ca as CaCO<sub>3</sub>(mg/L) = A x B x mol.wt. of CaCO<sub>3</sub> x 1000/vol. of sample

where A = ml of EDTA consumed ; mol.wt. of CaCO<sub>3</sub>=100

B = EDTA concentration

Calcium as Ca(mg/l)= 0.4 x Ca as CaCO<sub>3</sub>(mg/l)

- **Magnesium** was determined as the difference between total hardness and calcium as CaCO<sub>3</sub>.

Mg (mg/ l) = (Total hardness (as CaCO<sub>3</sub>mg / l) – Calcium hardness (as mg CaCO<sub>3</sub>/l)) x 0.243

- **Alkalinity** was determined by acid – base titration method. 20.0 ml of the sample was taken in a 250.0 ml conical flask and titrated with standard 0.1N sulphuric acid by using phenolphthalein and methyl orange

indicators. Phenolphthalein alkalinity registered total hydroxide and one half of the carbonate present in the sample. Methyl orange was used to determine total alkalinity.

Total alkalinity, mg CaCO<sub>3</sub>/l = AxBx50,000/vol of sample

where A = Volume of acid consumed (ml) with methyl orange as indicator

B = Normality of standard acid solution

Carbonate as CO<sub>3</sub><sup>2-</sup> (mg/l) = Phenolphthalein alkalinity(as mg CaCO<sub>3</sub>) x 1.2

Bicarbonate as HCO<sub>3</sub><sup>-</sup> (mg/l) = (Total alkalinity - 2 x phenolp. alk.) x 1.22

- **Chloride** was determined by argentometric method. 1.0ml of 5% potassium chromate solution was added to 20.0ml of the sample and titrated with standard 0.014N AgNO<sub>3</sub> solution till the colour changed to reddish brown.

mg Cl<sup>-</sup>/l = (A-B) x N x 35450/vol. of sample

Where A = vol. of AgNO<sub>3</sub> consumed for sample

B = vol of AgNO<sub>3</sub> consumed for blank

N = normality of AgNO<sub>3</sub>

- **Nitrate (UV Spectrophotometric screening method)** Nitrate - N was determined spectrophotometrically using Systronics UV-Vis. spectrophotometre with potassium nitrate standard solutions.

Stock nitrate solution

0.7218g of potassium nitrate dried in an oven at 105°C for 24hr was dissolved in water and diluted to 1.0l (1.0ml = 100µg NO<sub>3</sub> - N). This solution could be stored up to 6 months by adding 2.0ml CHCl<sub>3</sub>/l. Stock nitrate solution was diluted with water to form NO<sub>3</sub><sup>-</sup> calibration standards in the range of 0 to 7mg NO<sub>3</sub><sup>-</sup> - N/l as intermediate nitrate solutions. 1.0ml 0.1M HCl solution was added to 50.0ml clear sample and blank and mixed thoroughly. NO<sub>3</sub> - standards were treated in the same manner as samples. Absorbance was measured at 220nm and 275nm due to NO<sub>3</sub> - N and organic nitrogen respectively against a blank

solution. Twice the absorbance at 270nm was subtracted from the absorbance at 220nm and a calibration curve was drawn by plotting absorbance against concentration.  $\text{NO}_3^-$  - N and organic N concentrations of the samples were also determined in the same manner and  $\text{NO}_3^-$  - N conc. of the samples was obtained directly from the standard calibration curve .

- **Phosphate (Vis Spectrophotometric screening method)**

(Orthophosphate-Phosphorous (Ascorbic acid method ))- Phosphate - P was determined spectrophotometrically using Systronics UV-Vis. spectrophotometre with standard Potassium dihydrogen phosphate solution. Orthophosphate was converted into phosphomolybdate and is reduced with ascorbic acid in the presence of antimony. An intense blue complex develops that absorbs visible light at 880nm. The absorbance at 880nm is directly proportional to the concentration of orthophosphate.

a. Potassium antimony tartrate – ammonium molybdate solution: 2.1372g potassium antimony tartrate was dissolved in about 700ml demineralised water. 5.6g ammonium molybdate was added to it followed by 70ml concentrated sulphuric acid. The solution is made up to the mark in a one litre volumetric flask and shaken well.

b. Combined reagent solution was prepared by dissolving 0.50g of ascorbic acid in 100ml potassium antimony tartrate – ammonium molybdate solution.

c. Stock Phosphorous solution was prepared by dissolving 0.4387g of Potassium dihydrogen phosphate in 1000ml for 100ppm solution of phosphate as phosphorous. From this solution standard solutions of varying concentrations were prepared.

50ml each of standard, sample and blank solutions were taken in 100ml volumetric flasks separately and 10ml of combined reagent solution was

added to each one of them and shaken well. Absorbance was measured at 880nm after 10min and not later than 30min. A calibration curve was prepared for the standards by plotting absorbance against concentration. Phosphate-P concentration in the sample was directly determined from the curve.

- **Sodium (Flame Photometric Method)** Sodium concentration in mg/l was determined using standard NaCl solution. Stock sodium chloride solution was prepared by dissolving 2.542g of sodium chloride dried in an oven at 140°C in water (1.0ml = 1.0g Na<sup>+</sup>). Intermediate sodium chloride solution was prepared by diluting 100 ml stock sodium chloride solution to 1l with double distilled water. From this intermediate solution, 5.0 to 100.0ppm standard solutions were prepared and inserted into flame to calibrate the instrument. After calibration, the concentration of Sodium was obtained by inserting the samples into the flame.

Na in ppm = concentration of sample in ppm x dilution factor

Dilution factor = (vol of sample + vol of water)/vol of sample

- **Potassium (Flame Photometric method)** Potassium concentration in mg/l was determined using standard KCl solution. Stock potassium chloride solution was prepared by dissolving 1.907g of potassium chloride dried in an oven at 110°C in water and diluted to 1.0l (1.0ml = 1mg K<sup>+</sup>). Intermediate potassium chloride solution was prepared by diluting 100.0ml stock potassium chloride solution to 1l with distilled water. From this intermediate solution 5.0 to 100.0ppm standard solutions were prepared and inserted into the flame to calibrate the instrument. After calibration the concentration of potassium was obtained by inserting the samples into the flame.

K<sup>+</sup> in ppm = concentration of sample in ppm x dilution factor

Dilution factor = vol of sample + vol of water/vol of sample

- **Total Dissolved Solids** were calculated indirectly from electrical conductivity values in  $\mu\text{S}$ .

$$\text{Total dissolved solids} = 0.64 \times \text{EC} (\mu\text{S}/\text{cm})$$

- **Carbonate + Bicarbonate** ( $\text{CO}_3^{2-} + \text{HCO}_3^-$ ) conc. was calculated indirectly from alkalinity.

$$\text{CO}_3^{2-} + \text{HCO}_3^- = 1.31 \times \text{Alkalinity}$$

- **Dissolved Oxygen**

1. Collection of samples- The samples were collected using special BOD bottles (glass bottles with a turtle neck and a ground glass stopper). The bottles were directly filled by dipping them in the wells or by filling them up to the brim without any air bubbles. The sample bottle was submerged and allowed to fill without allowing air to mix with the sample. The bottle was completely filled and kept submerged until the cap was firmly in place.

2. Measurement of DO- To the sample collected in 300ml bottle, 1.0ml of 0.414M  $\text{MnSO}_4$  solution was added followed by 1.0ml alkali-iodide-azide ( $\text{NaOH}$ ,  $\text{NaI}$ ,  $\text{NaN}_3$ ) reagent. The solution was mixed by inverting the bottle a few times. When precipitate had settled sufficiently (to approximately half the bottle volume) 1.0ml conc.  $\text{H}_2\text{SO}_4$  was added to clear supernatant liquid above the manganese hydroxide flock. The bottle was restoppered and the contents were mixed by inverting several times until dissolution was complete. 200.0ml mixture solution was titrated with 0.025M hypo solution to pale straw colour. A few drops of starch solution were added and titration was continued up to first disappearance of blue colour. For 200.0 ml sample, 1.0ml 0.025M hypo = 1mg DO/l.

- **Biochemical Oxygen Demand (BOD):** BOD was also determined titrimetrically by adopting *in toto* the procedure adopted for the

measurement DO but only after incubation for five days at 20°C. BOD was then calculated on the basis of oxygen depleted when compared to DO before incubation.

- **Chemical Oxygen Demand (COD):** Chemical Oxygen Demand measures the ability of hot chromic acid solution to oxidize organic matter present in the sample. It is expressed as oxygen in ppm.

Adjustment for sample size - If water is expected to have higher or lower than normal COD, a sample ranging from 10ml to 50ml may be used with the volume, weight and concentration adjusted accordingly.

Sample size: 10, 20, 30, 40, 50 ml.

Standard  $K_2Cr_2O_7$ : 5,10,15,20,25 ml.

$H_2SO_4$  with  $Ag_2SO_4$ : 15,30,45,60,75 ml.

$HgSO_4$ : 0.2, 0.4,0.6, 0.8, 1.0 g.

Final volume before titration : 70, 140, 210, 280 , 350 ml .

## Procedure

0.4g of mercuric sulphate reagent is taken in 500ml conical flask and 20ml of sample is added and diluted to 20ml with distilled water and mixed well.

10ml of 0.025N  $K_2Cr_2O_7$  solution is added depending upon the expected COD.

30ml of  $H_2SO_4$ +Silver sulphate reagent is added and mixed well.

If colour changed to green, more  $K_2Cr_2O_7$  and  $H_2SO_4$ - $Ag_2SO_4$  reagent was added or alternatively the solution was discarded and a fresh sample with lesser aliquot was taken.

The contents were refluxed for 2 hours.

Cooled and added distilled water to make final volume to about 150ml.

3 to 4 drops of ferroin indicator are added. Colour change from blue green to reddish brown indicates the end point on completion of titration.

Blank: A blank sample is created by adding all reagents to a volume of distilled water. COD is measured for both the water and blank samples, and the two are compared. The oxygen demand in the blank sample is subtracted.

Calculations:

$$\text{COD in mg / l} = \frac{(B-A) \times \text{Normality of FASX} \times 1000 \times 8}{\text{Vol. of sample taken}}$$

Where

B = Volume of ferrous ammonium sulphate with blank

A= Volume of ferrous ammonium sulphate with sample

8= Milliequivalent weight of oxygen .

## **Results and Discussion:**

- Maximum **temperature** was recorded in May and minimum temperature was recorded in December, but the variation was never more than 4 to 5 degrees for any sample during the study period. Temperature was found to increase with the depth of the source. Open well water had lower temperature than bore well water. Also temperature was found to be less in post monsoon than during monsoon(1).
- The **pH** values for all the samples were almost uniform at all times except for an occasional variation in one or two cases. This may be attributed to the carbonate-bicarbonate buffer abundantly found in the soil(10). pH of all the samples was found to be within the BIS range of 6.5 to 8.5(2). Samples were mostly alkaline. The pH was very rarely found to be around 7.0. The pH limit for drinking water is 7.5 to 9.0. Majority of the samples most of the time showed less than 7.5 pH.
- Electrical Conductivity(**EC**) of water is determined by the concentration of ions present in it. The more the concentration of ions in the sample the more is its conductivity. All the samples had greater than 1000 $\mu$ S conductance although 500 $\mu$ S is the permissible value recommended by Central Ground Water Board(3). Higher EC is the reason behind the problem of scale formation in the study area.

**Table: 4-** The average of temperatures, pH and conductance recorded for every sample over two years is shown below against the depth of the source.

Sample No.	Temperature °C	Depth in feet	pH	Conductivity μS
BIS	-	-	6.5 - 8.5	500
WHO	-	-	7.0 - 8.5	-
1	30	28	7.0	1720
2	31	65	7.11	1430
3	30	68	7.0	1145
4	29	32	7.2	1110
5	28	68	6.1	645
6	30	31	7.6	1130
7	29	35	7.24	2910
8	29	34	7.23	1700
9	30	65	8.61	2040
10	28	27	7.23	1330
11	29	69	7.59	1940
12	28	30	7.47	1320

- Hardness** in water is mainly caused by Ca and Mg although Fe and Mg also contribute to actual hardness. Total hardness (carbonate and non-carbonate) is expressed as mg/l of CaCO<sub>3</sub>. It is a measure of the capacity of water to precipitate soap. Hardness in water results in excessive consumption of soap and wastage of fuel. Total hardness of all the samples was found to be higher during monsoon when compared to other times(6). Average total hardness of most of the samples in the study area was found to be higher than 300mg/l indicating that the water is very hard water. Total hardness in most cases is always higher than 300mg/l which is the permissible limit both by BIS as well as WHO standards(2,5).



- **Alkalinity** is the capacity of water to neutralise acid(11). It is a measure of bicarbonates, carbonates and hydroxides present in water. Alkalinity was found to be maximum in winter season and minimum in summer season(8). Total alkalinity of all the samples was found to be higher than permissible value (200mg/l(P) & 600mg/l(E) ) suggested by BIS as well as WHO at all times. Some of them sometimes touched the excessive limit as well. In view of higher alkalinity values also the ground water in gnanapuram and its surrounding localities can be considered as very hard water(13).Higher alkaline waters are usually unpalatable and cause bitter taste(12).
- **Chloride** is one of the major inorganic anions found in ground water. It originates in ground water from both natural and anthropogenic sources. High chloride content indicates heavy pollution. Chlorides in drinking water impart characteristic taste to it. Average chloride concentrations of all the samples was never found to exceed the permissible limit of 250mg/l (BIS & WHO) in the study area.
- EC of water is also an indirect measure of the **total dissolved solids** in the sample. A linear relationship was found to exist between electrical conductivity and total dissolved solids(TDS). TDS levels are also found to be higher than permissible limits. High levels of TDS is the cause of aesthetically displeasing colour, taste and odour of the ground water in the study area.

**Table: 5-** The average of total hardness, total alkalinity, total dissolved solids and chloride in (mg/l) recorded for every sample over two year period is shown below against the sample number.

Sample No.	Total Hardness ( mg CaCO <sub>3</sub> /l)	Total Alkalinity ( mg CaCO <sub>3</sub> /l)	Carbonate + Bicarbonate (mg/l)	Total Dissolved Solids (mg/l)	Chloride (mg/l)
BIS	300	200 - 600		-	250
WHO	300	200 to 600		500-1500	250
1	520	594	778.1	1100.8	95.85
2	260	313.5	410.7	915.2	159.75
3	460	330	432.3	732.8	181.05
4	460	379.5	497.2	710.4	69.225
5	260	148.5	194.5	412.8	53.25
6	360	396	518.8	723.2	90.525
7	560	940.5	1232.1	1862.4	250.275
8	600	544.5	713.3	1088	122.475
9	220	561	734.9	1305.6	149.1
10	460	445.5	583.6	851.2	79.875
11	220	577.5	756.5	1241.6	159.75
12	460	363	475.5	844.8	90.525

- Nitrate-Nitrogen** was estimated using a UV-Visible Spectrophotometer. Nitrates and nitrites are the most abundant forms of dissolved nitrogen in ground water. Nitrate levels in the ground water samples were not only high but remained almost constant throughout the period of study. There was a slight increase (.1-.3ppm) in winter. The maximum permissible limit of Nitrate - Nitrogen is 10mg/l (US Public Health Service). Almost all the samples had high NO<sub>3</sub> - N levels of nearly 10mg/l. This may be due to human activity, (as there is no agricultural activity in the vicinity)

and leaking septic tanks and sewage infiltration. Numerous studies have indicated a possible link between nitrate and cancer(14).

- **Orthophosphate-Phosphorus** was also determined spectrophotometrically. Orthophosphate forms in ground water are produced by natural processes, partially treated and untreated sewage, laundering and commercial cleaning fluids (runoff from agricultural sites may not be the reason in the case under study). Some samples were free from phosphate most of the time. A few samples showed Orthophosphate-Phosphorus in the range of .01-.03mg/l which is permitted in uncontaminated lakes (15,16). A particular sample showed a high conc. of 0.176 mg/l which may be attributed to local contamination.
- **Dissolved oxygen(DO)** levels indicate the ability of water to purify itself through biochemical processes. DO levels were found to decrease with an increase in the temperature of the sample. DO levels were maximum during monsoon and minimum in summer. The permissible level of DO according to BIS as well as WHO standards is 4.6-6.0(2,5). DO of the samples was never less than the permissible levels except for one or two rare cases.
- BIS as well as WHO have not mentioned the permissible levels for **BOD** thus indicating that it should not be present in water. Drinking water should be free from BOD/COD. All the samples showed BOD. Some of the samples have shown a definite BOD value ( $\approx$ 5-6mg/l) at all times , thus indicating that the ground water in the study area is inhabited and moderately contaminated by microbial population at all times(17).

**Table: 6** - The average of Nitrate - N, Orthophosphate-P, Dissolved Oxygen and BOD in (mg/l) recorded for every sample over two year period is shown below against the sample number.

Sample No.	Nitrate - N (mg/l)	Orthophosphate -P (mg/l)	Dissolved Oxygen (mg/l)	BOD (mg/l)
BIS	10.0	-	4.6 -6.0	-
WHO	10.0	-	4.6 - 6.0	-
1	11.9	-	7.2	5.5
2	11.22	-	7.0	2.5
3	11.8	-	6.0	3.0
4	11.2	-	7.0	6.0
5	12.3	-	5.1	1.5
6	5.11	0.038	4.0	4.0
7	11.69	0.176	6.0	4.0
8	10.15	0.011	8.0	6.5
9	11.8	0.013	7.2	2.0
10	19.6	-	6.0	6.0
11	10.2	0.009	7.2	1.0
12	11.12	0.01	7.2	3.0

- Calcium** is abundant in groundwater because of the presence of its minerals in the earth crust. **Magnesium** is relatively less abundant in groundwater but is extensively found in sea water. Both Ca and Mg cause hardness to water. Average calcium and magnesium concentrations in most cases are found to be higher than the permissible limit both by BIS as well as WHO (Ca-75 & Mg-30) standards(2,5). The average ratio of Ca to Mg is always found to be >1 thus ruling out salt water contamination(7) in the aquifers under study.

- Permissible limit of **Sodium** in the groundwater as per WHO as well as BIS standards is 100mg/l. All the samples showed high concentrations of Na but within the permissible limit except three (Sample No. 4,8 and 10). Several scientists have attributed excessive levels of Na (>150 mg/l) to sea water intrusion in the coastal belt (18,19). But none of the samples showed such high values for Na. As the study area is urban and close to two storm water drains carrying sewage it can be assumed that the composition of water in this study area is influenced by wastewater flowing through it from local households (20) .
- The likely sources of **potassium** in ground water are silicate minerals and igneous and metamorphic rocks. Permissible limit of K concentration in the groundwater as per WHO as well as BIS standards is 10mg/l. All the samples showed K in excess of the permissible limit except two (Sample No. 2 and 5). Main cause for increase in potassium levels in groundwater is agricultural activities. But since the study area is urban and is nowhere near an agricultural field that reason can be ruled out. Water softeners that regenerate using potassium chloride can also raise the level of potassium in water significantly. The research by Durkowski(2005)(21) demonstrated that such high potassium concentrations occur in ground water of urban areas due to sewage infiltration. Excessive K levels in the present case can also be attributed to the same factor. Excess amount of potassium present in the water sample may lead to nervous and digestive disorders(22). It is recommended that people with kidney disease or other conditions such as heart disease, coronary artery disease, hypertension, diabetes and those who take medication that interferes with how the body handles potassium should not drink ground water in this area.

**Table:7** - The average of Calcium, Magnesium, Sodium and Potassium in (mg/l) recorded for every sample over the two year period is shown below against the sample number.

Sample No.	Calcium (mg/l)	Magnesium (mg/l)	Sodium(mg/l)	Potassium (mg/l)
BIS	75	75	100.0	10.0
WHO	30	50	100.0	10.0
1	120	52.8	69.4	13.7
2	64	24.0	19.4	3.3
3	112	43.2	30.8	35.7
4	96	52.8	100.2	27.0
5	56	28.8	12.2	10.8
6	80	38.4	27.8	23.0
7	120	62.4	44.6	30.0
8	184	33.6	76.8	44.4
9	64	14.4	41.4	30.1
10	104	48.0	19.5	52.6
11	56	19.2	36.0	45.0
12	96	52.8	31.4	11.7

**Salt Water Intrusion:** Brackish and saline groundwater can be found in coastal aquifers. Many coastal aquifers in the world especially the shallow ones are experiencing intense salt water intrusion caused by both natural and man-induced processes(19). As the study area is only 2-3Km away from the shoreline of Bay of Bengal it was thought pertinent to study the salt water intrusion aspect in the groundwater aquifers. Salt water contamination may be identified by measuring the relative concentrations of some of the ions characteristic of sea water and those characteristic of groundwater in the samples under consideration.

- Chloride is a dominant ion found in seawater - carbonates and bicarbonates are abundant in groundwater. Therefore  $\text{Cl}^-/(\text{CO}_3^{2-} + \text{HCO}_3^-)$  ratio was considered to be an indicator.  $\text{Cl}^-/(\text{CO}_3^{2-} + \text{HCO}_3^-)$  was always found to be less than 0.5 in all the samples which ruled out salt water contamination in the groundwater being examined(23).
- **Total alkalinity(TA)/Total hardness(TH)** ratio was always found to be  $> 1$ . Since groundwater is rich in bicarbonates and sea water is very rich in chlorides and sulphates of calcium and magnesium (that impart hardness to water) an excess of TA over TH ruled out contamination from sea water intrusion(7).
- Groundwater is normally rich in calcium whereas sea water is rich in magnesium. Therefore **Ca/Mg** ratio is also indicative of seawater contamination. Ca/Mg ratio was always found to be  $> 1$ . This also ruled out contamination from sea water intrusion(7) in the groundwater aquifers.

**Conclusions & Recommendations:** From the foregoing discussion it can be concluded that the groundwater in the study area is **not palatable**. It is

1. foul smelling and foaming - because of contamination from sewage and high levels of TDS.
2. Unfit for bathing and washing (as it forms no lather with soap) - because total hardness is  $> 180\text{mg/l}$  and the water can be considered as very hard water.
3. Scale forming - because of high levels of TDS, total hardness and alkalinity.

4. Harmful to health (can lead to gastroenteritis and skin diseases) - because of contamination from sewage, presence of harmful microbes(BOD), high nitrate and potassium levels.

**Remedies and control measures:** Prevention is better than cure. Since purification of contaminated groundwater is an expensive and time taking process, it is better to try and collectively work together to avoid groundwater contamination at source stage itself. Since this study has identified contamination from sewage as the main cause for groundwater contamination in the study area - all steps to curtail it and prevent further deterioration should be taken up immediately. Suggestive measures to control sewage infiltration are mentioned below.

- ✓ open defecation and urination should be avoided
- ✓ septic tank leaks should be plugged immediately
- ✓ sewage seepage can be avoided by properly cementing the conduits and not allowing them to overflow
- ✓ domestic sewage should be properly channelized through a well structured and maintained drainage system
- ✓ UGD system should be properly maintained-manholes should not be allowed to overflow
- ✓ at source segregation and collection of solid waste should be practised
- ✓ bathing, washing clothes, utensils and animals near open and tube wells should be avoided
- ✓ people should be educated in the art of healthy living
- ✓ residents should impress upon the local corporator to prevail on the municipal corporation authorities for taking up desilting works on Errigedda and Gangulagedda immediately



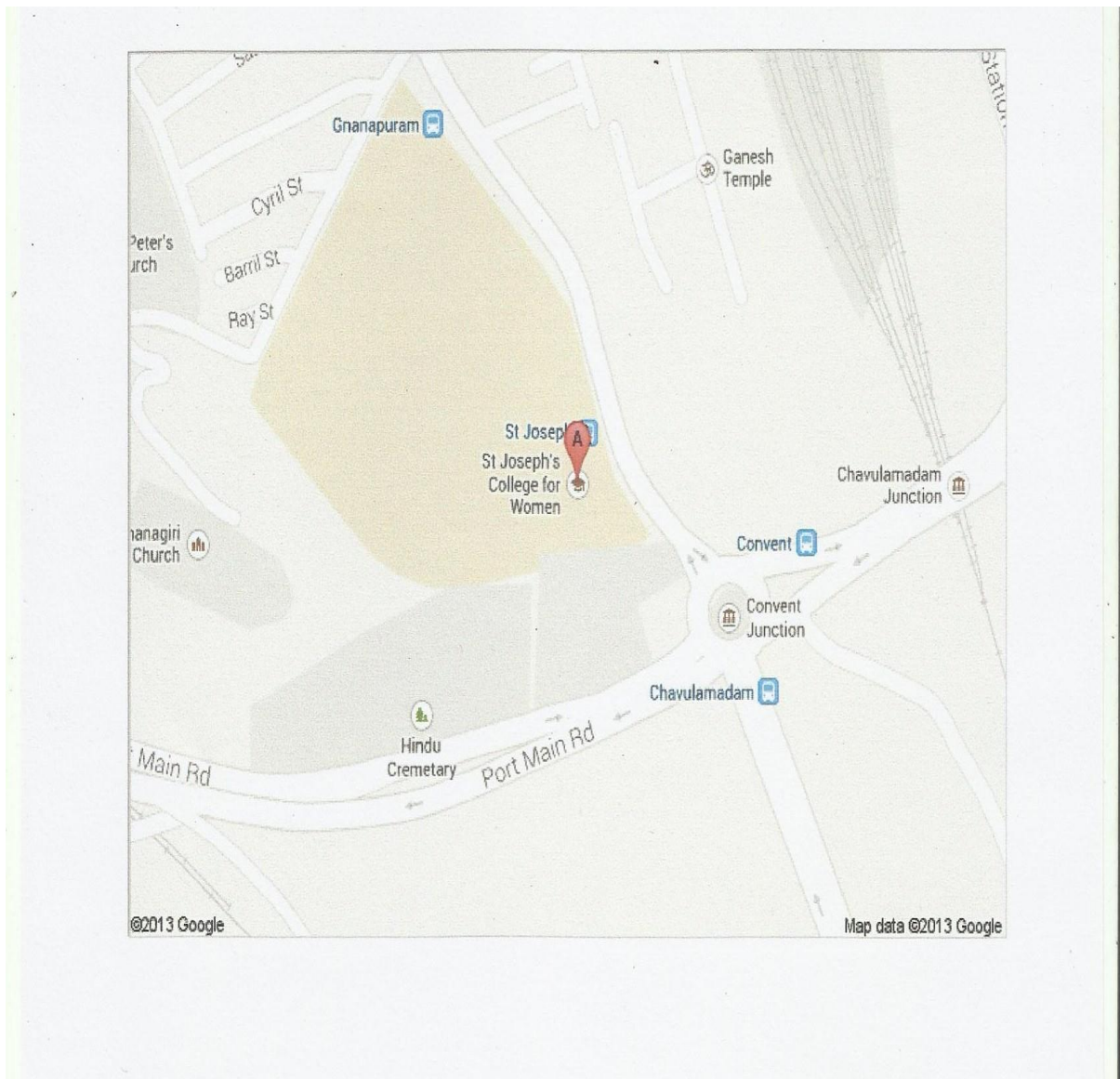
St. Joseph's College for Women draws 20-30% of its students and most of its supporting staff from the study area. The findings of the study along with the recommendations have been communicated to this target group in the college with a request to convey the same to the people in their localities. The college NSS units also intend to popularize and publicize these suggestive measures in the affected areas through their community outreach programmes.

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Appendix 1: Google Map of the study area:



Appendix 2 - Photographs of Sample Sources





