ЕКОЛОГІЧНЕ МОДЕЛЮВАННЯ ТА ПРОГНОЗУВАННЯ

UDC 631

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IMPACT OF CHECK DAMS ON THE HYDROGRAPHY OF A TROPICAL RIVER, BHARATHAPUZHA, KERALA, INDIA

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Hydrography of Bharathapuzha River, Kerala State, India was examined for finding out whether smaller impoundments create hydrological alterations in tropical rivers. Investigations were carried out in both upstream and downstream areas of the check dam. Seasonal variations were evident in the case of conductivity, alkalinity, phosphate, nitrate, nitrite, silicate, total dissolved solids (TDS) and total suspended solids (TSS), while hardness of water showed seasonal variations only in the upstream area. Significant variations in hydrography between upstream and downstream areas were observed in the case of light penetration, hardness, phosphate and TDS, but no significant variation were observed in other parameters. Long-term modeling studies are required to unequivocally establish that smaller impoundments act as traps for nutrients, and alter the hydrography of the river.

Key words: Bharathapuzha, hydrography, check dam, water quality, river, hydrography.

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ВЛИЯНИЕ КОНТРОЛЬНЫХ ДАМБ НА ГИДРОГРАФИЮ ТРОПИЧЕСКОЙ РЕКИ БХАРАТАПУЗЫ, КЕРАЛА, ИНДИЯ

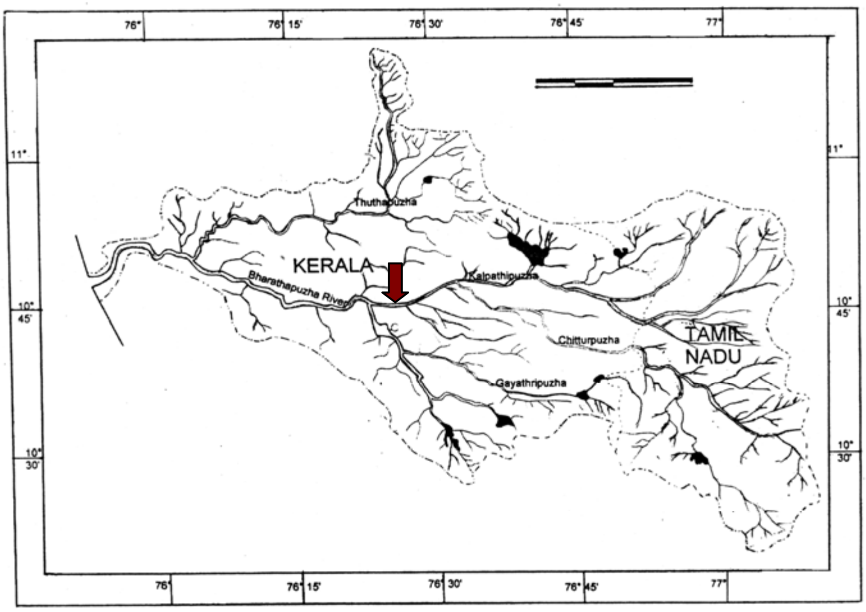
Данная статья посвящена исследованию гидрографии реки Бхаратапузы, штат Керала (Индия) с целью изучения влияния небольших водохранилищ на гидрологию тропических рек. Исследования проводились как в нижнем, так и в верхнем течении контрольных дамб. Сезонные изменения оказывали особое влияние на удельную проводимость, щелочность, фосфатность, уровень нитратов, нитритов, силикатов, полностью растворенных и взвешенных пород, твердых частиц. В то же время жесткость воды подвергалась сезонным изменениям лишь в верхних течениях. Существенные колебания в гидрографии верхнего и нижнего течений наблюдались при измерении глубины проникновения солнечных лучей, жесткости, фосфатности и количества растворенных твердых веществ; в случае сопоставления прочих параметров особые различия не наблюдались. Была обоснована необходимость в долгосрочных исследованиях (с применением методов моделирования) по изучению небольших водохранилищ: механизмы и результаты задержки питательных веществ, внесение изменений в гидрографию рек.

Ключевые слова: Бхаратапуза, гидрография, контрольные дамбы, качество воды, реки.

Rivers serve as transportation routes; as source of food, water and power; as sinks for waste products and as objects of artistic and metaphysical interest (Johnson *et al.,* 1995). Moreover, rivers form unique freshwater lotic ecosystems which form an abode for immense biodiversity. Investigations all over the world revealed that many rivers no longer support socially valued native species or sustain healthy ecosystems that provide important goods and services (Naiman *et al.,* 1995). The complete benefits out of rivers like power generation, irrigation, reservoir fisheries, ground water recharge and drinking water supply can be tapped in its full gravity for human welfare only if dams of suitable sizes are constructed across rivers, even though dam construction have negative impacts on lotic system. In India, the beneficial impacts of dams have been reported by many workers (Rangachari *et al.,* 2000). The impacts of dams upon natural ecosystems, particularly on rivers, have been profound, complex, varied, multiple and far-reaching (WCD, 2001). Changes in water quality of rivers due to the construction of dams have been recorded in literature (Petts, 1984; Hart *et al.,* 1991). However, water quality changes in the downstream and upstream areas of small impoundments such as check dams have not been well documented hitherto especially from tropical areas. The present paper gives an account of the hydrography in the upstream and downstream areas of check dam at Lakkidi in Bharathapuzha River, Kerala.

MATERIALS AND METHODS

Bharathapuzha, the second largest river in Kerala State, South India has its origin from the Anamalai Hills (Western Ghats) of Tamil Nadu (Fig. 1); it flows towards west coast through the Palakkad, Thrissur and Malappuram Districts of Kerala and debouches to Lakshadweep Sea at Ponnani. The Lakkidi check dam (10^0 45’ N and 76^0 26’ E) is a permanent concrete dam constructed across the Bharathapuzha river, measuring 90 metre in length, 2 metre in height and 0.5 meter in width. The check dam is bordered on either side with coconut, arecanut and banana plantations. The reservoir within the check dam is extensively used by the local populace for various purposes including bathing and washing.



Arrow mark shows location of Lakkidi check dam

Fig. 1. **Catchment area and location of *Lakkidi* check dam in *Bharathapuzha* River, Kerala, South India**

Water samples were collected monthly during morning hours from three sampling stations each in the upstream and downstream areas of the check dam during April 2005 to March 2006. The means provided are the pooled averages of monthly samples taken from three different sampling sites each from the upstream and downstream areas. The samples were analysed for temperature, Ph, conductivity, total hardness, alkalinity, dissolved oxygen, phosphate, nitrate, nitrite, sulphate, silicate, total dissolved solids (TDS), total suspended solids (TSS) following Trivedy and Goel (1986) and APHA (1992) procedures. The data collected were tabulated and seasonal variations were analysed using analysis of variance (One-way ANOVA). Two-way ANOVA was done for comparing the variations between streams, seasons and their interactions. Multivariate correlation analysis was employed to find out the relationship between various hydrographic parameters with in each stream.

RESULTS AND DISCUSSION

Seasonal variations of all water quality parameters in the upstream and downstream areas of Lakkidi check dam, Bharathapuzha River is given in table 1. Analysis of variance comparing seasons and areas of nutrients of upstream and downstream area of Lakkidi check dam are provided in table 2.

Table 1

Seasonal variations of different hydrographic parameters in the upstream and downstream areas of Lakkidi check dam

Parameter	Site		Premonsoon	Monsoon	Postmonsoon	Annual	F value (comparing seasons)
1	2	3	4	5	6	7	8
Temperature (^{0}C)	Up stream	Mean	28.65	28.65	28.60	28.63	0.002
		± SD	1.162	0.507	1.606	1.069	
	Down stream	Mean	28.75	28.80	28.20	28.58	0.250
		± SD	1.529	0.572	1.627	1.236	
Light Penetration$^\$$ (cm)	Up stream	Mean	57.25	37.93	48.95	48.04	2.054
		± SD	5.207	22.208	5.370	14.769	
	Down stream	Mean	24.34	19.87	26.96	23.72	2.073
		± SD	4.093	5.299	5.443	5.446	
pH	Up stream	Mean	7.33	7.28	7.33	7.31	0.106
		± SD	0.126	0.171	0.222	0.162	
	Down stream	Mean	7.23	7.26	7.25	7.24	0.063
		± SD	0.096	0.126	0.173	0.123	
Conductivity (µ mhos)	Up stream	Mean	322.50	292.75	367.50	327.58	9.065**
		± SD	38.301	16.153	12.124	39.260	
	Down stream	Mean	366.75	289.50	374.25	343.50	14.983**
		± SD	6.238	37.563	17.690	45.624	
Hardness$^\$$ (mg/l)	Up stream	Mean	10.87	8.22	8.54	9.21	11.484**
		± SD	1.445	0.240	0.199	1.455	
	Down stream	Mean	8.09	7.40	7.54	7.68	3.088
		± SD	0.410	0.403	0.425	0.484	
Alkalinity (mg/l)	Up stream	Mean	78.47	31.11	45.57	51.71	19.498**
		± SD	11.605	3.710	14.632	22.963	
	Down stream	Mean	66.96	29.47	45.11	47.18	17.474**
		± SD	3.687	1.248	15.112	18.009	
Dissolved Oxygen (mg/l)	Up stream	Mean	7.22	7.62	7.48	7.44	1.808
		± SD	0.233	0.287	0.355	0.317	
	Down stream	Mean	7.60	7.85	7.62	7.69	0.618
		± SD	0.539	0.202	0.229	0.345	
TDS$^\$$	Up stream	Mean	215.50	162.25	174.25	184.00	13.805**
		± SD	14.248	11.983	18.209	27.429	
	Down stream	Mean	183.50	119.50	161.00	154.67	9.805**
		± SD	15.438	30.227	11.747	33.443	

Continuation of the table 1

TSS	Up stream	Mean	3.50	6.70	5.25	5.15	11.775**
		± SD	0.744	0.497	1.348	1.607	
	Down stream	Mean	3.73	7.30	6.03	5.68	17.599**
		± SD	1.318	0.216	0.675	1.731	

* P < 0.05; ** P < 0.01; $^{\$}$ P < 0.01- comparing streams

The seasonal variations of water temperature in both upstream and downstream areas of Lakkidi check dam showed almost similar trends; seasonal variations were not statistically significant. Similarly temperature did not show any difference between up and down stream of check dam, which shows that check dam, is not a constraint for temperature distribution in the lotic system. But literature shows that major dams create temperature problems in the reservoir ecosystem (American Rivers, 2002). Since both these sites are located in the midland area of Kerala, without much geographical distance and check dams do not create deep impoundments, considerable variations in temperature cannot be expected. Similarly temperature did not show any significant correlation with any of the hydrographic parameters both in up stream and down stream areas. Water temperature in the rivers of Kerala did not exhibit great variations in different months and seasons (Jayaraman *et al.,* 2003; Mini *et al.,* 2003; Prasannakumari *et al.,* 2003).

Table 2

Seasonal variations of different hydrographic parameters in the upstream and downstream areas of Lakkidi check dam

Parameter	**Site**		**Premonsoon**	**Monsoon**	**Postmon-soon**	**Annual**	**F value** (comparing seasons)
Phosphate$^{\$}$ (μg/l)	Up stream	Mean	0.79	0.32	0.56	0.56	29.889**
		± SD	0.112	0.056	0.083	0.217	
	Down stream	Mean	0.45	0.20	0.31	0.32	8.836**
		± SD	0.110	0.061	0.075	0.131	
Nitrate (μg/l)	Up stream	Mean	16.94	20.01	49.44	28.79	7.132*
		± SD	10.208	12.165	17.024	19.547	
	Down stream	Mean	17.88	18.51	46.38	27.59	8.285**
		± SD	11.657	9.973	12.184	17.245	
Nitrite (μg/l)	Up stream	Mean	0.27	0.19	0.24	0.23	16.045**
		± SD	0.025	0.022	0.014	0.040	
	Down stream	Mean	0.27	0.19	0.26	0.24	4.709*
		± SD	0.039	0.025	0.050	0.051	
Sulphate (ppm)	Up stream	Mean	22.93	11.38	25.21	19.84	3.945
		± SD	9.647	5.152	6.891	9.248	
	Down stream	Mean	18.82	11.53	22.85	17.73	3.833
		± SD	5.577	5.752	6.228	7.212	
Silicate (μg/l)	Up stream	Mean	93.00	57.10	75.34	75.14	8.321**
		± SD	7.178	10.580	17.358	19.004	
	Down stream	Mean	88.92	57.69	77.68	74.76	8.127*
		± SD	2.498	11.495	15.203	16.816	

* P < 0.05; ** P < 0.01; $^{\$}$ P < 0.01- comparing streams

Unlike temperature, light penetration varied significantly between upstream and downstream areas in which upstream area showed low seasonal and annual mean which was in a negative correlation with total suspended solids. The high transparency in upstream may be due to impoundment formation and siltation. Lower reaches with high flow rate and turbulence reduces the transparency. In general, pH of water in both upstream and downstream areas of Lakkidi check dam showed only slight variations throughout the year

(7.23-7.33); variations were more or less uniform in both the study sites throughout the study period. The variations were not statistically significant in both the streams as well as among seasons. As the down stream water is the overflow water of upstream, there is no chance to vary pH much even though pH values reduced negligibly in down stream area.

The conductivity of water (μmhos) recorded almost similar tendencies. Temporal variations in both upstream and downstream areas of Lakkidi check dam showed significant difference among different seasons but did not show any significant variation between up and downstream; it varied between 274 and 385 in the upstream area, while in the downstream area the range was between 265 and 391. The annual average was 327.58± 39.26 and 343.5±45.624 respectively. Higher conductivity noted during post-monsoon months in both the streams of check dams may be due to decrease in freshwater flow. Similarly down stream showed high conductivity except in monsoon season, this may be due to dissolution of more ions from soil due to high turbulence. Very high conductivity reflects the production of higher concentrations of total dissolved solids in the form of inorganic salts.

The seasonal variations in total hardness was much pronounced in the upstream area of Lakkidi check dam and the variations were statistically significant ($F = 11.484$; $P<0.01$) with low value in monsoon and high in premonsoon season. The values of total hardness differed significantly between the upstream and downstream areas of the check dam ($F = 31.349$; $P<0.01$) with high values in upstream areas. The interactions between seasonal variations and streams were also significant in Lakkidi check dam. The accumulation of calcium and magnesium salts in the river during summer may contribute to higher values of hardness during pre-monsoon season, which may be diluted by more water flow due to precipitation during monsoon. Hardness showed positive relationship with almost all parameters in both upstream and downstream areas in which upstream relationships with nutrients were found to be significant. Hardness showed a negative and significant relationship was with TSS, which may be attributed to low TSS in upstream area. Hardness of water recorded in the upstream area of check dam may also be due to its stagnant nature and frequent use for bathing and washing.

In both the upstream and downstream areas of Lakkidi check dam, alkalinity (mg/l) showed almost similar trends with significant seasonal fluctuations with higher values during summer months. The high alkalinity during premonsoon season might be due to the anthropogenic activities and concentration of water due to lack of inflow. In the upstream the range of alkalinity was between 28.36 and 90.56 (annual average 51.71±22.963), whereas in the downstream area it was between 27.63 and 71.26 (annual average 47.18±18.009). The seasonal variations in alkalinity were highly significant in both upstream ($F = 19.498$; $P<0.01$) and downstream ($F = 17.474$; $P<0.01$) areas. Alkalinity was found to be significantly and positively related to nutrients like nitrite and silicate and to TDS, where as negatively related to TSS. Even though alkalinity did not show any significant difference between upstream and downstream areas, the high alkalinity in upstream may also be due to high nutrient sink in impoundment.

The dissolved oxygen concentration (mg/l) varied seasonally from 7.22 to 7.62; the annual average in the upstream area was 7.44±0.317 and that of downstream area, 7.69±0.345. The seasonal variations were not statistically significant both in upstream and downstream areas. Moreover, dissolved oxygen did not show any statistical difference between upstream and downstream areas with negligible high values in downstream areas which may be due to turbulence and high flow rate, which is throughout the year in downstream area. Upstream impoundment, usually form a waterlogged area which is usually clam with out much turbulence and hence much oxygen content fluctuation cannot be expected. But the high productivity in upstream area might be the reason for high oxygen content comparable to downstream turbulent water oxygen content. Dissolved oxygen saturation and stratification is one of the important ecological problems of major reservoirs (American Rivers, 2002), which was not found to be a problem for check dams as dissolved oxygen content did not show any special or temporal variation in the present study. The dissolved oxygen content of water was not found to be significantly correlated with other physical factors during the present study.

During the study period phosphate content (µg/l) of water in the upstream area varied seasonally between 0.32 and 0.79, whereas in the downstream area the values ranged from 0.2 to 0.45 µg/l. In both upstream and downstream areas phosphate content recorded considerable increase during summer months; the seasonal changes were also statistically significant in upstream ($F = 29.889$; $P < 0.01$) and downstream ($F = 8.836$; $P < 0.01$) stretches of the check dam. The seasonal fluctuation might be due to the nutrient enrichment during monsoon rains which sinks in to upstream area due to which upstream area had more content than downstream. Results of two-way ANOVA showed significant variations in phosphate content between upstream and downstream areas of Lakkidi check dam ($F = 46.142$; $P < 0.01$), which may be due to the nutrient sink and siltation due to check dam. Phosphate showed significant positive and negative relationship with other hydrographic parameters, both in upstream and downstream. One of the important ecological problems due to the dams is the impact of nutrient dynamics of the lotic system (American Rivers, 2002). But in the present study results reveal that the check dams are not creating problems as that of larger dams.

The seasonal variations of nitrate and nitrite content were also much apparent in both the streams, with maximum values during post-monsoon period; the nitrate and nitrite content differed significantly between seasons in the upstream and downstream areas. Seasonal variations in nitrate and nitrite content could be due to phytoplankton excretion, oxidation of ammonia and reduction of nitrate in addition to the decomposition of planktonic organisms apart from the monsoon input. The principal source of nitrogen is the rain water which in some cases may account for all nitrogen in surface waters (Visser, 1974). The increase in nitrate content during monsoon and post-monsoon seasons may be due to the influence of terrigenous matter carried by flood water as well as excess decomposition activity in the river (Reid and Wood, 1976; Desai *et al.,* 1995). Both, nitrate and the nitrite did not show any statistical difference between upstream and down stream area. Nitrate and nitrite showed different pattern of relationship with other hydrographic parameters but each nutrient had almost similar relationship pattern in up and downstream, which shows that check dams do not alter the nutrient dynamics much. Usually an elevated level of nitrogen can be expected from impoundment as it functions as a nutrient sink, which was on the other way round in the present study. This may be due to the utilization of nitrates and nitrites by plankton and aquatic macrophytes.

Sulphate concentration in both upstream and downstream areas showed wide fluctuations in both upstream and downstream areas; the variations were from 11.38 to 25.21 ppm and 11.53 to 22.85 ppm, respectively. The variations, however, were not statistically significant due to high variance. The annual average of sulphate in upstream area was 19.84±9.248 and that in downstream was 17.73±7.212. The seasonal variations were not significant between seasons and streams. Sulphate showed significant positive relationship with conductivity and nitrite both in up and down stream and a negative relationship with TSS. Sulphate content was low when compared to other nutrients and the fluctuations were high, which itself form a reason for statistical insignificance.

The diatom production, copepod abundance, food web structure and biogeochemical cycling in coastal seas depend on the amount of silica in the river discharges (Treguer *et al.,* 1995). The silicate content of water, in general, followed similar seasonal trends in both upstream (57.1 to 93 µg/l) and downstream (57.69 to 88.92 µg/l) areas. Higher values were recorded during post-monsoon and pre-monsoon periods due to terrestrial washing by monsoon and the seasonal variations in silicate content were significant in upstream area ($F = 8.321$; $P<0.01$) and downstream area ($F = 8.127$; $P<0.05$). Like nitrates, silicate also did not show and statistical difference between upstream and downstream. Silicate showed almost similar trend in upstream and downstream as far as the relationship with other parameters were concerned. Silicate showed positive and significant relation to alkalinity and hardness and a negative relationship with TSS. According to Silva *et al.* (2002) large number of reservoirs may increase silica fluxes in the river system and silicate leaching is primarily determined by the annual precipitation, discharge volume, climatic factors and catchment geochemistry. Presence of nine large dams in the upper reaches of Bharathapuzha would augment leaching of silicate to river water. As reported by Rao and George (1959) the lateritic nature of the drainage area may also be responsible for the high silicate concentration in river water.

In the upstream area of Lakkidi check dam the amount of TDS varied seasonally from 162.25 and 215.5 (annual average = 184±27.429), whereas in lower reaches the variation was between 119.5 and 183.5 (annual average = 154.67±33.443). In both the streams relatively higher values of TDS were recorded during pre-monsoon season; the variations were also statistically significant in up and downstream areas ($F = 13.805$ and 9.805 respectively; $P<0.01$). Results of two way ANOVA showed that the total TDS content differed significantly ($F = 15.739$; $P<0.01$) between both upstream and downstream areas of Lakkidi check dam with high values in upstream or the impoundment, which may be due to concentration of water due to stagnation and anthropogenic activities like bathing, washing etc. Also high alkalinity and harness of the water may be due to high TDS or vice versa as there was a significant positive correlation among them. The TDS of water in the present study was very high and it recorded significant seasonal variations in both the study areas. Primary sources for TDS in receiving waters are agricultural runoff, leaching of soil contamination and point source water pollution discharge from industrial or sewage treatment plants. In the present case increased TDS content of water may be due to agricultural run off from the surrounding fields.

In both upstream and downstream areas of Lakkidi check dam TSS registered more or less similar trends; the seasonal values ranged from 3.5 to 6.7 and 3.73 to 7.30, respectively. The annual average was 5.15±1.607 in the upstream and 5.68±1.731 in the downstream area of the check dam. TSS was higher during the monsoon seasons in both the streams. Results of one way ANOVA showed that the seasonal variations of TSS were statistically significant in upstream ($F = 11.775$; $P<0.01$) as well as downstream ($F = 5.68$; $P<0.01$) areas of the check dam. Frequent sand mining in the river bed and clay mining along the river sides in the study site had contributed towards high TSS in the river water. The difference between up and downstream TSS was not statistically significant but TSS gave similar relationships in upper and lower reaches of the check dam.

According to Ogbeibu and Victor (1995) lotic waters are characterized by lower nutrient levels and alkalinity. In Lakkidi area phosphate content in water was found to be related with light penetration, total hardness, alkalinity, nitrite, silicate and TDS of water. Similarly, nitrite content was significantly related to total hardness, alkalinity, phosphate, sulphate, silicate and TDS. The silicate content of water was found to be related to total hardness, alkalinity, phosphate, nitrite and TDS. While TDS content in water was significantly correlated with light penetration, total hardness, alkalinity, phosphate, nitrite and silicate contents in water, TSS was found to be inversely related with total hardness, alkalinity, pH, nitrite, sulphate, silicate and TDS.

In general, check dams in Bharathapuzha river did not alter the hydrography of the river. However, significant variations were observed in the case of light penetration, hardness, phosphates and TDS. Long-term studies are warranted to unequivocally establish that small impoundments such as check dams alter the hydrography of tropical rivers and act as nutrient traps.

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