THERMAL ECOLOGICAL STUDIES AT RANA PRATAP SAGAR

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ABSTRACT

This paper presents the results obtained on thermal ecological studies carried out at Rana Pratap Sagar (RPS) lake during 2002 – 2004. The study includes monitoring of several water quality parameters, biological & bacterial parameters and data on thermal stratification in respect of RPS reservoir. The study reveals that the RPS water is nearly homogeneous and shows weak thermocline and chemocline patterns. Based on monitoring data, the reservoir can be assigned mild eutrophic status.

INTRODUCTION

Rana Pratap Sagar is a man made fresh water reservoir on the river Chambal and is located about 65 km away from Kota city in the state of Rajasthan. It is a balancing reservoir between Gandhi Sagar on upstream and Jawahar sagar on its down stream. On its eastern bank there exists Rawatbhata Site, comprising of multi - nuclear facilities. There are four PHWR units of Rajasthan Atomic Power Station (RAPS) which are in operations, two are under construction and another two are under advanced stage of planning. In addition to nuclear power plants the Site also houses a Heavy Water Plant and other allied facilities such as cobalt facility and waste management facilities.

RAPS draws water from RPS lake through a 300 m long conduit pipe located at lake bottom about 20 m below the surface. Duly treated low level radioactive liquid effluents from RAPS facilities are injected to the warmed condenser outlet and then allowed to discharge to RPS in a controlled manner. The warm water is likely to remain at the surface and get mixed with lake water and cooled due to dilutions, evaporation from lake surface and wind currents. The heat release to the RPS lake through condenser outlet may effect the microbiological & water uality parameters, planktonic biodiversity, fish productivity etc. and thus it is imperative to conduct a study to assess the extent of maturation of the water body to identify its present trophic level in terms of eutrophication.

Thermo-ecological studies of this reservoir has been undertaken to assess the impact / influence of thermal effluent released from nuclear facilities on the overall biological productivity & biodiversity of RPS under a DAE – BRNS Project in collaboration with Environmental Survey Laboratory, RAPS. The basic objectives of the project is to study thermal structure of RPS in relation to biotic & abiotic factors, distribution of radionuclides in water column and to assess the ultimate repository of radio nuclides in the bottom sediments of the reservoir.

MATERIALS AND METHODS

Description of the Study Area

RPS is the largest man made reservoir of Rajasthan. The reservoir has water spread area of 19600 ha and the average depth is about 25 meters. The gross water storage capacity of RPS is about 2.9 billion cubic meters at its full level. The reservoir forms part of great Ganga basin and constructed on River Chambal.

Meteorological Data

During the study period air temperature varied between 6.8 to 47.1 oC and relative humidity from less than 3 to 100%. The average rainfall was recorded as 930 mm during the study period. The wind speed showed variations between 9.7 to 28.8 km/h.

Sampling Locations

The sampling locations are indicated in Figure 1. To complete the study five sampling stations were chosen at RPS lake for sampling namely one is *Control* which is located at about 5km upstream, near *Intake* jetty of RAPS, *Discharge* area of RAPS, *Dam* side which is located about 6 km down stream and the last one is *Sentab* which is about 9 km down stream away from the discharge area of RAPS. For the collection and analysis of samples of water and lake biota, standard methods (APHA, 1985) were followed. For quality assurance inter-laboratory tests were performed.

Monthly measurements on selected water quality parameters such as water transparency and primary productivity were carried out at all the five sampling stations. Studies were also conducted depthwise at all the sampling locations. Collection, identification and density estimations for planktonic, benthic and aquatic macrophyte communities were also made using standard keys.

Equipments such as Kemmerer sampler for collection of depth wise water samples, Ekman dredge for collection of bottom sediments, hand held WTW make pH meter with temperature probe for depth wise measurements and GPS for locating the precise position of the sampling were used in a motorized boat for carrying out sampling work.

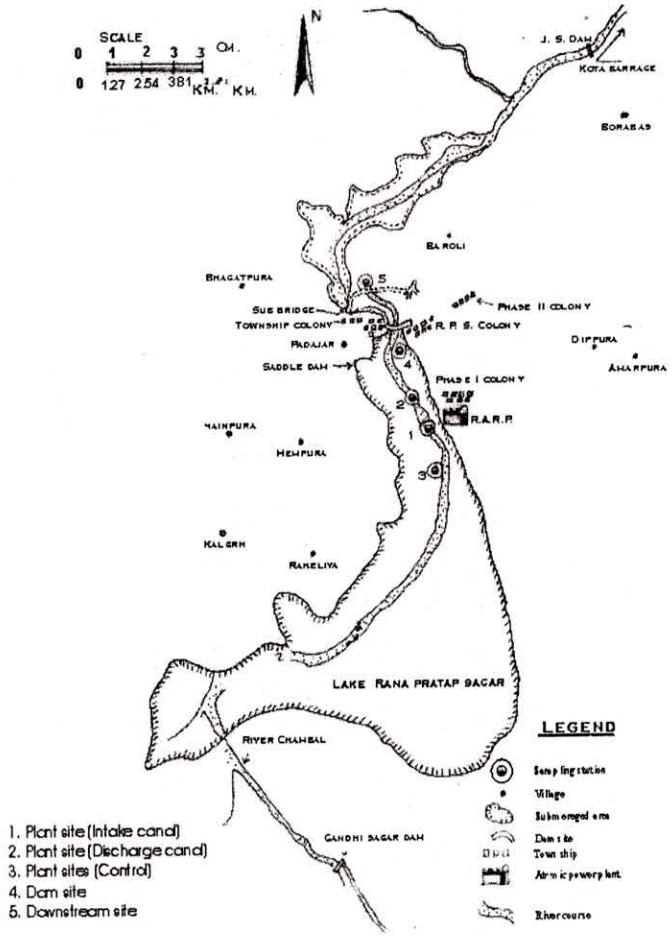

Fig. 1. Outline map of Rana Pratap Sagar

RESULTS AND DISCUSSIONS

Thermal Profiles

During the 1st year of study weak thermal stratification was recorded at depth of about 6 to 16 m during April at Dam side location. The difference in temperature was narrow at discharge point location. The thermocline during the 2nd year was observed at a depth of 18 meters and 20 meters with a gradient of 1.2 oC and 6.7 oC at Dam side location during June 2004. During the 2nd year thermal stratification was also noticed at Intake location with a difference of 4.5 oC at a depth of 8 to 10 m and at Control location at a depth of 6 to 8 m with a difference of

3.4 oC whereas at Discharge point location it was observed with a gradient of 4.5 oC at a depth of 4 to 6 meters during March 2004.

The data gathered so far indicated that there was no uniform pattern of thermal stratification in the entire reservoir. Further, the stratification was poor or totally lacking in the periods of winter and monsoon due to overturn and physical churning of water mass. The RPS water appears to be homogeneous as revealed from the parallel studies carried out on depth wise radioactive measurements (Verma, et *al.*, 2005).

Physico-Chemical Parameters

In all 24 water quality parameters were monitored on monthly basis at surface, middle and bottom water layers of RPS at all the five sampling stations. During the study the average depth of RPS was observed to be about 25 meters and thus the middle layer lies at about 10 to 13 meter from surface. The seasonal average values of salient parameters are summarized in Table-1.

Temperature and Hydrogen- ion-concentration

As expected the surface temperature of RPS was found to be lower during winter as compared to summer and monsoon. The temperature profile was observed to show a declining trend. The vertical gradient was observed to be about 8.7 oC in summer compared to 0.4 oC in winter season.

The pH value ranged from 7.6 to 9.4. Like temperature, the average pH values were observed to be lower in winter than summer and monsoon period. The pH profile showed declined trend during all the seasons. The vertical gradient was found to be 0.2 during winter as compared to 0.7 in summer season.

Electrical conductance

The conductivity ranged from 260 to 462 µS. The average vertical gradient varied between 10 to 14 µS. The highest conductivity was observed at Dam side location. Compared to control location, it was lower at discharge location.

Dissolved oxygen

The DO fluctuated between 0.2 to 12 mg/l. As expected the DO showed declined trend with the depth of lake and observed to be lowest during summer season. The DO at intake jetty and discharge location was observed to be fairly good even at the bottom layers which might be accounted due to luxuriant growth of aquatic weeds at theses locations.

BOD and COD

The average biochemical oxygen demand for surface, middle and bottom waters of RPS during the study period indicated variations between 0.6 to 3.0, 0.6 to 2.8 and 1.4 to 2.9 mg/l in winter, summer and monsoon respectively. Moreover, higher average BOD value was seen for

Table 1. Seasonal Average Physico-chemical Parameters in Rana Pratap Sagar

Sample Collected from	Temperature (^{0}c)			pH			Dissolved Oxygen (mg/ l)			BOD (mg/ l)			COD (mg/ l)			EC (µS)			Total Dis. Solids (mg/ l)		
	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S
Surface	30.2	21.0	30.8	8.5	8.1	8.5	9.6	10.6	8.4	2.9	3.0	2.8	29	48	64	299	337	325	133.0	118	137.7
Middle	30.0	20.9	25.7	8.3	8.0	8.0	7.5	8.0	4.1	2.3	1.1	0.8	35	29	50	284	321	332	123.2	92.5	126.6
Bottom	29.0	20.6	22.1	7.9	7.9	7.8	4.2	4.2	1.1	1.4	0.6	0.6	69	39	50	298	323	335	121.0	94.0	126.6

Sample Collected from	Bicar. Alkalinity (mg/ l)			Total Alkalinity (mg/ l)			NO_2 Nitrogen (µg/ l)			NO_3 Nitrogen (µg/ l)			NH_3 Nitrogen (µg/ l)			Orthophosphate (mg/ l)			Total Phosprus (mg/ l)		
	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S
Surface	93.8	99	104	101	99	104	6.0	9.0	15.0	2.0	4.0	2.0	2.0	6.0	4.0	0.16	0.11	0.07	0.69	0.39	0.36
Middle	100	104	106	100	104	106	3.0	8.0	27.0	2.0	7.0	5.0	0.0	7.0	0.0	0.20	0.07	0.09	0.55	0.78	0.50
Bottom	104	106	112	104	106	112	3.0	13.0	7.0	2.0	9.0	15.0	27.0	107	3.0	0.22	0.11	0.08	0.69	0.67	0.44

Sample Collected from	Dis. Silicate (mg/ l)			Sulphate (mg/ l)			Ca Hardness (mg/ l)			Mg Hardness (mg/ l)			Total Hardness (mg/ l)			Water Color (Hazen units)			Free CO_2 (mg/l)		
	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S
Surface	5.3	8.1	7.1	8.00	8.33	9.20	50.2	44.9	55.3	31.7	37.7	12.7	81.9	82.6	68.0	14.23	10	22.5	8.5	11.14	13.17
Middle	5.2	9.5	9.0	8.00	8.24	9.30	49.0	37.6	62.6	30.3	46.8	15.1	79.3	84.4	77.7	14.38	11	15.0	7.3	12.60	13.20
Bottom	5.0	9.5	9.7	8.43	9.44	10.16	50.0	52.4	63.4	35.0	32.8	16.3	85.0	85.2	79.7	16.88	11	15.0	10.8	14.40	15.46

winter as compared to summer and monsoon. The BOD pattern also showed the same declined trend as shown in case of DO.

The average COD values are found to be higher in summer season as compared to monsoon and winter seasons which may be due to excessive evaporation in summer season and resulting higher dissolved contents.

Water color and transparency

The water was observed more colored during summer season compared to monsoon period. The water color ranged between 14.2 to 22.5 Hazen units.

The overall oscillations in average transparency were 20 to 297 cm during the study period. The average transparency (excluding monsoon) was observed to be 221 cm. While comparing earlier records of water clarity, it may be seen that there has not been much variation in water clarity value of RPS during last three decades. According to one classification scheme (Sharma, et al, 1990) this reservoir can be assigned mild eutrophic status.

Alkalinity

The alkalinity was mainly due to bicarbonate alkalinity. The carbonate alkalinity was almost negligible and was observed to be present during June and September months whenever carbon dioxide was absent. The seasonal average alkalinity showed ascending trend with the depth of lake. The total alkalinity was observed to be lowest during monsoon and was comparatively higher during summer season. The vertical gradient was 6 to 8 mg/l during the study period.

Hardness

It ranged from 52 to 98, 46 to 100 and 74 to 102 mg/l in surface, middle and bottom layer water of RPS respectively. The average value was found to be higher during winter and lower during summer season.

Total dissolved solids

The seasonal average total dissolved solids varied from 92.5 to 137.7 mg/l. The average values were observed to be lower during winter as compared to monsoon and summer. The vertical gradient ranged from 12 to 25 mg/l.

Sulphate

It ranged between 5.9 to 13.1 mg/l. The seasonal average value of sulphate showed ascending trend with the depth of RPS Lake. It was observed to be lower in monsoon and higher during summer. The vertical gradient varied from 0.4 in monsoon to 1.0 mg/l in summer.

Dissolved silicates

The seasonal average value varied from 5.0 to 9.7 mg/l. Like hardness the silicates also showed higher values during winter season. The vertical gradient ranged from 0.3 to 2.6 mg/l.

Phosphorus

The seasonal average total phosphorus values varied from 0.36 to 0.69 mg/l. No distinct trend in phosphorus values could be observed. However, in general the orthophosphate was observed to be higher in the bottom layers.

Nitrite and nitrate nitrogen

Like phosphate no distinct trend in nitrogen parameters could be observed. However, The average nitrogen values were observed to be higher in summer and winter as compared to monsoon period. In general, the bottom layer maintained higher nitrate as compared to surface and middle layers, which may be due to its release from bottom sediments.

Ammonia nitrogen

The seasonal average value of ammonia nitrogen was observed to be higher during winter as compared to summer and monsoon periods.

The nitrogen and phosphorus did not show any significant variation and are well within the limits prescribed for drinking water. The low concentrations of these nutrients may be due to rapid utilization by phytoplankton and macrophyte communities, as reported elsewhere especially in case of eutrophic lakes (Sreenivasan, 1968).

Bacteriological Parameters

The seasonal range and average for bacteriological parameters statistics is given in Table-2. Total coliforms showed fluctuations between less than 2 (summer and winter) to 22 per 100 ml of the sample(monsoon). The mean SPC variations were between 40 to 1, 90,000 per ml of the sample. The SPC at discharge point location was higher than other study sites while MPN for Total coliforms and Faecal coliforms showed almost even distribution at all the sampling sites. The MPN for 70 samples per 100 ml of the sample were less than 2 out of the 266 samples analyzed during the study. This could be recorded as usual feature for open waters and as such does not indicate any local contamination due to anthropogenic factors.

Table 2. Seasonal range and average numbers for bacteriological parameters

PARAMETER	WINTER		SUMMER		MONSOON	
	RANGE	AVERAGE	RANGE	AVERAGE	RANGE	AVERAGE
MPN / 100 ml TC, 24 HRS.						
SURFACE	< 2 - 9	6.33	< 2 – 17	5.12	4 – 17	8.00
MIDDLE	< 2 – 6	4.0	< 2 – 5	4.33	< 2 –4	4.00
BOTTOM	< 2 – 14	10.5	< 2 – 9	5.25	< 2 – 8	5.00
48 HRS.						
SURFACE	4 – 17	9.0	< 2 -33	9.00	< 2 – 36	12.6
MIDDLE	4 – 22	11.4	< 2 - 9	3.83	< 2 – 34	13.00
BOTTOM	2 – 12	8.6	2 - 33	11.71	6 – 46	17.57
MPN / 100 ml FC, 24 HRS.						
SURFACE	< 2 – 11	4.75	< 2 – 17	5.85	2 – 17	7.27
COLUMN	< 2	< 2	< 2 – 14	6.00	< 2 – 17	13.00
BOTTOM	< 2 – 8	4.0	< 2 – 12	5.75	2 – 34	17.57
48 HRS.						
SURFACE	< 2 – 14	7.6	< 2 – 17	6.11	2 –12	5.72
MIDDLE	2 – 14	6.25	< 2 – 5	4.0	< 2 – 6	3.33
BOTTOM	< 2 – 6	5.0	2 - 33	8.14	< 2 – 12	7.00
SPC						
SURFACE	425 - 14066	3769	21 – 4840	1761	48 – 50175	7615
MIDDLE	80 - 6867	2940	410 – 70000	14964	623 – 19190	8389
BOTTOM	40 - 190000	39123	325 – 66705	16386	582 - 25230	7565

Macroinvertebrates

The average density of benthos varied between 462 to 4288 No. /m2 and rich deposition of molluscan fauna was observed at Sentab location. So far 40 types of benthos are recorded and identified. In the 2nd year the density of benthos was still higher and ranged between 5016 (summer) to 7832 No. /m2 in monsoon considering all the sampling locations. At Intake jetty and Control locations *Chironomus* larvae were observed. Comparing diversity of benthic fauna of Control with Discharge area it was observed that benthos species were higher at Control and minimum at Discharge area (44 No/m2) in March 2004. The presence of *Chironomus* also supports the eutrophic status of RPS (Cole, 1979).

Macrophytes

The seasonal range and average biomass in respect of pominent macrophytes are given in Table-3. 18 species of macrophytes have been recorded so far with *Potamogeton, Hydrilla,*

Vallisneria and *Najas minor* as prominent sp. The average biomass ranged between 0.480 to 2.068 k / m2.

Table 3. Seasonal Range and Average of Prominent Aquatic Macrophytes (Biomass kg/sq.m) of RPS Lake

Name of Species	Winter		Summer		Monsoon	
	Range	Average	Range	Average	Range	Average
Potamogeton	1.45 - 2.687	2.068	1.612 - 2.719	2.057	0.43 - 1.053	0.795
Hydrilla	0.51	0.51	0.516 - 1.721	1.032	0.41 – 1.177	0.832
Vallisneria	0.48	0.48	0.75 - 2.236	1.493	0.744 - 3.01	1.398
Najas minor	-	-	0.559	0.559	0.322 - 0.913	0.617

Plankton Biodiversity

The biodiversity of planktonic organisms has been fairly good in RPS which is evident from 91 phytoplankton and 77 zooplankton identified so far. The average density of phytoplankton ranged between 0.11 to 1677.77 Nos./ l .Quantitatively *Botryococcus braunii* was noticed in very high number from March to September. The zooplankters varied between 0.11 to 311.11 Nos / l and Rotifera dominated the same followed by Cladocera and Copepoda. The pattern of zooplankters in general remained same during the study. The dominant phyto and zooplankton of RPS during two years of the study in the three layers of the water body are listed below.

Layers	Phytoplankton	Zooplankton
Surface	*Peridinium palatinum, Microcystis aeruginosa, Fragilaria capucina, Aphanizomenon, Tabellaria, Pediastrum simplex.*	Nauplius larvae, *Keratella tropica Mesocyclops, Keratella cochlearis, Brachionus caudatus, Collotheca cornata*
Middle	*Fragilaria, Tabellaria, Aphanizomenon, Peridinium, Microcystis aeruginosa, Staurastrum chaetoceras.*	*K. cochlearis*, Nauplius larvae, *K. tropica, Mesocyclops, Testudinella patina* and *Mytilina ventralis.*
Bottom	*Fragilaria, Tabellaria, Aphanizomenon, Pediastrum simplex, Pediastrum duplex.*	Nauplius larvae, *Mesocyclops, K.tropica, K. cochlearis.*

Swayer (1966) considered *Microcystics* as an indicator of eutrophy. The presence of phytoplankton such as *Fragilaria, Cymbella, Microcystics, Aphanizomenon, Volvox ,Phormidium, Spirogyra, Ulothrix, Peridinum, Ceratium etc.* and zooplankters such as *Daphnia, Mesocyclops, Brachionus , Rotaria, Filinia, Arcella, Vorticella, Difflugia etc.,* exhibits the eutrophic status of RPS reservoir (Kaushik, 2003 & Wetzel, 1975).

Comparing biodiversity and density of plankton of Control location with other sampling locations especially with Discharge area and Dam side it was observed that phytoplankton density was higher at Dam side with low species diversity. Discharge area had higher density of phytoplankton than Control with almost the same diversity at both the locations. In case of blue green algae *Microcystis aeruginosa* and *Phormidium* showed high density at Discharge area. Among green algae *Cosmarium* showed higher density at Discharge area and was absent

at Control and Dam side locations. Similar trend have been shown by *Fragilaria capucina* among diatoms. This could be due to prevailing relatively higher temperature at this site which may be favourable for proliferation of these biota.

Zooplankton also showed similar trends with higher density at Dam side in comparison to Discharge area and Control locations. The species diversity was almost same at Discharge area, Control and Dam side during winter while during summer Dam side showed an increase in the diversity than Discharge area and Control locations. From the observed number of species it would be seen that the biodiversity of plankton appears to be fairly higher than many water bodies of Rajasthan (Sharma and Durve, 1985).

Primary Productivity

During the study period Chlorophyll "a" showed overall average value of 0.006 to 0.008 mg/m3 in monsoon and winter respectively. However, the cholorophyll contents observed at different sampling locations are fairly comparable.

The seasonal average data related to Gross Primary Productivity (GPP), Net Productivity (NPP) and Community Respiration (CR) are given in Table-4. The GPP manifested by surface water of RPS during the study period indicated seasonal average value 0.362, 0.499 and 0.285 gC/ m3/hr for winter, summer and monsoon respectively. The higher GPP average was seen for the intake jetty location as compared to other locations whereas the minimum GPP values were seen at dam side location. The values of chlorophyll were compared to GPP and phytoplankton density, it may be seen that the dam side did not show appreciably high GPP. This may be due to the fact that the planktonic counts at dam side also comprises of the algae drifted from lentic zone and their skeletal material devoid of chlorophyll thus exhibiting moderate GPP. From the productivity data, it is evident that RPS passes the mild eutrophic status (Madhusudan, *et al.*, 1984).

Table-4 : Seasonal Average of GPP,Net Primary Productivity and CR (gc/m3 /hr) in RPS Lake

Stations	Winter			Summer			Monsoon		
	GPP	NPP	CR	GPP	NPP	CR	GPP	NPP	CR
Control	0.312	0.062	0.187	0.325	0.162	0.325	0.375	0.062	0.312
Discharge Point	0.437	0.062	0.437	0.575	0.000	0.575	0.313	0.185	0.125
Intake Jetty	0.562	0.063	0.062	1.125	0.375	0.750	0.313	0.063	0.250
Dam Side	0.193	0.081	0.112	0.218	0.139	0.062	0.187	0.112	0.175
Downstream Sentab	0.306	0.131	0.275	0.255	0.161	0.093	0.237	0.149	0.092

GPP : Gross Primary Productivity, NPP : Net Primary Productivity, CR : Community Respiration

CONCLUSIONS

The subject study forms the comprehensive baseline data on ecological parameters in respect of RPS reservoir. Based on the monitoring data, the reservoir may be assigned as mild eutrophic trophic status. However, in view to confirm precise degree of trophic level and

available opportunities for harnessing various productivities further work needs to be planned. This may also be helpful in scientific and sustainable fisheries management of this reservoir.

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