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RESEARCH ARTICLE

An assessment of water quality and pollution in Puranawella Fishery Harbour, Dewinuwara, Sri Lanka.

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Abstract: Fishery harbours in Sri Lanka have been facing severe pollution problems since recent past. However, a systematic monitoring of the pollutant load has not been done. This study was carried out at Puranawella harbour, located in the southern coast of Sri Lanka, with the objective of assessing the severity of the pollution level. Investigation was carried out at seven sampling stations at three week intervals during the period from December 2010 to February 2011. Spatial and seasonal variations of physico-chemical parameters and phytoplankton abundances were examined together with bacteriological analyses. Among the characteristics studied, significant differences between sampling stations were observed for water transparency, chemical oxygen demand, orthophosphate, nitrite, oil and grease content of surface and bottom water as well as Cu and Pb in water and sediment. Water temperature, pH, salinity, total suspended solids, total dissolved solids, dissolved oxygen, biological oxygen demand, Pb in sediment and phytoplankton abundance showed significant variations among sampling months. Harbour water was characterized significantly by poor transparency (0.35m - 4.00m) and high amount of total suspended solids (0.015 - 0.072 gl^{-1}), total dissolved solids (6.98 - 43.79 gl^{-1}), high biological oxygen demand (0.44 - 8.08 mgl^{-1}), high chemical oxygen demand (0.78 - 23.4 mgl^{-1}), high orthophosphate (0.008 - 1.58 mgl^{-1}) and a high proportion of Nitrite (0.02 - 1.83 mgl^{-1}) indicating a severe eutrophication. Biological oxygen demand close to harbor jetty was 4.46 mgl^{-1}, which exceeded the recommended quality standard. Orthophosphate in surface waters exceeded the limit 0.015 mgl^{-1}, amount necessary for the establishment of heavy algal blooms. Oil and grease content of surface (9 - 82 mgl^{-1}) and bottom water layers (22 - 241 mgl^{-1}) inside the harbour also exceeded the recommended value of 10 mgl^{-1}. The concentration of Cu and Pb in water exceeded the standard value of 0.5 mgl^{-1}. MPN value of total coliforms (per 100 ml) ranged between 5 and 2400, which also exceeded the recommended standards. The phytoplankton density ranged between 16356 and 62500 cells/m^3. Results of this study revealed that the water quality of the harbour has been degraded and harbour is subjected to severe oil pollution, organic pollution and microbial contamination. Since this study was carried for only 3 months, a yearlong study is required to come to stronger conclusions.

Keywords: Harbour Pollution, Coliforms, Eutrophication, Oil, Heavy metals

Introduction

Coastal and marine ecosystems in the present world are being severely affected by rapid growth of human population and intensive urbanization in coastal regions. Hence, pollution in marine environments had become one of the serious issues and it has been expanded all over the marine ecosystem from deep sea to coastal waters. Most of the industries in the world are settled in coastal belts of the countries, especially, around major commercial harbours and airports due to ease of trade, which contribute to severe pollution.

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A fishery harbour is a complex center of activities which are potential waste generators and thus considered as a hot spot of coastal pollution. As the fishery harbour and its continuous waters are part of the coastal zone, pollution of the harbour directly affects the coastal zone and *vice versa* (Sciortino *et al.*, 1999). Discharge of burned oil and bilge water from fishing vessels to harbor waters, production of load of organic wastes which derived from fish degutting, market floor runoff, cleaning and garbage dumping are main reasons for degradation of water quality and water pollution in fishery harbours (Holmgren, 1994). Pumping of oily waters from washing boats, accidental oil spillage during refueling, solid waste derived from boat repairing that are washed into harbour with the rain runoff are the main boat generated sources of pollution (Namaratne and Dassanayake, 1991). In addition, other pollution sources in a fishery harbour includes improper dumping of fish offal and other garbage into harbour waters, dumping of untreated sewage from toilets and defecation inside the harbour premises. Due to such activities, harbour water becomes rich in faecal coliforms (Jayaweera *et al*., 1987; Holmgren, 1994). This crisis is exacerbated by flows of untreated wastewater and domestic water from land based external sources such as human settlements around harbour premises. Many industrial processes produce heavy metals and trace elements as by-products and they are discharged as waste into coastal waters (Robson and Neal, 1997) or they enter coastal waters via atmospheric and land based effluent sources. To improve the management of a fishery harbours its pollution level should be thoroughly assessed. This study was carried out at Puranawella harbour, one of the major fishery harbours located in the southern coast of Sri Lanka, with two objectives, to assess the pollution level as well as to collect information on the present status of anthropogenic activities which pollute the harbour.

Figure 1. Location of Puranawella fishery harbour

Materials and Methods

Site description

Puranawella fishery harbor (latitude 5^{o} 56'N and longitude 80^{o} 35' E) is located towards west of the point of Dondra (Dewinuwara), the southernmost point of Sri Lanka (Figure 1). The total area of the harbour basin is 11 hectares and it has berthing facilities for 333 multi day boats, 17 one day boats, 7 mechanized canoes and 4 traditional wooden boats (Mallawatantri, 2005).

Figure 2. Map of Puranawella fishery harbor indicating sampling stations (Stations 1- 7)

Selection of sampling stations and sample collection

Seven sampling stations were selected on random basis (Figure 2). Out of the seven stations, five were positioned inside the harbour basin (stations 1, 2, 3, 4 & 5) and two were positioned outside the harbour (stations 6 & 7). The samples of water, sediment and phytoplankton were taken from December 2010 to February 2011 at three week intervals during the day from10.00 am to 12.00 noon. A detail description of each sampling station in the study site is given in Table 1.

Analyses of samples

Water transparency was measured using a standard Secchi disc with a diameter of 20 cm. Temperature, pH and salinity of seawater were measured in-situ using a portable pH-temperature, conductivity meter (ADVA-ADM, Hungary) and refractometer, respectively. Total suspended solids (TSS) and total dissolved solids (TDS) of seawater samples were determined by gravimetric method. Dissolved oxygen (DO) and biological oxygen demand (BOD) of seawater samples were analyzed using modified Winkler's method (Golterman, 1971), chemical oxygen demand (COD) was determined by the permanganometric method (Golterman, 1971). Total reactive phosphate (orthophosphate) content of the seawater samples was determined by ascorbic acid method (Mackereth, 1965).

Nitrite concentration was determined using the protocol of sensitive diazotization method (Silva *et al.*, 1996). Floatable grease and oil contents in surface water layers and bottom waters were measured using partition gravimetric method (Marine Pollution Prevention Authority, 2006). Copper and lead concentrations in seawater and sediment samples were analyzed by atomic absorption spectrophotometer (Varian spectra 220). Faecal coliform count and total coliform count were determined by 5 tube most probable number (MPN) technique using the selective media (Clesceri *et al.*, 1989). Phytoplankton samples were collected using phytoplankton nylon net, with sieve size of 30 µm and quantifications were done using a sedgewick-rafter cell (counting chamber) with the aid of an optical microscope (NOVEX).

Table 1. Location, depth and descriptions of sampling stations of the study site shown in Figure 2.

Sampling Station #	Depth (m)	Latitude (ºN)	Longitude (ºE)	Description
Station 1	2.37	5º55' 22.502"	80º 34' 58.55"	Closer to the end of the longest southwest breakwater
Station 2	1.94	5º55' 29.847"	80º 35' 3.787"	Far northeast, but situated closer to the land and to the shortest northwest breakwater
Station 3	2.28	5º55' 20.72"	80º 35' 3.79"	Positioned in the middle of the harbour basin where few fishing boats are berthing around this station
Station 4	1.45	5º55' 19.497"	80º 35' 6.864"	Closer to a small part of beach where outboard motor boats anchored and to an opening of wastewater discharging channel
Station 5	3.07	5º55' 14.845"	80º 35' 3.792"	Closer to the main jetty of the harbour where many boats are anchored
Station 6	4.35	5º55' 29.88"	80º 34' 58.582"	Far northwest outside the harbour and closer to the end of northwest breakwater
Station 7	4.39	5º55' 17.99"	80º 34' 56.596"	Positioned in the open sea and closer to the southwest breakwater

Statistical analysis

One way ANOVA was carried out to analyze the variation of physico-chemical parameters and phytoplankton densities between sampling stations and sampling occasions.

Results and Discussion

Physicochemical parameters

Statistical analyses revealed that water transparency, chemical oxygen demand, orthophosphate and nitrite in surface waters varied significantly among sampling stations ($P<0.05$) whereas temperature, pH, salinity, total suspended solids, total dissolved solids, dissolved oxygen and biological oxygen demand showed a significant variation among sampling occasions ($P<0.05$) (Table 2).

Oil and grease content in both surface and bottom waters varied significantly among sampling stations ($P<0.05$) (Table 3). Also, the concentrations of copper and lead in both water and bottom sediment showed a significant variation among sampling stations ($P<0.05$) (Table 4).

Table 2. Mean values ± standard error of physicochemical parameters at each sampling station in Puranawella harbour.

Characteristics	Sampling station number							Significance
	1	2	3	4	5	6	7	
Temperature (ºC)	26.6 ± 0.55	26.7 ± 0.52	26.7 ± 0.36	26.5 ± 0.57	27.0 ± 0.48	26.6 ± 0.61	26.78 ± 0.54	BS^{NS} BST^{*}
pH	7.83 ± 0.16	7.78 ± 0.12	7.78 ± 0.18	7.80 ± 0.17	7.80 ± 0.12	7.84 ± 0.11	7.91 ± 0.09	BS^{NS} BST^{*}
Salinity (‰)	31.8 ± 3.25	31.3 ± 3.75	31.8 ± 3.25	28.5 ± 4.25	31.6 ± 3.89	32.5 ± 3.18	33.0 ± 2.68	BS^{NS} BST*
Transparency (m)	1.54 ± 0.20	1.30 ± 0.16	1.70 ± 0.31	0.45 ± 0.03	1.44 ± 0.31	3.91 ± 0.03	3.94 ± 0.03	BS* BST^{NS}
Total Suspended Solids (gl^{-1})	0.039 ± 0.01	0.041 ± 0.01	0.040 ± 0.01	0.037 ± 0.01	0.041 ± 0.01	0.032 ± 0.01	0.032 ± 0.01	BS^{NS} BST*
Total Dissolved Solids (gl^{-1})	36.48 ± 5.30	35.16 ±3.01	35.29 ±3.80	25.49 ± 8.09	33.15 ± 4.67	32.47 ± 5.35	29.64 ± 4.78	BS^{NS} BST*
Dissolved Oxygen (mgl^{-1})	6.68 ± 0.45	8.69 ± 1.27	7.50 ± 0.43	8.14 ± 0.83	6.49 ± 0.37	8.18 ± 0.87	9.83 ± 0.68	BS^{NS} BST*
Biological Oxygen Demand (mgl^{-1})	3.51 ± 0.99	3.99 ± 1.74	3.30 ± 0.86	3.80 ± 1.07	4.46 ± 0.66	3.03 ±1.04	2.69 ± 0.68	BS^{NS} BST*
Chemical Oxygen Demand (mgl^{-1})	4.68 ± 0.64	4.29 ± 1.17	4.29 ± 0.39	11.71 ± 3.95	8.98 ± 0.75	1.95 ± 0.50	1.17 ± 0.23	BS* BST^{NS}
Orthophosphate (mgl^{-1})	0.302 ± 0.24	0.140 ± 0.08	0.105 ± 0.03	0.881 ± 0.37	0.367 ± 0.11	0.084 ± 0.04	0.077 ± 0.03	BS* BST^{NS}
Nitrite (mgl^{-1})	0.257 ± 0.10	0.542 ± 0.43	0.181 ± 0.09	0.927 ± 0.11	0.683 ± 0.14	0.081 ± 0.01	0.050 ± 0.01	BS* BST^{NS}

BS = Between Stations, BST = Between Sampling Time, * =($P \leq 0.05$), NS(Not Significant) = ($P > 0.05$)

Table 3. Mean concentrations (± standard error) of floatable oil and grease in surface and bottom waters at each sampling station

Characteristic	Description	Sampling station number							Significance
		1	2	3	4	5	6	7	
Oil & Grease Content (mgl^{-1})	Surface	51.7 ± 8.6	30.5 ± 4.2	45.2 ± 6.6	45.2 ± 7.3	64.7 ± 8.1	15.5 ± 2.0	12.0 ± 1.3	BS* / BST^{NS}
	Bottom	189.7 ± 2.4	58.2 ± 2.4	118.0 ± 11.2	184.5 ± 2.8	228.5 ± 5.3	25.0 ± 0.4	23.2 ± 0.5	BS* / BST^{NS}

BS = Between Stations, BST = Between Sampling Time, * =($P \leq 0.05$), NS(Not Significant) = ($P > 0.05$)

(Recommended value – $10mgl^{-1}$, Primary water quality criteria for class SW-IV harbour water (Central Pollution Control Board, n.d.)

Table 4. Mean concentrations (± standard error) of copper and lead in water (mgl^{-1}) and sediment (mg/g dw) at each sampling station

Metal	Sampling station number							Significance
	1	2	3	4	5	6	7	
Copper (Cu) in Water (mgl^{-1})	0.46 ± 0.141	0.38 ± 0.10	0.58 ± 0.093	0.26 ± 0.085	0.35 ± 0.087	0.30 ± 0.144	0.043 ± 0.005	BS* / BST^{NS}
Lead (Pb) in Water (mgl^{-1})	1.18 ± 0.05	1.19 ± 0.031	1.08 ± 0.021	0.74 ± 0.150	1.12 ± 0.020	0.71 ± 0.164	0.61 ± 0.087	BS* / BST^{NS}
Copper (Cu) in Sediment (mg/ g dw)	0.085 ± 0.003	0.064 ± 0.044	0.062 ± 0.001	0.076 ± 0.002	0.11 ± 0.004	0.0022 ± 0.001	0.0008 ± 0.000	BS* / BST^{NS}
Lead (Pb) in Sediment (mg/ g dw)	0.14 ± 0.014	0.125 ± 0.023	0.11 ± 0.014	0.086 ± 0.011	0.11 ± 0.016	0.07 ± 0.005	0.05 ± 0.004	BS* / BST*

BS = Between Stations, BST = Between Sampling Time, * =($P \leq 0.05$), NS(Not Significant) = ($P > 0.05$)

MPN values for total coliforms and faecal coliforms per 100ml of collected water samples from each sampling station are given in Table 5. The lowest MPN values of total coliforms were recorded outside the harbor (St 6 & St 7). The highest MPN values of total coliforms and faecal coliforms were recorded at stations 4 and 5, located in the immediate vicinity of the wastewater channel from the residential area surrounding the harbour premises and at close proximity to the main jetty of the harbor. Phytoplanktons of *Asteromphalus sp., Biddulphia sp., Chaetoceros sp., Coscinodiscus sp., Cyclotella sp., Gyrosigma sp., Koliella sp., Navicula sp., Nitzschia sp., Nostoc sp., Oscillatoria sp., Pleurosigma sp., Rhabdonema sp., Spirogyra sp., Striatella sp., Suriella sp., Thalassiosira sp.* and *Triceratium sp.* were identified during the study period. Statistical analysis revealed that a significant variation of phytoplankton densities between sampling times and sampling occasions ($P \leq 0.05$) (Table 6). The mean value of biological oxygen demand near the jetty ($4.46\ mgl^{-1}$) (Table 2) exceeded the recommended value ($<4\ mgl^{-1}$) of environmental quality standard by Central Environmental Authority of Sri Lanka and primary water quality criteria for class SW-IV harbor water ($3\ mgl^{-1}$) (Central Pollution Control Board, n.d). Thus, it reflects that the organic pollution is pronounced near the jetty, indicating the presence of load of organic matter. The highest mean value of organic matter concentration was observed to be $11.71\ mgl^{-1}$ near the harbor jetty (Table 2). Orthophosphate concentration in the water varied between $0.008\ mgl^{-1}$ and $1.579\ mgl^{-1}$ and the mean values exceeded $0.015\ mgl^{-1}$ which is necessary for the establishment of large algal blooms (Wilson and Dickson, 1977) and for the waters to be highly productive (Lueshow *et al*., 1970). The orthophosphate concentration near the jetty was $0.367mgl^{-1}$, which is nearly 50 times higher than the value recorded by Hewapathirana and Bandulage during their investigation done in 2007.

Table 5. Most probable number (MPN) for total coliforms and faecal coliforms (per 100 ml of water) of water samples

Date	MPN Value for Total coliforms per 100 ml of water						
	Sampling station number						
	1	2	3	4	5	6	7
06/12/2010	540	920	1600	2400	2400	5	7
27/12/2010	140	26	33	1600	2400	7	9
17/01/2011	17	17	920	2400	1600	5	7
07/02/2011	110	22	11	540	2400	5	9
Recommended value: <100/100 ml - Central Environmental Authority of Sri Lanka (Hewapathirana and Bandulage, 2009)							

Date	MPN Value for Faecal coliforms per 100 ml of water						
	Sampling Station						
	1	2	3	4	5	6	7
06/12/2010	94	140	220	350	350	4	5
27/12/2010	23	4	5	350	540	2	2
17/01/2011	4	4	180	540	350	2	2
07/02/2011	17	4	2	94	350	2	7
Recommended value: < 20/100 ml - Central Environmental Authority of Sri Lanka (Hewapathirana and Bandulage, 2009)							

Table 6. Phytoplankton densities (cells/m^3) at each sampling station

Date	Sampling station number							Significance
	1	2	3	4	5	6	7	
06/12/2010	37383	46729	37383	65421	60748	18692	23364	
27/12/2010	42056	70093	51402	60748	56075	14019	32710	
17/01/2011	42056	126168	79439	51402	56075	18692	42056	
07/02/2011	9346	7009	11682	25701	18692	14019	9346	
mean density (cells/m^3)	32710	62500	44977	50818	47898	16356	26869	BS^{NS}
								BST*
BS = Between Stations, BST = Between Sampling Time, * =($P \leq 0.05$), NS(Not Significant) = ($P > 0.05$)								

Oil and grease content in surface water (9 mgl^{-1} - 82 mgl^{-1}) and in bottom water layers (22 mgl^{-1} - 241 mgl^{-1}) inside the harbour (Table 3) exceeded 10 mgl^{-1}, which is the value recommended for the harbours according to the primary water quality criteria for class SW-IV harbour waters (Central Pollution Control Board, n.d). The mean concentration of Pb in water (Table 4) at each station exceeded the standard value (0.5 mgl^{-1}) of EU Estuary and Harbor Basin Water (Sciortino *et al.*, 1999). Also, relatively high concentrations of copper and lead in water and sediments were found near the jetty where majority of boats are berthed and crude oil is discharged from the fishing vessels.

The highest MPN for total coliforms and faecal coliforms, was observed at the station 4 and 5 adjacent to the jetty (Table 5) and these values exceeded the recommended value for total coliforms (<100/100 ml), declared by CEA of Sri Lanka. Also, MPN values exceeded the recommended value for faecal coliforms (<20/100 ml), declared by CEA of Sri Lanka and standard for faecal coliforms (500/100 ml) in Primary water quality criteria for class SW-IV water (for harbour waters) (Central Pollution Control Board, n.d). Hence, people may have a potential risk of gastrointestinal infections through fish consumption as the fish are washed with highly polluted harbour waters by fish handlers. The presence of rich phytoplankton densities inside the harbour suggested an intense eutrophication with the presence of *Biddulphia sp., Coscinodiscus sp., Triceratium sp., Thalassiosira sp. and Oscillatoria sp.*, which were found to be the dominant species in the harbour during this study.

Conclusion

The water quality has been degraded and the harbour is subjected to severe oil pollution, organic pollution and microbial contamination in terms of faecal contamination. Discharge of burned oil and bilge water from fishing vessels, production of load of organic wastes derived from fish degutting, market floor runoff, cleaning and garbage dumping, accidental oil spillage during refueling, solid waste derived from boat repairing, untreated sewage from toilets and defecation inside the harbour premises were the identified main sources and activities which boost up the pollution in the harbour. Hence, promotion of practice of '3 R's - reduction, reuse and recycling for waste minimization, implementation of Hazard Analysis Critical Control Point programme (HACCP), implementation of set of procedures and assessing and monitoring programmes are recommended to ensure a safe fishery harbor. Since this study was only carried out for 3 months, a yearlong study is required to come to a stronger conclusion.

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