Asian Journal of Environment & Ecology

19(3): 32-47, 2022; Article no.AJEE.92562
ISSN: 2456-690X

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

V. Rohan Desai [aφ*] and Tejaswini Nikhil Bhagwat [b#]

[a] Department of Environmental Engineering, University BDT College of Engineering, Davangere, Karnataka, India.
[b] Department of Civil Engineering, University BDT College of Engineering, Davangere, Karnataka, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEE/2022/v19i3411

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/92562

Original Research Article

Received 15 August 2022
Accepted 22 October 2022
Published 31 October 2022

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 increasers 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

---

[φ] PG Student;
[#] Associate Professor;
**Corresponding author: E-mail: rohanrajdesai35@gmail.com;*

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.

1. INTRODUCTION

The increasing water demand to cover the needs of raising production and drinking water supply under climate change makes it imperative to plan for optimal use of water resources especially in semi-arid regions [1]. Water shortages in the semi-arid tropics that support 15% of the world's population. have tripled from 6% to 35% between 1960 to2005, and the gap continues to expand with population growth especially in Southern Asia [2,3]. The significance of reservoir in dry-season, especially in water scare 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 [4]. Hillside reservoirs and small dams in South India had been a strategic priority since ancient times for water security [5-7]. 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 [8,9]. 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.

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 [10]. 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 move vertically, and the vigorous agitation of water lead to toxic substance in sediment contaminant diffusing into water, which poses a direct threat to water safety and even results in incidents of dead fish. Water temperature changes with season and reservoirs would turn water over at the seasonal transition period, which accelerate the transformation of sediment contaminants in reservoirs and bring contaminants to surface [11,12]. Researches show that the released nutrients by turning over could promote the reproduce of algae in spring. The thermocline in summer would decrease the exchange of dissolved oxygen in bottom layer water, which reduces the content of oxygen in reservoirs. With rainstorm disturbance and and seasonal changes, the released contaminants are brought to the surface, which promote the growth of algae [13,14]. 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 [9,10,15]. High rates of sedimentation in many reservoirs and better care of long term sustainability have emphasized the importance of reservoir sedimentation.

The over-enrichment of nutrients can leads to the major source of water pollution in the semi arid tropics. The link between eutrophication- the over-enrichment of surface water with plant nutrients and the dangers of public health have long been predicted but poorly documented in developing countries. However, recent concerns about bacterial indicators such as (1) The spread of Escherichia coli and disease in sewage-enriched water, (2) Trihalomethanes in chlorine-treated eutrophic reservoirs, and (3) The occurrence of attendant human diseases, all in the eutrophic estuarine surface. As suspected, this is not only an aesthetic, aquatic community problem, but also a public health problem. An important component of the Environmental Protection Agency's (EPA's) national nutrition strategy is the National Nutrition Strategy for the Development in the Regional Nutrition Standards (U.S. EPA, 1998), which is a body-specific development of water [16,17]. Criteria that address the contamination problems are framed based on the technical guidance documents and thus are be used to assess the vulnerability of a potential nutrient-related trophic condition. Owing to the diverse geographical and climatic conditions, permissible nutritional standards need revision for reservoirs based on water availability. Instead, nutritional standards should be developed at the state, regional, or individual water body level [10,18,19]. Thus the objective of the present paper is to monitor the water quality status of a multipurpose reservoir located in semiarid trophics that serves for urban water supply and irrigation.

2. MATERIALS AND METHODS

2.1 Study Area

Shanti Sagara reservoir also known as Sulekere locally, which is inlet of the River Tungabhadra. The reservoir is constructed in the (11^{th} and 12^{th} century). Shanti Sagara is 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^2, 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.

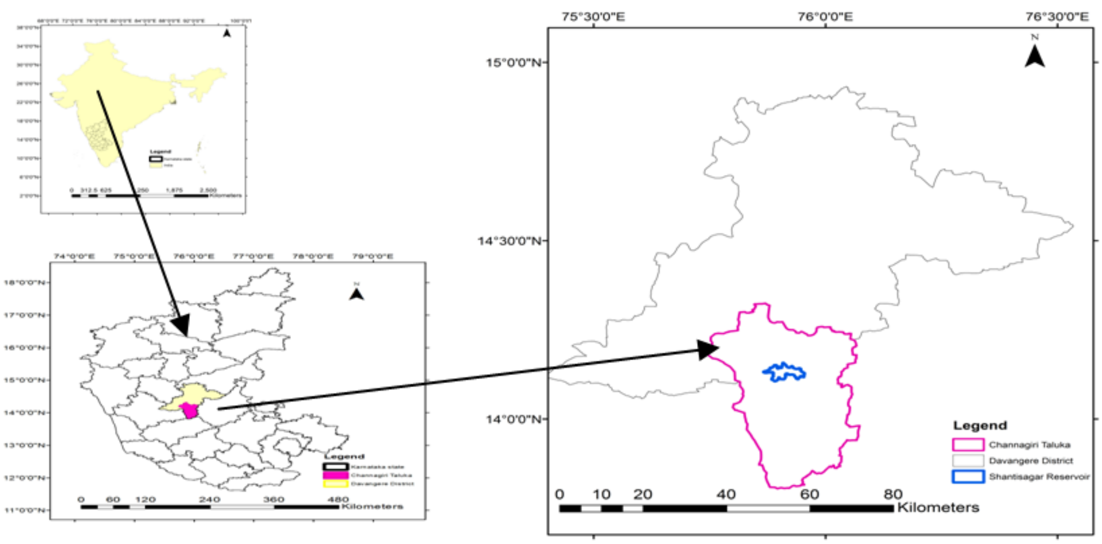

Fig. 1. Location of Shanti Sagara reservoir, Channagiri Taluk, Davanagere District, Karnataka

2.2 Experimental Details

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.

2.3 Water Sampling

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.

Water samples are collected within the Shanti Sagara reservoir. The collected samples were brought for the laboratory tests. Water samples were tested for the following parameters e.g. pH (Electrometric method), Turbidity test (Nephlo meter method), Total dissolved solids (Electrometric method), Chloride (Volumetric method), hardness (Volumetric method0, calcium (Volumetric method), Magnesium (Volumetric method), Dissolved oxygen (Winkler method), Biological oxygen demand (Dilution method).

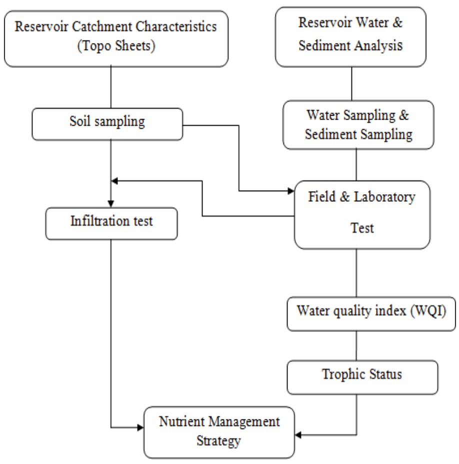

Fig. 2. Methodology adopted to investigate drinking water quality and nutrient management in Shanti Sagara reservoir

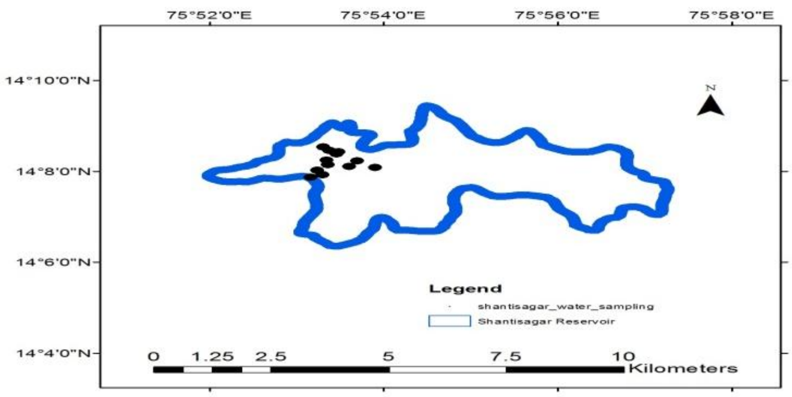

Fig. 3. Seasonal water sampling location in Shanti Sagara reservoir, Channagiri Taluk, Davanagere District, Karnataka

In six well distributed locations, Soil samples were collected in the reservoir catchment during the post monsoon (May, 2022). Soil parameters were analyzed inlaboratory 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.

Water quality index parameters are calculated by the method of weighted arithmetic mean method as follows Unit weight (Wu), Constant (K), Standard values of n^{th} parameter (Sn), Sub-index (Si), Mean concentration of n^{th} parameter (Mn), Actual values Av).

Calculate unit weight (W_u) for each parameter by using formula:

$$Wu = K / Sn \qquad \text{Eqn 1}$$

Where,

$$K = \frac{1}{\frac{1}{S1} + \frac{1}{S2} + ... + \frac{1}{Sn}} = \frac{1}{\sum \frac{1}{Sn}} \qquad \text{Eqn 2}$$

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

Where,

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

Mv =Mean concentration of the n^{th} parameter

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

Integrating Eqn 1 and Eqn 2, WQI is calculated:

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

In the year 1977, Carlson classified a trophic state index to find out trophic status of the specified reservoir (Table 1). By the developed of the TSI he established the relationship between secchi depth and used the secchi depth range to find out the trophic state index (TSI_{SD}).

Secchi depth TSI (TSI_{SD}) = 60-(14.41. [Ln (Secchi $depth_{average}$)]) Eqn 5

Total Nitrogen TSI (TSI_{TN}) = Ln(TN)*14.31* 54.45 Eqn 6

Total Phosphorous TSI (TSI_{TP}) = Ln(TP) *14.42+ 4.15 Eqn 7

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

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

3. RESULTS AND DISCUSSION

3.1 Water Quality Assessment

3.1.1 Physico-chemical parameters

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

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

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

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

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

3.2 Water Quality Index (WQI)

3.2.1 Pre monsoon

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

3.2.2 Post monsoon

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

3.3 Reservoir Trophic Status

TSI is mainly depend on (TP, TN, and secchi depth) and the criteria of the trophic state index is classified as (Nurnberg criteria & Swedish criteria) [20,21]. Hence Total Phosphorous (TP), Total Nitrogen (TN) and Secchi depth (SD) exceeds the value of the criteria by that we can classified which criteria is leading the TSI hence it is (Hypereutrophic) in both the criteria and secchi depth is found to be lesser than the criteria (Table 5).

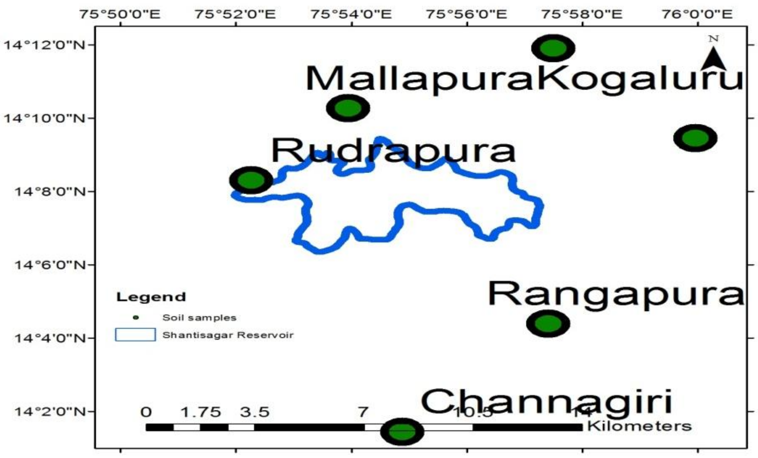

Fig. 4. Soil sampling locations of Shanti Sagara reservoir catchment (May, 2022)

Table 1. Criteria for the trophic status index classification (TSI)

Trophic status criteria	**(TP) µg/L**	**(TN) µg/L**	**(SD) in (m)**		**(TSI) µg/L**
			Mean	**Max**	
(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
µg/L	**25136**	**6860**	**0.498**		

Table 2a. Physico-chemical parameters surface water samples (pre monsoon 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
Desirablelimit	6.5	250	300	500	200	75	30	**5**	-	-
Permissiblelimits	8.5	1000	600	2000	600	200	100	**10**	5	5
VS1	8.34	44	96	300	140	21.6	10.08	**25.3**	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

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

Table 2b. Physico-chemical parameters water samples at 2m depth (Pre monsoon 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
Desirablelimit	6.5	250	300	500	200	75	30	**5**		
Permissiblelimits	8.5	1000	600	2000	600	200	100	**10**	5	5
VS1-D1	8.32	48	104	300	140	20.8	12.48	**14.5**	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

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

Table 3a. Physico-chemical parameters surface water samples (Post monsoon 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	**5**		
Permissiblelimits	8.5	1000	600	2000	600	200	100	**10**	5	5
VS1	8.5	54	102	350	142	48	54	**10**	6.51	0.6
VS2	8.4	54	98	350	136	34	64	**11.8**	6.31	0.7
VS3	8.4	60	102	320	140	40	62	**12.1**	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	**12.3**	6.11	0.2
H-S2	8.5	52	98	340	144	38	60	**12.7**	6.31	0.1

Location	pH	Cl	H	TDS	Alkali	Ca	Mg	T	DO	BOD
H-S3	8.4	54	112	350	148	56	56	**10.5**	6.31	0.3
H-S4	8.5	60	106	350	142	66	40	**11.7**	6.41	0.3
H-S5	8.4	60	104	350	146	38	66	**12.7**	6.61	0.6
H-S6	8.5	58	104	350	138	36	68	**12.6**	6.41	0.2

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

Table 3b. Physico-chemical parameters water samples at 2m depth (post-monsoon 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	**5**	-	-
Permissiblelimits	8.5	1000	600	2000	600	200	100	**10**	5	5
VS1-D1	8.5	60	122	350	144	36	86	**11.9**	6.41	0.5
VS2-D2	8.4	64	122	320	146	44	78	**11.9**	6.41	0.5
VS3-D3	8.4	62	110	320	138	38	72	**10.3**	6.41	0.4
VS4-D4	8.5	60	122	350	148	44	78	**11.4**	6.31	0
VS5-D5	8.5	60	104	340	144	44	60	**10.1**	6.21	0
VS6-D6	8.6	56	112	340	144	50	62	**11.2**	6.51	0.4
H-S1-D1	8.4	56	106	360	142	46	60	**11.1**	6.5	0.1
H-S2-D2	8.5	68	104	350	154	52	52	**10.4**	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	**10.9**	6.9	0.4
H-S5-D5	8.5	64	106	350	138	50	56	**10.9**	6.9	0.1
H-S6-D6	8.5	64	110	340	144	48	62	**11.5**	6.9	0.3

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

Table 4a. Shanti Sagara reservoir drinking WQI for pre monsoon December, 2021

Characteristics	Std.(sn) values	1/Sn	∑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
									WQI=	**74.86**

Standard values of n^{th} parameter (Sn), Constant (K), Unit weight (Wu), Actual values (Av), Mean concentration of n^{th} parameter (Mn), Sub-index (Si)

Table 4b. Shanti Sagara reservoir drinking WQI for post monsoon May, 2022

Characteristics	Std.(sn) values	1/Sn	∑1/Sn	K	Wu	Av	Mn	Mn/Sn	Si	Wu*SiWQI
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
									WQI=	**95.84**

Standard values of n^{th} parameter (Sn), Constant (K), Unit weight (Wu), Actual values (Av), Mean concentration of n^{th} parameter (Mn), Sub-index (Si)

Table 5. Shanti Sagara reservoir post monsoon Trophic State Carlson's Classification 1977

Sl. No.	Latitude	Longitude	TN mg/L	TP mg/L	SD (m)	TSI_{SD}	TSI_{TN}	TSI_{TP}	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
		Mean	**25.13**	**6.86**	**0.49**				
		mg/L	**25136**	**6860**					

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

Hypereutrophic: It is the geography of water body where rich in the nutrients and minerals present in the water such as phosphorous, nitrogen etc it lead to higher the water from the surface that dissolved oxygen reduce in the summer cause to fish kill, hypereutrophic classification leads to high nutrients and minerals present in the water forms algal scum (Cyanobacteria) and few amount of macrophytes which floats on the surface of the water and this hypereutrophic dominance the rough fish in the water (Fig. 5) [22,23].

Nitrogen and phosphorous are found to be more in post monsoon (May, 2022), runoff is contributed from the reservoir catchment. This indicates that external nutrient loading is high (Precipitation occurred) [24]. Low TN: TP ratios are found in the freshwater reservoirsfor five locations and these ratios are expected to deplete near the reservoir bed (Table 5). Changes in TN and TP availability, low TN: TP ratios indicate the phytoplankton growth, in the reservoir system at a given time. The results indicate excess P is released from the sediment relative to N (Table 5). Excess phosphorous released under anoxic conditions facilitates production of cyanobacteria and dominates when TN: TP ratios are low [25]. Internal P loading plays an important role in algal blooms. Nurnberg (1985) showed that 30% of hypolimnetic P was incorporated into plankton while another 30% remained as soluble reactive suggested that the internal load altered the balance of nutrient ratios to favor blue green algae [26].

3.4 Reservoir Nutrients

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.

3.5 External Load

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 settledown 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 [27,28].

Fig. 5. The presence of cyanobacteria and macrophytes

Table 6. Shanti Sagara reservoir bed soil characteristics and nutrient status for post monsoon (May, 2022)

Sl. No.	Location	Landuse	Soil Texture	TN kg/acre	TP kg/acre	MC (%)	SG (%)	LL (%)	PL (%)	Insitu DD (gms/cc)
1	Kogaluru	Cropland	Siltyclay	202	10	6.365	2.64	33.74	NIL	0.25
2	Santhebennur	Cropland	Sandyloam	217	9.6	6.42	2.71	34.91	NIL	0.19
3	Rangapura	Cropland	Siltyloam	201	11	13.05	2.73	37.82	12.51	0.15
4	Channagiri	Dryland	Sandy clayloam	205	10.5	6.45	2.6	31.03	NIL	0.24
5	Rudrapura	Bareland	Sandy clay	210	12.4	6.65	2.6	37.16	12.045	0.23
6	Mallapura	Cropland	Siltyclay	211	10.2	7.03	2.68	42.05	13.065	0.21

Total Nitrogen (TN), Total Phosphorous (TP), Moisture content (MC), Specific gravity (SG), Liquid limit (LL), Plastic limit (PL) and Insitu dry density (Insitu DD)

Table 7. Shanti Sagara reservoir bed silt characteristics and nutrient status for post monsoon (May, 2022)

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

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

3.6 Internal Load

However, as nutrients enter along with sediment and runoff in the reservoir, they build up in the sediment creating the potential for an internal load (Table 7). Phosphorus tends to accumulate in reservoir sediments leading to an excess of DRP (dissolved reactive phosphorous) in the water column during summer. The release of phosphorus (P) from anoxic sediments in the reservoir being the major source of P helped to reduce TN, TP ratios and create N limiting conditions owing to difference in temperature. This encourages the growth of cyanobacteria, which often grow algal bloom proportions [25]. Internal load High internal Phosphorous loads in shallow reservoirs are worldwide. There is evidence of recentincreases in the Trophic level index that is (Declining trophic state) of [29] that are characterized by high internal nutrient loads comparable to their catchment loads on an annual basis [25,4].

4. CONCLUSION

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 impact on water quality. Internal phosphorus (P) loading from sediment is associated with an increased (P) in water and is a threat to water quality status. Earlier studies have hypothesized that internal (P) loads may be as high as external places, especially in (P) developed landscapes such as agricultural areas, whereas Internal (P) loads in eutrophic conditions are infrequently quantified or differentiate to external (P) loads [27] The study suggests that the trophic status of the reservoir, measured quantitatively with the Trophic Level Index (TLI), could move from highly eutrophic to mesotrophic with high external and internal loads of both Nitrogen and Phosphorous in reservoirs located in semiarid climate. The measure of the nutrient load reductions is significant of a major challenge in being able to effect growth across trophic state for eutrophication in the reservoir [27,30]. The reduction of nutrients and eutrophication level in the water that limits primary production is often a critical element of eutrophication. This suggests reduction in external load entering the reservoir as the top priority in reservoir catchment this can be achieved that nutrient management soil 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.

ACKNOWLEDGEMENTS

Authors are grateful to Mr. Hanumanth B. K., Technical Assistant Engineer, Rudrapura Gram Panchayath, Channagiri for providing local details. Authors acknowledge the support provided by the Environment laboratory staff in carrying out the analysis. Authors acknowledge the support provided by the Indian council of Agricultural Research staff Taralabalu, Davangere in carrying out the analysis.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gunkel G, Lima D, Selge F, Sobral M and Calado S. Aquatic ecosystem servicesof

reservoirs in semi-arid areas: sustainability and reservoir management. Transactions on Ecology and the Environment. 2015; 197:1-14.
2. Kummu M, Ward PJ, Moel HD, Varies O. Is Physical Water Scarcity a new phenomenon?. Global assessment of water shortage over the last two millennia. Environmental Research Letter. 2010;5(3): 1-14.
3. Mady B, Lehmann P, Gorelick SM, Or D. Distribution of small reservoirs in semi-arid regions and associated evaporative losses. Environment Research Communications. 2020;2:1-10.
4. Luis AD, Cabral P. Small dams/ reservoirs site location analysis in a semi- arid region of Mozambique. Intrnational Soil and Water Conservation Research. 2021;9: 381-393.
5. Santisteban M, Grande JA, Torre ML, De la Valente T, Ceron JC. Acid mine drainage in semi-arid regions: The extent of the problem in waters of reservoirs in the Liberian pyrite Belt (SW Spain). Hydrology Research. 2015;46(1):1-12.
6. Cerco CF. Conowingo reservoir sedimentation and Chesapeake Bay: State of the science. Journal of Environmental Quality. 2016;45:882-886.
7. Chilagane NA, Kashaigili JJ, Mutayoba E, Lyimo P, Munishi P, Tam C et al. Impact of land use and land cover changes on surface runoff and sediment yield in the little Ruaha River catchment. Journal of Modern Hydrology. 2021;11:54-74.
8. Bhagwat TN, Lamani SN. Irrigation Water quality assessment in vanivilas sagar reservoir catchment. Journal of Research in Environmental and Earth Science. 2019;5(2):10-20.
9. Alahiane N, Elmouden A, Aithal A, Boutaleb S. Small dam reservoir siltation in the Atlas mountains of Central Morocco: Analysis of factors impacting sediment yield. Environmental Earth Science. 2016; 75:10-35.
10. Bergi J, Trivedi R. Seasonal variation of nutrients that influence the growth of *Cyanobacteria* in surface water reservoirs of river Tapi. Journal of Geoscience and Geomatics. 2022;10(1):18-30.
11. Cloutier RG, Sanchez M. Trophic status evaluation for 154 Lakes in Quebec, Canada: monitoring and recommendations. Water Quality Research of Journal Canada. 2007;42(4): 252-268.
12. Ghodrati M, Ghazaryan S. Agriculture water supply in semi-arid zone by underground dams. European Journal of Experimental Biology. 2013;3(3):706-711.
13. Hickey CW, Gibbs M. Lake sediment phosphorus release management decision support and risk assessment framework. New Zealand Journal of Marine and Freshwater Research. 2009;43(3): 819–856.
14. Huang J, Ji M, Xie M, Wang S, He Y, Ran J. Global semi-arid climate change over last 60 years. Climate Dynamics journal of Springer Science Media. 2016;46: 1131-1150.
15. Acharya S. Land use and land cover changes in the catchments impact the ecosystem in Phewa, Begnas and Rupa lakes, Nepal. Journal of Nepal Geological Society. 2020;60:195-205.
16. Istvanovics V. Eutrophication of lakes and reservoirs. Encyclopedia of Inland Waters. 2009;1: 157-165.
17. Mama CN, Okafor FO. Siltation In reservoirs. Nigerian Journal of Technology. 2011;30(1):1-6.
18. Filstrup CT, Downing JA. Relationship of chlorophyll to phosphorous and nitrogen in nutrient-rich lakes. Inland Waters of Journal. 2017;7(4):385-400.
19. Andaya LY. Water in the study of Southeast Asia. Kemanusiaan the Asian journal of Humanities. 2018;25(1):21-38.
20. Khadanga MK, Mishra RK, Sahu BK. Assessment of pollution and ecological risk index of heavy metals in the surface sediment of estuary and the coastal environment of Bay of Bengal. Journal of Environmental Informatics. 2022;39(1): 35-48.
21. Sharma DK. Impact of dams on river water quality. International Journal of Current Advanced Research. 2015;4(7):176-181.
22. River system and reservoir water quality: Case study of mazowe catchment, Zimbabwe. Copernicus Publications on Behalf of the International Association of Hydrological Sciences. 2018;377: 57-66.
23. Wenjie L, Zhuo D, Yi X, Shengfa Y, Wei Y. Influence of sedimentation on nitrogen and phosphorus in the three gorges reservoir. International Journal of River Basin Management. 2020;9(1):1-13.

24. Winton RS, Alamita E, Wehrli B. Reviews and syntheses: Dams, water quality Andtrophical reservoir stratification. Bio-geoscience Journal of European Geo-science. 2019;16:1657-1671.
25. Nikolai SJ, Dzialowski AR. Effects of internal phosphorous loading on nutrient limitation in a eutrophic reservoir. Elsevier Journal of Limnologica. 2014;49:33–41.
26. Zhou Z, Huang T, Ma W, Li Y, Zeng K. Impacts of water quality variation and rainfall runoff on Jinpen Reservoir, in Northwest China. Water Science and Engineering. 2015;8(4):301-308.
27. Ozkundakci D, Hamilton DP, Trolle D. Modelling the response of a highly eutrophic lake to reductions in external and internal nutrient loading. New Zealand Journal of Marine and Freshwater Research. 2011;45(2):165-185.
28. Ramesh N, Krishnaian S. Water quality assessment of Bellandur Lakes in Bangalore City, Karnataka, India. International Journal of Engineering Research and Technology. 2014;3(3): 1-5.
29. Junior JRDM, Amado AM, Vidal LDO, Mattos A, Becker. Extreme droughts drive trophical semi-arid Eutrophic reservoirs towards CO2 Sub-saturation. Acta Limnologica Brasiliensia. 2018;30(101): 1-20.
30. Song K, Adams CJ, Burgin AJ. Relative importance of external and internal phosphorus loadings on affecting lake water quality in agricultural landscapes. Ecological Engineering. Tundu C, Tumbare J and Onema JMK. Sedimentation and Its Impacts/Effects on. 2017;108:482-488.

© 2022 Desai and Bhagwat; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/92562