

# Trophic Status of Shanti Sagara Reservoir: Implications on Nutrient Management in Reservoir Catchment

## ABSTRACT

Water quality assessment of Shanti Sagara reservoir for drinking water supply and for water allocation to meet the demands in the semiarid climate is aimed. Seasonal water sampling (Pre monsoon, December 2021 & Post monsoon, May 2022) at 2 depths to investigate physico-chemical parameters and assess the Water Quality index based on IS 10500: 2012 is found to be poor in pre monsoon, December 2021 and very poor in post monsoon, May 2022. Trophic status of the reservoir assessed based on Carlson's Trophic State Classification (Secchi Depth, Total Nitrogen and Total Phosphorous) indicated that the reservoir is Hypereutrophic for Post Monsoon. This calls for assessment of internal nutrient load (silt characteristics) and external loading from the reservoir catchment (fertilizer from agriculture land) and the domestic water and the sewage water has contributed to high concentration of phosphorous (P) in Rudrapura and Jakli near Somalapura.

Soil texture (sandy clay, silty loam, silty clay and sandy clay loam) in the reservoir catchment compliments high concentration of suspended sediment that increases the turbidity in the reservoir. Turbidity present in the water alters the taste, colour and odour of the water and oxygen from the surface cannot be mixed to the bottom layer and oxygen is not released by photosynthesis in absence of light penetration (high turbidity levels) resulting in anoxic condition. Total Nitrogen (TN) in the catchment soil that contributes to the bottom of the reservoir is found to be high (201-217 kg/acre). Agriculture runoff in the month of (May, 2022) owing to precipitation results in high sediment concentration, that contributes to high nitrogen levels in the reservoir.

Nutrients in suspended Sediments that have entered the reservoir altered the nutrient cycle in the reservoir ecosystem. High nutrient concentration in the silt characteristics i.e total nitrogen (159-168 kg/acre) and phosphorous (10.1-13.4 kg/acre) is due to stratification caused do level to low in hypolimnion layer and anoxic condition during summer resulting in growth of Phytoplankton the eutrophication. The suggested nutrient management strategies for the reservoirs catchment are optimizing nutrient application to the crop land, microbial water treatment before supplying it for drinking purpose, soil conservation structures in the reservoir catchment to restrict sediment entry to the reservoir and sewage treatment plant for the rural settlement.

*Keywords: Reservoir water quality, Total Nitrogen (TN), Total Phosphorous (TP), Secchi Depth (SD), Water Quality Index (WQI), Nutrient Management.*

## 18 1. INTRODUCTION

19

20 The increasing water demand to cover the needs of raising production and drinking water  
21 supply under climate change makes it imperative to plan for optimal use of water  
resources especially in semi-arid regions (Gunkel et al., 2015). Water shortages in the semi-  
arid tropics that support 15% of the world's population. have tripled from 6% to 35%  
between 1960 to 2005, and the gap continues to expand with population growth especially  
in Southern Asia (Kummu et al., 2010; Mady et al., 2020). The significance of  
reservoir in dry-season, especially in water scarce rural semi-arid regions with limited  
infrastructure is precious and highly dependent in terms of costs of alternate water sources.  
Live stock and water for staple crop that require last watering to gain maturity stage  
besides human activities is the crucial for it economy (Luis and Cabral, 2021). Hillside  
reservoirs and small dams in South India had been a strategic priority since ancient times  
for water security (Santisteban et al., 2015). In recent decades, climate change mainly  
characterized by highly variable, unpredictable and often heavy rainfall has worsened  
the water deficit besides increasing sedimentation rates in the Reservoirs. Reservoirs  
mitigate floods, contribute to water table recharge and improve water storage for  
irrigation and livestock watering and domestic and recreation uses. They are very  
useful to improve community living especially in rural areas where frequent drought is  
experienced (Bhagwat TN and Lamani SN, 2019; Alahiane et al., 2016). Reservoirs, the  
key storage nodes in the drainage basin are necessary for sustainable development  
and adaptation to climate change. Thus, the construction of small and hillside dams is one  
of the best ways to help vulnerable communities to cope with water demand.

22

23 A large volume of contaminants in the basin including both point source and non-point  
source contaminants enter the reservoir during the process of storing water. The  
sedimentation rate is high in many reservoirs located in semiarid tropics. The main impacts  
of Sedimentation in reservoir are loss in capacity, hydropower generation and water  
quality deterioration. The process of reservoir sedimentation is slow, but the loss of  
usable water storage capacity over time is significant. It is estimated that about 0.5–1.0%  
of global water storage, on an average, is lost annually as a result of sedimentation  
(Bergi and Trivedi, 2020). The global cost that is replaced the lost storage is high  
and the operations after decades, reservoirs have experiences water quality  
deterioration owing to sediment deposition. Besides, rainstorm disturbance and  
temperature variation brought with the change of seasons have impact on sediment  
contamination. In summer, sudden rainstorm disturbance could cause overlaying water to  
24 move vertically, and the vigorous agitation of water lead to toxic substance in sediment  
25 contaminant diffusing into water, which poses a direct threat to water safety and even results  
26 in incidents of dead fish. Water temperature changes with season and reservoirs would turn  
27 water over at the seasonal transition period, which accelerate the transformation of sediment  
28 contaminants in reservoirs and bring contaminants to surface. Researches show that the  
29 released nutrients by turning over could promote the reproduce of algae in spring. The  
30 thermocline in summer would decrease the exchange of dissolved oxygen in bottom layer  
31 water, which reduces the content of oxygen in reservoirs. With rainstorm disturbance and  
32 and seasonal changes, the released contaminants are brought to the surface, which  
33 promote the growth of algae. Algal bloom has broken out in Reservoirs located in semi  
arid tropics during every summer. Release of Phosphorous greater than 0.025mg/l from  
sediments triggers phytoplankton growth. Higher the concentration of Phosphorous in the  
sediments more is the phytoplankton growth. This triggers the algae formation at the  
surface and spreads to the total surface of the reservoir (Bergi and Trivedi, 2020;  
Alahiane et al., 2016). High rates of sedimentation in many

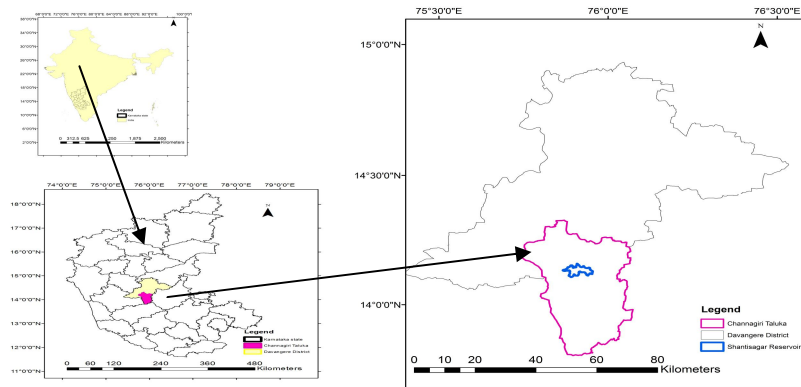
34 reservoirs and better care of long term sustainability have emphasized the importance of  
35 reservoir sedimentation.  
36

37 The over-enrichment of nutrients can leads to the major source of water pollution in the semi  
38 arid tropics. The link between eutrophication- the over-enrichment of surface water with plant  
39 nutrients and the dangers of public health have long been predicted but poorly documented  
40 in developing countries. However, recent concerns about bacterial indicators such as (1) The  
41 spread of Escherichia coli and disease in sewage-enriched water, (2) Trihalomethanes in  
42 chlorine-treated eutrophic reservoirs, and (3) The occurrence of attendant human diseases,  
43 all in the eutrophic estuarine surface. As suspected, this is not only an aesthetic, aquatic  
44 community problem, but also a public health problem. An important component of the  
45 Environmental Protection Agency's (EPA's) national nutrition strategy is the National  
46 Nutrition Strategy for the Development in the Regional Nutrition Standards (U.S. EPA,  
47 1998), which is a body-specific development of water. Criteria that address the  
48 contamination problems are framed based on the technical guidance documents and thus  
49 are be used to assess the vulnerability of a potential nutrient-related trophic condition. Owing  
50 to the diverse geographical and climatic conditions, permissible nutritional standards need  
51 revision for reservoirs based on water availability. Instead, nutritional standards should be  
52 developed at the state, regional, or individual water body level (Filstrup and Downing, 2017;  
53 Bergi and Trivedi et al., 2022). Thus the objective of the present paper is to monitor the water  
54 quality status of a multipurpose reservoir located in semiarid tropics that serves for urban  
55 water supply and irrigation.

## 56 2. Study Area

57 Shanti Sagara reservoir also known as Sulekere locally, which is inlet of the River  
58 Tungabhadra. The reservoir is constructed in the (11<sup>th</sup> and 12<sup>th</sup> century). Shanti Sagara is  
59 second largest freshwater reservoir in Asia and is located in Channagiri Taluk,  
Davanagere District, Karnataka (Fig. 1). Shanti Sagara reservoir has its surface area of 2651  
ha and catchment area 329.75 km<sup>2</sup>, maximum depth 8m, maximum width 4.6 km and its  
surface elevation is 612m. Water in the reservoir is used for urban water supply and  
irrigation. Drinking water is supplied from Shanti Sagara to Chitradurga, Karnataka  
Urban Water Supply and Drainage Board (KUWS&DB) has funded 80 crore to this  
project. Presently, Chitradurga city is getting 30 million litres of water a day from the Shanti  
Sagara. Besides, it irrigates 4,700 acres (1,900 ha) of land and more than 170 villages are  
benefited by it.

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100 **Fig. 1: Location of Shanti Sagara reservoir, Channagiri Taluk, Davanagere District, Karnataka**

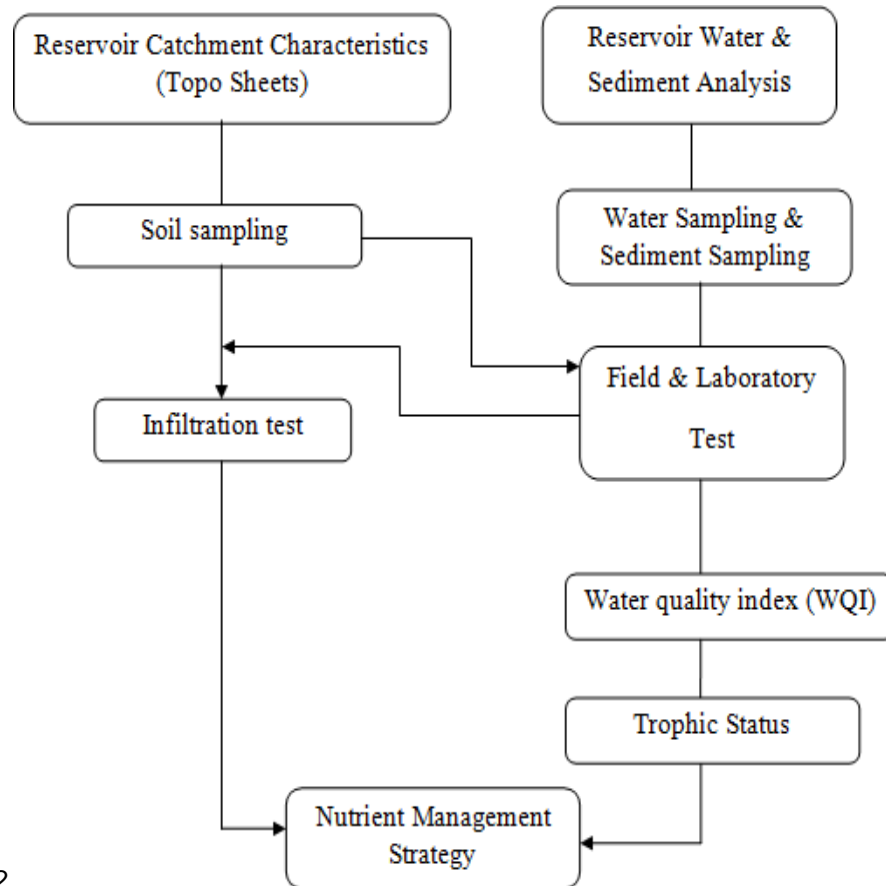
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101 **3. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY**

100 The methodology adopted to investigate water quality and understand the trophic status of Shanti Sagara reservoir is presented in fig. 2. Seasonal water, reservoir bed silt and reservoir catchment soil samples were collected and analyzed. The properties of water, silt and soil were studied.



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101 **Fig.2 Methodology adopted to investigate drinking water quality and nutrient**  
102 **management in Shanti Sagara reservoir.**

103 **3.1 Water Sampling**

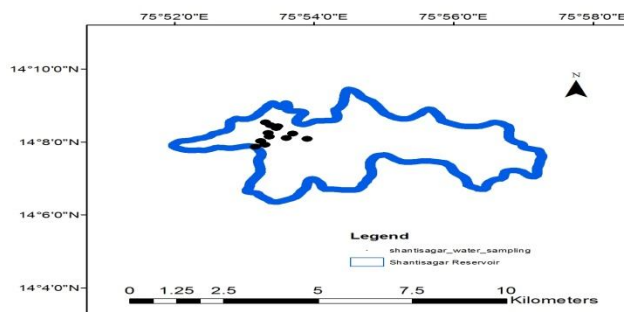
104 Seasonal water sampling for pre-monsoon December, 2021 (12 samples from the surface of the reservoir and 12 samples from the 2m depth of the reservoir) and in post-monsoon May, 2022 (12 samples from the surface of the reservoir and 12 samples from the 2m depth of the reservoir) of Shanti Sagara reservoir was planned to understand the changes in physico-chemical characteristics of water (Fig. 3). The collected samples were carefully handled in the water bottles and marked the location of the water sample taken for the references during the laboratory analysis. Based on drinking water standards water quality index for the water samples, at different depths were computed. For four different locations of Shanti Sagara reservoir catchment the sediment (Silt) samples were also collected.

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107 Water samples are collected within the Shanti Sagara reservoir. The collected samples were  
 108 brought for the laboratory tests. Water samples were tested for the following parameters e.g.  
 109 pH (Electrometric method), Turbidity test (Nephlo meter method), Total dissolved solids  
 110 (Electrometric method), Chloride (Volumetric method), hardness (Volumetric method), calcium  
 (Volumetric method), Magnesium (Volumetric method), Dissolved oxygen (Winkler method),  
 Biological oxygen demand (Dilution method).

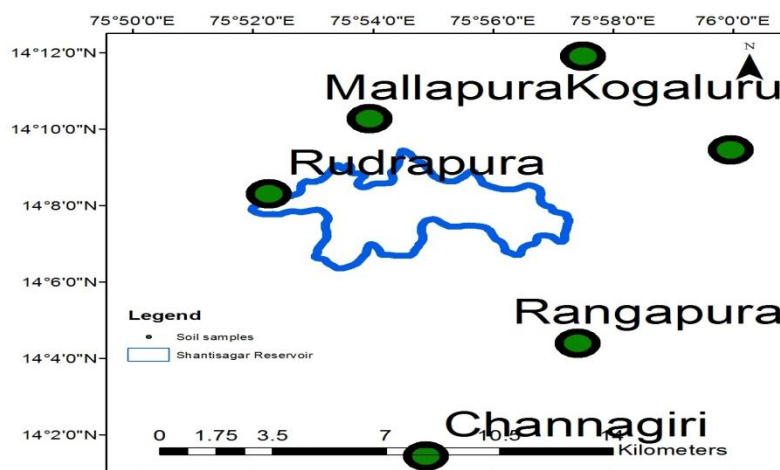


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112 **Fig. 3: Seasonal water sampling location in Shanti Sagara reservoir, Channagiri Taluk,**  
 113 **Davanagere District, Karnataka**

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In six well distributed locations, Soil samples were collected in the reservoir catchment during the post monsoon (May, 2022). Soil parameters were analyzed in laboratory using standard procedures. Insitu infiltration test were carried out to understand losses from the precipitation. Trophic status of the Shanti Sagara reservoir is determined by integrating the results obtained from the analysis of water, sediment and soil. The physiochemical water parameters, soil and sediment characteristics indicate the Nutrient management strategies to be adopted for the Shanti Sagara Reservoir.



124 **Fig. 4 Soil sampling locations of Shanti Sagara reservoir catchment (May, 2022).**

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126 Water quality index parameters are calculated by the method of weighted arithmetic mean  
127 method as follows Unit weight (W<sub>u</sub>), Constant (K), Standard values of n<sup>th</sup> parameter (S<sub>n</sub>),  
128 Sub-index (S<sub>i</sub>), Mean concentration of n<sup>th</sup> parameter (M<sub>n</sub>), Actual values A<sub>v</sub>).

129 Calculate unit weight (W<sub>u</sub>) for each parameter by using formula

130 
$$W_u = \frac{K}{S_n} \text{-----Eqn 1}$$

131 Where,

132 
$$K = \frac{1}{\frac{1}{S_1} + \frac{1}{S_2} + \dots + \frac{1}{S_n}} = \frac{1}{\sum \frac{1}{S_n}} \text{-----Eqn 2}$$

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142 Calculate the Sub-Index (Si) value by using formula

143 Where, 
$$Si = \frac{[(Mn - Av)]}{[(Sn - Av)]} * 100 \text{ -----Eqn 3}$$

144 Mv =Mean concentration of the n<sup>th</sup> parameter

145 Av=Actual values of the parameter in pure water (generally Av=0, for most parameters  
146 except for pH) (For pH, Sn =8.5 & Av=7)

147 Integrating Eqn 1 and Eqn 2, WQI is calculated

148 
$$(WQI) = \sum \frac{Wu * Si}{Wu} \text{ -----Eqn 4}$$

149 In the year 1977, Carlson classified a trophic state index to find out trophic status of the  
150 specified reservoir (Table 1). By the developed of the TSI he established the relationship  
151 between secchi depth and used the secchi depth range to find out the trophic state index  
152 (TSISD).

153 Secchi depth TSI (TSISD) =60-(14.41. [Ln (Secchi depthaverage)]) -----Eqn 5

154 Total Nitrogen TSI (TSITN) = Ln(TN)\*14.31\*54.45 ----- Eqn 6

155 Total Phosphorous TSI (TSITP) =Ln(TP) \*14.42+4.15 ----- Eqn 7

156 **Table 1: Criteria for the Trophic status index classification (TSI).**

Trophic Status criteria	(TP)	(TN)	(SD) in (m)		(TSI)
	µg/L	µg/L	Mean	Max	µg/L
(Nurnberg criteria)					
(1) Oligotrophic	<10	<350	-	-	
(2) Mesotrophic	10-30	350-650	-	-	
(3) Eutrophic	31-100	651-120	-	-	>100
(4) Hypereutrophic	>100	>1200	-	-	>1200
(Swedish criteria)					
(1) Oligotrophic	<15	<400	>3.96		
(2) Mesotrophic	15-25	400-600	2.43-3.96		>100
(3) Eutrophic	25-100	600-1500	0.91-2.43		>1500
(4) Hypereutrophic	>100	>1500	<0.91		<0.91
	<b>µg/L</b>	<b>25136</b>	<b>6860</b>	<b>0.498</b>	

157 Silt samples are collected within the Shanti Sagara reservoir. The collected samples were  
158 brought for the laboratory tests. Silts samples were tested for the following parameters e.g.  
159 pH (Electrometric method), Turbidity test (Nephlo meter method), Total dissolved solids  
160 (Electrometric method), Sieve analysis test (Mechanical (dry) sieve analysis method), Total  
161 Nitrogen (Volumetric Method) and Total Phosphorous (Volumetric method).

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163 Soil samples collected from the Shanti Sagara reservoir catchment and were brought for the  
 164 laboratory tests (Fig. 4). Soil samples were tested for the following parameters e.g. Specific  
 165 gravity (Pycnometer Method), Sieve analysis test (Mechanical (dry) sieve analysis method),  
 166 Moisture content of the soil (Oven drying method), insitu dry density of soil (Core cutter  
 167 method), Liquid limit and plastic limit (Casagrande apparatus method), Infiltration (Single ring  
 168 infiltrometer method), Total Nitrogen (Volumetric Method), Total phosphorous (Volumetric  
 169 method), etc.

#### 170 4. Water quality assessment

##### 171 4.1 Physico-chemical parameters

##### 172 4.1.1 Pre monsoon

173 Surface and 2m depth of water samples in Pre monsoon (December, 2021) indicated that  
 174 pH, chloride (Cl), hardness(H), TDS, alkalinity (Alkali), calcium (Ca), magnesium (Mg),  
 175 dissolved oxygen (DO) and biological oxygen demand (BOD) are within permissible limits  
 176 (Table 2a). Turbidity in the surface and 2m depth water samples were found to high  
 177 exceeding the permissible limits indicated that small sized particles are in suspension and  
 178 hinder light penetration. This intern suggests less amount of dissolved oxygen and triggered  
 179 to form eutrophication in the surface water (Table 2b).

180 Surface water samples were collected on 30-12-2021 and analyzed in the laboratory

181 **Table 2a: Physico-chemical parameters Surface Water Samples (Pre monsoon**  
 182 **December,2021)**

Location	pH	Cl	H	TDS	Alkali	Ca	Mg	T	DO	BOD
Units		mg/L	mg/L	ppm	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
Desirable limit	6.5	250	300	500	200	75	30	<b>5</b>	-	-
Permissible limits	8.5	1000	600	2000	600	200	100	<b>10</b>	5	5
VS1	8.34	44	96	300	140	21.6	10.08	<b>25.3</b>	8.09	0.3
VS2	8.21	50	94	300	136	27.2	6.24	5.92	8.09	0.11
VS3	8.25	50	100	310	138	22.4	10.56	6.59	7.7	0.11
VS4	8.34	52	92	310	134	21.6	9.12	6.64	7.6	0.1
VS5	8.41	52	96	300	102	11.2	16.32	8.43	7.8	0.3
VS6	8.32	36	94	310	146	16	12.96	6.19	7.51	0.1
H-S1	8.35	48	98	310	166	24.8	8.64	5.27	8.49	0.39
H-S2	8.31	44	96	300	144	20	11.04	6.12	8.79	0.41
H-S3	8.31	52	96	320	152	20.8	10.56	6.01	7.79	0.51
H-S4	8.25	46	86	320	126	21.6	7.68	5.81	7.59	0.2
H-S5	8.2	46	94	300	152	22.4	9.12	5.76	8.57	0.4
H-S6	8.31	46	98	320	140	20	11.52	6.31	7.98	0.31

183 **Vertical (V), Horizontal (H), Chloride (Cl), Hardness (H), Alkalinity (Alkali), Calcium (Ca), Magnesium**  
 184 **(Mg), Dissolved oxygen(DO) and Biological Oxygen Demand (BOD). Values that exceed permissible**  
 185 **limits are in Numbers in bold.**

186 Water samples were also collected at a depth of 2m from the surface at the same locations  
 187 and the analysis is presented in (Table 2b).  
 188

189 **Table 2b: Physico-chemical parameters Water Samples At 2m Depth (Pre monsoon**  
 190 **December,2021)**

Location	pH	Cl	H	TDS	Alkali	Ca	Mg	T	DO	BOD
Units		mg/L	mg/L	ppm	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
Desirable limit	6.5	250	300	500	200	75	30	<b>5</b>	-	-
Permissible limits	8.5	1000	600	2000	600	200	100	<b>10</b>	5	5
VS1-D1	8.32	48	104	300	140	20.8	12.48	<b>14.5</b>	7.6	0.01
VS2-D2	8.23	44	108	320	132	22.4	12.48	6.09	7.99	0.2
VS3-D3	8.29	42	100	310	134	20.8	11.52	5.55	7.5	0.1
VS4-D4	8.31	44	98	310	136	18.4	12.48	5.54	7.31	0.3
VS5-D5	8.42	50	100	300	114	29.6	6.24	7.18	8.29	0.21
VS6-D6	8.34	46	98	310	136	24	9.12	6.17	8.19	0.3
H-S1-D1	8.31	52	96	310	124	16	13.44	6.34	7.79	0.2
H-S2-D2	8.35	52	98	310	154	20	11.52	5.8	8.59	0.99
H-S3-D3	8.34	52	92	320	134	20	10.08	5.28	8.29	0.39
H-S4-D4	8.23	52	98	320	138	19.2	12	6.63	8	0.22
H-S5-D5	8.34	50	98	320	150	20	11.52	6.95	8.39	0.4
H-S6-D6	8.42	48	96	310	144	18.4	12	5.71	7.5	0.11

191 **Vertical (V), Horizontal (H), Depth (D), Chloride (Cl), Hardness(H), Alkalinity (Alkali), Calcium (Ca),**  
 192 **Magnesium (Mg), Dissolved oxygen(DO) and Biological Oxygen Demand (BOD). Values that exceed**  
 193 **permissible limits are in Numbers in bold.**

194 **4.1.2 Post monsoon**

195 Surface and 2m depth of water samples in Post monsoon (May, 2022) indicated that pH,  
 196 chloride (Cl), hardness(H), TDS, alkalinity (Alkali), calcium (Ca), magnesium (Mg), dissolved  
 197 oxygen (DO) and biological oxygen demand (BOD) are within permissible limits (Table 3a).  
 198 Turbidity in the surface and 2m depth water samples are high in most of the locations were  
 199 found to high that exceeding the permissible limits indicated small sized particles are in  
 200 suspension and hinder light penetration. This intern suggests less amount of dissolved  
 201 oxygen and triggered to form eutrophication, algae bloom and cyanobacteria (Table 3b).  
 202 Surface water samples were collected on 10-05-2022 and analyzed in the laboratory.

203 **Table 3a: Physico-chemical parameters Surface Water Samples (Post monsoon May,**  
 205 **2022).**

Location	pH	Cl	H	TDS	Alkali	Ca	Mg	T	DO	BOD
Units		mg/L	mg/L	ppm	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
Desirable limit	6.5	250	300	500	200	75	30	<b>5</b>	-	-
Permissible limits	8.5	1000	600	2000	600	200	100	<b>10</b>	5	5
VS1	8.5	54	102	350	142	48	54	<b>10</b>	6.51	0.6
VS2	8.4	54	98	350	136	34	64	<b>11.8</b>	6.31	0.7
VS3	8.4	60	102	320	140	40	62	<b>12.1</b>	6.41	0.8
VS4	8.5	54	108	350	150	38	70	8.61	6.41	0.3
VS5	8.3	56	102	350	154	36	66	8.82	6.41	0.4
VS6	8.3	52	108	350	162	38	70	8.14	6.51	0.5
H-S1	8.5	52	104	320	144	34	70	<b>12.3</b>	6.11	0.2

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H-S2	8.5	52	98	340	144	38	60	<b>12.7</b>	6.31	0.1
H-S3	8.4	54	112	350	148	56	56	<b>10.5</b>	6.31	0.3
H-S4	8.5	60	106	350	142	66	40	<b>11.7</b>	6.41	0.3
H-S5	8.4	60	104	350	146	38	66	<b>12.7</b>	6.61	0.6
H-S6	8.5	58	104	350	138	36	68	<b>12.6</b>	6.41	0.2

206 Vertical (V), Horizontal (H), Depth (D), Chloride (Cl), Hardness(H), Alkalinity (Alkali), Calcium (Ca),  
 207 Magnesium (Mg), Dissolved oxygen (DO) and Biological Oxygen Demand (BOD). Values that exceed  
 208 permissible limits are in Numbers in bold.

209 Water samples were also collected at a depth of 2 m from the surface at  
 210 the same locations and the analysis is presented in (Table 3b).

211 **Table 3b: Physico-chemical parameters Water Samples At 2m Depth (Post-monsoon**  
 212 **May,2022).**

Location	pH	Cl	H	TDS	Alkali	Ca	Mg	T	DO	BOD
Units		mg/L	mg/L	ppm	mg/L	mg/L	mg/L	NTU	mg/L	mg/L
Desirable limit	6.5	250	300	500	200	75	30	<b>5</b>	-	-
Permissible limits	8.5	1000	600	2000	600	200	100	<b>10</b>	5	5
VS1-D1	8.5	60	122	350	144	36	86	<b>11.9</b>	6.41	0.5
VS2-D2	8.4	64	122	320	146	44	78	<b>11.9</b>	6.41	0.5
VS3-D3	8.4	62	110	320	138	38	72	<b>10.3</b>	6.41	0.4
VS4-D4	8.5	60	122	350	148	44	78	<b>11.4</b>	6.31	0
VS5-D5	8.5	60	104	340	144	44	60	<b>10.1</b>	6.21	0
VS6-D6	8.6	56	112	340	144	50	62	<b>11.2</b>	6.51	0.4
H-S1-D1	8.4	56	106	360	142	46	60	<b>11.1</b>	6.5	0.1
H-S2-D2	8.5	68	104	350	154	52	52	<b>10.4</b>	6.6	0.1
H-S3-D3	8.6	70	106	350	140	38	68	8.52	6.9	0.4
H-S4-D4	8.6	62	102	350	144	42	60	<b>10.9</b>	6.9	0.4
H-S5-D5	8.5	64	106	350	138	50	56	<b>10.9</b>	6.9	0.1
H-S6-D6	8.5	64	110	340	144	48	62	<b>11.5</b>	6.9	0.3

213 Vertical (V), Horizontal (H), Depth (D), Chloride (Cl), Hardness(H), Alkalinity (Alkali), Calcium (Ca),  
 214 Magnesium (Mg), Dissolved oxygen (DO) and Biological Oxygen Demand (BOD). Values that exceed  
 215 permissible limits are in Numbers in bold.

## 216 4.2 Water Quality Index (WQI)

### 217 4.2.1 Pre monsoon

218 Seasonal Water quality index (WQI) for Shanti Sagara reservoir in pre monsoon,  
 219 (December, 2021) has been calculated by arithmetic index method which are specified the  
 220 equations previously (Brown et al., 1972). By this equations related to drinking water  
 221 standards specifications of (IS 10500: 2012) the selected physico-chemical parameters of  
 222 drinking water has been calculated with water quality index (Table 4a). The water quality  
 223 status of Shanti Sagara reservoir is in range 51-75 which is poor and should be treated  
 224 before consumption of water.  
 225

226 **Table 4a: Shanti Sagara reservoir drinking WQI for Pre monsoon December, 2021.**

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Characteristics	Std. (sn) values	1/Sn	$\sum 1/Sn$	K	Wu	Av	Mn	Mn/sn	Si	Wu*Si WQI
pH	8.5	0.11	0.73	1.35	0.15	7	8.31	0.97	87.33	13.93
Chlorides	1000	0.01	0.73	1.35	0.01	0	55.5	0.05	5.55	0.07
Hardness	600	0.01	0.73	1.35	0.02	0	104.6	0.17	17.44	0.03
TDS	2000	0.05	0.73	1.35	0.06	0	317.2	0.15	15.86	0.01
Alkalinity	600	0.01	0.73	1.35	0.02	0	140.4	0.23	23.40	0.05
Calcium	200	0.05	0.73	1.35	0.06	0	22.8	0.11	11.44	0.07
Magnesium	100	0.01	0.73	1.35	0.01	0	11.5	0.11	11.5	0.15
Turbidity	5	0.2	0.73	1.35	0.27	0	7.26	1.45	145.2	39.37
Do	5	0.2	0.73	1.35	0.27	14.6	7.86	1.57	70.20	19.04
BOD	5	0.2	0.73	1.35	0.27	0	0.4	0.08	8	2.16
									<b>WQI=</b>	<b>74.86</b>

227 Standard values of n<sup>th</sup> parameter (Sn), Constant (K), Unit weight (Wu), Actual values (Av), Mean  
228 concentration of n<sup>th</sup> parameter (Mn), Sub-index (Si).

#### 229 4.2.2 Post monsoon

230 Seasonal Water quality index (WQI) for Shanti Sagara reservoir in post monsoon,  
231 (May, 2022) has been calculated by arithmetic index method which are specified the  
232 equations previously (Brown et al., 1972).By this equations related to drinking water  
233 standards specifications of (IS 10500:2012) the selected physicochemical parameters of  
234 drinking water has been calculated with water quality index (Table 4b). The water quality  
235 status of Shanti Sagara reservoir is in range 76-100 which is very poor and should be treated  
236 before consumption of water.  
237

238 **Table 4b: Shanti Sagara reservoir drinking WQI for Post monsoon May, 2022.**

Characteristics	Std. (sn) values	1/Sn	$\sum 1/Sn$	K	Wu	Av	Mn	Mn/Sn	Si	Wu*Si WQI
pH	8.5	0.11	0.73	1.35	0.15	7	8.46	0.99	97.33	15.52
Chlorides	1000	0.01	0.73	1.35	0.01	0	56.78	0.05	5.67	0.00
Hardness	600	0.01	0.73	1.35	0.02	0	107	0.17	17.83	0.04
TDS	2000	0.05	0.73	1.35	0.00	0	343	0.17	17.15	0.01
Alkalinity	600	0.01	0.73	1.35	0.02	0	144	0.24	24	0.05
Calcium	200	0.05	0.73	1.35	0.06	0	42	0.21	21	0.14
Magnesium	100	0.01	0.73	1.35	0.01	0	64	0.64	64	0.86

\*

Turbidity	5	0.2	0.73	1.35	0.27	0	10	2	200	54.23
Do	5	0.2	0.73	1.35	0.27	14.6	6.4	1.28	85.41	23.16
BOD	5	0.2	0.73	1.35	0.27	0	0.33	0.06	6.6	1.78
									<b>WQI=</b>	<b>95.84</b>

239 Standard values of n<sup>th</sup> parameter (Sn), Constant (K), Unit weight (Wu), Actual values (Av), Mean  
 240 concentration of n<sup>th</sup> parameter (Mn), Sub-index (Si).

### 241 4.3 Reservoir Trophic Status

242 TSI is mainly depend on (TP, TN, and secchi depth) and the criteria of the trophic  
 243 state index is classified as (Nurnberg criteria & Swedish criteria). Hence Total Phosphorous  
 244 (TP), Total Nitrogen (TN) and Secchi depth (SD) exceeds the value of the criteria by that we  
 245 can classified which criteria is leading the TSI hence it is (Hypereutrophic) in both the criteria  
 246 and secchi depth is found to be lesser than the criteria (Table 5).

247 **Table 5: Shanti Sagara reservoir Post monsoon Trophic State Carlson's Classification**  
 248 **1977.**

SL no	Latitude	Longitude	TN mg/L	TP mg/L	SD (m)	TSI <sub>SD</sub>	TSI <sub>TN</sub>	TSI <sub>TP</sub>	Ratio of (TN :TP)
1	14.131	75.887	27.27	2.1	0.495	70.13	101.7	14.84	12.98
2	14.133	75.885	29.3	6.5	0.5	69.98	102.7	31.14	4.65
3	14.137	75.891	31.08	7.1	0.495	70.13	103.6	32.41	5.22
4	14.134	75.890	18.45	7.9	0.5	69.98	96.16	33.95	2.33
5	14.132	75.895	25.47	10.4	0.5	69.98	100.7	37.91	2.43
6	14.130	75.892	19.25	7.2	0.5	69.98	96.77	32.61	2.67
<b>Mean</b>			<b>25.13</b>	<b>6.86</b>	<b>0.49</b>				
<b>mg/L</b>			<b>25136</b>	<b>6860</b>					

247 **Total Nitrogen (TN), Total Phosphorous (TP), Secchi depth (SD) and Trophic State index (TSI).**

248 **Hypereutrophic:** It is the geography of water body where rich in the nutrients and minerals  
 249 present in the water such as phosphorous, nitrogen etc it lead to higher the water from the  
 250 surface that dissolved oxygen reduce in the summer cause to fish kill, hypereutrophic  
 251 classification leads to high nutrients and minerals present in the water forms algal scum  
 252 (Cyanobacteria) and few amount of macrophytes which floats on the surface of the water and  
 253 this hypereutrophic dominance the rough fish in the water (Fig. 5).



254 **Fig. 5 The presence of cyanobacteria and macrophytes.**

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255 Nitrogen and phosphorous are found to be more in post monsoon (May, 2022), runoff is  
 256 contributed from the reservoir catchment. This indicates that external nutrient loading is high  
 257 (Precipitation occurred). Low TN: TP ratios are found in the freshwater reservoirs for five  
 258 locations and these ratios are expected to deplete near the reservoir bed (Table 5). Changes  
 259 in TN and TP availability, low TN: TP ratios indicate the phytoplankton growth, in the  
 260 reservoir system at a given time. The results indicate excess P is released from the sediment  
 261 relative to N (Table 5). Excess phosphorous released under anoxic conditions facilitates  
 262 production of cyanobacteria and dominates when TN: TP ratios are low (Nikolia and  
 263 Dzialowski, 2014). Internal P loading plays an important role in algal blooms. Nurnberg  
 264 (1985) showed that 30% of hypolimnetic P was incorporated into plankton while another 30%  
 265 remained as soluble reactive phosphorus suggested that the internal load altered the balance of nutrient  
 266 ratios to favor blue green algae.

## 267 5. Reservoir Nutrients

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Reservoir management has historically focused on controlling external nutrient loads to improve water quality, but internal mechanisms also contribute to eutrophication processes, that cannot be neglected. Therefore the nutrient cycle requires assessment of both external and internal load

### 272 5.1 External load

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Reservoir management has focused in controlling the external loads but the formation of the eutrophication process cannot be neglected. However, the nutrient entering into the water from the catchment characteristics, by the usage of agriculture crops, fertilizing and sewage disposal from the rural areas entering in to the reservoir from the catchment, as more as nutrients usage in the land for the crop yield, irrigation and agricultural purpose the nutrients added in land that leads to from the eutrophication in the water from runoff the sediments enters into the water and settled down in the bottom of the reservoir (Table 6), for a period change in temperature the water starts formation of algae blooms and water gets eutrophic in the surface water that is nuisance for the aquatic life and consumption of water (Ozkundakci et al., 2011; Ramesh and Krishnaiah, 2014).

283 **Table 6: Shanti Sagara Reservoir bed Soil Characteristics and Nutrient status for Post**  
 284 **monsoon (May, 2022).**

SL no	Location	Land use	Soil Texture	TN kg/acre	TP kg/acre	MC (%)	SG (%)	LL (%)	PL (%)	Insitu DD (gms/cc)
1	Kogaluru	Crop land	Silty clay	202	10	6.365	2.64	33.74	NIL	0.25
2	Santhebennur	Crop land	Sandy loam	217	9.6	6.42	2.71	34.91	NIL	0.19
3	Rangapura	Crop land	Silty loam	201	11	13.05	2.73	37.82	12.51	0.15
4	Channagiri	Dry land	Sandy clay loam	205	10.5	6.45	2.6	31.03	NIL	0.24
5	Rudrapura	Bare land	Sandy clay	210	12.4	6.65	2.6	37.16	12.045	0.23

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6	Mallapura	Crop land	Silty clay	211	10.2	7.03	2.68	42.05	13.065	0.21
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286 **Total Nitrogen (TN), Total Phosphorous (TP), Moisture content (MC), Specific gravity (SG),**  
 287 **Liquid limit (LL), Plastic limit (PL) and Insitu dry density (Insitu DD).**

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 289 Moreover, the high nutrient concentration also owing to the domestic water and the  
 290 sewage water has contributed to high concentration of phosphorous (P) in Rudrapura and  
 291 Jakli near Somalapura.

292 **5.2 Internal load**  
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294 However, as nutrients enter along with sediment and runoff in the reservoir, they build up in  
 295 the sediment creating the potential for an internal load (Table 7). Phosphorus tends to  
 296 accumulate in reservoir sediments leading to an excess of DRP (dissolved reactive  
 297 phosphorous) in the water column during summer. The release of phosphorus (P) from  
 298 anoxic sediments in the reservoir being the major source of P helped to reduce TN, TP  
 299 ratios and create N limiting conditions owing to difference in temperature. This encourages  
 300 the growth of cyanobacteria, which often grow algal bloom proportions (Nikolai and  
 301 Dzialowski, 2014). Internal load High internal Phosphorous loads in shallow reservoirs are  
 302 worldwide. There is evidence of recent increases in the Trophic level index that is (Declining  
 303 trophic state) of (Junior et al., 2018) that are characterized by high internal nutrient loads  
 304 comparable to their catchment loads on an annual basis (Nikolai and Dzialowski, 2014;  
 305 Luis and Cabral, 2021).

Table 7: Shanti Sagara Reservoir bed Silt Characteristics and Nutrient status for  
 311 **Post monsoon (May, 2022).**  
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SL no	pH	TDS (mg/L)	Total Nitrogen (kg/acre)	Total Phosphorous (kg/acre)
1	7.3	430	159	10.1
2	7.5	410	162	11.4
3	7.2	620	161	13.4
4	7.3	500	168	10.3

314 **6.0 CONCLUSION**

315  
 316 Water quality index based on physico-chemical parameter was found to be poor in the pre monsoon, December  
 2021 and very poor in the post monsoon, May 2022. Internal loading and external loading in the process of  
 eutrophication have a significant  
 317 impact on water quality. Internal phosphorus (P) loading from sediment is associated with  
 318 an increased (P) in water and is a threat to water quality status. Earlier studies have  
 319 hypothesized that internal (P) loads may be as high as external places, especially in (P)  
 320 developed landscapes such as agricultural areas, whereas Internal (P) loads in eutrophic  
 321 conditions are infrequently quantified or differentiate to external (P) loads (Ozkundakci et al.,  
 322 2011). The study suggests that the trophic status of the reservoir, measured quantitatively  
 323 with the Trophic Level Index (TLI), could move from highly eutrophic to mesotrophic with  
 324 high external and internal loads of both Nitrogen and Phosphorous in reservoirs located in

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325 semiarid climate. The measure of the nutrient load reductions is significant of a major  
326 challenge in being able to effect growth across trophic state for eutrophication in the  
327 reservoir (Ozkundakci et al., 2011; Song et al., 2017). The reduction of nutrients and  
328 eutrophication level in the water that limits primary production is often a critical element of  
329 eutrophication. This suggests reduction in external load entering the reservoir as the top  
330 priority in reservoir catchment this can be achieved that nutrient management soil  
331 conservation structure and sewage treatment plant for rural settlements.

Limited silt samples were collected from the reservoir bed and the chlorophyll a was not accounted while calculating the trophic status of the reservoir. The results would have given us the better picture for environmental policy decisions in the assessment process.

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