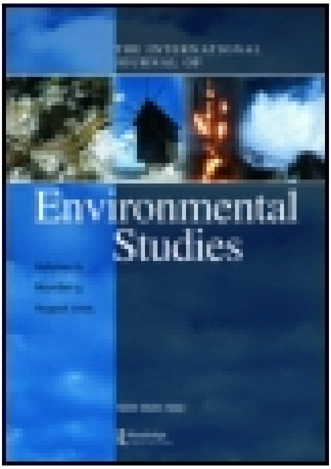

International Journal of Environmental Studies
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/genv20

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Published online: 24 Feb 2007.

To cite this article: S. Bijoy Nandan (1997) Retting of coconut husk - a unique case of water pollution on the South West coast of India, International Journal of Environmental Studies, 52:1-4, 335-355, DOI: 10.1080/00207239708711110

To link to this article: http://dx.doi.org/10.1080/00207239708711110

Intern. J. Environmental Studies, 1997, Vol. 52, pp. 335–355
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RETTING OF COCONUT HUSK – A UNIQUE CASE OF WATER POLLUTION ON THE SOUTH WEST COAST OF INDIA

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(Received in final form 2 October 1995)

The extensive backwaters of Kerala are the sites for a flourishing cottage industry – the coir industry. This enterprise almost exclusively located along the 590 km coastal belt of Kerala, provides direct employment to over half a million people in the state and produces nearly 90% of the total coir goods in the world. The shallow bays and lagoons of the 30 backwater systems of the state are traditional areas for the retting of coconut husk for the production of the coir fibre. The paper examines the environmental status of the retting grounds in Kerala, in relation to the biotic communities. The study revealed that retting activity has caused large scale organic pollution along with the mass destruction of the flora and fauna, converting sizeable sections of the backwaters into virtual cesspools of foul smelling stagnant waters. High values of hydrogen sulphide, ammonia, BOD_5 associated with anoxic conditions and low community diversity of plankton, benthic fauna, fish, shell fish, wood boring and fouling organisms were the outstanding feature of the retting zones.

Keywords: Water pollution; retting; environmental quality; fauna

INTRODUCTION

Retting is a native method prevalent along the coast of Kerala since ages as an indigenous practice for the processing of coconut husk. The extensive backwaters provide facilities for retting in 357 villages along the coastal belt of the state and the average production of coir fibre is reported to be 30,000 metric tonnes/year [1]. The continued and intensive exploitation of these backwaters for retting of coconut husk has caused

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deleterious effect on the fishery resources of the state and several backwaters have transformed into hot spots of pollution (Fig. 1). This has led to a clash between the coir industry on the one hand and the fishing industry on the other, along the coastal belt of the state.

Studies on the environmental status of the retting grounds in Kerala are only of recent origin and remain an unique ecosystem about which there is only limited information [2–6]. Retting of jute for the production of jute fibre is widely practiced in the water bodies of West Bengal, Orissa, Assam and Uttar Pradesh. The ecological scenario that has emerged in the jute retted waters [7] are similar to those in the coconut husk retting zones in Kerala. This paper discusses the environmental and biotic status of the waterbodies afflicted by retting activity.

STUDY SITES

The present investigation was carried out in the Kadinamkulam backwater (lat. 80°35'–80°40'N and long. 76°45'–76°52'E), the largest among the backwaters in Thiruvananthapuram district, Kerala, with an area of 347 ha. Four stations representing different ecological conditions were selected, viz. station I (Kortrakiri), an interior bay of the estuary used entirely for retting; station II (Edanjimoola), an open region free from retting; station III (Perumathura) an area free from retting and exposed to fresh water influx and sea-estuary mixing and station IV (Madanvila), a typical pit situated on the banks of the backwater used exclusively for retting (Fig. 2). A typical retting zone in the Kadinamkulam backwater is shown in Plates 1 and 2.

METHODS AND MATERIALS

Surface and bottom water samples were collected from the four stations from October 1987 to September 1988 for the estimation of salinity, dissolved oxygen, carbon dioxide, hydrogen sulphide, BOD_5, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, phosphate-phosphorus, silicate-silicon, sulphate-sulphur, polyphenols and tannin and lignin like substances (TALLS). Sampling and analysis of water samples for the above mentioned parameters were done based on standard methods[8, 9]. Bottom water samples were collected by a locally designed bottom water sampler of 1 litre capacity. Temperature was measured with a centigrade thermometer.

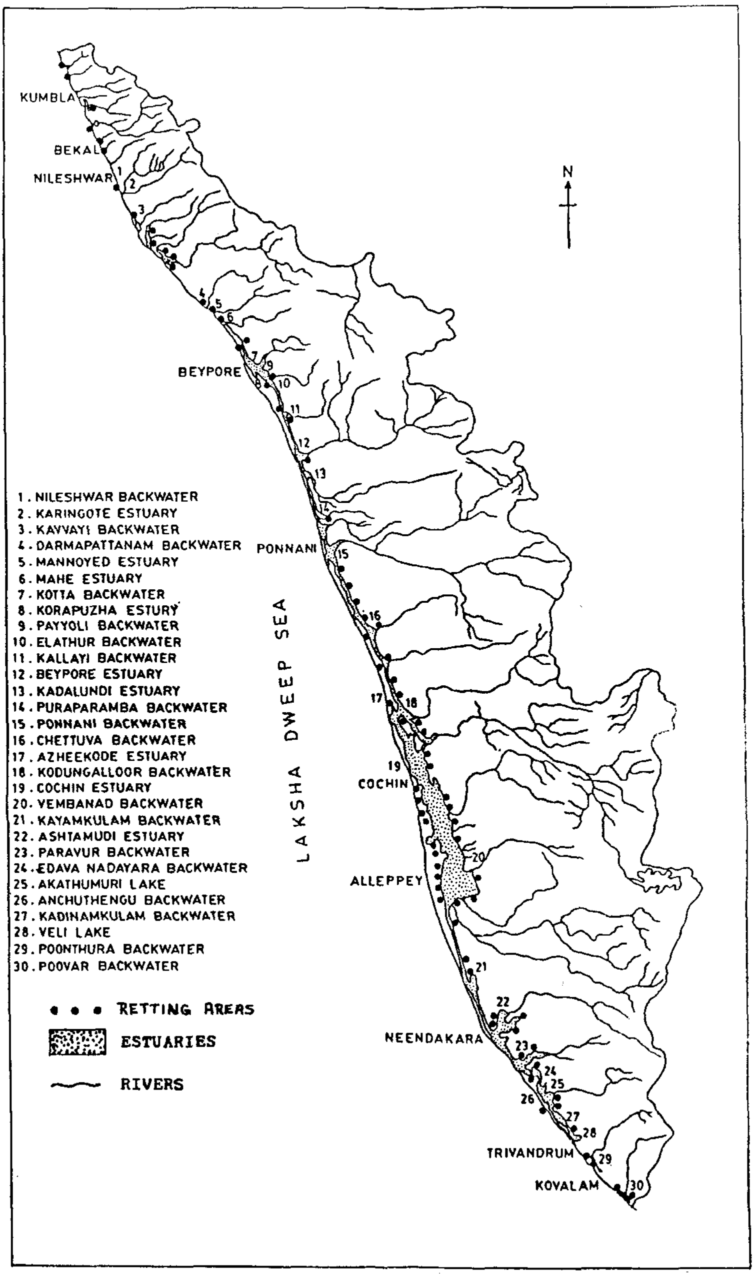

FIGURE 1 Map of Kerala indicating the retting areas.

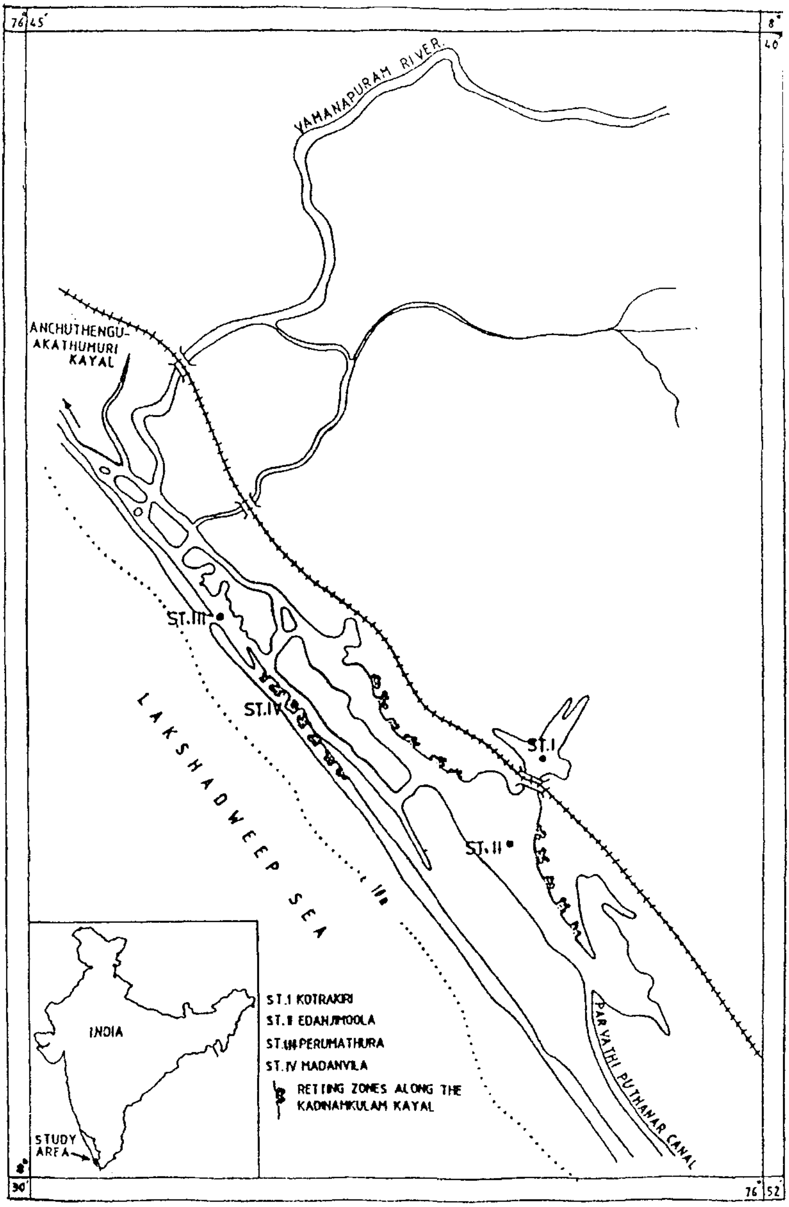

FIGURE 2 Map of Kadinamkulam estuary indicating the study sites.

PLATE 1 A typical retting zone in the main basin of the Kadinamkulam estuary showing the heavily polluted nature of the water body. (See Colour Plate 1)

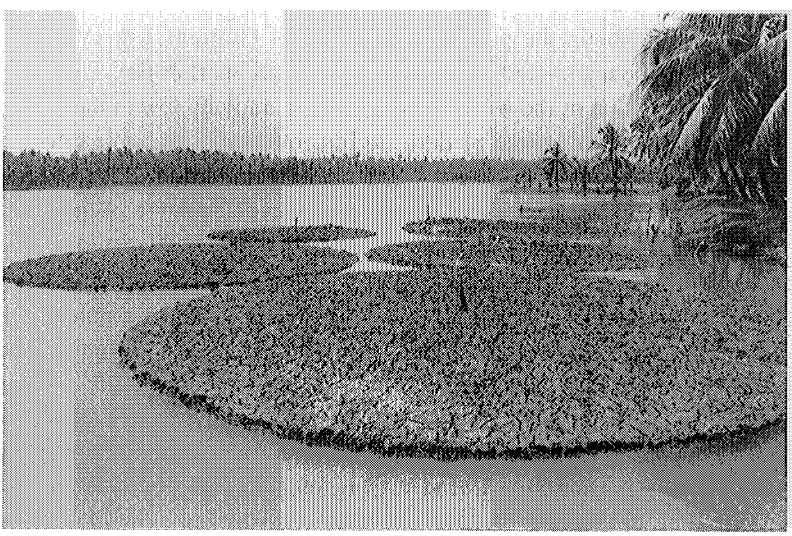

PLATE 2 Closer view of a cluster of huge coir nets containing bundles of husk, locally called 'Malis' steeped in water for retting. (See Colour Plate 2)

Transparency was recorded by the Secchi disc [10], the pH by pH meter (Elico Model LI-120) and Eh (Redox potential) by portable Eh meter (PYE UNICAM model 293). Gross and net primary productivity was studied based on the light and dark bottle method [11]. Sediment samples were analysed for pH, Eh, organic carbon, organic matter and grain size based on standard procedure [12]. The composition, percentage distribution, occurrence and abundance of the zooplankton, benthic fauna, wood boring and fouling organisms and fish and shell fish fauna were studied [13–16]. Statistical analysis of the data on environmental and biotic parameters were carried out to study their interactions at different levels based on the 4-way analysis of variance (ANOVA) [17]. A model has been proposed based on the path analysis equation[18] to study the impact of retting on the environmental quality and fauna. The indices of diversity ($\bar{H}$), dominance (c), richness (d) and evenness (e) of the zooplankton and benthic fauna were computed [19].

RESULTS AND DISCUSSION

1. Environmental Quality of Water and Sediment

The annual ranges of environmental parameters in the retting and nonretting zones are indicated in Table I. The surface and bottom water temperatures were higher in the polluted retting zones (stations I & IV) when compared to the unpolluted nonretting zones (Stations II & III). The depth of light penetration of the water body was comparatively low in the retting zones, due to the presence of dark, turbid, ret liquor and coir pith – a material left over after the separation of the coir fibre from the husk. Acidic nature of the water and sediment was a notable feature of the water quality of the retting zones. The low pH of the retting zones could be due to the pectinolytic hydrolysis of the organic matter present in the husk. Depletion of dissolved oxygen leading to anoxic condition, coupled with the simultaneous production of large amounts of hydrogen sulphide was the most conspicuous environmental change observed in the retting zones. The release of hydrogen sulphide leads to the frothing of the ret liquor and a white scum along with a whitish film is formed eventually over the retting zones, particularly during the pre monsoon and early monsoon periods. The production of large amounts of hydrogen sulphide due to retting activity in the backwaters of Kerala is thus an unique phenomenon. Hydrogen sulphide production has earlier been reported from the Norwe-

TABLE I Annual ranges of environmental parameters in the retting and non retting zones of the Kadinamkulam backwater

Sl. No.	Parameters	*Retting Zones*		*Non Retting Zones*	
		Station I	*Station IV*	*Station II*	*Station III*
	WATER				
1.	Temperature (°C)	26 – 34	26 – 34	27 – 33	25 – 32.5
2.	Transparency (cm)	8 – 94.6	10 – 98	16 – 119	18 – 94
3.	pH	5.48 – 7.97	6 – 7.91	6.17 – 8.26	6.62 – 7.92
4.	Eh (mV)	116 – 415	–126 – 426	240 – 434	248 – 476
5.	Salinity (X 10^{-3})	2.55 – 28	7.43 – 30.19	8.15 – 29.80	11.36 – 31.70
6.	Carbon dioxide (mg/l)	2.10 – 7.61	2.41 – 7.76	1.96 – 5.47	0 – 4.80
7.	Dissolved oxygen (mg/l)	0 – 0.72	0 – 0.88	0.96 – 6.21	2.28 – 6.21
8.	Hydrogen sulphide (mg/l)	7.60 – 40.2	8.90 – 41.10	0 – 4	0 – 3.60
9.	Ammonia-nitrogen (μg at/l)	6.78 – 36.7	0 – 31.08	0 – 14.30	0 – 11.70
10.	Nitrate-nitrogen (μg at/l)	0 – 3.18	0 – 3.14	0 – 3.38	0 – 4
11.	Nitrite-nitrogen (μg at/l)	0 – 3.41	0 – 3.96	0 – 1.97	0 – 1.66
12.	Phosphate-phosphorus (μg at/l)	0.10 – 1.40	0.10 – 1.44	0 – 1.39	0 – 1.41
13.	Sulphate-sulphur (μg at/l)	0.08 – 0.78	0 – 0.61	0.20 – 0.87	0.34 – 0.84
14.	Silicate-silicon (μg at/l)	19.6 – 110.2	19.40 – 114.30	30.40 – 126	30.70 – 129.4
15.	BOD_5 (mg/l)	4.96 – 24.39	–	–	0 – 3.74
16.	Polyphenol (mg/l)	0 – 11.18	0 – 12.26	Nil	Nil
17.	TALLS (mg/l)	0 – 12.24	0 – 10.86	Nil	Nil
	SEDIMENT				
18.	Temperature (°C)	26 – 34	27 – 33	27 – 34	27 – 32
19.	pH	5.63 – 7.98	5.03 – 8.19	6.37 – 8.29	6.72 – 8.09
20.	Eh (mV)	–116 – –400	–120 – –420	–34 – –180	–64 – 116
21.	Organic carbon (%)	1.90 – 7.40	3.77 – 13.79	1.40 – 4.90	0.31 – 1.60
22.	Organic matter (%)	4.13 – 12.75	6.49 – 23.77	2.41 – 8.44	0.53 – 2.75
23.	Silt & clay (%)	16.2 – 61.6	10.1 – 50.6	12.17 – 54.4	18.1 – 71.8

gian Fjords[20] and Chesapeake bay [21]. Such habitats with large amounts of hydrogen sulphide have been designated as 'Sulphureta' [22]. The size and magnitude of the sulphureta observed in the retting zones of the Kadinamkulam backwater during the present study showed that it portends to the adjacent regions of the backwater.

The BOD_5 values at the retting zone varied from 4.96 to 24.39 mg/l whereas that at the non retting zone from zero to 3.74 mg/l. The large amounts of organic compounds like pectin, pentosan, tannin, polyphenol and α-ketoglutaric acid released during retting activity were so high at stations I and IV, leading to high BOD_5 values coinciding with the depletion in dissolved oxygen. According to the Bureau of Indian Standards[23]: IS: 10500. The permissible limit for BOD_5 in inland surface water is 20 mg/l; that of dissolved oxygen is 3 mg/l and sulphide is 2 mg/l. When the water quality of the retting zones in the present study were examined in this context, it was seen that the quality was very much below the standards creating an extremely hostile situation for all forms of aquatic life.

According to Vaccaro[24] denitrification is the most important event resulting in the loss of NO_3-N. The fairly long period of anoxic condition coupled with the rich microflora present may be cited as important factors that facilitate denitrification frequently reducing NO_3-N to zero level concentrations in the retting zones. Nitrate showed a positive linear relationship with dissolved oxygen at the retting and non retting zones. According to Smith *et al.* [25] in anoxic systems, phosphate is usually released in large quantities. This observation agrees with the present study in the retting zones which confirms the presence of higher values of PO_4-P synchronised with oxygen depletion coupled with the rise in temperature and production of large quantities of hydrogen sulphide. The higher phosphate contents in the retting zones could be attributed to the retting process which leads to organic enrichment in the water consequent to large scale decomposition of the coconut husks. Polyphenol concentration in the surface and bottom waters at the retting zones ranged from zero to 12.26 mg/l whereas tannin and lignin like substances (TALLS) varied from zero to 12.24 mg/l. At the nonretting zones polyphenol and TALLS were not present.

Organic carbon and organic matter of the sediments were higher in the retting zones when compared to that of the nonretting zones. ANOVA of the environmental parameters revealed that they showed significant spatial and temporal variations in the four stations of the present study (Tab. II).

TABLE II ANOVA of the environmental parameters and fauna in the retting and nonretting zones of the Kadinamkulam backwater

Parameter	*Between Stations*		*Between Seasons*		*Between Fortnights*		*Between Surface Water, Bottom Water and Sediment*	
	DF	*F*	*DF*	*F*	*DF*	*F*	*DF*	*F*
Temperature	3	1.50	2	147**	7	4.48**	3	60.39**
Transparency	3	10.03**	2	27.58**	7	1.11	–	–
pH	3	44.56**	2	15.51**	7	3.31**	2	12.31**
Eh	3	26.41**	2	160.98**	7	4.06**	2	4014.54**
Salinity	3	63.81**	2	151.65**	7	20.13**	1	126.27**
Carbon dioxide	3	77.54**	2	196.54**	7	16.47**	1	82.14**
Dissolved oxygen	3	548.66**	2	139.08**	7	1.80	1	18.23**
Hydrogen sulphide	3	2482.80**	2	610.86**	7	13.74**	1	39.95**
Ammonia-nitrogen	3	315.50**	2	192.31**	7	3.75**	1	71.77**
Nitrate-nitrogen	3	12.89**	2	19.46**	7	4.11**	1	9.89**
Nitrite-nitrogen	3	103.70**	2	35.38**	7	23.41**	1	6.22*
Phosphate-phosphorus	3	10.21**	2	166.47**	7	42.43**	1	28.05**
Sulphate-sulphur	3	369.10**	2	537.20**	7	7.07**	1	46.73**
Silicate-silicon	3	34.49**	2	649.19**	7	10.32**	1	46.16**
BOD$_5$	1	487.72**	2	48.94**	7	5.94**	1	3.59
Polyphenols	3	44.61**	2	30.17**	7	9.26**	1	20.12**
TALLS	3	30.16**	2	21.64**	7	10.16**	1	16.76**
Organic carbon	3	49.71**	2	369.32**	7	3.57**	–	–
Primary productivity	1	119.43**	2	29.73**	7	5.0**	1	5.57**
Zooplankton	3	161.04**	2	46.93**	7	1.79	–	–
Benthos	3	31.22**	2	59.55**	7	1.86	–	–

**1% level of significance
*5% level of significance

When the different environmental parameters of the retting zones of the present study were compared to similar studies conducted in the Edava-Nadayara backwater [26], Cochin backwater [27], backwaters of Kozhikode [28] and jute retted waters of West Bengal [7], it was found that the water quality condition has further deteriorated leading to the creation of 'hot spots' of pollution in the region (Tab. III).

2. *Productivity of the Retting Zones*

The gross primary productivity values in the retting zone (St-I) varied from zero to 0.29 g C/m^3/day and the net productivity from zero to 0.24 g C/m^3/day in the surface and bottom waters. In the nonretting zone (St-III)

TABLE III Ranges of environmental parameters from other retting zones on the Indian coast

Retting Zones	*Water Temperature (°C)*	*Dissolved Oxygen (mg/l)*	*pH*	*Hydrogen Sulphide (mg/l)*	*Nitrate-nitrogen (mg at/l)*	*Phosphate-phosphorous (mg at/l)*	*BOD_5 (mg/l)*
Edava-Nadayara backwater	26.5–32	0–7.16	4.20–8.90	0–52.46	0.02–1.41	0.02–1.33	–
Cochin backwater	25.4–33	0–4.8 (ml/l)	–	0–4.97 (ml/l)	–	–	0–513.76
Backwaters of Kozhikode	25 –32	0–6.8	4.2 –5.6	–	–	–	–
Jute retted waters of West Bengal	17.8–30	0–4.6	7.1 –8.6	–	0–8.33 (ppm)	0–12.4 (ppm)	–

the gross and net productivity values varied from 0.10 to 1.60 g C/m^3/day and 0.01 to 1.44 g C/m^3/day in the surface and bottom waters respectively. The total depletion of dissolved oxygen giving rise to anoxic condition, coupled with the production of large quantities of organic matter and hydrogen sulphide were found to be detrimental to the gross and net productivity values in the retting zones during the present study. The monsoon period showed the highest mean seasonal value at the retting and nonretting zones. Variations (ANOVA) of the productivity values between stations, fortnights and surface and bottom waters were significant at 1% level (Tab. II).

3. *Impact of Retting on the Plankton and Benthos*

Qualitatively and quantitatively the zooplankton and benthic population was a depleted one in the retting zones. The biomass values of the plankton were low at the retting zones when compared to the non retting zones. It showed a maximum and minimum seasonal mean value of 8.62 ml/haul and 7 ml/haul respectively during the post monsoon at station III followed by 8.18 and 6.12 at station II; 6.31 and 5 at station I and 3.50 and 1.75 at station IV. Of the total number of zooplankton present in the four stations, station I contributed 13.96%; station II, 41.38%; station III 37.67% and station IV, 6.97%. The zooplankton population in the Kadinamkulam backwater was composed of 9 groups (Fig. 3). Rotifers and copepod nauplii showed maximum percentage incidence at the retting zones, whereas at the nonretting zones rotifers, copepods, and copepod nauplii showed the maximum occurrence and abundance. Variations (ANOVA) of the different planktonic groups between stations and seasons were significant at 1% level (Tab. II).

Station I contributed 28.48% of the entire benthic fauna, 54.66% at station II, 19.33% at station III and 9.91% at station IV (Fig. 4). The pre monsoon period was characterised by high concentrations of dissolved hydrogen sulphide and sharp depletion in the dissolved oxygen concentration. The brief spell of aerobic condition that was observed during August to October also did not materially improve the benthic faunal abundance. Nematodes, Insects and oligochaetes were tolerant and resistant to the anoxic condition developed in the retting zones. A maximum incidence of the benthic organisms were found at the four stations during the monsoon period. ANOVA of the different groups of benthic fauna

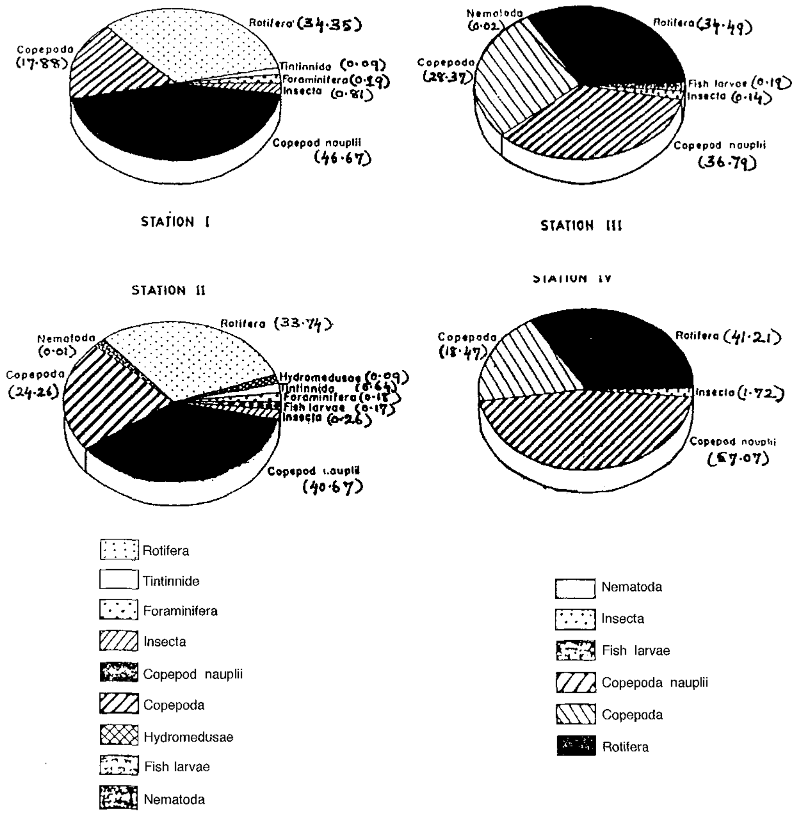

FIGURE 3 Total percentage composition of different zooplankton groups in the Kadinamkulam estuary.

between stations and seasons were significant at 1% level (Tab. II). When the present data on the plankton and benthic fauna were compared with that of the earlier studies conducted in the retting zones of Edava-Nadayara backwater [26]. Cochin backwater[27] and backwaters of Kozhikode region [29], it was observed that the composition, incidence and diversity of fauna has further decreased. Tintinnids were present only at stations I and II. At the nonretting zones, five species were present, namely *Tintinnopsis tocantinensis*, *I. sacculus*, *I. Cylindrica*, *I. bermudensis* and *Favella philippinensis*. Of these only *T. tocantinensis*, *T. bermudensis* and *T. sacculus* were observed at the retting zone. Rotifers were represented

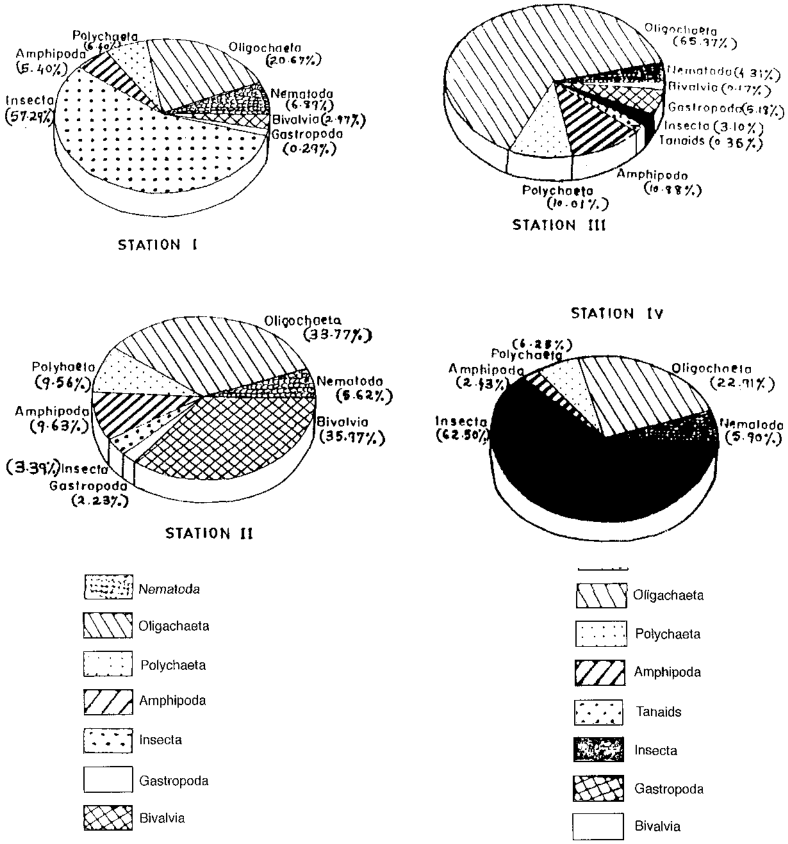

FIGURE 4 Total percentage composition of different benthic groups in the Kadinamkulam estuary.

by *Brachionus* sp. only in the retting zone whereas *Brachionus* sp. and *B. plicatilis* were present at the nonretting zones. Copepods formed 24.51% of the total planktonic population at the four stations. Calanoid, cyclopoid and harpacticoid copepods formed the copepod population in the Kadinamkulam backwater (Tab. IV). *Chironomus arunsi*, *C. calligaster*, *Pentaneura* sp., *Gerris* sp., *Micronecta* sp. and *Culex* sp. formed the insect population at the retting zones whereas only *C. arunsi* and *Gerris* sp. formed the population at the nonretting zones (Tab. IV). Nematodes belonging to the benthic fauna were composed of three species. Retting zones showed the presence of a highly tolerant nematode, *Oncholaimus*

TABLE IV Total percentage composition of planktonic copepod and insect species in the retting and nonretting zones of the Kadinamkulam backwater

Species	Stations							
	Retting Zones				Non Retting Zones			
	I	%	*IV*	%	*II*	%	*III*	%
COPEPODA								
Pseudodiaptomus mertoni	+	38.72	–		+	17.98	–	
P. compactus	–		–		+	11.96	–	
Acartia tropica	+	61.28	+	100	+	58.98	+	73.76
A. centrura	–		–		+	11.08	+	12.42
Acrocalanus gracilis	–		–		–		+	13.82
Oithona sp.	+	94.4	–		+	64.92	+	67.82
Mesocyclops leuckarti	+	5.56	–		+	31.81	+	32.18
Corycaeus sp.	–		–		+	3.27	–	
Euterpina acutifrons	–		–		+	64.9	–	
Tisbella pulchella	–		–		+	15.09	–	
INSECTA								
Chironomus calligaster	–		+	31.67	–		–	
C. arunsi	+	41.73	+	30.78	+	47.29	+	51.17
Pentaneura sp.	+	27.36	+	21.17	–		–	
Gerris sp.	+	9.58	+	10.85	+	52.71	+	48.82
Micronecta sp.	+	7.42	+	5.51	–		–	
Culex sp.	+	13.91	–		–		–	

+ present – absent

oxyuris, which could survive in the anoxic, carbon dioxide and hydrogen sulphide rich zones. A similar observation was made, on the studies of nematodes in the estuaries of Germany [29]. Nematodes in the nonretting zones were represented by 3 species namely *Desmodora* sp., *Eurystomina* sp., and *Theristus* sp. whereas at the retting zones *O. oxyuris*, *Desmodora* sp., *Eurystomina* sp. and *Theristus* sp. were present. 21.8% of the benthic fauna were composed of oligochaetes at the retting zones and 49.8% at the nonretting zones. The general diversity of the oligochaete and polychaete population was low in the retting zones when compared to the nonretting zones. (Tab. V). Amphipods showed very low occurrence, incidence, abundance and diversity at the retting zones (Tab. V). The benthic insect population at the retting zones were composed of *Chironomus arunsi*, *C. calligaster*, *C. tentanus*, *Pentaneura* sp., *Eristalis* sp., and *Palpomyia* sp. whereas those at the nonretting zones were represented by *C. arunsi* and *Pentaneura* sp. only. The planktonic and benthic insect population

TABLE V Total percentage composition of benthic faunal species in the retting and nonretting zones of the Kadinamkulam backwater

Species	*Stations*							
	Retting Zones				*Non Retting Zones*			
	I	*%*	*IV*	*%*	*II*	*%*	*III*	*%*
OLIGOCHAETA								
Peloscolex sp.	+	7.19	+	6.06	+	8.20	+	3.10
Tubifex tubifex	+	61.44	+	72.73	+	20.05	–	
Nais sp.	+	5.88	–		+	22.5	+	11.52
Limnodrilus hoffmeisteri	+	25.49	+	21.21	–		–	
Branchiodrilus sp.	–		–		+	28.54	+	14.38
B. semperi	–		–		+	30.52	+	14.92
Pontodrilus sp.	–		–		+	8.20	+	29.06
POLYCHAETA								
Ceratonereis sp.	+	27.17	–		+	25	+	46.67
Branchiocapitella sp.	+	29.17	+	6.11	–		–	
Nereis chingrihattensis	+	22.92	+	16.67	+	33.87	+	26.67
Prionospio ciriferra	+	18.75	+	22.22	+	25.81	+	20
Capitellid sp.	–		–		+	13.71	+	6.67
Lycastis indica	–		–		+	1.61	–	
AMPHIPODA								
Gammaropsis atlantica (♂&♀)	+	32.5	–		+	25.4	+	26.66
G. digitata (♂&♀)	+	11.48	+	25	+		+	14
Gitanopsis pusilla (♂&♀)	+	32.50	+	62.5	+	6.46	+	14
Cheriophotis megacheles (♂&♀)	+	27.5	–		+	25.11	+	19.28
Lembos podoceroides (♂&♀)	+	7.5	–		+	10.65	+	8.33
Grandierella megnae (♂)	–		–		+	9.12	+	16.67
Quadrivisio bengalensis (♂&♀)	–		–		+		–	
Parhylae hawaiensis	–		–		+	4.92	+	3.33

\+ present – absent

showed a higher numerical density at the retting zones. This was due to the presence of tolerant chironomid worms, thus accounting for the increased diversity of insect fauna at stations I and IV (retting zones).

The diversity ($\bar{H}$), richness (c), and evenness (e) of the zooplankton and benthic communities were low at the retting zones when compared to the nonretting zones (Tab. VI). Thus could be attributed to the deteriorating environmental quality associated with long years of retting of coconut husk in the region. Higher dominance index (d) observed in the retting zones resulted in the occurrence of opportunistic (indicator) species. Dominance by certain groups such as Rotifera, Copepod nauplii, Oligochaeta, Polychaeta and Insecta were observed at the retting zones. This

TABLE VI Ranges of diversity index ($\bar{H}$), dominance index (c), richness index (d) and evenness index (e) of the planktonic and benthic species in the Kadinamkulam backwater

	Planktonic Species							
	Retting Zone				Non retting Zone			
	$\bar{H}$	c	d	e	$\bar{H}$	c	d	e
Tintinnida	0 – 1.06	0 – 1	0 – 1.02	0 – 0.96	0 – 1.56	0 – 0.64	0 – 1.38	0 – 1
Rotifera	0.03 – 0.79	0 – 0.99	0.10 – 0.37	0.5 – 0.70	0.47 – 1.20	0.02 – 0.74	0.21 – 0.61	0.42– 0.92
Copepoda	0 – 0.10	0 – 1	0 – 0.26	0 – 0.13	0.15 – 0.46	0.09 – 0.89	0.10 – 0.41	0.14 – 0.67
Insecta	0 – 1.54	0 – 0.89	0 – 1.92	0 – 0.96	0 – 0.71	0 – 0.80	0 – 0.58	0 – 1.01
	Benthic Species							
Nematoda	0 – 0.99	0 – 1	0 – 2.88	0 – 0.90	0 – 1.01	0 – 0.96	0 – 2.89	0 – 1.07
Oligochaeta	0 – 1.20	0 – 0.65	0 – 2.16	0 – 0.86	0 – 1.46	0 – 0.55	0 – 4.55	0 – 0.91
Polychaeta	0 – 1.32	0 – 1	0 – 2.73	0 – 1.48	0 – 1.49	0 – 0.50	0 – 2.81	0 – 1.67
Amphipoda	0 – 1.26	0 – 0.55	0 – 1.97	0 – 1.49	0 – 1.82	0 – 0.52	0 – 2.61	0 – 1.54
Insecta	0 – 1.36	0 – 1	0.82 – 2.16	0 – 1.47	0 – 0.71	0 – 0.23	0.26 – 0.72	0 – 1.02

observation is in conformity with that of Whittaker [30]. *Brachionus* sp. *Acartia tropica*, Copepod nauplii, *C. calligaster* and *Pentaneura* sp. belonging to plankton and *O. oxyuris*, *T. tubifex*, *L. hoffmeisteri*, *Branchiocapitella* sp., *C. calligaster*, *C. tentanus* and *Eristalis* sp. belonging to benthic fauna were designated as indicators of sulphide pollution from the retting zones of the present investigation.

The path analysis of the environmental parameters, zooplankton and benthic fauna revealed that the deteriorating water quality condition had direct effects on the fauna. The residual effects were low indicating that the impact of retting activity was severe and detrimental to the fauna, accounted by the model used for the study of cause and effect relationships (Tab. VII & VIII).

4. *Effect of Retting on the Fish, Shellfish, Wood Boring and Fouling Organisms*

The fish, shellfish, wood boring and fouling organisms of the retting zones were found to be greatly depleted when compared to the nonretting zones.

TABLE VII Direct and indirect effects of the components on zooplankton in the retting zones of the Kadinamkulam backwater

No.	*Components*	*Direct Effect*	*Indirect effects via Biomass of Plankton*	*Total Correlation*
1	pH	0.67	0.22	0.82
2	Dissolved oxygen	0.87	0.43	0.87
3	Hydrogen sulphide	0.82	0.46	0.76
4	BOD_5	0.79	0.36	0.71

Residual effect – 0.472

TABLE VIII Direct and indirect effects of the components on benthic fauna in the retting zones of the Kadinamkulam backwater

No.	*Components*	*Direct Effect*	*Indirect effects via Biomass of benthic fauna*	*Total Correlation*
1	pH	0.69	0.34	0.80
2	Dissolved oxygen	0.84	0.41	0.79
3	Hydrogen sulphide	0.76	0.46	0.72
4	BOD_5	0.71	0.31	0.69

Residual effect – 0.441

Martesia striata (Linnaeus) (18%), *Sphaeroma terebrans* Bate (20%) and *Sphaeroma annandalei* Stebbing (12%) formed the wood boring and fouling population at the non retting zones whereas only *S. terebrans* Bate (6%) was present in the retting zones.

A total of 37 species of fishes, 5 species of prawns, and 2 species of crabs and bivalves were collected from the nonretting zones (Tab. IX). Of the 20 species of fishes and one species of wood boring organism recorded from the retting zone, none of them survived and were collected dead. None of the shell fish forms were recorded from the polluted retting zones. This clearly showed that the retting activity in the backwaters has led to the low diversity of fauna not only in the retting zones but also in the nonretting zones.

RECOMMENDATIONS

To control the pollution due to retting activity and conserve the depleting aquatic resources of the state, the following recommendations are put forth.

a. Retting activity in the interior bays of the estuaries may be discouraged as it would create 'hot spots' of pollution in the estuary.

b. Retting of coconut husk may be encouraged in specially constructed "retting tanks". Establishing of such cluster of retting tanks may be helpful in eventually delinking retting from the estuary proper.

c. Application of *In situ* bioremediation[31] techniques to control the increasing organic and sulphide pollution in the backwater systems.

d. As the retting activity is basically a biological process involving a spectrum of bacteria, fungi and yeast suitable strains of flora could be developed from them by biotechnological methods, which could in turn regulate and suppress the toxicity of sulphide and other phenolic compounds released during the process.

e. Areas worst hit ecologically, due to several years of retting, may be closed for the activity for a few years so that those areas can recover their health.

CONCLUSION

The study revealed that the entire coastal waterbodies of Kerala are getting increasingly polluted due to the retting of coconut husk and has resulted in

TABLE IX Percentage composition of fish and shellfish fauna of the retting and nonretting zones in the Kadinamkulam backwater

Species	Percentage composition	
	Retting Zone	*Non retting Zone*
FISH		
Megalops cyprinoides	6.74	2.77
Sardinella sp.	2.24	1.93
Stolephorus indicus	7.86	2.49
Chanos chanos	2.25	4.15
Tachysurus maculatus	1.12	0.83
Hyporhamphus limbatus	–	2.49
Hemiramphus cantori	4.49	3.32
Rychoramphus georgi	2.25	1.94
Sphyraena jello	7.86	4.43
Mugil cephalus	13.48	6.09
Liza macrolepis	8.98	3.32
L. parsia	8.98	4.71
Valamugil scheli	–	1.94
Pranesus duodecimalis	–	3.32
Chanda commersonii	–	4.43
Epinephelus tauvina	–	2.49
Therapon jarbua	4.49	3.60
Sillago sihama	–	3.60
Caranx sexfasiatus	–	2.77
Lutjanus fulviflamma	–	2.49
Pertica filamentosa	–	2.21
Gerres oyena	2.25	1.93
Gerreomorpha setifer	1.12	0.83
Leiognathus equulus	–	2.21
L. splendens	–	0.27
Upeneus sulphureus	–	0.27
Scatophagus argus	–	0.83
Tilapia mossambica	10.1	4.43
Etroplus suratensis	11.2	5.82
E. maculatus	4.49	5.54
Eleotris fusca	–	3.32
Glossogobius giuris	2.21	1.66
Pseudogobius javanicus	–	2.21
Thysanophrys indicus	–	2.21
Brachirus orientalis	–	2.21
Cynoglossus lida	1.12	0.27
Chelondon patoca	1.12	0.55
SHELLFISH		
Penaeus indicus	–	10.17
Penaeus monodon	–	5.38
Metapenaeus dobsoni	–	4.79
Metapenaeus monoceros	–	7.18
Macrobrachium idilla	–	5.99
Scylla serrata	–	9.58
Neptumus pelagicus	–	7.18
Villorita cyprinoides	–	41.32
Crassostrea madrasensis	–	8.38

the formation of a curious and complex ecosystem of microaerobic and anaerobic properties in the extensive backwater system on the south west coast of India. Anoxic condition of the water body coupled with the production of large amounts of hydrogen sulphide was an outstanding feature of the water quality in the retting zones, leading to the total depletion of aquatic resources of these backwaters. Retting activity has also led to the large-scale reclamation of the backwaters, resulting from the accumulation of coir pith, ret liquor and other coir products, thereby converting them into foul smelling, clogged canals.

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