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EFFICIENCY STUDY OF TWO WETLAND TREATMENT SYSTEMS AT BHUBANESWAR, INDIA

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Domestic wastewater

Nutrients

biological treatment.

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ABSTRACT

The present study deals with the biological treatment of municipal wastewater of two treatment systems namely Vani Vihar lake and Niccopark lake at Bhubaneswar. Water and plant samples were collected from three locations covering post-monsoon, winter and summer seasons from both the systems. Twentysix parameters including nutrients and other trace elements were studied from each location.The pH increased (0.84%-8.76%) from inlet towards the outlet point in both the systems irrespective of seasons. Increase in DO (10.43-150%) and decrease in BOD from inlet to outlet indicate achievement of partial treatment by both the systems. TDS, TSS, EC and hardness reduced sufficiently by both the systems. Nutrients like NO_2 –N and NH_3-N increased towards the outlet points than in inlet points in both the systems exceptional being in post-monsoon at Niccopark lake. NO_3-N was increased in summer season in both the systems. PO_4-P and SiO_4 concentrations reduced significantly towards the outlet point. Some of the elemental concentrations (Cu, Zn, Cr, Pb, Co, Ni) were very less in water sample, but have their signature in the plant samples collected from both the systems. Other elemental concentrations (Na, K, Ca, Fe, Mn, Cd) got significantly reduced from the inlet point towards the outlet point through the process of bioaccumulation by the plants inside the systems. Factor analysis suggests similar pattern of bioavailability of Mn, Na, Zn, Fe and Ni in both the treatment systems. On the other hand the sources and bioavailability pattern of Pb, Cr and Cd are similar in both the treatment plants.

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INTRODUCTION

Domestic sewage is the primary source of water pollution in India, especially in and around large urban centers. The lack of investment in appropriate infrastructure to manage these wastes has been a major factor in deterioration of water quality across the country. About 85% of the waste water produced is contributed from domestic sector, but the sewage treatment facilities are inadequate in most cities and almost absent in rural India.Thus, there is a big gap in treatment of domestic wastewater. Municipal wastewater is mainly comprised of water (99.9%) together with relatively small concentrations of suspended and dissolved organic and inorganic solids. The organic substances present in sewage are carbohydrates, lignin, fats, soaps, synthetic detergents, proteins and their decomposition products, as well as various natural and synthetic organic chemicals from the process industries. Municipal wastewater also contains a variety of inorganic substances from domestic and industrial sources, including a number of potentially toxic elements such as arsenic, cadmium, chromium, copper, lead, mercury, zinc, etc.

Study Area

The present study was undertaken in Bhubaneswar City, Orissa, India, covering an area of about 233 km^2 at Latitude – 20 ^{0} 12' N to 20 ^{0} 25' N and Longitude – 85 ^{0} 44' E to 85 ^{0} 55' E. The city has an undulating ridge and valley topology and is covered by number of natural drainage channels. The drainage is controlled by the Kuakhai and Daya rivers, girdling the city on the north and the south. Apart from this, a number of open drains running west to east cress-cross the city, some of which finally joins to form Gangua Nallah. Gangua receives more than 105 Million Litre Per Day (MLD) of wastewater within the city of which 47.6 MLD is from domestic sources, 29.3 MLD from industrial areas (mainly from the Patia and Chandaka industrial estate) and 30.35 MLD from mixed sources. This huge generation and discharges may have potential threats to the biotic life dependant on the water bodies receiving this, including humans

Study Site

The present study was undertaken at two sewage treatment system namely BDA- Nico park and treatment system near Vani Vihar, Bhubaneswar.

Treatment System Near BDA-NICCO Park, Bhubaneswar

The treatment system consist of a sedimentation chamber (7 crisscross baffle makes it 8 chambered) followed by two number of duckweed ponds in series and a final fish pond. Two such 'layout-setups' in parallel have been constructed leaving the main effluent drain in-between (Fig.1) and the present situation is given in Figure 2.

The technical specifications of the treatment system during construction near BDA- NICCO PARK

i) Catchments area	:	5.16 km^2
ii) Available land area	:	3.3 ha
iii) Duckweed pond	:	9900 m^2
iv) Fish pond	:	6133 m^2
v) Projected inflow of waste water	:	3.95 MLD
vi) Designed for quantity of effluent	:	3.95 MLD
iv) Fish pond (2 nos.)	:	8085 m^2
v) Projected inflow of waste water (dry season)	:	6.0 MLD
vi) Designed for quantity of effluent	:	4.5 MLD
vii) Maximum storm water discharge	:	2613 MLD

MATERIALS AND METHOD

Sampling Stations

For sampling purpose, 3 sampling stations at both the treatment systems were selected as described below;

N1: Inlet point of the treatment system near the Nicco Park
N2: Near duckweed pond at Nicco Park
N3: Outlet point at Nicco Park
B1: Inlet point at Vani Vihar
B2: Near duckweed pond at Vani Vihar
B3: Outlet point at Vani Vihar

Waste water and plant samples were collected from the above stations and were brought to the environmental laboratory of Eastern Academy of Science and Technology (EAST), Phulnakhara, Bhubaneswar for analysis of various physico-chemical parameters. Standard methods (APHA,1998) was followed for the collection and analysis of water samples. Water samples were collected from all the six stations for the analysis of various parameters. DO was fixed with Winkler's A and Winkler's B on the spot (Trivedy and Goel, 1984). pH was measured on the spot and water for the analysis of nutrients and metal analysis was collected in clean plastic bottles and brought to the lab for further analysis. Dissolved trace elements were analyzed as per he standard methods (Boutron,1972; Gorlach and Boutron, 1990; Jetty, 1994; Isozaki *et al.,* 1981; Cheng *et al.,* 1987; Hiraide *et al.,* 1980; Anderson and Ingri, 1991).

RESULTS AND DISCUSSION

pH

The pH in all the 3 stations of both the treatment systems are slightly alkaline in nature in all the three seasons of sampling and varied between 7.01 and 7.91. In general the pH in the 3 stations of the treatment system near Nicco Park (Fig. 4) is higher than that of the treatment system near Vani Vihar (Fig. 5). The higher pH at the treatment system near Nicco Park than that of treatment system near Vani Vihar might be contributed due to higher rate of decomposition.

Dissolved Oxygen (DO)

The dissolved oxygen (DO) content varied from 0.2 mg/l to 2.54 mg/l at the treatment system near BDA Nicco-park (Fig. 6) and from 0.6 mg/l to 3.2 mg/l near Vani Vihar (Fig. 7). In both the treatment plants DO is always higher in the outlet point than the inlet points. The lowest DO was recorded from the duckweed ponds of both the treatment plants in all the seasons which is due to the defunct nature of the pond and ultimate higher decomposition rate which is reflected by higher BOD.
water.impact. Regression analysis was performed to establish the relationship between BOD and DO and the regression graph (Fig. 10) shows there exist a negative relationship between DO and BOD which is a natural phenomenon.

Total Dissolved Solids (TDS) and Total Suspended Solids (TSS)

TDS in all the 6 sampling stations varied between 160 mg/L to 766 mg/L during the entire 3 seasons of sampling.The TDS concentration gradually declined from the inlet to outlet points in both the treatment plants. Figure 11 shows the TDS concentration of both the treatment systems.

The TSS concentration in all the sampling stations in both the treatment system varied between 13.6 mg/L to 88.3 mg/L during the entire periods of sampling. The TSS concentration was always higher in the inlet points than that of the outlet points which suggested that the settling of TSS is achieved through the duckweed pond. The concentration of TSS is always higher in the treatment system near the Niccopark than that of the treatment system near Vani Vihar which implies clearly about the higher load at the treatment plant at Nicco-Park (Fig. 12).

Nutrient Analysis

The concentration of different nutrients in the water samples of both the treatment plants during different seasons of sampling is presented in Table 1. The NO_2-N concentrations (as per Strickland and Parson, 1972) in both the treatment system varied between 0.03 mg/l to 0.73 mg/L during the entire periods of study. Among the seasonal samplings the NO_2-N concentration was always lower during the post-monsoon season

Table 1: Seasonal variation of different nutrients (mg/L) in different stations.

Seasons	Stations	NO_2-N	NO_3-N	NH_3-N	TN	PO_4-P	TP	SiO_4
Post-monsoon	N1	0.06	4.53	0.14	8.76	2.98	5.43	4.09
	N2	0.09	7.32	0.27	12.32	3.27	6.12	3.26
	N3	0.12	3.21	0.24	7.89	2.16	4.98	3.19
Winter	N1	0.71	4.12	0.31	9.83	6.00	9.86	11.30
	N2	0.76	9.12	0.42	16.72	6.72	12.30	13.70
	N3	0.56	2.83	0.27	8.08	5.54	8.76	10.10
Summer	N1	0.68	3.99	0.34	8.16	7.04	10.30	12.30
	N2	0.79	12.70	1.46	21.01	7.62	13.90	14.10
	N3	0.58	4.68	0.31	8.61	5.97	9.34	10.70
Post-monsoon	B1	0.03	1.44	0.03	3.2	2.44	4.92	5.06
	B2	0.21	2.11	0.06	4.32	2.76	4.67	6.43
	B3	0.18	0.62	0.09	1.76	2.45	4.14	4.72
Winter	B1	0.32	2.82	0.10	4.11	4.51	5.76	9.4
	B2	0.71	4.51	0.19	7.54	3.31	6.12	10.5
	B3	0.71	4.54	0.20	7.06	6.89	10.98	9.3
Summer	B1	0.39	3.01	0.09	5.13	5.12	8.67	9.7
	B2	0.76	4.79	1.27	9.87	4.32	7.54	10.1
	B3	0.71	4.36	0.29	8.98	8.01	13.23	9.5

Table 2: Percentage increase/decrease of nutrients and other parameters.

Parameters	% of increase/ decrease at outlet point than inlet points					
	In the treatment system near NICCO Park			In the treatment system near Vani Vihar		
	Post-Monsoon	Winter	Summer	Post-Monsoon	Winter	Summer
pH	-8.76	-0.84	-1.80	-5.48	-0.95	-2.91
DO	+10.43	+50.00	+150.00	+10.34	+31.25	+22.22
BOD	-14.29	-22.22	-24.36	-14.75	-24.56	-17.19
TDS	-72.45	-7.81	-14.21	-70.37	-2.76	+0.33
TSS	-43.31	-63.74	-50.76	-36.89	-25.00	-29.95
EC	-53.03	-24.94	-30.61	-68.51	-61.20	-45.62
Hardness	-51.16	-22.94	-26.88	-71.11	-60.28	-45.75
NO_2-N	+100.00	-20.25	-13.74	+500.00	+118.02	+83.68
NO_3-N	-29.14	-31.21	+17.38	-56.94	+60.76	+44.72
NH_3-N	+71.43	-12.90	-8.82	+200.00	+97.57	+217.00
TN	-9.93	-17.80	5.51	-45.00	71.78	75.05
PO_4-P	-27.52	-7.67	-15.20	0.41	52.73	56.45
TP	-8.29	-11.16	-9.32	-15.85	90.63	52.60
SiO_4	-22.00	-10.62	-13.01	-6.72	-1.06	-2.06

Table 3: Percentage reduction/increase of different elements by both the treatment plants in water samples.

Elements	In the treatment system near BDA-Niccopark			In the treatment system near Vani Vihar		
	Post-monsoon	Winter	Summer	Post-monsoon	Winter	Summer
Na	-8.50	-21.90	-31.96	-16.78	-11.83	-9.45
K	-20.11	-29.37	4.23	-13.37	-23.30	-8.74
Ca	55.84	-2.64	52.92	-10.03	-16.40	-1.50
Fe	-19.00	-48.46	13.86	-17.89	-9.70	2.33
Cu	NA	NA	NA	NA	NA	NA
Zn	NA	NA	NA	NA	NA	NA
Cr	NA	NA	NA	NA	NA	NA
Pb	NA	NA	NA	NA	NA	NA
Cd	NA	NA	NA	-15.63	-32.35	-8.82
Ni	NA	NA	NA	NA	NA	NA
Co	NA	NA	NA	NA	NA	NA
Mn	-4.65	-20.41	-5.36	-11.11	-8.62	-3.77

which might be due to the dilution effect. The average NO_2-N concentration was always higher in the treatment system near BDA-Nicco-Park than Vani Vihar being the exception during the summer season.

Table 4: Percentage reduction/increase of different elements by both the treatment plants in plant samples.

Elements	In the treatment system near BDA-Niccopark			In the treatment system near Vani Vihar		
	Post-monsoon	Winter	Summer	Post-monsoon	Winter	Summer
Na	-78.24	-67.23	-67.80	-7.10	-13.85	-27.95
K	-5.27	-3.54	-10.13	-17.35	-12.28	-9.20
Ca	0.08	-1.49	6.83	-20.59	-13.44	-8.39
Fe	-31.26	-31.01	-30.09	-41.14	-39.42	-31.66
Cu	24.14	21.88	33.33	-46.03	NA	NA
Zn	-65.43	-67.38	-66.07	-59.71	-53.99	-47.87
Cr	127.10	37.27	36.54	-8.94	NA	NA
Pb	133.10	159.67	141.87	-29.63	-24.12	-23.91
Cd	56.40	36.24	28.46	-0.86	-16.14	-21.04
Ni	2.45	-16.65	-16.88	-7.13	-19.35	-15.70
Co	8.70	7.87	6.39	-23.74	-11.94	-19.15
Mn	-26.14	-29.01	-25.28	-4.94	-30.89	-19.57

Table 5: t-test value of parameters at both the treatment plants (Taking all the seasons into account).

Parameters	t	d.f.	Significant level
	Treatment system near Vani Vihar		
Trace elements in water	1.014	35	0.5
Trace elements in plant	2.676	35	0.1
Nutrients	3.021	20	0.1
	Treatment system near Nicco Park		
Trace elements in water	0.967	35	0.5
Trace elements in plant	2.345	35	0.1
Nutrients	3.679	20	0.1

Table 6: Factor analysis for the trace elements concentration in the plant samples of both the treatment plants

Treatment plant Near Nicco-Park				Treatment plant near Vani Vihar			
Elements	F-1	F-2	F-3	Elements	F-1	F-2	F-3
Mn	0.98			Ni	0.926		
Na	0.948			Fe	0.919		
Zn	0.939			Mn	0.888		
Pb	-0.793		0.538	Zn	0.875		
Cr	-0.694			Pb	0.779		0.415
Ni	0.657	0.539		Na	0.725	0.4	
Fe	0.627	0.603		K		0.963	
Cd	-0.615		0.593	Ca		0.925	
Ca		0.986		Cd	0.439	0.756	
K		0.911		Cu			-0.959
Cu			0.9	Cr			-0.933
Co		0.404	0.87	Co	0.555	0.49	0.63
Eigen Value	5.216	3.028	2.555	Eigen Value	5.025	3.15	2.715
% of variance	43.471	25.237	21.288	% of Variance	41.872	26.247	22.628
Cumulative variance	43.471	68.708	89.996	Cumulative variance	41.872	68.119	90.747

Among the seasonal samples, the BOD concentration was lower during the post-monsoon season than other two seasons of sampling which is due addition of some amount of oxygen due to the monsoon

Among the inorganic nitrogenous nutrients the concentration of NO_3-N (Grasshaff *et al.,* 1999) is higher among all others and varied between 0.62 mg/L to 12.70 mg/L during the entire periods of study. The concentrations of NO_3-N is always higher in the duckweed ponds of both the treatment system during all the seasons being the exception in the winter season in the treatment system near Vani Vihar, where the concentration is slightly higher in the outlet point than the duckweed pond .This gives an indication that the degradation of the weeds might have contributed the highest concentration at the duckweed pond and further

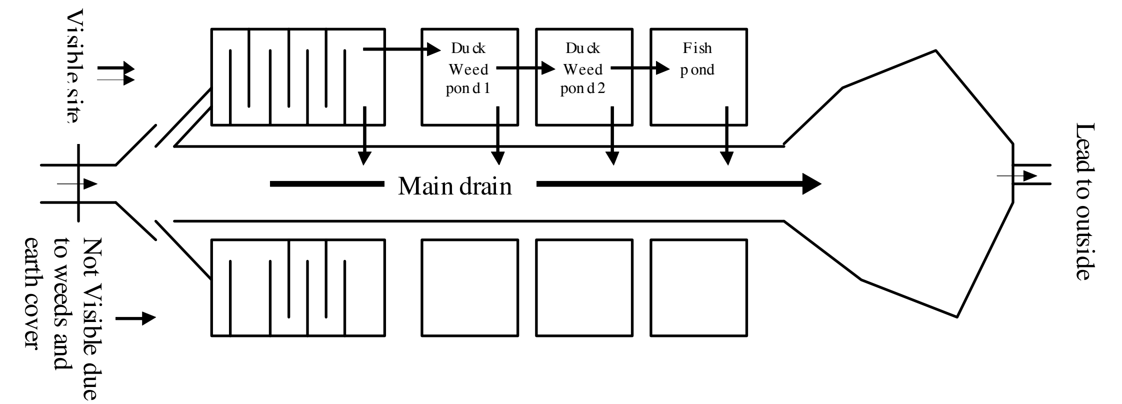

Figure 1: The detail flow diagram of the treatment system during construction

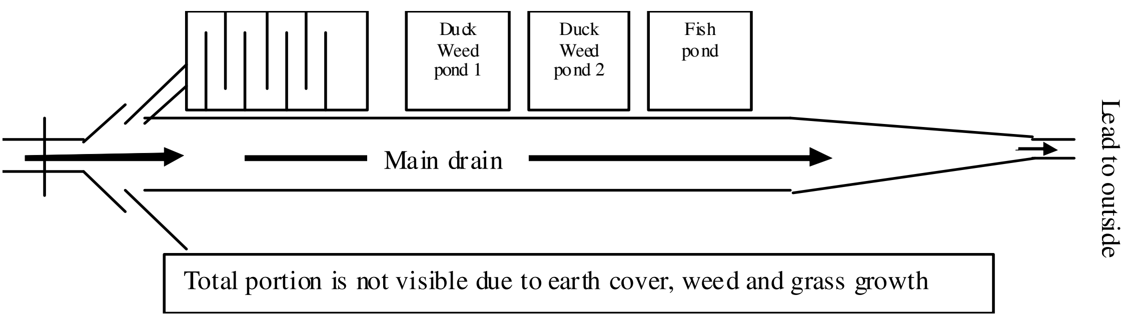

Figure 2: The detail flow diagram of the treatment system situation at present

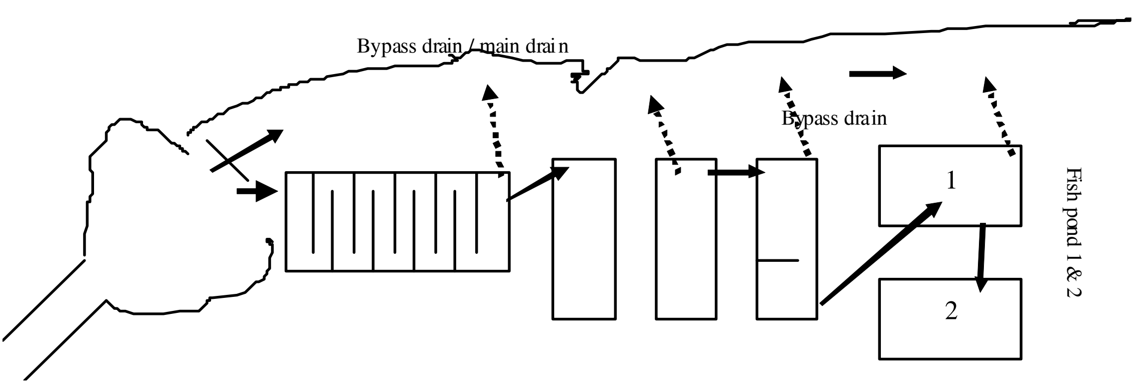

Figure 3: The detail flow diagram of the treatment system situated near Vani Vihar

decrease of the NO_3-N concentration towards the outlet points is due to the sufficient utilization of the nutrients by the plants in side the duckweed ponds.

The NH_3-N concentration in both the treatment systems varied between 0.03 mg/L to 1.47 mg/L during the entire periods of study . In general the NH_3-N concentration was higher at the duckweed ponds in both the treatment plants with a few exceptions. The NH_3-N concentration of the treatment system near the BDA-Nicco-Park was comparatively higher than Vani Vihar.

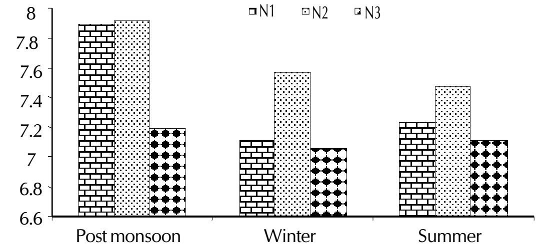

Figure 4: Seasonal variation of pH at 3 samplin ations

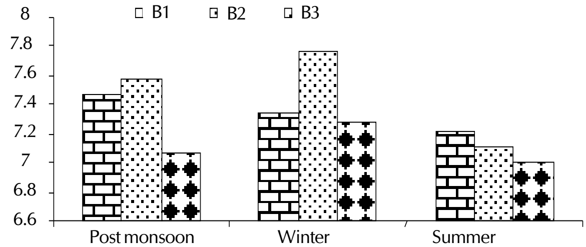

Figure 5: Seasonal variation of pH at 3 sampling

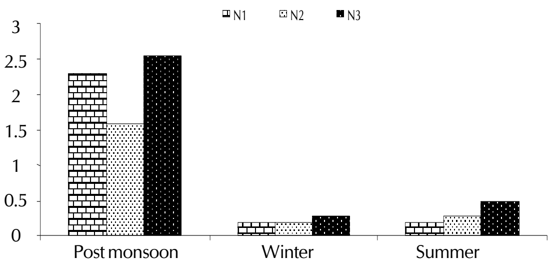

Figure 6: Dissolved Oxygen (DO) content in different seasons of treatment system at BDA-NICCO PARK

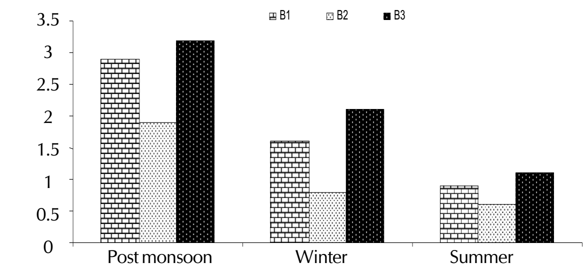

Figure 7: Dissolved Oxygen (DO) content in different seasons of treatment system at Vani Vihar

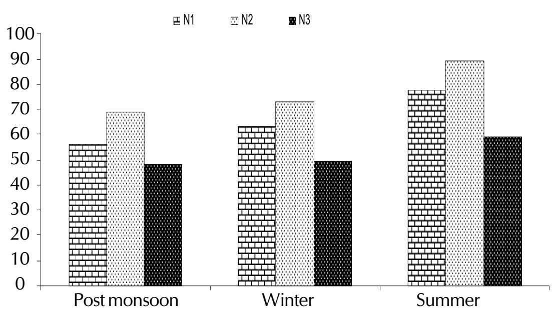

Figure 8: BOD content in different seasons of treatment plant at BDA-NICCO PARK

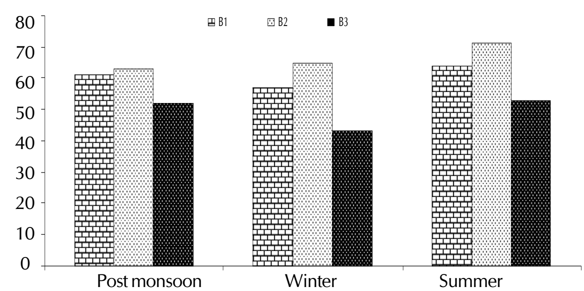

Figure 9: BOD content in different seasons of treatment plant at Vani Vihar

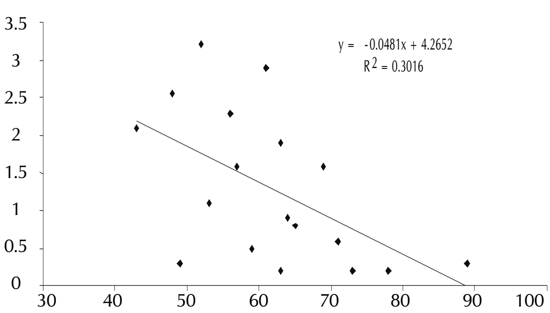

Figure 10: Regression graph between DO and BOD

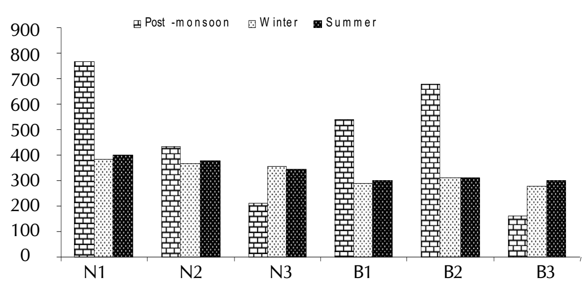

Figure 11: Total Dissolved Solids (TDS) concentrations in different seasons at both the treatment system

Total nitrogen concentration in all the sampling points ranged from 1.76 mg/L to 21.01 mg/L. The concentration of TN was always higher at the treatment system near Nicco Park than Vani Vihar . The TN concentration was higher at the duckweed pond than the inlet point and outlet point of both the treatment systems. Among the seasonal samplings the TN concentration was always higher during the summer season than other seasons which were reflected by the higher NO_2-N, NO_3-N and NH_3-N.Inorganic phosphate (IP) concentration varied between 2.16 mg/L and 8.01 mg/L during the entire study period. The concentration of IP was higher in the duckweed pond of the treatment system near Nicco Park than all other stations of the treatment system and lowest at the outlet point in all the seasons . But near Vani Vihar the IP concentration was higher at the outlet point which is attributed by the washing of clothes and detergent inputs at the point.

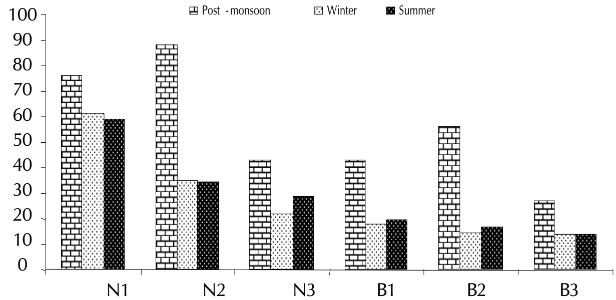

Figure 12: Total suspended Solids (TSS) concentrations in different seasons at both the treatment system

The concentration of total phosphate (TP) varied between 4.14 mg/L and 13.90 mg/L during the entire periods of sampling. In general the concentration of TP in the treatment plant near BDA Nicco-park was always higher at the duckweed pond and in the treatment system near the Vani Vihar it was higher at the outlet point which is reflected by the IP concentration. The TP concentration exhibited a clear seasonal pattern being higher during the summer and lower during the post-monsoon irrespective of stations in both the treatment system.

The SiO_4 concentration varied between 3.19 mg/L and 14.10 mg/L during the entire periods of study. The SiO_4 concentration was lower in the inlet and outlet points of the treatment plant near Nicco Park than near Vani Vihar.The Concentration of SiO_4 was higher at the duckweed pond than other stations. The SiO_4 concentration gradually increased from the post-monsoon season to the summer season.

Nutrients removal was often harmed by inadequate denitrification inhibition of phosphorous removal by nitrate, over aeration, over dosage of chemicals, and improper operation of settling pretreatment tanks (Qiu *et al.*, 2010). *Eichhornia crassipes* as an aquatic macrophyte shows nutrients removal from municipal wastewater treatment plant (Kutty *et al.*, 2009). In order to evaluate the efficiency of both the treatment system the percentage increase or decrease of studied environmental variables were taken into account. The concentrations of different environmental variables and nutrients were increased or decreased to some extent while passing through the treatment system. The detailed percentages of reduction of different nutrients in the outlet point in comparison to the inlet point are presented in Table- 2.

Trace elements in water

During the present study twelve trace elements (Na, K, Ca, Co, Cu, Cr, Zn, Fe, Mn, Ni, Pb and Cd) were analyzed for the purpose from the water samples of all six stations of the two treatment systems. The concentrations of increase or decrease concentrations of the different elements in the water samples of both the treatment system during different seasons were presented in Table-3 . Almost all the elements in the water samples of both the treatment system were declined from the inlet towards the outlet point except Fe. This suggested that the accumulation of Fe is not complete during the summer season in both the treatment system. The reduction of Cd is maximum during the winter season.

Concentration of different elements in plant samples

The process of bioremediation through bioaccumulation by plant species of trace elements is a slow and effective process (Manish, 2009). The process of bioremediation of 12 elements were studied from plant samples collected from all 6 stations in three seasons. The increase or decrease concentrations of the different elements in the plant samples of both the treatment systems during different seasons were presented in Table- 4. Among the 12 elements, the concentrations of 6 elements (Na, K, Fe, Zn, Ni, Mn) were declined in both the treatment systems and reduced through the course of bioaccumulation through the treatment systems irrespective of seasons. The concentrations of Pb, Cd, Co and Cr were increased towards the outlet points in the BDA Nicco-Park which is of concern as all these elements have toxic effect. The concentrations of all these 4 elements were reduced during the course of treatment through the treatment system at Vani Vihar .

Statistical Analysis

t-test was carried out for comparing the significant difference among the inlet and outlet points in both the treatment systems. The detailed significant level along with t values for the comparison of different parameters among the inlet and outlet points of both the treatment system is given in Table- 5.

Factor analysis was carried out for the elements in the plant samples for the evaluation of similar accumulation of different elements for both the systems separately and are presented in Table-6. Factor analysis was carried out for the trace elements concentrations in the plant samples for accessing the accumulation processes. The varimax rotated factor analysis were calculated using eigen values greater than 1.0 and sorted by results having values greater than 0.4 being considered significant influences towards the biological and geo- chemical processes (Sahu *et al.,* 1998; Panigrahi *et al.,* 1999; Rath *et al.,* 2000). For the treatment system near BDA Nicco-Park the Factor-1 is positively loaded elements like Mn, Na, Zn, Ni and Fe and negatively loaded with Pb, Cr and Cd, which suggested that the acuumulation of Pb, Cd and Cr are different than that of the Mn, Na, Zn, Ni and Fe. This also gives an indication about the slow absorption of toxic elements by the plants. The Factor 2 is positively loaded with Ni, Fe, Ca, K and Co, this suggests that the accumulation of these elements follows a similar path which might be dependent upon the bioavailability of these elements. The Factor-3 is loaded positively with Pb, Cd, Cu and Co which might be due to low concentration of these elements in the water and slow accumulation rate.

For the treatment system near Vani Vihar Ni, Fe, Mn, Zn, Pb, Na, Cd, Co are loaded positively in the Factor-1 this suggest the similar pattern of bioavailability and accumulation rate of these elements. Positive loading of Na, K, Ca in the Factor-2 is a general phenomenon and simultaneous loading of Cd and Co might be due to the low concentration of both the elements. Cu and Cd are negatively loaded with the Pb and Co which suggests the differential pattern of either elements in the treatment plant by the plants.

CONCLUSION

The domestic waste water entering into the respective treatment system is much higher than the estimated capacity of the treatment plant, which should be taken care of.

In both the treatment plants settling tank, duckweed pond and fish pond are not properly maintained which affects the overall efficiency of the treatment system.

Some hazardous elements like Pb and Cd were higher in the plant samples at outlet point of the treatment system near Nicco Park which are of grave concern. This might be due to the defunct condition of the treatment system and improper harvesting of the plants from the duckweed pond, which should be taken care.

The partly treated or untreated sewerage ultimately reaches the river system which is a matter of great concern.

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