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ECOLOGICAL STUDIES OF FUNGI IN A TRICKLING FILTER TYPE SEWAGE PLANT OF KARACHI

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Abstract

The occurrence, distribution and relative abundance of fungi was examined in a trickling filter type sewage treatment plant of Karachi. At least 50 species of filamentous fungi belonging to 25 genera were isolated from samples of waste water of Karachi using the dilution plate technique. Species dominance and diversity indices were used to determine the structure and organization of fungal communities. In the system examined, the dominance was high and the general diversity was of a low magnitude. Furthermore, dominance was inversely related with diversity and its two components – richness and equitability. These components were positively correlated with each other, however, equitability was relatively more important in governing the overall diversity of fungal communities.

Introduction

Fungi have been reported as important members of microbial populations affecting biological waste treatment in tricking filter type treatment plant (Cooke 1968, 1970; Cooke & Hirsch 1958); in activated sludge process (Cooke & Pipes, 1970) and waste stabilization ponds (Cooke & Matsuura, 1969). These studies were mainly restricted to the isolation and identification of fungi present in these systems.

Trickling filter plant embodies self sufficient microbial communities which work for the decomposition of sewage (Cooke, 1959b). However, the dynamic changes which may occur in the structure and organization of fungal communities during the treatment of waste water has not been examined and critically evaluated. The present paper deals with the study of structure and composition of fungal communities and the relationship between dominance and diversity of fungi present in a trickling filter system.

Material and Methods

Description of the system: The system examined was the Karachi Municipal Corporation treatment plant No. 1 (KMC-TPI) located in the Sind Industrial Estate area, Karachi. Raw sewage enters the treatment plant service tank where all the floating materials are held up and the effluent is pumped into a distribution pit No. 1. The distribution pit effluent then enter the grit chamber where the flow rate is maintained at

60 cm/sec to remove all the mud and particulate matter and the resulting effluent is collected in a distribution pit No. 2. The effluent then enters the primary clarifier where after settling for 2 h it is pumped to another distribution pit No. 3. The effluents from clarifier units then finally enter the trickling filter unit containing a bed of rocks covered with slime in which organisms causing major changes are held. A portion of the trickling filter effluent is recirculated back to the primary clarifiers while the rest is discharged as the final effluent into the receiving streams. The solids which settle in the primary clarifiers constitute the raw sludge. This is pumped into the digester where anaerobic digestion of the sludge occurs. Digested sludge is drawn off to the drying beds, which after drying for 3–5 weeks is used as manure.

Samples collection and analysis: Samples were collected from the following sites as shown in Fig. 1: raw sewage from distribution pit No.1; grit chamber effluents from distribution pit No.2; primary clarifier effluents from distribution pit No. 3; and trickling filter effluents from the under drains.

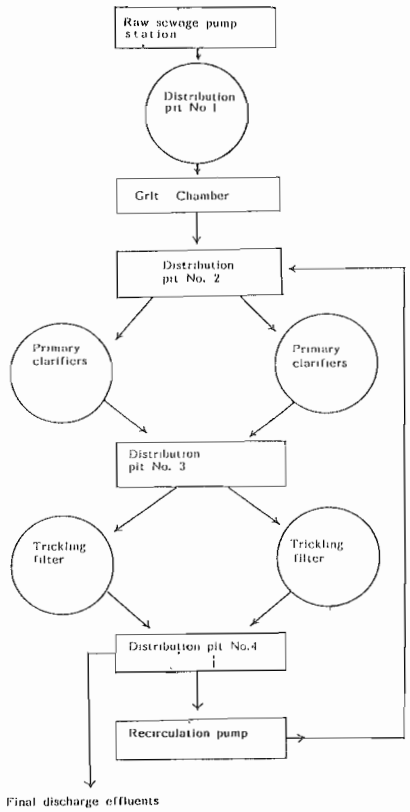

Fig. 1. Flow diagram of waste water at (KMC – TP I).

Samples from all sites were collected in sterilized plastic bottles at monthly intervals during Jan–Dec, 1981 at a specific time (9–10 A.M.).For the isolation of fungi 1 ml of the original samples and/or their appropriate dilutions prepared in sterile water blanks were plated on Czapek Dox agar (Cooke, 1963). The medium was supplemented with 3 mg/ml each of pencillin and streptomycin to avoid bacteria. At the same time, 15 ml of the sample was poured in a previously weighed conical flask and kept in an oven at 95°C to obtain the dry weight of the sample residue. The total fungal counts of the sample was expressed per dry weight of the sample residue.

Dominance, general diversity, richness and equitability of fungal species: The dominance of fungal communities present in each sample was ascertained using the index proposed by Simpson (1949): $C = \frac{\Sigma n_i^2}{N}$,

where 'C' is Simpson's index,

n_i, is the number of colonies of the ith mold,

N is the total number of colonies of all the molds and

n_i/N is the proportion of colony counts belonging to the ith species to the total number of colonies count in a given sample.

The general diversity has two major components (a) species richness (b) equitability or eveness component. The general diversity was determined by the information theory function $\bar{H} = \Sigma p_i \log p_i$, where p_i is the proportion of the colonies count of the ith mold, to the total colony counts of all the molds (Margalef, 1957) and also by McIntosh's $1 - \frac{\sqrt{\Sigma n_i^2}}{N}$ based on euclidean distance measurement.

Equitability was measured by index $E = \frac{\bar{H}}{\log_{10} S}$ where $\bar{H}$ is general diversity according to information theory and S is the number of species. Species richness was calculated as $d = \frac{S}{\sqrt{N}}$ (Menhinnick, 1964) where 'd' is species richness and S and N are total number of species and total number of individuals.

Relationship among dominance, species richness, equitability and general diversity: The relationship among dominance and diversity measures were determined by computing linear correlation and regression equation as described in Steel & Torrie (1976).

Results

The total colony counts of raw waste water (RS) fluctuated between 4.301 to 7.775 $\log_{10}$/gm dry wt ($\bar{X}$ = 6.025 ± 0.848). Whereas the total colony counts of trickling filter effluents (PTE), which is the final discharge of the plant, flactuated between 5.240 to 8.56 ($\bar{X}$ = 6.191 ± 1.002) $\log_{10}$/gm dry wt. In the treated effluents an average increase of 2.75% was observed in the total counts (Table 1).

Table 1. Number of mold colonies isolated from samples of waste water collected from trickling filter treatment plant (KMC – TP I)

Months 1981	No. of colonies (log_{10}/gm dry wt) in waste water samples*			
	RS	GCE	PCE	PTE
Jan	6.079	6.004	5.127	5.240
Feb	5.635	5.885	6.100	5.531
Mar	4.301	4.301	5.178	4.782
Apr	5.344	5.501	5.283	5.459
May	7.775	7.514	8.768	8.562
June	7.024	7.301	6.577	6.856
July	5.836	7.422	–	–
Aug	6.247	6.060	6.856	6.450
Sept.	6.580	6.975	6.942	7.164
Oct.	5.778	7.010	5.574	6.155
Nov.	6.348	6.594	5.754	6.025
Dec	5.363	5.626	5.501	5.879
$\bar{X}$ and SE	6.025	6.187	6.150	6.191
	0.848	0.899	1.036	1.002
CV%	14.090	14.544	16.853	16.200

*RS: raw sewage: GCE: Grit Chamber effluent; PCE: Primary clarifier effluent; PTE: Primary trickling filter effluent.

Table 2 represents a list of species of fungi isolated during the study as well as the number of times these were collected from all of the sampling sites. Of the 50 species of fungi isolated, 37 species were present in raw waste water, 21 in grit chamber effluents, 27 in the primary clarifier effluents and 23 in the trickling filter effluents.

Monthly variation in diversity and dominanace of the fungal communities of raw waste water is given in Table 3. In these samples 11 species of fungi viz., *Aspergillus flavus, A. niger, A. terreus, A. sydowii, Penicillium canescens, P. jenseni, P. janthinellum, Fusarium solani, Cladosporium cladosporioides, Paecilomyces marquandii* and *Geotrichum* sp. appeared as the dominants. The highest dominance being observed in January. The dominant species being *A. flavus* which covered 88.7% of the total populations.

In the samples of grit chamber effluents, 16 species of fungi appeared as dominants (Table 3). Among these were *A. flavus, A. niger, A. sydowii, P. lilacinum, P. herquei, P. jenseni, Paecilomyces marquandii, Fusarium solani, Mucor* sp., *Geotrichum* sp. *Dre-*

Table 2. Types and frequency of fungi isolated from trickling fliter type treatment plant (KMC-TP 1)

Fungi	Sampling points			
	RS	GCE	PCE	PTE
	Occurrence frequency (%)			
Aspergillus flavus	100	66	82	72
A. wentii	8	–	–	–
A. niger	75	83	82	82
A. unguis	25	16	9	27
A. sulphureus	–	–	9	9
A. terreus	41	50	9	18
A. tamarii	8	8	–	–
A. sydowi	50	58	–	36
A. panamensis	–	–	9	9
A. glaucus	–	8	–	–
A. fumigatus	–	–	9	–
A. caespitosus	–	–	9	9
A. hennebergi	8	–	–	–
Alternaria tenuis	8	–	18	9
Curvularia lunata	8	–	–	–
C. pallescens	8	–	–	–
C. eragrostidis	8	–	–	–
Cladosporium cladosporiodes	50	58	54	54
Cunninghamella sp.	8	–	–	–
Drechslera hawaiiensis	25	16	27	36
Fusarium solani	66	58	36	54
Fusarium sp.	16	–	9	–
Graphium sp.	–	–	–	9
Gliocladium sp.	–	–	9	–
Geotrichium sp.	8	–	–	–
Mucor sp.	41	8	36	45
Phoma sp.	8	8	18	18
Paecilomyces marquandii	16	8	–	–
Philaphora sp.	8	–	–	–
Penicillium jeneseni	91	16	36	36
P. canescens	91	50	36	45
P. lilacinum	8	8	9	–

P. purpurogenum	–	–	9	9
P. funiculosum	–	–	9	–
P. janthinellum	66	33	27	18
P. roseopurpureum	–	–	9	–
P. herquei	16	25	9	18
P. olsoni	8	–	–	–
Penicillium sp.	25	25	–	–
Rhizopus nigricans	8	8	–	9
Stysanus stemonitis	8	–	–	–
Stachybotrys atra	–	–	18	–
Scopulariopsis sp.	8	–	–	–
Sepedonicum sp.	–	–	9	–
Stibella sp.	–	–	–	9
Trichoderma harzianum	41	25	18	36
Trichoderma sp.	8	–	–	–
Trichothecium sp.	8	–	–	–
Tetracocosporium paxianum	8	–	–	–
Verticillium sp.	16	–	–	–

RS: Raw Sewage; GCE: Grit Chamber Effluents; PCE: Primary Clarifier Effluent; PTE: Primary Trickling Filter Effluent.

* Based on number of times of appearance out of a total samples of 12, 12, 11 and 11 at each sampling point, respectively.

chlera hawaiensis, Cladosporium cladosporioides and white floccose non sporing colony. The highest dominance in these samples was observed in July with *P. janthinellum* covering 97.42% of the total population.

Among the species isolated from the primary clarifier effluents (Table 3), 19 species of fungi were ranked as first, second or third dominants. These included *A. flavus, A. niger, A. sydowii, A. unguis, A. fumigatus, A. caespitosus, A. glaucus, Penicillium lilacinum, P. canescens, P. purpurogenum, P. herquei, P. jenseni, Mucor* sp., *Cladosporium cladosporioides, Geotrichium* sp., *Trichoderma harzianum, Phoma* sp. *Drechslera hawaiiensis* and *Fusarium solani*. Dominance was found high in August with *P. canescens* as the dominant fungus occupying 94.2% of the total populations (Table 3).

Twelve species of fungi viz., *A. flavus, A. niger, A. unguis, A. fumigatus, C. cladosporioides, F. solani, Phoma* sp., *D. hawaiiensis, Geotrichium* sp., *T. harzianum, P. jenseni, P. canescens* and *P. lilacium* were found to be the dominant species in samples of trickling filter effluents (Table 3). Highest dominance in these samples was also observed in August with *P. jenseni* being the dominating fungus covering 93.1% of the total population (Table 3).

Table 4 expresses the relationship (correlation coefficient) among dominance diversity and its components, species richness and equitability. The relationship between general diversity and dominance showed a highly significant inverse relationship in all the samples collected from various stages of the treatment plant, whereas a significant positive correlation existed between general diversity $\bar{H}$ and its component species richness and equitability.

Discussion

Earlier studies carried out by (Cooke & Hirsch, 1958; Cooke, 1970; Cooke & Matsuura, 1969; Cooke & Pipes, 1970) were mainly related to the isolation and identification of fungi present in sewage treatment systems and polluted habitats. However, the present report deals with the structure and organization of fungal communities and the relationship among dominance diversity and its components in a waste treatment system.

In the KMC treatment plant, the total colony counts/gm dry wt. of the trickling filter effluents which is the final discharge of the plant increased by 2.75% as compared to that of raw waste water. However, Cooke (1959a, 1970) had reported a decrease in total colony counts as the waste water passed through the successive stages of the treatment plant. Similar results have been reported by Becker & Shaw (1955) from trickling filter type treatment plant at Pullman. In addition Cooke & Pipes (1970) had also observed relatively fewer colonies in the settling basin effluents than in sludges from an activated sludge type treatment plant in Chicago. Thus it appears that the effluents of KMC treatment plant is carrying an unusually a high population of fungi which could be attributed to the malfunctioning of the treatment plant. It is interesting to note that Zain & Altaf (1978) also observed no substantial difference in the waste water quality of raw and treated effluencts of this plant.

A total of fifty species of fungi were isolated which is significantly low as compared to the species reported from Ohio and Lebanon (USA) sewage treatment plants (Cooke, 1970). The influents of the sewage treatment plants are mostly of domestic origin in which the C:N ratio may possibly be adequate enough to support fungal growth. Cooke (1968a) has shown fungi to grow well under conditions in which the C:N is 9–12:1 which is the C:N ratio of natural soil. The influent in KMC treatment plant, however, is a mixture of domestic and industrial wastes, which may effect the growth of fungal populations. The difference in the number of species may also be attributed to quality and nature of the waste water and also the selectivity of the medium used.

Certain species of fungi were found regularly throughout the system, whereas others appeared sporadically. Among the most frequently occurring species were *A. flavus, A. niger, P. canescens, P. jenseni* and *F. solani.* This could be attributed to the nature and quality of waste water which changes from time to time, thus making the habitat

Table 3. Variation in species richness equitability, General Diversity and Dominance of Mold Communities in sample of tricking filter treatment (KMC – TP 1)

Months	$d=\frac{S}{\sqrt{N}}$	$E=\frac{\bar{H}}{\bar{H}_{max}}$	$\bar{H}=\Sigma p_i \log p_i$	$Mc=1-\frac{\sqrt{\Sigma n_i^2}}{N}$	$C=\Sigma pi^2$	Dominant species Ranking I dominant (%)	II dominant (%)	III dominant (%)
Raw Waste Water (RS)								
Jan	0.830	0.274	0.232	0.112	0.788	*A. flavus*	*Aniger*	–
						–	*P. jenseni*	–
						(88.7)	(2.8)	
Feb	1.431	0.867	0.733	0.539	0.211	*P. canescens*	*A. sydowii*	*P. jenseni*
						(29.1)	(25.0)	(20.8)
Mar	2.475	0.889	1.019	0.653	0.120	*A. flavus*	*P. canescens*	*A. sydowii*
						–	–	*C. cladosporioides*
						–	–	*P. jenseni*
						(21.87)	(18.75)	(9.37)
Apr	2.309	0.822	0.888	0.581	0.175	*P. canescens*	*A. flavus*	*P. janthinellum*
						(32.4)	(18.9)	(13.5)
May	2.200	0.863	0.899	0.595	0.164	*A. terreus*	*A. flavus*	*P. cenescens*
						(32.0)	(16.0)	(12.0)
Jun	1.549	0.877	0.683	0.506	0.242	*P. canescens*	*P. janthinellum*	*A. flavus*
						–	–	*A. terreus*
						(40.0)	(20.0)	(13.3)
Jul	1.964	0.904	0.863	0.605	0.155	*P. janthinellum*	*A. niger*	*A. flavus*
						–	*P. jenseni*	*F. solani*
						(23.8)	(19.0)	(9.5)
Aug	0.845	0.528	0.528	0.369	0.396	*P. canescens*	*P. jenseni*	*A. flavus*
						(54.2)	(31.4)	(5.0)
Sep	0.586	0.497	0.449	0.343	0.430	*P. jenseni*	*P. canescens*	*A. niger*
						–	–	*P. marquandii*
						(53.7)	(37.6)	(2.6)
Oct	2.357	0.850	1.046	0.664	0.112	*A. niger*	*A. flavus*	*F. solani*
						–	*C. cladosporiodes*	–
						(19.2)	(15.3)	(11.53)
Nov	1.809	0.716	0.773	0.476	0.246	*P. canescens*	*P. jenseni*	*Geotrichum sp.*
						(47.7)	(18.18)	(6.8)
Dec	2.667	0.930	0.968	0.652	0.119	*A. flavus*	–	–
						A. sydowii	–	–
						C. cladosporioides	–	–
						(17.6)	–	–
$\bar{X}$	1.751	0.7514	0.7567	0.5079	0.2631			
S^2	0.7046	0.2076	0.2476	0.1634	0.1948			
CV%	47.939	60.641	65.767	79.592	167.795			

Grit Chamber Effluent (GCE)								
Jan	1.109	0.863	0.520	0.42	0.334	*A. flavus*	*A. sydowii*	*A. niger*
						(46.1)	(30.7)	(15.3)
Feb	2.020	0.918	0.775	0.56	0.191	*A. flavus*	*F. solani*	–
						–	*P. Janthinellum*	–
						(33.0)	(16.6)	–
Mar	1.924	0.886	0.886	0.600	0.159	*Geotrichum* sp.	*A. sydowii*	*C. cladosporioides*
						(29.62)	(14.81)	(11.11)
Apr	1.335	0.938	0.565	0.68	0.276	*F. solani*	*A. flavus*	*Mucor* sp.
						Geotrichium sp.	–	–
						(33.3)	*(22.2)*	*(11.1)*
May	2.324	0.883	0.842	0.574	0.179	*C. cladosporioides*	*A. niger*	–
						(33.3)	(20.0)	–
Jun	2.213	0.942	0.796	0.576	0.18	*C. cladosporioides*	*A. niger*	–
						(30.0)	(20.0)	
						–	*A. terreus*	–
						(97.42)	(0.85)	–
Aug	1.796	0.910	0.910	0.633	0.182	*A. flavus*	*A. niger*	*P. canescens*
						–	*A. unguis*	*P. herqueii*
						(19.3)	(16.1)	(12.9)
Sep	0.639	0.429	0.363	0.196	0.674	*P. canescense*	*P. marquandii*	*A. niger*
						–	–	*P. janthinellum*
Oct	0.956	0.772	0.697	0.506	0.243	*A. flavus*	*P. canescens*	*P. jenseni*
Nov	0.808	0.371	0.354	0.192	0.658	*P. canescense*	*A. niger*	*A. flavus*
						–	*F. solani*	*D. hawaiiensis*
						(80.6)	(6.45)	(1.61)
Dec	0.884	0.666	0.401	0.300	0.489	*A. niger*	*A. sydowii*	*C. cladosporioides*
						–	–	*P. herqueii*
						(65.0)	(25.0)	(5.0)
$\bar{X}$	1.3619	0.7226	0.5979	0.4207	0.3697			
S^2	0.6698	0.2780	0.2635	0.1968	0.2595			
CV%	60.097	72.976	85.859	105.450	137.808			

Table 3 (Contd.)

Months	$d=\frac{S}{\sqrt{N}}$	$E=\frac{\bar{H}}{\bar{H}_{max}}$	$\bar{H}=\Sigma p_i \log p_i$	$Mc=1-\frac{\sqrt{\Sigma n_i^2}}{N}$	$C=\Sigma pi^2$	Dominant species Ranking I dominant (%)	II dominant (%)	III dominant (%)
Primary Clarifier Effluent (PCE)								
Jan	1.080	0.557	0.470	0.275	0.525	*A. flavus* – (71.42)	*A. caespitosus* *Mucor sp.* (7.14)	*C. cladosporoides* *P. lilacinum* (4.76)
Feb	0.400	0.567	0.270	0.194	0.650	*A. niger* (78.57)	*Geotrichum sp.* (17.85)	*A. flavus* (3.57)
Mar	1.525	0.587	0.587	0.335	0.442	*A. canescens* (65.11)	*Phoma* sp. (9.30)	*D. hawaiiensis* (6.9)
Apr	2.236	0.921	0.921	0.626	0.14	*A. niger* – (25.0)	*A. fumigatus* *T. harzianum* (15.0)	*A. flavus* *Geotrichum sp.* (10.0)
May	1.000	0.613	0.477	0.335	0.441	*F. solani* (61.1)	*A. sydowii* (25.0)	*A. unguis* (5.5)
Jun	1.333	0.911	0.549	0.45	0.301	*A. niger* – (44.0)	*C. cladosporioides* *P. purpurogenum* (22.0)	*A. glacus* – (11.0)
Jul	N.S.*	N.S.	N.S.	N.S.	N.S.	–	–	–
Aug	0.580	0.860	0.136	0.057	0.888	*P. canescens* (94.2)	*P. herquei* (2.6)	–
Sep	0.536	0.705	0.549	0.413	0.343	*P. canescens* (42.2)	*A. terreus* (39.2)	*C. cladosporioides* (7.2)
Oct	1.524	0.673	0.726	0.438	0.315	*A. flavus* (53.2)	*P. canescens* (12.9)	*C. cladosporioides* (8.0)
Nov	2.020	0.898	0.759	0.543	0.208	*A. niger* (33.3)	*A. flavus* (25.0)	–
Dec	0.928	0.828	0.578	0.449	0.302	*A. niger* (41.37)	*C. cladosporioides* (31.03)	*F. solani* (17.24)
$\bar{X}_2$	1.1965	0.7381	0.5474	0.3740	0.4140			
S^2	0.5972	0.1475	0.2181	0.1596				
CV%	64.592	52.044	85.324	106.827	111.366			

*N.S: not sampled

Primary Trickling Filter Effluent (PTE)								
Jan	1.279	0.679	0.528	0.397	0.362	*A. flavus* (54.5)	*F. solani* (22.7)	*P. jenseni* (9.0)
Feb	0.832	0.714	0.341	0.266	0.537	*A. flavus* (69.2)	*A. niger* (23.0)	*T. harzianum* (7.6)
Mar	2.425	0.942	0.942	0.642	0.126	*Phoma sp.* (23.5)	– –	– –
Apr	2.599	0.941	1.078	0.698	0.089	*D. hhawaiiensis* *F. solani* – (13.7)	*A. flavus* *Geotrichium sp.* *T. harzianum* (10.3)	*P. lilacinum* *A. fumigatus* *C. cladosporioides* (6.8)
May	1.961	0.840	0.840	0.571	0.181	*P. jenseni* – (30.7)	*A. flavus* *A.unguis* (19.2)	– – –
Jun	0.75	0.638	0.304	0.225	0.601	*A. niger* (75.0)	*A. flavus* (18.7)	*C. cladosporioides* (6.2)
Jul	N.S.*	N.S.	N.S.	N.S.	N.S.	–	–	–
Aug	0.659	0.179	0.161	0.067	0.869	*P. jenseni* (93.1)	*A. flavus* (2.04)	*T. harzianum* (1.36)
Sep	1.154	0.913	0.275	0.255	0.544	*F. solani* (66.6)	*A. niger* (33.3)	– –
Oct	1.376	0.726	0.783	0.538	0.213	*P. canescens* – (31.57)	*C. cladosporioides* – (26.31)	*A. flavus* *A. niger* (14.47)
Nov	1.032	0.421	0.401	0.206	0.634	*P. canescens* (78.94)	*A. niger* (5.26)	*P. jenseni* (3.94)
Dec	0.583	0.547	0.329	0.252	0.558	*C. cladosporioides* – (70.2)	*A. niger* – (25.5)	*Fusarium* sp. *T. harzianum* (2.1)
$\bar{X}_2$	1.3318	0.6854	0.5438	0.3742	0.4285			
S^2	0.7017	0.2360	0.3119	0.2069	0.2503			
CV%	62.900	70.883	102.706	121.580	116.769			

*N.S. not sampled

Table 4. Pearsons product moment correlation coefficient and regression equations among species richness, equitability, general diversity and dominance of fungal populations in samples of trickling filter treatment plant (KMC-TPI)

Attributes community organization	Sampling stations			
	Raw waste water	Grit chamber effluents	Primary clarifier effluents	Primary trickling filter effluents
Dominance and species richness	$r = -0.8161^{***}$ $c = -0.13-0.225d$ $d = 0.975-2.954c$	$r = -0.8646^{***}$ $c = -0.976-0.325d$ $d = 0.524-2.297c$	$r = -0.4908^{n.s}$ $c = 0.215-0.200d$ $d = 0.600-1.201c$	$r = -0.8849^{***}$ $c = -0.009-0.315d$ $d = 0.270-2.480c$
Dominance and equitability	$r = -0.8966^{***}$ $c = -0.367-0.840E$ $E = 0.5-0.956c$	$r = -0.9721^{***}$ $c = -0.253-0.906E$ $E = -0.332-1.042c$	$r = 0.3163^{n.s}$ $c = 0.175-0.402E$ $E = 0.552-0.248c$	$r = -0.8198^{***}$ $c = 0.110-0.876E$ $E = 0.355-0.766c$
Dominance and General diversity	$r = -0.9584^{***}$ $c = 0.306-0.753\bar{H}$ $\bar{H} = 0.436-1.218c$	$r = -0.6476^{**}$ $c = -0.183-0.647\bar{H}$ $\bar{H} = -0.458-0.502c$	$r = -0.3177^{n.s}$ $c = 0.252-0.350\bar{H}$ $\bar{H} = 0.411-0.288c$	$r = -0.9560$ $c = -0.011-0.767\bar{H}$ $\bar{H} = -0.034-1.191c$
Species richness and general diversity	$r = 0.9102^{***}$ $d = -0.253+2.652\bar{H}$ $\bar{H} = 0.184 + 0.327d$	$r = 0.7709^{***}$ $d = -0.323+2.639\bar{H}$ $\bar{H} = 0.334 + 0.225d$	$r = 0.7802^{**}$ $d = -0.003+2.103\bar{H}$ $\bar{H} = 0.211+0.289d$	$r = 0.9451^{***}$ $d = 0.176+2.125\bar{H}$ $\bar{H} = -0.016+0.420d$
Species richness and equitability	$r = 0.7167^{***}$ $E = 0.382+0.211d$ $d = -0.076+2.433E$	$r = 0.8083^{***}$ $E = -0.061+2.00d$ $d = 0.27+0.326E$	$r = 0.4718^{n.s.}$ $E = 0.422+0.212d$ $d = 0.436+1.046E$	$r = 0.7189^{**}$ $E = 0.365+0.239d$ $d = -0.41+2.154E$
General diversity and equitability	$r = 0.9047^{***}$ $E = 0.177+0.759\bar{H}$ $\bar{H} = -0.053+1.078E$	$r = 0.5298^{***}$ $E = 0.248+0.732\bar{H}$ $\bar{H} = 0.369+0.38eE$	$r = 0.8663^{***}$ $E = 0.258+0.750\bar{H}$ $\bar{H} = -0.124+1.000E$	$r = 0.6747$ $E = 0.408+0.506\bar{H}$ $\bar{H} = -0.073+0.899E$

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$; n.s. = non significant

of the system more suitable for the dominant species. The habitat tends to select only a few successfully adaptable species to dominate. These species of fungi were also found to be the leading dominants in the system. The dominance was observed more during summer and autumn season. This may be due to the fact that these fungi are mostly saprophytic in nature and are also responsible for the deterioration of food materials during summer and are found associated with decaying leaves and wood in autumn and thus may contribute a large number of spores to the waste waters.

The variation in fungal communities of waste treatment systems occurs mainly due to fluctuation in the abundance of population and to a lesser extent due to changes in the number of species. Therefore, relatively low species diversity and high dominance was observed at most sampling sites. Similar observations were made by Bell *et al.*, (1982) who reported low species diversity in the study of seasonal variations of the predominant heterotrophic bacterial population of fresh water rivers. Odum (1971) maintains that communities in physically stressed situations tend to have lower diversities. Tramer (1969) also suggested that plant communities from rigorous environment will vary in diversity according to their relative abundance (eveness) component whereas diversity in non rigorous environment will be a function of species richness.

In the study of relationship between dominance and diversity indices, a significant negative correlation was found between these parameters. Similar results have been reported by Berger & Parker (1970) between dominance (P_{max}) and diversity using Simpson's (1949) index. Shaukat *et al.*, (1978) also demonstrated dominance to be inversely related to species richness in desert terrestrial vegetation.

A significant positive correlation was observed between diversity H and its components richness and equitability. This agrees with the findings of Shaukat *et al.*, (1978). In our studies also the results indicate diversity to be predominantly controlled by eveness component in the system.

In plant communities the dominants exerts a powerful influence on the ecosystem (Odum 1971). The working of the waste water treatment systems are also based on the fundamentals of an ecosystem (Cooke, 1959b), and like plant communities the dominant species of fungi in waste treatment systems also exert a powerful influence on the ecosystem and thus contribute in the removal of pollutants.

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