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Original Research Paper

Hydrological Impact of a Tidal Regulator on Land and on Water in a Tropical Estuary of Kerala, India

E. Shaji
Department of Geology, University of Kerala, Kariavattom, Trivandrum-695 581, Kerala, India

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ABSTRACT

An opportunity to study the effects of artificial structures like tidal regulators on the near-shore environment is provided by the manually operated tidal regulator constructed across a man-made canal in an estuarine environment in the tropical climatic setting of the southern coastal State of Kerala in India. The regulator was constructed across a man-made canal at Pozhikkara in 1957 to control the salt water intrusion into Paravoor Kayal (Kayal = back water or estuary) and to protect a natural estuary. This protection was originally being afforded by a feature locally known as 'Pozhi', which is in fact a natural sand bar occurring along the coast separating backwaters from the sea during the summer, but allowing the sea and the backwater to merge by its erosion during the monsoon. This natural sandbar, thus, protected the Paravoor estuary from sea water ingress from the Lakshadweep sea (of the Indian Ocean) during the summer season. When a situation, where the natural sandbar could not protect the estuary and the inland paddy crops from saline water ingress arose, the concept of an artificial tidal regulator was evolved by the farmers of the Ithikara Ela (Ela = paddy field). An artificial canal was constructed 500 m south of the sandbar by cutting the main land, thus, connecting the lake and the sea. Thereby, around 1 sq. km of land was separated from the main land to become an island with 87 houses and 300 inhabitants. During 1985 the performance of the regulator started deteriorating, finally leading to its collapse in 1990. The water levels in the wells, the EC, pH, TH, Ca, Mg, Na, K, CO_3, HCO_3, SO_4 and Cl were determined in this study. The hydrological impacts of this regulator were (i) the hydraulic continuity of the aquifer has been disturbed, (ii) the dug wells, which used to yield fresh water on the separated land mass, became dry within five years of commissioning of the regulator, as the canal became effluent in nature, (iii) the dug wells were consequently deepened and salt water intrusion began and at present more than 25 wells are saline due to salt water intrusion into the freshwater aquifer of the 1 sq km area, (iv) the Paravoor estuary is becoming more saline day-by-day due to the free flow of saline water through the canal, and (v) the Paravoor estuary is getting filled up with ocean sediments during high tides and sand terraces are being formed within the lake. All these are direct outcome of the badly maintained tidal regulator. As a remedial step the spillway shutters should be refitted immediately. This will help protect the deteriorating environment and ecosystem of Paravoor estuary and the adjoining land. Rainwater harvesting is recommended for the polluted wells. The artificial tidal regulator project was implemented without a proper environmental impact assessment. Detailed environmental impact assessment is essential before implementing such schemes in coastal areas at the interface of varied environments, especially like an estuarine one in the tropics.

INTRODUCTION

Interface marine/estuarine habitats have extensively been trinkered with worldwide, usually with an aim to protect the livelihood of its human population. Usually such protective steps lack prescience and fail, subsequent restoration is either impossible or never attempted. A number of recent studies have examined the role of estuaries and the impacts of reduced water quality on the socioeconomic conditions of local population (Brockway et al. 2006, Prandle 2004). Giannico & Souder (2005) have identified the different impacts of tide regulators, especially on fish, while Thampatti & Padmakumar (1999) examine the effects, especially on agriculture, of a similar but functional tidal regulator at Tanneermukkom in Kerala.

The present paper examines the saline intrusion onto land, the marine sediment influx into an estuary, to identify the impacts of manipulation of natural interfaces which are in balance in the form of the tidal regulator in this case, and suggests some remedial restorative measures. The study area viz., Pozhikkara is located 15 km south of Kollam town (erstwhile Quilon), a trading city of Kollam district, Kerala state in southern India (Fig. 1a,b). The district lies between 8°45' and 9°27' N latitudes and 76°29' and 77°17' E longitudes. The length of the coastline in the district is 37 km. Along the coast sea water intrusion is minimal except at certain pockets during summer. Pozhikkara has a natural estuary, the widened tidal mouth of a lake or river where freshwater comes into contact with sea water and where tidal effects are evident. The name Pozhikkara is derived from the term 'Pozhi' in regional language Malayalam meaning the natural sand bars occurring along the coast during the summer which prevent the mixing of sea and the Kayal, which in this specific instance separate the Paravoor estuary and Lakshadweep sea (CESS 1998) (Figs. 1 and 2). This natural sandbar was protecting the estuary from sea water ingress during summer periods since time immemorial. The coast just south of Pozhikkara is a nesting site for endangered marine turtles (Jayakumar & Dillepkumar 2004).

The Paravoor estuary is connected to the Ithikara Thodu (Thodu = rivulet) at its eastern part and is the source of water for paddy cultivation in the Ithikara paddy field, which is located 10-15 km east of the sandbar. At a stage when the natural sandbar could not protect the estuary and the paddy crops from saline water ingress during summer, the concept of an artificial spillway evolved and the farmers pressurised the government of Kerala in 1957 to construct a tidal regulator, locally called cheerpu, at Pozhikkara. As shown in Figs. 1a,b and 3, an artificial canal of 600 m length and 30 m width was constructed in 1958 by acquiring land from local people and a spillway shutter-cum-bridge constructed. This is the tidal regulator, which was commissioned in 1968 (Fig. 4). The head of the elongated land has been cutoff and 1 sq km of land became an island (Fig 1a,b and 2). As per the Census of India (2001), the island has 87 houses with 300 inhabitants. The well inventory data revealed that 30 domestic wells exist in that area. The natural sandbar was located on this island and subsequently closed for the construction of a coastal highway (Fig. 5), and the coast is now protected with an artificial rubble barrier. During high tides and low tides, the tidal regulator used to control the inward and outward flow. Currently, neither the natural sandbar nor a functional tidal regulator exists.

MATERIALS AND METHODS

This study has been carried out as a part of Kollam district groundwater management study during 2000 (Field Study Programme of the Central Ground Water Board (India), Kerala region for 2000-2001 and the monitoring in subsequent years). The field investigation involved well inventories and water sample collection for chemical analyses and local enquiry regarding the merits and demerits of the regulator. Pre-monsoon and post-monsoon water levels and quality were monitored. The chemical analyses were carried out at the chemical lab of CGWB, Kerala Region, Trivandrum.

RESULTS AND DISCUSSION

Environmental impacts of the regulator: After commissioning of the regulator, the farmers benefited to a great extent as they could manage paddy cultivation two times a year. However, its impact started manifesting from the very next year onwards. Since, this project covered a wide range of activities and interests at that times it was beyond the scope of the Irrigation Department of the government to present a general framework and an objective and suitable approach for environmental impact assessment, hence, environmental impact assessment studies were not attempted. Presently, the so called Ithikara Ela (paddy field) has been transformed into a brick-making centre and paddy cultivation abandoned permanently. Hence, the original stakeholders, viz., the farmers and the administrators as well as political organizations had lost interest in the maintenance of the regulator, since it was no longer a crucial player in the economy of the area.

Sea water intrusion into the coastal aquifers of the cutoff land: The coastal province of the study area comprises tertiary sediments and quaternary alluvium. The tertiary formations begin with the Mio-Pliocene Warkalai beds, followed upwards by Quilon beds and Vaikom beds, which are overlain by 5-7 m thick coastal alluvium. A one metre thick fossiliferous limestone is sandwiched between a lignite bed of 3 m thickness above and a 9 m thick sandstone bed below, west of Pozhikkara (Lakshminarayanan 1981). The well section data show that the top layer is soil and alluvium followed by laterite resting on tertiary formations. Laterite is exposed in the northern wall of the canal (Fig. 6). The thirty domestic dug wells in use tap water from the laterite cappings.

It is reported that all the old wells were deepened after construction of the canal since the water level had gone down. The hydraulic continuity had been lost and regional groundwater flow from the main land also had stopped. Discontinuous heterogeneity has been created in the aquifer resulting in

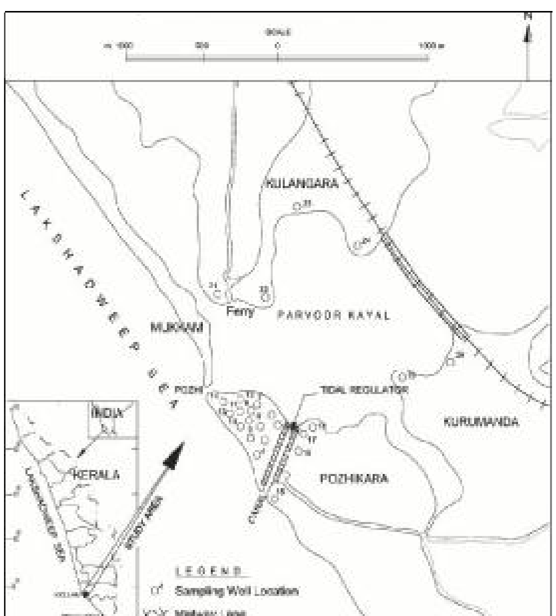

Fig. 1a: Location map showing study area of Pozhikkara, Paravoor estuary in Kerala, India.

Fig. 1b: Digital globe satellite imagery from Google Earth clearly shows the buildup of sediment shoals in the Paravaur estuary close to the tidal regulator at Pozhikkara in Kerala, India

Table 1: Well inventory data from the cut-off northern part of the sandbar at Pozhikara study area (all are dug wells).

Sl. No.	Locations as marked in Fig. 1	Total Depth (mbgl)	Static water level (mbgl) April 2000	Static water level (mbgl) Nov. 2000	EC values in micro Siemens/cm at 25°C April 2000	EC Nov. 2000	EC Apr. 2004	EC Nov .2004
1	Babu Bhavan	4.5	4.3	4.1	1140	1058	1240	2004
2	Vadakan Vila	4.63	4.6	2.51	1400	1350	1560	1410
3	Vavara Vila	4.83	4.73	2.68	1060	1000	1065	995
4	Masjid Well	6.18	6.15	4.16	14500	14000	13500	13000
5	Aji Bhavan	2.63	2.60	2.52	7170	7020	7200	7050
6	Thonikadavu 1	6.28	6.10	6	600	450	706	520
7	Thonikadavu 2	4.83	4.2	4.1	780	700	816	712
8	Saraswati Bhavanam	4.93	4.26	4.1	400	350	410	350
9	Thonikadavu 3	6.23	5.7	5.62	2200	2100	2100	2050
10	Puthenveedu	6.49	6.39	6.22	7100	6900	7000	6900
11	Podikunju	4.36	4.3	4.2	13000	13000	13500	13000
12	Abdul Rahuman	4.36	4.3	4.2	1700	1400	1600	1300
13	Vadakevila	4.43	4.30	4.18	4280	4110	4510	4270
14	Puthenveedu	4.2	4.0	3.92	4300	4100	4510	4270
15	CGWB OW	9.51	6.68	4.28	356	300	520	410
16	Babu Bhavan	8.31	6.78	4.68	350	280	350	280
17	Zeena Manzil	8.3	6.8	4.58	320	300	350	280
18	Sai House	7.38	6.99	4.63	380	290	3990	290
19	Thottathil	4.36	4.16	3.0	450	400	450	400
20	Karamana	4.86	4.32	3.33	800	750	870	800
21	Madathil	5.36	4.36	3.21	1100	850	1200	900
22	Babu Vila	5.83	4.16	2.83	1300	600	1300	660
23	Thomas	8.34	6.13	3.83	400	300	400	350
24	Rekha Nivas	8.36	6.86	3.93	700	500	750	600

mbgl-Metres below ground level; EC-Electrical conductivity

Table 2: Chemical analysis data of groundwater of polluted (saline) and nonpolluted wells.

Location No., name	Year	pH	EC	TH as $CaCO_3$	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl
15, CGWB OW	2000	7.48	356	66	13	8.3	41	0.6	0	34	34	64
	2004	6.9	520	108	22	13	77	2	0	104	42	89
13, Vadakevila	2000	6.92	4286	Tr.	Tr.	Tr.	>400	Tr.	Tr.	Tr.	Tr.	1292
5, Aji Bhavan	2000	6.6	7170	-	-	-	>600	-	-	-	-	2457
4, Masjid Well	2000	5.4	14500	-	-	-	>2000	110	-	-	-	2840
	2004	5.6	13500	-	-	-	>2000	120	-	-	-	2910

CGWB-Central Ground Water Board; OW-observation well, EC-electrical conductivity, TH-total hardness

reversal of groundwater flow directions in the island. The canal is effluent in nature and receives water from the zone of saturation as it lies below the water table. The groundwater started flowing into the canal and wells started drying out in summer. Initially, quality of the water was good. When the extracted volumes of groundwater from the study area and base flow to the canal exceeded the recharge, salinisation of the aquifer began, with the sea water flowing on to the land.

The present groundwater and sea water flow patterns in the study area are illustrated in Fig. 2. It is clear from the figure that the normal groundwater gradient of the study area is reversed (northern bank of the canal) (Shaji 2002). Additionally, it assumes a sharp interface between freshwater and

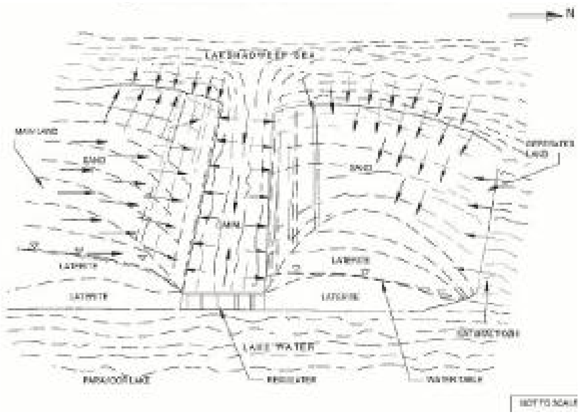

Fig. 2: The tidal regulator at the inlet/outlet and the flow patterns of the aquifer, the estuary and the sea.

Fig. 3: The artificial canal, which separated a 1 sq km area (to the right) from the mainland. At its far end the canal joins the sea.

Fig. 4: The tidal regulator in its present condition.

Fig. 5: The relicts of the old natural sandbar, the remnants of a coastal road and the coast protected by an artificial rubble barrier.

Fig. 6: Laterite cutting on the northern bank of the canal through which groundwater seeps into the canal.

Fig. 7: Masjid well, the water sample from this well records the maximum EC value (salinity).

Fig. 8: The regulator without shutters enabling free flow of water in both directions: towards sea and towards estuary.

Fig. 9: Filling up of Paravoor estuary with sea sand, arrow shows the elongated sand bar or shoal.

salt water. In reality, there tends to be a mixing of salt water and freshwater in a zone of diffusion around the interface. If the aquifer is subject to hydraulic head fluctuations caused by tides, the zone of mixed water will be enlarged.

Details of the wells inventoried in the island and the inventory data are listed in Table 1. All the water samples are non-potable except a few collected from the middle portion of the island. The EC ranges between 1000 and 4500 µS/cm at 25°C. The Masjid well (well No. 4 in Fig. 1 and Fig. 7) has the highest EC value. The detailed analysis revealed that the chloride concentration is high in the samples (1200-2840 ppm) showing that its concentration has increased due to saline water intrusion. The wells located in the centre of the island have relatively good quality of water. The chemical analysis results of polluted (saline) and non-polluted samples are presented in Table 2.

The wells inventoried on the southern bank of the canal (Fig. 1a,b, sample Nos. 16, 17, 18) indicated that the water is potable except for one sample very close to the sea. The sampling station 15 is being monitored by the CGWB for the last 20 years and no salinity has been reported so far. It implies that the regional groundwater flow is higher than the sea water ingress and even today the seaward groundwater gradient is normal (Fig. 2). From the analysis it is clear that on the main land, sea water intrusion is minimal and a minimum freshwater flow to the sea is maintained.

However, it is quite alarming to note from the chemical data that the total dissolved solids show an increasing trend in domestic wells very close to the estuarine banks (refer sampling locations 19, 20, 21, and 22). This means that the saline water is intruding into the aquifers from the estuary, which is a grave situation indicating lack of flushing of the estuary.

Salinity of the backwaters: Paravoor estuary was saline only at the time of high tides during summer, but usually it got neutralised during rainy season. During 1985 the performance of the shutters deteriorated and collapsed by 1990. Ultimately the shutters were unable to stop the sea water ingress into the estuary, thus, increasing the salinity of the estuary many-fold.

Filling up of the Paravoor Kayal: The collapsed spillway shutter has been defunct since 1990, and by the end of 1999 the irrigation department removed the shutter for repair or fitting a new one. Now the regulator is without shutters as shown in Fig. 8. If the shutter is closed, the natural sand bar will once again be created along the coast by wave motion and the sand will not enter the estuary. However, once the shutter is dysfunctional the sea sand gets transported to the interior of the estuary, which gets filled up gradually. During the months of November and December every year, high tide may continue for 12 hours per day. At that time large volumes of sand will be transported into the estuary. The sandy shoal that formed last year is clearly visible in Fig. 1b and 9. It is reported by the local people that one-third of the estuary has already been filled up. If this continues for another five years the Paravoor estuary will disappear by being filled up with sand, ultimately leading to flooding and submergence of the adjoining land during monsoon season. The bio-aquatic degradation is leading to ecological imbalances and threatening the economic well-being of the populace in the vicinity of the lake. Even the movement of boats is hindered by the sandy promontories in the lagoon. The regulator is a real threat to the lake and life, unless it is properly maintained.

Restoration: In the water quality-compromised island areas rainwater harvesting should be practised. The extraction of groundwater from the wells should be minimised, especially during summer months to prevent further salinity ingress. The shutters of the spillway should be refitted immediately to avoid further damage to the surrounding area and to the ecosystem of the estuary. Laying large diameter concrete pipes beneath the coastal road will help drain the floodwater during monsoon and protect the natural sand bar. The shutter operations should be monitored by an expert and should be based on scientific studies of hydrogeology and sediment transport rather than on the whims and fancies of government officials or the now defunct farmers. Any developmental project along or near the coast should be scrutinised thoroughly and environmental impact assessment carried out to find the feasibility of the project, prior to implementation. For sustainable development, identification and integration of environmental objectives, formulation of an operational strategy and provision of adequate technical, financial and institutional support are very vital.

CONCLUSION

The tidal regulator constructed at Pozhikkara was for a right cause, but later transformed into a creator of environmental problems. The main aim of the regulator was to stop the sea water ingress into the lake and paddy fields of the Ithikara Ela. But the present condition is such that the paddy fields have been transformed into brick kilns. The Paravoor estuary has become more saline. The one sq km of land that got separated from the main land due to construction of the canal has become an island. The freshwater laterite aquifer has become saline due to sea water ingress. Eighty seven island families are in dire straits as far as freshwater for domestic purposes are concerned. Paravoor estuary is in dying stage with sand smothering it. The health of the ecosystem is fast deteriorating.

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REFERENCES

Brockway, R., Bowers, D., Hoguane, A., Dove, V. and Vassele, V. 2006. A note on salt intrusion in funnel shaped estuaries: Application to the Incomati estuary, Mozambique. Estuarine, Coastal and Shelf Science, 66: 1-5.

CESS 1998. Natural Resources Inventory for Hazard Management for Kollam District: A Systems Approach. Project submitted to the State Committee on Science and Technology, Govt. of Kerala, India. Centre for Earth Science Studies Report, pp.1-20.

Giannico, G. and Souder, J.A. 2005. Tide Gates in the Pacific Northwest: Operation, Types and Environmental Effects. Oregon Sea Grant, Oregon State University, 32 p.

Jayakumar, C. and Dillepkumar, N. 2004. Study of turtles, traditional practices and rights of fishermen in the Kerala coast and development of an education strategy for protecting the coastal biodiversity through a community based turtle conservation programme. Thanal Conservation Action and Information Network, Trivandrum, India (http://krpcds.org/report/turtle.pdf)

Lakshminarayanan 1981. Hydrogeological Conditions in Quilon District, Kerala. Central Ground Water Board, Southern Region, Hyderabad, 23p.

Prandle, D. 2004. Saline intrusion in partially mixed estuaries. Estuarine, Coastal and Shelf Science, 59: 385-397.

Shaji, E. 2002. Pozhikkara irrigation regulator-environmental impact on land and water - A case study. Proc. of the 14th Kerala Science Congress, pp. 3-7.

Thampatti, K.C.M. and Padmakumar, K.G. 1999. Rice bowl in turmoil: The Kuttanad wetland ecosystem. Resonance, pp. 62-70.