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Efficiency of Natural Biological Adsorbents to Remove Pollutants from Textile, Dye and Printing Industry Effluent

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Abstract

Adsorption is considered to be one of the most promising techniques for wastewater treatment over the last decades. The present study was conducted to treat the Textile, dye and printing industry effluents using naturally occurring biological adsorbents (*Areaca catechu, Moringa pterygosperma, Quercus infectoria* and *Tamarindus indica*). The treatment was carried out on various concentrations (of dye effluents). Highest removal of pollutant was observed at lower effluent concentrations (25% and 50%) as compared to higher effluent concentrations (75 % and 100%). The reduction in pollution load may be due to the coagulative/chelative property of the adsorbents which could be used as low cost and safe biological adsorbents for removing toxic substances in Textile, dye and printing industry effluents.

Keywords: Natural Biological Adsorbents, Textile Dye and Printing Industry Effluent, Batch Experiment

1. Introduction

Among various industries, the textile industry ranks first in usage of dyes for coloration of fabrics. Today more than 900 types of dyes

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have been incorporated in the colour index (Rashmi *et al.*, 2006). Decolourisation has become an integral part of the textile waste treatment process. Textile processing consumes enormous quantity of water and chemicals for various operations like washing, dyeing etc. Among the different pollutants of aquatic ecosystem, dyes are important group of chemicals, since they are widely used in textile industry to colour their products (Baskar *et al.*, 2006). Dyes absorb and reflect sunlight-entering water and so can interfere with the growth of bacteria and hinder photosynthesis in aquatic plants (Allen *et al.*, 2006). Dyes are generally synthetic aromatic compounds and some may be embodied with heavy metals in their structure. Dyes also cause allergic dermatitis, skin irritation, cancer and mutation. During dye production and textile manufacturing processes, a large amount of wastewater containing dye materials with intensive colour and toxicity can be introduced into the aquatic systems. On an average, 200-300 liter of fresh water is used for each kg of textile material produced. Nearly 10-25 percent of the effluent comes from the final washing process, which is called wash water contains traces of colouring materials, heavy metals and other inorganic chemicals. Therefore, it is desirable to remove colouring materials from effluents.

Pollutants in industrial effluents can cause direct toxicity both to human and other living beings due to their presence beyond specific limits. Due to high water consumption of the textile industry, it is essential to study its reuse and many processes have been studied to treat textile industry effluent. The conventional methods for treating dye containing effluent are chemical coagulation, chemical oxidation and photochemical degradation, and membrane filtration including aerobic and anaerobic biological degradation (Kara *et al.*, 2006). These methods are either expensive or cannot cope with high concentrations of contaminants. All these methods have significant disadvantages such as incomplete ion removal, high-energy requirement and production of toxic sludge or other waste products that require further disposal.

Traditional methods may not be able to meet the effluent standards where several strongly complex organic and inorganic ligands are present. On the other hand, advance technologies may be economically unacceptable. For solving the problems of heavy metal removal and recovery from industrial wastes we have a choice between simple and relatively economical, traditional and advanced technologies.

Several non conventional materials available in the form of industrial wastes (fly ash, blast furnace slag and flue dust) and agricultural wastes (saw dust, rice husk, waste tea, coffee, bagasse, and coconut shell) have been used as adsorbents by several researchers. Recent investigations on the chemical modification of low cost adsorbents have revealed the possibility of maximising the adsorption potential of non-conventional materials for removal of pollutant (Sarvanane *et al.*, 2002).

The use of natural biological adsorbents to remove pollutant (Biosorption) is an alternative and cost effective technology emerging in the last years based on the active sites of biomaterial and metallic ions in the system (Veglio, 1997; Volesky 1999 and Pagnanelli *et al.*, 2002). Adsorption is the physicochemical process, which offers great potential for treating effluents containing undesirable components, and renders them safe and reusable (Rai *et al.*, 1998; Kapadia, 2000, Ranganathan, 2000; Anima, *et al.*, 2004). The major advantages of adsorption process for water pollution control are low investment in terms of cost, simple design easy operations and no side effects of toxic harmful substances (Annadurai, 2000).

Growing popularity of natural biological adsorbents in industrial effluent treatment is emerging as an effective alternative technology to overcome the problems associated with physico-chemical methods and can be treated as a new application area, which has put this technique at par with other techniques. Keeping in view the above fact, the present study was an attempt to remediate textile dye and printing industry effluent through the use of natural biological adsorbents.

2. Materials and Methods

Textile dye and printing industry effluent was collected from Textile Industry Maral Overseas Limited, Khalbujarg, District Khargoan, Madhya Pradesh. The effluent was collected in sterile cans. For characterisation of dye effluent the physico chemical analysis of the effluent was done using methods of APHA (1998). The selection of the natural biological adsorbents for the present study though was not based on any specific reasons but their sorption, coagulation/chelation property was taken into consideration after a preliminary study. The natural biological adsorbents selected were -

1. Fruit (powered) of Betel nut (*Areaca catechu*) Linn var name Supari, Family - Arecaceae
2. Fruit (powered) of Gall oak (*Quercus infectoria*) Linn var name Manjuphal, Family - Fagaceae
3. Pod (powered) of Drumstick (*Moringa pterygosperma*) Gaertn var name Sajana, Family - Morigaceae
4. Seeds (powered) of Tamarind (*Tamarindus indica)* var name Imli, family – Caesalpinioideae

3. Batch Experiments and Adsorption Isotherms

Sorption studies were conducted by the batch technique using wastewater from textile dye and printing industry effluent. Batch experiments were carried out to determine the adsorption isotherms of pollutants onto the adsorbents in 250 mL glass flask. The flasks were shaken at a constant rate, allowing sufficient time for adsorption equilibrium. It was assumed that the applied shaking speed allows all the surface area to come in contact with pollutants over the course of the experiments. The study was performed at room temperature to be representative of environmental relevant conditions. All experiments were carried out in duplicate and the average value was used for further calculation. The pH of the solution was measured with a HACH-pH meter and other parameters i.e. conductivity, total hardness, COD, BOD, sulphates and nitrates were carried out as per the method described in APHA (1998). The flasks were plugged and kept closed to avoid the fluctuation of pH due to the exchange of gases during the experiment. The effects of various parameters on the rate of adsorption process were observed by varying contact time, adsorbent concentration, temperature, and pH of the solution.

The solution volume (V) was kept constant. The amount of pollutants adsorbed per unit mass is calculated as -

$$Q_e = \frac{(C_i - C_e)\,V}{m},$$

where C_i and C_e are the initial and equilibrium concentration (mg/L), m is the mass of the adsorbent (g) and V is the volume of the solution (mL). Percent Pollutants Removal (% PR) was calculated using the equation - % PR =

$$\frac{(C_i - C_e)}{C_i} * 100.$$

Statistical analysis was performed using the statistical software packages.

4. Results and Discussion

Textile dye and printing industry produces effluents in large amounts and also faces disposal problems. As the effluent may affect the land surface and water bodies adversely, proper disposal is necessary. According to Allen (2006) the constituents of textile, dye and printing industry effluent are synthetic chemicals and these have been various salts and toxic heavy metals. The color was dark blue and pH was alkaline 10 (Table 1). The colour is the major problem of dyeing industries.

Table 1: Physico-chemical parameters of Textile, dye and printing Industry effluent

Sl. No.	Parameters	Value (mg/l)
	pH	10.9
	Conductivity	10.75
	Colour	Dark blue
	Chemical Oxygen Demand (COD)	2122
	Biological Oxygen Demand (BOD)	236
	Total hardness	620
	Sulphate	4032
	Nitrate	175
	Carbonate	1224
	Bicarbonate	610
	Chloride	10656
	Calcium	2400
	Magnesium	960
	Sodium	7176
	Potassium	312
	Zinc	4.56
	Copper	2.69
	Iron	10.26
	Manganese	5.79
	Lead	0.89
	Mercury	0.06
	Nickel	0.19
	Chromium	2.49
	Cadmium	2.06

Table 2: % Removal of Textile, dye and printing industry effluent using biological adsorbent *Areaca catechu* at different concentrations

S.No.	Parameters	Conc. (%)	Initial Conc. (%)	Remaining Conc. . (%)	Reduction in Conce. (%)	Qe	Log Ce	Log Qe	IN Ci/Ce	k*10-3	% Reduction
1	pH	25	9.1	8.03	1.07	0.0214	0.90	-1.66959	1.13	4.2	11.758
		50	9.6	8.54	1.06	0.0212	0.93	-1.67366	1.12	3.9	11.042
		75	10	9.43	0.57	0.0114	0.97	-1.9431	1.06	2.0	5.700
		100	10.9	9.76	1.14	0.0228	0.99	-1.64207	1.12	3.7	10.459
2	Conductivity (mMho)	25	9.63	10.12	-0.49	-0.0098	1.01	#NUM!	0.95	-1.7	-5.088
		50	10	10.38	-0.38	-0.0076	1.02	#NUM!	0.96	-1.2	-3.800
		75	10.33	10.65	-0.32	-0.0064	1.03	#NUM!	0.97	-1.0	-3.098
		100	10.75	11.23	-0.48	-0.0096	1.05	#NUM!	0.96	-1.5	-4.465
3	Total Hardness (mg/l)	25	162	65	97	1.94	1.81	0.287802	2.49	30.4	59.877
		50	287	198	89	1.78	2.30	0.25042	1.45	12.4	31.010
		75	473	404	69	1.38	2.61	0.139879	1.17	5.3	14.588
		100	620	589	31	0.62	2.77	-0.20761	1.05	1.7	5.000
4	Chemical Oxygen Demand (COD) (mg/l)	25	989	811	178	3.56	2.91	0.55145	1.22	6.6	17.998
		50	1106	989	117	2.34	3.00	0.369216	1.12	3.7	10.579
		75	1608	1513	95	1.9	3.18	0.278754	1.06	2.0	5.908
		100	2122	2045	77	1.54	3.31	0.187521	1.04	1.2	3.629

S.No.	Parameters	Conc. (%)	Initial Conc. (%)	Remaining Conc. . (%)	Reduction in Conce. (%)	Qe	Log Ce	Log Qe	IN Ci/Ce	k*10-3	% Reduction
5	Biological Oxygen Demand (BOD) (mg/l	25	116	49	67	1.34	1.69	0.127105	2.37	28.7	57.759
		50	191	138	53	1.06	2.14	0.025306	1.38	10.8	27.749
		75	213	169	44	0.88	2.23	-0.05552	1.26	7.7	20.657
		100	236	203	33	0.66	2.31	-0.18046	1.16	5.0	13.983
6	Sulphate (mg/l)	25	1276	1195	81	1.62	3.08	0.209515	1.07	2.2	6.348
		50	2117	2047	70	1.4	3.31	0.146128	1.03	1.1	3.307
		75	3651	3594	57	1.14	3.56	0.056905	1.02	0.5	1.561
		100	4032	3987	45	0.9	3.60	-0.04576	1.01	0.4	1.116
7	Nitrate (mg/l)	25	38	52	-14	-0.28	1.72	#NUM!	0.73	-10.5	-36.842
		50	89	113	-24	-0.48	2.05	#NUM!	0.79	-8.0	-26.966
		75	132	161	-29	-0.58	2.21	#NUM!	0.82	-6.6	-21.970
		100	175	209	-34	-0.68	2.32	#NUM!	0.84	-5.9	-19.429

Table 3 : % Removal of Textile, dye and printing industry effluent using biological adsorbent *Moringa pterygosperma* at different concentrations.

S.No.	Parameters	Conc. (%)	Initial Conc. (%)	Remaining Conc. (%)	Reduction in Conce. (%)	Qe	Log Ce	Log Qe	IN Ci/Ce	k*10-3	% Reduction
1	pH	25	9.1	7.8	1.3	0.026	0.89	-1.58503	1.17	5.1	14.286
		50	9.6	8.61	0.99	0.020	0.94	-1.70333	1.11	3.6	10.313
		75	10	9.76	0.24	0.005	0.99	-2.31876	1.02	0.8	2.400
		100	10.9	10.2	0.7	0.014	1.01	-1.85387	1.07	2.2	6.422
2	Conductivity (mMho)	25	9.63	10.19	-0.56	-0.011	1.01	#NUM!	0.95	-1.9	-5.815
		50	10	10.44	-0.44	-0.009	1.02	#NUM!	0.96	-1.4	-4.400
		75	10.33	10.79	-0.46	-0.009	1.03	#NUM!	0.96	-1.5	-4.453
		100	10.75	11.36	-0.61	-0.012	1.06	#NUM!	0.95	-1.8	-5.674
3	Total Hardness (mg/l)	25	162	59	103	2.06	1.77	0.313867	2.75	33.7	63.580
		50	287	202	85	1.7	2.31	0.230449	1.42	11.7	29.617
		75	473	401	72	1.44	2.60	0.158362	1.18	5.5	15.222
		100	620	600	20	0.4	2.78	-0.39794	1.03	1.1	3.226
4	Chemical Oxygen Demand (COD) (mg/l)	25	989	802	187	3.74	2.90	0.572872	1.23	7.0	18.908
		50	1106	983	123	2.46	2.99	0.390935	1.13	3.9	11.121
		75	1608	1509	99	1.98	3.18	0.296665	1.07	2.1	6.157
		100	2122	2053	69	1.38	3.31	0.139879	1.03	1.1	3.252

S.No.	Parameters	Conc. (%)	Initial Conc. (%)	Remaining Conc. (%)	Reduction in Conce. (%)	Qe	Log Ce	Log Qe	IN Ci/Ce	k*10-3	% Reduction
5	Biological Oxygen Demand (BOD) (mg/l)	25	116	43	73	1.46	1.63	0.164353	2.70	33.1	62.931
		50	191	131	60	1.2	2.12	0.079181	1.46	12.6	31.414
		75	213	161	52	1.04	2.21	0.017033	1.32	9.3	24.413
		100	236	197	39	0.78	2.29	-0.10791	1.20	6.0	16.525
6	Sulphate (mg/l)	25	1276	1164	112	2.24	3.07	0.350248	1.10	3.1	8.777
		50	2117	2038	79	1.58	3.31	0.198657	1.04	1.3	3.732
		75	3651	3571	80	1.6	3.55	0.20412	1.02	0.7	2.191
		100	4032	3974	58	1.16	3.60	0.064458	1.01	0.5	1.438
7	Nitrate (mg/l)	25	38	49	-11	-0.22	1.69	#NUM!	0.73	-10.5	-28.947
		50	89	110	-21	-0.42	2.04	#NUM!	0.79	-8.0	-23.596
		75	132	158	-26	-0.52	2.20	#NUM!	0.82	-6.6	-19.697
		100	175	206	-31	-0.62	2.31	#NUM!	0.84	-5.9	-17.714

Table 4 : % Removal of Textile, dye and printing industry effluent using biological adsorbent *Quercus infectoria* at different concentrations.

S.No.	Parameters	Conc. (%)	Initial Conc. (%)	Remaining Conc. (%)	Reduction in Conce. (%)	Qe	Log Ce	Log Qe	IN Ci/Ce	k*10-3	% Reduction
1	pH	25	9.1	8.1	1	0.020	0.91	-1.69897	1.17	3.9	10.989
		50	9.6	8.7	0.9	0.018	0.94	-1.74473	1.11	3.3	9.375
		75	10	9.5	0.5	0.010	0.98	-2	1.02	1.7	5.000
		100	10.9	10.6	0.3	0.006	1.03	-2.22185	1.07	0.9	2.752
2	Conductivity (mMho)	25	9.63	10.22	-0.59	-0.012	1.01	#NUM!	0.95	-2.0	-6.127
		50	10	10.51	-0.51	-0.010	1.02	#NUM!	0.96	-1.7	-5.100
		75	10.33	10.89	-0.56	-0.011	1.04	#NUM!	0.96	-1.8	-5.421
		100	10.75	11.36	-0.61	-0.012	1.06	#NUM!	0.95	-1.8	-5.674
3	Total Hardness (mg/l)	25	162	63	99	1.98	1.80	0.296665	2.75	31.5	61.111
		50	287	211	76	1.52	2.32	0.181844	1.42	10.3	26.481
		75	473	416	57	1.14	2.62	0.056905	1.18	4.3	12.051
		100	620	589	31	0.62	2.77	-0.20761	1.03	1.7	5.000
4	COD (mg/l)	25	989	811	178	3.56	2.91	0.55145	1.23	6.6	17.998
		50	1106	992	114	2.28	3.00	0.357935	1.13	3.6	10.307
		75	1608	1511	97	1.94	3.18	0.287802	1.07	2.1	6.032
		100	2122	2062	60	1.2	3.31	0.079181	1.03	1.0	2.828

S.No.	Parameters	Conc. (%)	Initial Conc. (%)	Remaining Conc. (%)	Reduction in Conce. (%)	Qe	Log Ce	Log Qe	IN Ci/Ce	k*10-3	% Reduction
5	BOD (mg/l)	25	116	49	67	1.34	1.69	0.127105	2.70	28.7	57.759
		50	191	143	48	0.96	2.16	-0.01773	1.46	9.6	25.131
		75	213	173	40	0.8	2.24	-0.09691	1.32	6.9	18.779
		100	236	210	26	0.52	2.32	-0.284	1.20	3.9	11.017
6	Sulphate (mg/l)	25	1276	1174	102	2.04	3.07	0.30963	1.10	2.8	7.994
		50	2117	2043	74	1.48	3.31	0.170262	1.04	1.2	3.496
		75	3651	3589	62	1.24	3.55	0.093422	1.02	0.6	1.698
		100	4032	3986	46	0.92	3.60	-0.03621	1.01	0.4	1.141
7	Nitrate (mg/l)	25	38	44	-6	-0.12	1.64	#NUM!	0.73	-4.9	-15.789
		50	89	107	-18	-0.36	2.03	#NUM!	0.79	-6.1	-20.225
		75	132	154	-22	-0.44	2.19	#NUM!	0.82	-5.1	-16.667
		100	175	203	-28	-0.56	2.31	#NUM!	0.84	-4.9	-16.000

Table 5: % Removal of Textile dye and printing industry effluent using biological adsorbent *Tamarindus indica* at different concentrations.

S.No.	Parameters	Conc. (%)	Initial Conc. (%)	Remaining Conc. (%)	Reduction in Conce. (%)	Qe	Log Ce	Log Qe	IN Ci/Ce	k*10-3	% Reduction
1	pH	25	9.1	7.9	1.2	0.024	0.90	-1.61979	1.15	4.7	13.187
		50	9.6	8.6	1	0.020	0.93	-1.69897	1.12	3.7	10.417
		75	10	9.4	0.6	0.012	0.97	-1.92082	1.06	2.1	6.000
		100	10.9	10.5	0.4	0.008	1.02	-2.09691	1.04	1.2	3.670
2	Conductivity (mMho)	25	9.63	10.31	-0.68	-0.014	1.01	#NUM!	0.93	-2.3	-7.061
		50	10	10.54	-0.54	-0.011	1.02	#NUM!	0.95	-1.8	-5.400
		75	10.33	10.78	-0.45	-0.009	1.03	#NUM!	0.96	-1.4	-4.356
		100	10.75	11.31	-0.56	-0.011	1.05	#NUM!	0.95	-1.7	-5.209
3	Total Hardness (mg/l)	25	162	66	96	1.92	1.82	0.283301	2.45	29.9	59.259
		50	287	213	74	1.48	2.33	0.170262	1.35	9.9	25.784
		75	473	414	59	1.18	2.62	0.071882	1.14	4.4	12.474
		100	620	592	28	0.56	2.77	-0.25181	1.05	1.5	4.516
4	COD (mg/l)	25	989	809	180	3.6	2.91	0.556303	1.22	6.7	18.200
		50	1106	986	120	2.4	2.99	0.380211	1.12	3.8	10.850
		75	1608	1501	107	2.14	3.18	0.330414	1.07	2.3	6.654
		100	2122	2054	68	1.36	3.31	0.133539	1.03	1.1	3.205

S.No.	Parameters	Conc. (%)	Initial Conc. (%)	Remaining Conc. (%)	Reduction in Conce. (%)	Qe	Log Ce	Log Qe	IN Ci/Ce	k*10-3	% Reduction
5	BOD (mg/l)	25	116	52	64	1.28	1.72	0.10721	2.23	26.7	55.172
		50	191	140	51	1.02	2.15	0.0086	1.36	10.4	26.702
		75	213	167	46	0.92	2.22	-0.03621	1.28	8.1	21.596
		100	236	198	38	0.76	2.30	-0.11919	1.19	5.9	16.102
6	Sulphate (mg/l)	25	1276	1169	107	2.14	3.07	0.330414	1.09	2.9	8.386
		50	2117	2038	79	1.58	3.31	0.198657	1.04	1.3	3.732
		75	3651	3582	69	1.38	3.55	0.139879	1.02	0.6	1.890
		100	4032	3980	52	1.04	3.60	0.017033	1.01	0.4	1.290
7	Nitrate (mg/l)	25	38	46	-8	-0.16	1.66	#NUM!	0.83	-6.4	-21.053
		50	89	104	-15	-0.3	2.02	#NUM!	0.86	-5.2	-16.854
		75	132	151	-19	-0.38	2.18	#NUM!	0.87	-4.5	-14.394
		100	175	207	-32	-0.64	2.32	#NUM!	0.85	-5.6	-18.286

pH Study: Determination of pH as a function of remediation of textile dye and printing industry effluents with the use of natural biological adsorbents viz. betel nut, gall oak, sajana, and tamarind, the initial pH and the final pH (after treatment with biological adsorbents) varied. After treatment with all the four biological adsorbents the final pH value decreased at all the concentrations (25%, 50%, 75% and 100%). The decrease was maximum at lower concentrations (25 % and 50%) as compared to higher concentrations (75% and 100%) (Table 2-5). The change in pH value was maximum in case of gall oak followed by betel nut, drumstick and tamarind. The hierarchy of biological adsorbents was gall oak > betel nut > drumstick > tamarind. The change in pH attributed to the higher degree of ionization of metal ion at higher pH and the reduced competition of H^+ ions with the metal ion for adsorption sites. Similar results have been reported by Renu Bala *et al.* (2005); Kumar *et al.* (2008); Sharma *et al.* (2008); Beltran *et al.* (2009). The sorption capacity is considered to be a function of pH value (Singh *et al.*, 1993; Biswal *et al.*, 1998 and Shrivastava *et al.*, 2001). Deshkar *et al.* (1990) and Singh *et al.* (1993) have observed that the absorption usually increases at higher pH value may be due to enhanced ion exchange and adsorption. Babu and Chaudhuri (2005) reported that the seeds of *S. potatorum* and *Moringa oleifera* contain natural polyelectrolytes, which can be used as coagulants to clarify turbid water.

Conductivity Study : Determination of conductivity as a function of remediation of textile dye and printing industry effluents with the use of natural biological adsorbents viz. betel nut, gall oak, sajana, and tamarind, the initial Conductivity and the final conductivity (after treatment with biological adsorbents) varied. In case of conductivity, a general increase was noticed with treatment of all the selected natural biological adsorbents viz. betel nut, gall oak, sajana, and tamarind at the various concentrations (25%, 50%, 75% and 100%) of textile, dye and printing industry effluent studied. The trend of conductivity increase was maximum in case of drumstick followed by betel nut, gall oak and tamarind. The increase was maximum at lower concentrations (25 % and 50%) as compared to higher concentrations (75% and 100%) (Table 2-5). The descending order of biological adsorbents was drumstick > betel nut > gall oak > tamarind. It appears that the adsorption and neutralisation of various free H^+ ions is responsible for the increased conductivity of the effluent that took place with the addition of various biological adsorbents. They either released certain cations, which in turn neutralized and removed H+ from the medium (Baisakh *et al*., 1996; Verma and Rehal 1996; Ahmed Ram, 1996 Verma and Shukala, 2000; Vasudevan and Latha , 2000). The similar trend has been observed by Renu Bala *et al.* (2005); Sharma *et al.* (2006) and Beltran *et al.* (2009). The increased trend of conductivity shows the ionizable nature of dye, which was used in dye effluent. The increase could be due to the release of anions present within the biological adsorbents.

Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) Study: Determination of COD and BOD as a function of remediation of textile dye and printing industry effluents with the use of natural biological adsorbents viz. betel nut, gall oak, sajana, and tamarind, the initial COD and BOD and the final COD and BOD (after treatment with biological adsorbents) varied COD and BOD in textile, dye and printing industry effluent decreased in all concentrations of effluent studied (Tables 2-5). It was lower in high concentrations and was normal in low concentrations. The decrease was maximum in case of drumstick followed by tamarind, betel nut and gall oak. The hierarchy of biological adsorbents was - for COD - drumstick > tamarind > betel nut > gall oak for BOD - drumstick > tamarind > betel nut > gall oak. The decrease of COD and BOD of the different concentrations of the effluent due to the addition of biological adsorbents, which act as a good adsorbent and their bioflocculant property interacting with pollutants present in the dye effluent.

Renu Bala *et al.* (2005) reported that the decreased trend of COD and BOD is due to the coagulation and flocculation processes of the biological adsorbents in the effluent. Achalya *et al.* (2005) stated that the galactomanans are effective in the removal of heavy metals. Preetha *et al.* (2005) also observed that the biosorption property of *R. arrihizus* for Zn (II) uptake was decreased with increased biomass loading. Kumar *et al.* (2008) noticed that the seed powder of *Strychnos potatorum* effectively removes toxic pollutants at higher concentrations and low pH. Jackson *et al.* (1990) reported that live or dead cultured cells of *Datura innoxia*, a higher plant can be used to remove Ba^{2+} from solutions. Kadirvel (1993) recorded complete removal of BOD and COD from the dyeing waste water by using carbonized coir pith.

Total hardness Study: Determination of total hardness, a function of remediation of textile dye and printing industry effluents with the use of natural biological adsorbents viz. betel nut, gall oak, sajana and tamarind varied at all the studied concentrations. The total hardness of the effluent is mainly governed by the Ca and Mg ions in different forms. The total hardness was also decreased in all the concentrations of the effluent, after treatment with biological adsorbents. The decrease in total hardness was maximum in case of drumstick followed by betel nut, gall oak and tamarind. The decrease was maximum at lower concentrations (25 % and 50%) as compared to higher concentrations (75% and 100%) (Table 2-5). The descending order of biological adsorbents was drumstick > betel nut > gall oak > tamarind. This indicates that the solids formed in this process get adsorbed on surface of biological adsorbents, thereby making the total hardness of the dye effluent to fall. Decrease in hardness at different concentrations of the dye effluent suggests that the biological adsorbents either have adsorbed various ionic species present in the media or have caused their chelation. Similar observations have been reported by Ansari *et al.* (2000) and Muyibi & Alfugara (2003).

Sulphate and Nitrate Study: The concentration of Sulphate and Nitrate also varied in the studied dye effluent. Sulphate concentration was decreased while Nitrate concentration was increased at all the concentrations of the effluent. The decrease of Sulphate and increase of Nitrate are higher at lower effluent concentration (25 % and 5%) and lower at higher effluent concentration (75% and 100%) (Table 2-5). The decrease was maximum in case of drumstick followed by betel nut, gall oak and tamarind. Similarly, increase was maximum in case of tamarind followed by gall oak, drumstick and betel nut. The trend for decrease of Sulphate was - drumstick > betel nut > gall oak> tamarind and increase of Nitrate was - tamarind > gall oak > drumstick > betel nut. The decrease in Sulphate due to the adsorbent and coagulant property of biological adsorbents and increase in Nitrate indicate the presence of nitrogen in the dye molecule. Similar results have been reported by Renu Bala *et al.* (2006); Sharma *et al.* (2006) and Beltran *et al.* (2009). Vasanthy and Thamaraiselvi (2007) also reported that the suitability of utilization of the powered peel of *Citrus reticulate* for the nitrate removal does not pose any health hazard later.

The biological adsorbents that were selected in the present study are environment friendly, cost-effective, and locally available adsorbents for the adsorption of pollutants from textile, dye and printing industry effluent. Results from this study showed that adsorption of pollutants increases with the amount of adsorbent. This may be explained because of the fact that adsorption is a surface phenomenon where adsorbate molecules occupy specific sites on the adsorbent. These sites are commonly known as active centers. The concentration of these active centers on the surface is further related to the pore size and pore volume available after impregnation. This explains why increasing the quantity of adsorbent results in increased adsorption. Results revealed that initially the percent removal increased rapidly; however, after some times the rate becomes almost constant. This is because all the available active centers on the adsorbent have been occupied and there are no further sites and hence no further adsorption is possible. The time when this phenomenon occurs, therefore, may be termed optimum time.

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