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# Physico-Chemical, Biological and Bacteriological Study of Sarada River

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The water quality of river Sarada was determined based on the analysis of different physico-chemical, biological and bacteriological parameters during the period from January 1997 to December 1997. The study revealed a fluctuating behaviour of different parameters throughout the study period. It is observed that quality of some water samples is good for drinking purposes and others are unsuitable for drinking and irrigation purposes.

**Key Words: Physico-chemical characteristics, Water quality index, Sarada river.**

## INTRODUCTION

Anakapalli is one of the most important industrial cities in Andhra Pradesh (India). It is located in the district of Visakhapatnam and is situated at longitude 83° 16′ 15″ east and latitude 17° 45′ 35″ north. It is famous for sugar and jaggery industry.

In the present paper, we have studied the effluent from a sugar mill factory, which is located on the eastern banks of the river Sarada producing an average of 1,005,735 tonnes of sugar during the season. Part of the effluent is let out into the river, which is a source of drinking water for that area in and around. The present study deals with the water quality of different areas located along with the stretch of the Sarada river, Anakapalli by calculating the water quality index (WQI).

## EXPERIMENTAL

During the period from January 1997 to December 1997 water samples were collected in plastic cans. Later the samples were brought to the laboratory with necessary precaution. All samples were labelled properly. Some parameters like temperature, pH and dissolved oxygen were measured on site. The samples were analyzed for the following physico-chemical parameters.

**Physical parameters:** Atmospheric temperature (°C), water temperature (°C), pH (hydrogen ion concentration), electrical conductivity, total dissolved

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solids (mg/L), total solids (mg/L), total suspended solids (mg/L) and turbidity (NTU) by adopting procedures from APHA[1].

**Chemical parameters:** Dissolved oxygan (mg/L), biochemical oxygen demand (mg/L), chemical oxygen demand (mg/L), chlorides (mg/L), phosphorus (mg/L), nitrates (mg/L), total alkalinity (mg/L), total hardness (mg/L), calcium and magnesium hardness. Similarly biological and bacteriological studies were done using standard methods.

A total of 110 water samples were collected from 3 different spots during different seasons over a period of one year (January 1997 to December 1997) in sterile water bottles. Spot-I was at the point of source generally utilized for drinking water. Spot-II and Spot-III were used for bathing and cleaning purposes. The total bacteria per mL and coliforms per 100 mL of water were determined on nutrient agar and McConkey's agar respectively by standard pour plate method described by APHA[1]. Data were analyzed after logarithmic transformation.

Fourteen parameters were taken for calculating water quality index[2, 3].

We calculated the WQI from the point of view of the suitability of river waters for human consumption. The weights for various parameters are assumed to be inversely proportional to the recommended standards.

$$W_i = K/S_i$$

where, $W_i$ = unit weight of the parameter

$S_i$ = standard for that parameter

K = constant of proportionality (for simplification it is taken as 1.0).

The quality rating ($Q_i$) corresponding to the relative value of individual parameter ($V_i$) in the polluted water with respect to its standard or permissible value ($S_i$) has been calculated as follows:

$$Q_i = (V_i/S_i) \times 100$$

The overall water quality index (WQI) may be calculated by

$$WQI = \frac{\Sigma(Q_i W_i)}{\Sigma(W_i)}$$

Generally a strong correlation always exists among the water quality parameters; hence a systematic calculation and interpretation was done in order to have an idea of rapid water quality monitoring method.

Interpretation of correlation coefficient gives an idea of rapid water quality monitoring method and if some of the correlations are found significant at 5, 1 and 0.1% level, these become useful in assessing the water quality parameters. The correlation coefficient 'r' was calculated from the following equation:

$$R = \frac{[(N\,\Sigma XY - \Sigma X\,\Sigma Y)/N]}{\sqrt{(\Sigma X^2 - N(X)^2)(\Sigma Y^2 - N(Y)^2)}}$$

where $X = \Sigma X/N$ and $Y = \Sigma Y/N$

## RESULTS AND DISCUSSION

The results obtained from the analysis of the effluent and water samples of river Sarada were shown in Tables 1 and 2 respectively. Bacterial and biological characters are given in Tables 3–5. The standard values of different physico-chemical parameters, used for characterization of water quality are shown in Table-4. The mean values of various physico-chemical parameters during different seasons for the calculation of WQI are presented in Table-6. The ratings of WQI are given in Table-7.

TABLE-1
PHYSICO-CHEMICAL PARAMETERS OF SUGAR MILL EFFLUENT

| S. No. | Parameters | Value |
|---|---|---|
| 1. | Temperature (°C) | 26–30 |
| 2. | pH | 6.5–8.8 |
| 3. | Total solids | 870–4,500 |
| 4. | Total suspended solids | 220–800 |
| 5. | Total volatile solids | 400–2,200 |
| 6. | Total dissolved solids | 200–3,800 |
| 7. | COD | 600–3,380 |
| 8. | BOD | 300–2000 |
| 9. | Free $CO_2$ | 12.64–24.91 |
| 10. | COD/BOD | 1.3–2.0 |
| 11. | Conductivity | 2.25–2.38 |
| 12. | Total alkalinity | 160–120 |
| 13. | Total hardness | 160–400 |
| 14. | Calcium hardness | 100–320 |
| 15. | Magnesium hardness | 30–88 |
| 16. | Phosphates | 8.90–39.20 |
| 17. | Chlorides | 18.60–42.79 |
| 18. | Calcium | 42.75–166.83 |
| 19. | Magnesium | 9.30–25.73 |

The reported values refer to the mean value of the water sample collected at different areas along with the stretch of Sarada river. The results implicate that the quality of water considerably varies from location to location. This wide variation is mainly due to discharge of effluents into the river from near by sugar industry. This wide variation was reflected in the electrical conductivity and total dissolved solids values. The pH values were found to comply with the standards for drinking waters.

TABLE-2
PHYSICO-CHEMICAL PARAMETERS OF WATER OF SARADA RIVER

| S. No. | Parameters | Max. value | Min. value | Average value |
|---|---|---|---|---|
| 1. | Atmosphere | 30.4 | 15.2 | 22.8 |
| 2. | Water temp. (°C) | 28.2 | 17.6 | — |
| 3. | Colour | — | Grayish black | — |
| 4. | Odour | — | Nothing disagreeable | — |
| 5. | Taste | — | Palatable | — |
| 6. | pH | 8.00 | 7.85 | 7.9 |
| 7. | Electrical conductivity | 220.00 | 200.00 | 210.5 |
| 8. | Turbidity | 2.60 | 2.40 | 2.5 |
| 9. | Dissolved oxygen | 7.8 | 7.0 | 7.4 |
| 10. | Chemical oxygen demand | 1090 | 280 | 685 |
| 11. | Total hardness | 450 | 120 | 285 |
| 12. | Total dissolved solids | 1790 | 580 | 1185 |
| 13. | Total solids | 2530 | 1510.0 | 2015 |
| 14. | Total suspended solids | 788.0 | 278.0 | 533 |
| 15. | Chlorides | 231.0 | 153.2 | 192.1 |
| 16. | Nitrates | 68.2 | 40.00 | 54.1 |
| 17. | Sulphates | 98.0 | 25.0 | 61.5 |
| 18. | $Ca^{2+}$ | 164.5 | 45.0 | 104.75 |
| 19. | $Mg^{2+}$ | 296.70 | 25 | 160.85 |

1. Except temperature (°C), electrical Conductivity (μmho/cm), turbidity (NTU) all other units are in mg/L.
2. Values are average of 24 readings (twice in every month, throughout the year).

Turbidity varies from 1.8 to 2.6 NTU (average of 2.2), so turbidity is within the highest desirable limit. Total dissolved solids ranged beyond the highest desirable limits as prescribed by ISI. So turbidity is also within the highest desirable limit.

Total solid, total dissolved solid, total suspended solids, chemical oxygen demand and bio-chemical oxygen demand were reported of higher values. The DO values are low throughout the study period. This is attributed to the effluent that normally carries a large amount of oxygen demanding waste, disposed into Sarada river from the nearby sugar mill effluent. The high DO values in monsoon period may be due to the re-oxygenation from the atmospheric oxygen caused by the high flow of water.

TABLE-3
RESULT OF BACTERIAL ANALYSIS OF WATERS OF SARADA RIVER DURING DIFFERENT SEASONS

| Season | Total Count/mL | | | Coliform Count/100 mL | | |
|---|---|---|---|---|---|---|
| | S I | S II | S III | S I | S II | S III |
| Pre-monsoon (March–May) | 2383 ± 222 (1800–4000) | 6414 ± 665 (3400–6900) | 20445 ± 1745 (11000–25000) | 300.11 ± 65 (0–400) | 400.22 ± 40 (250–720) | 2044.44 ± 150 (1700–3000) |
| Monsoon (June–August) | 4202 ± 222 (3000–5200) | 9066.76 ± 504 (7990–12000) | 30333.32 ± 1800 (20000–40000) | 400.0 ± 72 (90–950) | 702.32 ± 97 (390–1190) | 6101.10 ± 510 (3400–9100) |
| Post-monsoon (September–October) | 2888.98 ± 206 (2100–4000) | 6474.44 ± 406 (4300–8100) | 20600 ± 1903 (11000–30000) | 170.78 ± 30 (0–490) | 212.2 ± 35 (100–400) | 2911.1 ± 220 (2000–4000) |
| Winter (December–February) | 1905.65 ± 110 (1200–2200) | 5121.22 ± 220 (4100–6300) | 12033.22 ± 1247 (6000–19100) | 70 ± 24 (0–200) | 120.22 ± 20 (0–200) | 1710.10 ± 115 (1100–21000) |

TABLE-4
STATUS OF WATER QUALITY BASED ON ISI STANDARDS

| Collection centre | Class A Total coliform < 50 | Class B Total coliform < 50 | Class C Total coliform < 50 |
|---|---|---|---|
| Spot-I | 7 (6.48) | 28 (25.93) | 1 (0.93) |
| Spot-II | 1 (0.93) | 27 (25) | 8 (7.41) |
| Spot-III | 0 | 0 | 36 (33.33) |
| Total | 8 (7.41) | 55 (50.93) | 45 (41.66) |

TABLE-5
BIOLOGICAL CHARACTERS OF WATERS OF SARADA RIVER
MICROBIAL COLONY

| S. No. | Month | Fungi | Algal flora | Fungal Species |
|---|---|---|---|---|
| 1. | January | 20 | *Synedra* | *Geotrichum* |
| 2. | February | 18 | *Nostac* | *Oospora* |
| 3. | March | 25 | *Navicula* | *Rhizopus* |
| 4. | April | 21 | *Scendesmus* | *Penicillium* |
| 5. | May | 24 | *Clostridium* | *Alternaria* |
| 6. | June | 22 | *Cosmarium* | *Helminthosporium* |
| 7. | July | 26 | *Chlorella** | *Mucor* |
| 8. | August | 30 | *Anabaena** | *Aspergillus* |
| 9. | September | 28 | *Cladophora* | |
| 10. | October | 24 | *Lyngbya** | |
| 11. | November | 26 | *Cladosphora* | |
| 12. | December | 28 | *Pediastrum* | |

*Indicators of pollution.

TABLE-6
WATER QUALITY RATING FOR RIVER WATERS (EXCEPT EC (μmhos/cm), TURBIDITY (NTU), TOTAL ALKALINITY AND ALL OTHER EXPRESSED IN mg/L

| S.No. | Parameters | Standard values | Observed values | $W_n$ | $Q_n$ | $W_n \log Q_n$ |
|---|---|---|---|---|---|---|
| 1. | Turbidity | 5.00 | 1.75 | 0.0482 | 39.0 | 0.0777 |
| 2. | pH | 6.5–8.5 | 7.55 | 0.0258 | 35.43 | 0.0464 |
| 3. | EC | 500.00 | 220.00 | 0.0009 | 64.55 | 0.0051 |
| 4. | Total dissolved solids | 300.00 | 300.08 | 0.0004 | 60.00 | 0.0007 |
| 5. | Total suspended solids | 500.00 | 140.50 | 0.0004 | 28.00 | 0.0050 |
| 6. | Chloride | 250.00 | 170.00 | 0.0017 | 40.00 | 0.0007 |
| 7. | Sulphate | 250.00 | 60.00 | 0.0018 | 26.00 | 0.0016 |
| 8. | Nitrate | 0–30.0 | 20.00 | 0.8085 | 12.30 | 0.9095 |
| 9. | Dissolved oxygen | 4–6 | 6.00 | 0.0404 | 60.21 | 0.0755 |
| 10. | Chemical oxygen demand | 4–5 | 280.00 | 0.8018 | 3991.00 | 0.3428 |
| 11. | Biological oxygen demand | 5.0 | 195.00 | 0.0606 | 4875.00 | 0.02253 |
| 12. | $Ca^{2+}$ | 100.00 | 120.00 | 0.0042 | 14.28 | 0.0039 |
| 13. | $Mg^{2+}$ | 25.00 | 110.00 | 0.00556 | 18.34 | 0.0165 |
| 14. | Total hardness | | 310.00 | 0.0005 | 42.00 | 0.0015 |

TABLE-7
THE RATING OF WQI IS SHOWN BELOW

| WQI Level | Water quality rating |
|---|---|
| 0–25 | Excellent |
| 26–50 | Good |
| 51–75 | Poor |
| 76–100 | Very poor |
| >100 | Unfit for drinking purposes |

TABLE-8
CORRELATION COEFFICIENT (R) AMONG VARIOUS RIVER WATER QUALITY PARAMETERS

| | pH | EC | TDS | TSS | TH | $Cl^-$ | $SO_4^-$ | $NO_3^-$ | DO |
|---|---|---|---|---|---|---|---|---|---|
| pH | | | | | | | | | |
| EC | 0.244* | | | | | | | | |
| TDS | 0.282* | 0.909* | | | | | | | |
| TSS | –0.671* | 0.905 | 0.498** | | | | | | |
| TH | –0.849** | –0.124* | –0.173* | –0.666* | | | | | |
| $Cl^-$ | –0.186 | 0.956 | 0.909 | 0.539*** | 0.485* | | | | |
| $SO_4^-$ | –0.295** | 0.948** | 0.856* | 0.576* | 0.354* | 0.676** | | | |
| $NO_3^-$ | –0.107 | –0.341 | –0.304* | 0.095* | –0.309** | –0.659* | –0.596 | 1*** | 1.01*** |

*Significance at 5% level, r > 0.5139, **Significance at 1% level, r > 0.6411,
***Significance at 0.1% level, r > 0.7

TABLE-9
DRINKING WATER STANDARDS

| S.No. | Characteistics | Limits, mg/L | S.No. | Characteistics | Limits, mg/L |
|---|---|---|---|---|---|
| 1. | Colour | 5 | 16. | Fluoride | 1 |
| 2. | Odour | Unobjec-tionable | 17. | Phenolic Compounds (as $C_6H_5OH$) | 0.001 |
| 3. | Taste | Agreeable | 18. | Mercury | 0.001 |
| 4. | Turbidity (NTU) | 5 | 19. | Cadmium | 0.01 |
| 5. | Total Dissolved Solids | 500 | 20. | Arsenic | 0.05 |
| 6. | pH | 6.5–8.5 | 21. | Cyanide | 0.05 |
| 7. | Total hardness (as $CaCO_3$) | 300 | 22. | Lead | 0.05 |
| 8. | Calcium (as $CaCO_3$) | 75 | 23. | Zinc | 5.00 |
| 9. | Magnesium | 30 | 24. | Chromium (as $Cr^{6+}$) | 0.05 |
| 10. | Copper | 0.05 | 25. | Mineral oil | 0.01 |
| 11. | Iron | 0.3 | 26. | Residual Chlorine | 0.2 |
| 12. | Manganese | 0.1 | **Radioactive Materials** | | |
| 13. | Chlorides (as $Cl^-$) | 250 | 27. | α-Emitters (Mc/Ml) | 10.8 |
| 14. | Sulphates (as $SO_4^{2-}$) | 200 | 28. | β-Emitters (Mc/Ml) | 10.7 |
| 15. | Nitrates (as $NO_3^-$) | 45 | | | |

**[Source: CPCB, ref. 2 ].

The amount of calcium in all samples was reported above the maximum permissible limits (45–164 mg/L). The amount of magnesium varies from 25 to 296 mg/L as $CaCO_3$ equivalent for samples, which is above the permissible limits[2]. All the water samples analyzed are free from sulphate pollution as $SO_4^{2-}$ contents vary from 25–98 mg/L.

The maximum allowable limit[2] of $NO_3^-$ in drinking water is 45 mg/L. It was found that some water samples showed beyond the permissible limit (60 mg/L) and some water samples are free from nitrate pollution as the amount of $NO_3^-$ varies from 20–37.65 mg/L.

The rating of water quality index (WQI) of water samples was calculated and represented in Table-7. The results of WQI values of these samples are found to be in the range of 100 to 310 except for tap water (20.00). The water quality index is well within the limits in some sampling stations. However, in the samples collected where the sugar mill effluent mixes with river water, the water quality index is in rising levels due to discharge of effluent and sewage waters. Hence it is suggested to take necessary precautions before the waters are used for drinking purposes. The drinking water standards are given in Table-9.

In the present study microbial colonies like fungi, bacteria and actinomycetes were noticed throughout the study period showing high amount of bacterial colonies, to fungi and actinomycetes. Among algal flora, the pollution indicators like *Oscillatoria, Nitzschia, Anabaena, Lyngbya* and *Chlorella* were also noticed.

The correlation co-efficient 'r' for various physico-chemical parameters of water samples were presented in Table-8. The highest correlation was found between TDS and conductivity (0.90). The values of 's' are at 0.1% significant level positive for dissolved oxygen and also chemical oxygen demand, Dissolved oxygen and total hardness, Dissolved oxygen and nitrate; negative for dissolved oxygen and inorganic phosphate, dissolved oxygen and $Ca^{2-}$ and also the values of 'r' are at 0–1.5 significance level.

The 'r' value is significant at 1% level for chemical oxygen demand and nitrate (positive), total dissolved solids and $SO_4^{2-}$ (positive), $NO_3^-$ and $Mg^{2+}$ (negative), and $SO_4^{2-}$ with both of $Ca^{2+}$ and $Mg^{2+}$ (negative). The 'r' is at 5.0% significant level for pH and electrical conductivity (negative), electrical conductivity and $Ca^{2+}$ (negative), chemical oxygen demand and total dissolved solids. Hardness with each of $NO_3^-$, total phosphate (negative) and total phosphate with both of $SO_4^{2-}$ (negative). It was evident from the above calculations that many positive and negative correlations do exist among the water quality parameters. Statistical work would help the correlation coefficient determination greatly facilitating the tasks of rapid monitoring of water quality parameters.

From the present study it is concluded that physico-chemical parameters of the water shows the values above the CPCB[2] standards and it will have deleterious effect on all aquatic flora and fauna of Sarada river, if proper effluent treatment is not maintained. From the WQI values, it is suggested that further improvement is required to treat the sugar mill effluent.

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## REFERENCES

1. APHA-1989, Standard Methods for the Examination of Water and Wastewater, American Public Health Association, Washington D.C. (1980).
2. CPCB, Potable Water Quality Standards, Central Pollution Control Board, New Delhi (1991).
3. R.A. Deininger and J.J. Macinuas, A Water Quality of Environmental and Industrial Health, School of Public Health, University of Michigan, Ann Arbor, Michigan (1971).

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