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Surveillance on Water Quality in Pursuit of Mangrove Afforestation along the Coastal and Inland Aquatic Environments of Malappuram District, Kerala, India

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Abstract

Mangroves are considered to be the most productive ecosystems in the world. Their contribution in enhancing biodiversity and stabilizing coastal environments is widely accepted. Reintroduction of mangrove vegetation need be prioritized in the context of predicted consequences of global warming, sea level rise, coastal erosion and other natural as well as manmade disturbances. The primary objective of this study is to demarcate environments that uphold adequate water quality ideal for mangrove afforestation along the coastal and inland water bodies of Malappuram district, Kerala. Collection of water samples were carried out from38 locations representing diverse habitats during pre-monsoon, monsoon and post-monsoon seasons. Physico-chemical characterizations of collected samples were carried out following standard methods. On the basis of salinity and related attributes, high salt tolerant species like Avicennia marina, Avicennia officinalis, Rhizophora mucronata and Aegiceras corniculatum were found to beideal for afforestation in 10 sites. Low salt tolerant species like Sonneratia casiolaris and Exocaria agallocha were noted to be ideal for planting in 8 sites. Species like Sonneratiaalba which showed a tolerance limit over a wider range has beenfound ideal for afforestation in 14 selected sites. However medium salt tolerant species like Rhizhophora apiculata, Bruguiera gymnorrhiza and Bruguiera cylindrica were found to be unfit for afforestation in any of the sites studied. On an overall assessment of the tolerance limit of mangrove species to salinity, 11 inland and estuarine aquatic environments of Malappuram District are ideal for afforestation during all seasons of the year.

Keywords: Mangroves, Coastal stretches, pH, Salinity Tolerance, Afforestation.

Introduction

Mangrove ecosystems are highly productive and ecologically sensitive areas that provide physical protection for the associated communities and more importantly play a major role in supporting tropical estuarine and coastal food webs[1]. They serve as an ideal nursery and breeding ground to most of the marine and brackish water fishes and other organisms[2]. Their services in the maintenance of coastal environments are many.

*I*n spite of their immense role in protecting human resources as well as biodiversity, these unique habitats have been facing tremendous threats all over the world. Current estimate revealed that extend of mangroves ranges from 1110000 to 240000 km^2 worldwide[3].

India has a mangrove cover of about 6749 km^2, the fourth largest mangrove bearing nation in the world[4]. Reports on mangrove habitats in Kerala revealed that the state once had a mangrove cover of 700km^2 that now drastically declined to17km^2. It indicates that, as in many other parts of the world, the vegetation has diminished in its extent severely and has acquired a 'threatened' status in Kerala[5]. Increasing human population in the mangrove associated coastal environments is being the prime reason in many countries that have eventually resulted in their over exploitation in the form of timber, fuel wood, fodder and other non-wood forest products[6].

Mangrove restoration is re-introduction and re-establishment of assemblages of native mangrove species to sites that can support them. Restoration programs are gaining significance worldwide in light of the increasing erosion and degradation process associated with the coastal environments. Such restoration efforts require database on the growth requirements of mangrove species together with growth sustaining conditions of the sites proposed for afforestation.

Kerala has a coastline of 590 kms. Of the 14 districts, 10 districts have direct or indirect coastlines. Despite various coastal protection measures being undertaken over decades, much of the coastal environments are undergoing erosion and thereby degradation. In this context the present study has been carried out to demarcate sites ideal for species specific mangrove afforestation in the coastal environments of Malappuram District, Kerala, which in recent times have been subjected to drastic coastal erosion.

Materials and Methods

Study Area: Malappuram District of Kerala state is bounded by Nilgiri hills on the east, Arabian Sea on the west and Kozhikode and Thrissur / Palghat districts towards the north and south respectively. The coast line of the districtextends from Chaliyam in the north to Perumpadappu in the south, extending to approx.50 kms. The region is characterized by a network of estuaries, back waters and confluence point of major rivers like Chaliyar, Kadalundy, Tirur and Bharathapuzha. The famous Kadalundi Bird Sanctuary and Kadalundi – Vallikkunnu Community Reserve falls in this area. Altogether 38 sites (Figure-1) were selected for the present study of which 11aremarine, 4 estuarine and remaining 23 forms part of major and minor inland aquatic habitats (Table-1).

Table-1
Details of sampling sites

Location ID	Name	Description
S1	Srayil Kadavu	Inland water body
S2	Uppungal Kadavu	Inland water body
S3	Kappirikad	Shoreline
S4	Palappetty	Shoreline
S5	Naranippuzha Bridge	Inland water body
S6	Thuruvanam	Inland water body
S7	Athani Bridge	Inland water body
S8	Biyyam Lake	Inland water body
S9	Pulikkakadavu	Inland water body
S10	Kundukadavu	Inland water body
S11	Veliancode	Shoreline
S12	Pookaithakadavu	Inland water body
S13	Puthuponnani bridge East	Inland water body
S14	Puthuponnani bridge West	Estuarine
S15	Puthuponnani Munambam	Estuarine
S16	Ponnani Harbour	Shoreline
S17	Eswaramangalam	Inland water body
S18	Athaloor Nedat Kadavu	Inland water body
S19	Chammaravattom Kadavu	Inland water body
S20	Pallikadavu Munambam	Estuarine
S21	Murikkummad 1	Inland water body
S22	Murikkummad 2	Inland water body
S23	Mangalam Bridge	Inland water body
S24	Kootayi	Shoreline
S25	Vakad-Azhikal	Shoreline
S26	Paravanna	Shoreline
S27	Anjody-Tanur	Shoreline
S28	Tanur	Shoreline
S29	Poorapuzha East	Inland water body
S30	Poorapuzha Estuary	Estuarine
S31	Alungal	Shoreline
S32	Kadalundi Railway Bridge East	Inland water body
S33	Kadalundi Mosque	Inland water body
S34	Kadalundi Bridge	Shoreline
S35	Kadalundi Community Reserve	Inland water body
S36	Athanikkal Bridge	Inland water body
S37	Olipram Kadavu	Inland water body
S38	Thayyilakadavu	Inland water body

Collection and analysis of water Samples: Water samples were collected from all the 38 locations during pre-monsoon, monsoon and Post monsoon seasons of the year. Water samples collected were analyzed for various physico-chemical parameters like pH, Electrical Conductivity (µs), Resistivity(Ω), Turbidity (NTU), Total Dissolved Solids (ppm), Salinity (ppm), Acidity (mg/l), Alkalinity (mg/l), Calcium (mg/l), Magnesium (mg/l), Total hardness (mg/l), Chloride (mg/l), Sodium (mg/l), Potassium (mg/l), Sulphate (mg/l), Phosphate (mg/l) and Dissolved oxygen (mg/l) following standard procedures[7,8]. Salinity and allied parameters so analyzed were compared with the tolerance limit of various mangrove species for assessing the suitability of sites for effecting species specific afforestation, mainly with respect to the seasons.

Results and Discussion

The range of various water quality parameters and their mean values experienced during different seasons of the year are depicted in Table-2 and Table-3 respectively.

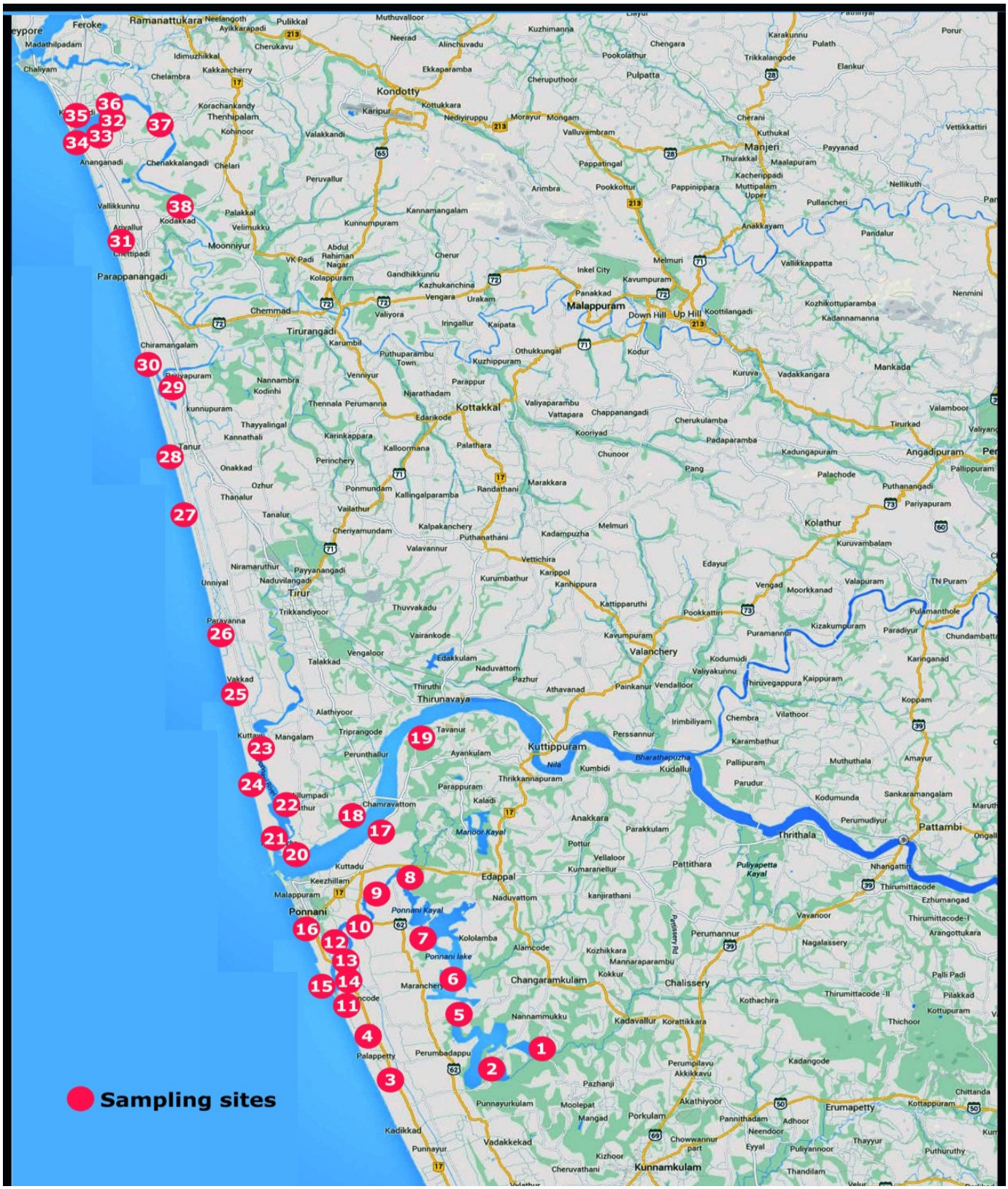

Figure-1
Sampling sites along the coastal environments of Malappuram District

Table-2A
The range of various water quality parameters experienced in the study sites during various seasons

Location ID	pH	Electrical Conductivity (µ s)	Resistivity (Ω)	Turbidity (NTU)	Total Dissolved Solids (ppm)
S1	6.37-6.61	62.62-457.2	2892-15610	2-4.6	36.1-235.6
S2	6.35-7.48	75.33-242.1	4029-12950	3.9-9.7	38.57-123.9
S3	6.57-7.54	46600-50440	19.31-21	4-7.2	23840-25910
S4	6.92-7.55	47200-50690	19.28-20.7	4-8.5	24150-25950
S5	6.04-8.59	175.8-534.2	534.2-5519	0.6-21	90.96-262.6
S6	6.077.8	95.72-222.3	163.8-1111	0.6-3	49.7-113.9
S7	7.02-8.06	19.41-345.2	3428-10730	1.1-4.8	46.37-163.9
S8	6.88-7.58	250-48230	20.25-4010	2.5-9.4	133.1-24650
S9	6.87-8.07	601.1-48430	20.19-1626	1.7-10	307.4-24800
S10	6.47-7.98	1864-49780	19.68-303.7	2.7-8.7	948.9-25460
S11	6.27-7.57	46070-50690	19.28-20.8	7-9.2	23520-25910
S12	7.12-7.92	5397-50560	19.35-408.6	6.2-10	1228-25830
S13	6.48-7.47	841-73860	19.29-132.2	7.2-54	3778-25940
S14	6.83-7.81	6588-50910	19.26-148.3	9.7-24	3370-25980
S15	7.25-7.55	15530-50680	19.25-63	1.1-11.2	7939-25930
S16	6.94-7.68	40200-50720	19.23-24.04	2.6-9.4	20760-26010
S17	7.03-8.63	154.1-11660	4.246-6390	8.1-14.6	34.87-5930
S18	7.80-8.57	118.5-19605	4973-8240	3.2-35.3	60.67-98.95
S19	6.40-8.34	89.09-14260	68.42-11020	2.7-24.3	45.48-5930
S20	7.12-8.04	394.4-47280	20.7-2473	1.5-22.8	202.5-24140
S21	6.77-7.54	1877-49820	19.59-9350	5.7-32.8	958.8-25680
S22	6.72-7.48	510-49210	19.8-510	3.3-25.3	983.3-24230
S23	7.13-7.25	378-28390	53.57-378	4.7-7.4	175.6-23900
S24	6.85-7.81	40310-50820	19.21-24.31	2.7-6.6	20570-26040
S25	7.01-7.61	46090-51090	19.24-21.2	4.2-27	23580-26020
S26	6.65-7.65	47310-50630	19.28-20.71	3.9-21	24150-25720
S27	6.66-7.38	44330-50770	19.29-20.5	6.4-19.3	24380-25900
S28	7.47-7.81	44330-50755	19.23-20.5	3.1-16.2	2496-25960
S29	6.79-8.08	291.7-50700	20.05-3768	0.6-7.3	140.9-24940
S30	7.15-8.64	4879-50755	3.693-1052	6.1-15.2	135.1-25940
S31	7.2-7.9	47890-49520	19.38-20.41	3.8-86	24500-25820
S32	7.18-7.27	748.1-50580	19.34-114	7.8-30.6	382.6-25890
S33	7.15-7.57	3783-50550	19.28-1307	8.9-36.8	1936-25800
S34	7.42-7.75	1130-50450	19.36-258.2	6.4-20.9	1677-25850
S35	6.71-7.67	1260-50700	19.31-675.5	3-40.1	740.3-25930
S36	7.23-7.9	234.7-49590	19.68-139.7	6.8-10.6	578.6-25570
S37	7.6-8.17	161.1-47760	20.75-4669	6.5-7	91.48-24.330
S38	6.67-8.17	126.1-44520	21.94-7501	5.2-9.3	66.06-22720

Table-2B
The range of various water quality parameters experienced in the study sites during various seasons

Location ID	Salinity(ppm)	Acidity (mg/l)	Alkalinity (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Total hardness (mg/l)
S1	34.30-211.6	4.4-17.6	20-90	1.6-12.8	1.944-7.77	12-56
S2	38.57-122.6	3.96-13.2	20-50	3.2-28.8	2.43-8.746	42-84
S3	31470-34700	1.76-17.6	40-190	240-1240	1239-4398	5700-21200
S4	31930-43840	1.76-13.2	40-170	640-1840	972-3539	5600-20400
S5	90.96-265.8	3.52-8.84	50-90	1.6-24	1.944-10.7	24-82
S6	48.21-112.5	2.2-4.4	40-80	3.2-12	1.94-3.888	20-44
S7	49.49-141.5	4.4-13.2	40-70	6.4-14.4	1.944-5.832	24-60
S8	122.5-32420	3.96-17.6	20-160	6.4-1520	6.804-1288	44-9100
S9	300.9-32730	2.64-74.8	20-170	6.4-94	2.916-1692	68-7200
S10	972.3-33560	2.2-48.4	20-170	25.6-440	34.62-2843	600-11700
S11	31070-43990	2.64-13.2	20-170	280-1360	1361-4520	2200-6800
S12	1286-34310	1.32-13.2	80-170	34-560	102.1-1725	500-8500
S13	4129-34780	1.32-13.2	60-200	49.6-840	291-1628	1480-8800
S14	4129-34890	2.64-8.8	60-180	43.2-640	216.8-588.1	1000-3900
S15	9381-34830	2.2-13.2	40-180	49.6-640	315.9-3906	2400-16200
S16	26830-34950	1.32-17.6	80-190	320-1840	97.2-1531	4500-7100
S17	77.05-6910	1.32-8.8	40-120	9.6-1200	5.832-729	48-6000
S18	74.99-118.5	4.4 in all the seasons	70-140	9.6500	4.86-693	44-4100
S19	48.87-8575	6.6-13.2	70-120	8-700	5.823-1908	44-9600
S20	197.7-31970	4.4-8.36	20-160	9.6-80	7.776-2722	56-11400
S21	992.3-34220	8.8-20.68	40-140	12.8-1040	35.96-778	180-5800
S22	1004-33480	4.4-8.8	80-150	17.6-440	4.86-118.6	200-4800
S23	171.5-31770	1.76-13.2	40-140	8-40	45.68-753.3	40-288
S24	26670-34990	8.36-8.6	40-190	240-1120	1118-2722	3700-14000
S25	31010-34850	3.96-8.8	40-170	560-2080	1094-5054	6000-26000
S26	31360-34510	1.32-8.8	60-190	400-1280	0.972-1312	5500-8200
S27	32340-34680	3.96-22	110-220	600-2720	413-2138	3800-31000
S28	32180-35030	4.4-13.2	160-180	450-960	413-2138	4300-11200
S29	121.2-33360	1.76-17.6	80-90	6.4-2040	189.5-1385	44-9600
S30	133.7-34810	8.8-26.4	40-180	40-2040	72.9-413	400-10200
S31	32590-34720	2.2-8.8	20-150	440-2640	12.64-5783	6800-30400
S32	381.4-34800	1.32-8.8	60-170	9.6-580	69.98-887	176-4900
S33	2084-34550	1.32-4.4	100-170	28.8-560	81.75-1288	360-6700
S34	1792-34560	3.96-17.6	60-180	25.6-240	25.6-3128	400-1371
S35	675.4-34630	2.2-8.8	80-190	124-300	27.22-189.5	124-1300
S36	143.2-34260	1.32-8.8	60-170	36.8-560	4.86-1337	40-6900
S37	82.97-32040	1.32-8.8	50-170	15.2-20	0.972-35.96	20-196
S38	67.8-30240	4.4 in all the seasons	20-160	3.2-1040	413.1-2333	28-12200

Table-2C
The range of various water quality parameters experienced in the study sites during various seasons

Location ID	Chloride (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Sulphate (mg/l)	Phosphate (mg/l)	Total dissolved oxygen (mg/l)
S1	22.13-77.45	2.6-12.1	6.4-33.8	5-18	11.2-19	5.4-5.6
S2	19.91-75.24	0.5-10.4	7.1-61.1	7-34	5-15.2	2.4-5.2
S3	22131-48689	1350-48080	2600-23920	85-2400	150-175	4.4-7.2
S4	2434-34304	3175-49680	2500-23720	130-2750	175-185	3.2-6
S5	86.31-24344	9-71.2	6.8-57.3	5-13	12-38	4.4-7.6
S6	26.55-79.67	3-41.1	7.5-60.3	3-60	5-31	4.4-6.4
S7	22.13-61.96	9.9-20.1	10.7-61.3	3-55	5.5-14	1.2-6.4
S8	73.03-26578	13.2-63.25	6.5-2775	17-2150	3-5	3.2-9.2
S9	174.8-12504	6.5-11450	50.5-27480	10-4300	5-36	3.2-7.6
S10	66.39-31869	750-23400	1040-27520	39-3000	28-88	5.2-7.2
S11	270-30541	9550-15640	4500-26280	25-3500	156-185	3.2-6.4
S12	2656-35631	920-11050	1100-26880	27-2850	12-31	4.4-6
S13	3320-20139	1025-10700	2550-26680	9-3250	2-32	3.6-8.4
S14	2877-44041	1450-6400	1125-26600	5-2900	1-14	1.6-6
S15	2146-37623	2100-15550	2550-26480	75-1650	175-185	1.6-8.4
S16	7746-367383	5375-47080	2250-23840	90-2200	165-186	0.8-6.4
S17	0.98-9516	5.7-7850	60.8-4950	8-600	12-32	5.2-6.4
S18	15.49-28.77	1.5-12.9	9.7-61.8	3=60	10-48	5.2-6.81
S19	26.55-5090	12.1-1400	10.2-5300	7-500	4-36	6-8.8
S20	106.2-15271	117-13840	109-26280	20-180	30-35	2.4-6.4
S21	995.9-43156	640-11400	260-26880	16-2500	35-38	2.4-6.4
S22	2656-32533	1090-5600	1010-26680	13-30	155-182	5.6-6.8
S23	92.95-14399	10.6-10400	8.5-27480	18-370	165-181	2.4-7.2
S24	5754-28328	2150-40580	2500-24520	150-2550	155-182	0.8-8.4
S25	7667-27664	4500-46280	400-24120	300-1900	165-181	0.8-6.4
S26	3652-33418	4000-52200	3750-23640	60-2900	183.5-195	1.2-6.8
S27	4525-26557	100-38280	4550-24260	200-34500	151-190	3.2-6.4
S28	21246-29213	600-54600	53.50-23240	45-1900	160-180	1.6-32
S29	26.56-12394	60.5-3090	55-5200	10-4550	10-50	2.8-8
S30	157.1-21094	59-20050	54.5-5002.5	10-300	61-150	3.6-6.4
S31	183.69-45591-	1350-38010	4900-17730	150-2900	156-175	4-8.6
S32	553.3-10180	39-20550	106-4100	9-4450	71-90	4.8-6.4
S33	2000-8189	3425-12400	2750-4600	30-2150	11-14	4.4-5.6
S34	2213-26336	3300-12000	2800-4700	22-3500	171-185	5.2-6.8
S35	663.9-21910	1030-6300	1100-5050	30-3600	12-36	6-9.2
S36	327.5-15935	18-16800	52.5-4350	10-1750	12.2-16	5.2-8.8
S37	44.26-66.39	3.2-20300	10.1-3400	45-4050	9-14.5	4.4-8.4
S38	26.56-15769	11.4-18900	0.5-4150	4-56	13-34	4.4-8

Table-3
Mean values of various physico chemical parameters experienced in the study site during different seasons

Sl. No.	Parameters	Pre-monsoon	Monsoon	Post-monsoon
1	pH	7.46	7.27	7.28
2	Electrical Conductivity(μ s)	40059	14847	16146
3	Resistivity (Ω)	588	2263	1924
4	Turbidity (NTU)	9.02	11.07	11.21
5	Total Dissolved Solids (ppm)	20447	7933	6922
6	Salinity(ppm)	27761	10195	9455
7	Acidity (mg/l)	9.26	11.0	4.47
8	Alkalinity (mg/l)	148.42	92.89	61.05
9	Calcium (mg/l)	668.9	477.8	142.2
10	Magnesium (mg/l)	1219.6	1010.9	320.5
11	Total hardness (mg/l)	6729.6	5334.3	1672.0
12	Chloride (mg/l)	17291	9817	6490
13	Sodium (mg/l)	10606	13953	1362
14	Potassium (mg/l)	3692	13870	1480
15	Sulphate (mg/l)	2047	526	49.16
16	Phosphate (mg/l)	74.43	72.33	70.27
17	Total dissolved oxygen (mg/l)	5.84	5.36	4.36

pH of water samples varied over a narrow range in each season, throughout the year. Comparatively wider range of pH was noted in the Post-monsoon season (6.27-8.64) followed by Monsoon (6.04-8.34) and Pre-monsoon seasons (6.40-8.63). Mean value of pH from all the sites was higher during pre-monsoon season (7.46) followed by post monsoon (7.28) and monsoon season (7.27). Acidity of water samples during monsoon season ranged from 4.4-74.8, followed by premonsoon season (4.4-17.6) and post monsoon season (1.32-26.4). Mean value of acidity of water samples from monsoon season was higher (11.0 mg/l), followed by pre monsoon season (9.26 mg/l) and post monsoon seasons (4.47 mg/l). Alkalinity of water samples during post monsoon season ranged from 20-220, followed by premonsoon season (20-200) and monsoon season (40-190). Mean value of alkalinity was higher during pre-monsoon season (148.42 mg/l), followed by monsoon (92.89 mg/l) and post monsoon season (61.05 mg/l). Also the turbidity water samples during post monsoon season ranged from 0.6-40.1, followed by pre monsoon season (3-32.8) and monsoon season (1.1-8.6). Mean value of turbidity of water samples was higher during post monsoon season (11.21 NTU) followed by monsoon (11.07 NTU) and pre monsoon seasons (9.02 NTU). Dissolved oxygen content of water samples during post monsoon season ranged from 0.8-8.4, followed by pre monsoon season (2.4-9.2) and monsoon season (2.4-8.4). Mean value of DO was higher during pre-monsoon season (5.84 mg/l) followed by monsoon (5.36 mg/l) and post monsoon (4.36 mg/l). Among various parameters, salinity is found to have supreme influence on the growth and development of mangrove species[9-11]. Salinity is also found to be linked to other parameters like total dissolved solids, electrical conductivity, resistivity, hardness, calcium, magnesium, chloride and sodium.

Range of salinity concentration reported in the Premonsoon, Monsoon and Postmonsoon season were 97.68-43990 ppm, 34.30-33180 ppm and 36.52-33500 ppm respectively. Mean

value of salinity was higher in pre monsoon season (27761 ppm) followed by monsoon (10195 ppm) and post monsoon seasons (9455 ppm). Highest salinity of 43990 ppm was reported in site 11 (Veliancode) in the Premonsoon season and lowest value of 34.30 ppm was reported in site 1 (Srayil Kadavu) in the Monsoon season.

Total Dissolved Solid content of water samples during pre-monsoon season ranged from 98.95-26040, followed by monsoon (34.87-24750) and post-monsoon seasons (36.1-25140). Mean value of TDS content was higher during pre-monsoon season (20447 ppm) followed by monsoon (7933 ppm) and post monsoon season (6922 ppm). Similarly range of Electrical Conductivity (EC) in the Pre-monsoon, Monsoon and Post-monsoon seasons were (222.3-51090), (109.5-49520) and (19.41-49200) respectively.

Mean value of EC was higher in pre monsoon season (40059 µs), followed by post monsoon season (16146 µs) and monsoon season (14847 µs). Highest EC was reported in the Premonsoon season at site 25 (Vakad-Azhikal) and lowest value at site 7 (Athani Bridge) in the Post monsoon season. Resistivity content of water samples during post-monsoon season ranged from 3.693-15610, followed by monsoon (20.3-9350) and pre-monsoon seasons (19.2-4973). An exact reverse pattern in EC was noticed with resistivity. Mean value of resistivity was higher during monsoon season (2263 **Ω),** followed by post monsoon (1924 **Ω**) and pre monsoon seasons (588 **Ω**).

Total hardness content in the Premonsoon, Monsoon and Postmonsoon seasons ranged from 38-21200 mg/l, 40-31000mg/l and 12-7100 mg/l, respectively. Maximum value of 31200 mg/l was noticed at site 27 (Anjody-Tanur) in the Monsoon season and a minimum of 12 mg/l was reported at site 1 (Srayil Kadavu) in the Post monsoon season. Mean value of Total Hardness was higher in pre monsoon season (6729.6 mg/l), followed by monsoon (5334.3 mg/l) and post monsoon seasons (1672 mg/l).

Associated parameters like calcium and magnesium also fluctuated in the same manner as that of Hardness. Calcium content of water samples during monsoon season ranged from 11.2-2720, followed by pre-monsoon (8.8-2040) and post-monsoon season (1.6-840). Mean value of calcium was higher during pre-monsoon season (148.42 mg/l), followed by monsoon (477.8 mg/l) and post monsoon season (142.2 mg/l). Similarly magnesium content of water samples during monsoon season ranged from 1.944-5881, followed by pre-monsoon season (1.944-4398) and post-monsoon season (0.972-1531). Mean value of magnesium was higher during pre-monsoon season (1219.6mg/l), followed by monsoon season (1010.9mg/l) and post monsoon season (320.5 mg/l).

Premonsoon, Monsoon and Post monsoon seasons showed varying range of Chloride like 28.77-44041 mg/l, 15.49-48689 mg/l and 22.13-33639 mg/l respectively. Mean value of chloride was higher during pre-monsoon season (17291 mg/l) followed by monsoon (9817mg/l) and post monsoon seasons (6490 mg/l). Highest value of 48689 mg/l at site 3 (Kappirikad) and lowest value of 15.49 mg/l at site 18 (Athaloor Nedat Kadavu) was reported in the Monsoon season.

Sodium concentration in each season was reported as Premonsoon (3-23400 mg/l), Monsoon (0.5-49680 mg/l) and Post monsoon season (3.2-9550 mg/l). Mean value of sodium was higher in monsoon season (13953 mg/l), followed by pre monsoon (10606 mg/l) and post monsoon seasons (1362 mg/l). Higher value of 49680 mg/l was noticed at site 11 (Veliancode) in the Post monsoon season and a low value of 0.5 mg/ was observed at site 2 (Uppungal Kadavu) in the Monsoon season.

Apart from salinity and related parameters, nutrient content in the water samples like Phosphate, Sulphate and Potassium were assessed. Phosphate content of water samples during monsoon season ranged from 1-190, followed by post-monsoon season (3-185) and pre-monsoon season (5-186). Mean value of Phosphate content was higher during pre-monsoon season (74.43 mg/l), followed by monsoon (72.33 mg/l) and post monsoon season (70.27 mg/l). Sulphate content also showed a similar trend as that of phosphate. Sulphate content of water samples during pre-monsoon season ranged from 10-4550, followed by monsoon season (3-2750) and post-monsoon season (3-300). Mean value of sulphate content was higher during pre-monsoon season (2017 mg/l), followed by monsoon (526 mg/l) and post monsoon season (49.16 mg/l). However a different trend was noticed with the potassium content. Concentration of Potassium in the Premonsoon, Monsoon and Post monsoon seasons ranged from 6.40-6100 mg/l, 33.8-27520 mg/l and 0.5-5350 mg/l respectively.

Mean value of Potassium was higher during monsoon season (13870 mg/l), followed by pre monsoon (3692 mg/l) and post monsoon seasons (1470 mg/l). Site 38 (Thayyilakadavu) in the Post monsoon season and site 10 (Kundukadavu) in the Monsoon season were reported for maximum (27520 mg/l) and minimum (0.5 mg/l) values of Potassium.

As salinity and related parameters holds immense role in the growth and development of mangroves, the seasonal variation in salinity and the tolerance limit of different species of mangroves (Table-4) to salinity have been taken into account for assessing the potentialities of sites for mangrove afforestation.

Experimental evidences indicate that at higher salinity, mangrove species spend more energy to maintain water balance and ionic concentration, compared to primary production and growth[12]. However low salinity associated with long periods of flooding contributes to mangrove degradation through reduction of cell rigidity and decrease in respiration. Mangroves are poor competitors under non saline conditions where fresh water marsh plants easily out-class them[1]. All this refers to the fact that an optimum level of salinity, varying from species to species is necessary for the survival of mangroves.

Table-4
Optimized range of Salinity for the growth of different mangrove species

Mangrove species	Salinity Tolerance Limit	Reference
Avicennia marina	>25 ppt	13,14
Avicennia officinalis	>25 ppt	13
Rhizhophora mucronata	30 ppt	15,16
	>25 ppt	13
	15-25 ppt	14
Rhizophora apiculata	15 ppt	15,16
	15-25 ppt	13,14
Bruguiera gymnorrhiza	15-25ppt	13,14
Bruguiera cylindrica	15-25ppt	13
Sonneratia alba	2-18 ppt	15
	>25 ppt	14
Aegiceras corniculatum	>25 ppt	13
Exocaria agallocha	<15 ppt	13
Sonneratia casiolaris	<15 ppt	13

The data revealed that the mangrove species A*vicennia marina, Avicennia officinalis, Rhizhophora mucronata* and *Aegiceras corniculatum* are high salinity tolerant groups and hence can be recommended for planting in different sites studied at different seasons. These plants are noted to be ideal for afforestation in30 sampling locations in the Pre monsoon season, 10 sampling sites in the Monsoon season and 11 sampling sites in the Post monsoon season. The results have showed that, irrespective of season, 10 sampling sites along the coastal and inland aquatic environments of Malappuram district are very much ideal for afforestation of mangrove species like A*vicennia marina, Avicennia officinalis*, *Rhizhophora mucronata and Aegiceras corniculatum*.

Low salinity tolerant mangrove species like *Sonneratia casiolaris* and *Exocaria agallocha* were found to be ideal for planting practices in 8 sites in the premonsoon, 28 siteseach in the Monsoon and Post monsoon seasons respectively. The data suggests the possibilities of afforestation of mangrove species like *Sonneratia casiolaris* and *Excoecaria agallocha* at 8 sites along the coastal ecosystems of Malappuram district, as these sites sustains the requirements of these mangrove species in all the seasonsof the year.

Sonneratia alba, preferably a low to high salinity tolerant mangrove species was found to be suitable for afforestation in 32 sites in the premonsoon season, 20 sites in the monsoon season and 14 sites in the post monsoon season. The results of the present study thus highlight the possibilities of afforestation using *Sonneratia alba*at 14 sites in all the seasons. None of the sampling sites in all the three seasons were found to be suitable for the afforestation of mangrove species like *Rhizhophora apiculata, Bruguiera gymnorrhiza* and *Bruguiera cylindrica*as they are falling under moderate salinity tolerant group.

On an overall assessment it has been noticed that irrespective of season, the number of sites wherein afforestation practices can be carried out using high salinity tolerant species were 10 (S3-Kappirikad, S4-Palappetty, S11-Veliancode, S16-Ponnani Harbour, S24-Kootayi, S25-Vakad-Azhikal, S26-Paravanna, S27-Anjody-Tanur, S28-Tanur and S31-Alungal); low to high salinity bearing species were 14 (S3-Kappirikad, S4-Palappetty, S11-Veliancode, S13-Puthuponnani bridge East, S14-Puthuponnani bridge West, S15-Puthuponnani Munambam, S16-Ponnani harbour, S24-Kootayi, S25-Vakad-Azhikal, S26-Paravanna, S27-Anjody-Tanur, S28-Tanur, S31-Alungal and S34-Kadalundi Bridge) and low salinity tolerant species were 8(S1-Srayil Kadavu, S2-Uppungal Kadavu, S5-Naranippuzha, S6-Thuruvanam, S7-Athani Bridge, S17-Eswaramangalam, S18- Athaloor-Nedat Kadavu and S19-Chammaravattom Kadavu).

As some of the above mentioned sites are falling in pure marine coasts, introduction of species ideal to such locations in terms of water quality will not be feasible due to drastic wave / tide influxes. After considering such practical difficulties,the present study proposes species specific mangrove afforestation along the shorelines of 11 inland and estuarine aquatic environments (S1-Srayil Kadavu, S2-Uppungal Kadavu, S5-Naranippuzha, S6-Thuruvanam, S7-Athani Bridge, S13-Puthuponnani bridge East, S14-Puthuponnani bridge West, S15-Puthuponnani Munambam, S17-Eswaramangalam, S18- Athaloor-Nedat Kadavu and S19-Chammaravattom Kadavu)of the district in all seasons of the year.

Conclusion

The present study investigates the possibilities of mangrove afforestation along the coastal and inland aquatic environments of Malappuram district in terms of selected hydro geochemical parameters. Water samples were collected from 38 locations in all the seasons (pre monsoon, monsoon and post monsoon) and are characterized in the laboratory for its major physico chemical parameters. On the basis of analytical results of water samples and also on the basis of standard optimum growth requirements of selected mangrove species, the possibilities of

afforestation practices along the study area in all the seasons of the year have been discussed.

Salinity and salinity dependent attributes are reported to be influential to the growth and development of mangroves. Highly salt tolerant mangrove species like A*vicennia marina, Avicennia officinalis* and *Rhizhophora mucronata* were found to be ideal for afforestation in 30 sites in the Pre-monsoon, 10 sites in the Monsoon and 11 sites in the Post-monsoonal season. Low salinity tolerant species like *Sonneratia casiolaris* and *Exocaria agallocha* were noted to be ideal for planting in 8 locations in the Pre monsoon season and 28 sampling sites each in the Monsoon and Post monsoonal seasons respectively. Moderate salinity tolerant species like *Rhizhophora apiculata, Bruguiera apiculata* and *Bruguiera cylindrica* were found to beunfitfor afforestation as none of the sites studied sustains the required conditions.

The results of the present study thus highlight the possibilities of mangrove afforestation along the shorelines of 11 inland and estuarine aquatic environments of Malappuram district, which in turn will be an infallible approach in the management of coastal environments from erosion and enhancement of biodiversity.

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