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Performance of Sewage Treatment Plants - Coliform Reduction

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FOREWORD

The predominant cause of water pollution in India is the presence of Fecal Coliform, mainly due to large amount of untreated sewage discharged into the water bodies. Many a times, even if treated sewage is discharged into a water body, still high Coliform levels remain as a significant pollution issue. Although, conventional treatment technologies also reduce the Coliform level significantly, still these levels are high enough to pose a health hazard in the receiving water bodies.

For regulation of pollution, Central Pollution Control Board (CPCB) has been providing Minimal National Standards (MINAS) for all the important pollutants. These standards are used by the State Pollution Control Boards/ Pollution Control Committees to regulate pollution in their respective States/UTs. The techno-economic feasibility of MINAS is ensured through detailed studies on the performance of various technological options. Keeping this in mind for setting Coliform standards, CPCB with the help of Indian Institute of Technology, Roorkee and Anna University, Chennai carried out a detailed study on performance of all the prevailing treatment technologies in terms of Coliform reduction.

The results of the two Studies are presented is this Report. IIT Roorkee had also carried out experiments on measures for further reduction in Coliform level after the conventional treatment. The two Institutes also compiled the information from the world literature on global technological options for Coliform reduction in sewage.

I hope the information contained in the Report would be useful to the concerned Authorities, Organizations, Academic Institutions, researchers and others involved in planning the urban waste management in India.

(J. M. Mauskar)

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CHAPTER 1

INTRODUCTION

1.1 Water quality monitoring studies carried out by various national and international agencies (including the Central Pollution Control Board) often report that the freshwater bodies in India contain high levels of organic and microbial pollutants. Concerted national efforts to restore and improve the water quality of Indian rivers started with the launching of Ganga Action Plan (GAP) in 1985. Pollution abatement works under taken by this Plan and subsequently National River Action Plant (NRAP) attempt to address the water quality problems through interception and diversion of urban wastewater to sewage treatment plants before disposal. The organic pollutant (measured as BOD) removal performance of conventional technologies employed in a majority of STPs under these and other programs have been extensively studied and reported, whereas microbial pollutant (measured as MPN of total and fecal coliforms) removal performance is not. Few STPs in India analyze and maintain records of microbiological quality of wastewater. However, in order to set criteria for designing STPs, it is important to have standards for coliform to be achieved in different situations. Limit of fecal coliform in treated sewage has been a subject of discussion for quite a long time. Ministry of Environment, Govt. of India has constituted a Committee in 1999 to recommend coliform standards for treated sewage discharged into river and lakes. The Committee has recommended limits for fecal coliform along with limit for BOD. The recommendations are given at Para 1.2.1. Subsequently a High Powered Committee appointed by the Hon'ble Supreme Court constituted a sub-committee chaired by Chairman, CPCB to recommend coliform standards in treated sewage discharged into river Yamuna in Delhi Stretch. The Committee gave its recommendations as at Para 1.2.2. As a follow up of the recommendations of the above two expert committees a project was sponsored by CPCB to study reduction of coliform in conventional treatment technologies being adopted in India. The study was carried out by CPCB, IIT-Roorkee and Anna University - Chennai.

The Centre for Environmental Studies, Anna University (CES), the Indian Institute of Technology, Roorkee (IIT- R) and CPCB as a part of their commissioned study evaluated the performance of a few sewage treatment plants in the country in respect of removal of organics, suspended mater and enteric microbes. Different types of treatment processes were covered in the evaluation. The three institutions also documented reported data on the subject. Chapter 2 of this report deals with objective & methodology, literature review by the institutions are summarized in chapter 3, findings along with results of the studies are summarized in chapter 4, and recommendations are given in chapter 5.

1.2 Recommendations of the Past Two Committees on Coliform Standards

The issue of setting standards for coliform organisms has been addressed by two expert committees constituted by the Government of India in the year 1999 and 2004.

1.2.1 The National River Conservation Directorate in the year 1999 constituted an expert group on water quality, wastewater standards and technology options for sewage treatment. The group made, among others, the following recommendations on criteria / standards for coliform organisms in environmental surface waters and in treated sewage:

For class B surface waters: Criteria for **coliform** organisms

a) Fecal coliform (MPN) 500/100mL desirable and 2500/100 mL Maximum permissible

b) Fecal streptococci (MPN) 100/100 mL desirable and 500/100 mL Maximum permissible.

Note: *Corresponding existing CPCB criteria for (a) is 500 MPN/100 mL maximum for Total Coliform. Numbers for FC and FS are not specified.*

For Treated Sewage Discharge: Standards

Parameter	**Not to exceed**	**Discharge into/on**
BOD (mg/L)	30	Water body
	100	Land for irrigation
TSS (mg/L)	50	Water body
	200	Land for irrigation
Fecal Coliform (MPN/100 mL)	1,000 desirable 10,000 maximum permissible	Water body or for agriculture, aquaculture, forestry.

Note: *Agriculture; for produce not eaten raw*

1.2.2 The Ministry of Urban Development and Poverty Alleviation constituted in the year 2004 a Committee to determine norms for coliform level in treated wastewater specific to the stretch of the river Yamuna in Delhi. The Committee made the following recommendations:

Criteria for the stretch of Yamuna in Delhi – Class Water

(a) Fecal Coliform (MPN/100 mL)	500	desirable
	2500	Maximum permissible
(b) BOD_3 Day 27^0 C (equal to BOD_5 Day 20^0 C numerically)	3 mg/L or less	

Note*: Criteria at (a) is the same as recommended by the previous Committee of NRCD, 1999*

Standard for Discharge of Treated Sewage into the Stretch of Yamuna in Delhi:

Parameter	Not to exceed	Remarks
(a) BOD 3 day	10 mg/L	Immediate goal
(b) Fecal coliform	2500 MPN/100ml @	See note below

@ *The NRCD Committee recommended 10,000 as maximum and 1000 MPN/100 ml as desirable for all bodies*

Note: *Tertiary treatment after conventional treatment (activated sludge or trickling filter) is required to achieve the recommended standards for BOD and fecal coliform. Tertiary treatment options include chemicals aided flocculation, sedimentation with or without post granular media filtration and / or chlorination.*

CHAPTER 2

OBJECTIVES AND METHODOLOGY

2.1 Objectives

In order to develop rationale for setting standards for regulation of coliform in wastewater, it is essential to carry out study of the existing sewage treatment plants to evaluate their effectiveness and performance in terms of coliform reduction. Keeping this in mind CPCB initiated a study to evaluate performance of the existing sewage treatment plants in the country with the help of two reputed institutes in the subject i.e. Anna University, Chennai and IIT, Roorkee. Despite being identified as one of the major water polluting parameters, limiting coliform standards are yet to be prescribed in India for disposal of domestic wastewater. With the objective to make the regulatory protocol more comprehensive and regulatory standards more stringent, the Central Pollution Control Board (CPCB) proposes to conduct a detailed study to evolve appropriate microbiological standards for disposal of urban domestic wastewater with best practicable technologies available in the country. CPCB has sought the participation of the Center for Environmental Studies (CES), Anna University and IIT, Roorkee to undertake the studies in some of the Southern States & Northern States.

There are three main issues involved in prescribing standards for microbial pollutants. These are:

a. Selection of best indicator microorganisms to reveal the presence of pathogens continues to be a matter of debate. In addition, measurement of microbial pollutants is time consuming and expensive. Reasonably equipped laboratory facilities and qualified analyst are required for accurate analysis and quantification of the microbiological parameters.

b. While extensive literature is available on microbiological performance of conventional treatment technologies, the actual performance of existing STPs in this regard has rarely been evaluated. Prescribing standards based only on data available in literature, without a solid background study supported by first-hand field data under Indian conditions may lead to more lenient or overly stringent limits.

c. Microbiological standards need to be developed, keeping in view the techno-economic viability and ease of operation and maintenance of the treatment technology to achieve the prescribed standards. Hence, there also arises a need to identify and assess treatment technologies appropriate under Indian conditions to achieve the prescribed microbiological standards.

2.2 Methodology

The Central Pollution Control Board commissioned a study with the Centre for Environmental Studies, Anna University, Chennai and the Indian Institute of Technology, Roorkee for suggesting appropriate microbiological standards for disposal of urban domestic wastewater treated with best practicable technologies available in the country. Following methodologies/steps have been adopted in the study:

a) Review of the literature focusing on the microbiological quality status of water resources of the country.

b) Identifying the parameters for assessing microbiological quality of water and wastewater.

c) Listing of the public health effects of microbial pollutants based on epidemiological studies carried out in India and abroad.

d) Synthesizing data available in literature on reduction of microbial pollutants in wastewater treatment processes.

e) Assessment in the field the performance of sewage treatment plants (STP) with respect to selected microbial parameters.

f) Evolving microbiological standards for treated urban wastewater (sewage) corresponding to various modes of disposal.

g) Evolvement of strategies to improve the microbiological quality of water resources of the country.

Above components are considered and data generated and recommendations advanced in respect of these components by the two Institutes are presented in a synthesized form in this document. Microbiological standards based on the above inputs for treated urban wastewater (sewage) corresponding to various modes of disposal are discussed.

2.3 Evaluation by CES

CES evaluated five treatment plants. Salient features of the treatment plants are provided in the statement in Table 2.1.

Table 2.1 Salient features of the treatment plants evaluated by CES

S.No	Name of STP period of observation	Location	Core treatment Processes	Capacity (m^3/day)	Year of Installation	Organizing Managing Agency	Discharge/ Re-use
1.	Decentralized wastewater treatment plant (May, 2004-Jan, 2005)	Anna University, Chennai	Anaerobic – Aerobic Baffled Filter	50	2002	Centre for Environmental Studies	River Discharge
2.	Nesapakkam (2003-2004)	Nesapakkam, Chennai	Activated sludge	23,000	1974	Water supply Sewerage Board	River Discharge
3.	Chennai Petroleum Corporation Ltd (2003-2004)	Manali, Chennai	Biological, chemical and physical tertiary treatment of procured secondary treated sewage	11,350	1991	Chennai Petroleum corporation Ltd.	Reuse for industrial cooling
4.	Pondicherry (2003-2004)	Karuvadikuppam Pondicherry	Oxidation Ponds	13,000	1980	Public works Department	Agricultural use
5.	Vrishabhavathy Valley, (2003-2004)	Bangalore	Trickling Filter	1,80,000	1974	Bangalore water supply sewage Board	River discharge

Proportionate flow composite samples of wastewater at inlet to the plants and at outlet after treatment were collected for physical, chemical characterization and grab samples four times on the sampling data for microbiological analysis by MPN method. The samples were collected fortnightly. Analytical procedures adopted were as per Standard Methods for the Examination of water and wastewater, APHA, 1999. CES had determined Fecal strep, E.Coli and a few Pathogens in addition to total and Fecal Coliform numbers, Reported relevant results are provided in chapter 4 in a summarized form.

2.4 Evaluation by I.I.T., Roorkee

I.I.T. Roorkee evaluated six treatment plants. Salient features of the plants are provided in the statement in Table: 2.2

Table 2.2 Salient Features of the Treatment Plants Evaluated By IIT(R)

S.No	Name of STP period of observation	Location	Core treatment processes	Capacity m^3/day	Year of installation	Organizing and managing agency	Discharge / reuse
1.	Yamuna Nagar (2004-2006)	Yamuna nagar, Haryana	UASB, polishing pond (a)	25,000	2,000	PWD state	Canal
2.	Saharanpur	Saharanpur U.P	UASB polishing pond	38,000	1998	U.P Jal Nigam	River
3.	Lakkerghat (2004-2006)	Rishikesh, Uttrakhand	Oxidation ponds.	6,000	1992	Payjal Sansdhan vikas	River
4.	Kankhal (2004-2005)	Hardwar, Uttrakhand	Activated sludge	18,000	1992	Payjal Sansdhan vikas	River
5.	Vasant Kunj	Delhi	Activated sludge extended aeration	14,000	1998	Delhi Jal Board	Park watering
6.	Swarg Ashram	Rishikesh	Anaerobic filters	500	2001	Sansdhan vikas	River irrigation

Proportionate flow composite samples of wastewater at inlet to the plants and at the outlet after treatment were collected for physical, chemical characterization and grab samples for microbiological analysis. Analyses were carried out following Standard Methods for Examination of water and Wastewater, APHA, 1999. The IIT (R) had determined, Fecal sterp, E.Coli and Helminth eggs in addition to total and fecal coliform numbers.

The Institute came to the following conclusions (STP wise):

UASB Plant, Saharanpur

- Starting Fecal coliform number $4.3x10^4$ to $9.3x10^6$

- Alum and polyaluminium chloride (PAC) at the optimum dosage of 20 mg/L and 24 mg/L (as Ae), respectively, reduced the turbidity to < 1 NTV. Ferric chloride and Ferrous sulphate at the optimum dosage of 39.6 mg/L and 17.6 mg/L (as Fe), respectively, reduced the turbidity to 5 NTU and 3.3 NTU. PAC and ferric chloride treatment resulted in the final of pH=6.8 and 6.9 respectively, whereas Alum and ferrous sulphate resulted in pH=6.4 and 6.1. The former may be better from consideration of pH of the final effluent.

- Sludge volume was around 50 mL/L for the three coagulants and 110 mL/L for PAC
- Total coliform and Fecal coliform after the coagulation & settling were 9,300 MPN/100 mL and 4,300 to 2,300 MPN/100mL, respectively. Chemical treated dose could not achieve 1000 MPN/100mL of Fecal coliform.
- Post PAC, alum, chlorination at 3 mg/L dose resulted in zero Fecel coliform number. Even at 2 mg/L dose the numbers were much below 500 MPN/100mL.

Oxidation Pond, Rishikesh

- Starting fecal coliform number $9.3x10^4$ MPN/100 mL and total coliform $24x10^4$ MPN/100 mL
- Alum was used as the coagulant in the test. The optimum dose from turbidity consideration was found to be 100 mg/L of alum. The corresponding coliform numbers were 4,600 and 1,100 MPN/100 mL of Total and Fecel coliform, respectively. Higher doses of alum further reduce the number of coliform but turbidity increase. Volume of sludge at the optimum dose was 70mL/L.
- Post alum treatment chlorination at even one mg/L reduced total and fecal coliform numbers to 23 and 9 MPN/100 mL. Increase in dosage reduced the number further.
- The Institute suggested that improvements to pond system such as sand filtration, reducing the depth of final ponds could further reduce the coliform numbers. Chemical treatment, chlorination need to be considered if the suggested improvements do not result in meeting acceptable levels.

Activated Sludge Plant, Kankhal

- Starting total and fecal coliform numbers $2.3x10^4$ MPN/100ml and $0.93x10^4$ MPN/100 ml, respectively.
- At an alum dosage of 20 mg/L (Al_2O_3) total and fecal coliform numbers were reduced to 4,300 and 900 MPN/100ml and at the dosage of 30 mg/L to 1,600 and 200 MPN/100 mL.
- Chlorination of the effluent at 2mg/L dosage without chemical treatment resulted in 930 and 230 MPN/100mL for total and fecal coliform. The levels progressively got reduce as increased concentrations.

Activated Sludge Extended Aeration Plant, Vasant Kunj

- Starting total and fecal coliform numbers 6,400 and 2,300 MPN/100mL
- At an alum dosage of 20 mg/l (Al_2O_3) total and fecal coliform organisms were reduced to 2,100 and 1,100 MPN/mL and at 30mg/L to 1,100 MPN/mL.
- At a chlorine dose of 2 mg/L even without pre chemical treatment coliform numbers were reduced to 1,100 and 230 MPN/100mL, respectively for total and fecal coliforms.

2.5 Evaluation by CPCB

CPCB evaluated performance of STPs located in Delhi. There are 30 STPs in Delhi. The details of these STPs are as follows:

Table 2.3 Salient Features of the Treatment Plants Evaluated by CPCB

SI.No	Name of STP	Location	Core treatment processes	Capacity m^3/day	Year of installation	Organizing and managing agency	Discharge / reuse
1.	Coronation Pillar STP's 1) (10) 2) (10 + 20)	Coronation Pillar, Mukharji nagar, Delhi	Activated sludge process (ASP), trickling filter & ASP	45.46 45.46 90.92	1957	Delhi Jal Board	Najafgarh drain to Yamuna River
2.	Delhi Gate (2.2)	Delhi Gate, Nalah, Delhi	High rate bio-filters Densadeg technology	10.00	1995	Delhi Jal Board	River Yamuna
3.	Ghitorni (5)	Ghitorni, Delhi	Activated sludge process	22.73		Delhi Jal Board	River Yamuna
4.	Keshopur STPs 1) (12) (20) (40)	Keshopur, outer ring road, Delhi-18	All the three plants designed on activated sludge process	54.55 90.92 181.84	1)1956 2)1976 3)1986	Delhi Jal Board	Najafgarh drain to Yamuna river
5.	Kondli STP's 1) (10-Phase-I) 2) (25 -Phase-II) 3) (10-Phase-III)	Kondli, Delhi	All three activated sludge process	45.46 113.65 45.46	1)1979 2)1990 1995	Delhi Jal Board	Shahdara drain to Yamuna River
6.	Mehrauli STP (5)	Mehrauli, New Delhi	Extended aeration	22.73	2003	Delhi Jal Board	River Yamuna
7	Najafgarh STP (5)	Najafgarh, New delhi	Activated sludge proc.	22.73	2000	Delhi Jal Board	Najafgarh Drain to Yamuna river
8	Nilothi STP (40)	Nilothi, New delhi	Activated sludge process	181.84	2002	Delhi Jal Board	Najafgarh Drain to Yamuna river
9	Narela STP (10)	Narela, New Delhi	Activated sludge process	45.46	2003		Najafgarh Drain to Yamuna river

Table 2.3 Salient Features of the Treatment Plants Evaluated by CPCB [Contd...]

S. No.	Name of STP	Location	Core treatment processes	Capacity m^3/day	Year of installation	Organizing and managing agency	Discharge / reuse
10	Okhla STP's 1) (12) 2) (16) 3) (30) (37) (45)	Okhla, Mathura Road, New Delhi-20	All the plants designed on activated sludge process	54.55 72.73 136.38 168.20 204.57	1937-1990	Delhi Jal Board	New Agra Canal/Old Agra Canal near Jasola Village/Sarita Vihar Bridge
11	Papankalan STP (20)	Papankalan, New Delhi	Activated sludge process	90.92	2002	Delhi Jal Board	Najafgarh Drain to Yamuna river
12	Rithala STP's 1) (40) Old 2) (40) New	Sec-11, Rohini, Delhi	Activated sludge process & High rate aerobic ASP & biofor/biofilter	181.84 181.84	1)1990 2)2002	Delhi Jal Board	Rohini/ Nangloi Drain Yamuna River d/s Wazirabad Barrage
13	Rohini STP (15)	Rohini, Delhi	Activated sludge process	68.19	-	Delhi Jal Board	Supplementary drain to Najafgarh drain to Yamuna river
14	Sen N.H. STP (2.2)	Sen N.H. Nalah, Ring Road, Delhi	High rate Bio filter	10.0	1995	Delhi Jal Board	Yamuna River
15	Timarpur O.P. (6)	Timarpur, delhi	Oxidation ponds	27.27	1980	Delhi Jal Board	Najafgarh Drain to Yamuna river
16	Yamuna Vihar STP's 1) Ph-I (10) 2) Ph-II (10)	Yamuna Vihar, Delhi	Activated sludge process	45.46 45.46	1)1998 2)2002	Delhi Jal Board	Shahdara drain to Yamuna River
17	Vasant Kunj STP's 1) (2.2) 2) (3.0)	Vasant kunj, New Delhi	ASP & Extended aeration	10.00 13.63	1)1992 2)1998	Delhi Jal Board	Partly to Sanjay Van to open drain (Kushak drain) to Barapulla drain to Yamuna river
	Total 30			2330			

CHAPTER 3

REVIEW OF RESEARCH WORK

3.0 This chapter deals with literature review and highlights the water quality problems related to water borne diseases. Section 3.1 deals with literature review in respect of removal of organics, suspended mater and enteric microbes. Section 3.2 deals with literature review in respect of Guidelines recommended by International Agencies. Section 3.3 deals with literature review in respect of public health effects due to microbial pollutants in wastewater. Section 3.4 deals with summary of literature review.

3.1 Literature Review In Respect Of Removal Of Organics, Suspended Mater And Enteric Microbes:

Efficiencies of primary and secondary sewage treatment process in coliform removal are stated in the manual on sewage and sewage treatment published by Ministry of Urban development as follows:

Primary treatment and Secondary treatment : 40 to 60 percent, Trickling filter : 80 to 90 percent and Activated sludge : 90-96 percent. Comment on this data would be to refer to Table 3.1 in which raw sewage fecal coliform is reported in the range of 10^8 MPN/100 ml. If four percent of this is not removed even in activated sludge treatment the number in the treated effluent would be $4x10^6$ MPN/100 ml. This is the number, approximately, for activated sludge treated sewage.

CES quoted 100 percent that is three log units reduction of total coliform in stabilization ponds and constructed wetlands, 79 to 83 percent in oxidation ditches, 90 percent is alum treated and 99 percent in land treatment.

Noah Arre et.al., 2003 reported about 99 percent or more of total coliform and fecal coliform removal in activated sludge process compared to CPHEEO figures. The research papers highlighted the role of ciliated protozoa in removal of coliform organisms.

3.1.1 Coagulation

A process, which is often applied during the treatment of drinking water, is coagulation and flocculation followed by sedimentation. Coagulants like aluminium sulphate, ferric chloride, calcium hydroxide and coagulant aids viz. polyelectrolytes are used. Studies about this treatment process indicate that a relatively high percentage removal of pathogenic microorganisms (>90%) can be obtained. The results obtained by various researchers are summarized in Table 3.2.

The results indicate that if higher amounts of organic substances are present in the water this may influence the process of coagulation and flocculation and reduce the removal efficiency.

Table 3.1: Summary of the Findings of Different Authors on Coliform and Other Pollutants Removal Efficiency of Different Technologies

Type of sewage treatment technology		Removal efficiency (%)																	Reference
		BOD	COD	TC			FC			E.coli			FS			Helminth eggs			
				I	O	R / %	I	O	R/ %	I	O	R/ %	I	O	R/ %	I	O	R/ %	
UASB system	UASB reactor alone	69.5	61.7	-	-	-	-	-	-	1.0x 10^7	2.0x 10^6	80.0	-	-	-	19.5	5	74.3	R. Keller et al, 2004
	UASB followed by Oxidation pond system	-	-	-	-	-	-	-	99.9999	-	-	-	-	-	-	-	-	-	Seghezzo et al. 2003
		-	-	-	-	-	-	-	99.99	-	-	-	-	-	-	-	-	100	Dixo et al, 1995
		-	-	-	-	-	-	-	97- 99	-	-	-	-	-	-	-	-	-	Ghosh et al, 1998
		-	-	-	-	-	-	-	99.9-99.99	-	-	-	-	-	-	-	-	-	Steen et al, 1999
Pond System	Stabilization Pond system (Anae-robic ponds followed by Faculta-tive ponds)	80	76.5	2.4 x 10^8	2.0x 10^7	91.66	2.1x 10^7	4.6x 10^3	99.98	-	-	-	2.2x 10^7	2.3x 10^4	99.89	-	-	99.3	B.El. Hamouri et al, 1995
		89	90	-	-	-	-	-	-	-	-	99.99	-	-	-	-	0	100	A.Kouraa et al, 2002
	Oxidation (Facult-ative) Pond	-	-			96.9	-	-	99.1	-	-	-	-	-	99.3	-	-	-	Bahloui et al, 1997
		-	-	-	-	-	-	-	99.6	-	-	-	-	-	-	-	-	100	Mandi et al, 1993
Activated Sludge Process		-	-	-	-	-	-	-	-	-	-	91-99	-	-	-	-	-	-	Curds & Fey, 1969
		-	-	7.0 x 10^7	3.5 x 10^5	99.5	5.7 x 10^7	1.3 x 10^5	99.7	-	-	-	-	-	-	-	-	-	Noah Arre et al, 2003
		85-93	-			90-95	-	-	-	-	-	-	-	-	-	-	-	-	Arceivala, 1998
		-	-	-	-	98.3	-	-	99.1	-	-	-	-	-	-	-	-	75.0	Rose et al,
		-	-	-	-	98-99	-	-	98- 99	-	-	-	-	-	-	-	-	-	Saleem et al, 2000
Activated Sludge process+ Chlorination		-	-	-	-	99.99	99.99	-	-	-	-	-	-	-	99.99				Gohary et al, 1998
		-	-	-	-	99.2 - 100	99-100	-	-	-	-	-	-	-	-	-	-	-	Fattouh et al, 2002

Table 3.2 : Removal of Microorganisms by Coagulation and Flocculation

Type of coagulant	Dose (ppm)	Microbial parameter	pH	% Reduction	Reference*
$Al_2(SO_4)_3$	15	Coxsackie virus	6.7-7.4	95.7	Chang et al (1958)
		Coliphage F_2		99.45	Selton & Drewry (1973)
		Coliform bacteria		63.8	
		Bacteria count		75.1	Chang et al (1958)
	20-25	Coxsackie virus		94.8-98.6	Chang et al (1958)
		Coliform bacteria		94.4-99.8	Berg (1971)
		Bacteria count		98.7-99.8	Chang et al (1958)
	40-50	Coliphage T4, MS2	5.4-6.1	89.6-99.9	Berg (1971)
					Chaudhari &Engelbrecht (1970)
	76	Coliphage F_2	7.1	99.6	Selton & Drewry (1973)
$FeCl_3$	20-25	Coxsackie virus	6.8-7.8	92.1-93.8	Chang et al (1958)
		Coliform bacteria		61.6-93.8	Chang et al (1958)
		Bacteria count		78.0-94.8	Berg (1971)
	40	Coliphage F_2		99.1	Selton & Drewry (1973)
$Ca(OH)_2$		Polio virus	11.0-11.3	96.5-99.9	Berg et al (1968)
		Natural coliphages		97.3	Hofman (1978)
		Coliform bacteria		98.9	
		Ps. aeruginosa		94.5	
		Clostridia spores		97.3	

3.1.2 Filtration

An important treatment process from a hygienic point of view is the filtration of polluted water in sand or soil. The reduction of the microorganisms is caused by physical and biological processes. The contribution of both processes of purification is difficult to quantify. Important factors in the biological processes are the presence of protozoa, metazoa, bacteria and may be bacteriophages and Bdellovibrios (Burman, 1962; Husman, 1963). The reduction capacity of sand filters with respect to viruses investigated by various investigators is given in *Table 3.3***.**

Table 3.3 : Reduction percentage in number of viruses due to filtration

Type of filtration	Type of organism	% Reduction	Reference
Infiltration(dunes,sand)	Poliovirus 1,2,3) Bacteriophage)	99.99	Robeck etal (1962)*, Lance et al (1976), Hoesktra* (1977), Chang et al (1958)*.
Slow sand filtration	Poliovirus Coxsackie virus	22-96 93	Robeck etal (1962)*, Chang et al (1958)*.
Rapid sand filtration	Poliovirus Bacteriophage T4	0-50 0-87	Robeck etal (1962)*, Guy et al (1977).

Comparing the available data of the different infiltration experiments, it is concluded that dune infiltration is obviously a very effective treatment for the removal of bacteria and other

pathogenic organisms because more than 4 log units reduction in the number of micro-organisms can be obtained.

3.1.3 Disinfection Processes

3.1.3.1 Chlorine Treatment

Under optimal conditions chlorine is a very powerful disinfectant. Chlorine is commonly used in its elemental form or as hypochlorite. Depending on the pH of the water and on the presence of ammonia, the chlorine may take the form of HOCl, OCl^- , Cl_2 or chloramines. Chlorine is a strong oxidizing agent and attacks chemical constituents of the bacterial cell and viruses and reacts with a large number of other substances both organic and inorganic.

The microbial inactivation efficiency of chlorine and chlorine compounds towards bacteria, bacterial spores, viruses, pathogenic protozoa, and metazoa parasites is also affected by the composition of the water, while the resistance of these organisms may also differ significantly (Table 3.4).

Table 3.4 : Inactivation of Microorganisms during Chlorine Treatment

Type of organism	Temp. (^{0}C)	Free chlorine (mg/l)	Contact time (min.)	% Surviving	Reference
E.Coli		0.03	5	0.4	Clarke & Kabler (1954)
Coxcaskie virus A2		0.6	9.7	0.4	
Polio virus 1,3	2-6; 25-28	0.2	4	0	Kelly (1957)
Polio virus 2			15-30	0	
E.coli		0.1	<1;<1	0-1	Clarke et al (1956)
S.typhi			<1;1		
Adeno virus			<1;<1		
Coxcaskie virus A2			40;4		
E. histolytica cysts			630;150		
B. anthracis			1440;360		
E.coli	10	0.4	0.12	1	Kott et al (1974)
Poliovirus 2		0.4	0.75	1	
Fecal coliform bacteria	-			0.97-2.2	
Clostridia spores		0.13-0.25	30	24-86	Kool & Kranen (1977)
'Natural' Bacteriophages				9-47	
S.mansoni		1.35	30	0	Mercado-Burgos (1975)

3.1.3.2 Ozone Treatment

Ozone has been used for many years during the preparation of drinking water in Europe and particularly in France where this disinfectant was first applied at Nice in 1907. Kessel et al (1943) showed that 0.05-0.45 ppm ozone destroyed the same amount of Poliovirus in two minutes as 0.5-1 ppm chlorine did in few hours. Coin et al (1964) concluded that ozone is a very powerful disinfectant for poliovirus and inactivation up to 4 log units can be obtained if there exists a residual ozone content of 0.4 mg/l and a contact time longer than three minutes.

Table 3.5 : Inactivation of Microorganisms with Ozone Treatment

Type of organism	Residual ozone (mg/l)	Contact time (min)	Reduction (log units)	Reference
E.coli Coliphage Poliovirus	0.02; 0.14	4	4 ; - 0.62 ; >4 0.51 ; >3	Evison (1972)
E.coli C.albicans Ps.aeruginosa S.marcescens B.cereus (spores) B.globigii Coliphage T1,T2,T3 S.aureus	0.13 0.16 0.18 0.38 0.74 0.76 2.5 3.5	3 60 2 5	4 2.40 >4 >4 >3 2.70 >5 >5	Haufele & Sprockhoff (1973)
E.coli S.aureus S.typhimurium S.flexneri Ps.aeruginosa V.cholera	0.4-0.5	0.25	0	Burleson et al (1975)
Polioviris 1 Polioviris 2	0.6-1.0 0.3	1-2 1	5 3	Katzenelson et al (1976)
M.fortuitum C.parapsilosi	1.1 0.23	1.25 0.40	2.52 >3	Faroog et al (1977)

From the results in Table 3.5 it may be concluded that ozone is a very powerful disinfectant for bacteria, fungi and viruses considered. It is obvious that the enteric viruses considered are much more resistant to ozone treatment than bacteria of the coli group. An important impediment for the inactivation ability of ozone is the presence of organic matter in large quantities.

3.1.4 Pond Treatment Technology

Among the various treatment processes for sewage, stabilization pond deserve primary consideration in India because of the abundance of light and suitable temperature in addition to the other advantages like low-cost i.e. cheapness in construction, simplicity in operation and ease of maintenance and producing high-quality effluent that enables water re-use in irrigation (Maynard et al., 1992; N.M. Parhad et al, 1976). The only disadvantage of pond system is that, the land area requirement is relatively more. The stabilization ponds are classified as follows (Arceivala, 2003):

3.1.4.1 Aerobic Stabilization Ponds

Aerobic waste stabilization ponds are shallow ponds of less then 0.5m depth so designed as to maximize light penetration and the growth of algae through photosynthetic action. Aerobic conditions are maintained throughout the depth of the pond at all times.

3.1.4.2 Anaerobic Stabilization Ponds

Anaerobic waste stabilization ponds require no dissolved oxygen (DO) for microbial activity as the anaerobic and facultative organisms use oxygen from compounds like nitrates and sulphates as their hydrogen acceptors, and give products like methane and carbon dioxide. Such ponds, can therefore, accept higher organic leadings, and operate without algal photosynthesis. Light penetration is unimportant and they can be built deeper, about 3-4m being more common. But the anaerobic effluent is generally not fit for discharge without further treatment. They are, thus, often provided in tandem with facultative ponds, which follow them. The anaerobic ponds are now replaced by up flow anaerobic sludge blankets (UASB), which are relatively more efficient.

3.1.4.3 Facultative Stabilization Pond

Facultative waste stabilization ponds are partly aerobic and partly anaerobic. They are often about 1-2m in depth, favoring algal growth along with the growth of facultative microorganisms. Such ponds are predominantly aerobic during the sunshine hours as well as or some hours of the night. In the few remaining hours, the pond bottom waters may turn anaerobic. Stabilization ponds are open, flow though earthen basins specifically designed and constructed to treat sewage and biodegradable industrial waste.

Facultative ponds are loosely known, otherwise as oxidation ponds are relatively shallow bodied (1m – 1.5m depth) of wastewater contained in an earthen basin. In this system upper layer works under aerobic conditions, while the anaerobic conditions prevailed at the bottom. The aerobic layer acts as a good check against odor evolution from the pond (Manual GOI, 1993). Considerable interaction exists between the aerobic and anaerobic zones. Organic acids and gases, products of decomposition in the anaerobic zone, are released and become soluble food for organisms in the aerobic zone. Biological solids produced in the aerobic zone ultimately settle to the bottom where they die, providing food for the anaerobic benthic organisms.

The results of the oxidation pond treatment are: the oxidation of the original organic matter and the production of algae, which are discharged with the effluent. This results in a net reduction in BOD since the algae are more stable than the organic matter in wastewater, and degrade slowly in the river stream into which the effluent is discharged. A special relationship exists between bacteria and algae in the aerobic zone. Here the bacteria use oxygen as an electron acceptor to oxidize the wastewater organics to stable end products such as CO_2, NO_3^- and PO_4^-. The algae in turn use these compounds as a material source and with sunlight as energy source, produce oxygen as an end product. The oxygen is then used by the bacteria (Peavy et al, 1985, Manual GOI, 1993). A minimum of 60d detention time is often required for flow through facultative ponds receiving untreated wastewater. Higher detention times (90-120d) have been specified frequently. A high degree of coliform removal is assured even with a 30d detention (Metcalf and Eddy, 2003).

Considerable work has been done in India and elsewhere on the performance of stabilization pond with respect to the removal of BOD and reduction of indicator bacteria. N.M. Parhad et al studied three stabilization pond of different design located at Nagpur city, India. Sample were collected and analyzed for BOD, coliforms, E. coli, Bacterial count and enterococci. The comparative analysis of observations and survey of results of the three stabilization ponds are given in Table 3.6.

Table 3.6 : Comparative Analysis of Observations and Survey of Results of the Three-oxidation Ponds at Nagpur (Prahad et al, 1976)

S. No.	Para-meters	ange	Pond at Bezonbagh		Ponds at institute's campus			Ponds at Bhandewadi			
			Inf.	Eff.	Inf.	Pond I (Eff.)	Pond II (Eff.)	Inf.	Pond I (Eff.)	Pond II (Eff.)	Pond III (Eff.)
1.	BOD in ppm	Min.	180.0	52.0	78.0	49.0	29.0	240.0	25.0	19.0	25.0
		Max	262.6	70.6	161.0	100.0	83.0	485.0	108.0	99.0	53.0
	% Reduction	Min.	-	63.9	-	22.0	34.2	-	62.9	73.5	83.9
		Max	-	77.6	-	55.5	73.6	-	90.8	96.6	93.0
2.	Bacterial count/ml	Min.	$7.7x10^{6}$	$4.3x10^{6}$	$2.0x10^{6}$	$5.8x10^{5}$	$1.5x10^{5}$	$3.6x10^{6}$	$6.4x10^{5}$	$1.5x10^{5}$	$5.1x10^{4}$
		Max	$2.3x10^{7}$	$1.4x10^{7}$	$5.9x10^{7}$	$3.7x10^{6}$	$1.4x10^{6}$	$6.1x10^{7}$	$1.2x10^{7}$	$4.6x10^{6}$	$3.7x10^{6}$
	% Reduction	Min.	-	6.0	-	9.8	74.1	-	25.0	76.3	82.5
		Max	-	66.9	-	98.1	99.5	-	96.0	99.7	99.9
3.	Coliform /100ml	Min.	$6.0x10^{6}$	$5.7x10^{5}$	$3.3x10^{6}$	$5.4x10^{5}$	$9.2x10^{4}$	$4.5x10^{6}$	$2.2x10^{4}$	$6.6x10^{3}$	$3.0x10^{2}$
		Max	$3.5x10^{8}$	$7.9x10^{6}$	$5.4x10^{7}$	$5.4x10^{5}$	$1.6x10^{6}$	$1.8x10^{8}$	$2.4x10^{3}$	$4.1x10^{5}$	$8.4x10^{4}$
	% Reduction	Min.	-	82.1	-	77.5	83.7	-	86.7	97.7	99.5
		Max	-	98.4	-	96.9	99.7	-	99.9	99.99	99.99
4.	E.coli /100ml	Min.	$1.0x10^{6}$	$3.4x10^{5}$	$3.3x10^{6}$	$4.0x10^{5}$	$5.9x10^{4}$	$4.5x10^{6}$	$1.1x10^{4}$	$1.4x10^{3}$	$7.6x10$
		Max	$1.1x10^{8}$	$3.3x10^{6}$	$5.4x10^{7}$	$5.4x10^{6}$	$9.6x10^{5}$	$1.0x10^{8}$	$1.6x10^{6}$	$2.1x10^{5}$	$4.7x10^{4}$
	% Reduction	Min.	-	57.0	-	77.5	83.7	-	90.0	98.7	99.7
		Max	-	99.0	-	99.3	99.7	-	99.98	99.99	99.99
5.	Entero-cocci	Min.	$2.3x10^{5}$	$3.2x10^{4}$	$2.3x10^{4}$	$7.9x10^{3}$	$7.0x10^{2}$	$1.1x10^{5}$	$4.5x10^{2}$	$2.0x10^{2}$	$2.2x10$
		Max	$1.0x10^{7}$	$6.5x10^{5}$	$2.4x10^{6}$	$4x10^{5}$	$3.5x10^{4}$	$7.9x10^{6}$	$1.0x10^{5}$	$5.9x10^{3}$	$1.1x10^{4}$
	% Reduction	Min.	-	78.7	-	65.7	97.0	-	94.9	99.7	99.8
		Max	-	98.8	-	95.8	99.9	-	99.94	99.99	99.99

From the results it appears that out of the three ponds studied, ponds at Bhandewadi i.e. the one having three cells (operated in series) gave the highest percentage reduction of indicator bacteria and BOD. The influences of DO, pH, particulate and dissolved constituents in WSP effluent on sunlight inactivation of fecal microorganism was reported by Davis and Colley (1999).

Table 3.7: Influences of DO, pH, Particulate and Dissolved constituents in WSP effluent on sunlight inactivation of Fecal Microorganisms (Davis and Colley, 1999)

Factors	Fecal indicators			
	Enterococci	**E.Coli**	**F-DNA Phage**	**F-RNA Phage**
DO	Increase	Increase	-	Increase
PH	-	Increase	-	-
WSP Dissolved matter	Increase	-	-	Increase
WSP Solids	Increase	-	-	Increase

Increase- Increase in inactivation rate with increase in factor

Table 3.8 shows percentage removals from waste stabilization ponds reported in the literature for fecal coliforms (FC), viruses and intestinal parasites (IP) in a number of countries around the world.

Table 3.8 : Percentage Removal of Fecal coliforms (FC), Viruses and Intestinal parasites (IP) From Waste Stabilization Ponds Worldwide (Maynard et al., 1992)

Country	Retention time (d)	Removal FC (%)	Removal viruses (%)	Removal IP(%)	References
Tanzania	8	90.8			Yhdego, 1992
Kenya	3	89.5			Grimason et al., 1996
	27.6			H:99.96-100	Ayres et al., 1993
Morocco		73-95	VC:9.5-90	H:100	Lesne et al., 1991
	7	99.6			Mandi et al., 1993
	7.5	74.4-84.3			Mezrioui et al., 1995
Tunisia		99.97		H:99.99	Ghrabi et al., 1993
S.Africa	3	99.99			Jagals and Lues, 1996
Israel		90			Pedahzur et al., 1993
India			78-95		Chalapati Rao et al., 1981
				H:38.5-100	Veerannan, 1977
Thailand	20	88			Polprasert et al., 1983
New Zealand		92-99.9			Turner & Lewis, 1995
Australia					
	16	98.8-99.96			Macdonald & Ernst, 1986
	3			100	Macdonald & Ernst, 1986
France	40-70	99.95			Picot et al., 1992
				G:99.7-100	Wiandt et al, 1995
Portugal		96.5			Mendes et al., 1995
U.K.	3	40-90			Toms et al., 1975
Cayman Island	3	66-79			Frederick, 1995
Peru	5.5			100	Yanez et al., 1980
Brazil	15	83.5-95.3			Dixo et al., 1995
			91-100		Oragui et al., 1995
			VC:62.5-100		Oragui et al., 1993
	9.8			H:87-100	Mara & Silva, 1986
		99.99			Arridge et al., 1995

VC= Vibrio cholerae;   H= Helminths;   G= Giardia.

The main factors contributing to indicators as well as pathogen removal in waste stabilization ponds are due to sunlight inactivation, pH and dissolved oxygen.

Stabilization pond systems can provide a very high degree of removal of microorganisms from reclaimed waters but large land area requirements is the major constraint.

Hamouri et al (1994) obtained a removal of 80% for BOD and 76.5% for COD removals as well as 91.66% of Total Coliforms, 99.98% of fecal coliform, 99.89% of fecal streptococci and 99.3% of Helminthes egg removal during waste- water treatment in a HRAP (High Rate Algal Pond) system. He also studied the effect of season on fecal coliform and fecal streptococci removal rates as given in Table 3.9 (a), 3.9 (b).

Table 3.9 (a) Physico-Chemical Characteristics of Rabat's Wastewater Before and After Treatment in a HRAP (Hamouri et al, 1994)

Parameters	**Raw**	**Treated**	**Rate of Remova (%)**
Total coliform/100ml	$2.4x10^8$	$2.0x10^7$	91.66
Fecal coliforms/100ml	$2.1x10^7$	$4.6x10^3$	99.98
Fecal streptococcus /100ml	$2.2x10^7$	$2.3x10^4$	99.89

Table 3.9(B) Rabat's Wastewater Counts (Geometric Mean) of Fecal Bacteria Throughout the Year and Their Removal Rate in a HRAP (Hamouri Et Al, 1994)

Parameters	**Wastewater**		
	Raw	**Settled**	**Treated**
pH	7.4	7.3	8.1
SS (mg/l)	220	160	390
COD (mg/l)	695	439	163
BOD_5(mg/l)	417	275	50

A. Kouraa et.al (2002) studied the performance of a combined waste stabilization pond after three years of functioning. The combined ponds showed good functioning condition and excellent performance either for organic load (90%), fecal coliform (6log unit) or Helminth eggs (100%) and produced a high perennial effluent quality. The effluent could be used for non-restrictive irrigation, with a clear improvement of culture production and hygienic quality for both fruits and soil. The total efficiency and effluent quality is reported in Table 3.10

Table 3.10: Total efficiencies and quality according to health aspects (Kouraa et.al, 2002)

	Hot period		**Cold period**		**All the year**	
	Removal (%)	**Effluent mg/l**	**Removal (%)**	**Effluent mg/l**	**Removal (%)**	**Effluent mg/l**
COD	90	52	89	46	90	48
BOD_5	89	16	89	15	89	16
TSS	85	28	85	22	85	25
Helminth egg/l	100	0	100	0	100	0
Fecal coliform (MPN/100ml)	7 log U	< 1log U	6 log U	< 1 logU	7 log U	< 1 logU

Some researchers have reported some improvements and facts of the Oxidation ponds. Bahlaoui et al, 1997, studied the spatio-temporal dynamics and removal efficiency of pollution indicator (total coliforms, fecal coliforms and fecal streptococci) and some pathogenic bacteria (Pseudomonas aeruginosia and Aeromonas spp.) in two high rate oxidation ponds (HROP) pilot plants in Table 3.11.

Table 3.11: Seasonal Removal Efficiency of Pollution Indicator Bacteria in Each Experimental HROP (Bahlaoui et al, 1997)

Sampling period[a]	**HROP B**				**HROP A**			
	TC	**FC**	**FS**	**Retention time**[b] **(days)**	**TC**	**FC**	**FS**	**Retention time**[c] **(days)**
(1)	96.9	99.1	99.3	8	95.3	97.9	98.6	6
(2)	65.2	71.0	86.9	8	58.6	64.1	78.9	4
(3)	93.5	96.9	98.6	8	89.5	93.4	98.3	5
(4)	83.8	87.2	95.2	8	90.4	94.0	94.4	12

(1)[a] = 1988.02.09-10.04: [b] = Retention time is constant.
(2) = 1988.10.11-1989.01.24: [c] = Mean value of retention time for each period.
(3) = 1989.01.31-09.19: (4) = 1989.09.26-1990.01.30:

Further, the removal efficiency of fecal-indicator bacteria by HROP is maximum in summer than winter, but the removal efficiency of pathogenic bacteria indicated poor results. However, the HROP sanitary performance shows a better efficiency as compared to conventional wastewater treatment lagoons. Bahlaoui et al, 1998 again reported the effect of environmental factors on different bacterial population in the HROP in Table 3.12.

Table 3.12 : Mean and Standard Deviation (SD) of Environmental and Bacteriological Variable at Different Sampling Points Before and After Treatment HROP (Bahlaoui et al, 1998)

Parameters	Raw wastewater		Primary pond outflow		HROP A outflow		HROP B outflow	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
WT (°C)	-	-	16.6	10.3	17.0	7.2	17.0	7.2
PH	7.85	0.47	7.81	0.43	8.66	0.58	8.63	0.52
DO (mg/L)	-	-	0.22	0.11	11.66	9.20	12.62	8.32
Total COD (mg/L)	541	408	382	163	322	157	271	181
Dissolved COD (mg/L)	249	368	190	136	102	51	83	44

WT= Water temperature,

They found that, in complex aquatic environments, factors (such as pH, total COD, dissolved COD, temperature and D.O.) affecting fecal indicator bacteria are interrelated and their importance may vary by site, by season and by year. Oxidation ponds have become very popular in small communities because their low construction and operating cost offer a significant financial advantage over other treatment methods. Ponds are also used extensively for the treatment of individual wastewater and mixtures of industrial and domestic wastewater amenable to biological treatment (Metcalf and Eddy, 1995). Omura et al (1985) reported that more than 99% of coliform were inactivated in an Oxidation pond system comprising a series of facultative and maturation ponds which have hydraulic retention time of 8- 20 d.

3.1.5 Activated Sludge Process

The Activated Sludge Process (ASP) provides an excellent method of treating either raw sewage or more generally the settled sewage. ASP is a biological wastewater treatment process that has primary objectives of the oxidation of biodegradable organic matter into carbon dioxide and new biomass, and incorporation of colloidal matter into settleable solids. Activated sludge consists of highly active aerobic microorganisms like bacteria in activated sludge are in the range of 1- 10×10^{12}/g VSS(Metcalf and Eddy, 1995)**.**

In the activated sludge process, the dispersed growth reactor is an aeration tank or basin containing a suspension of the wastewater and microorganisms, the mixed liquor. Thus the activated sludge process is an aerobic suspended–culture process with sludge return and may be either a complete mixed or a plug flow process (Peavy et. al, 1985). The contents of the aeration tank are mixed vigorously by aeration devices, which also supply oxygen to the biological suspension. Aeration devices commonly used, include submerged diffusers that release compressed air and mechanical surface aerators that introduce air for agitating with the liquid surface. Hydraulic retention time in the aeration tanks usually ranges from 3- 8 hours but can be higher with high BOD_5 wastewaters. Following the aeration step, the microorganisms are separated from the liquid by sedimentation and clarified liquid is secondary effluent. A portion of the biological sludge is recycled to the aeration basin to maintain a high mix liquor suspended solids (MLSS) level and to maintain the proper food to microorganism ratio to permit rapid

breakdown of organic matter. The rest sludge is allowed to pass through the sludge loading system for further treatment and disposal (Qasim, 1986).

Several variations of the basic activated sludge processes, such as extended aeration and oxidation ditches, are commonly used, but the principles are similar. (Metcalf and Eddy, 1995). The overall removal efficiency of BOD_5 is 85-93% for complete mix ASP and 95-98% for extended aerator systems. Where as the coliform removal efficiency has been reported to be 90-95% and 90-98% in complete mix and extended aerated ASPs respectively (Arceivala, 1998). James M.M. (1985) had reported 97% removal of coliform by conventional activated sludge treatment. The microbiological removal efficiency in Activated sludge process plant with respect to Total coliform and Fecal coliform was studied by Noah Arre et al, 2003 as given in Table 3.13.

Table 3.13: Microorganisms Removal Efficiency in an Activated Sludge Process Plant (Noah Arre et al, 2003)

Date	Raw sewage		Secondary effluent	
	Total coliform (MPN/100ml)	Fecal coliform (MPN/100ml)	Total coliform (MPN/100ml)	Fecal coliform (MPN/100ml)
7/10/02	50×10^6	50×10^6	35×10^4	23×10^4
21/10/02	70×10^6	50×10^6	17×10^4	11×10^4
4/11/02	95×10^6	90×10^6	20×10^4	8×10^4
18/11/02	50×10^6	30×10^6	25×10^4	17×10^4
25/12/02	80×10^6	50×10^6	35×10^4	11×10^4
12/03/03	80×10^6	70×10^6	70×10^4	8×10^4

Ciliated protozoa play the dominant role in the removal of Escherichia coli from wastewater by predation or flocculation. The E. coli population is generally reduced by 91 to 99 percent in the activated-sludge process. (Curds and Fey, 1969). ASP involves the production of an activated mass of microorganisms capable of aerobically stabilizing the waste. The effluent from a properly activated sludge plant in general is clear and sparkling, containing low amount of organic matter. The bacterial removal ranges from 90- 98% (Metcalf & Eddy, 2003).

3.1.5.1 Up-flow Anaerobic Sludge Blanket (UASB)

Among Several anaerobic bioreactors, UASB reactors are most widely and successfully used for several types of effluents (high strength industrial wastewater to low strength domestic wastewaters) especially in tropical climates. In the Up flow Anaerobic Sludge Blanket (UASB) process, the wastewater to be treated is introduced in the bottom of reactor. The wastewater flows upward through a layer of very active sludge to cause anaerobic digestion of organics of the wastewater. The gas produced under anaerobic condition cause internal circulation, which helps in the formation and maintenance of the biological granules (Metcalf and Eddy, 1995). At the top of the reactor, three-phase separation between Gas – Solid – Liquid takes place. Any biomass leaving the reaction zone is directly re-circulated from the settling zone. The process is suitable for soluble wastewaters as well as wastewaters containing particulate matter.

The UASB system has a number of advantages over aerobic treatment processes as follows:

i) The energy input of the system is low as no energy is required for oxygenation.
ii) Lower production of excess sludge per unit mass of organic matter stabilized.
iii) Lower nutrients requirements due to lower biological synthesis.
iv) The degradation of waste organic material leads to the production of Biogas, which is the valuable source of energy.

The success of UASB process lies in its capability to retain a high concentration of biologically active aggregated biomass in the form of granules or bio – pellets. This enhances the ability of UASB reactor to operate at high organic loading rates and maintain a high Solid Retention Time (SRT) at a Low Hydraulic Retention Time (HRT) (Metcalf & Eddy, 2003). The maximum COD and TSS Removal (%) at different temperatures reported by B. Lew et. al. (2004) is depicted in Table 3.14 and Table 3.15.

Table 3.14: Maximum COD Removal (%) at Different Temperatures (B.Lew.et.al.2004)

Temperature (°C)	28°C	20°C	14°C	10°C
Classical UASB COD removal (%)	82	72	70	48
Hybrid UASB + filter COD removal (%)	82	72	60	38

Table 3.15: Effluent TSS Concentration (mg/l) at Different Temperatures (B. Lew.et.al.2004)

Temperature (°C)	28°C	20°C	14°C	10°C
Classical UASB	17	25	60	120
Hybrid UASB + filter	17	25	80	150

The overall performance of the UASB system with respect to TSS, COD, COD filter, BOD, E. Coli. and Helminths eggs removal (reported by R. Keller et al, 2004) is depicted in Table 3.16.

Table 3.16: Performance of the UASB system (R. Keller et.al, 2004)

Waste water Characteristics	**Mean (standard deviation) mg/l**				**Geometric mean/100ml**	
	TSS	**COD**	**COD (filtered)**	**BOD**	**E.Coli (MPN/ 100ml)**	**Helminth (egg/l)**
Raw wastewater	168 (63)	499 (369)	194 (51)	187 (85)	$1.0x10^7$	19.5
Treated waste water	62 (18)	191 (45)	99 (26)	57 (31)	$2.0x10^6$	5
% of Removal efficiency (η)	63.0	61.7	48.9	69.5	80.0	74.3

The BOD and COD removal efficiency, for sewage, is taken as 75–85% and 74–78% respectively as process design parameters for UASB reactor (Soli J Arceivala, 2003). Removal efficiencies of 90 – 95% for COD have been achieved at COD loading ranging from 12 – 20 kg $COD/m^3.d$ on a variety of wastes at 30 to 35^0C with UASB reactor (Metcalf & Eddy, 2003). Removal efficiencies of 50-70% for COD have been achieved at COD loading ranging from 1-2 kg $COD/m^3.d$ on a variety of wastes at 30 to 35^0C with UASB reactor (Manual on Sewerage and Sewage Treatment, GOI, 1993).

3.2 Guidelines recommended by International Agencies

WHO recommended microbiological quality guidelines are provided in table 3.17, Table 3.18 consists of USEPA guidelines for effluent reuse and Table 3.19 consists of Reuse standards for domestic wastewater.

WHO guide lines for use of wastewater in agriculture take into account whether the use is for restricted or unrestricted crop irrigation and the primary consideration is spread of disease. The guidelines focus on limiting the number of viable fecal intestinal nematode eggs and coliform, application procedure and crop restrictions. The guideline value for fecal coliform is 1000 FC/100 ml which is likely to produce an annual risk of viral infection of less than 10^{-4}. The guideline value is achievable with disinfection of secondary treated sewage (well operator plant!). Lowering of the value further does not result in significant health related benefits and is also not cost effective. WHO guidelines (1989) propose a nematode egg guideline of less than one egg/L. Ingestion of less than 10 eggs is reported to have a high probability of causing infection.

Table 3.17: WHO recommended microbiological quality guidelines

Category	Reuse conditions	Exposed group	Intestinal nematodes (eggs/litre)	Fecal coliforms (cells/litre)	Treatment to achieve the microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks	Workers consumers, public	<1	<1000	Series of stablization ponds
B	Irrigation of cereal crops, industrial and fodder crops, pasture, trees	Workers	<1	Not standard	8-10 day retention in stabilization ponds
C	Localized irrigation of crops in category B if no human	None	Not applicable	Not applicable	At least primary sedimentation

Table 3.18: USEPA guidelines for effluent reuse

Type of reuse	Reclaimed quality
Urban reuse	pH 6-9, BOD <10 mg/l, Turbidity < 2 NTU; No fecal coliforms/100 ml; 1 mg/l residual chlorine.
Agricultural reuse	pH 6-9, BOD < 30 mg/l, SS <30 mg/l; Fecal coliforms <200/100 ml; residual chlorine.
Ground water recharge	pH 6.5-8.5, Turbidity <2 NTU; No fecal coliforms/100ml; 1 mg/l residual chlorine; other parameters as potable standards.

Table 3.19 Standards for Domestic Wastewater Reuse.

Sl. No.	Reuse purpose	WHO	USEPA	ICMSF
1	Agriculture/Irrigatrion	<1000 FC/100mL	10-1000 FC/100mLa 2.2-100 FC/100 mLb	-
2	Aquaculture	<1000 FC/100mL	<70FC/ 100mL	<500 E.C/100 mL
3	Ground water recharge	<50 FC/100mL	Site specific and user dependent.	-
4	Recreational purposes	-	<200 TC/100mL	-
5	Bathing	-	-	-
6	Domestic	<1 FC/100 mL	-	-

3.3 Public Health Effects Due to Microbial Pollutants in Wastewater

An overview on water borne diseases, their agents and possible effects on public health are given in following subsections :

3.3.1 Waterborne Diseases

"Any disease whose etiological agent is shed in the faeces, urine, or other excretions of active cases of the disease or by carriers, is washed into the aquatic environment from terrestrial niches wherein it multiplies or is part of the aquatic microflora because it multiplies therein is potentially transmitted by the water borne routes, by aerosols generated from the waters or by their application to land" (Pipes, 1978).

Waterborne diseases are those transmitted through the ingestion of contaminated water that serves as the passive carrier of the infectious agent. The classic waterborne diseases, cholera and typhoid fever, which frequently ravaged densely populated areas throughout human history, have been effectively controlled by the protection of water sources and by treatment of contaminated water supplies. In fact, the control of these classic diseases gave water supply treatment its reputation and played an important role in the reduction of infectious diseases.

Other diseases caused by Bacteria, Viruses, Protozoa, and Helminths may also be transmitted by contaminated drinking water. However, it is important to remember that waterborne diseases are transmitted by faecal-oral route, from human to human or animal to human, so that drinking water is only one of several possible sources of infection compare to other sources (Esrey, 1990; Pipes, 1978; and Rowe, 1995).

There is an assumed relationship about waterborne disease, which has been so longstanding that it has become conventional wisdom. The risk of waterborne disease to the user population is measured by the incidence of that disease in a population, which has been in contact with the contaminated water. However, there are several potentially waterborne diseases all of which can be transmitted by the routes other than water, and a relatively small fraction of the cases of these diseases is reported through the normal public health channels. Thus, the retrospective epidemiological study rarely provides information, which can be used to examine possible quantitative relationship. The ideal epidemiological study would be a prospective one in which the number of cases of a specific disease in a defined population having a particular water contact is measured and compared with the density of the etiological agent of that disease in the water (Pipes, 1978; and Rowe, 1995).

3.3.2 Water-Washed Diseases

Water washed diseases are those closely related to poor hygiene and improper sanitation. In this case, the availability of a sufficient quantity of water is generally considered more important than the quality of the water. The lack of water for washing and bathing contributes to disease that affect the eye and skin, including infectious conjunctivitis and trachoma, as well as to diarrheal illnesses, which are a major cause of infant mortality and morbidity in developing countries. Diarrheal diseases may be directly transmitted through person-to-person contact or indirectly through contact with contaminated foods and utensils used by persons whose hands are faecally contaminated. When enough water is available for hand washing, the incidence of diarrheal diseases has been shown to decrease, as has the prevalence of enteric pathogens such as S*higella spp* (Rowe, 1995).

3.3.3 Water Based Diseases

Water based diseases are caused by the pathogens that either spend all (or essential parts) of their lives in water or depend on aquatic organisms for the completion of their life cycles. Examples of such organisms are the parasitic helminth *Schistosoma spp* and the bacterium *Legionella spp*, which cause Schistosomiasis and Legionnaires, respectively (Rowe, 1995).

3.3.4 Water Related Diseases

Water related diseases such as yellow fever, dengue, filariasis, malaria, onchocerciasis, and sleeping sickness, are transmitted by insects that breed in water (e.g., mosquitoes that carry malarial parasite) or live near water (e.g., the flies that transmit the filarial infection onchocerciasis). Such insects are known as vectors.

Table 3.23 give the details about water borne, water washed, water based and water related diseases and its route of transmission into the human host with some examples.

Table 3.23 : Classification of infective diseases in relation to water supply

S. No.	Class	Cause	Example
1	Waterborne	Pathogens that originate in faecal material and are transmitted by ingestion.	Cholera, Typhoid fever
2	Water-washed	Organisms that originated in faeces are transmitted through contact because of inadequate sanitation or hygiene.	Trachoma
3	Water-based	Organisms that originated in the water or spend part of their life cycle in aquatic animals and come in direct contact with humans in water or by inhalation.	Schistosomiasis, Legionella
4	Water-related	Microorganisms with life cycles associated with insects that live or breed in water.	Yellow fever

Source: Rowe, 1995; Maier, 2002.

3.3.5 Water Borne Diseases and Outbreaks

A report by the Secretary-general of the United Nations Commission on Sustainable Development has concluded that there is no sustainability in current uses of fresh water by either developing or developed nations. The report states that worldwide water usage has been growing at more than 3 times the world's population increase. The report also concludes that water shortages, combined with increased pollution of water was causing widespread public health problems, limiting economic and agricultural development (thus jeopardizing global food supplies), and harming a wide range of ecosystems (Toze, 1997).

Polluted and/or untreated water have a large health risk by causing waterborne diseases. Despite large advance in water and wastewater treatment, waterborne diseases still pose a major worldwide threat to public health. It has been reported that waterborne pathogens infect around 250 million people each year resulting in 10-20 million deaths (Anon, 1996). Many of these infections occur in developing nations, which have lower levels of sanitation, problems associated with low socio-economic conditions, and less public health awareness than in more developed nations. However, it has been documented that the incidence of waterborne disease in the US has actually increased in the past 20 years (Craun, 1986; Payment and Hunter, 1996; and Toze, 1997).

3.3.6 Transmission Routes of Pathogen

Generally, wastewater contains many types of pathogens. When these are introduced into the environment some can remain infectious for long periods of time and under certain conditions, they will be able to replicate in the environment. Though the presence of pathogens presents a potential threat to human health, the actual risk of disease depends on the infectious dose of the pathogen that must reach a human host (Carr, 2001).

In general, pathogenic microorganisms may be transmitted from the source to a new victim in a number of ways including direct person-to-person spread and indirect routes including inanimate objects (fomites), food, and water or insect vector.

Disease transmission is determined by several pathogen related factors listed below (Feachem *et al*., 1983):

- An organism's ability to survive or multiply in the environment (some pathogens require the presence of specific intermediate hosts to complete their lifecycle).
- An organism's ability to infect the host (some pathogens can cause infections when present in small numbers others may require a million or more organisms to cause infections).
- Latent period (many pathogens are immediately infectious, others may require a period of time before they become infective).

Disease transmission is also affected by the host's characteristics and behaviour (Rowe, 1995):

- Age
- Sex
- Personal hygiene
- Food hygiene
- Health status
- Nutritional status
- Immunity

The pathogen host relationship and possible transmission route into the host cells are illustrated in Figure 2.5 (Rowe, 1995; Ashbolt, 2001).

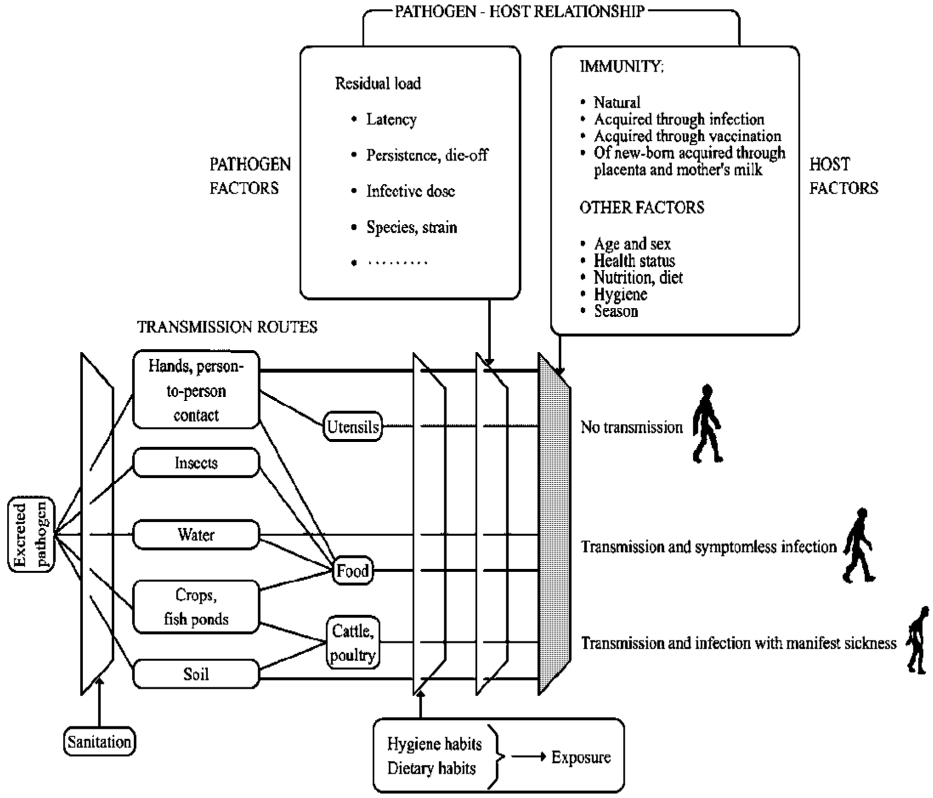


Figure 2.5. Transmission routes of pathogen (Rowe, 1995)

3.3.7 The microorganisms associated with waterborne diseases (typhoid fever, cholera, shigellosis, hepatitis, jaundice fever, diarrhea, amoebiasis etc) found in polluted waters are several members of bacteria, viruses, protozoa, and helminthes (Feachem et al, 1983) (Table 3.20).

Table 3.20: Infectious Agents Potentially Present in Raw Domestic Wastewater (Hurst et al, 2002),(Metcalf & Eddy, 2003)

Agent	**Disease**	**Clinical Symptoms**	**Incubation Period**	**Source**
Bacteria				
E.coli (entero-pathogenic)	Gastroenteritis	Diarrhea	2-6 days	Human feces
Salmonella typhi	Typhoid fever	High fever, diarrhea, ulceration of small intestine	7-28 days	Human feces and urine
Leptospira	Leptospirosis	Jaundice or fever	2-20 days	Urine from infected animals
Shigella	Shigellosis	Bacillary Dysentery	1-7 days	Human feces
Vibrio Cholerae	Cholera	Extremely heavy diarrhea, dehydration	9-72 hrs	Human feces

Viruses				
Enteroviruses	Polio, Gastroenteritis, Heart anomalies, Meningitis	Paralytic disease, respiratory illness.	3-14 days	Human feces
Hepatitis A	Infectious Hepatitis	Jaundice, Fever, Anorexia	15-50 days	Human feces
Rota virus	Acute Gastroenteritis	Gastroenteritis with nausea and vomiting	2-3 days	Human feces
Protozoa				
Entamoeba histolytica	Amoebiasis	Abdominal Pain with bloody diarrhea	2-4 weeks	Human feces
Giardia Lamblia	Giardiasis	Diarrhea, nausea, indigestion	5-25 days	Human and animal feces
Cryptosporidium parvum	Cryptosporidiosis	Diarrhea	1-2 weeks	Human and animal feces

However, pathogen has to be present in sufficient concentrations to initiate infection and to develop the diseases or the susceptible host has to come into

contact with pathogens at minimum critical dose i.e. infective dose (ID) level (Clark et al, 1996) (Tables 3.21 & 3.22). Generally enteric viruses and protozoa have low infectious dose in comparison to bacterial pathogens. Infection and development of clinical symptoms depend on a number of specific and non-specific host factors such as age, immunity status, gastric acidity, nutritional status, vitamin A deficiency, and possibly genetic predisposition (Hurst et al, 2002).

Table 3.21: Pathogens in Wastewater (Yates, 1998)

S. No.	**rganisms**	**Number/liter**
1	almonella	23-80000
2	Shigella	10-10000
3	E.Coli	Unknown
4	Vibrio	10-100000
5	Leptospira	Unknown
6	Polio Virus	182-492000
7	R Rota virus	400-85000
8	Hepatitis A	Unknown
9	Giardia Lamblia	530-100000
10	Entamoeba Histolytica	4
11	Cryptosporidium	5-5180

Table 3.22: Infectious Dose of Selected Pathogens (Noah Arre, 2003)

S. No	Organisms	Infectious Dose
1	Escherichia coli (enteropathogenic)	10^6- 10^{10}
2	Clostridium perfringens	1.0- 10^{10}
3	Salmonella typhi	10^4- 10^7
4	Vibrio cholerae	10^3- 10^7
5	Shigella flexneri 2A	180
6	Entamoeba histolytica	20
7	Shigella dysentariae 1	10
8	Giardia lamblia	10
9	Viruses	1.0- 10
10	Ascaris lumbricoides	1.0- 10

***Sources: EPA manual guidelines for wastewater**

Infectious dose represents the numbers of organisms necessary to initiate infection

(i) Clinical Features

A range of syndromes, including acute dehydrating diarrhea (cholera), prolonged febrile illness with abdominal symptoms (typhoid fever), acute bloody diarrhea (dysentery), and chronic diarrhea (Brainerd diarrhea).

(ii) Etiologic Agent

Common agents include *Vibrio cholerae*, *Campylobacter*, *Salmonella, Shigella,* and the diarrheogenic *Escherichia coli*.

(iii) Incidence

Each year, an estimated 4 billion episodes of diarrhea result in an estimated 2 million deaths, mostly among children. Waterborne bacterial infections may account for as many as half of these episodes and deaths.

(iv) Sequel

Many deaths among infants and young children are due to dehydration, malnutrition, or other complications of waterborne bacterial infections.

(v) Transmission

Contaminated surface water sources and large poorly functioning municipal water distribution systems contribute to transmission of waterborne bacterial diseases. Chlorination and safe water handling can eliminate the risk of waterborne bacterial diseases

(vi) Risk Groups

Over 2 billion persons living in poverty in the developing world are at high risk. Certain U.S. groups (residents of periurban "colonias" and remote rural areas with poor water treatment and delivery systems) are also at risk.

(vii) Surveillance

Sporadic cases are under-reported. CDC surveillance may detect a small proportion of outbreaks in the United States; outbreaks abroad are often missed.

(viii) Trends

Despite global efforts during the water and sanitation decade, improvements in water and sanitation infrastructure have barely kept pace with population increases and migrations in the developing world.

3.3.8 World Wide Human Infections and Deaths from Water Borne Diseases:

(i) Typhoid Fever

The disease is endemic in almost all part of the country with periodic outbreaks of water born or food born disease. In India in 1992, about 3,52,980 cases with 735 deaths were reported. In 1993 the number was 3,57,452 cases and 888 death, whereas in 1994, about 2,78,451 cases and 304 death due to typhoid fever reported.

(ii) Malaria

An overall 1.87 million cases of malaria and 1006 deaths were reported from the country in 2003.In 2004 reveals that the largest number of cases in the country were reported by Orissa, followed by Gujrat, Chattisgarh, West Bengal, Jarkhand, U.P., Rajestan and the largest number of death were reported by Orissa, followed by West Bengal, Mizoram, Assam, Meghalaya, Karnataka, and Tripura.

(iii) Hepatitis

Out break of hepatitis are more common, with around 60,000 cases reported in the United States each year. These outbreaks will occur due to poor water supply and sanitary facilities.

(iv) Amoebic Dysentery

Protozoan infection can be serious nonetheless, as illustrated by an epidemic in Chicago in 1933 in which over 1400 people were affected and 98 deaths resulted when drinking water was contaminated by sewage containing Entamoeba histolytica.

(v) Diarrhea Cases

Health services have been badly hit due to flooding of 235 health centers. Report of water born disease is being received from Govt. control room, NGOs and National UN Volunteer Doctor. As per the disease Surveillance cell report people from 178 blocks are affected. (Orissa flood, 2001)

Health Situation	Progressive Cases	Deaths
Diarrhea cases	52707	37
Suspected malarial	24686	12
Acute jaundice	84	2

(vi) Enteric Fever

An out breaks on Maharashtra, India, affected 415 individual, and all of them presented with enteric fever. This was attributed to fecal contamination of water. Poor sanitation facilities and waste disposal mechanism can therefore be seen as one of the main contributing factors of almost all water born disease (Kulkarni AP et al , 1996).

(vii) Gastroenteritis

An outbreak that took place in Central Norway 1994 and 1995. The epidemics were associated with contamination of drinking water by stools from pinkfooted geese. Camphylobacter jejuni was isolated in untreated water.and 50%(n=1000) of the individual were examined were diseased. It can therefore be said that the interaction of man and domestic animals or birds poses a serious threat towards the health of human (Virslot 1996).

(viii) Hepatitis Outbreak In Islamabad

An outbreak of Hepatitis E virus in Islamabad, Pakistan in 1993-94 affected 36,705 individual. The break down in water treatment was associated with these outbreaks. The attack rate was the highest in the age group 11-30 yrs and the attack rate among pregnant women was even higher i.e. 21.6%. A study conducted on the illness associated with water born disease showed that the following are common symptoms; diarrhea (75%), abdominal cramps (80%), appetite loss (69%), nausea (68%), and the mean duration of these diseases were 7.4 days (Forgarty J., 1995).

(ix) Cholera

Major outbreaks of cholera have been takes place in South Africa, Malawi, Zimbabwe, Switzerland and Mozambique recently. These outbreaks were attributed to lack of safe drinking water and adequate sanitation. By the end of June 2001,South Africa had 1,03,425 cases, 212 deaths and the case fatality rate of 0.02%. This was reported as a break through in the history of cholera outbreak, because other country has the case fatality rates of more than 20% to 50% (Health System Research & Epidemiology , South Africa, 2001).

(x) Outbreaks in Kenya

In Nakuru District, Kenya (2001), the total of 28128 records was reviewed and 1568 cases was identified as having water born disease (typhoid fever, gastroenteritis, amoebiases, and dysentery). The overall prevalence rate of water born disease was 56/1000 population for the two facilities and 39/1000-population and 17/1000 population in the hospital and health center respectively. Outbreaks were observed to be seasonal, and most of these occurred in March and May each year.

3.3.9 Deaths from Water Borne Diseases Each Year (WHO 1992)

Disease	**No. of Infected Person**	**No. of Deaths**
Diarrhoea	2 billion	4 million
Amoebiasis	500 million	NA
Typhoid	1 million	25,000
Cholera	21000	10,000

3.3.10 Water and Health

Waterborne diseases constitute one of the major public health hazards in developing countries. Worldwide, in 1995, contaminated water and food caused more than 3 millions deaths, of which more than 80% were among children under, age five. Besides the conventional pathogens which are transmitted by water, several emerging waterborne pathogens have become increasingly important during the last decade or so. These include Vibrio cholerae, Cryptosporadium parvum, shiga toxin producing E.coli especially enterohaemorrhagic E.coli (EHEC), Yersinia enterocolitica, Camphylobacter jejuni, Calciviruses and Microsporadia. In India, more than 70% of the epidemic emergencies are either water-borne or are water-related.

No country is immune. Even in Organisation for Economic Co-operation and Development (OECD) countries, the number of outbreaks reported in the last decade demonstrates that transmission of pathogens by drinking water remains a significant problem and that, despite substantial advances in recent years, access to safe drinking water is still a major public health challenge.

The typical characteristic of disease caused by pathogens in drinking water is the occurrence of acute symptoms due to replication of the pathogen in the host. In contrast, consumption of chemically contaminated drinking water typically leads to chronic diseases. A few of the recent incidents related to microbial contamination of drinking water are listed in Table 3.24.

Table 3.24 : Incidents due to Drinking Water Contamination by Microbes

Sl. No	Year	Place	Cause	Number of person ill (dead)
1	2001	Pamplona, SPAIN	Legionella-infection in hospital	18 (3)
2	2001	Paris, FRANCE	Legionella-infection in hospital	12 (6)
3	2001	Murcia, SPAIN	Legionella-infection in village	315 (2)
4	2000	Walkerton, CANADA	Heavy downpour washes pathogenic enterohemoragic E.col*i* (EHEC) from liquid cow manure into drinking water supply.	2,000
5	1998	La Neuveville, CHINA	Defective pump causes back-up of wastewater and overflow into ground water; pathogens: Shigella sonnie, Campylobacter jejuni.	1,600
6	1998	All of Switzerland	Legionella-infection	78 (8)
7	1993	Milwaukee, USA	Defective filters in drinking water processing plant cause spread of highly chlorine resistant Oocysts of C*ryptosporadium parvum*.	403,000
8	1979/80	Ismaning, DENMARK	Contamination of a drinking water source by defective sewer line causes spread of bacterial dysentery (*Shigella spp* and others)	2,450
9	1963	Zermatt, CHINA	Discharge or untreated waste water into Zmuttbach, a stream used as drinking water source, and simultaneous malfunction of chlorinating plant in Zermattld to the spread of Salmonella typhii.	437

Source: Koster, 2001

Table 3.25 (adapted from WHO (1999)) illustrates the number of waterborne outbreaks in Europe following a survey conducted in 1997. Of the 52 European countries asked for information on waterborne disease outbreaks, 26 returned information and 19 provided information specifically on outbreaks.

Table 3.25: Reported Waterborne Disease Outbreaks Associated with Drinking and Recreational Water in 19 European Countries, 1986 – 96

Country	Agent or disease (no. of outbreaks)	Total no. of outbreaks	No. of cases (with details)
Albania	Amoebic dysentery (5), typhoid fever (5), cholera (4)	14	59 (3)
Croatia	Bacterial dysentery (14), gastroenteritis (6), hepatitis A (4), typhoid (4), cryptosporidiosis (1)	29[1]	1931 (31[1])
Czech Republic	Gastroenteritis (15), bacterial dysentery (2), hepatitis A (1)	18[2]	76 (3)
England & Wales	Cryptosporidiosis (13), gastroenteritis (6), giardiasis (1)	20	2810 (14)
Estonia	Bacterial dysentery (7), hepatitis A (5)	12	1,010 (12)
Germany	No outbreaks reported	0	0
Greece	Bacterial dysentery (1), typhoid (1)	2	16 (1)
Hungary	Bacterial dysentery (17, gastroenteritis (6), salmonellosis (4)	27[3]	4884 (27)
Iceland	Bacterial dysentery (1)	1	10 (1)
Latvia	Hepatitis A (1)	1	863 (1)
Lithuania	No outbreaks reported	0[4]	0
Malta	Gastroenteritis (152), bacterial dysentery (4), hepatitis A (4), giardiasis (1), typhoid (1)	162	19 (6)
Norway	No outbreaks reported	0	0
Romania	Bacterial dysentery (36), gastroenteritis (8), hepatitis A (8), cholera (3), typhoid (1), methaemoglobinaemia (1)	57	745 (1)
Slovak Republic	Bacterial dysentery (30), gastroenteritis (21), hepatitis A (8), typhoid (2)	61	5173 (61)
Slovenia	Gastroenteritis (33), bacterial dysentery (8), hepatitis A (2), amoebic dysentery (1), giardiasis (1)	45	Not available
Spain	Gastroenteritis (97), bacterial dysentery (47), hepatitis A (28), typhoid (27), giardiasis (7), cryptosporidiosis (1), unspecified (1)	208	Not available
Sweden	Gastroenteritis (36), campylobacteriosis (8), Norwalk like virus (4), giardiasis (4), cryptosporidiosis (1), amoebic dysentery (1), *Aeromonas* sp. (1)	53[5]	27,074 (47)

Source : WHO 1999

1 Discrepancies in data were noted in different sections of the questionnaire
2 One year of reporting only
3 Outbreaks associated with drinking water (n = 12) and recreational water (n= 15)
4 Ten years of reporting only
5 In one outbreak *Campylobacter* sp., *Cryptosporidium* sp. and *Giardia lamblia* were identified as aetiologic agents (all three are listed in the relevant column)

Table 3.26: WHO Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture

Category	Reuse condition	Exposed group	Intestinal nematode[b] (arithmetic mean no. per 100 ml)[c]	Faecal coliforms (geometric mean no. per 100 ml)[c]	Wastewater treatment*
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks [d]	Workers, consumers, public	≤ 1	≤ 1000	As series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees [e]	Workers	≤ 1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and fecal coliform removal
C	Localized irrigation of crops in category B if exposure to workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by irrigation technology, but not less than primary sedimentation.

The guidelines modified accordingly.

* Wastewater treatment expected to achieve the required microbiological guidelines

a Ascaris and Trichuris species and hookworms.
b During the irrigation period.

c A more stringent guideline (≤ 200 faecal coliforms / 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.

d In the case of fruit trees, irrigation should ceases two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should be used.

Shuval *et al.* (1986) reviewed all the available epidemiological evidence on the health effects of agricultural use of wastewater. Their main conclusions were reported in the technical report of the WHO Guidelines (1989). They are summarized and added as an Appendix 2.3, with some supporting details.

3.4 Summary of Literature Review

Reuse of wastewater has vast potential to reduce the pressures on the world's freshwater resources. Infection by pathogenic microorganisms is a major risk associated with reuse. The type and number of microbial pathogens and their infection potential vary with the socioeconomic and sanitation conditions of the community generating the wastewater. There are a range of options available for the treatment and reuse of wastewater, the choice of which depends on type of pathogens present, their resistance to treatment and environmental attenuation processes, the intended use for the wastewater and the potential for contact with workers and general public. In this context, the review examined the current knowledge relating to the microbial quality of water bodies and their impacts, methodologies relating to the detection and enumeration of the microbial pathogens in wastewaters and the efficacy of treatment technologies for removal of pathogens. The following conclusions can be made from the review of literature.

1 There are wide ranges of microbial pathogens (viruses, bacteria, Fungi, protozoa, helminth ova etc.) present in urban wastewaters and there is a need to monitor

receiving bodies to control unforeseen incidences of diseases. A majority of these pathogens are of faecal origin, contaminate the environment and then gain access to new hosts through ingestion.

2 Though the sensitivity and accuracy in the detection of pathogenic and indicator organisms is improving through the development of new methods, the detection, isolation and identification of different microbial pathogens in receiving bodies on regular basis would be difficult, time consuming and expensive.

3 As most of the microbial pathogens present in wastewaters are of faecal origin, the detection of indicator organisms of faecal origin like Total Coliforms, Faecal Coliforms, Faecal Streptococci etc., and their enumeration by MPN tests continue to be the most commonly monitored parameters. While a number of potential replacements (e.g. bacteriophage, bifidobacteria, bacteriodes etc.) for Faecal Coliforms have been studied for their possible use, none have been found to be completely suitable. Faecal Coliforms still remain the major organisms used to indicate faecal pollution and the performance of treatment processes.

4 Viruses are more resistant to waste treatment and environmental conditions. There is no effective and economic method for the easy detection and enumeration of viruses in the environment. It is difficult to detect due to problem encountered during their culture, including high costs.. Thus it has no potential to be considered as a criterion for monitoring of receiving bodies in developing countries, at least in the nearest future.

5 The World Health Organisation lists intestinal nematodes as the greatest health risk involving agricultural/ aquacultural uses of wastewater, partly due to the resistance of the eggs to environmental factors and partly because the ingestion of less than 10 eggs has been shown to have a high probability of causing infection (WHO, 1989).

6 Approved methods and media for the isolation of the common bacterial pathogens and indicator bacteria from wastewater are well established.

7 Wastewater is a valuable resource. Major uses of recycled wastewater include agricultural/horticultural irrigation, aquaculture, wetlands, domestic uses like toilet flushing and bathing and industrial cooling. Wherever planned recycling is not practiced, indirect recycling takes place through the use of surface and ground water for various needs of the community. A properly developed framework policy and standard is essential for safe and efficient management of wastewater as a resource.

8 Waste Stabilization Ponds (WSP) are particularly more efficient in removing excreted pathogens compared to all other treatment processes which require a tertiary treatment process, such as chlorination (with all its inherent operational and environmental problems) or ozonation or ultra-violet treatment to achieve the destruction of faecal bacteria. The algae in the WSPs are responsible for introducing conditions that kill faecal bacteria long detention time. pH >9 and the combination of a high dissolved oxygen concentration and a high visible light intensity are rapidly fatal to Faecal Coliforms.

9 There is a need for a detailed investigation on the occurrence, movement and behaviour of the microbial pathogens in surface water, soil and groundwater as well as their resistance to various forms of treatment under tropical conditions.

10 There are several alternative approaches to the setting of microbiological guidelines for wastewater reuse, which have different outcomes as their objective (a) no potential risk (b) no measurable excess cases of infection, and (c) a model-generated estimated risk below a defined acceptable risk

11 While making policy, it is important to consider all available health protection measures, not just wastewater treatment, and so create a realistic wastewater reuse policy that ensures that those in contact with wastewater are genuinely protected. Crop restriction, irrigation technique, human exposure control etc. should also be considered as health protection measures to be used in conjunction with wastewater treatment.

12 The development of microbial quality standards for urban wastewater should involve an in depth examination of occurrence in the environment, human exposure potential, adverse health effects, risk to the population, methods of detection, treatment technologies and costs. The literature review supports a strong need for developing standards for biological quality of urban wastewater meant for reuse rather than that for mere disposal. The indicators that may be considered for setting such biological standards may include Total Coliforms, Faecal Coliforms, *E.Coli*, Faecal Streptococci and Helminthes Eggs.

CHAPTER 4

FINDINGS

4.0 The major findings of the studies on evaluation of the performance of a few sewage treatment plants in the country in respect of removal of organics, suspended mater and enteric microbes are summarized below. Different types of treatment processes were covered in the evaluation. Summary of results of the study is provided in section 4.1 of this chapter, post treatment effects are provided in section 4.2 and section 4.3 discusses the results of the study in detail for each STP individually.

4.1 Summary of Results:

Table 4.1: Summary of Results of Anna University
(Figures in parameters are arithmetic average)

Treatment plant	Total Coliform MPN/100 mL Influent X 10^6	Total Coliform MPN/100 mL Effluent X 10^4	Percent Reduction	Fecal Coliform MPN/100 mL Influent X 10^6	Fecal Coliform MPN/100 mL Effluent X 10^4	Percent Reduction
AABF	5 – 500	5 - 380	99.0-99.2	2.90 - 500	3.7 – 190	98.7-99.6
ASP	6.8 - 5,000	50 - 6,800	92.6-98.6	5 - 3,700	37 - 3,800	92.6-98.9
Tertiary Treated	0.68 – 98	<2 (all but one day)	97.1-99..9	1.1 - 68	<2 (all but one day)	98.2-99.9
OP	3.8 – 680	0.05 - 900	99.9-98.7	0.7 - 98	0.038 – 500	99.9-94.9
TF	6.8 –500	2 - 3,000	99.7-94	3.8 - 370	2 - 1,100	99.5-97.0

Table: 4.2: Annual performance of the five sewage treatment plants for Physico-chemical characteristics

Characteristics		DEWATs		Nesapakkam		CPCL		Pondicherry		V. Valley	
		Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
TSS (mg/L)	Min	288	17	450	33	67	2	93	19	168	31
	Max	1037	358	1482	534	328	164	730	286	764	299
	Avg	594	189	1059	234	206	23	397	154	383	106
	SD	233	123	318	169	85	42	229	86	223	96
COD-T (mg/L)	Min	272	53	519	56	104	3	235	98	277	69
	Max	1120	207	1656	288	421	160	800	240	560	181
	Avg	637	118	1232	128	230	57	497	171	429	115
	SD	256	57	275	59	88	46	177	54	92	44
COD-S (mg/L)	Min	128	24	149	37	66	0	64	32	75	37
	Max	352	133	635	203	261	107	480	208	240	117
	Avg	233	65	397	102	139	34	210	99	159	65
	SD	75	37	132	49	67	31	127	52	62	29
BOD-T (mg/L)	Min	206	19	236	15	36	0.8	77	36	74	31
	Max	749	138	671	90	174	65	356	123	320	75
	Avg	343	59	520	53	93	14	212	55	181	43
	SD	174	36	108	26	47	17	116	33	61	15
BOD-S (mg/L)	Min	80	14	98	5	18	0.4	37	15	35	15
	Max	344	70	379	73	88	37	217	45	185	57
	Avg	201	30	238	33	46	8	102	29	95	29
	SD	78	18	75	21	22	10	59	9	50	13

Table: 4.3. Annual performance of the five sewage treatment plants for microbiological characteristics

Characteristics		DEWATs		Nesapakkam		CPCL		Pondicherry		V. Valley	
		Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
Total Coliforms	Min	500	5	680	50	68	0.0002	380	0.78	680	38
	Max	5000	380	500000	6800	9800	0.37	68000	3000	190000	5000
	Avg	5926	43	32152	1325	893	0.15	12492	565	21235	712
	SD	11125	65	77099	1691	1559	0.58	150501	587	38918	1183
Faecal Coliforms	Min	380	3.7	500	37	50	0.0002	380	0.78	500	19
	Max	5000	190	370000	5000	6800	0.98	38000	1100	68000	3800
	Avg	4555	28	22672	823	633	0.078	8506	371	9611	427
	SD	9887	38	57296	1034	1054	0.23	9787	321	14636	775
E.Coli	Min	190	0.68	98	18	38	0.0002	190	0.5	380	19
	Max	3800	98	180000	3800	3700	0.68	37000	980	38000	1900
	Avg	2569	15	12730	459	366	0.056	5387	243	4958	225
	SD	6301	21	29621	644	631	0.17	6540	237	7802	395
Faecal Streptococci	Min	13	0.29	68	5	1.3	0.0002	13	0.5	78	1.1
	Max	1300	3.8	5000	180	680	0.19	980	68	980	50
	Avg	2691	1.2	1373	51	95	0.016	393	10	317	10
	SD	393	1.2	1593	47	185	0.048	326	18	305	17

Note: All values X 10^4MPN/100 mL

Table 4.4 : Summary of Results of IIT, Roorkee

(Figures in parameters are arithmetic average)

Treatment plant	Total Coliform MPN/100 mL Influent X 10^6	Total Coliform MPN/100 mL Effluent X 10^4	Percent Reduction	Fecal Coliform MPN/100 mL Influent X 10^6	Fecal Coliform MPN/100 mL Effluent X 10^4	Percent Reduction
UASB	2.3 – 23	1.9 - 23	99.2-99	0.23 - 15	0.023 – 23	99.9-98.5
UASB	1.6 - 43	1.1 - 23	99.3-99.5	0.39 - 23	0.11 – 4.3	99.7-99.8
OP	4.3 –930	1.5-430	99.7-99.5	0.023 - 230	0.15-210	99.3-99.1
ASP	1.5 – 4.3	9.3 - 930	93.8	0.21 – 1.5	0.15 – 930	99.3
Anaerobic Filter	28	450	83.9	6.8	130	80.9

Table 4.5: Sewage Treatment Plants in Delhi

Sl.No	Name of the STP's & Capacity (mgd)	Design capacity (MLD)	Actual flow (MLD)	Type of STP	Present Status
1	Coronation Pillar STP's 1) (10) 2) (10 + 20)	 45.46 45.46 90.92	 40.87 63.46 56.55	Activated sludge process (ASP), trickling filter & ASP	Under utilised Over the Des. Cap. Under Utilized
2.	Delhi Gate (2.2)	10.00	10.00	High rate bio-filters Densadeg technology	Running on designed capacity
3.	Ghitorni (5)	22.73	Nil	Activated sludge process	Not in operation
4.	Keshopur STPs 1) (12) 1) (20) 2) (40)	 54.55 90.92 181.84	 46.55 95.10 106.46	All the three plants designed on activated sludge process	i)12 mgd not running, sewage passes through PST. ii) Over the Des. Cap. iii) Under- utilized
5.	Kondli STP's 1) (10-Phase-I) 2) (25 -Phase-II) 3) (10-Phase-III)	 45.46 113.65 45.46	 56.55 57.96 28.36	All three activated sludge process	Over the capacity Under- utilized Under- utilized
6.	Mehrauli STP (5)	22.73	4.95	Extended aeration	Under-utilized
7.	Najafgarh STP (5)	22.73	2.27	Activated sludge proc.	Under- utilized
8.	Nilothi STP (40)	181.84	15.0	Activated sludge process	Under- utilized
9.	Narela STP (10)	45.46	2.50	Activated sludge process	Under- utilized
10.	Okhla STP's 1) (12) 2) (16) 3) (30) (37) (45)	 54.55 72.73 136.38 168.20 204.57	 39.09 40.91 136.98 159.11 181.84	All the plants designed on activated sludge process	Under- utilized Under- utilized Running in cap. Under-utilized Under-utilized
11.	Papankalan STP (20)	90.92	37.73	Activated sludge process	Under-utilized
12	Rithala STP's 1) (40) Old 2) (40) New	 181.84 181.84	 46.28 185.07	Activated sludge process & High rate aerobic ASP & biofor/biofilter	Under-utilized Over the des. cap.
13.	Rohini STP (15)	68.19	Nil	Activated sludge process	Not in operation
14.	Sen N.H. STP (2.2)	10.0	10.0	High rate Bio filter	Running on designed capacity.
15.	Timarpur O.P. (6)	27.27	4.79	Oxidation ponds	Under-utilized
16.	Yamuna Vihar STP's 1) Ph-I(10) 2) Ph-II(10)	 45.46 45.46	 27.27 14.77	Activated sludge process	Under-utilized Under-utilized
17.	Vasant Kunj STP's 1) (2.2) 2) (3.0)	 10.00 13.63	 3.18 4.36	ASP & Extended aeration	Under-utilized Under-utilized
Total	**30**	**2330**	**1478**		

Table 4.6: Performance Evalution of Sewage Tretment Plants in Delhi

Sl. No.	Name of STP & Capacity (mgd)	Design Capacity, M LD	Actual flow, MLD	Performance Evaluation of STP' (24 Hour composite Monitoring for every three hourly samples)										% reduction		
				Influent Quality					Effluent Quality							
				pH	TSS	COD	BOD	Cond.	pH	TSS	COD	BOD	Cond.	TSS	COD	BOD
1	Cor. Pillar(10)	45.46	40.87	7.2	179	317	112	908	7.4	35	61	18	1090	80.45	80.76	83.93
	(20+10)	136.38	120.01	6.44	342	172	48	1700	6.9	93	48	15	1730	72.81	72.09	68.75
2	Keshopur(12*)	54.55	46.55	-	-	-	-	-	-	-	-	-	-	-	-	-
	(20)	90.92	95.1	7.3	404	560	282	1390	7.6	78	149	45	1390	80.69	73.39	84.04
	(40)	181.84	106.46	7.3	404	560	282	1390	7.8	21	55	10	1520	94.80	90.18	96.45
3	Okhla(12)	54.55	39.09	7.3	498	517	204	1440	7.8	21	54	10	1460	95.78	89.56	95.10
	(16)	72.73	40.91	7.4	291	486	207	1510	7.7	83	108	48	1400	71.48	77.78	76.81
	(30)	136.38	136.98	7.4	647	551	222	1480	7.6	76	153	45	1470	88.25	72.23	79.73
	(37)	168.2	159.11	7.3	480	515	249	1590	7.8	32	62	12	1540	93.33	87.96	95.18
	(45)	204.57	181.84	7.3	480	515	249	1590	7.7	27	51	19	1530	94.38	90.10	92.37
4	Narela (10)	45.46	2.5	7.4	426	447	100	1720	8	38	72	8	1720	91.08	83.89	92.00
5	Y. Vihar (Ph.-I 10,	45.46	27.27	7.1	391	505	174	1110	7.7	44	84	17	1050	88.75	83.37	90.23
	Ph.-II 10)	45.46	14.77	7.2	405	538	199	1020	7.5	39	44	20	1070	90.37	91.82	89.95
6	Timarpur O.P -(6)	27.27	4.79	6.7	412	272	106	1650	7.3	11	26	4	1650	97.33	90.44	96.23
7	Najafgarh (5)	22.73	2.27	7.4	165	205	54	810	7.7	29	38	1	687	82.42	81.46	98.15
8	Nilothi (40)	181.84	15	7.7	432	328	90	2340	7.8	21	26	4	1960	95.14	92.07	95.56
9	Dr. SenN.H.(2.2)	10	10	7.5	370	585	236	1680	7.4	36	46	16	1660	90.27	92.14	93.22
10	Delhi Gate (2.2)	10	10	7.5	263	605	147	1020	7.3	26	62	20	1030	90.11	89.75	86.39
11	Papankalan (20)	90.92	37.73	7.6	142	275	103	2190	7.9	39	46	10	1580	72.54	83.27	90.29
12	Kondli Ph.-I (10)	45.46	56.55	7.3	363	507	241	1390	7.8	68	140	27	1390	81.27	72.39	88.80
	Ph.-II (25)	113.65	57.96	7.3	604	588	261	1550	7.6	45	50	34	1350	92.55	91.50	86.97
	Ph.-III (10)	45.46	28.36	7.3	519	615	237	1530	7.8	16	50	14	1220	96.92	91.87	94.09
13	Mehrauli(5)	22.73	4.95	7.8	251	326	126	1090	8.1	12	35	7	1180	95.22	89.26	94.44
14	Rithala {(40 Old)	181.84	46.28	7.2	330	399	205	1260	7.5	75	54	14	1240	77.27	86.47	93.17
	(40 New)}	181.84	185.07	7.2	330	399	205	1260	7.3	47	151	55	1230	85.76	62.16	73.17
15	Vasant Kunj (2.2)	10	3.18	7.5	379	460	323	1710	7.8	23	43	7	1450	93.93	90.65	97.83
	(3)	13.63	4.36	7.4	479	565	306	1400	7.9	49	80	20	1470	89.77	85.84	93.46
16	Rohini (15)	68.19	Nil	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Ghitorni (5)	22.73	Nil	-	-	-	-	-	-	-	-	-	-	-	-	-
Total		**2330**	**1478**													

- Keshopur 12 mgd STP is not running fully, it is observed that the sewage passes through Primary Settling Tank. All values are in mg/l except pH and conductivity (µ mhos/cm)

Table 4.7 : Performance of Bacteriological reduction through Sewage Treatment Plants in Delhi

Sl. No.	Name of the STP & capacity (mgd)	Performance evaluation of Sewage Treatment Plants in Delhi				% Reduction	
		Influent Bacteriological Quality		Effluent Bacteriological Quality			
		Total Coliform (Nos/100ml)	Faecal Coliform (Nos/100ml)	Total Coliform (Nos/100ml)	Faecal Coliform (Nos/100ml)	Total Coliform	Faecal Coliform
1.	Najafgarh (5)	10900000	5100000	320000	120000	**97.06**	**97.65**
2.	Papankala (20)	13100000	10300000	120000	70000	**99.08**	**99.32**
3.	Delhi gate (2.2)	26000000	19000000	1700000	1100000	**93.46**	**94.21**
4.	Dr. Sen N. H. (2.2)	133000000	102000000	240000	21700	**99.82**	**99.98**
5.	Nilothi (40)	61000000	50000000	120000	70000	**99.80**	**99.86**
6.	Cor. Pillar (10)	39000000	32000000	200000	110000	**99.49**	**99.66**
7.	Cor. Pillar (30)	78000000	44000000	700000	200000	**99.10**	**99.55**

(Table 4.7 continued…)

Sl. No.	Name of the STP & capacity (mgd)	Performance evaluation of Sewage Treatment Plants in Delhi				% Reduction	
		Influent Bacteriological Quality		Effluent Bacteriological Quality			
		Total Coliform (Nos/100ml)	Faecal Coliform (Nos/100ml)	Total Coliform (Nos/100ml)	Faecal Coliform (Nos/100ml)	Total Coliform	Faecal Coliform
8.	Narela (5)	17000000	10000000	110000	40000	**99.35**	**99.60**
9.	Vasant Kunj (3)	6900000	3900000	178000	101000	**97.42**	**97.41**
10.	Vasant Kunj (2.2)	71000000	46000000	17000	8000	**99.98**	**99.98**
11.	Okhla (12)	370000000	65000000	2900000	230000	**99.22**	**99.65**
12.	Okhla (16)	51000000	27000000	990000	530000	**98.06**	**98.04**
13.	Okhla (30)	204000000	107000000	115000000	25000000	**43.63**	**76.64**
14.	Okhla (37)	197000000	111000000	1280000	710000	**99.35**	**99.36**
15.	Okhla (45)	197000000	111000000	4100000	600000	**97.92**	**99.46**
16.	Y. Vihar (Ph.-I 10)	1210000000	410000000	19400000	4600000	**98.40**	**98.88**
17.	Y. Vihar (Ph.-II 10)	1570000000	370000000	8500000	5200000	**99.46**	**98.59**
18.	Keshopur (20)	430000000	135000000	91000000	7200000	**78.84**	**94.67**
19.	Keshopur (40)	430000000	135000000	11500000	5100000	**97.33**	**96.22**
20.	Kondli (Ph.-I 10)	670000000	320000000	24000000	13900000	**96.42**	**95.66**
21.	Kondli (Ph.-II 25)	910000000	480000000	5500000	1800000	**99.40**	**99.63**
22.	Kondli (Ph.-III 10)	570000000	370000000	2700000	140000	**99.53**	**99.96**
23.	Rithala (40 Old)	1080000000	710000000	32000000	4600000	**97.04**	**99.35**
24.	Rithala (40 New)	1080000000	710000000	49000000	5900000	**95.46**	**99.17**
25.	Mehrauli (5)	290000000	210000000	490000	20000	**99.83**	**99.99**
26.	Dr. Sen N.H (2.2) (After Bio-filter)	133000000	102000000	179000	13500	**99.87**	**99.99**
27.	Dr. Sen N.H (2.2) (After U.V. reatment)	133000000	102000000	27000	11200	**99.80**	**99.99**

Fig 4.1 : Wastewater generation and treatment status in Delhi

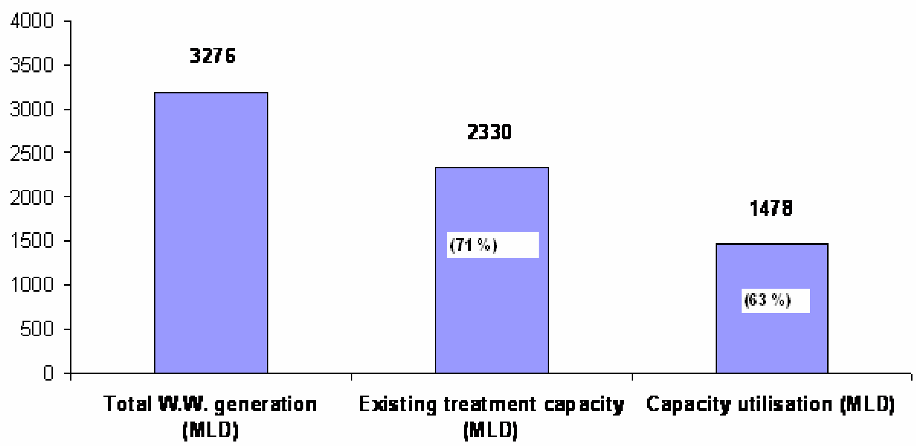


Fig. 4.2 Percent Reduction in Total Coliform

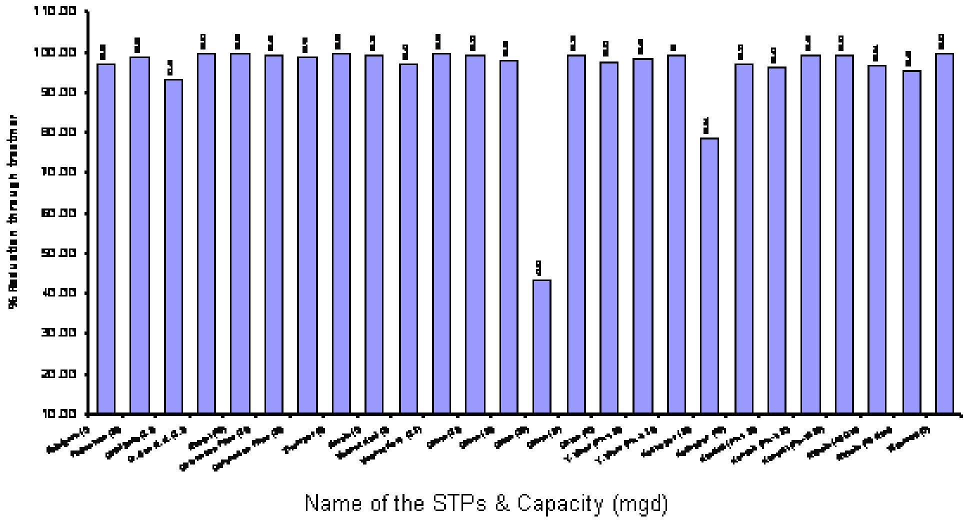
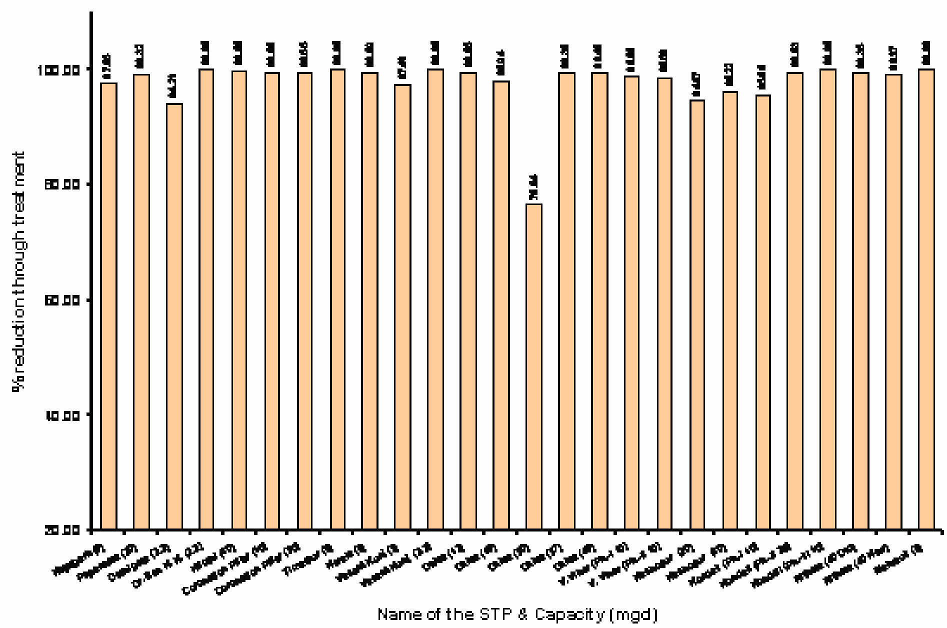


Fig 4.3 Percent Reduction in Fecal Coliform



4.2. Post Treatment

4.2.1. Post Treatment of UASB Reactor Effluent by Coagulation Followed by Chlorination

The observations revealed that the treatment of wastewater by UASB alone cannot sufficiently meet the effluent discharge standards. As per Indian standards, to discharge effluents into rivers or streams SS, BOD, COD, Total Coliform and Fecal Coliform should be less than 100mg/l, 30mg/L, 250mg/L, 10000MPN/100ml and 2500MPN/100ml respectively. However, the UASB effluent cannot bring out the quality up to the standards and therefore cannot be used for restricted irrigation without proper post-treatment.

Coagulation and flocculation of organic matter and microorganisms is of practical importance in wastewater treatment and chemical coagulation of biologically treated wastewaters is most often used as the initial step in water renovation systems (Gao *et al.*, 2002). Therefore, the coagulation-flocculation was provided as post-treatment for the effluent of an UASB reactor treating domestic wastewater. This study makes use of four coagulants i.e. alum, ferric chloride, ferric sulphate and polyaluminium chloride. To remove pathogens, chlorination was also applied after coagulation-flocculation process.

The physico-chemical and microbiological characteristics of the UASB reactor effluent observed are summarized in Table 4.8

Table 4.8 Characteristics of the UASB reactor effluent

Parameter	**Values**
PH	7.1-7.6
Turbidity (NTU)	35-55
Alkalinity (mg/L)	373-450
TSS (mg/L)	65-110
COD (mg/L)	109.48-256
BOD (mg/L)	38-55
Total Coliform (MPN/100ml)	$2.3x10^5$-$2.3x10^7$
Fecal Coliform (MPN/100ml)	$4.3x10^4$-$9.3x10^6$
Fecal Streptococci (MPN/100ml)	$2.3x10^4$-$4.3x10^5$

Different set of experiments consists of laboratory jar-test assays to choose the adequate coagulant dosage were used. The following dosages for different coagulant were tested as depicted in Table 4.9

Table 4.9 Different Coagulant dosage used for Jar test

Coagulant	**Dosage (mg/L)**	**Dosage as Al/Fe (mg/L)**
Alum	25-125 (as Al_2O_3)	6.7 to 33.4 mg/L (as Al)
PAC	45-120 (as Al_2O_3)	12.0 to 32.0mg/L (as Al)
Ferric Chloride	20-120 (as $FeCl_3$)	6.6 to 39.6 mg/L (as Fe)
Ferric Sulphate	20-120 (as $Fe_2(SO_4)_3$)	2.9 to 17.6 mg/L (as Fe)

The jar-test assay was performed with one-liter standard flasks by establishing the following operating conditions:

- Coagulation Speed : 100 rpm; Coagulation time: 2 minutes
- Flocculation speed : 20 rpm; Flocculation time: 20 minutes
- Settling time : 30 minutes

After the designated settling period, 200 ml of supernatant was withdrawn with a syringe from about 10 mm below the free surface. Physico-chemical and microbiological parameters were analyzed for treated and untreated wastewater as per described in Standard Methods (APHA, 1998).

4.2.2 Determination of the optimal coagulant dose and Turbidity removal

A wide range of coagulants and disinfectants can be used for water and wastewater treatment. The most common coagulants used include ferric sulphate, aluminum sulphate, and ferric chloride, and the disinfectants used are chlorine, sodium hypochlorite, and chlorine dioxide. An efficient water treatment chemical reagent should ideally be able to disinfect microorganisms, partially degrade and oxidize the organic and inorganic contaminants, and remove colloidal/ suspended particulate materials and heavy metals (Jiang *et al.*, 2006).

The effectiveness of coagulation was calculated by measuring the residual turbidity. The comparative performance of the four coagulants w.r.t turbidity removal at different doses has been shown in Fig 4.4. Alum and PAC can remove more than 95% of turbidity. The effluent turbidity with **Alum** and **Polyaluminium Chloride (as Al)** was observed <1 NTU at optimum doses of **20 mg/L (75 mg/L as Al_2O_3)** and **24 mg/L (300)** with Iron salts i.e. **$FeCl_3$** and **$Fe_2(SO_4)_3$ (as Fe)** an effluent turbidity of 5 NTU and 3.3 NTU were achieved at optimum doses of **39.6 mg/L** and **17.6 mg/L [both 120 mg/L as $FeCl_3$** and **$Fe_2(SO_4)_3$]** likewise. Thus, they are capable to remove turbidity at 85-91%. Marchioretto and Reali (2001) also found 89% turbidity removal at an optimum ferric chloride dose of 21.45 mg/L as Fe. There is no colloidal restabilization occurs for PAC coagulant at higher doses, while restabilization occurs for alum at higher does i.e. more than 25 mg/L (as Al).It should be noted, although the alum dose is same as PAC, but proper dosage control is necessary to prevent restabilization.

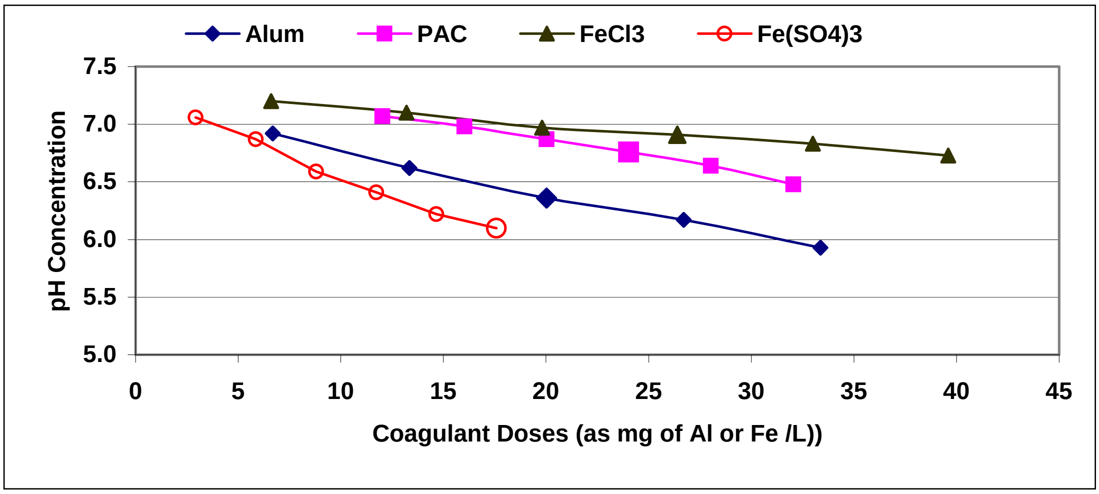


Fig. 4.4 Comparative turbidity removal performance with four coagulants

4.2.3 Variation in pH values at optimum doses of different coagulants

The pH concentration at optimum doses of different coagulants is shown graphically in Fig 4.5. It shows that the pH reduction is higher with alum and ferrous sulphate and lower with PAC and $FeCl_3$. At optimum doses of Alum, PAC, ferric chloride and ferrous sulphate the pH were noted 6.4, 6.8, 6.9 and 6.1 respectively. The results implied that under effluent pH discharge restrictions, PAC and $FeCl_3$ are much more useful coagulants.

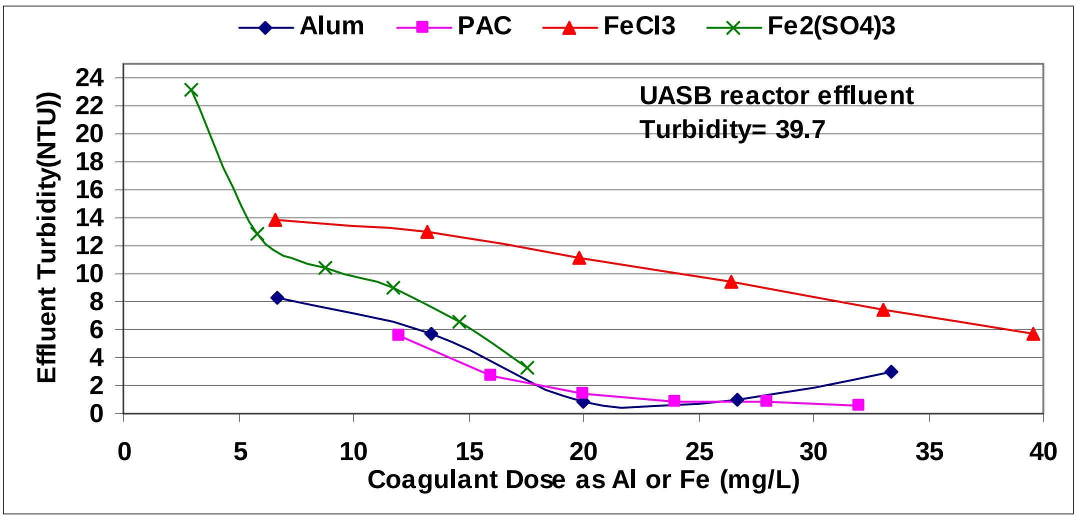


Fig 4.5 Variation in pH concentration at optimum doses of different coagulants

4.2.4 Suspended Solids Removal

The suspended solids concentration in UASB reactor effluent ranges from 65-110 mg/L with an average value of 90 mg/L. After coagulation, it reduces below 30 mg/L. More than 75% of suspended solids were removed by coagulation-flocculation process. The suspended solids removal efficiency was 78% at an alum dose of 20 mg/L (as Al), 75% by PAC at the dose of 24 mg/L (as Al). Finch and Smith (1986) reported a 90% SS removal at an optimum alum dose of 80 mg/L (as Al). A high SS removal efficiency (84%) was obtained using Ferric Sulphate (as Fe) at the dose of 18mg/L (Fig. 4.6). However, much higher doses of $FeCl_3$ is needed for SS removal. Chung and Bhagat (1973) reported that 40 mg/L ferric sulphate and ferric chloride (as Fe) provided upto 90 % SS removal efficiency.

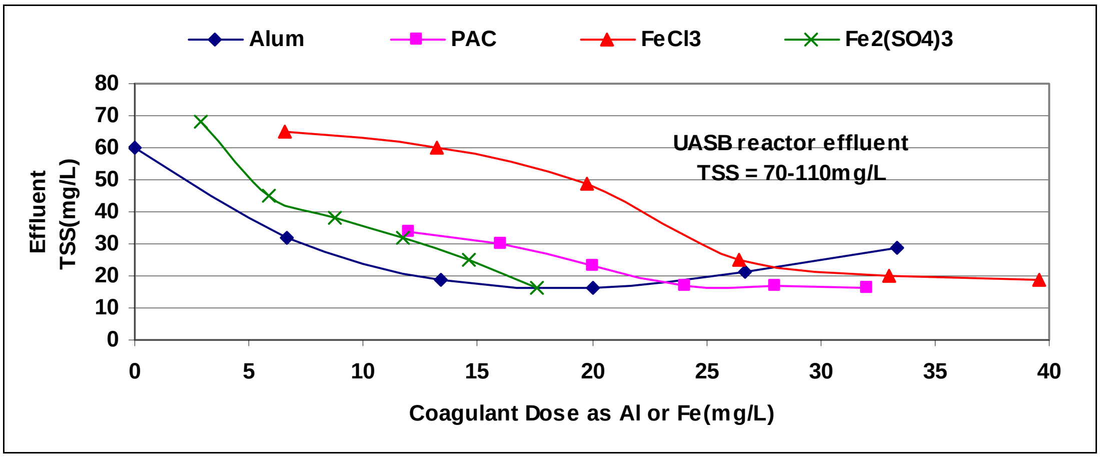
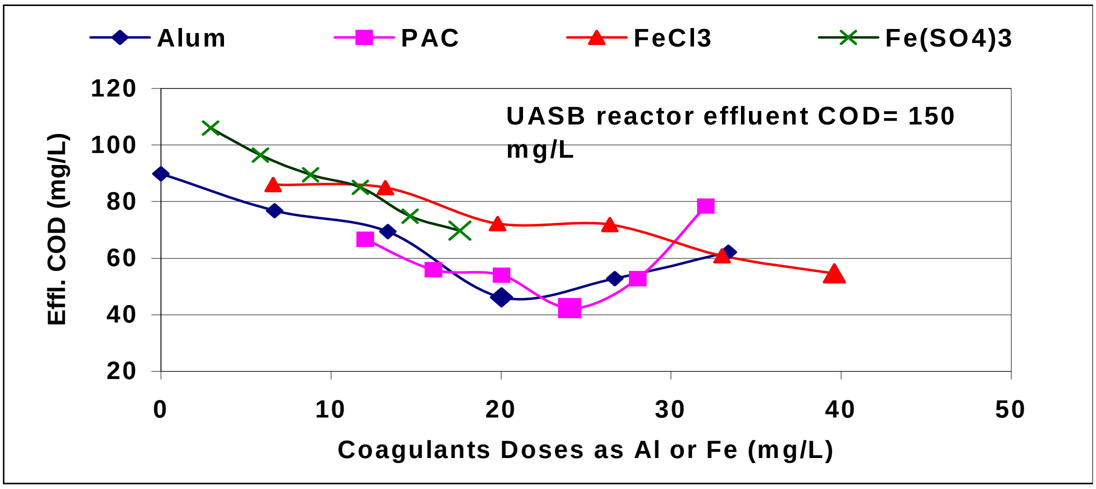


Fig 4.6: Comparative SS removal performance with four coagulants

4.2.5 BOD and COD Removal

Significant organic removal was achieved by coagulation and flocculation as post-treatment process (Fig. 4.7). An optimum alum (as 20 mg Al /L) and PAC (as 24 mg Al /L) dose significantly removes BOD_5 and COD by 73% and 70 % respectively. An effluent BOD and COD concentration of 5 & 13 mg/L and 42 & 46 mg/L were obtained with optimum alum and PAC doses. Finch and Smith (1986) found that alum is capable to remove BOD_5 at 70% with an optimum dose of 80 mg/L (as Al). Ferric chloride and ferric sulphate removes BOD_5 and COD by 79% and 64% likewise. Marchioretto and Reali (2001) obtained a removal of 63% and 73% for BOD and COD at an optimum dose of 21.45mg/L (as Fe) using ferric chloride. At optimum dosage of 40 mg/l, ferric sulphate and ferric chloride (as Fe) provide very good COD removal i.e. upto 70.5% (Chung and Bhagat, 1973; Tessele *et.al.*,2005).



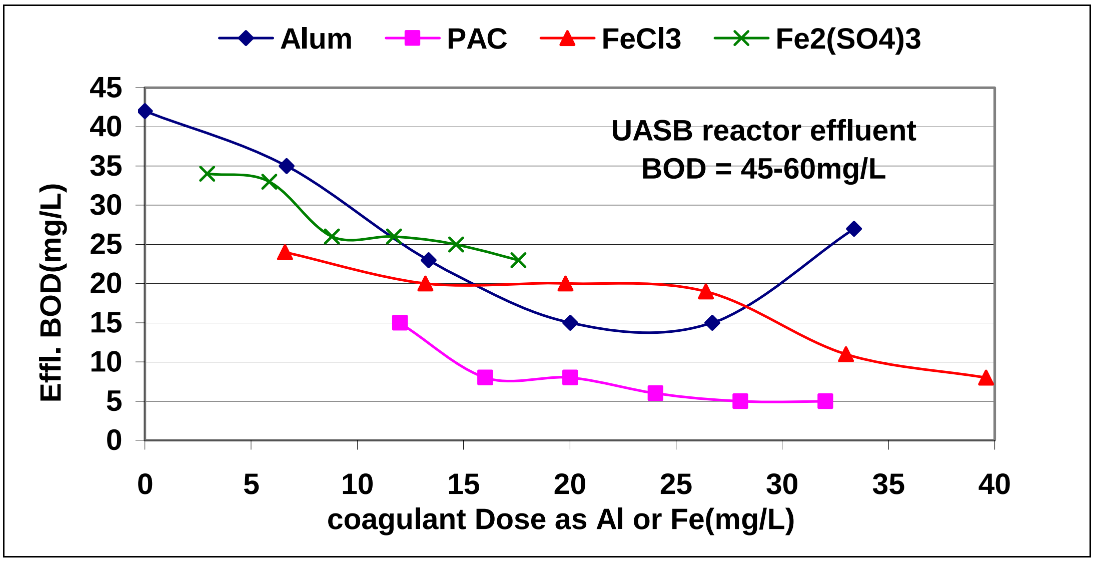
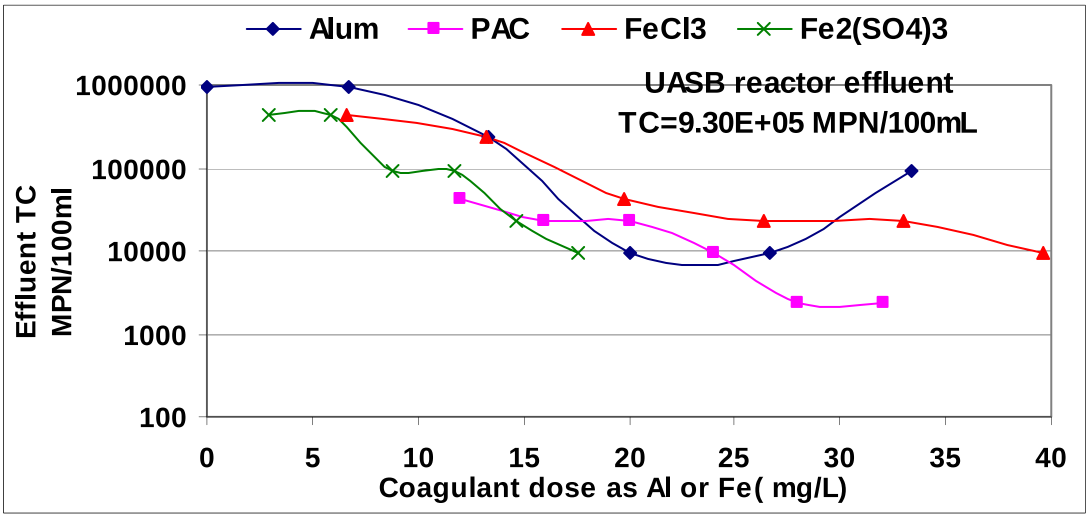


Fig. 4.7: Comparative BOD and COD removal performance with four coagulants

4.2.6 Pathogen removal

Pathogen removal is one of the most contentious parameters in treatment and analysis of domestic sewage. In this study, TC and FC indicators was selected for microbiological quality analysis. The TC and FC count in sewage was in the range of 10^6 to 10^9 MPN/100ml. Anaerobic treatment systems such as UASB can reduce coliforms by only one log order i.e. 90%. Post treatment systems like tertiary lagoons or facultative ponds are specially designed to remove the coliforms to meet the discharge standards. They yield effluent with marginal quality but at the cost of huge area and longer retention time. In some cases, the final effluent may need further disinfection (Tandukar *et al*., 2005).

In our study an effluent concentration of 9300 MPN/100 ml and 4300-2300 MPN/100 ml for TC and FC were achieved using alum and PAC doses of 20 and 24 mg of Al /L). Finch and Smith (1986) obtained a 99.9% FC removal at an optimum alum dose of 80 mg/l (as Al). An effluent concentration of 9300 MPN/100ml and 4300 MPN/100 ml for TC and FC were reported at optimum dosage of ferric chloride and ferrous sulphate (39.6 and 17.6 mg of Fe/L). The data revealed that both iron coagulants removed TC and FC at 99% and 99.5% at their optimum dosage, whereas alum and PAC reduces TC and FC at 99.5% and 99.9% respectively. Marchioretto and Reali (2001) observed that at dosage of 21.45 mg/l, ferric chloride (as Fe) removed TC and FC at 99.9% and 99.99% respectively. Tessele *et.al.*(2005) reported a 99.9% and 99.99% coliforms removal (TC and FC) with 25 mg/L of Fe ($FeCl_3$).



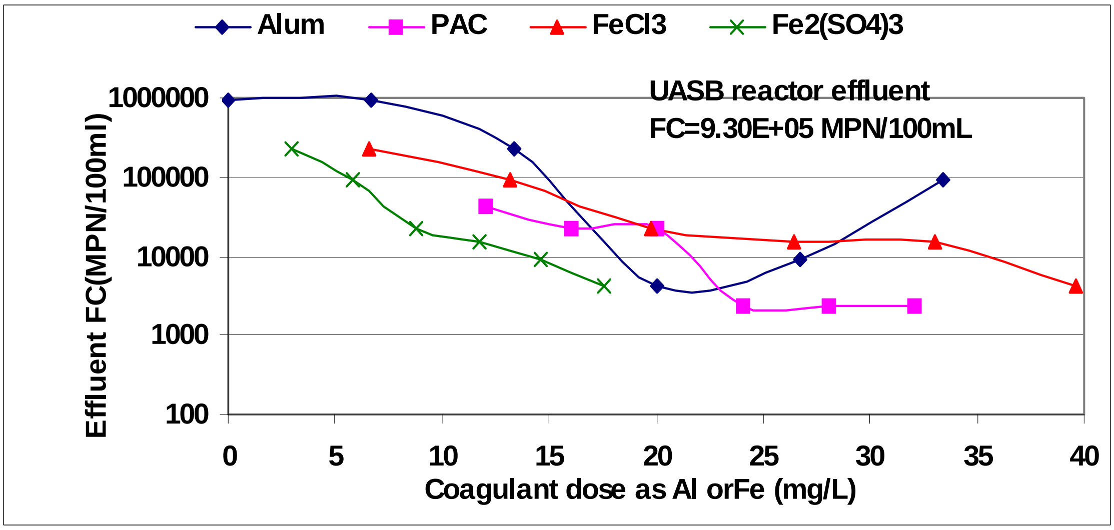


Fig. 4.8 Comparative TC and FC removal performance with four coagulants

4.2.7 Sludge Production

The sludge produced in the physical-chemical treatment is due to the presence of organic matter and total solids in suspension in wastewater, which removes effectively by using the coagulants. The amount and the characteristics of the sludge produced during the coagulation-flocculation process depend upon the amount and type of coagulant used and on the operating conditions.

After performing the jar test, the contents of the glasses was transferred to the Inhofe cone of I L capacity and the sludge production is determined by direct reading as ml of sludge settled per liter of water treated. This method has the disadvantage that the flocks formed may break when the contents of the glass (in which the jar test was performed) are transferred to the Imhoff cone. From the experimental data, we observed that ferric chloride produces the least volume of sludge i.e. 41 ml/L. However, we could not achieve the effluent characteristics within permissible limit at the optimum dose of ferric chloride. Chung and Bhagat (1973) reported a sludge production of 70 and 65 ml/L at optimum dosage of ferric chloride and ferric sulphate i.e. 40 mg of Fe/L. Furthermore, alum as a coagulant provides better effluent quality and less sludge production (47 ml/ L) as compared to other coagulants. All the data obtained from sludge production measurement has been illustrated graphically in Figure 4.9

The alum sludge produced may be reused as a coagulant in primary sewage treatment, because the alum sludge contains a large portion of insoluble aluminum hydroxides that can be utilized. It will ease the burden of water treatment works relating to sludge treatment and disposal.

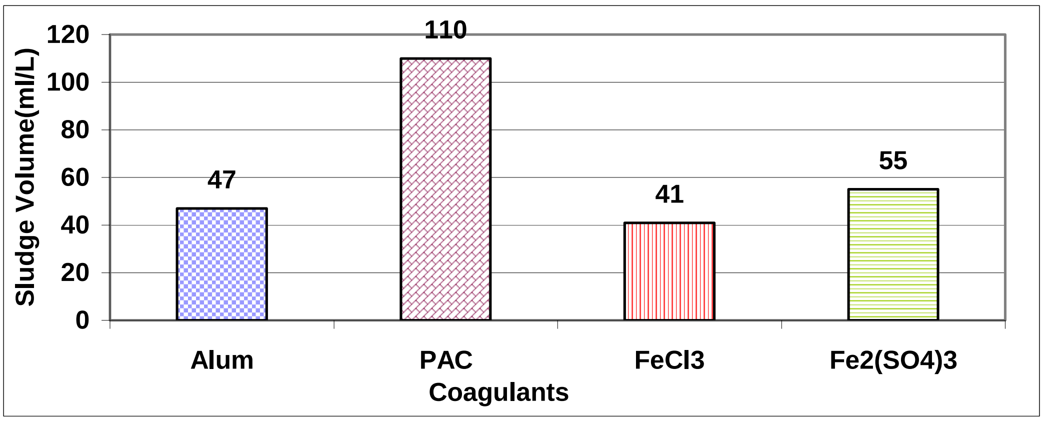


Fig 4.9. Sludge production with different coagulants at optimum doses.

4.2.8 Coagulation-flocculation followed by Chlorination

Chlorination is by far the most common method of wastewater disinfection and is used worldwide for the disinfection of pathogens before discharge into receiving streams, rivers or oceans. Chlorine is known to be effective in destroying a variety of bacteria, viruses and protozoa, including *Salmonella*, *Shigella* and *Vibrio cholera*. In our study, we performed chlorination after coagulation and flocculation. The clear supernatant was siphoned carefully and chlorine solution added in range of doses 1 to 5 mg/L with a contact time of 30 minutes. It was observed that a chlorine dose of 3 mg/L removed all the FC numbers from the sample after coagulation with optimum alum and PAC doses i.e. 20 and 24 mg of Al/L. Whereas, 4mg/L of chlorine dose was needed after coagulation with iron coagulants to remove all the fecal coliforms **(Fig.4.10).**

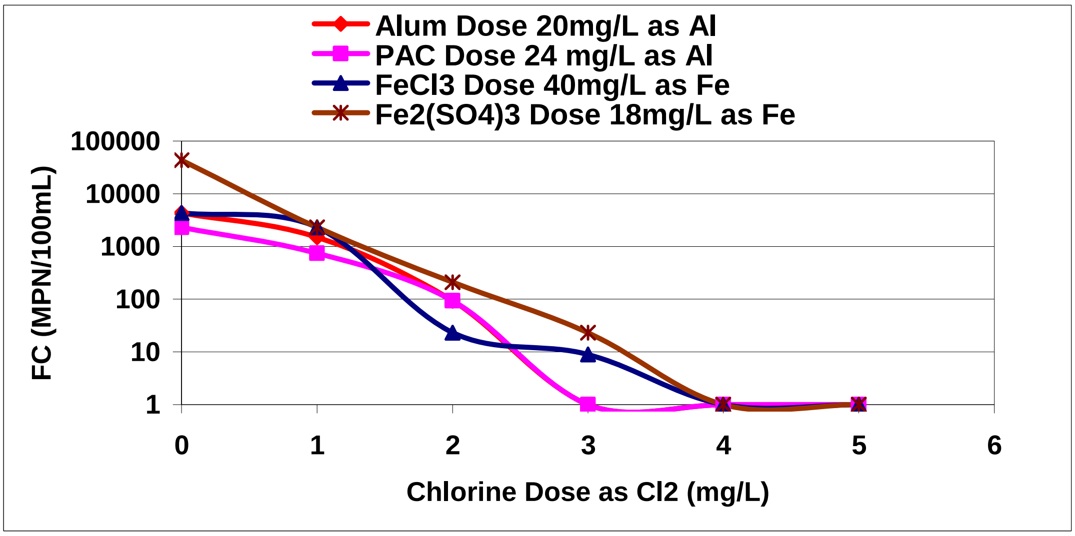
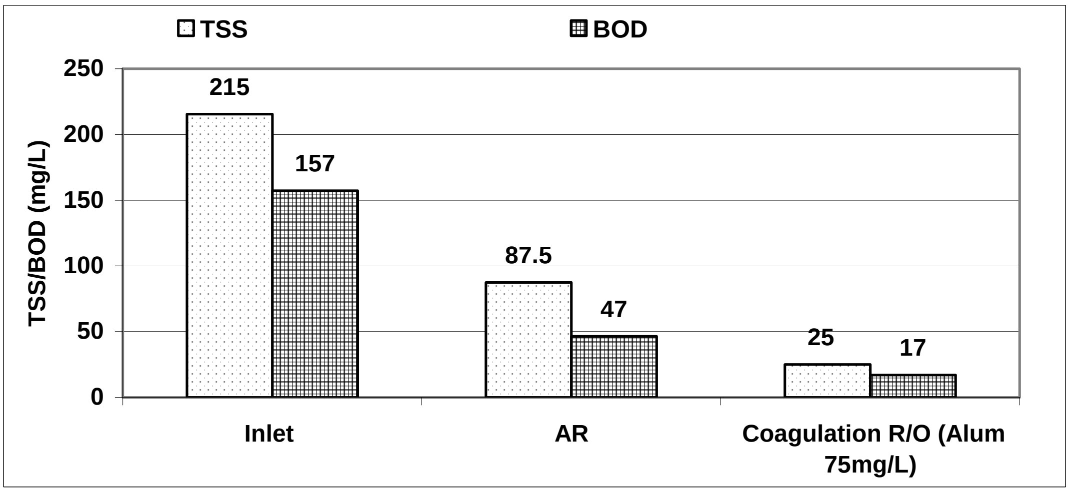


Fig 4.10. Removal of FC with chlorination after coagulation with different coagulants at optimum doses.

4.2.9 Cumulative Efficiency of the Treatment System (UASB) Upto Augmentative Requirements

It can be seen that the normal treatment by UASB system provides efficiencies upto 59.3% for TSS and 70% for BOD. However, with the augmentation through coagulation-flocculation the efficiency correspondingly increases to 89.17% and 88.37% respectively (Fig 4.11 & fig 4.12).



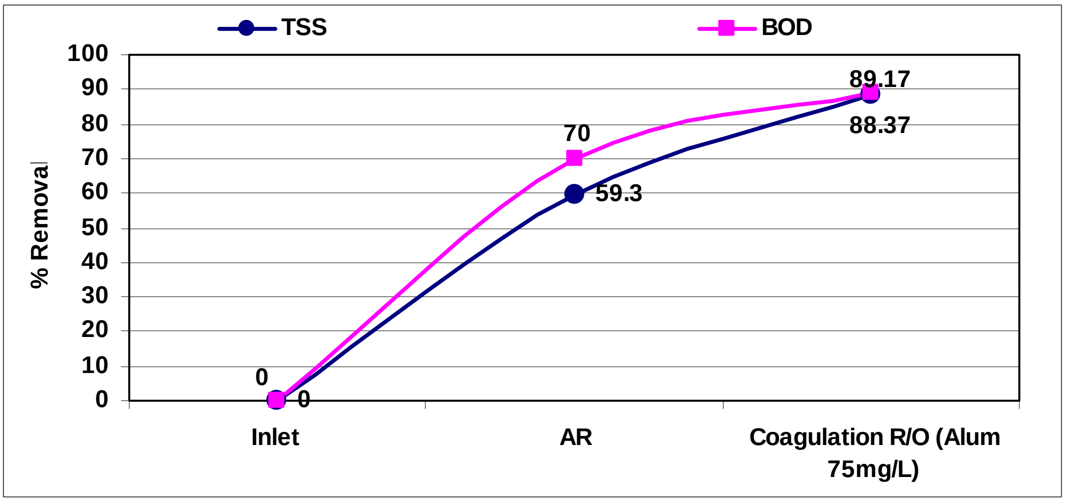
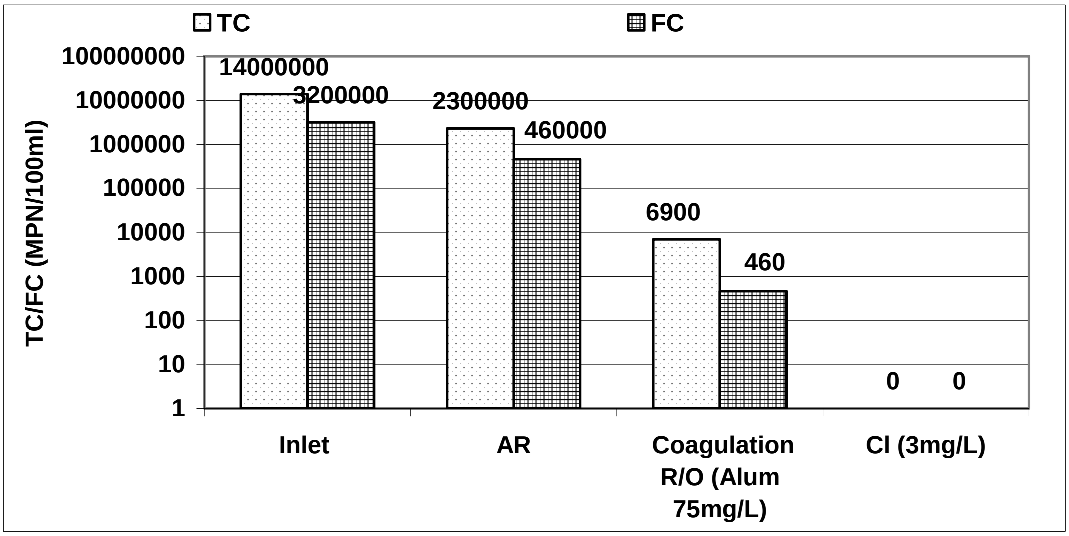


Figure 4.11 & Figure 4.12 : Cumulative efficiency of the UASB system w.r.t. TSS and BOD removal upto augmentative requirement

Similarly the UASB system removes TC and FC up to 85.62% and 83.57% respectively. Whereas, coagulation-flocculation with optimum alum and PAC doses, the efficiency increases to 99.98% and 99.95% respectively (fig 4.13 & fig 4.14).

Further with additional chlorination the total TC and FC removal up to 100% have been possible. Therefore, these results points towards the augmentative requirements of existing treatment system for total removal of the pathogenic content of the water.



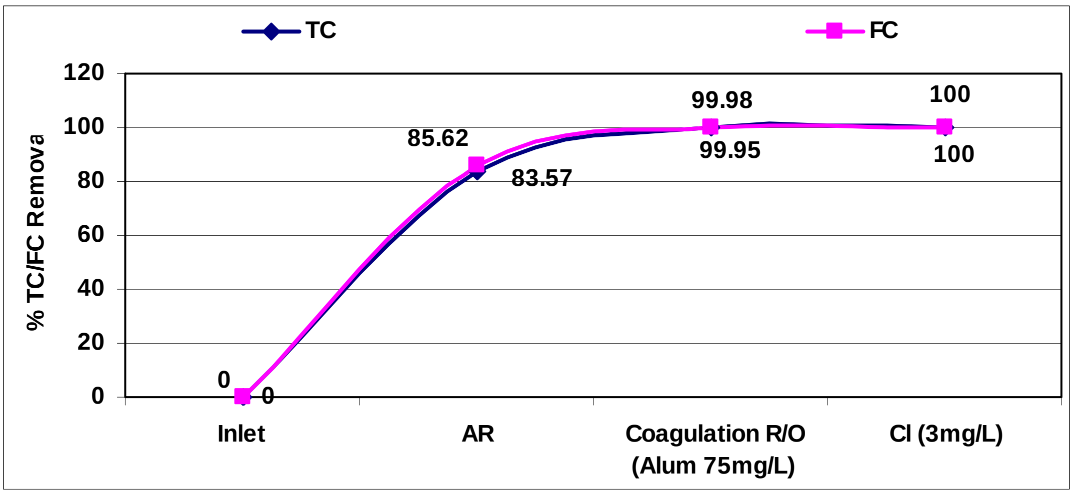


Figure 4.13 & Figure 4.14: Cumulative efficiency of the UASB system w.r.t. TSS and BOD removal upto augmentative requirement

4.2.10 Post Treatment of Plant Effluent by Coagulation Followed by Chlorination

The observed effluent concentration of Fecal coliform at OP, Rishikesh was not meeting the standard of discharging the effluent into surface waters or for restricted irrigation. To meet the requirement of discharging the effluent into river water, post treatment of STP effluent is necessary.

Therefore, coagulation of treated effluent with Alum [$(Al_2SO_4)_3.16\ H_2O$] was practiced for this purpose and it was found that it reduced the organic matter and mostly suspended matter at significant level. The results are shown in Table 4.10.

Table 4.10 Post Treatment of Oxidation pond effluent by Coagulation using Alum as Coagulant

Doses (mg/L)	Turbidity (NTU)	pH	Sludge (ml/L)	TSS	BOD	COD	TC	FC
0	30.37	7.95	0	78	36	119	240000	93000
10	25.62	7.42	9	67	28	83	210000	75000
20	18.98	7.10	12	57	24	62	120000	64000
30	17.46	6.91	18	52	21	60	93000	43000
40	15.14	6.64	22	48	20	57	93000	23000
70	5.14	6.34	46	27	12	46	23000	4600
100	0.78	5.92	70	15	9	36	4600	1100
130	1.85	5.15	80	12	8	32	430	21
160	4.54	4.40	86	15	10	31	43	11
200	7.08	4.14	90	14	9	32	3	3
250	7.92	4.00	92	16	11	36	3	3

The alum dose was practiced within a range of 10 mg/L to 250 mg/L. As alum doses increased the pH of water was decreased. The maximum removal of coliforms was obtained at an alum dose of 200 mg/L. At this dose the Total and Fecal coliforms concentration were 3 MPN/100 ml but the sludge production was 92ml/L and the effluent pH decreased at 4. The optimum alum dose for post treatment of effluent from oxidation pond, Rishikesh was obtained 100mg/L on the basis of minimum turbidity (0.78 NTU) whereas 130 mg/L of alum dose was reported as optimum dose on the basis of high coliforms (TC and FC) removal.
Both the alum doses (100 and 130 mg/L) was found appropriate to remove the usual organic as well as microbial pollutants effectively (figure 4.15- figure 4.20). Although the lowest concentration of coliforms (i.e. 430 and 21 mMPN/100ml for TC and FC respectively) was observed at an alum dose of 130 mg/L.

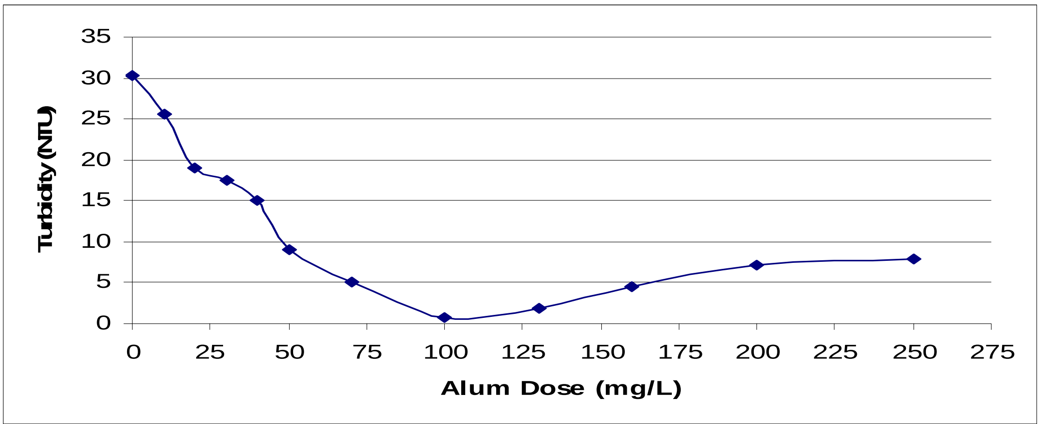


Fig. 4.15 Removal of Turbidity with different Alum Doses

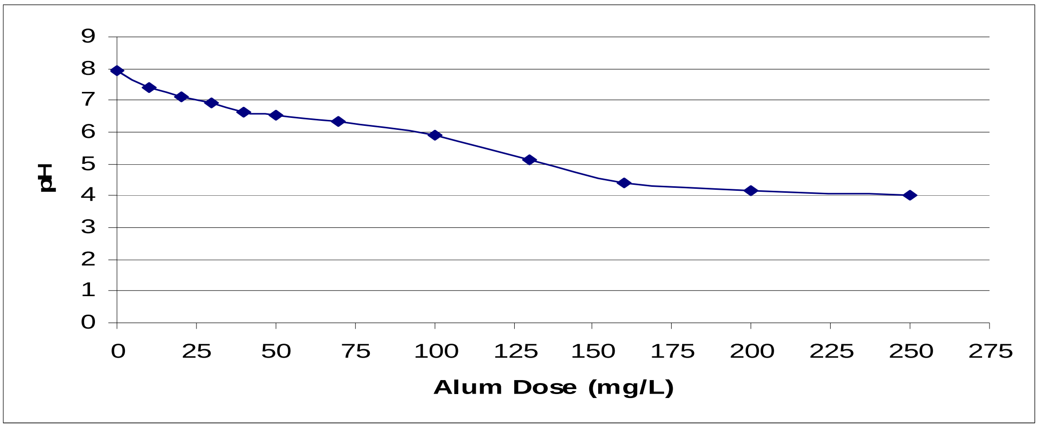


Fig. 4.16 Variations in pH value with different Alum Doses

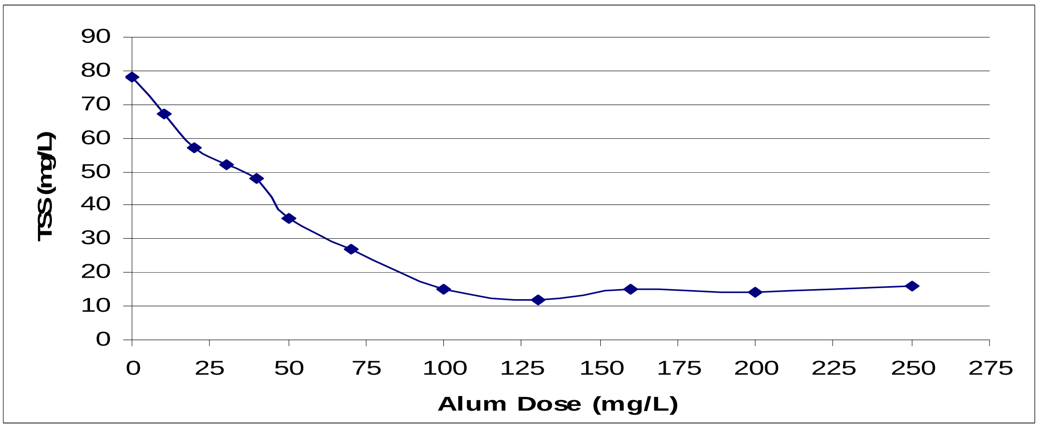


Fig. 4.17 Removal of TSS with different Alum Doses

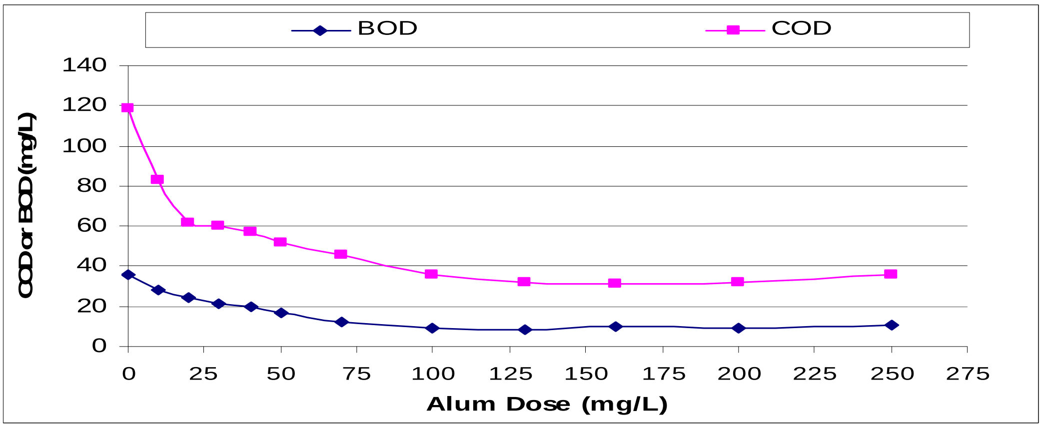


Fig. 4.18 Removal of BOD and COD with different Alum Doses

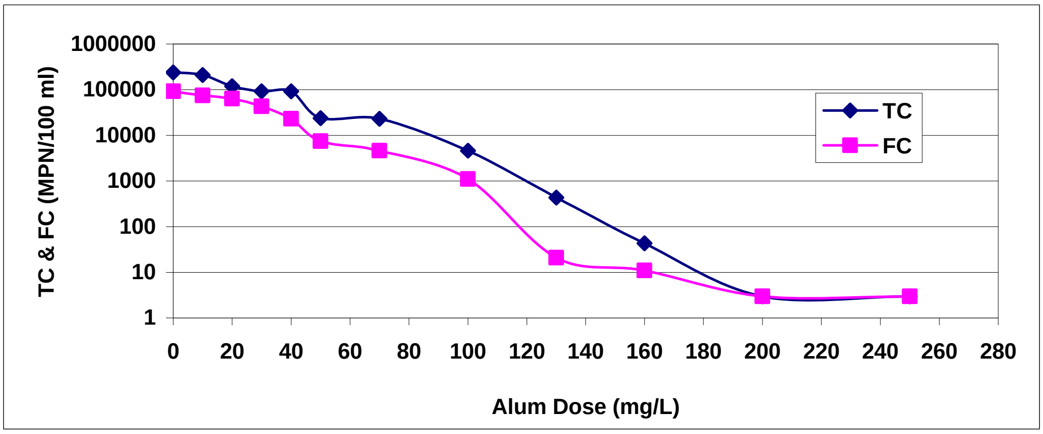


Fig. 4.19 Removal of TC and FC with different Alum Doses

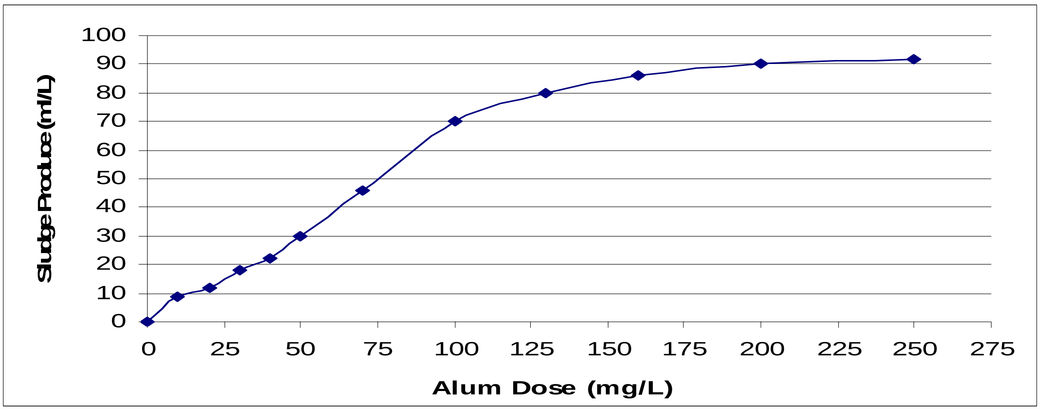


Fig. 4.20 Production of sludge with different Alum Doses

4.2.11 Chlorination

After Coagulation with optimum alum Dose of 100 mg/l, Chlorination was done which reduced total coliform and fecal coliform numbers at a significant level (Table 4.11).

Table 4.11 : Descriptive data of the coliforms removal by chlorination of the samples obtained after coagulation- flocculation

Chlorine Dose (mg/L)	TC (MPN/100ml)	FC (MPN/100ml)
0	4600	1100
1	23	9
2	3	3
3	1	1
4	1	1
5	0	0

Chlorination is by far the most common method of wastewater disinfection. It is used worldwide for the disinfection of pathogens before effluent discharge into receiving streams, rivers or oceans. Chlorine is known to be effective in destroying a variety of bacteria, viruses and protozoa, including *Salmonella*, *Shigella* and *Vibrio cholera*. In our study, we added chlorine after coagulation and flocculation. The clear supernatant was siphoned carefully and chlorine solution added in range of doses 1 to 5 mg/L with a contact time of 30 minutes. It was observed that a chlorine dose of 5mg/L removed all the FC numbers from the sample after coagulation with optimum alum dose (100 mg/L).

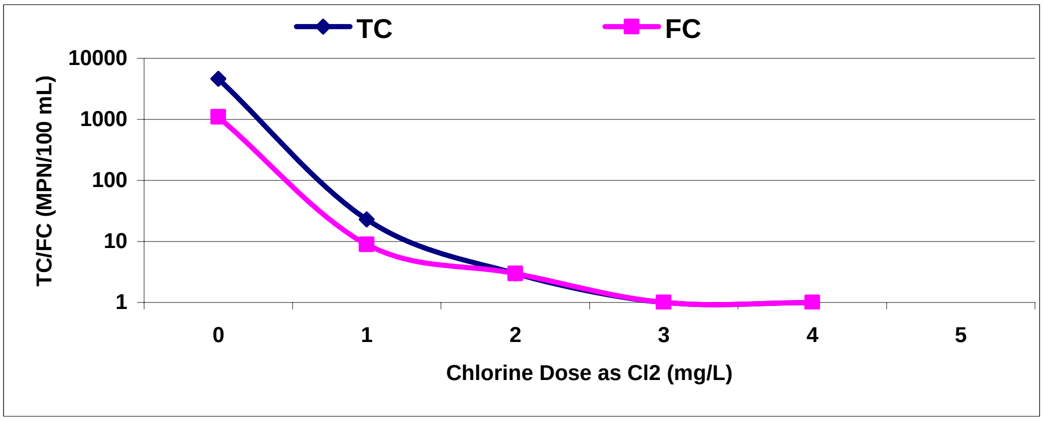
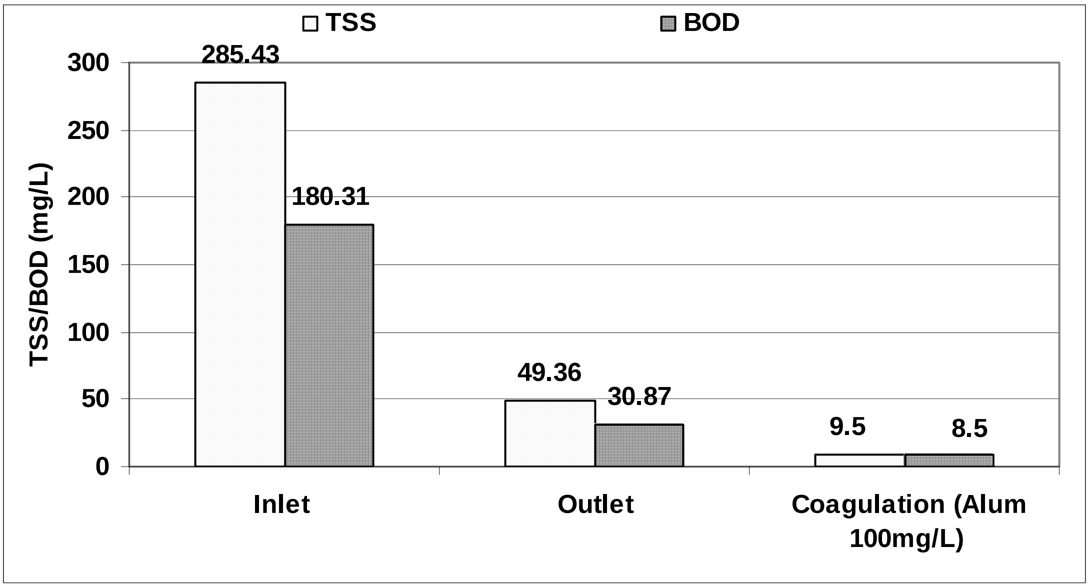


Fig. 4.21 Removal of TC and FC with chlorination after coagulation with optimum Alum dose (100 mg/L)

4.2.12 Cumulative Efficiency of the Treatment System (Oxidation Pond) Upto Augmentative Requirements

It can be seen that the normal treatment by Pond system provides efficiencies upto 82.7% for TSS and 82.87% for BOD. However, with the augmentation through coagulation-flocculation the efficiency correspondingly increases to 96.67% and 95.28% respectively (Fig 4.22 & Fig 4.23).



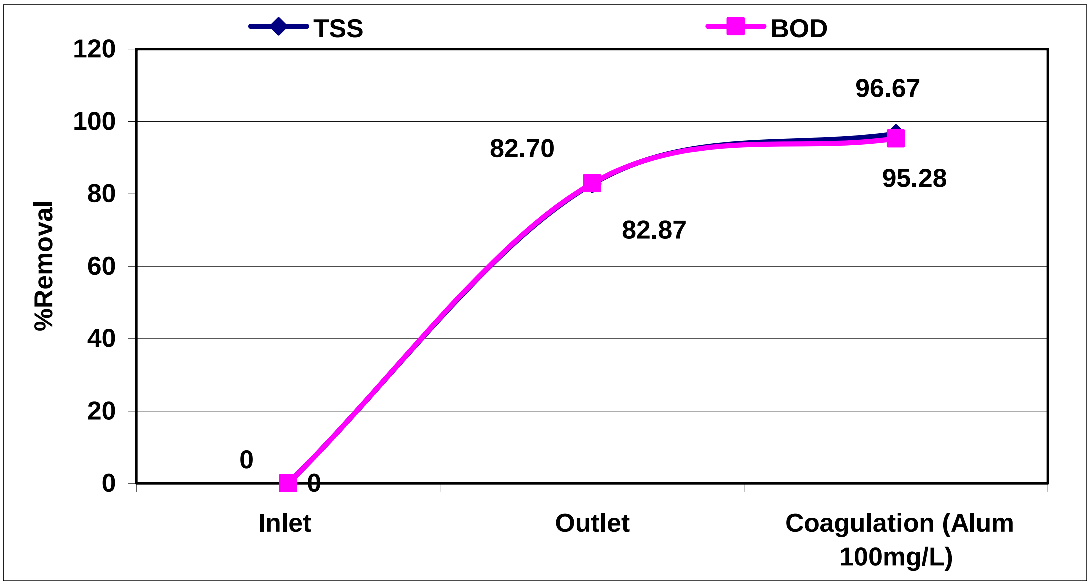
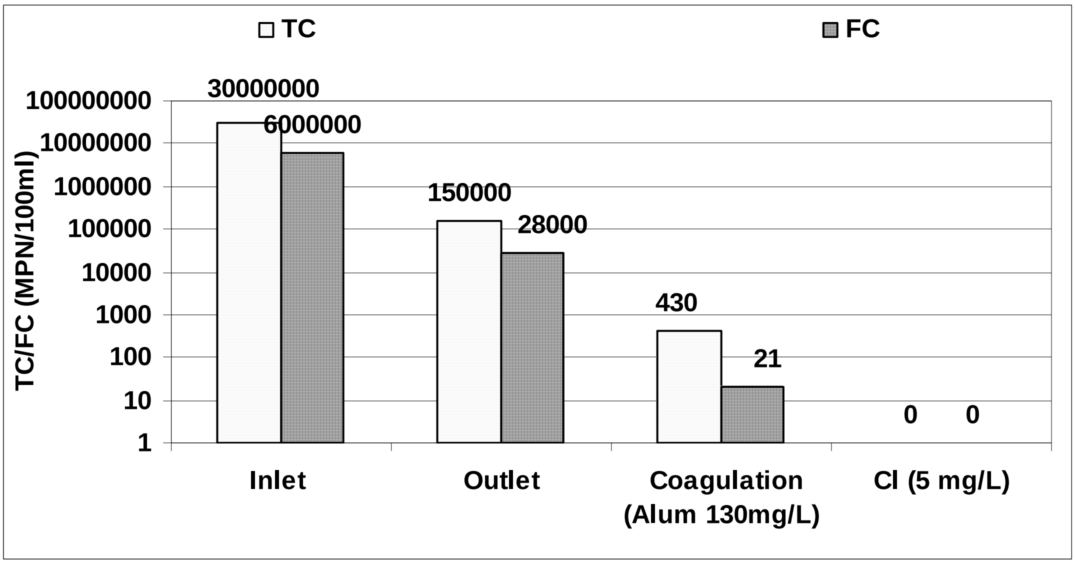


Figure 4.22 & Figure 4.23 : Cumulative efficiency of the Pond system w.r.t. TSS and BOD removal up-to augmentative requirement

Similarly the Pond system removes TC and FC upto 99.50% and 99.53% respectively. Whereas, coagulation – flocculation with optimum alum dose, the efficiency increases to 99.9985% and 99.99965% respectively (fig 4.24 & fig 4.25).

Further with additional chlorination the total TC and FC removal upto 100% have been possible. Therefore, these results points towards the augmentative requirements of existing treatment system for total removal of the pathogenic content of the water.



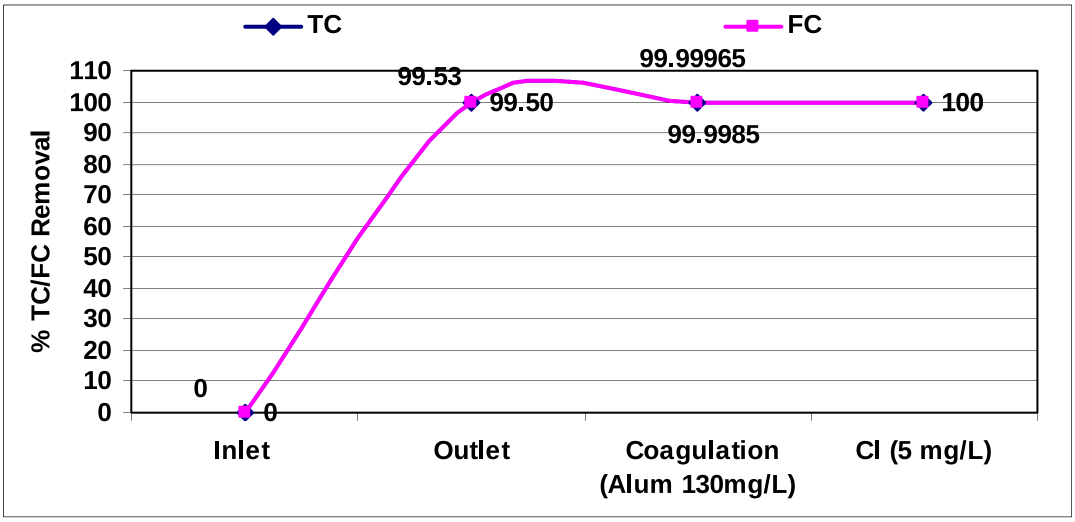


Figure 4.24 & Figure 4.25: Cumulative efficiency of the Pond system w.r.t. TSS and BOD removal up to augmentative requirement

4.2.13 Conclusions

From this study, following conclusions are put forward for evolving recommendations in Stabilization Pond system including augmentative requirements:

1. Significant reduction of indicator microorganism (Total Coliform, Fecal Coliform and Fecal Streptococci) can be achieved by Oxidation Pond. During the study period this reduction lie between 2log to 3log i.e. 99% to 99.90% for all above given indicator microorganism. Significant reduction of organic pollutants w.r.t. BOD & COD was also achieved i.e. lies between 79%-85% and 77- 79% respectively.
2. The FC: FS ratio is significant factors which enlighten about source of fecal pollution. The ratio of fecal coliform to fecal streptococci (FC/FS) was always found greater than 4 during the study period. It shows that humans were the major contributor to fecal pollution or a very less microbial pollution was supplied by animal wastes.
3. Significant correlations were occurred between indicator microorganisms (TC, FC and FS) and Physico-chemical parameters (TSS, Turbidity and

BOD). The relation of TSS and Turbidity with all indicator parameter is the strongest except BOD. These interrelationships can be helpful in routine monitoring of STP's and up gradation of STP efficiency.

4. As the number of FC in effluent was always more than 1000MPN/100ml so it is not fit for unrestricted irrigation as per WHO (1989).
5. An effluent concentration of Helminthes eggs varied from 0-0.8 eggs/ L (Mean 0.2 eggs/ L). Which is less than the permissible limit (<1 eggs/L) for unrestricted irrigation as suggested by WHO (1989).
6. In winter and autumn season BOD was more (35.5 & 35.8 mg/L) than the permissible limit (~30mg/L) to discharge in inland surface waters so it is not safe to dispose this water in river during these periods without any additional treatment.
7. The optimum alum dose of 100mg/L and a chlorine dose of 2 mg/L were found appropriate to reduce the organic as well as microbial pollutants at permissible levels. Therefore, the post treatment of STP effluent by Coagulation along with chlorination is mandatory before discharged it into the surface waters or its uses for another purposes.

4.2.14 Scope For Further Work

This study revealed that the sewage treatment plant of Lakkarghat (Rishikesh) is working well, in its capacity but for improving the quality of treated water a suitable post treatment is required so that the treated water should be safe in discharging into the river and reuse for irrigation purpose. So following post treatment or modification in existing technology can be done:

- In this study coagulation by alum is only tried, there are other coagulant and coagulant aids which can be tried for improving the quality of treated water.
- Other types of technology like slow sand filter with varying size of media can be practiced to make better quality of treated water.
- Since for given surface area, the oxidation ponds which have shallow depth can remove more bacteria, so this can be done by increasing the depth of pond-5 up to 2 – 2.5 m and decreasing the depth of last two ponds i.e. pond-2 and pond-1, up to 30 cm only. At presently last two ponds have depth 60 cm and 65 cm respectively. So by providing such type of geometry in a model scale it can be practiced weather it is beneficial or not for this treatment system.
- If bacterial removal does not reach up to desired limit, disinfection by chlorination or other mean should be done simultaneously with the suitable post treatments.

4.2.15 Post Treatment of Plant Effluent By Coagulation Followed By Chlorination

It was observed that effluent concentration of TC and FC at ASP Haridwar effluents was more than the permissible limit (1000MPN/100 ml) prescribed by WHO (1989) for Unrestricted Irrigation. Therefore, Coagulation and Chlorination was provides as the post treatment of the STP effluent to achieve the permissible limits w.r.t. microbiological quality of the effluent. Aluminum Sulphate ($Al_2(SO_4)_3.16H_2O$) was used as a coagulant and the reduction of indicators microorganisms were observed with various doses i.e. 10, 20,30,40,50 mg/L as Al_2O_3. The results of coagulation- flocculation are shown in Table 4.12.

4.2.16 Coliforms removal by coagulation- flocculation

The alum dose was practiced within a range of 10 mg/L to 50 mg/L as Al_2O_3. Optimum dose was taken as 50mg/L because of maximal and desirable reduction of coliforms numbers. At an optimum alum dose of 50mg/L the TC and FC concentration was reduced at 300 and 10 MPN/100 ml respectively.

Table 4.12 Effect of Coagulation- Flocculation upon Total and Fecal Coliforms reduction

Alum Doses as Al_2O_3 (mg/L)	TC (MPN/100mL)	FC (MPN/100mL)
0	23000	9300
10	9300	9000
20	4300	900
30	1600	200
40	900	40
50	300	10

4.2.17 BOD, TSS and Turbidity removal by coagulation- flocculation

At the optimum alum dose (50 mg/L) 50 of BOD and suspended solids and 61.76% of turbidity removal was obtained. Whereas the effluent BOD, TSS and turbidity were 15 mg/L, 11mg/l and 2 NTU respectively (Table 4.13).

Table 4.13 Effect of Coagulation- Flocculation upon the removal of BOD, TSS and Turbidity

Parameters	BOD (mg/L)	TSS (mg/L)	Turbidity (NTU)
STP Effluent	24	30	5.23
After Coagulation – Flocculation (50 mg/L for as Al_2O_3)	11	15	2
Removal (%)	50.0	50.0	61.76

4.2.18 Coagulation- flocculation of STP effluent followed by Chlorination

The chlorination was also done with same alum doses at two chlorine doses of 1 and 2 mg/L and a contact time of 30 minutes. The results are shown in table 4.14.

Table 4.14 Descriptive data of the coliforms removal by chlorination of the samples obtained after coagulation-flocculation

AlumDoses as Al_2O_3 (mg/L)	TC (MPN/100mL)		FC (MPN/100mL)	
	1mg/L Cl_2	2mg/L Cl_2	1mg/L Cl_2	2mg/L Cl_2
0	9300	300	2300	200
10	9000	200	1600	100
20	900	40	430	40
30	200	20	110	20
40	40	1	20	1
50	10	Nil	Nil	Nil

The observations revealed that at an optimum alum dose of 50 mg/L as Al_2O_3 followed by a chlorine dose of 2 mg/L (contact time: 30 minutes) are sufficient to remove almost complete Total coliforms and Fecal coliforms from the effluent of ASP Haridwar.

The chlorination of the STP effluent was also practiced without its any pretreatment by coagulation- flocculation (Table 4.15).

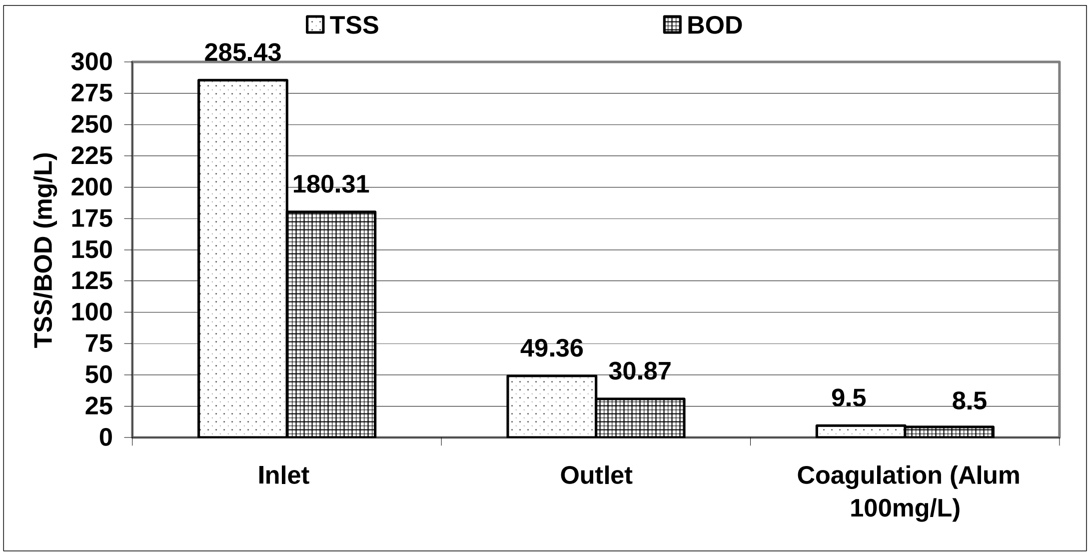
Table 4.15 Effect of Chlorine Doses on Total and Fecal Coliforms removal

Dose (mg/L Chlorine)	**TC (MPN/100mL) [Contact time: 30 min]**	**FC (MPN/100mL) [Contact time: 30 min]**
0	23000	9300
1	2300	930
2	930	230
3	230	80
4	80	40
5	40	2
6	2	Nil
7	Nil	Nil
8	Nil	Nil

It was observed that a chlorine dose of 8 mg/L with a contact time of 30 minutes is sufficient to kill all the coliforms present in the sample.

4.2.19 Cumulative Efficiency of the Treatment System (ASP) Upto augmentative Requirements

It can be seen that the normal treatment by Activated sludge process system provides efficiencies upto 94.12% for TSS and 87.46% for BOD. However, with the augmentation through coagulation-flocculation the efficiency correspondingly increases to 97.12% and 93.76% respectively (Fig 4.26 & fig 4.27).



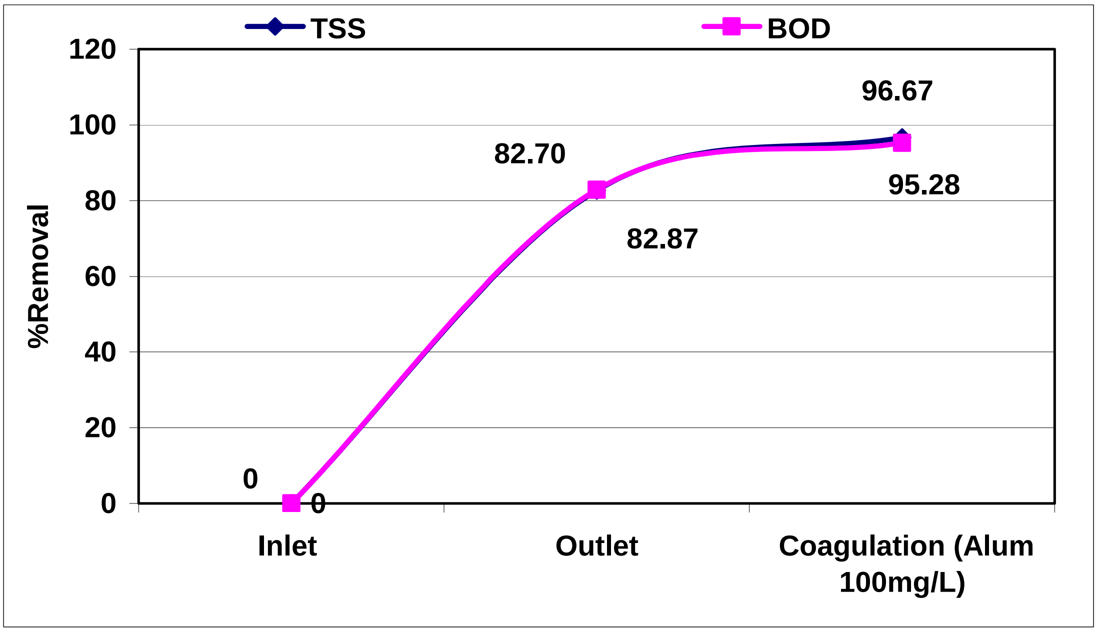
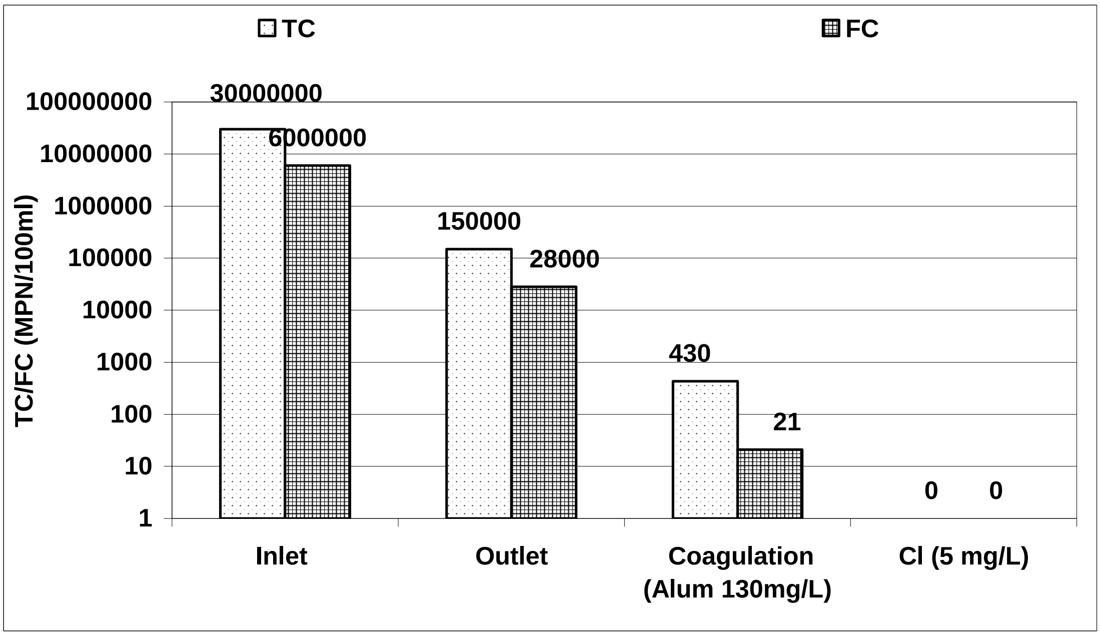


Figure 4.26 & Figure 4.27 : Cumulative efficiency of the ASP system w.r.t. TSS and BOD removal up to augmentative requirement

Similarly the ASP system removes TC and FC upto 99.50% and 99.49% respectively. Whereas, coagulation-flocculation with optimum alum dose, the efficiency increases to 99.994% and 99.9994% respectively (fig 4.28 & fig 4.29).

Further with additional chlorination the total TC and FC removal upto 100% have been possible. Therefore, these results points towards the augmentative requirements of existing treatment system for total removal of the pathogenic content of the water.



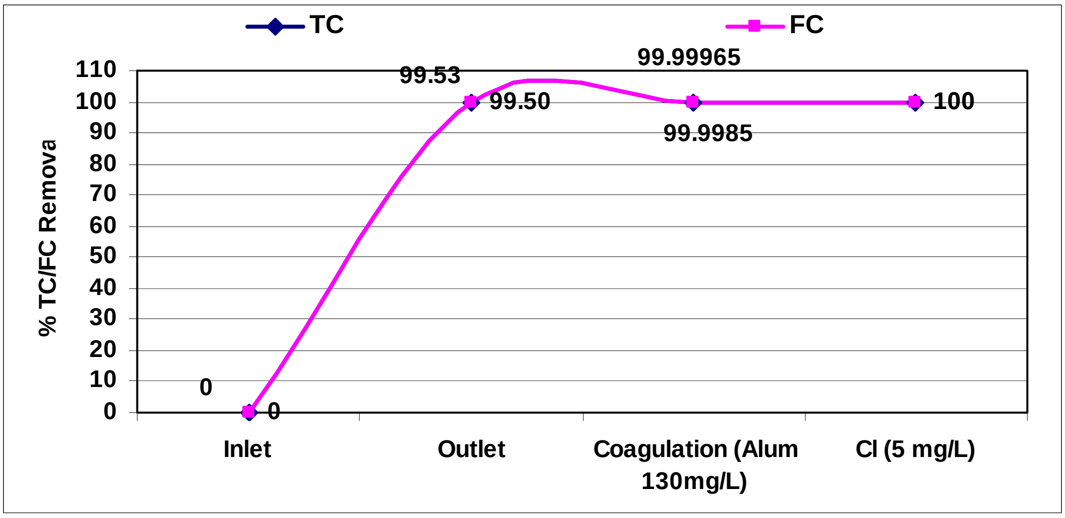


Figure 4.28 & Figure 4.29: Cumulative efficiency of the ASP system w.r.t. TSS And BOD removal upto augmentative requirement

4.2.20 Observations and Discussion

On the basis of the observed data at Activated Sludge Process, Kankhal (Haridwar) following observations are made**:**

1. In the **Raw sewage** BOD, COD and TSS was found vary from 95- 230 mg/L (Mean 141.1mg/L), 192- 464 mg/L (Mean 270mg/L) and 87-373 mg/L (Mean 243mg/L) respectively. As per Metcalf & Eddy (1995) Typical COD concentration in the Untreated Domestic sewage ranges from 250-1000 mg/L.

2. The BOD, COD and TSS concentration in **Effluent** ranges from 9-42mg/L (Mean 17.7 mg/L), 25.8 – 62 mg/L (Mean 36.2 mg/L) and 4- 40 mg/l (Mean 14.3 mg/L) respectively.

3. The **mean removal efficiency** of BOD, COD and TSS were found to be 86.65, 86.2 and 93.2 respectively. Most of the researchers have mentioned the removal efficiency of BOD for ASP in the range of 85-93%.

4. TC, FC and FS concentrations in the system **influent** was varied from $1.5x10^6$ – $4.3x\ 10^{12}$ MPN/100mL (Mean 50000000 MPN/100mL) , $2.1\ x10^5$ – $1.5x\ 10^{10}$ MPN/100mL (Mean 17750000 MPN/100mL) and $4.3x10^3$ – $7.5x\ 10^7$ MPN/100mL (Mean 760000 MPN/100mL).

5. Observations revealed that the **effluent** concentration of TC, FC and FS was ranges from $9.3x10^3$- $4.3x\ 10^8$ MPN/100mL (Mean 250000 MPN/100mL), $1.5\ x10^3$ –$9.3x\ 10^6$ MPN/100mL (Mean 91500 MPN/100mL) and $2.3x10^2$- $9.3x\ 10^5$ MPN/100 ml (Mean 6800 MPN /100mL).

6. The percentages mean removal efficiency of TC, FC and FS was found 99.3, 99.32 and 98.80. As per Metcalf & Eddy (2003), reduction of bacteria in ASP is 90-98%. Earlier studies in activated sludge plants have usually showed similar 90-99% enteric bacteria reduction (Koivunen et. Al, 2003).The mean value of FC in treated effluent (91500 MPN/100mL) greater than the permissible limits i.e. 1000 MPN/100mL, as specified by WHO (1989) for unrestricted irrigation.

7. The Helminthes Eggs concentration in the system influent was varied from 32- 66.6 eggs/ L. whereas the effluent concentration of ranges from 0.8-3 eggs/ L (Mean 1.9 eggs /L). The percentages mean removal efficiency Helminthes eggs was found 95.8. Even such a good eggs removal efficiency the effluent still contain the helminthes eggs concentration (1.9 eggs /L) more than the permissible limit (<1 eggs/L) for unrestricted irrigation as suggested by WHO (1989).

As far as concerned about the impact of seasonal variation upon the plant efficiency following observations are made:

1. The effluent TSS was found almost similar (Mean 14.3 mg/L) during all the seasons. While as no significant variation in TSS removal was observed throughout the seasons (Fig 4.30).

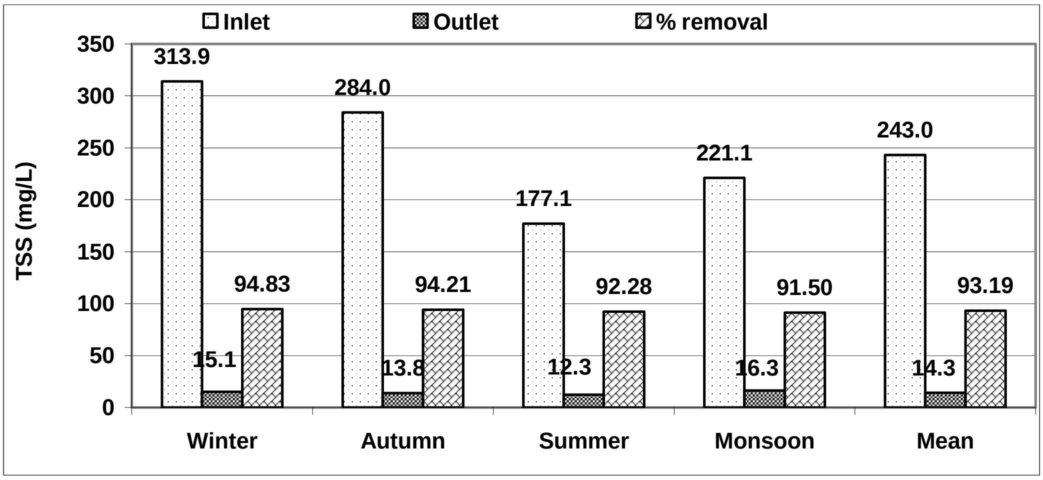


Fig. 4.30. Impact of Seasonal variations on the TSS concentration of Influent, Effluent and percentage TSS removal efficiency of Plant

2. The effluent BOD was reported almost similar (Mean 17.7mg/L) during all the seasons. The BOD removal efficiency (Mean 86.65%) was also similar during entire study period (Fig 4.31).

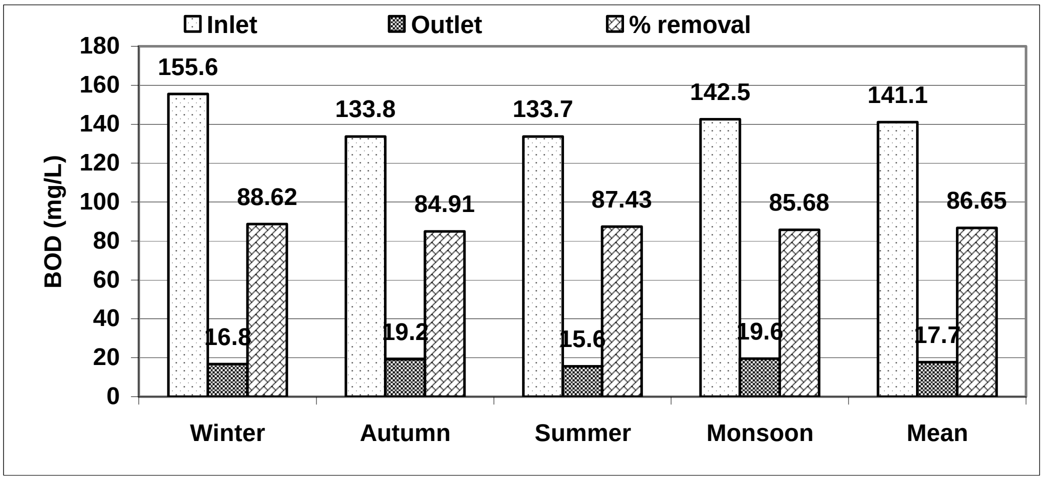


Fig. 4.31. Impact of Seasonal variations on the BOD concentration of Influent, Effluent and percentage BOD removal efficiency of Plant

3. Almost similar COD removal efficiency (Mean 86.20%) of STP was observed during all the seasons (Fig 4.32).

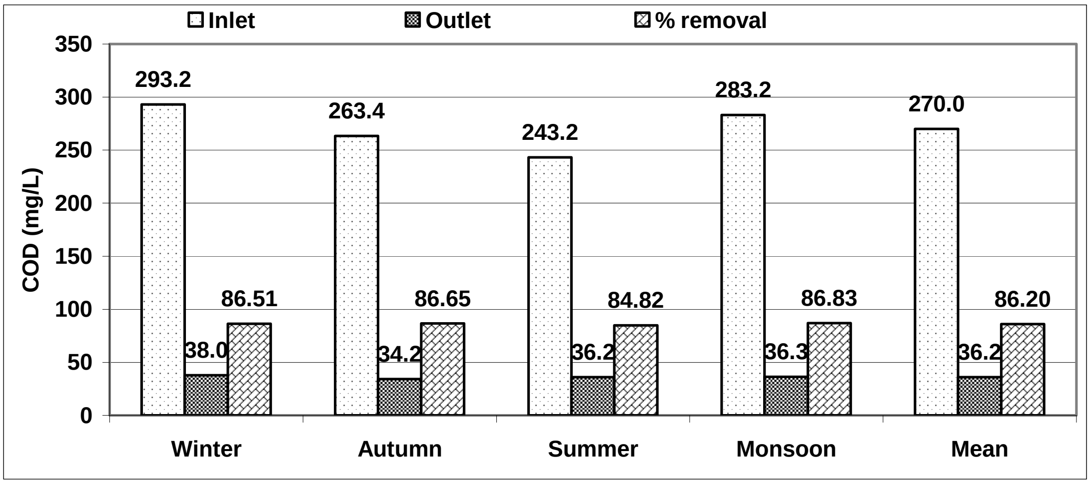
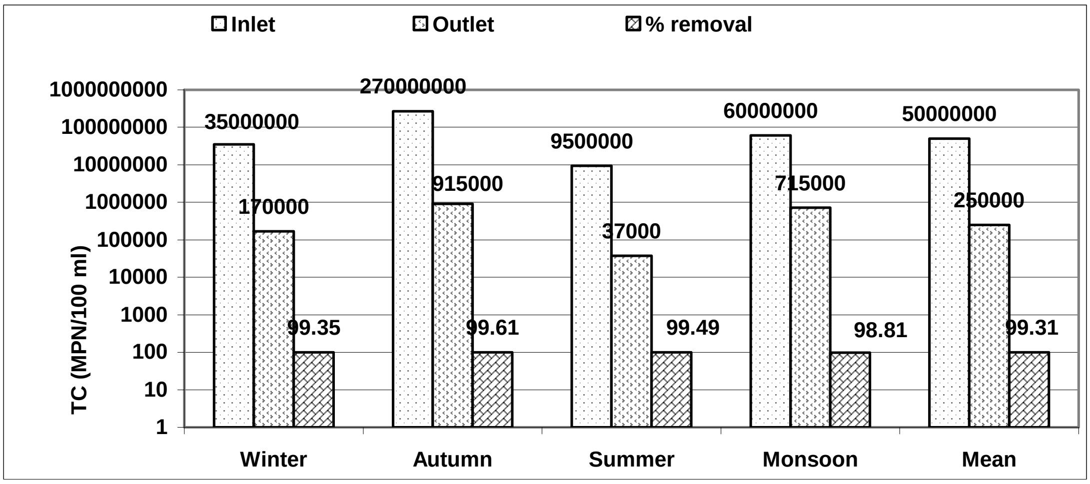


Fig.4.32. Impact of Seasonal variations on the COD concentration of Influent, Effluent and percentage COD removal efficiency of Plant

4. We observed the maximum effluent concentration of TC and FC during monsoon and autumn period. While lower TC and FC concentration during summer and winter period. The STP removal efficiency w.r.t. TC and FC was found similar during all the seasons i.e. 2- 2.5 log (99%) removal (Fig 4.33).



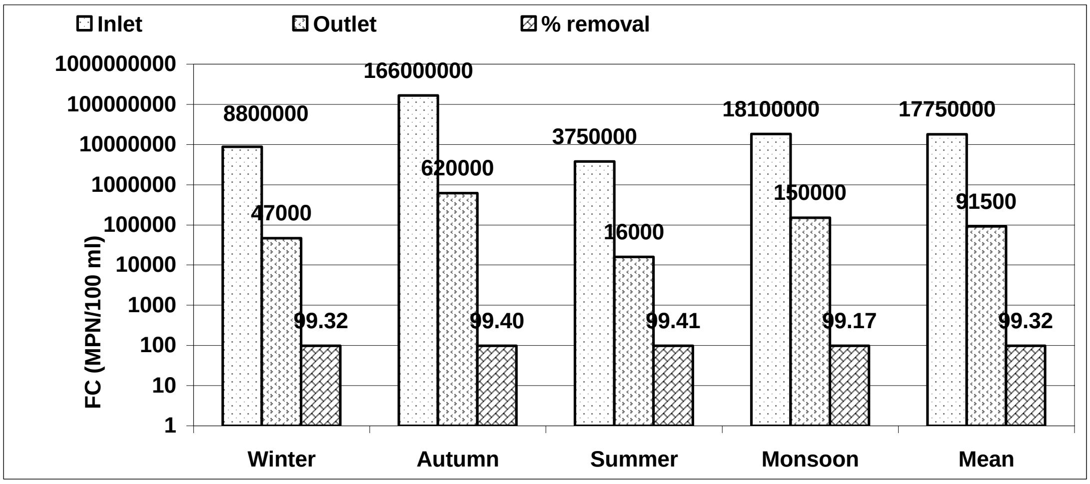


Fig 4.33. Impact of Seasonal variations on the Microbiological characteristics (TC and FC) of Influent, Effluent and their removal efficiency

5. The highest effluent concentration of fecal streptococci was noted in summer while lowest during winters. The maximum FS removal was observed in autumn and monsoon whereas minimum in winters and summers (Fig 4.34).

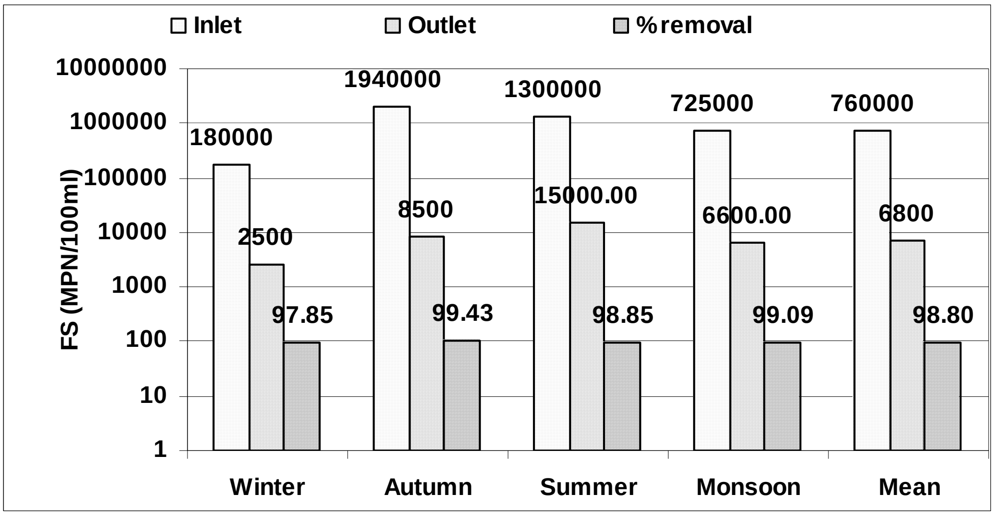


Fig 4.34 Impact of Seasonal variations on the fecal streptococci concentration of Influent, Effluent as well as their removal efficiency

4.2.21 Conclusions

From this study, following conclusions are put forward for evolving recommendations in Activated sludge process system including augmentative requirements:

1. TC and FC concentration in the treated effluent exceeded Log 3 or 1000 MPN/ 100ml signifying it unfit even for unrestricted irrigation. Whereas the effluent concentration of organic pollutants likes BOD, COD and SS were found within the limits.
2. Effluent turbidity and TSS have a good correlation with the effluent concentrations of indicator microorganisms i.e. TC, FC and FS (correlation coefficient r^2=0.7 appx.). But BOD shows less significant correlation with these indicator microorganisms. These interrelationships shows that microbial numbers in secondary treatment effluents could be best modeled as a function of effluent BOD, TSS, turbidity. The relationship between key wastewater constituents e.g., BOD, Turbidity, SS, and coliforms could be very useful in routine STP monitoring and up gradation of efficiency within time.
3. The coliforms removal efficiency of activated sludge process varies according to operational parameters and Biological flora present in activated sludge. Operational parameters like MLSS, SVI and F/M were correlated with the effluent concentrations of TC, FC and FS. By controlling these operational parameters plant can be operated in an efficient way. Operation of biological treatment of wastewater with higher level of MLSS (3000-3500), lower F/M ratio (0.2-0.35) and SVI within a range of 80- 150 ml/g tended to result in increased removal of microbial indicators and pathogens.
4. The ciliated protozoa were principally responsible for destroying coliforms during wastewater treatment A decrease in indicator bacterial concentration as well as low BOD, COD, SS and turbidity in the effluent was observed when crawling and attached protozoan population were dominant in

aeration tank, which confirm earlier demonstration of the importance of concerning protozoan community in clarification of sewage effluent.

5. High purification performances with respect to Coliform, BOD and Suspended solids is possible after addition or maintain the high density of grazing protozoan in activated sludge aeration tank. It is suggested that a basic routine for activated sludge plants under such circumstances should comprise a daily microscopic examination of the mixed liquor.

6. Lab scale and Full–scale experiments are necessary to understand the dynamics of ciliated protozoa in sewage treatment systems at different loading rate and how to maintain these organisms keeping effluent quality better. Subsequently this knowledge can be used for successful application of grazers to removal of excess bacteria. This study of the indicator value of the key groups of ciliates is useful in monitoring the activated sludge performance.

7. Integration of microbial seasonal monitoring with process control factors (HRT, SRT, MLSS, Oxygen Uptake Rates (OUR) and key constituents (BOD, SS, temperature, pH) may lead to more robust approach for assuring better microbiological quality of the treated water.

8. It was observed that even after efficient removal of suspended solids and organic load, secondary treated wastewaters still contained significant numbers of enteric bacteria. It indicates that a considerable number of microbes were free in the water and could not be removed by the settling process. Therefore, an additional tertiary treatment step is needed to remove microorganisms more efficiently or to achieve the standard limits.

9. The **Coagulation- flocculation** with an optimum alum dose of 50 mg/L as Al_2O_3 followed by a chlorine dose of 2 mg/L (contact time: 30 minutes) are sufficient to remove almost complete Total and Fecal coliforms removal from the effluent of ASP Haridwar.

10. **Chlorine disinfection** is easy to implement, requiring only chemical storage facilities, pumping and application equipment to ensure the correct dose is applied to sewage flow. A chlorine dose of 6-8 mg/L with a contact time of 30 minute removed all the Total and Fecal coliforms from the STP effluents (without any pretreatment with coagulation and flocculation).

4.2.22 Impact of Protozoan Population on Coliform removal

More than 20 samples of activated sludge were investigated to detect the community structure of ciliated protozoa from Activated Sludge Process, Kankhal (Hardwar) and Extended Aeration Process, Vasant Kunj (Delhi). A wide range of species (21 sp.) have been observed in aeration tank (listed and classified in Table 4.16) which belong to three main groups namely: Ciliates, flagellates and amoeba. The mixed liquor fauna from the STP Vasant Kunj were compared using Frequency distribution of bacterivorous ciliates.

Table 4.16 Frequency of occurrence of most predominant ciliated protozoans found at two sewage treatment plants

S.No.	Biota	Classification	Extended Aeration, Delhi
1	**Aspidisca**	crawling ciliates	++++
2	**Epistylis**	stalked ciliates	+
3	**Vorticella**	stalked ciliates	+
4	**Opercularia**	stalked ciliates	++
5	**Arcella**	Testae amoeba	+
6	**Zoothamnium**	stalked ciliates	+
7	**Chilodonella**	crawling ciliates	++++
8	**Blepharisma**	free swimming ciliates	+
9	**Carchesium**	stalked ciliates	+
10	**Rotatoria**	Rotifer	+
11	**Euplotes**	crawling ciliates	++
12	**Beggaitoa**	filamentous bacteria	+++++
13	**Spirillus**	filamentous bacteria	++++
14	**Paramecium**	free swimming ciliates	+++
15	**Metopus**	free swimming ciliates	+++
16	**Waterflea (Cladocera)**	free swimming ciliates	+
17	**Colurella**	crawling ciliates	++
18	**Vahlkamphia limicola**	Amoeba	+
19	**Litonotus**	Free swimming Carnivores ciliates	+++
20	**Colpidium**	free swimming ciliates	++
+ = Extremely Low, ++ = Few, +++ = Average, ++++ = Many, +++++ = Extremely Many			

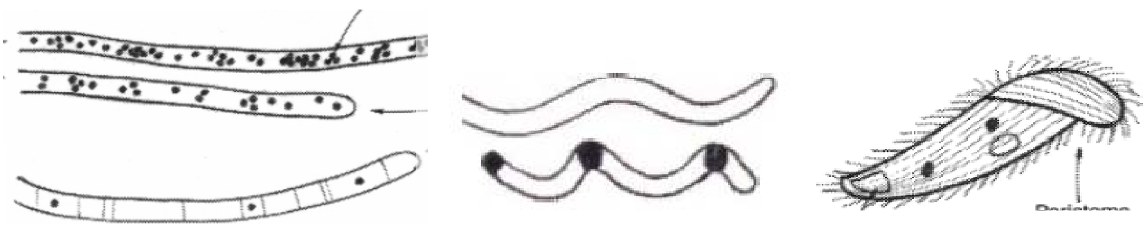
In the present study, an attempt was made to demonstrate whether any correlation is there between the existing protozoan population of extended aeration plant and the qualities of the effluents they delivered. The identification and enumeration of protozoa in activated sludge mixed liquor can provide rapid information on plant operating condition and performance (Al-Shahwani et. al, 1991). The effluent from Delhi plant were always very turbid and contained high concentration of SS, BOD, and COD. We found our observations more consistent to those obtained by Curds and Cockburn, 1970b. Plants which delivered turbid low- quality effluent either did not contain ciliated protozoa or contained only a few species in small numbers. Plants producing highly clarified, good quality effluent usually contained a large variety of ciliates species. The operational parameter values obtained for both of the treatment plant is shown in Table 4.17.

Table 4.17 : Data obtained from the aeration tank of STP Vasant Kunj

Parameters	Values
MLSS	4600 mg/L
SV30	≈800mg/L
DO (Aeration Tank)	<1 mg/L
F/M	0.6
HRT	10- 24 hrs
SRT	12- 15 days

A little lower density of ciliate protozoan community was found at Extended Aeration plant, Delhi. Ciliated protozoa improve the quality of the effluent have an elevated BOD and are highly turbid due to the presence of many dispersed bacteria (Madoni, 1994). An effluent BOD of 21 mg/l, Turbidity of 13 NTU and SS of 82 mg/l were reported at Vasant Kunj STP. Curds and Cockburn (1970a) found that Activated sludge plants which delivered turbid low-quality effluents either did not contain ciliated protozoa or contained only a few species in small numbers.

However, we observed higher coliform removal at EA plant, Delhi. The probable reason would be that filamentous bacteria feed on bacteria and they can play a significant role to remove the bacteria at maximum level. Two filamentous bacteria i.e. Beggiota & Spirillus found predominantly at Extended Aeration plant, Vasant Kunj, Delhi. The presence of filamentous bacteria in aeration tank also provides entrapment of bacteria onto and inside the filaments, resulting enhanced removal of microorganisms of interest by settling at sedimentation tank. Findings showed that more than 3 log Coliform removal at Vasant Kunj plant with a mean removal efficiency of 99.93%. Curds et. al. (1969) describe that Bacterivorous ciliates ingest large numbers of dispersed bacteria which are not associated with flocs and whose growth would generate high turbidity of the effluent. In the absence of ciliated protozoa, in fact, effluents have much higher BOD and are generally turbid because of the presence of many dispersed bacteria. As we observed, longer HRT, SRT and higher MLSS may be considered as significant factor responsible for higher coliforms removal at extended aeration plant Delhi. According to Ratsak et. al, 1996 at longer retention time some protozoan species would be able to remove practically all large bacteria, flagellates and small ciliates. Our findings are in good agreement with the observations reported by many researchers, as they revealed that higher MLSS and longer HRT and SRT tended to results in increased removal of indicator microorganisms (WERF, 2004; George, I., 2002; Loge et al, 2002; NG et al, 1993; Koivunen et. al, 2003).



A B C

Fig. 8.5.15. Microbiota most commonly occurred in aeration tank at EA, Delhi A. Beggiatoa B. Spirillus C. Metopus

Another major factor for higher coliform removal at Delhi plant may be due to segregation of sludge flocs (Poor settling, SV_{30}= 800mg/L) in aeration tank or small size flocs. Ratshak et. al. (1996) stated that smaller flocs have a relatively large grazing surface area. Bacterivorous ciliates ingest large numbers of dispersed bacteria which are not associated with flocs, remains in suspended forms. Ciliated protozoa have a strong affinity to feed upon suspended bacteria in lieu of those found attached to surface or inside the sludge flocs during activated sludge treatment Curds and Cockburn, 1970(b). Gurijala and Alexander (1990) found that less hydrophobic species (low density) only the non- growing species appeared to be eliminated by grazing (Ratsak et. al, 1996). As far as concerned the low ciliate population density at Delhi plant, we found the lack of aeration (<1mg/L DO in aeration tank) and high organic loading (BOD= > 275mg/L; Mean COD= 623 mg/L) at input. Curds & Cockburn (1970b) stated that crawling ciliates decrease with increasing loading. Madoni (2003) founds that degree of aeration, shock load of toxic discharge, under or over loading, excessive sludge wastage and lack of aeration affect ciliate population in aeration tank unfavorably. Like bacteria, protozoan must have oxygen to survive. Thus lack of DO will severely limit both the kind and number of protozoans.

4.2.23 Coliform removal by coagulation- flocculation

Coagulation-flocculation was done with alum dosage of 10,20,30,40, 50 and 60mg/L as Al_2O_3. Optimum alum dose was taken as 60mg/L because of minimum numbers of coliforms i.e. 750 MPN/100 mL for Total Coliforms and 230MPN/100mL for Fecal Coliforms were reported at this dose. These results are shown in Table 4.18.

Table 4.18. Effect of Coagulation- Flocculation upon Total and Fecal Coliforms reduction

Alum Doses as Al_2O_3 (mg/L)	TC (MPN/100mL)	FC (MPN/100mL)
0	6400	2300
10	2300	2100
20	2100	1100
30	1100	1100
40	1100	930
50	930	750
60	750	230

4.2.24 BOD, TSS and Turbidity removal by coagulation- flocculation

At the optimum alum dose (60 mg/L) 50% of BOD, 59.47% of suspended solids and 76.02% of turbidity removal was obtained. Whereas the effluent BOD, TSS and turbidity was 26 mg/L, 35mg/l and 4.1 NTU respectively (Table 4.19).

Table 4.19 Effect of Coagulation- Flocculation upon the removal of BOD, TSS and Turbidity

Parameters	BOD (mg/L)	TSS (mg/L)	Turbidity (NTU)
STP Effluent	52	86.36	17.1
After Coagulation - Flocculation (60 mg/L for as Al_2O_3)	26	35	4.1
Removal (%)	50	59.47	76.02

4.2.25 Coagulation- flocculation of STP effluent followed by Chlorination

The chlorination was also done with same alum doses at two chlorine doses of 1 and 2 mg/L and a contact time of 30 minutes. The results are shown in Table 4.20

Table 4.20 : Descriptive data of the coliform removal by chlorination of the samples obtained after coagulation-flocculation

Alum Doses as Al_2O_3 (mg/L)	TC (MPN/100mL)		FC (MPN/100mL)	
	1mg/L Cl_2	2mg/L Cl_2	1mg/L Cl_2	2mg/L Cl_2
0	11000	9300	11000	9300
10	9300	750	9300	750
20	7500	430	7500	430
30	1100	200	1100	200
40	200	80	200	80
50	80	40	80	40
60	40	20	20	20

The observations revealed that at an optimum alum dose of 60 mg/L as Al_2O_3 followed by a chlorine dose of 2 mg/L (contact time: 30 minutes) are sufficient to remove Total coliform and Fecal coliform significantly from the effluent of Vasant kunj STP.

The chlorination of the STP effluent was also practiced without its any pretreatment by coagulation- flocculation (Table 4.21).

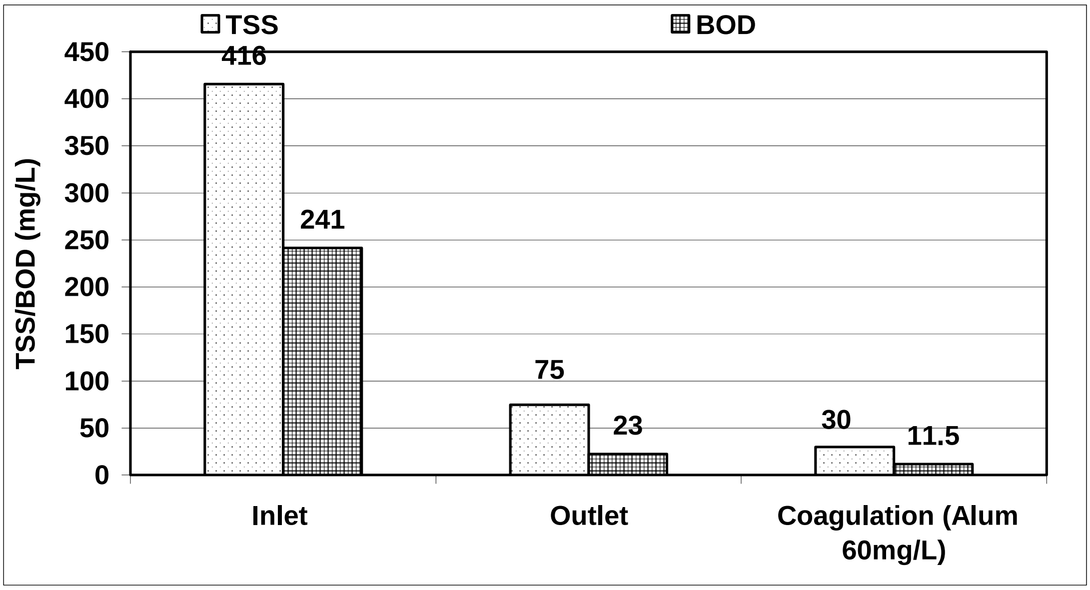
Table 4.21 Effect of Chlorine Doses on Total and Fecal Coliform removal

Dose (mg/L Chlorine)	TC (MPN/100mL) [Contact time: 30 min]	FC (MPN/100mL) [Contact time: 30 min]
0	43000	21000
1	23000	1100
2	1100	230
3	230	230
4	230	80
5	80	20
6	20	2
7	2	NIL
8	NIL	NIL

It was observed that a chlorine dose of 8 mg/L with a contact time of 30 minutes is sufficient to kill all the coliform present in the effluent sample.

4.2.26 Cumulative Efficiency of the Treatment System (Extended Aeration) Upto Augmentative Requirements

It can be seen that the normal treatment by Extended Aeration system provides efficiencies upto 81.97% for TSS and 90.46% for BOD. However, with the augmentation through coagulation-flocculation the efficiency correspondingly increases to 92.79% and 95.23% respectively (Fig 4.35 & fig 4.36).



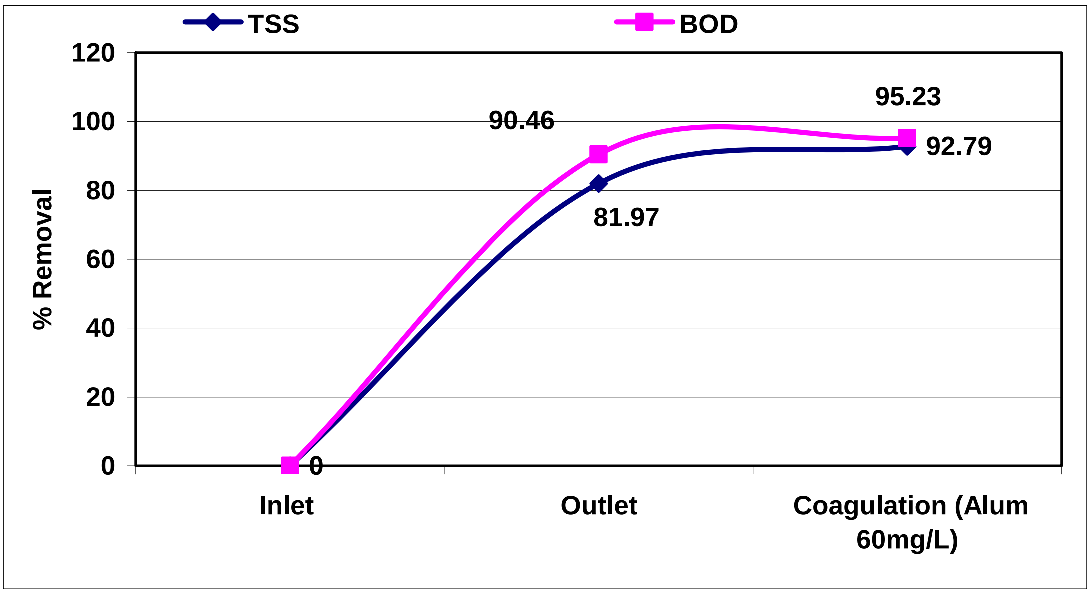
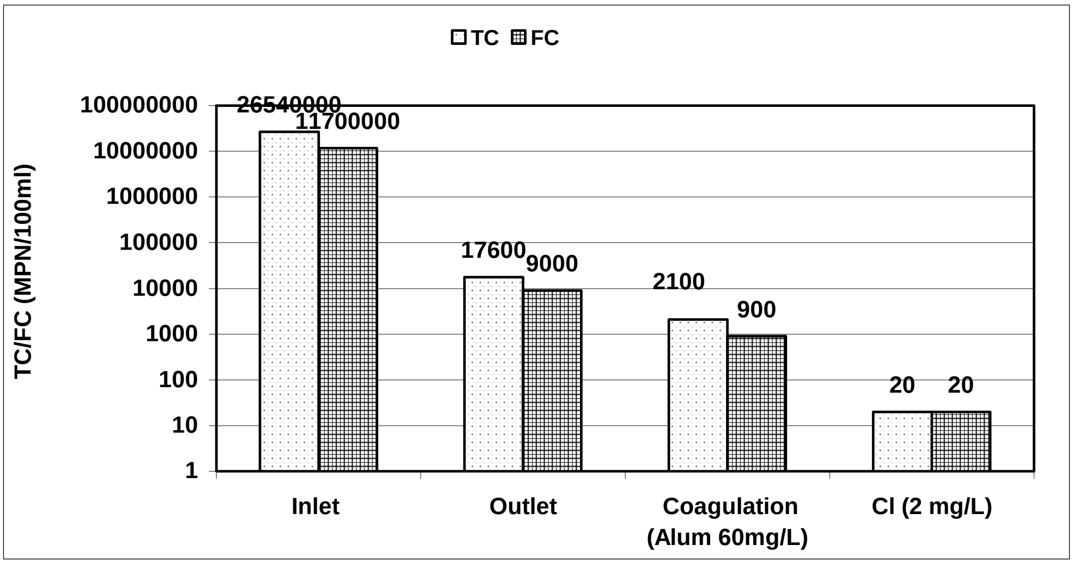


Figure 4.35& Figure 4.36 : Cumulative efficiency of the EA system w.r.t. TSS and BOD removal upto augmentative requirement

Similarly the EA system removes TC and FC upto 99.93% and 99.93% respectively. Whereas, coagulation-flocculation with optimum alum dose, the efficiency increases to 99.992% and 99.9925% respectively. Further with additional chlorination the total TC and FC removal almost 100% have been possible. Therefore, these results points towards the augmentative requirements of existing treatment system for total removal of the pathogenic content of the water (fig 4.37& fig 4.38).



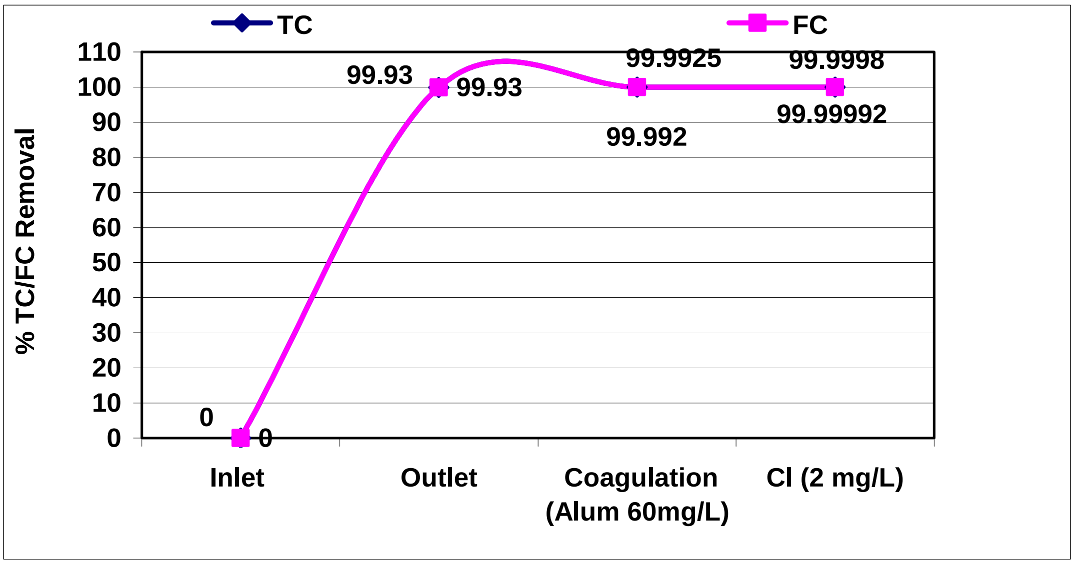


Figure 4.37 & Figure 4.38 : Cumulative efficiency of the EA system w.r.t. TSS and BOD removal upto augmentative requirement

On the basis of the observed data following observations are made**:**

1. In plant **Influent** the concentration of BOD, COD and TSS was found to vary from 202-284mg/L (Mean – 241 mg/L), 524- 726 mg/L (Mean 655 mg/L) and 301-469 mg/L (Mean 416mg/L) respectively. As per Metcalf & Eddy (1995) Typical COD concentration in the Untreated Domestic sewage ranges from 250-1000 mg/L.

2. The plant **effluent** BOD, COD and TSS Concentration was found to be in the ranges of 16-39 mg/L (Mean 23 mg/L), 50-101 mg/L (Mean 70 mg/L) and 55- 107 mg/L (Mean 75 mg/L) respectively.

3. The **mean removal efficiency** of BOD, COD and TSS has been found to be 90.4, 89.1 and 82% respectively.

4. The results showed that in **influent** concentration of TC, FC and FS varied from $9.3 \times 10^6 - 2.3 \times 10^8$ MPN/100mL (Mean 2.7×10^7 MPN/100mL), 2.3 x

10^6 – 9.3 x10^7 MPN/100 mL (Mean 1.1 x 10^7 MPN/100mL) and 1.1x 10^5 – 4.6x10^6 MPN/100mL (Mean 8.5 x 10^5 MPN/100mL).

5. TC, FC and FS concentrations in the system **effluent** was significantly lower than the influent. The effluent has concentration of TC, FC and FS varied from 1.5x 10^3 – 2.3x10^5 MPN/100mL (Mean 1.7 x 10^4 MPN/100mL), 1.1x 10^3 – 9.3 x10^4 MPN/100mL (Mean 9.0 x 10^3 MPN/100mL) and 2.1x 10^2 – 2.3x10^4 MPN/100mL (Mean 1.6 x 10^3 MPN/100mL)
6. The mean removal efficiency of TC, FC and FS was 99.92, 99.92 and 99.80. Arceivala (2004) stated that Extended Aeration system is capable for higher coliform removal than conventional activated sludge system. El. Gohary et. al,
7. 1998 reported that a removal of more than 99% in indicators of fecal pollution in terms of fecal coliform and fecal streptococci was achieved through the biological treatment process i.e. Activated sludge process.

As far as concerned about the impact of seasonal variation upon the plant efficiency following observations are made:

1. The effluent TSS was found almost similar ranges i.e. 75mg/L during all the seasons. While as no significant variation in TSS removal was observed throughout the seasons (fig. 4.39)

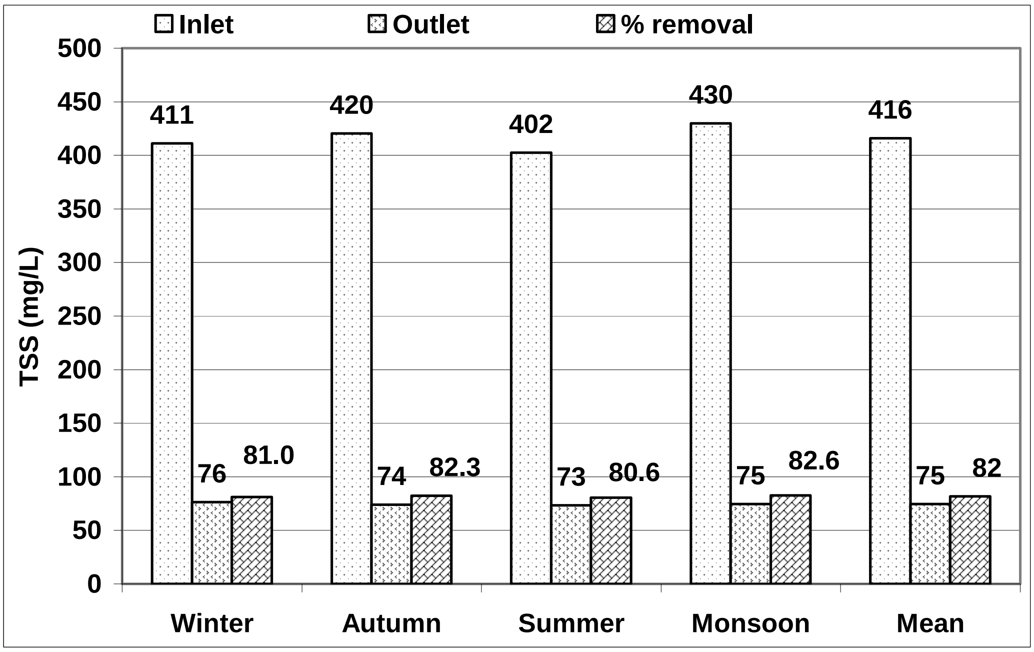


Fig. 4.39 Impact of Seasonal variations on the TSS concentration of Influent, Effluent and percentage TSS removal efficiency of Plant

2. The effluent BOD (i.e. ≈23 mg/L) as well as BOD removal during all the seasons were reported almost similar (Fig 4.40).

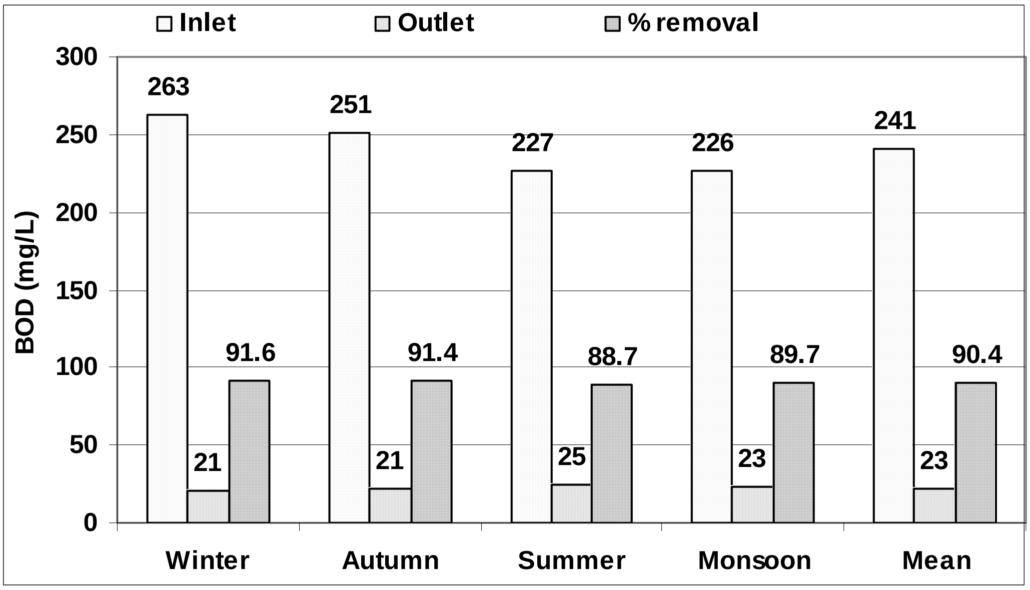


Fig.4.40 Impact of Seasonal variations on the BOD concentration of Influent, Effluent and percentage BOD removal efficiency of Plant

3. The little higher effluent COD was reported during summer and Monsoon period i.e. 72 and 76 mg/l respectively. Whereas the COD removal efficiency were similar i.e. ≈70 % during the entire study period.

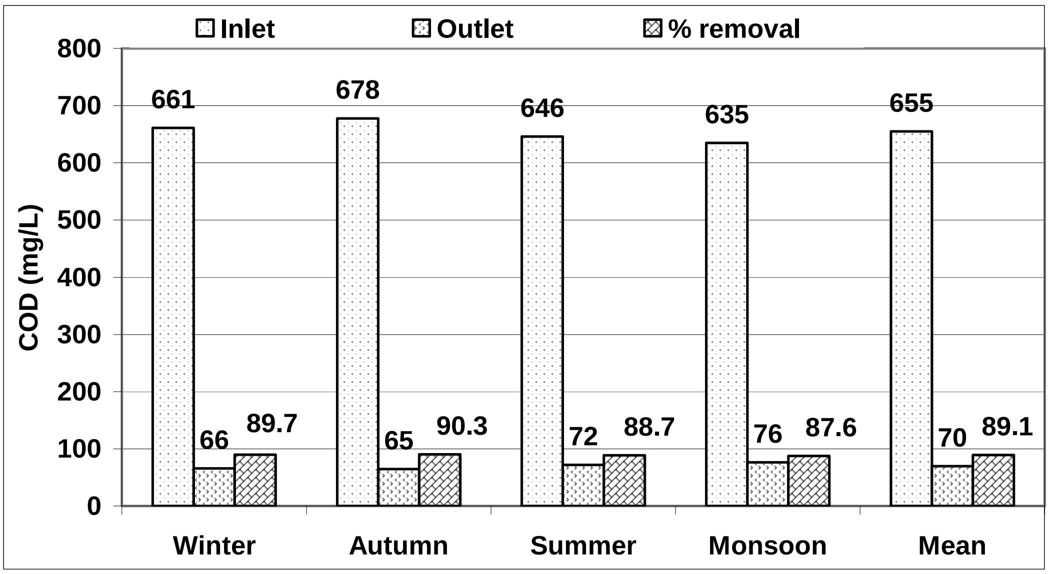
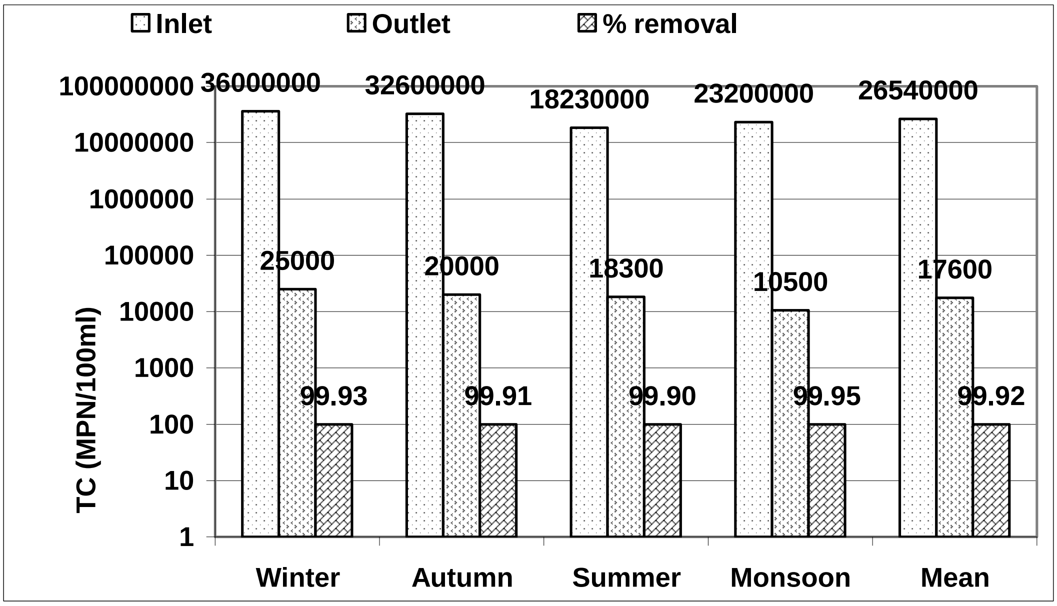


Fig. 4.41 Impact of Seasonal variations on the COD concentration of Influent, Effluent and percentage COD removal efficiency of Plant

4. The lowest effluent concentration of Total Coliform and fecal coliform was observed during monsoon period whereas the highest effluent TC concentration was noted during winter period. The highest FC concentration in the effluent was noted during winters and autumn period. Almost 3 log removal was observed for TC and FC during entire study period.



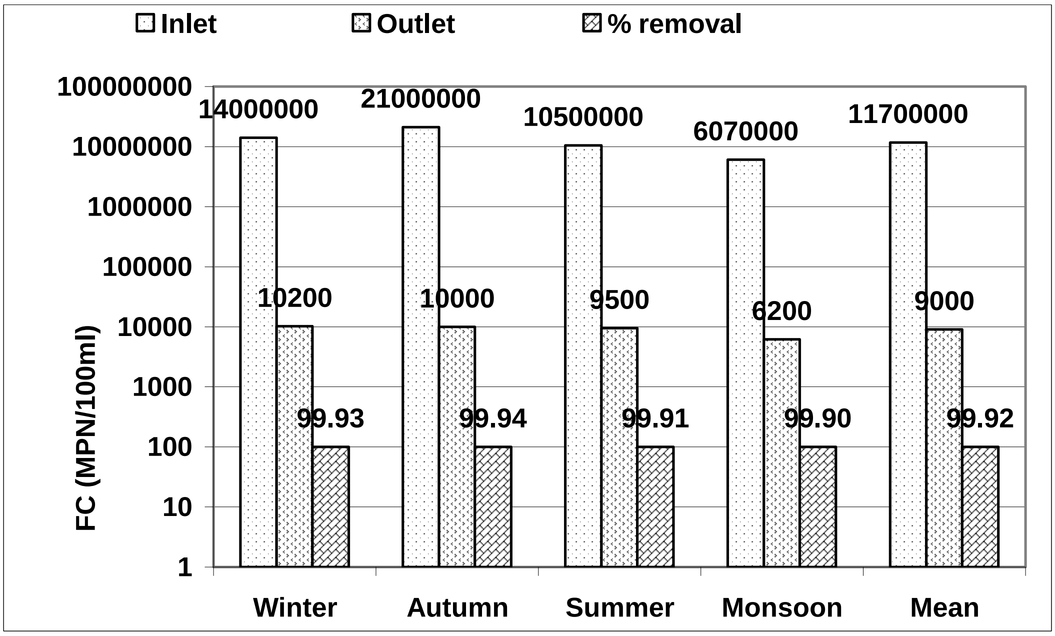


Fig 4.42. Impact of Seasonal variations on the Microbiological characteristics (TC and FC) of Influent, Effluent and their removal efficiency

5. The effluent FS concentration was reported highest in autumn and lowest in monsoon period. Furthermore the similar FS removal observed during entire study period.

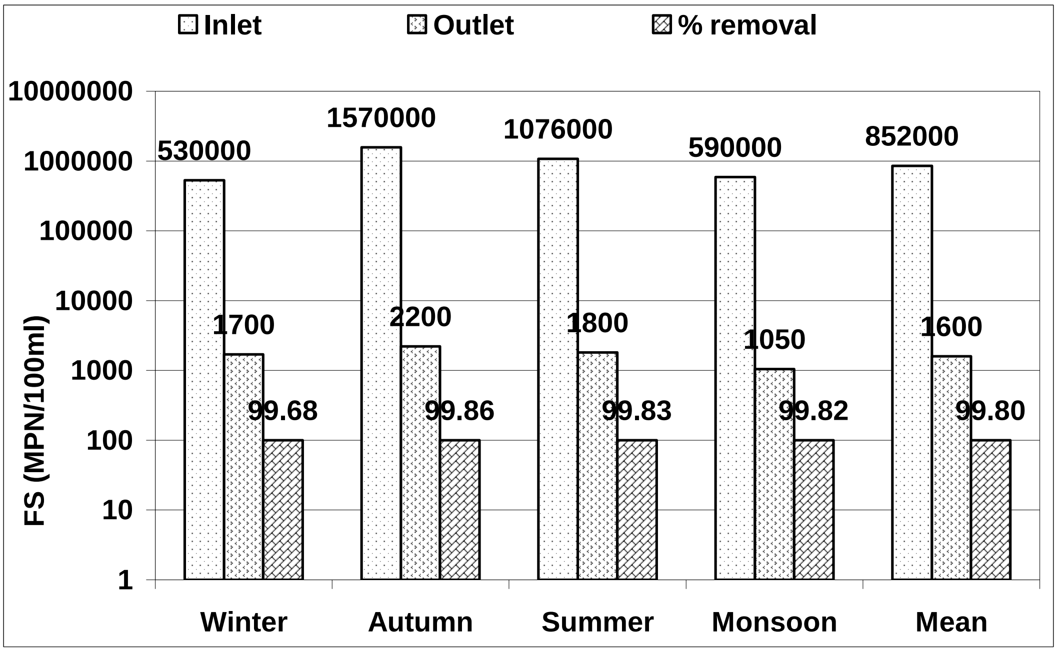


Fig 4.43. Impact of Seasonal variations on the fecal streptococci (FS) concentration of Influent, Effluent and FS removal efficiency

4.2.27 Conclusions

From this study, following conclusions are put forward for evolving recommendations in extended aeration treatment system including augmentative requirements:

TC and FC concentration in the treated effluent exceeded Log 3 or 1000 MPN/ 100ml signifying it unfit even for unrestricted irrigation. Whereas the effluent concentration of organic pollutants likes BOD, COD and SS were found within the limits.

The effluent turbidity and TSS show good correlation with the effluent concentrations of indicator microorganisms i.e. TC, FC and FS. Whereas effluent BOD show less significant correlation with indicator microorganisms as compare to SS and Turbidity. These interrelationships show that microbial numbers in secondary treatment effluents could be best modeled as a function of effluent TSS and turbidity. The relationship between Turbidity and SS with coliforms could be very useful in routine STP monitoring and up gradation of efficiency within time.

The coliforms removal efficiency of extended aeration process, Vasant kunj, Delhi were reported highest i.e. more than 3 log removal (>99.9%) among the all studied plant. But the effluent concentration of fecal coliforms was noted around 10000 MPN/100 ml, which is more than the WHO prescribed limit (1000 MPN/100ml) for reuse of waste effluent for unrestricted irrigation.

A very less protozoan fauna were encountered in aeration tank of Vasant Kunj STP as compared to ASP Haridwar. It may be considered as one of the possible reason of high effluent BOD, Turbidity, COD and TSS as compared to effluent quality of ASP Haridwar.

It was observed that even after efficient removal of suspended solids and organic load, secondary treated wastewaters still contained significant numbers of enteric bacteria. It indicates that a considerable number of microbes were free in water and could not be removed by the settling process. Therefore, an additional tertiary treatment step is needed to remove microorganisms more efficiently or to achieve the standard limits.

The **Coagulation- flocculation** with an optimum alum dose of 60 mg/L as Al_2O_3 followed by a chlorine dose of 2 mg/L (contact time: 30 minutes) are sufficient to remove significant coliform removal from the effluent of STP Vasant kunj, Delhi. A chlorine dose of 8 mg/L with a contact time of 30 minute removed all the Total and Fecal coliform from the STP effluents (without any pretreatment with coagulation and flocculation).

(4.2.28) 0.5 MLD Swarg Ashram Sewage Treatment Plant, Rishikesh (Uttrakhand)

4.2.29 Observations and Discussion

The observation revealed that the mean effluent concentration of organic (BOD, COD,SS) as well as microbial pollutant (TC, FC & FS) is not identical to the standards prescribed for effluent discharge in surface waters and for irrigational purposes.

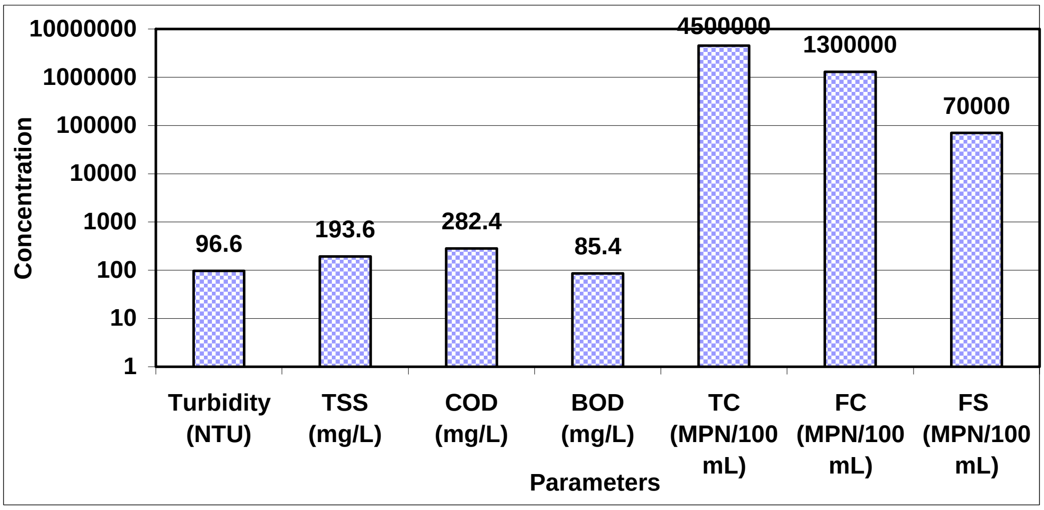


Fig. 4.44 Mean concentration of various pollutants in STP effluent

Therefore, the STP Swarg Ashram is incapable to remove the organic as well as microbial pollutants efficiently as shown in fig 4.45.

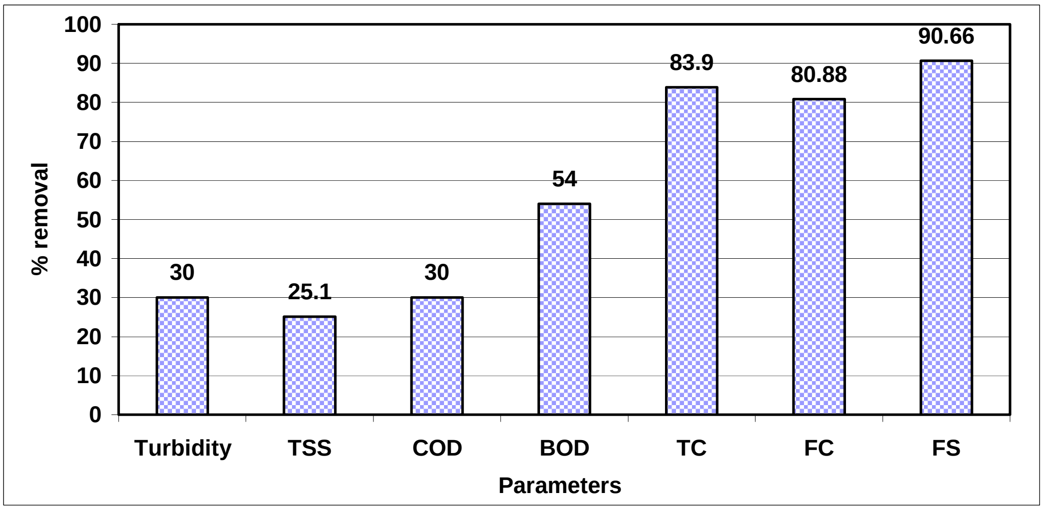


Fig. 4.45 Mean removal efficiency of various pollutants w.r.t. performance of STP Swarg Ashram

4.2.30 Conclusions

From the results of the present work following conclusions can be drawn:

1. The sewage treatment plant at Swarg Ashram has very poor performance in removal of organic, inorganic as well as microbial pollutants from the sewage.
2. Effluent characteristics of all most all the parameters of the sewage do not commensurate with effluent discharge standards.
3. By observing the concentrations of effluent parameters, the plant was abandoned and with the following suggestions:

Its performance should be upgraded like by cleaning filter beds and back washing etc.

- Check the working of both the filters (Downflow and Upflow) and their filter media, with respect to its design, if not provide it according to its design size, shape, depth etc.
- Clean up all the chambers of the plant like inlet, grit, and also primary sedimentation tank.

(4.2.31) 25 MLD Up-flow Anaerobic Sludge Blanket (UASB) Plant, Yamuna Nagar (Haryana)

4.2.32 Observations and Discussion

From the above experimental results following observations are made:

1. There were no significant variations observed in effluent pH and TDS values after treatment during all the study period.
2. In the raw sewage BOD, COD, TSS were found vary from 110-250 mg/L, 310- 428 mg/L and 201- 303 mg/L respectively.
3. The Plant effluent BOD, COD & TSS were found 25- 39 mg/L (Avg.31mg/L), 67- 107 mg/L (96 mg/L) & 40-97 mg/L (Avg. 76 mg/L) respectively. The observations revealed that the effluent BOD is more than the permissible limit i.e. 30 mg/L for discharge the effluent into surface waters.
4. The mean removal efficiency of BOD, COD and TSS were found to be 77.14, 73.87 and 66.8 respectively. Which is not satisfactory while as the two polishing pond are provided as a post treatment unit for UASB reactor outlet.
5. Observations revealed that the influent has concentration of TC, FC and FS varied from $2.3x\ 10^6 – 2.3x10^7$ MPN/100 ml, $2.3x\ 10^5 – 1.5\ x10^7$ MPN/100 ml and $2.3x\ 10^5 – 4.3x10^6$ MPN/100 ml. and for Helminthes eggs it varied from 44.5- 72 eggs/ L.. The effluent has concentration of TC, FC and FS varied from $1.9x\ 10^4 – 2.3x10^5$ MPN/100 ml (Avg. $4.6x\ 10^4$ MPN/100 ml), $2.3x\ 10^2 – 2.3\ x10^5$ MPN/100 ml (Avg. $1.8x\ 10^4$ MPN/100 ml) and $4.3x\ 10^2 – 2.3x10^4$ MPN/100 ml (Avg. $5.2x\ 10^3$ MPN/100 ml) and for Helminthes eggs it varied from 1- 2 eggs/ L (Avg. 1.3 eggs/L).
6. It was found that the removal efficiency w.r.t. TC, FC, FS and Helminthes eggs are 98.91, 98.94, 98.62 and 97.64 respectively. The mean value of FC in final treated effluent is 2.3×10^4MPN/100 ml, which is more than the permissible limit (i.e. 1000 MPN/ 100ml) specified by WHO (1989) for unrestricted irrigation. The Mean concentration of helminthes eggs in

7. effluent was found 1.3 eggs/ L. It is also above the permissible limit (< 1 eggs/L) as recommended by WHO for unrestricted irrigation.

4.2.33 Conclusions

1. The plant is incapable to remove the concerned microbial parameters i.e. Total
2. Coliform, Fecal Coliform, Fecal Streptococci and Helminthes eggs efficiently. The STP effluent does not fulfill the microbiological standard criteria as per recommended by WHO (1989) for unrestricted irrigation.
3. No significant correlation between Physico-chemical and microbiological parameters for influent and effluent was found at this plant.
4. The purpose of sewage treatment is to remove the contaminants in the wastewater at low cost, so that the final effluent can be discharged into receiving water with minimal impact on the subsequent use of water. Sewage treatment must be viewed as whole, rather than as a series of separate process stages. Furthermore, upstream process, namely preliminary treatment and primary treatment have an effect on the downstream, secondary process selection and performance (Thomas et al., 1995).

4.3 Physico-chemical and Microbiological Characteristic

The changes in Physico-Chemical characteristics such as pH, TSS, BOD, COD and TSS of sewage samples from five STPs collected during the period of sampling are presented and discussed in this section.

4.3.1 Decentralized wastewater treatment system (DEWATs)

Table 4.22 summarizes the physico-chemical characteristics of samples collected from DEWATs during the month of May 2004 to January, 2005. The raw sewage was neutral to slightly alkaline and was slightly alkaline after treatment.

Table: 4.22 Performance of Decentralized wastewater treatment system (May 2004 to January, 2005)

Month and Date of Sampling	PH		TSS (mg/L)		COD (mg/L)				BOD (mg/L)			
					Total		Soluble		Total		Soluble	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
May (03.05.04)	6.96	7.98	653	300	490	149	261	117	222	138	173	70
May (12.05.04)	6.76	8.06	482	285	501	207	181	37	275	109	80	20
June (02.06.04)	6.46	8.32	663	355	272	144	184	80	217	69	192	40
June (14.06.04)	6.26	8.14	629	358	277	128	176	101	206	49	169	33
July (12.07.04)	6.92	7.99	786	158	810	76	323	45	350	37	276	19
July (19.07.04)	6.80	8.02	723	211	709	85	293	58	305	52	240	15
August (25.08.04)	6.78	8.15	383	71	917	53	352	24	590	19	344	14

[Table: 4.22 Continued…]

September (03.09.04)	7.06	7.95	1037	265	1120	171	351	133	749	79	296	20
November (01.11.04)	7.12	7.59	327	108	581	59	128	37	216	24	139	17
November (25.11.04)	7.02	7.66	288	62	603	69	171	37	266	62	150	51
December (14.12.04)	7.04	7.73	336	96	640	203	149	69	354	35	161	35
January (05.01.05)	6.86	7.92	825	89	720	321	75	44	360	195	35	28

Monthly variations in COD (Total and Soluble) value of raw and treated sewage samples are presented in Figure 4.46. During the month of September a very high organic load (COD-T) was observed in raw sewage samples. It was also observed that the COD removal was very high during the month of August 2004 around 94 and 93% for COD-T and COD-S respectively. Ratio between COD-T and COD-S was on an average 2.5 and 2.1 for both raw and treated sewage samples.

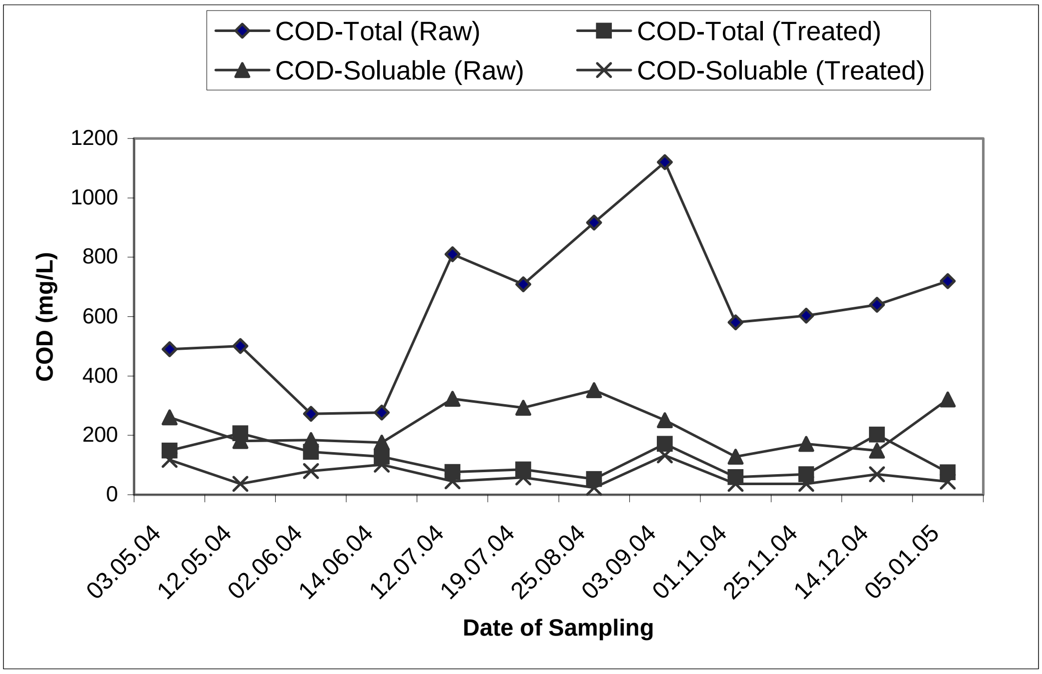


Figure 4.46 Variation in COD (Total & Soluble) of DEWATs samples

Variations in BOD (Total and Soluble) of raw and treated samples during May 2004 – December, 2004 are given in Figure 4.47. It was found that the BOD-T removal efficiency of the treatment plant was 38 to 97%with an average removal efficiency of 78% and for BOD-S it varied from 60 to 96%.

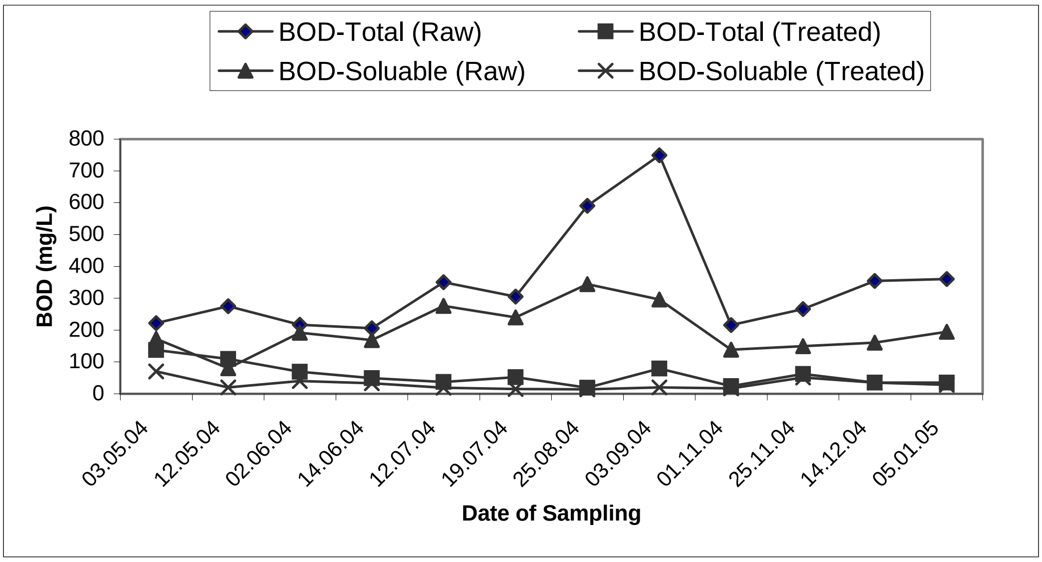


Figure 4.47 Variation in BOD (Total & Soluble) of DEWATs samples.

While treating primary treated sewage in an anaerobic baffled filter with plastic media, Bodik *et al.,* (2002) observed 93.4% BOD removal and 78.6% of COD removal. Kobayashi *et al.,* (1983) treated low strength kitchen waste in an anaerobic filter with PVC media and reported an average removal of 79%, 73% of BOD and COD removal, respectively. The Anaerobic baffled reactor is known to reduce BOD mainly in the suspended form, which settles in the reactor (Ludwig, 1998). Dama *et al.,* (2002) evaluated the baffled reactor for treating domestic wastewater and observed 60% reduction in COD at 60 h HRT.

From the Figure 4.48 it can be observed that, during the month of September 2004 the TSS value for raw sample was very high (1037 mg/L) in the month of November 2004 and it was very low (288 mg/L) with average value of 573 mg/L. In the case of treated samples, a minimum of 17 mg/L and maximum of 358 mg/L were observed. TSS removal varied from 41% to 95% during May to December 2004. Bodik *et al.,* (2002) have reported a TSS removal of around 84% with anaerobic baffled reactor.

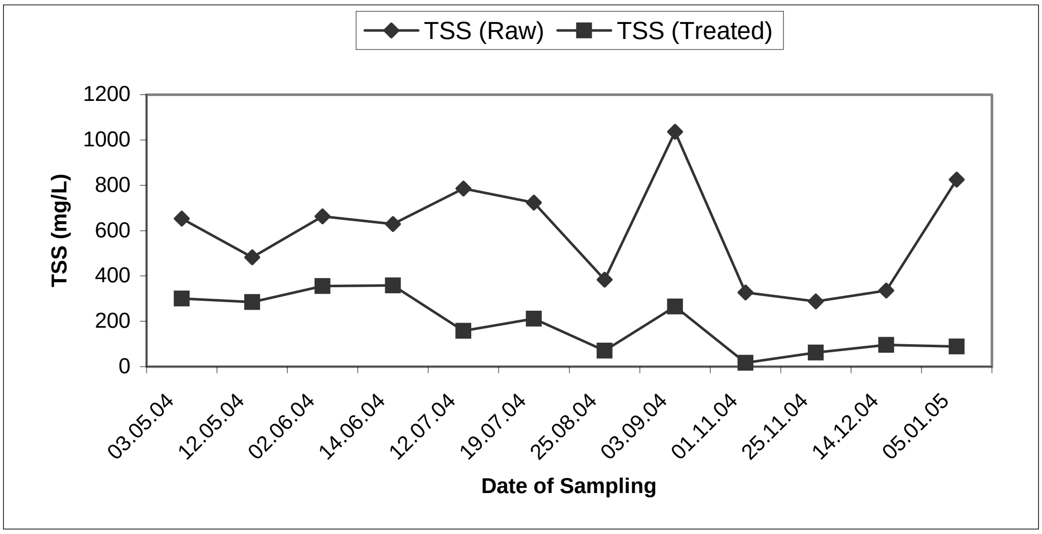


Figure 4.48 . Variation in TSS of DEWATs samples

Table: 4.23 Microbial load of Decentralized Wastewater Treatment System (May 2004 to January 2005)

Month and Date of Sampling	Sampling time	Flow rate (L/h)	Microbial Indicators (X 10^4MPN/100 mL)							
			Total Coliform		Fecal Coliform		*E.Coliform*		Fecal Streptococci	
			Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
May (03.05.04)	8.00 AM	72	670	69	670	69	370	37	-	-
	10.00 AM	225	980	9.89	670	6.7	670	3.7	50	0.37
	8.00 PM	180	980	67	980	67	370	9.8	-	-
May (12.05.04)	10.00 AM	210	580	68	500	11	370	5	100	0.68
	12.00 Noon	220	3700	9.8	980	9.8	500	0.68	-	-
	6.00 PM	180	50000	68	37000	11	6800	6.8	-	-
June (02.06.04)	8.00 AM	120	680	50	500	50	190	37	-	-
	10.00 AM	180	3700	9.8	3700	6.8	1900	3.7	68	3.7
	8.00 PM	180	980	9.8	680	9.8	370	5	-	-
June (14.06.04)	10.00 AM	180	670	5	670	3.7	500	0.98	67	0.68
	12.00 Noon	210	3700	37	3700	19	1800	6.8	-	-
	6.00 PM	180	980	37	980	37	670	5	-	-
July (12.07.04)	8.00 AM	72	6800	6.8	5000	5	5000	3.7	-	-
	10.00 AM	225	6800	9.8	5000	5	2300	3.7	370	0.29
	8.00 PM	180	9800	6.8	6800	3.7	3700	2.9	-	-
July (19.07.04)	10.00 AM	210	6800	9.8	5000	6.8	3700	1.9	680	0.5
	12.00 Noon	210	5000	6.8	2900	3.7	2300	2.3	-	-
	6.00 PM	180	5000	5	3700	3.7	370	0.98	-	-
August (25.08.04)	10.00 AM	210	5000	9.8	1300	6.8	1100	5	500	0.38
	12.00 Noon	220	38000	11	19000	9.8	9800	6.8	-	-
	6.00 PM	180	50000	50	50000	38	38000	11	-	-
September (03.09.04)	8.00 AM	120	6800	50	5000	11	1900	7.8	-	-
	10.00 AM	180	7800	11	6800	7.8	5000	6.8	1300	0.78
	8.00 PM	180	38000	98	19000	68	9800	50	-	-
November (25.11.04)	8.00 AM	120	500	19	500	9.8	380	6.8	-	-
	10.00 AM	180	980	98	680	98	680	50	13	0.68
	8.00 PM	180	3800	68	1900	68	980	38	-	-
November (01.11.04	10.00 AM	180	680	38	380	19	380	6.8	19	3.8
	12.00 Noon	210	5000	19	3800	19	1900	6.8	-	-
December (14.12.04)	8.00 AM	72	1900	68	680	38	680	38	-	-
	10.00 AM	225	6800	380	5000	190	5000	98	50	1.1
	8.00 PM	180	1900	98	980	68	500	50	-	-
January (05.01.05)	10.00 AM	220	980	9.8	680	6.8	680	3.7	13	0.5
	12.00 Noon	220	500	6.8	290	3.7	230	2.2	-	-
	6.00 PM	180	500	5	370	3.7	370	2.5	-	-

The variations in microbial load at different time intervals of raw and treated wastewater are illustrated in **Figures 4.49 to 4.53**

- In 8 AM samples, the bacterial load was high in July and September 2004. Interestingly, the treatment of wastewater was better during these months when compared to other months.

- In 10 AM samples, during the study period bacterial load increased and decreased intermittently. The order of treatment efficiency was: September>July>August. Least efficiency of treatment was observed in May 2004.
- In 12 Noon samples, bacterial load of raw wastewater increased stepwise during May 2004 – August 2004. Better treatment was observed in July 2004 and August 2004 as compared to May 2004 and June 2004.
- In 6 PM samples bacterial load was higher, May 2004 and August 2004. It can be due to animal waste contamination (Govindan, 1985). The better treatment also observed in these months as compared to June 2004 and July 2004.
- In 8 PM samples, stepwise increase in bacterial load was observed in raw wastewater. High bacterial load was observed in September, July, June and May 2004. The better treatment was observed in July 2004 as compared to other months. Least treatment was observed in the month of May 2004.

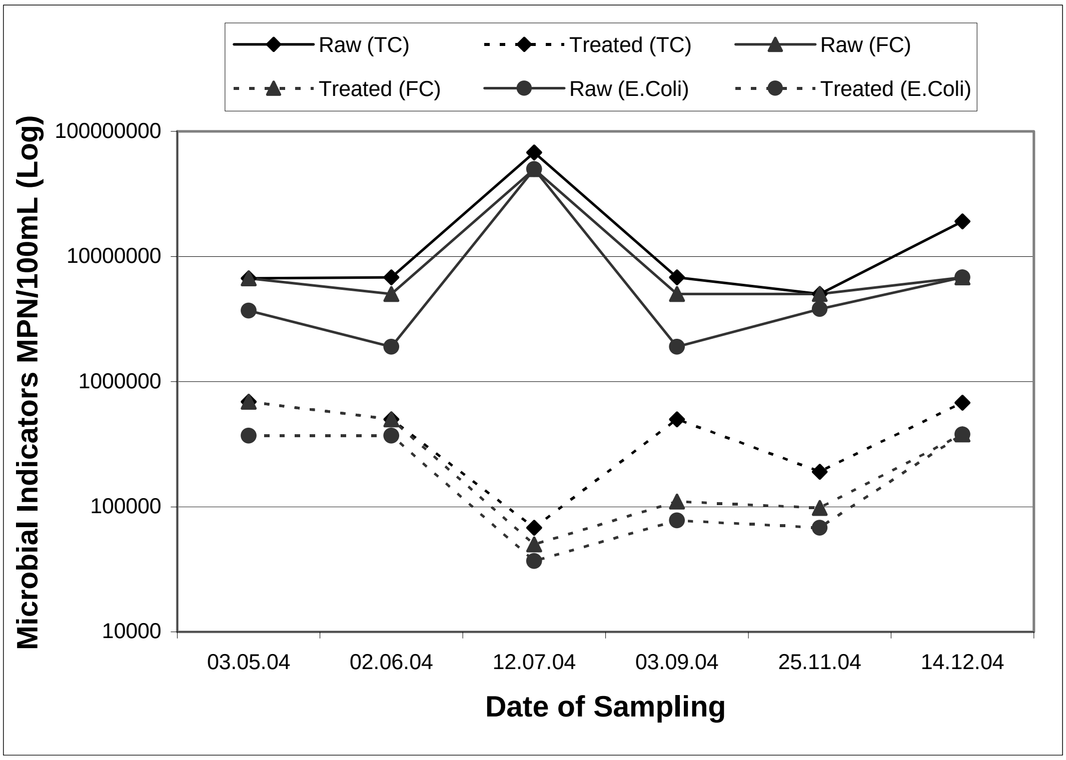


Figure 4.49 Variation in microbial load of DEWATs at 8.00 AM samples

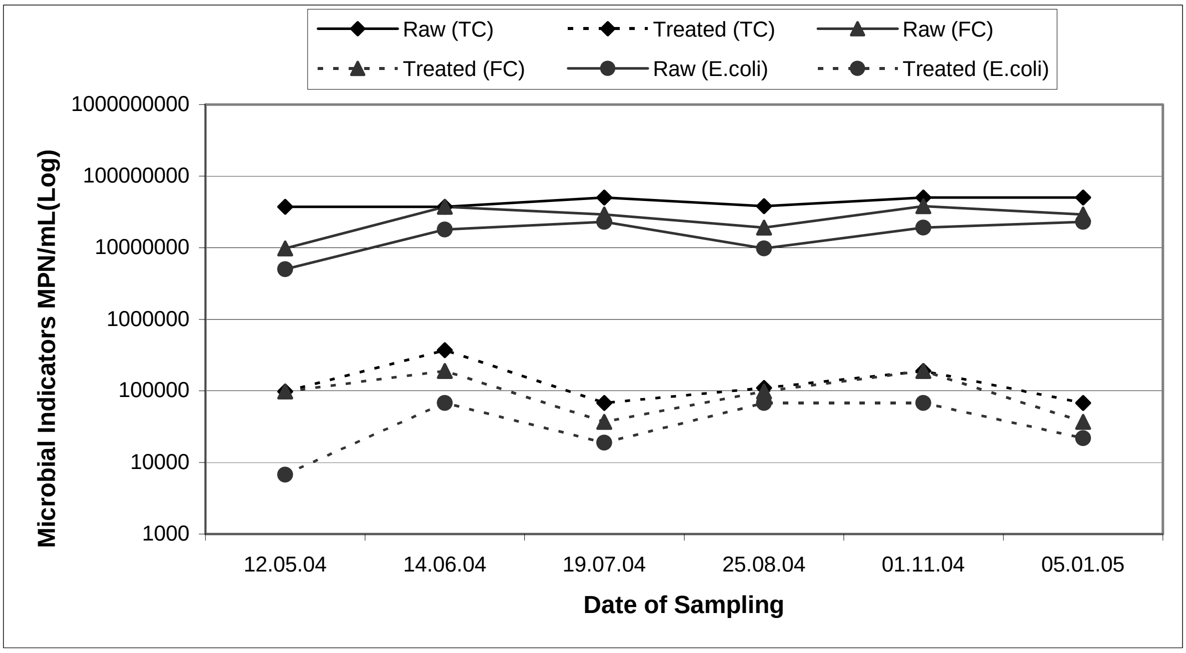


Figure 4.50 Variation in microbial load of DEWATs at 12.00 Noon Samples

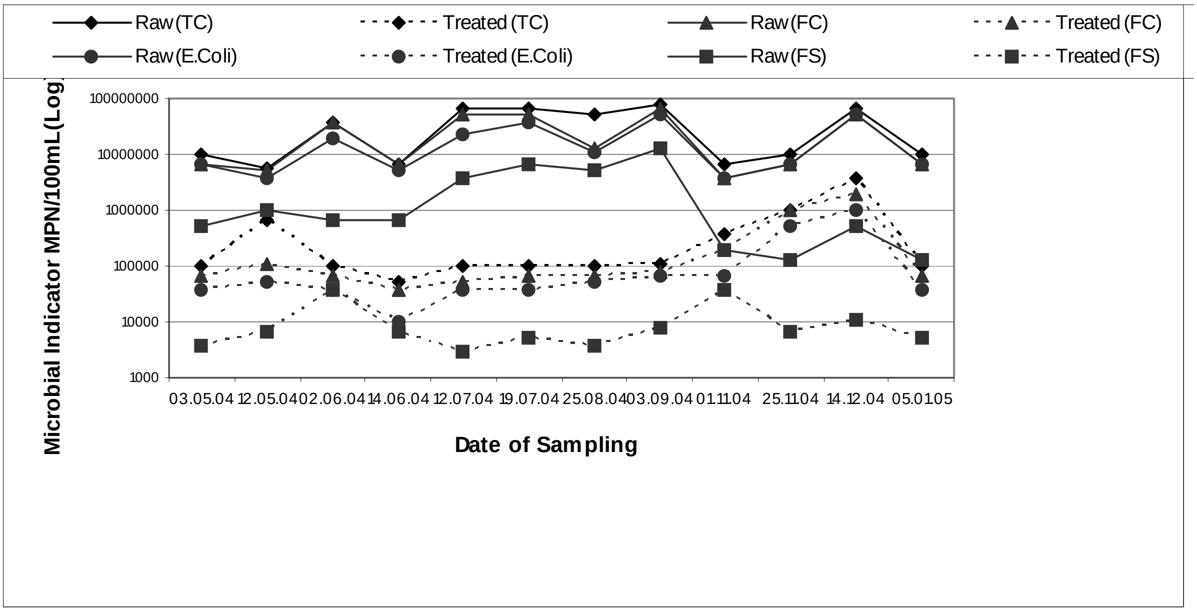


Figure 4.51 Variations in microbial load of DEWATs at 10.00 AM samples

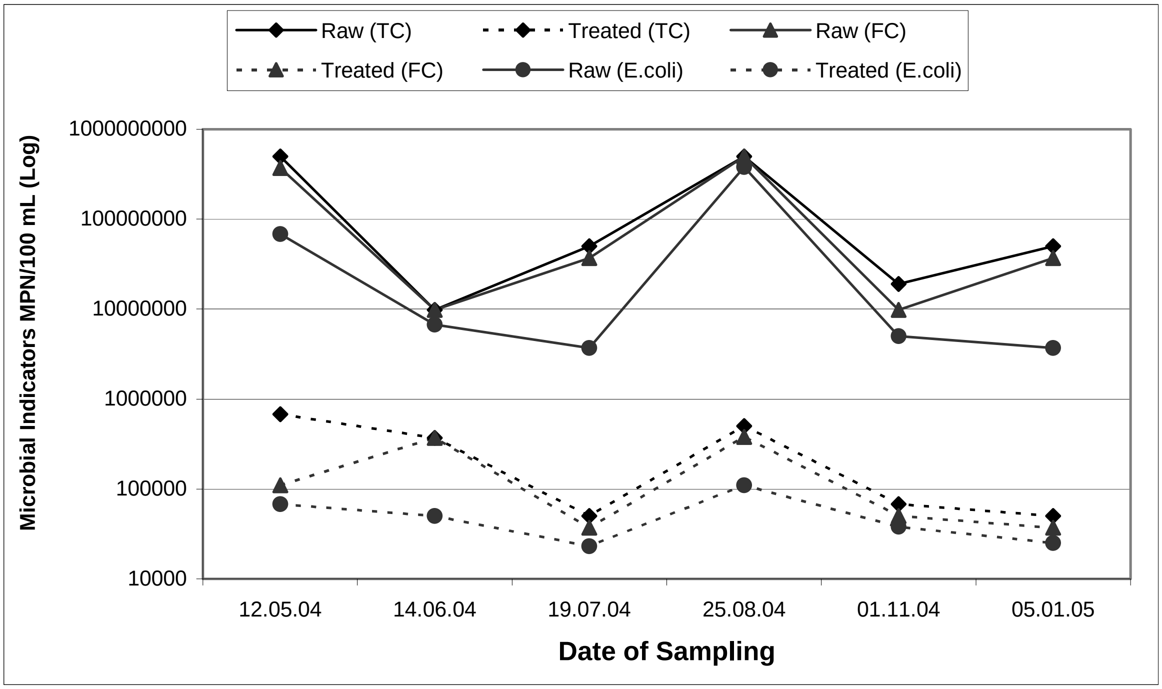


Figure 4.52 Variation in microbial load of DEWATs at 6.00 PM samples

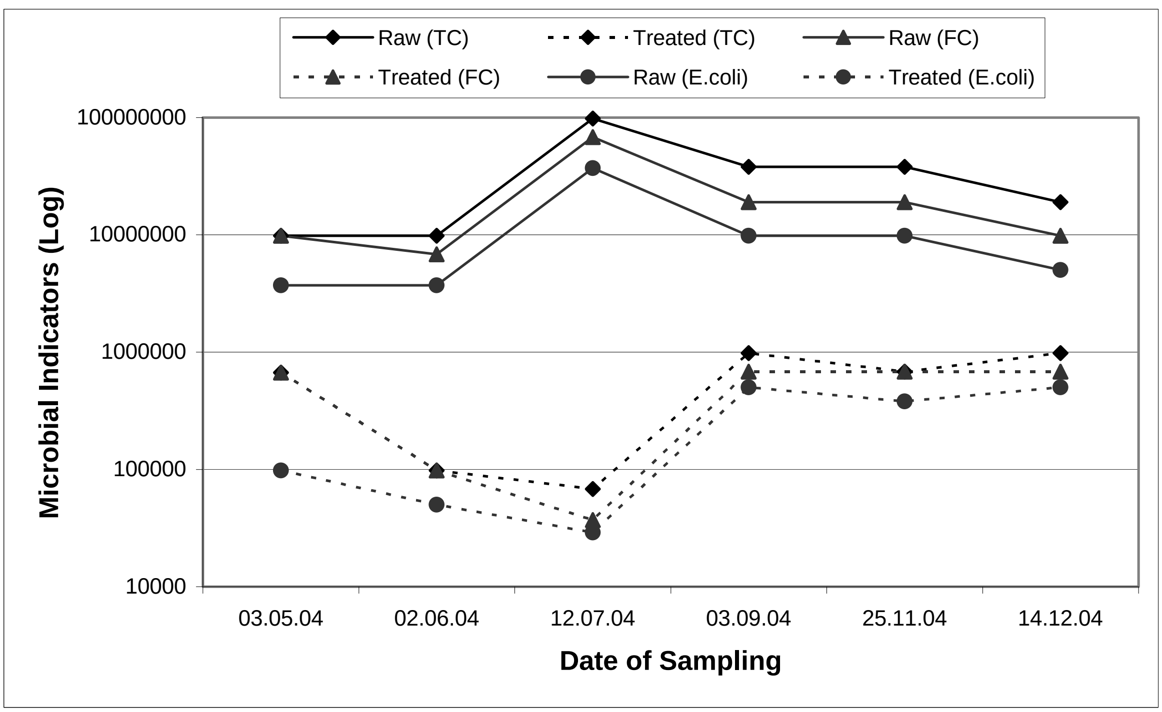


Figure 4.53 Variation in microbial load of DEWATs at 8.00 PM samples

4.3.2 Nesapakkam Sewage Treatment Plant

Table 4.24 presents the Physico-chemical characteristics of Nesapakkam samples collected during May 2004 – January, 2005. Treated effluent from the treatment plant was alkaline, pH of the effluent increasing marginally after treatment.

Table: 4.24 Performance of Nesapakkam sewage treatment plant (May 2004 to January 2005)

Month and Date of Sampling	PH		TSS (mg/L)		COD (mg/L)				BOD (mg/L)			
					Total		Soluble		Total		Soluble	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
May (11.05.04)	7.26	8.02	1463	534	1290	112	458	104	467	81	300	68
May (26.05.04)	7.14	7.99	904	95	1200	77	149	64	493	67	125	41
June (11.06.04)	7.30	8.18	740	192	1098	136	618	128	503	84	379	73
June (28.06.04)	7.33	8.05	1077	270	1533	120	400	114	579	82	276	50
July (15.07.04)	7.43	8.12	1412	432	1226	197	352	192	671	90	207	44
August (02.08.04)	7.22	7.90	1143	379	1226	96	373	80	632	54	316	45
August (28.08.04)	7.23	7.89	1312	142	1656	288	635	203	556	44	286	19
September (14.09.04)	7.25	7.93	1080	33	1552	107	400	80	430	26	180	20
October (01.10.04)	7.32	8.36	909	167	1029	56	363	37	488	53	252	31
October (13.10.04)	7.42	8.25	1482	454	1344	168	384	136	581	21	221	14
November (03.11.04)	7.35	8.37	1256	395	1099	112	384	96	445	15	187	5
November (19.11.04)	7.45	8.27	926	69	1296	139	416	91	613	49	245	27
December (07.12.04)	7.30	8.08	450	35	519	88	176	46	236	24	98	13
December (16.12.04)	7.26	8.15	613	164	1158	120	361	76	546	59	233	20
January (20.01.05)	7.35	8.03	1120	147	1254	487	45	82	560	258	48	26

It was observed that, during December 2004 organic load was very low in raw sewage samples, may due to the dilution effect of heavy rains. Very high COD-T (95%) and COD-S (90%) removal was observed during October 2004.

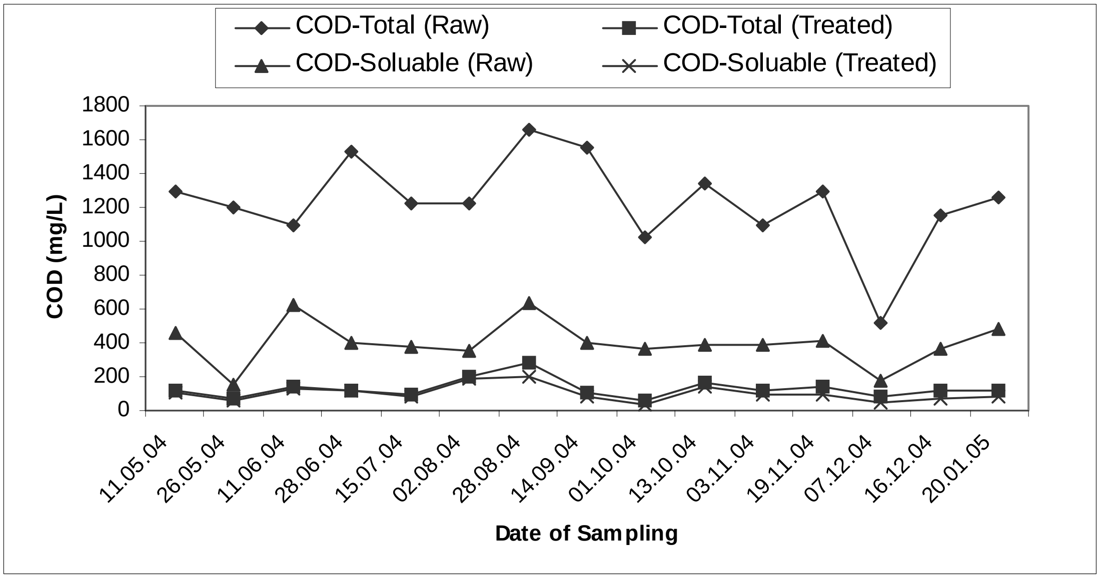


Figure 4.54 Variation in COD (Total & Soluble) of Nesapakkam samples.

A very high BOD (T & S) removal of around 97% was observed during November 2004 (Figure 4.55). Average BOD-T and BOD-S removal efficiency of the sewage treatment plant was around 90 and 86%, respectively. COD-T to BOD-T ratio of the raw sewage was in the range of 1.83 to 3.61 and for treated samples it varied from 1.00 to 6.55. The high value of COD-T: BOD-T indicates that a large fraction of the organic matter in treated samples was non-biodegradable or less biodegradable (Ingallinella *et al*., 1998).

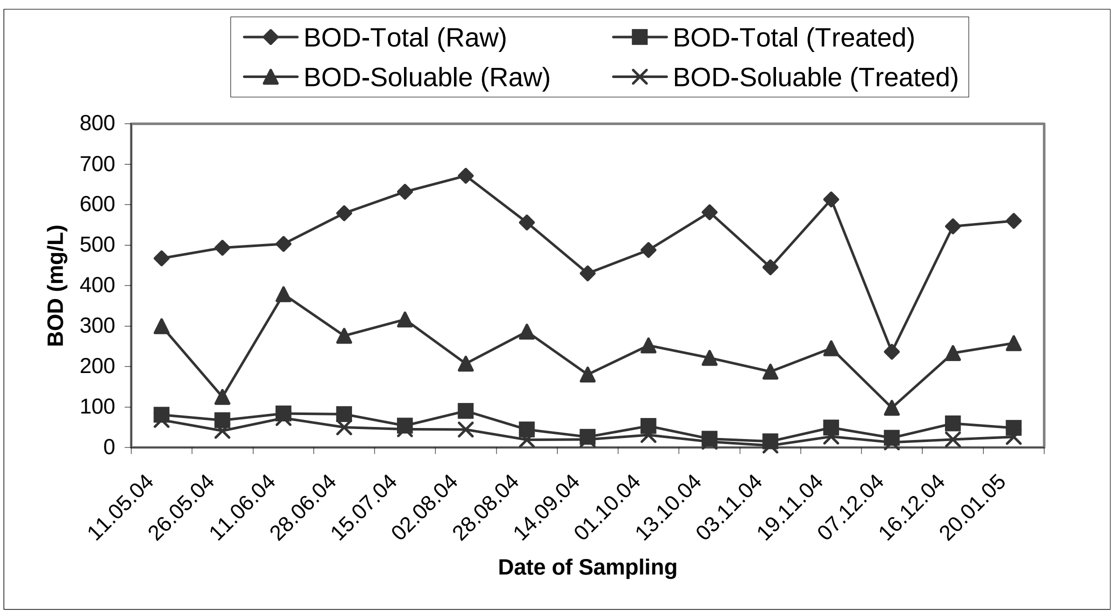


Figure 4.55 Variation in BOD (Total & Soluble) of Nesapakkam samples

Figure 4.56 indicates that TSS in raw sewage was minimum (450 mg/L) in December 2004 and maximum (1482 mg/L) during October 2004 with an average of 1055 mg/L. In the treated effluent it varied from 33 mg/L to 534 mg/L during September 2004 and May 2004, respectively with an average of 240 mg/L. The removal efficiency of the treatment plant was in the range of 63% to 97%.

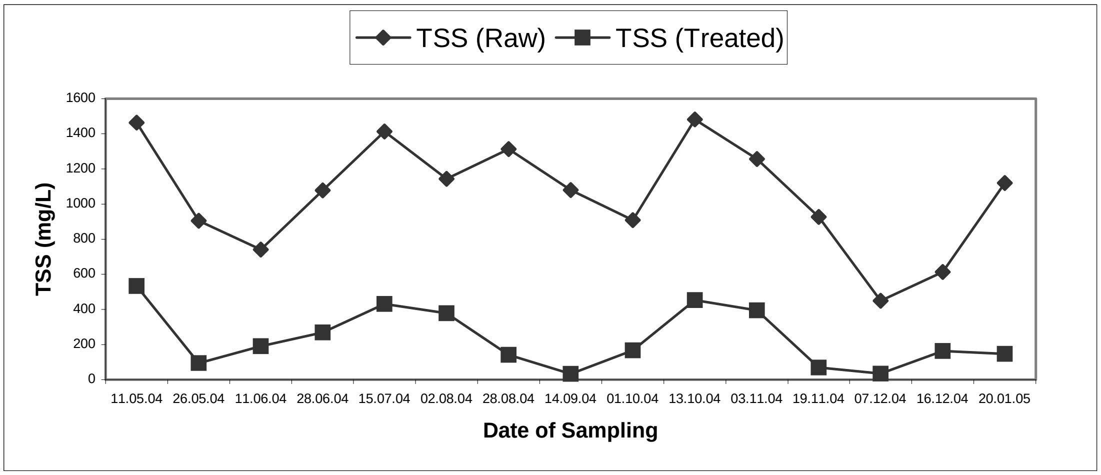


Figure 4.56 Variation in TSS of Nesapakkam samples

Table: 4.25 Microbial load of Nesapakkam Sewage Treatment Plant samples (May 2004 to January 2005)

Month and Date of Sampling	Sampling time	Flow rate (m^3)	Microbial Indicators ($X\ 10^4$ MPN/100 mL)							
			Total Coliforms		Faecal Coliforms		*E.Coli*		Faecal Streptococci	
			Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
May (11.05.04)	8.00 AM	40	3700	980	3700	980	500	190	-	-
	10.00 AM	45	19000	370	9800	370	980	68	680	37
	8.00 PM	28	1900	98	980	68	680	68	-	-
May (26.05.04)	10.00 AM	45	9800	68	6800	68	980	68	500	7.8
	12.00 Noon	36	9800	50	6800	37	680	9.8	-	-
	6.00 PM	-	-	-	-	-	-	-	-	-
June (11.06.04)	8.00 AM	35	6700	670	5000	670	3700	500	-	-
	10.00 AM	35	500000	670	370000	670	180000	500	5000	50
	8.00 PM	25	6700	1900	6700	1900	3700	980	-	-
June (28.06.04)	10.00 AM	35	5000	500	5000	500	3700	370	980	98
	12.00 Noon	40	98000	980	19000	670	6700	500	-	-
	6.00 PM	25	6700	190	6700	190	3700	98	-	-
July (15.07.04)	10.00 AM	35	680	98	500	68	370	37	68	5
	12.00 Noon	40	980	68	680	50	500	29	-	-
	6.00 PM	35	980	68	680	50	370	37	-	-
August (02.08.04)	8.00 AM	40	50000	180	9800	98	5000	18	-	-
	10.00 AM	45	50000	670	37000	500	9800	370	1800	180
	8.00 PM	28	6700	670	5000	500	3700	67	-	-
August (28.08.04)	10.00 AM	45	11000	980	9800	680	6800	130	5000	30
	12.00 Noon	36	50000	500	13000	380	7800	190	-	-
	6.00 PM	35	98000	1900	68000	680	50000	500	-	-
September (14.09.04)	8.00 AM	35	1100	680	980	500	680	380	-	-
	10.00 AM	35	9800	980	5000	680	3800	380	1900	50
	8.00 PM	25	11000	500	5000	380	3800	190	-	-

[Table: 4.25 Continued…]

Month and Date of Sampling	Sampling time	Flow rate (m^3)	Microbial Indicators (X 10^4MPN/100 mL)							
			Total Coliforms		Faecal Coliforms		*E.Coli*		Faecal Streptococci	
			Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
October (13.10.04)	8.00 AM	30	11000	680	6800	500	5000	110	-	-
	10.00 AM	35	98000	5000	68000	1900	50000	680	110	13
	8.00 PM	25	5000	680	5000	500	1900	190	-	-
October (01.10.04)	10.00 AM	40	50000	500	50000	380	19000	190	680	50
	12.00 Noon	35	9800	980	6800	500	3800	500	-	-
	6.00 PM	30	6800	5000	5000	3800	1900	1900	-	-
November (19.11.04)	8.00 AM	35	9800	980	6800	500	3800	380	-	-
	10.00 AM	40	38000	5000	9800	1100	6800	1100	500	78
	8.00 PM	30	6800	380	5000	380	1300	110	-	-
November (03.11.04)	10.00 AM	35	50000	980	50000	980	38000	680	110	11
	12.00 Noon	35	98000	6800	68000	1300	50000	980	-	-
	6.00 PM	30	38000	5000	19000	3800	3800	1100	-	-
December (16.12.04)	8.00 AM	30	6800	1900	5000	980	3800	680	-	-
	10.00 AM	35	68000	5000	68000	5000	50000	3800	680	98
	8.00 PM	30	6800	1900	3800	980	3800	680	-	-
December (07.12.04)	10.00 AM	35	5000	500	3800	130	1900	130	680	6.8
	12.00 Noon	35	19000	980	9800	980	9800	680	-	-
	6.00 PM	30	6800	190	5000	98	3800	68	-	-
January (20.01.05)	10.00 AM	45	9800	980	5000	680	3800	380	1900	50
	12.00 Noon	40	980	68	680	50	500	29	-	-
	6.00 PM	35	980	68	680	50	380	37	-	-

Variations in microbial load at different time intervals in raw and treated wastewater during the treatment are depicted in Figures 4.57 to 4.61

- In 8 AM samples, treatment was better in the month of August and June 2004. The treatment appeared to be least effective in the month of September, 2004.
- In 10 AM samples, the raw sewage showed intermittent variations in bacterial load and very high load was observed in June 2004. Better treatment efficiency was also observed in the same month as compared to other months.

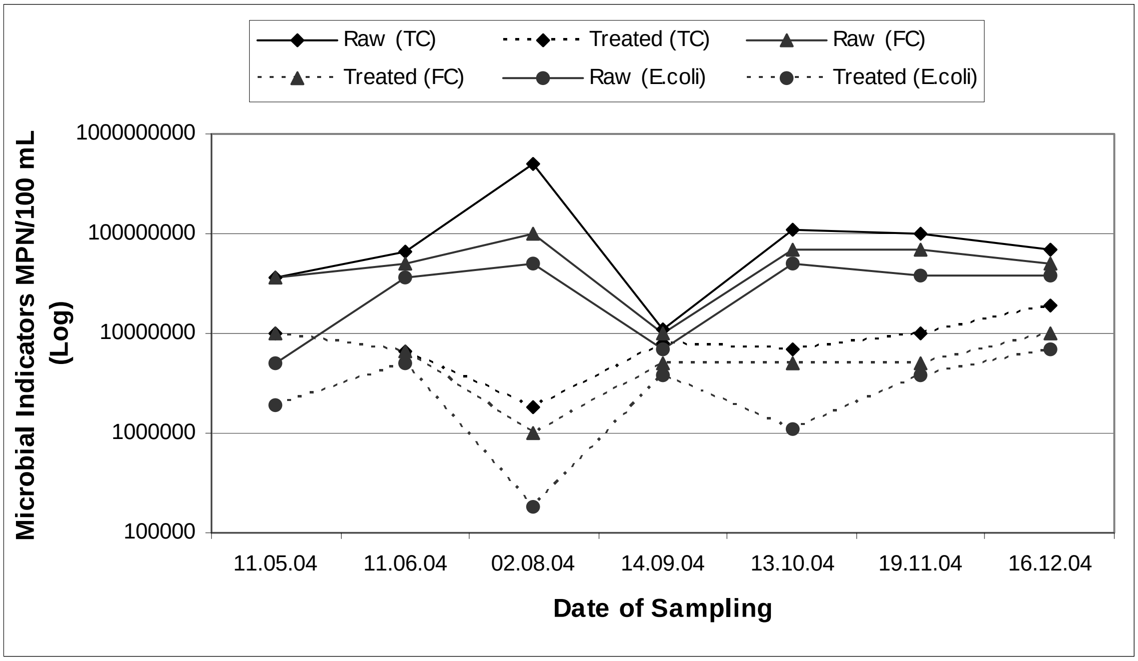


Figure 4.57 Variation in microbial load of Nesapakkam STP at 8.00 AM samples

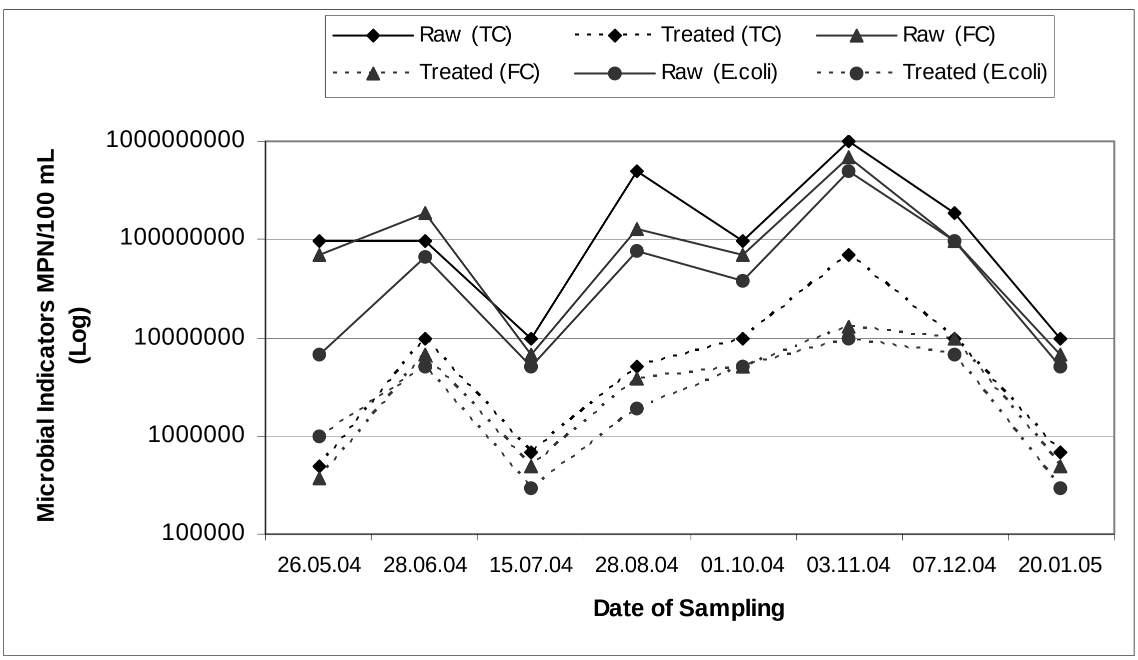


Figure 4.58 Variation in microbial load of Nesapakkam STP at 12.00 Noon Samples

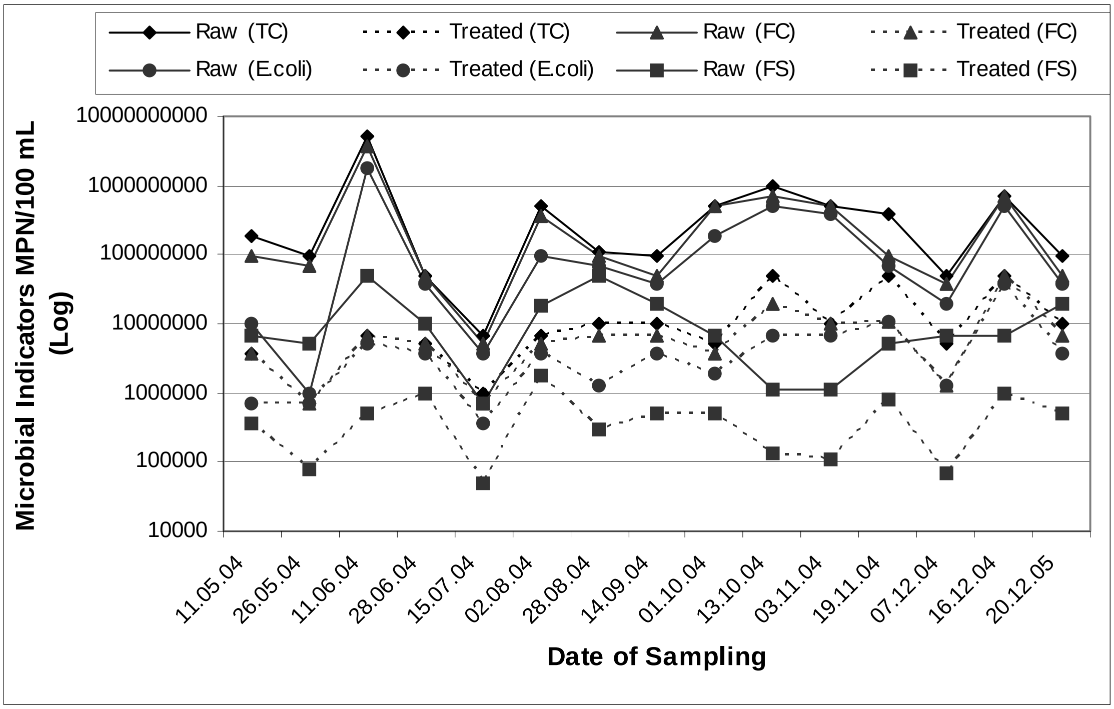


Figure 4.59 Variations in microbial load of Nesapakkam STP at 10.00 AM samples

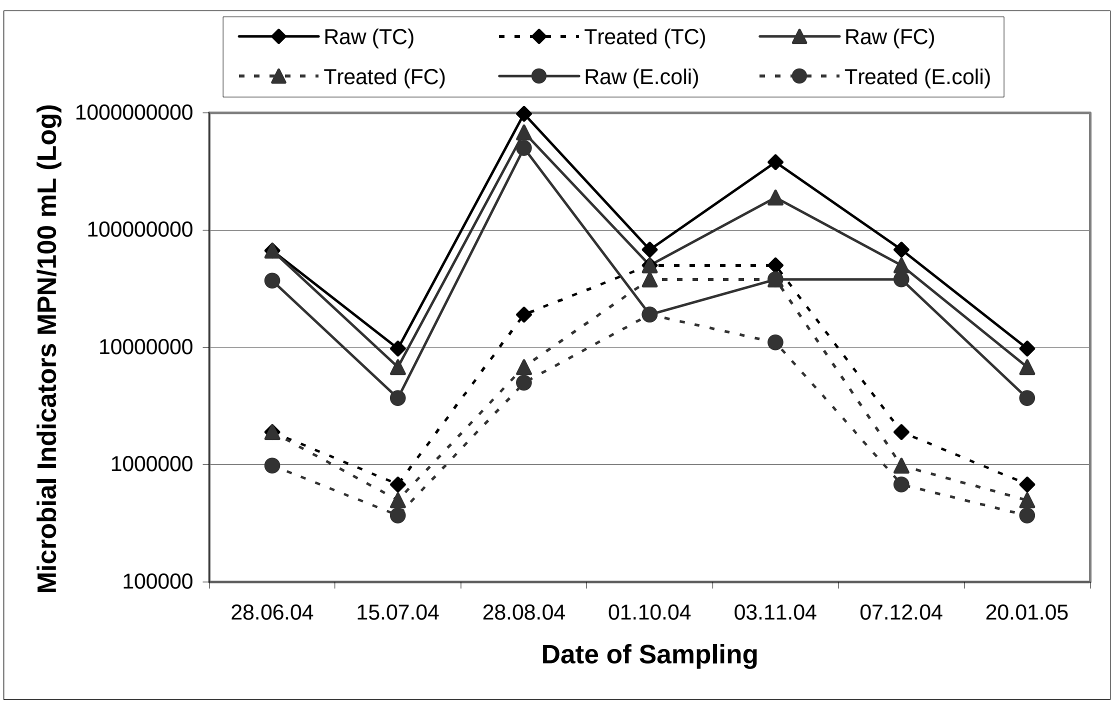


Figure 4.60 Variation in microbial load of Nesapakkam STP at 6.00 PM samples

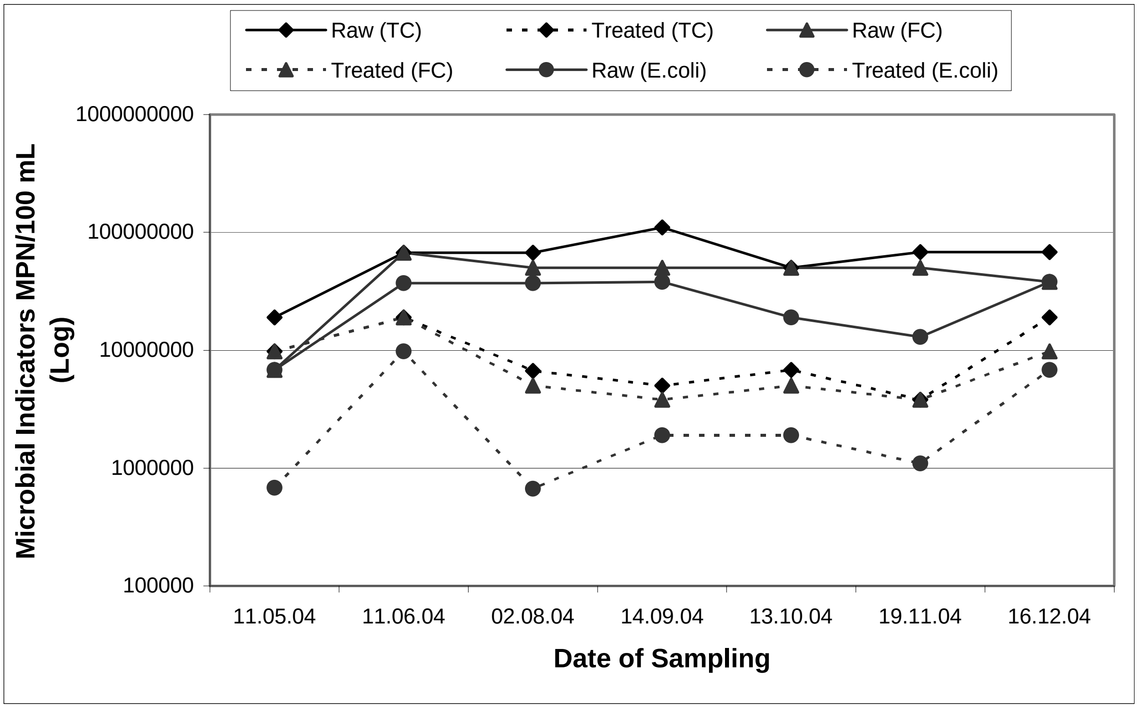


Figure 4.61 Variation in microbial load of Nesapakkam STP at 8.00 PM samples

4.3.3 Chennai Petroleum Corporation Ltd.Tertiary Treatment Plant

The performance of tertiary treatment plant from May 2004 – January 2005 is given in Table 4.26. The pH of raw sewage sample was slightly alkaline and treated effluent from the RO was slightly acidic due to the pretreatment and addition of acids before feeding in to the RO unit.

Table: 4.26 Performance of TTP at Chennai Petroleum Corporation Ltd. (May 2004 to January 2005)

Month and Date of Sampling	PH		TSS (mg/L)		COD (mg/L)				BOD (mg/L)			
					Total		Soluble		Total		Soluble	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treate d
May (04.05.04)	8.08	8.13	264	14	144	88	128	53	110	1	69	0.8
May (19.05.04)	7.87	8.09	67	5	277	11	85	7	166	3	38	2
June (15.06.04)	7.92	9.93	280	13	213	58	142	21	128	4	88	3
June (23.06.04)	7.87	10.05	149	2	218	2.6	66	0	174	0.8	53	0.4
July (06.07.04)	7.79	9.95	258	8	210	28	196	16	96	5	38	3
July (23.07.04)	7.90	9.93	243	10	266	32	218	21	75	5	47	5
August (31.08.04)	7.79	10.05	264	36	309	160	235	80	80	30	20	14

[Table 4.26 Continued…]

Month and Date of Sampling	PH		TSS (mg/L)		COD (mg/L)				BOD (mg/L)			
					Total		Soluble		Total		Soluble	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
September (23.09.04)	7.68	9.93	284	164	421	80	261	53	53	12	31	12
October (05.10.04)	7.55	6.32	187	6	384	128	203	107	59	23	53	11
October (19.10.04)	7.60	9.77	281	7	197	80	72	32	164	16	69	11
November (08.11.04)	7.55	9.87	328	11	104	64	85	53	57	65	47	11
November (30.11.04)	7.52	7.92	129	29	171	69	117	47	99	23	78	37
December (10.12.04)	7.36	7.87	83	12	234	20	80	12	36	6	21	-
December (22.12.04)	7.40	7.98	117	10	171	18	117	6	46	5	18	-
January (12.01.05)	7.33	7.75	158	22	125	85	22	8	56	25	8	2

From Figure 4.62 it can be observed that the COD (T&S) removal was in the range of 39% to 99% and 38 to 100%, respectively during May 2004 – January 2005. The very high organic load removal of the treatment plant may due to the tertiary treatment followed by chemical addition, stripping and RO.

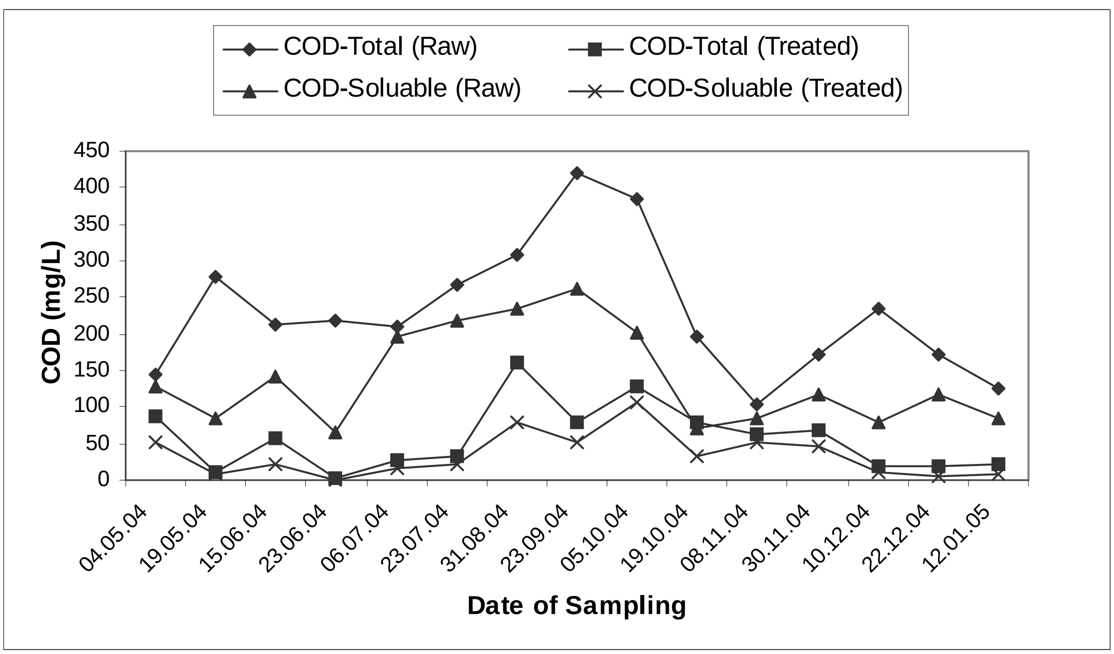


Figure 4.62 Variation in COD (Total & Soluble) of CPCL – TTP samples

Monthly variations in BOD (T&S) of raw and treated sewage samples collected during May 2004 – January 2005 are given in Figure 4.63 From the figure it is evidenced 100% removal of BOD –T was attained during the study period with an average removal efficiency of 81%. BOD-S removal was in the range of 30% to 99% with an average of 82% during our study period.

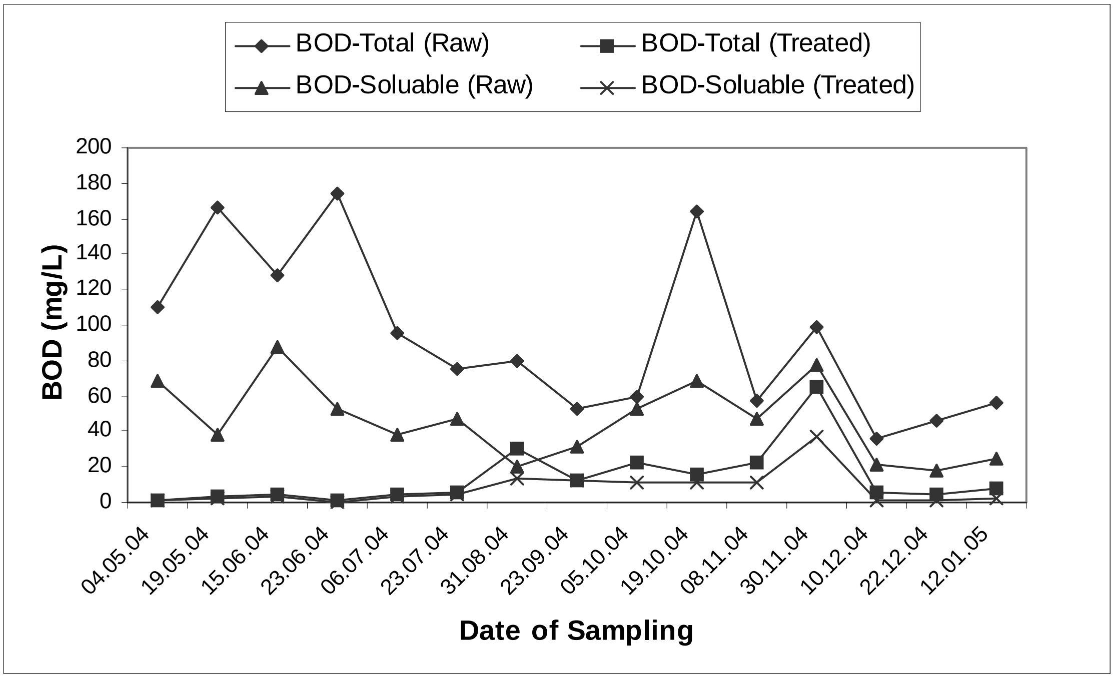


Figure 4.63 Variation in BOD (Total & Soluble) of CPCL – TTP samples

Thakur *et.al.,* (1977) have reported that addition of alum is effective in COD removal (52% to 62%) and it also improves the clarity of the sewage. They have also reported that 78% to 88% of COD removal can be achieved through addition of lime at an alkaline pH (pH 11).

From Figure 4.64, it is evident that TSS concentration of raw sewage varied from 67 mg/L to 328 mg/L with an average of 210 mg/L. In the treated effluent, it ranged from 2 mg/L to 164 mg/L during May 2004 – December 2004 with an average of 32 mg/L.

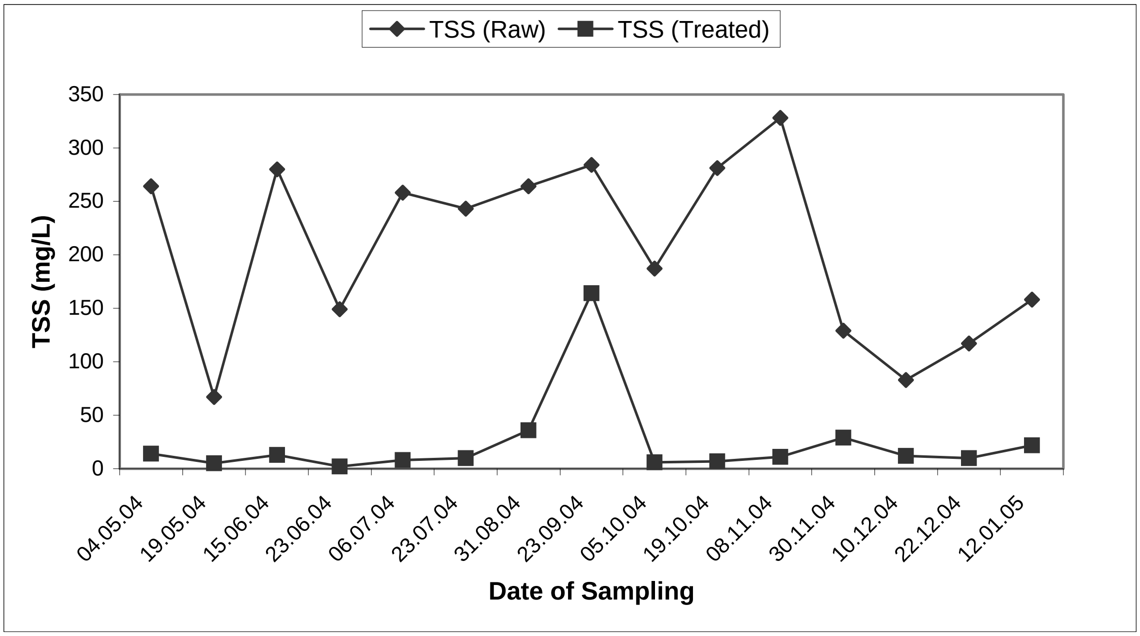


Figure 4.64 Variation in TSS of CPCL – TTP samples

Table: 4.27 Microbial Load of Chennai Petroleum Corporation Limited (TTP) Samples (May 2004 to January 2005)

Month and Date of Sampling	Sampling time	Flow rate (m^3/h)	Microbial Indicators (X 10^4MPN/100 mL)							
			Total Coliforms		Faecal Coliforms		*E.Coli*		Faecal Streptococci	
			Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
May (04.05.04)	8.00 AM	320	370	<2	370	<2	190	<2	-	<2
	10.00 AM	320	980	<2	980	<2	500	<2	37	<2
	8.00 PM	320	370	<2	370	<2	370	<2	-	<2
May (19.05.04)	10.00 AM	300	980	<2	980	<2	190	<2	370	<2
	12.00 Noon	300	370	<2	370	<2	98	<2	-	<2
	6.00 PM	300	680	<2	980	<2	98	<2	-	<2
June (15.06.04)	8.00 AM	375	680	<2	680	<2	500	<2	-	<2
	10.00 AM	375	500	<2	680	<2	370	<2	6.8	<2
	8.00 PM	375	680	<2	680	<2	500	<2	-	<2
June (23.06.04)	10.00 AM	315	110	<2	230	<2	98	<2	50	<2
	12.00 Noon	315	110	<2	290	<2	98	<2	-	<2
	6.00 PM	315	68	<2	110	<2	68	<2	-	<2
July (06.07.04)	8.00 AM	350	680	<2	500	<2	500	<2	-	<2
	10.00 AM	350	9800	<2	6800	<2	3700	<2	680	<2
	8.00 PM	350	3700	<2	2900	<2	2300	<2	-	<2
July (23.07.04)	10.00 AM	325	680	<2	500	<2	370	<2	50	<2
	12.00 Noon	325	1100	<2	980	<2	680	<2	-	<2
	6.00 PM	325	1900	<2	980	<2	980	<2	-	<2
August (31.08.04)	10.00 AM	300	980	11	980	9.8	500	6.8	50	1.9
	12.00 Noon	300	980	37	500	9.8	190	6.8	-	-
	6.00 PM	300	500	7.8	370	7.8	110	6.8	-	-
September (23.09.04)	8.00 AM	375	680	<2	380	<2	98	<2	-	<2
	10.00 AM	375	500	<2	190	<2	98	<2	38	<2
	8.00 PM	375	3800	<2	980	<2	680	<2	-	<2
October	10.00 AM	375	380	<2	380	<2	98	<2	50	<2

(05.10.04)	12.00 Noon	375	380	<2	110	<2	68	<2	-	-
	6.00 PM	375	680	<2	380	<2	98	<2	-	-
October (19.10.04)	8.00 AM	350	380	900	190	500	68	500	-	-
	10.00 AM	350	980	130	500	130	380	80	1.3	27
	8.00 PM	350	1100	240	500	130	380	80	-	-
November (08.11.04)	10.00 AM	300	68	5	50	3	38	1	1.9	0.7
	12.00 Noon	300	98	6.8	68	3	68	3.8	-	-
	6.00 PM	300	110	3.8	98	3.8	68	1.1	-	-
November (30.11.04)	8.00 AM	325	190	5	98	3.8	50	1.1	-	-
	10.00 AM	325	500	9	380	5	380	3.8	38	0.4
	8.00 PM	325	98	6.8	68	5	68	3.8	-	-
December (10.12.04)	8.00 AM	315	680	6.8	500	5	500	3.8	-	-
	10.00 AM	315	980	5	980	3.8	130	3.8	38	0.7
	8.00 PM	315	110	5	68	5	38	1.1	-	-
December (22.12.04)	10.00 AM	375	380	6.8	190	3	190	5	9.8	0.5
	12.00 Noon	375	680	9.8	380	6.8	190	5	-	-
	6.00 PM	375	500	6.8	190	5	190	3.8	-	-
January (12.01.05)	10.00 AM	350	500	0.068	190	0.068	98	0.038	1.3	0.019
	12.00 Noon	350	1100	0.05	290	0.038	98	0.011	-	-
	6.00 PM	350	680	0.05	110	0.038	68	0.019	-	-

Variations in microbial load of raw and treated wastewater are depicted in Figures 4.65 to 4.69

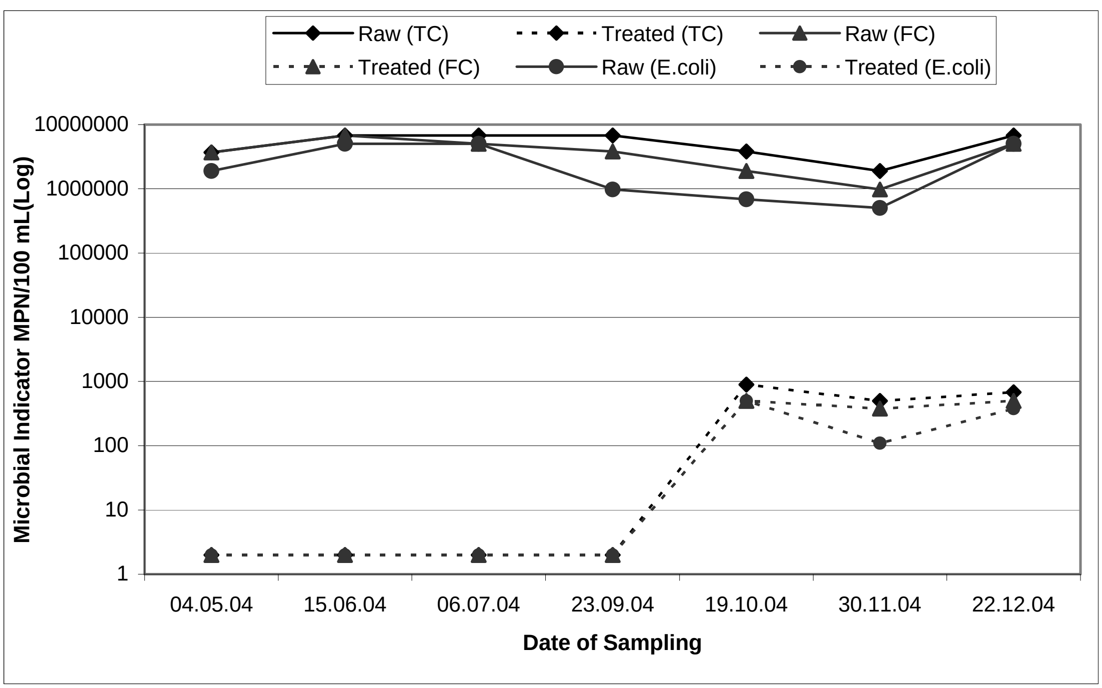


Figure 4.65 Variation in microbial load of CPCL –TTP at 8.00 AM samples

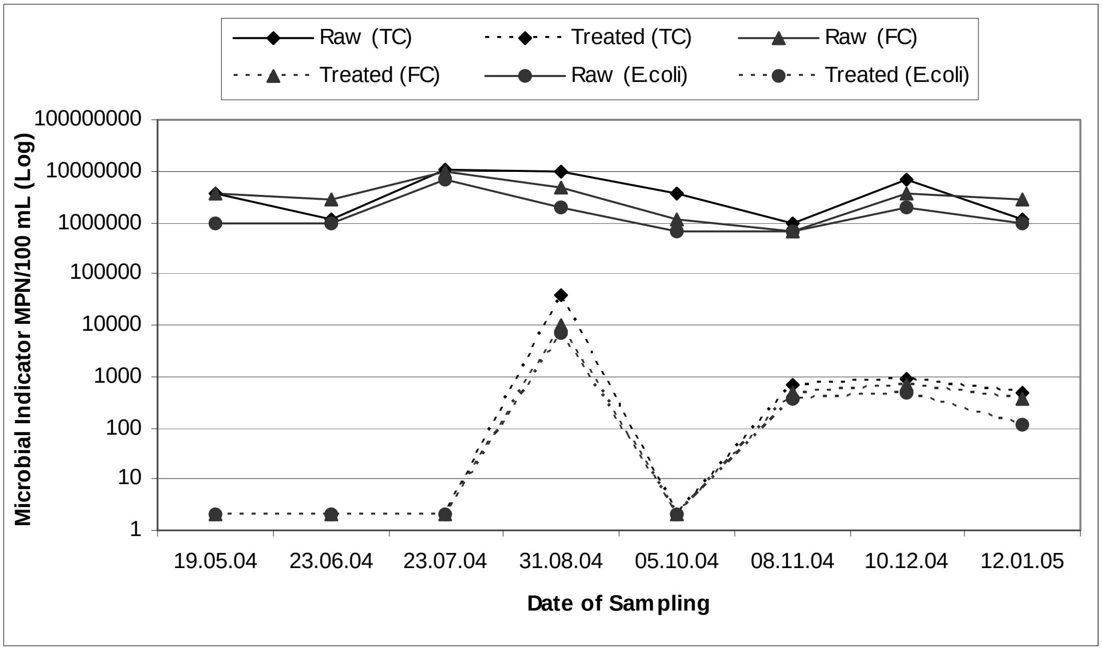


Figure 4.66 Variation in microbial load of CPCL – TTP at 12.00 Noon Samples

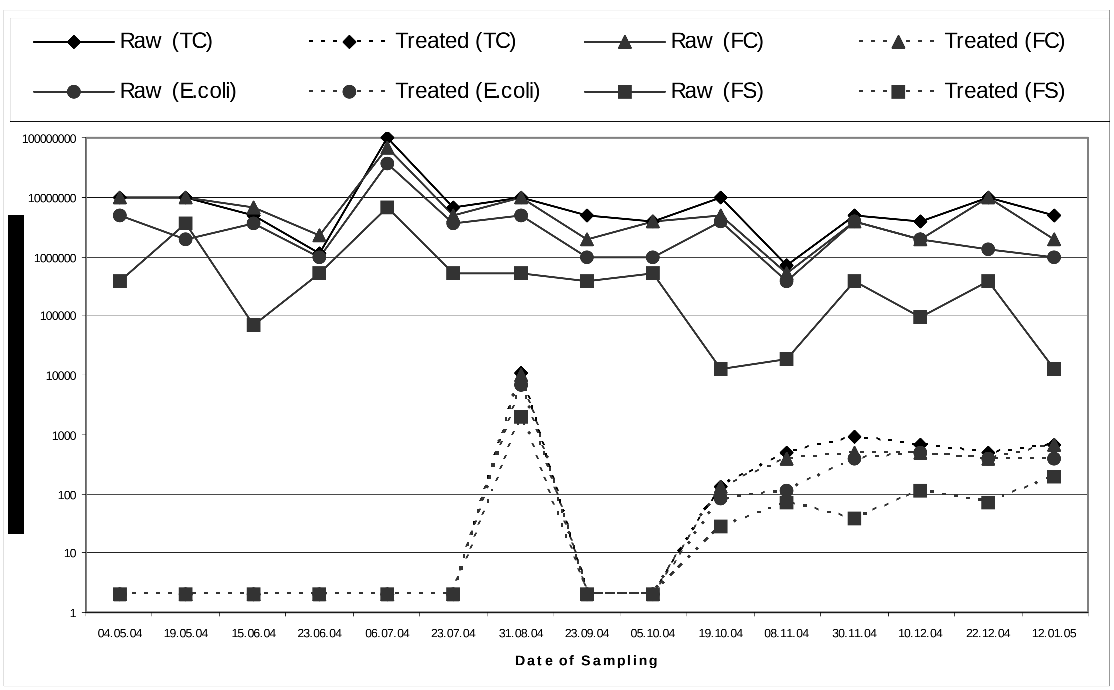


Figure 4.67 Variations in microbial load of CPCL – TTP at 10.00 AM samples

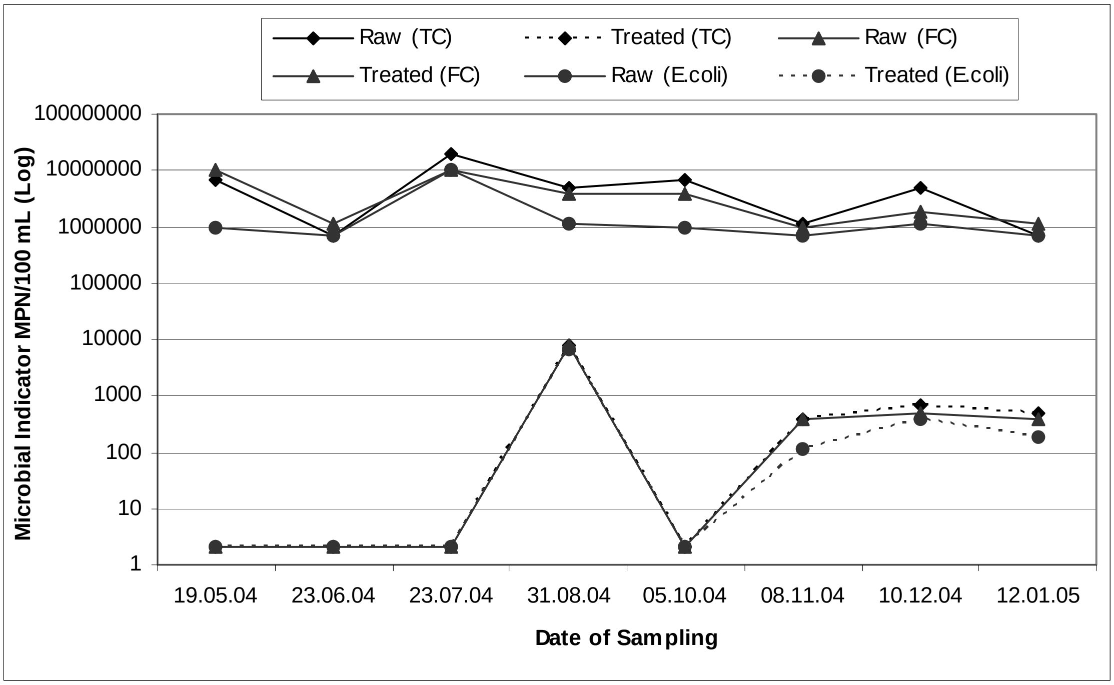


Figure 4.68 Variation in microbial load of CPCL –TTP at 6.00 PM samples

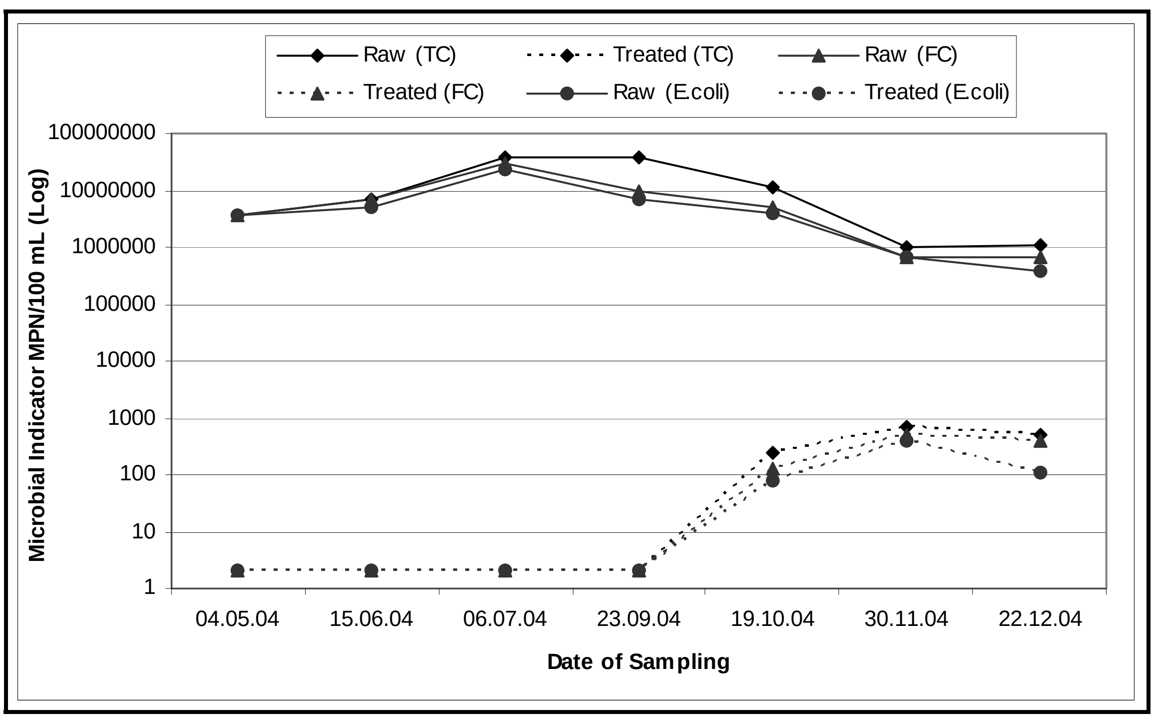


Figure 4.69 Variation in microbial load of CPCL-TTP at 8.00 PM samples

- 10 AM samples, (Raw) in July 2004 showed very high bacterial load while the least bacterial load was observed in 6 PM samples of June 2004. Tertiary treated samples showed bacterial count of <2 due to RO processes. The expected removal (% based on raw waste concentration) of coliforms in different processes of tertiary treatment systems is 99 to 100% (CPHEEO, 1993).
- Intermittent coliform reductions observed from the figures are not due to the treatment processes. It is mainly due to the change in the sampling location.

While the samples collected at the inlet of the TTP showed *E.coli, Micrococcus spp.*, and *Streptococcus faecalis*, the outlet samples did not have these bacteria. Wastewater samples collected from Intermittent Storage Pond (ISP) showed *E.coli* and *Streptococcus faecalis* only.

It is well known that when chemicals such as lime, ferric chloride and polyelectrolytes are used for coagulation process, as in the case of TTP, the lime increases the pH of wastewater and causes increased bacterial adsorption on sand filters. The lime treatment reduces the number of microorganisms by flocculation in sedimentation or floatation processes; the hydroxide alkalinity too has anti-microbial effect. Lime is reported to be very effective in killing of *E.coli, Salmonella typhi* and *Shigella flexneri* (Roper and Marshal, 1979; and Grabow *et al*., 1977). Chlorine can be used to retard the microbial growth in pipes and treatment units (Droste, 1997).

The microbial load of the treated effluent shows that flocculation, sedimentation, multi stage filtration, chlorination and reverse osmosis render it free from bacteria. Among the five different STPs studied, the TTP at CPCL showed complete removal of bacteria (100%). The treated water quality from the tertiary treatment system is comparable to that of drinking water.

4.3.4 Pondicherry Sewage Treatment Plant

Raw and treated samples were collected from inlet and outlet of the treatment plant during May 2004 – January 2005 and the results of physico-chemical analysis results are presented in Table 4.28. It was observed that the raw sewage samples of the treatment plant were neutral and treated effluent was slightly alkaline in nature. There was no observable change in temperature during the sampling period.

Table: 4.28 Performance of Pondicherry Sewage Treatment Plant (May 2004 to January 2005)

Month and Date of Sampling	pH		TSS (mg/L)		COD (mg/L)				BOD (mg/L)			
					Total		Soluble		Total		Soluble	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
May (17.05.04)	7.32	7.46	727	286	694	219	480	208	356	37	150	33
May (28.05.04)	7.29	7.50	590	212	640	106	144	68	327	53	92	36
June (22.06.04)	7.34	7.59	211	82	800	218	197	77	355	37	146	31

July (05.07.04)	7.36	7.62	275	80	608	206	394	106	280	45	217	15
August (12.08.04)	7.14	7.45	650	244	581	197	251	176	286	123	152	45
August (18.08.04)	7.13	7.47	730	258	384	240	64	53	242	123	142	35
September (16.09.04)	7.22	7.56	276	189	405	240	181	101	91	41	42	37
October (14.10.04)	7.17	7.44	271	124	400	128	181	102	81	41	47	19
October (27.10.04)	6.91	7.69	93	19	235	152	128	112	77	38	37	35
November (16.11.04)	7.02	7.40	238	98	304	128	75	32	112	46	68	25
December (23.12.04)	6.97	7.41	764	120	560	110	240	68	248	35	92	29
January (31.01.05)	7.06	7.98	368	120	325	189	115	72	72	52	45	22

Monthly variations in COD (Total and Soluble) of raw and treated sewage samples are presented in Figure 4.70. During June 2004, a very high organic load (COD-T) was observed in raw sewage samples. From the figure it is evidenced that the COD-T removal was very high (77%) during December 2004 and COD-S (73%) during July 2004.

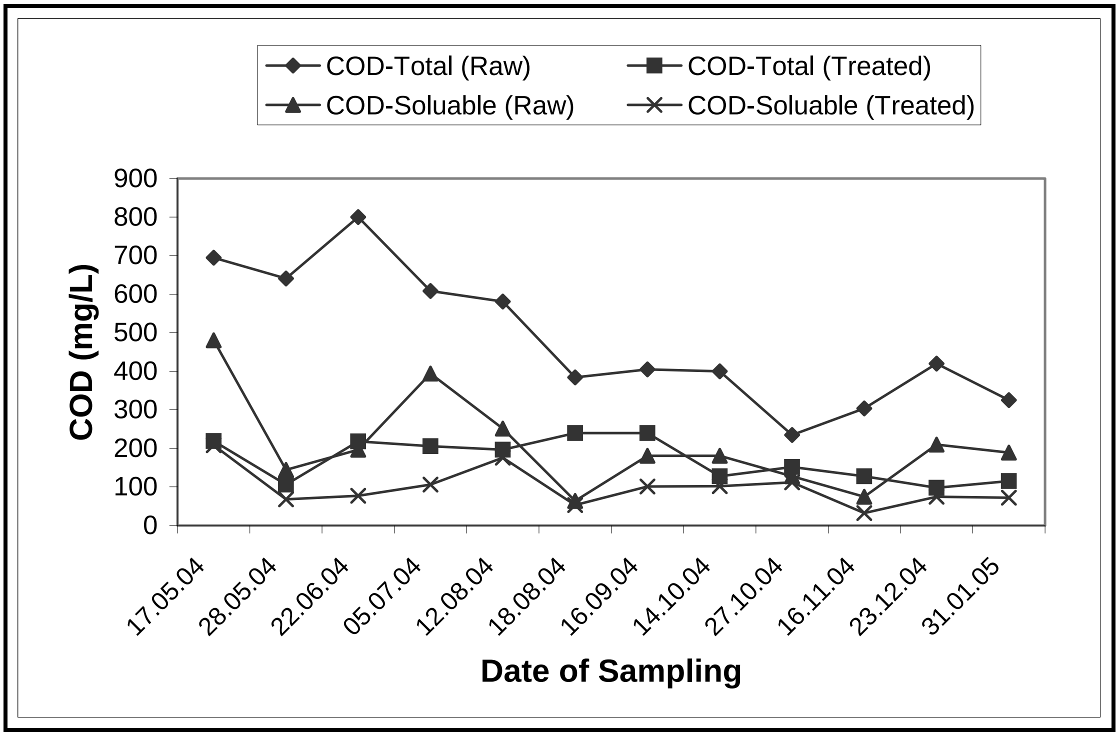


Figure 4.70 Variation in COD (Total & Soluble) of Pondicherry samples

Variations in BOD (Total and Soluble) of raw and treated samples during May – December, 2004 are given in Figure 4.71 BOD-T removal efficiency of the treatment plant was very high (93%) July 2004 and for BOD-S it was around 80% in October 2004.

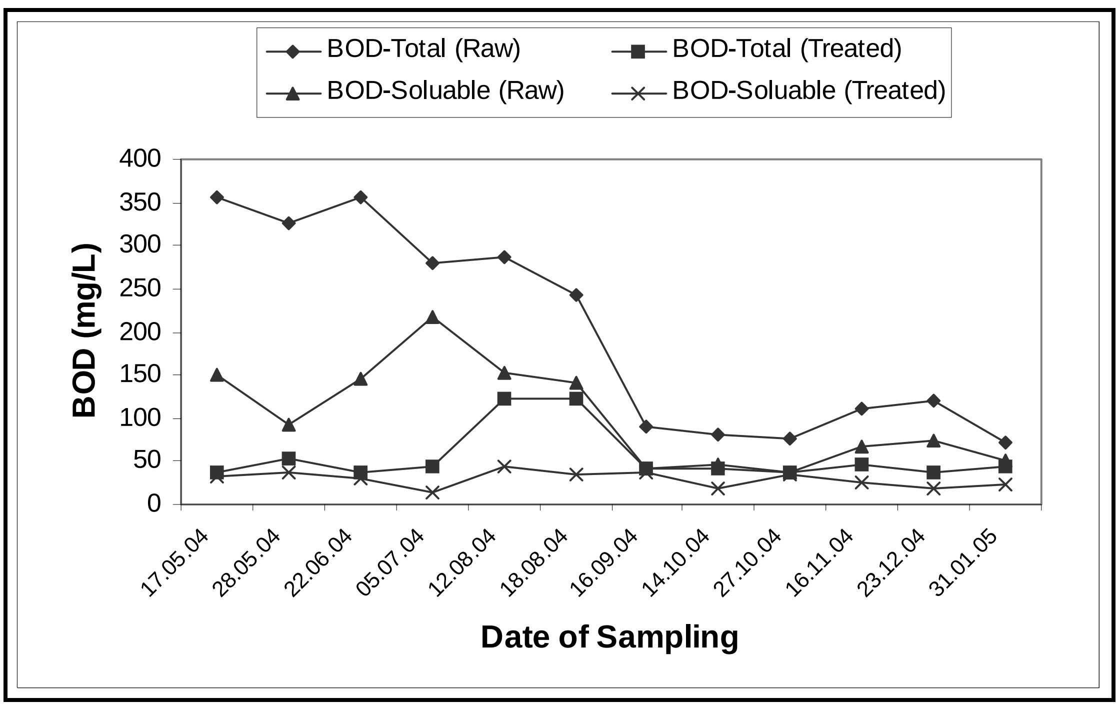


Figure 4.71 Variation in BOD (Total & Soluble) of Pondicherry Samples.

In raw sewage the COD-T to BOD-T ratio varied from 1.6 to 4.9 and it was in the range of 1.6 to 5.9 in treated samples. COD-S to BOD-S ratio in raw and treated samples varied from 0.5 to 4.3 and 1.3 to 7.1, respectively with an average ratio of 2.0 for raw and 3.7 for treated sample.

Gunnerson *et al.*,(1984) and Aran (1988) have pointed out that stabilization pond treatment produces a better effluent through reduction of BOD than conventional biological treatment process. A maximum of 60% of BOD removal in oxidation pond has been reported by Govindan, 1990. He has also reported that 3 ponds in series removed 80% of total BOD from the raw sewage.

Baozhen wang *et al.*, (1995) have reported the performance of eco-ponds under warm climatic condition for various pollutants such as TSS 80-95%; BOD 85-98% and COD 80-93%.

From Figure 4.72 it can be observed that, during our study period the TSS concentration varied from 93 – 730 mg/L with an average of 400 mg/L for raw sewage and 19 – 286 mg/L for treated sample with an average value of 157 mg/L. Removal efficiency during May 2004 – January 2005 was in the range of 32% to 80%.

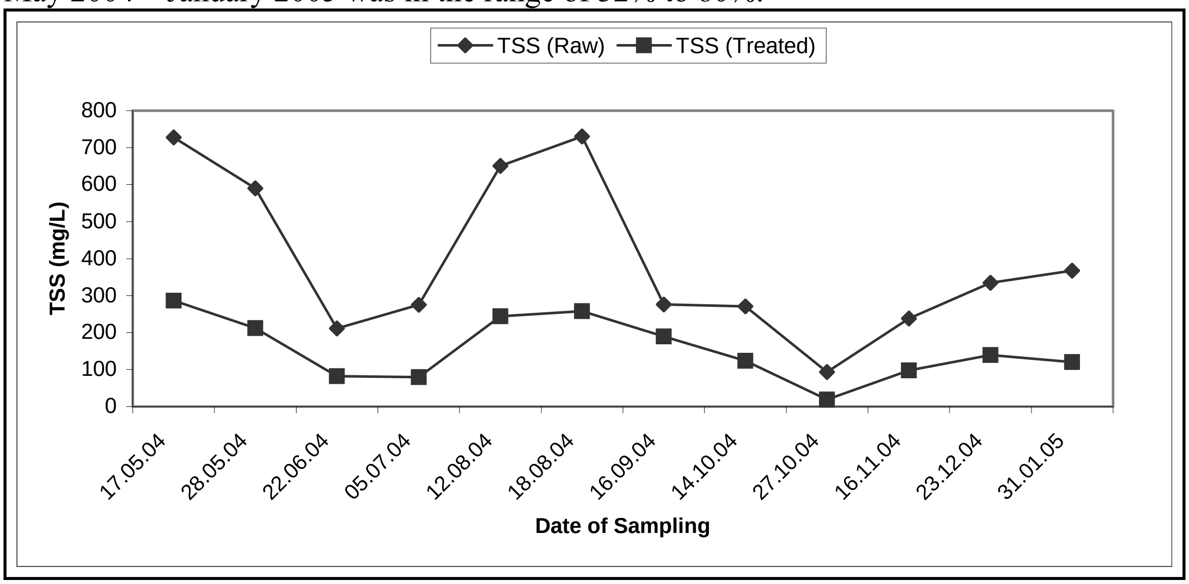


Figure 4.72 Variation in TSS of Pondicherry samples

Table: 4.29 Microbial load of Pondicherry sewage treatment plant samples (May 2004 to January 2005)

Month and Date of Sampling	Sampling time	Total Coliforms		Faecal Coliforms		*E.Coli*		Faecal Streptococci	
		(X 10^4MPN/100 mL)							
		Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
May (17.05.04)	8.00 AM	3700	67	1900	67	980	37	-	-
	10.00 AM	9800	500	5000	370	3700	370	980	6.7
	8.00 PM	6700	500	5000	370	3700	370	-	-
May (28.05.04)	10.00 AM	3700	980	3700	980	1900	680	500	5
	12.00 Noon	5000	680	5000	680	3700	190	-	-
	6.00 PM	9800	500	9800	370	6800	370	-	-
June (22.06.04)	10.00 AM	5000	5	5000	5	6700	3.7	110	0.5
	12.00 Noon	980	0.78	1900	0.78	670	0.5	-	-
	6.00 PM	980	2	670	2	500	0.67	-	-

[Table: 4.29 Continued…]

Month and Date of Sampling	Sampling time	Total Coliforms		Faecal Coliforms		*E.Coli*		Faecal Streptococci	
		(X 10^4MPN/100 mL)							
July (05.07.04)	8.00 AM	5000	680	5000	500	5000	370	-	-
	10.00 AM	5000	190	5000	370	5000	98	680	5
	8.00 PM	37000	370	37000	500	37000	370	-	-
August (12.08.04)	8.00 AM	7800	980	6800	680	5000	500	-	-
	10.00 AM	7800	380	5000	110	1100	68	680	68
	8.00 PM	11000	500	7800	380	5000	190	-	-
August (18.08.04)	10.00 AM	11000	3000	9800	1100	6800	980	500	6.7
	12.00 Noon	9800	780	6800	680	5000	500	-	-
	6.00 PM	9800	680	6800	500	5000	380	-	-
September (16.09.04)	10.00 AM	6800	380	6800	110	3800	68	78	3.8
	12.00 Noon	6800	380	5000	190	3800	98	-	-
	6.00 PM	9800	68	5000	11	5000	9.8	-	-
October (27.10.04)	8.00 AM	19000	680	9800	380	5000	190	-	-
	10.00 AM	19000	500	6800	380	3800	110	13	1.1
	8.00 PM	68000	1900	38000	980	19000	500	-	-
October (14.10.04)	10.00 AM	38000	1100	19000	680	9800	500	98	3.8
	12.00 Noon	50000	980	38000	500	11000	190	-	-
	6.00 PM	9800	1100	6800	680	3800	380	-	-
November (16.11.04)	10.00 AM	1900	110	980	68	500	50	13	3.8
	12.00 Noon	1900	98	1900	68	500	50	-	-
	6.00 PM	38000	190	19000	190	9800	110	-	-
December (23.12.04)	8.00 AM	380	78	380	50	190	38	-	-
	10.00 AM	5000	980	5000	980	3800	680	380	68
	8.00 PM	1100	190	780	130	680	110	-	-
January (31.01.05)	10.00 AM	7800	380	5000	110	1100	68	680	6.8
	12.00 Noon	6800	380	5000	190	3800	98	-	-
	6.00 PM	9800	68	5000	11	5000	9.8	-	-

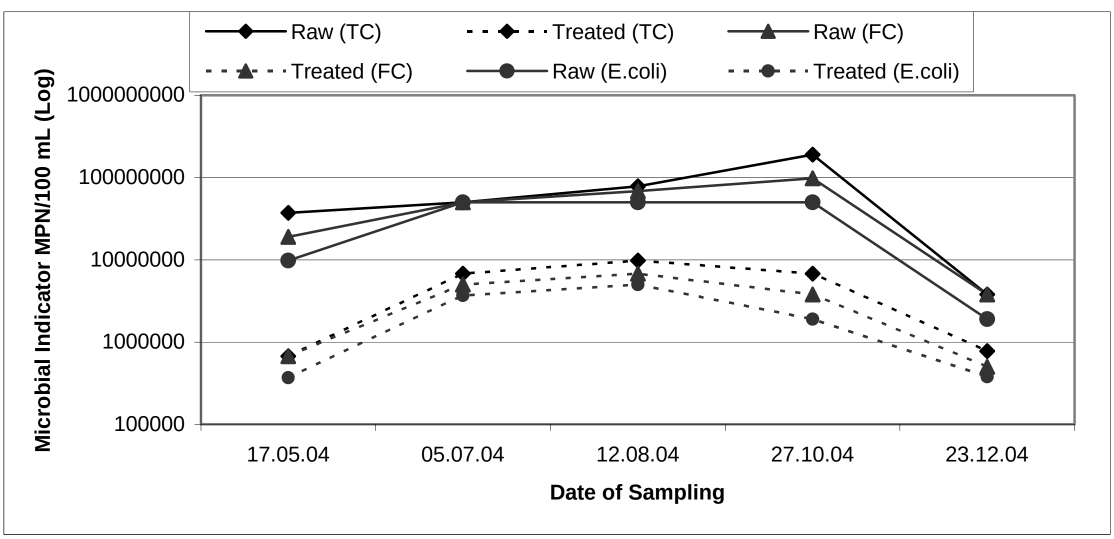


Figure 4.73 Variation in microbial load of Pondicherry STP at 8.00 AM samples

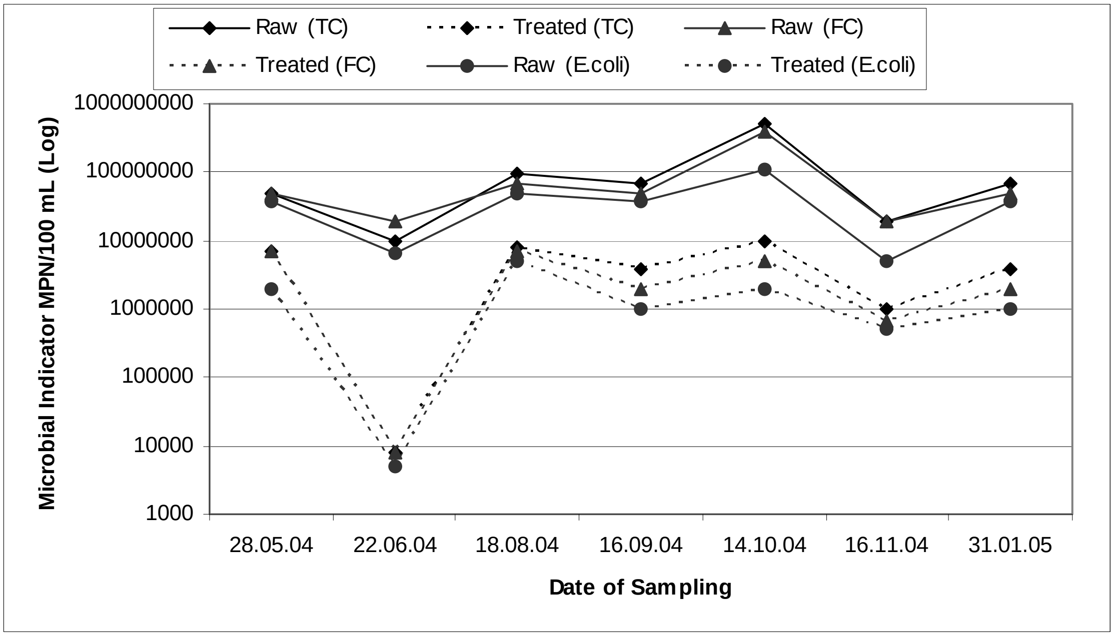


Figure 4.74 Variation in microbial load of Pondicherry STP at 12.00 Noon Samples

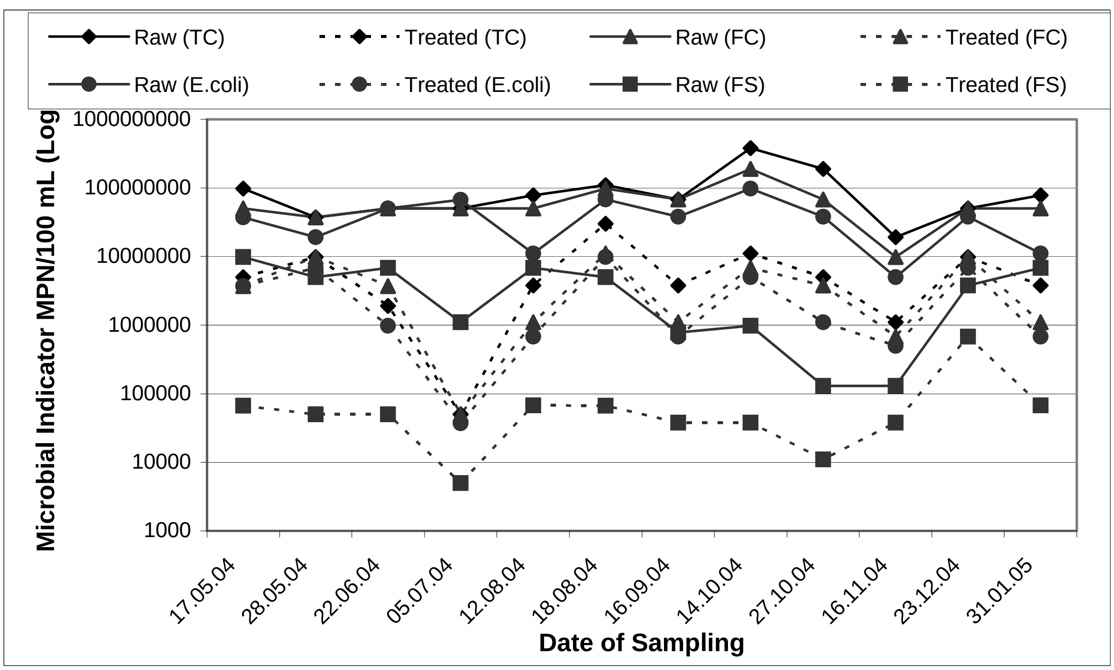


Figure 4.75 Variations in microbial load of Pondicherry STP at 10.00 AM samples

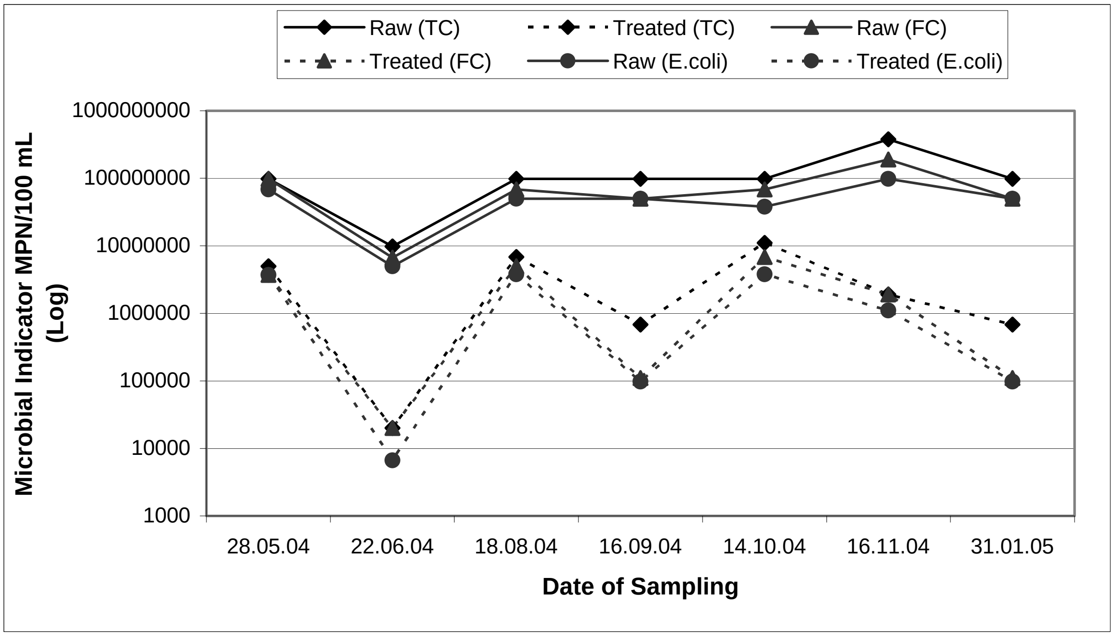


Figure 4.76 Variation in microbial load of Pondicherry STP at 6.00 PM samples.

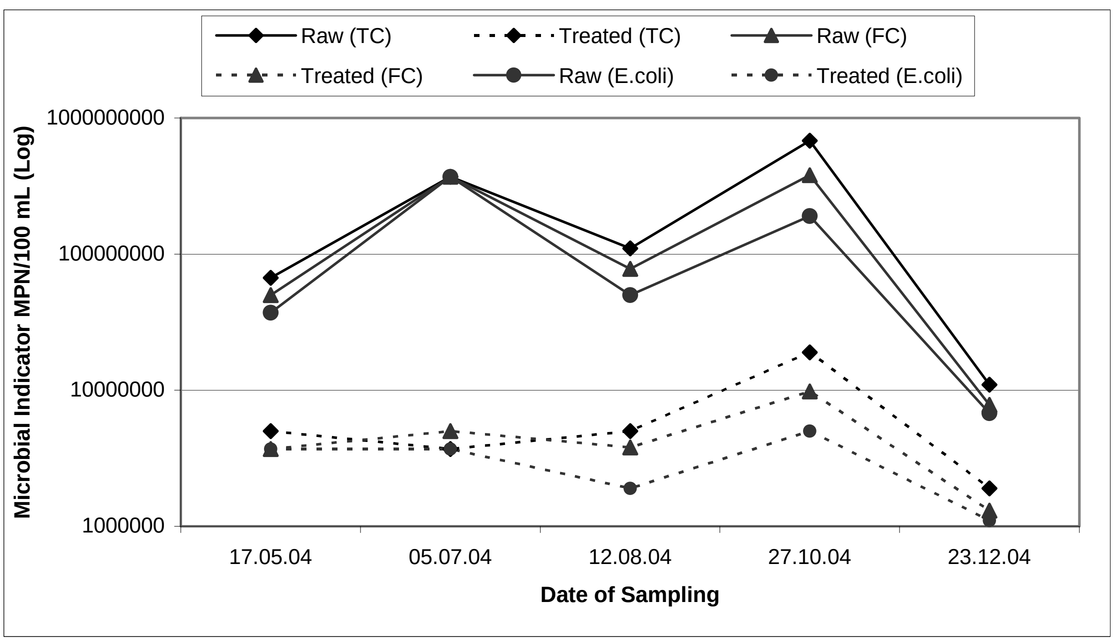


Figure 4.77 Variation in microbial load of Pondicherry STP at 8.00 PM Samples.

- Better treatment was evident in 8 AM samples collected in May 2004 as compared to samples collected in July and August 2004. The better treatment can be due to the high retention of wastewater in stabilization pond. Higher bacterial loads were observed in August 2004 and May 2004.

- In 10 AM samples, the high bacterial load was observed May 2004 and better treatment is observed in July 2004.

- In 12 Noon samples, performance was better in June 2004 and the high bacterial load was observed in August 2004. It showed 7800/100 mL of FC (i.e. below the relaxed faecal coliform guideline of 10,000 FC/100 mL (Blumenthal *et al*., 2001).
- In 6 PM samples, lesser bacterial loads as well as better treatment were observed in June 2004.
- In 8 PM samples, higher bacterial load and better treatment were observed in the month of July 2004 as compared to other months.

While *E.coli*, *Pseudomonas spp., Vibrio spp., Micrococcus spp., Bacillus spp.,* and *Staphylococcus spp.,* were present in the raw wastewater, the treated water exhibited the presence of *E.coli, Streptococcus spp., Pseudomonas spp.,* and *Micrococcus spp.* The *Bacillus spp*., efficiently removed from the oxidation pond.

The efficient treatment observed in the stabilization pond can be due to lower flow rate of wastewater higher retention time. The present observations confirm the view of Meenambal and Govindan (1984), who reported that, the reduction of microorganisms in WSPs is governed by the length of retention time during treatment, chemical composition of waste and rate of degradation, antagonistic forces in the biological flora and pH.

WHO guidelines (1996) recommend sewage retention in stabilization ponds for 8 to 10 days for irrigation of cereal, fodder and industrial crops and trees. For irrigation of crops likely to be eaten uncooked, the guidelines recommend a faecal coliform limit of 1000 organisms / 100 mL. Facultative ponds also effect high bacterial reduction. The efficiency being particularly high in multi cell ponds operated 'in series'. Where coliform and faecal streptococci removals will be as high as 99.99%. Intestinal pathogens belonging to Salmonella and Shigella groups are reported to be completely eliminated in stabilization ponds. Cysts of *Entamoeba histolytica* and Helminth larvae are also eliminated. Single-cell and two-cell stabilization ponds are reported to remove TC in the range of 90-95% and 95-98%, repectively (CPHEEO, 1993). Govindan (1987) has reported that the stabilization ponds remove 97-99% of TC. Mara and Cairncross (1989) have reported that the removal of excreted bacteria in stabilization pond was 1-6 Log_{10}. Constructed wetlands remove 3 Log units, 100% TC and 96% Salmonella (Arceivala, 1998; Kedlec and Knight, 1996 and Rengasamy, 2000).

4.3.5 Vrishabhavathy Valley Sewage Treatment Plant

Samples were collected from raw and treated effluent of the sewage treatment plant during July 2004 – January 2005 and analyzed. Results are presented in Table 4.30.The raw sewage samples were neutral to slightly alkaline in nature and remained to be slightly alkaline after treatment.

Table: 4.30 Performance of Vrishabhavathi valley sewage treatment plant (July 2004 to January, 2005)

Month and date of sampling	pH		TSS (mg/L)		COD (mg/L)				BOD (mg/L)			
					Total		Soluble		Total		Soluble	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
July (21.07.04)	7.62	7.95	587	299	464	181	149	85	232	45	185	32
August (04.08.04)	7.23	7.85	282	63	490	133	75	58	124	75	75	57
August (20.08.04)	7.53	7.92	168	31	352	96	117	37	74	44	72	23
September (09.09.04)	7.83	8.09	243	147	427	165	208	117	156	35	63	25
October (07.10.04)	7.12	7.62	249	31	277	69	85	53	151	31	35	15
November (23.11.04)	7.05	7.76	243	47	432	69	171	37	144	43	129	27
December (29.12.04)	7.22	7.73	764	120	560	110	240	68	248	35	92	29
January (08.01.05	7.37	7.92	528	112	428	225	98	65	320	112	32	24

Monthly variations in COD-T and COD-S are depicted in Figure 4.78. The average COD-T removal of 72% with a range from 61% to 84% was observed. The COD-S removal was in the range of 23 to 78% with an average removal efficiency of 52%.

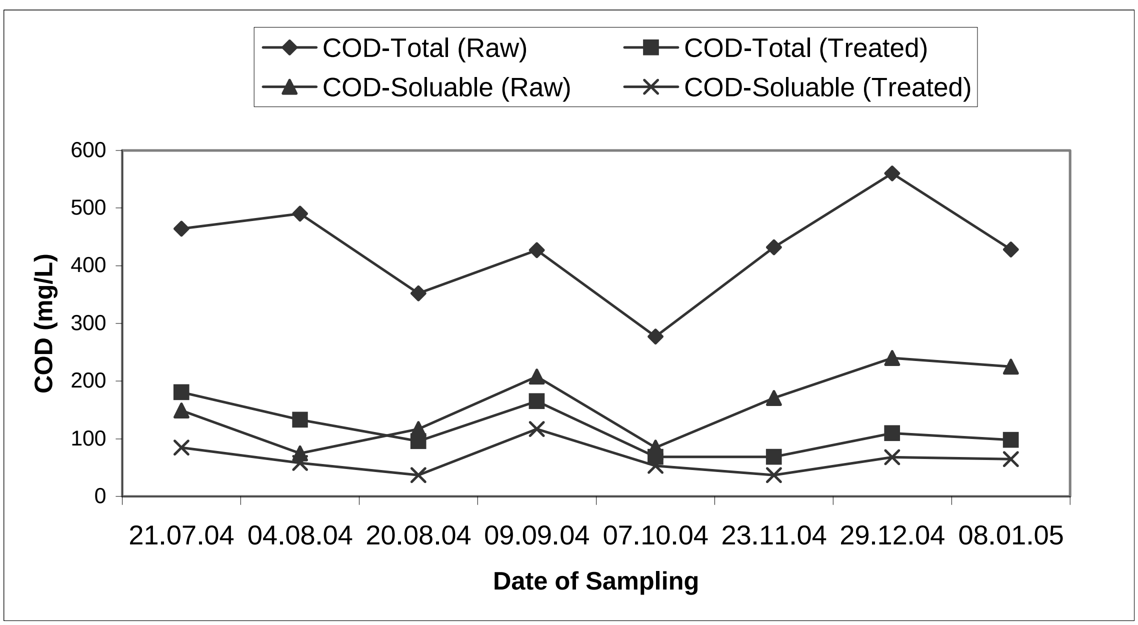


Figure 4.78 Variation in COD (Total & Soluble) of V.Valley samples

Variations in BOD (T&S) in raw and treated sewage samples are given in Figure 4.79. The average BOD-T removal of 68% and BOD-S removal was 63%. COD-T to BOD-T ratio in raw and treated sample varied from 2.0 – 4.8 and 1.8 – 4.7, respectively during study period.

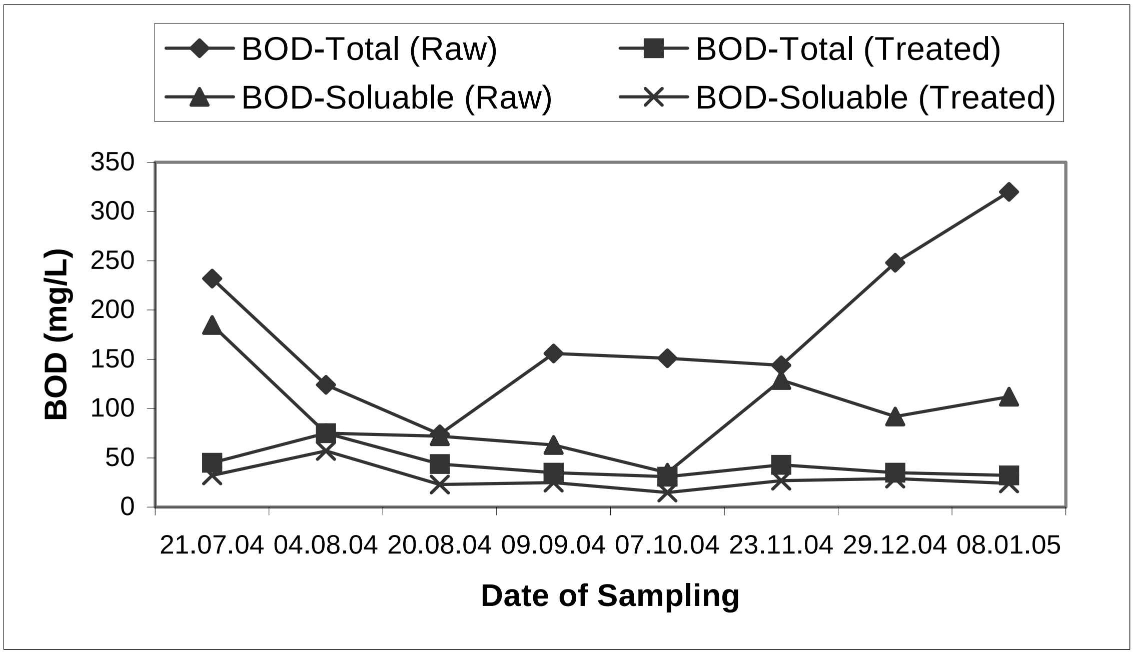


Figure 4.79. Variation in BOD (Total & Soluble) of V.Valley samples

Mitra and Gupta (2000) have reported 75% to 77% of COD and BOD removal from wastewater in trickling filters.

From Figure 4.80 it can be seen that TSS removal in raw sewage varied from 168 – 764 mg/L with an average of 362 mg/L during May 2004 – January 2005. In the treated samples it varied from 31 mg/L to 299 mg/L with an average of 105 mg/L. The TSS removal effecicnency of the treatment plant was in the range of 40% to 88%.

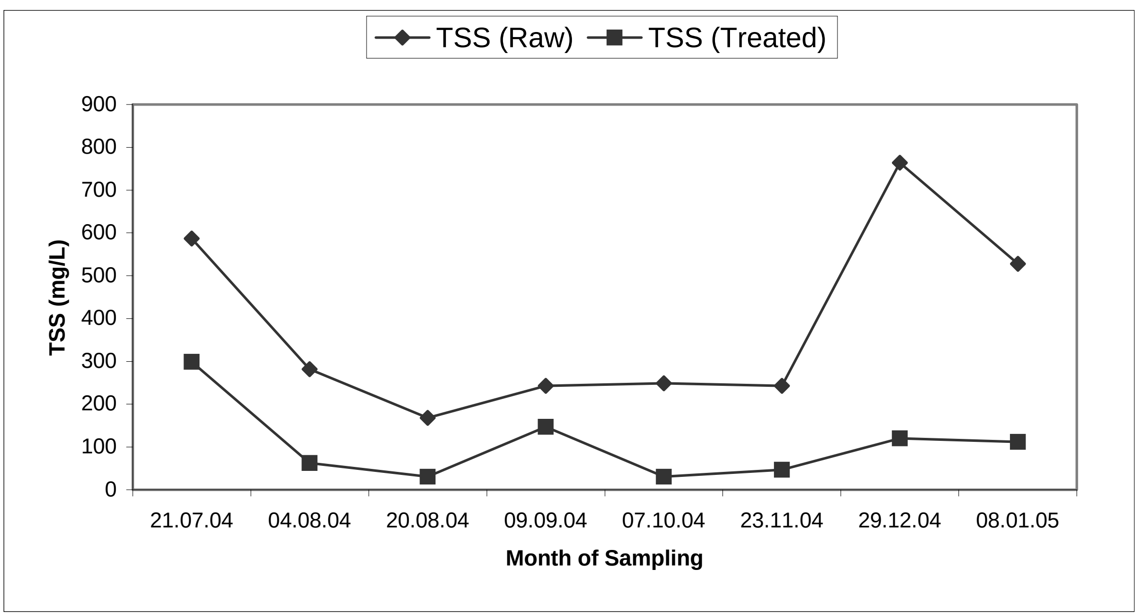


Figure 4.80 Variation in TSS of V.Valley samples

Table: 4.31 Microbial load of Vrishabhavathi Valley sewage treatment plant samples (July 2004 to January 2005)

Month and Date of Sampling	Sampling time	Flow rate (m^3/h)	Microbial Indicators (X 10^4MPN/100 mL)							
			Total Coliforms		Faecal Coliforms		E.Coli		Faecal Streptococci	
			Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
July (21.07.04)	10.00 AM	86.34	6800	500	5000	50	1900	37	190	1.2
	12.00 Noon	97.34	6800	190	3700	68	1200	37	-	-
	6.00 PM	60.88	6800	500	5000	370	980	190	-	-
August (04.08.04)	8.00 AM	56.18	19000	680	6800	380	5000	190	-	-
	10.00 AM	86.34	50000	680	9800	98	5000	50	980	1.9
	8.00 PM	38.46	19000	980	6800	680	3800	380	-	-
August (20.08.04)	10.00 AM	75.60	19000	380	9800	190	6800	110	380	6.8
	12.00 Noon	86.34	38000	5000	11000	3800	9800	190	-	-
	6.00 PM	32.84	38000	3800	19000	1100	9800	680	-	-
September (09.09.04)	8.00 AM	32.84	9800	500	5000	380	3800	110	-	-
	10.00 AM	86.34	6800	98	5000	68	3800	38	110	5
	8.00 PM	38.46	6800	78	3800	68	1900	50	-	-
October (07.10.04)	10.00 AM	36.80	6800	380	5000	190	1100	110	78	1.1
	12.00 Noon	58.29	50000	380	38000	380	11000	190	-	-
	6.00 PM	32.84	1300	500	1300	380	980	110	-	-
November (23.11.04)	8.00 AM	26.87	680	38	680	19	500	19	-	-
	10.00 AM	57.00	1100	68	980	68	500	38	110	5
	8.00 PM	29.00	5000	38	3800	38	3800	19	-	-
December (29.12.04)	10.00 AM	56.24	6800	500	5000	380	5000	380	500	50
	12.00 Noon	75.60	19000	980	9800	980	9800	500	-	-
	6.00 PM	36.84	780	50	500	38	380	19	-	-
January (08.01.05)	10.00 AM	41.2	6800	68	5000	68	1900	38	190	5
	12.00 Noon	44.6	6800	190	3700	68	1200	37	-	-
	6.00 PM	36.8	6800	500	5000	370	980	190	-	-

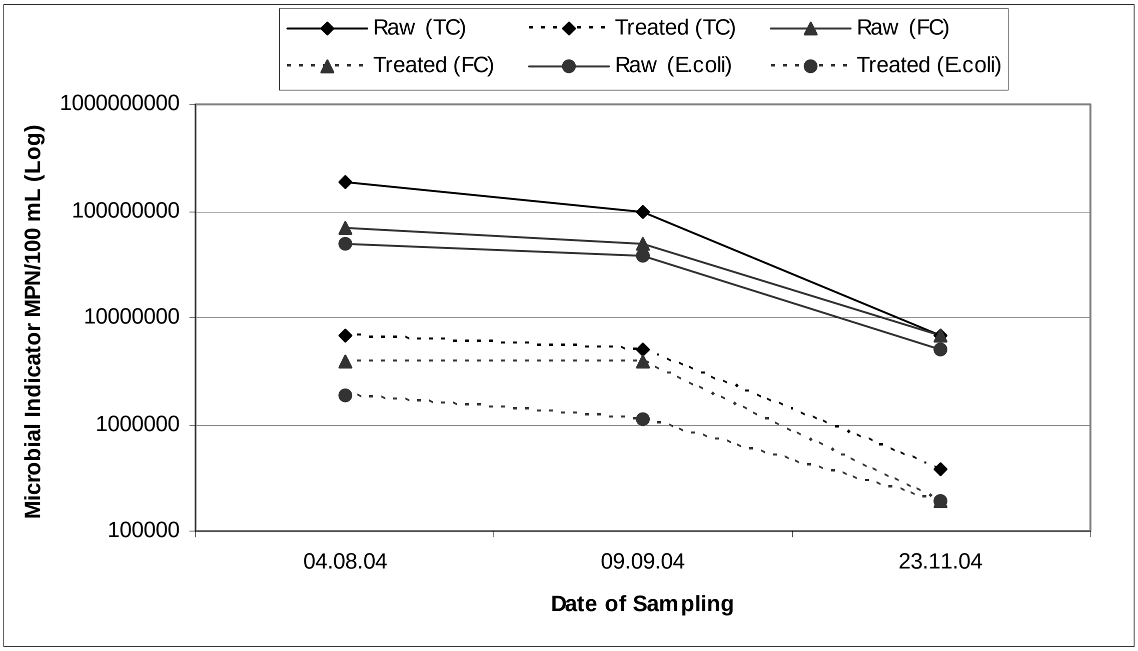


Figure 4.81 Variation in microbial load of V.Valley STP at 8.00 AM samples

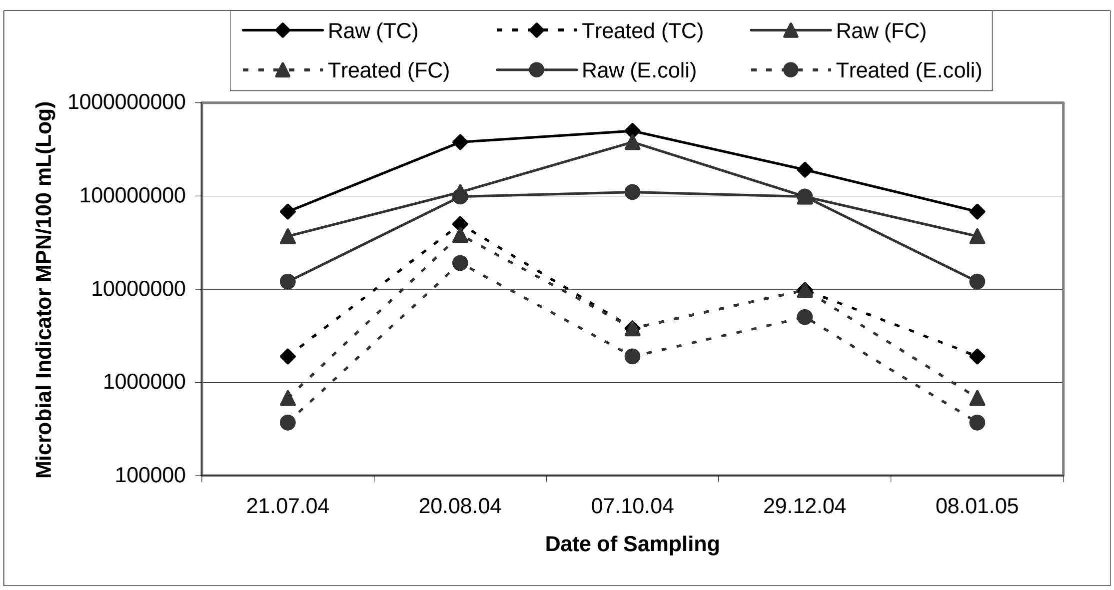


Figure 4.82 Variation in microbial load of V.Valley STP at 12.00 Noon samples

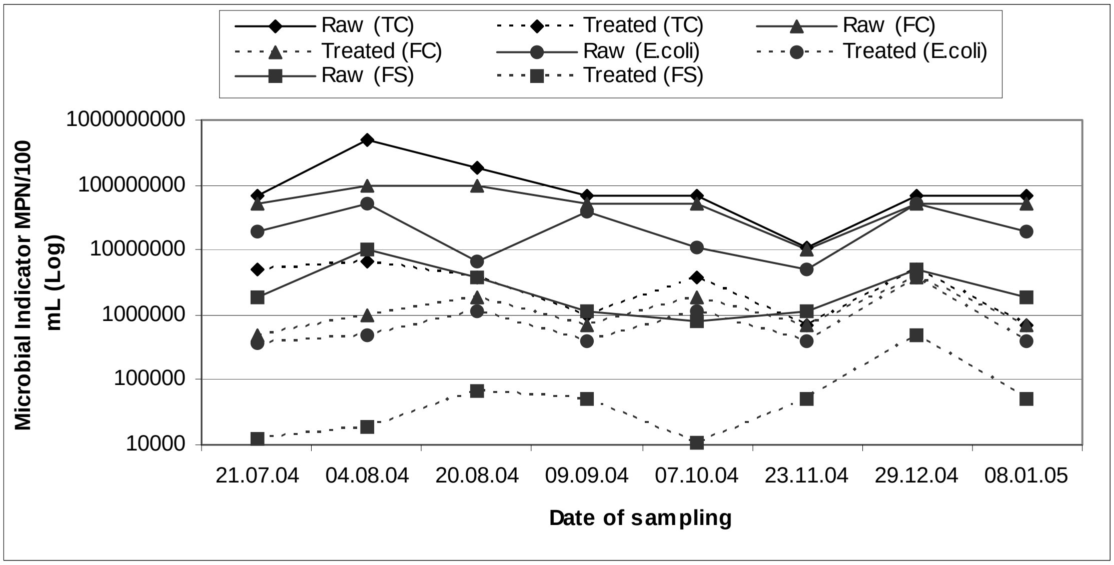


Figure 4.83 Variations in microbial load of V.Valley STP at 10.00 AM samples

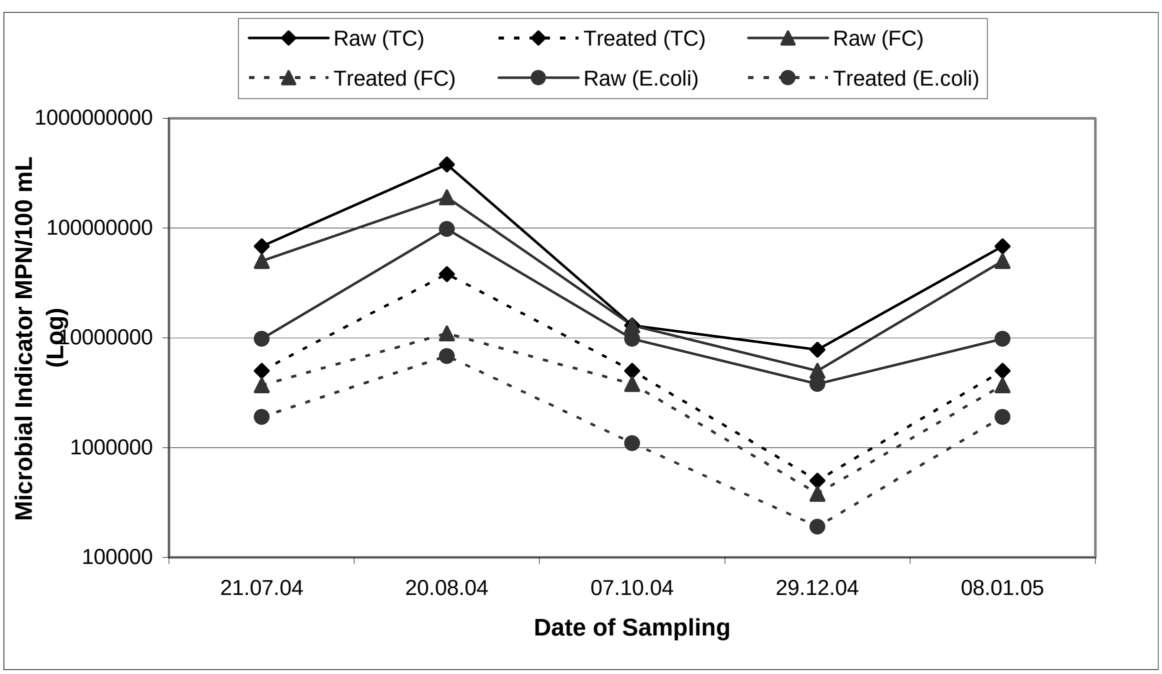


Figure 4.84 Variation in microbial load of V.Valley STP at 6.00 PM samples

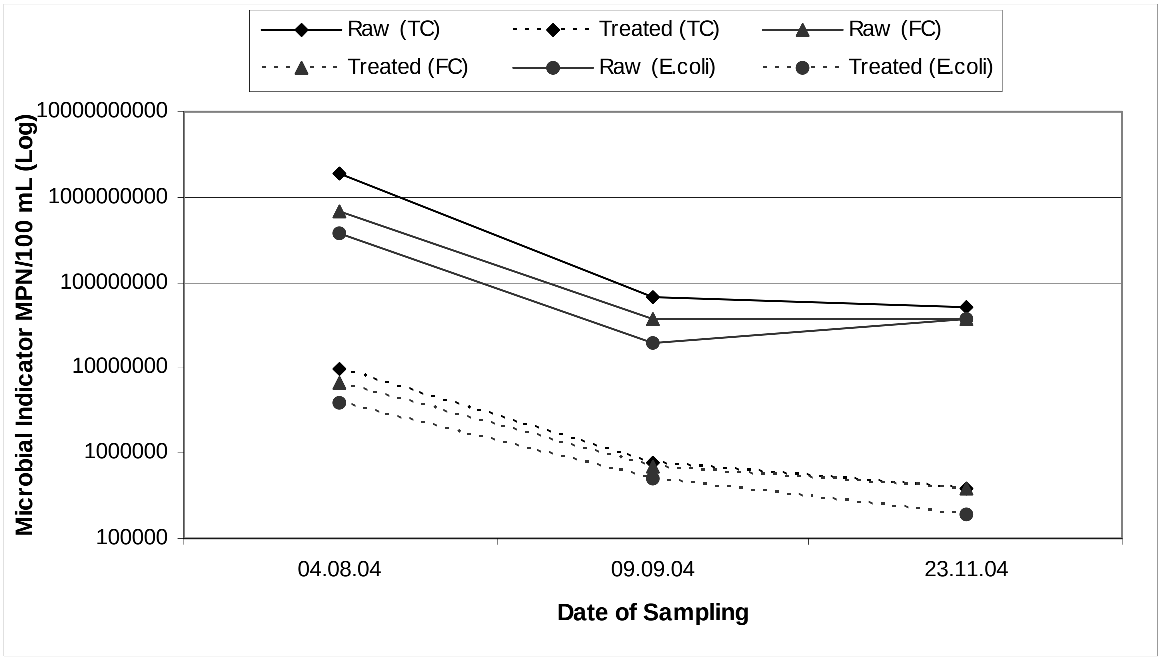


Figure 4.85 Variation in microbial load of V.Valley STP at 8.00 PM samples

4.3.6 30 MLD Up flow Anaerobic Sludge Blanket (UASB) Sewage Treatment Plant, Saharanpur, Uttar Pradesh

Various Physico-chemicals and microbiological parameters analyzed for the Influent and effluent of the plant as well as the derived efficiency of the plant with respect to these parameters are listed in Table 4.32 Descriptive Data and Removal efficiency of UASB plant, Saharanpur

Table 4.32

Date	Sampling point	pH	Temp (°C)	DO (mg/L)	TDS (mg/L)	Turbi-dity NTU	TSS (mg/L)	Alkali-nity (mg/L)	COD (mg/L)	BOD (mg/L)	TC (MPN/ ml)	FC (MPN/ 100 ml)	FS (MPN/ 100 ml)	Helmi-nthes (eggs/L)
09/ 02/ 06	**Inlet**	7.2	27.6	0.0	579	133	198	496	360(T) 184.2(S)	180(T) 94(S)	$1.2x10^{7}$	$7.5x10^{6}$	$4.3x10^{5}$	-
	Reactor Outlet	7.3	27.5	0.5	514	54	72	432	124(T) 98(S	78.6(T) 60(S)	$2.3x10^{6}$	$1.5x10^{5}$	$4.3x10^{3}$	-
	Outlet	8.1	27.8	1.6	486	26	25	390	67(T) 39.(S)	27(T) 14(S)	$9.3x10^{4}$	$7.5x10^{3}$	$1.5x10^{3}$	-
	% removal	-	-	-	-	80.45	87.37	-	81.39	85.00	99.23	99.90	99.65	-
23/ 02/ 06	**Inlet**	7.3	26.8	0.2	590	146	215	478	381(T) 169.2(S)	172(T) 89.5(S)	$4.3x10^{7}$	$3.9x10^{6}$	$2.3x10^{5}$	-
	Reactor Outlet	7.3	26.4	0.5	546	68.3	97	455	112(T) 84.6(S)	89.5(T) 65.2(S)	$9.3x10^{6}$	$7.5x10^{5}$	$1.5x10^{3}$	-
	Outlet	7.9	26.9	0.8	491	29	33	397	71(T) 35.6(S)	28(T) 19.5(S)	$1.13x10^{5}$	$3.9x10^{4}$	$2.1x10^{3}$	-
	% removal	-	-	-		80.14	84.65	-	81.36	83.72	99.74	99.0	99.09	-
10/ 03/ 06	**Inlet**	7.5	26.9	0.5	599	139	243	497	315(T) 164.2 (S)	121(T) 85.3(S)	$9.3x10^{6}$	$1.1x10^{6}$	$7.5x10^{5}$	-
	Reactor Outlet	7.2	26.4	0.4	578	67.8	87	468	125(T) 98(S)	84.2(T) 45(S)	$7.5x10^{6}$	$2.3x10^{5}$	$1.5x10^{3}$	-
	Outlet	7.9	27.0	1.6	489	26.7	32	412	61(T) 39.4(S)	25(T) 15.6(S)	$2.3x10^{5}$	$7.5x10^{3}$	$4.3x10^{3}$	-
	% removal	-		-	-	80.79	86.83	-	80.63	79.34	97.53	99.32	99.43	-
25/ 03/ 06	**Inlet**	7.2	26.6	0.2	589	142	150	488	399(T) 164(S)	201(T) 81.5(S)	$2.3x10^{7}$	$6.4x10^{6}$	$9.3x10^{4}$	-
	Reactor Outlet	7.5	26.8	0.5	497	89.9	98	456	137.1(T) 89.7(S)	59.8(T) 35(S)	$1.1x10^{6}$	$2.3x10^{5}$	$1.1x10^{3}$	-
	Outlet	8.1	26.9	1.1	435	22.4	22	385	83.1(T) 45.3(S)	25(T) 14.2(S)	$9.3x10^{4}$	$2.8x10^{3}$	$1.1x10^{3}$	-
	% removal	-	-	-	-	84.23	85.33	-	79.17	85.76	99.60	99.96	98.82	-

[Table 4.32 Continued…]

Date	Sampl-ing point	pH	Temp (°C)	DO (mg/L)	TDS (mg/L)	Turbi-dity NTU	TSS (mg/L)	Alkali-nity (mg/L)	COD (mg/L)	BOD (mg/L)	TC (MPN/ 100 ml)	FC (MPN/ 100 ml)	FS (MPN/ 100 ml)	Helmi-nthes (eggs/L)
05/ 04/ 06	**Inlet**	7.4	26.5	0.5	578	99.5	237	448	300.1(T) 178(S)	157(T) 65(S)	$3.9x10^{7}$	$2.3x10^{7}$	$4.3x10^{5}$	-
	Reactor Outlet	7.2	25.4	0.6	548	58	94.6	439	146(T) 69.8(S)	79.5(T) 32(S)	$9.3x10^{6}$	$2.8x10^{5}$	$2.3x10^{3}$	-
	Outlet	7.6	26.8	4.6	512	25	27.5	398	58(T) 39.8(S)	23(T) 19.8(S)	$3.9x10^{4}$	$1.1x10^{4}$	$9.3x10^{2}$	-
	% removal	-	-	-	-	74.87	88.40	-	80.67	85.35	99.90	99.95	99.78	-
19/ 04/ 06	**Inlet**	7.5	25.4	0.4	570	174	266	430	386 (T) 164 (S)	175(T) 70(S)	$9.3x10^{6}$	$2.1x10^{6}$	$4.3x10^{5}$	46
	Reactor Outlet	7.8	24.6	0.6	566	59.4	60	423	139(T) 91(S)	38(T) 28(S)	$2.3x10^{6}$	$2.3x10^{6}$	$2.3x10^{4}$	-
	Outlet	7.7	27.2	4.5	600	30.4	30	457	109.7(T) 99.2(S)	22(T) 12(S)	$2.3x10^{4}$	$9.3x10^{3}$	$4.3x10^{2}$	NIL
	% removal	-	-	-	-	82.52	88.72	-	71.58	87.42	99.75	99.56	99.9	100
19/ 05/ 06	**Inlet**	7.3	29.3	1.5	601	96.6	276	446	342.3(T) 169.6(S)	160(T) 65(S)	$2.3x10^{7}$	$4.3x10^{6}$	$2.3x10^{5}$	67
	Reactor Outlet	7.3	28.5	2.0	529	40.9	98	415	156.8(T) 110.7(S)	54(T) 34(S)	$2.3x10^{6}$	$2.3x10^{5}$	$4.3x10^{4}$	-
	Outlet	7.8	29.5	2.8	577	37.6	40	405	121(T) 119(S)	28(T) 20(S)	$2.3x10^{5}$	$4.3x10^{4}$	$4.3x10^{3}$	0.4
	% removal	-	-	-	-	61.07	85.50	-	64.65	82.5	99.0	99.0	98.13	99.40
31/ 05/ 06	**Inlet**	7.3	30.3	1.8	533	92.8	153	415	415(T) 105(S)	215(T) 85(S)	$4.3x10^{7}$	$9.3x10^{6}$	$1.5x10^{8}$	32
	Reactor Outlet	7.6	30.2	1.2	483	89.3	86	395	125(T) 75(S)	62(T) 44(S)	$3.9x10^{5}$	$2.3x10^{5}$	$1.2x10^{6}$	-
	Outlet	8.6	32.5	8.5	455	38.0	57	335	60(T) 20(S)	31(T) 20(S)	$2.3x10^{4}$	$2.3x10^{4}$	$1.5x10^{5}$	0.1
	% removal	-	-	-	-	59.05	62.74	-	85.54	85.58	99.94	99.75	99.9	99.68
12/ 06/ 06	**Inlet**	7.2	28.8	0.0	570	88.6	128	385	227(T) 115(S)	135(T) 90(S)	$2.3x10^{7}$	$2.3x10^{6}$	$2.3x10^{6}$	47
	Reactor Outlet	6.9	26.5	0.7	499	21.4	46	370	122(T) 69(S)	59(T) 38(S)	$2.3x10^{6}$	$2.3x10^{5}$	$4.3x10^{5}$	-
	Outlet	7.4	30.2	4.1	524	59.4	30	310	78(T) 38(S)	41(T) 33(S)	$2.3x10^{4}$	$2.1x10^{4}$	$1.1x10^{4}$	NIL
	% removal	-	-	-	-	32.96	76.56	-	65.63	69.63	99.9	99.08	99.52	100
22/ 06/ 06	**Inlet**	7.2	27.5	0.0	499	94.9	159	415	196.4(T) 88.40(S)	120(T) 81(S)	$9.3x10^{6}$	$2.3x10^{6}$	$9.3x10^{5}$	-
	Reactor Outlet	7.1	26.9	0.8	513	41.5	44	398	112.3(T) 65.64(S)	58(T) 42(S)	$4.3x10^{6}$	$9.3x10^{5}$	$2.3x10^{4}$	-
	Outlet	8.1	27.9	5.3	472	29.4	29	370	88.3(T) 32.11(S)	28(T) 37(S)	$4.3x10^{4}$	$1.1x10^{4}$	$9.3x10^{2}$	-
	% removal	-	-		-	69.02	81.76		55.05	76.67	99.54	99.52	99.78	-

[Table 4.32 Continued…]

Date	Sampl-ing point	pH	Temp (°C)	DO (mg /L)	TDS (mg/L)	Turbi-dity NTU	TSS (mg/L)	Alkali-nity (mg/L)	COD (mg/L)	BOD (mg/L)	TC (MPN/ 100 ml)	FC (MPN/ 100 ml)	FS (MPN/ 100 ml)	Helmi-nthes (eggs/L)
04/ 07/ 06	Inlet	7.5	29.5	0.0	574	115	139	432	245.9(T) 114.9(S)	110(T) 25(S)	$2.3x10^{7}$	$4.3x10^{6}$	$4.3x10^{5}$	-
	Reactor Outlet	7.3	29.0	1.2	480	37.5	47	415	109.9(T) 72.65(S)	46(T) 10(S)	$2.3x10^{6}$	$9.3x10^{5}$	$9.3x10^{4}$	-
	Outlet	7.8	30.5	4.2	496	32.9	28	343	83.57(T) 35.39(S)	25(T) 5(S)	$1.1x10^{5}$	$1.1x10^{4}$	$9.1x10^{3}$	-
	% removal	-	-	-	-	71.36	79.86		66.02	77.27	99.52	99.74	99.02	-
24/ 07/ 06	Inlet	7.4	29.6	0.1	511	184	600	380	271.2(T) 140.2(S)	169(T) 88.9(S)	$4.3x10^{7}$	$9.3x10^{6}$	$9.3x10^{5}$	-
	Reactor Outlet	7.8	28.5	0.3	470	88.8	82	375	85.37(T) 46.8(S)	48.3(T) 24.9(S)	$4.3x10^{6}$	$2.3x10^{6}$	$4.3x10^{4}$	-
	Outlet	7.3	30.1	4.2	434	42.7	55	320	52.36(T) 28.6(S)	33.5(T) 21.78(S)	$2.3x10^{5}$	$2.3x10^{4}$	$1.1x10^{3}$	-
	% removal		-		-	76.79	90.83	-	80.69	80.18	99.47	99.75	99.48	-
07/ 08/ 06	Inlet	7.3	28.4	0.2	590	109	232	465	290.7(T) 124.2(S)	172(T) 78.3(S)	$2.3x10^{7}$	$6.3x10^{6}$	$2.1x10^{5}$	-
	Reactor Outlet	7.4	28.1	0.5	547	55.3	58.3	398	96.67(T) 53.88(S)	58(T) 28.9(S)	$4.3x10^{6}$	$2.3x10^{5}$	$1.5x10^{4}$	-
	Outlet	8.3	29.5	3.7	458	27.1	33	376	58.9(T) 24.71(S)	21(T) 19.8(S)	$1.5x10^{5}$	$2.1x10^{4}$	$2.3x10^{3}$	-
	% removal	-	-	-	-	75.14	85.78	-	79.74	87.79	99.35	99.67	99.90	-
04/ 09/ 06	Inlet	7.4	28.0	0.0	502	79.2	138	370	212.8(T)	170	$4.3x10^{7}$	$1.5x10^{7}$	$2.3x10^{6}$	-
	Reactor Outlet	7.5	28.7	0.5	452	39.7	62	362	90.39(T) 69.78(S)	76(T) 36(S)	$1.5x10^{6}$	$1.5x10^{6}$	$4.3x10^{2}$	-
	Outlet	7.9	27.8	4.6	459	36	41	355	67.25	27	$2.3x10^{5}$	$7.5x10^{3}$	$2.4x10^{2}$	-
	% removal			-		54.55	70.29	-	68.41	84.12	99.47	99.95	99.63	-
19/ 09/ 06	Inlet	7.6	28.0	0.7	501	90.1	178	387	190.58(T))	110	$9.3x10^{6}$	$3.9x10^{5}$	$6.4x10^{4}$	-
	Reactor Outlet	7.2	28.0	0.0	494	48.0	43	395	97.52(T) 116.9(S)	60(T) 30(S)	$2.3x10^{5}$	$2.3x10^{3}$	$2.3x10^{3}$	-
	Outlet	7.7	30.0	4.8	529	28.6	9	392	77.81	22	$9.3x10^{4}$	$4.3x10^{3}$	$7.5x10^{2}$	-
	% removal		-	-	-	68.26	94.94		59.17	80.0	99.00	98.90	99.19	-
11/ 10/ 06	Inlet	7.2	26.8	0.0	643	137	206	435	322.4(T)	190	$1.5x10^{6}$	$4.3x10^{5}$	$9.3x10^{4}$	-
	Reactor Outlet	6.8	26.4	0.0	560	28.2	54	458	130.8(T) 89.08(S)	54(T) 60(S)	$4.3x10^{5}$	$9.3x10^{4}$	$9.3x10^{2}$	-
	Outlet	8.4	27.0	3.5	522	46.4	80	368	109.29	24	$1.1x10^{4}$	$2.3x10^{3}$	$7.7x10^{3}$	-
	% removal	-	-	-	-	66.13	61.17	-	66.10	87.37	99.27	99.47	91.65	-
26/ 10/ 06	Inlet	7.2	26.0	0.0	479	112	215	450	252.61(T)	195(T)	$2.3x10^{7}$	$9.3x10^{5}$	$9.3x10^{4}$	-
	Reactor Outlet	7.6	25.4	0.0	487	78.3	66	489	105.87(T)	60(T)	$2.3x10^{6}$	$4.3x10^{4}$	$2.3x10^{4}$	-
	Outlet	7.1	26.2	3.6	486	51.0	54	490	116.29	42(T)	$3.9x10^{5}$	$2.1x10^{4}$	$4.3x10^{2}$	-
	% removal	-	-	-	-	54.46	74.88	-	53.96	78.46	98.30	97.74	99.0	-
09/ 11/ 06	Inlet	7.3	26.0	0.0	550	147	272	397	291.44	115	$4.3x10^{6}$	$2.3x10^{6}$	$4.3x10^{4}$	-
	Reactor Outlet	7.1	25.5	0.0	512	44.1	51	448	81.77(T)	40(T)	$2.3x10^{6}$	$9.3x10^{5}$	$1.5x10^{4}$	-
	Outlet	7.5	26.2	4.8	298	18.0	15	402	71.28	21	$4.3x10^{4}$	$1.1x10^{3}$	$9.3x10^{3}$	-
	% removal	-	-	-	-	87.76	94.49	-	75.54	81.74	99.0	99.95	99.0	-
22/ 11/ 06	Inlet	7.2	28.4	0.2	568	138	367	380	377.61	170	$2.3x10^{6}$	$2.3x10^{6}$	$9.3x10^{5}$	-
	Reactor Outlet	7.0	28.0.	1.1	541	69.8	54	400	112.89	54	$2.3x10^{6}$	$2.3x10^{5}$	$9.3x10^{4}$	-
	Outlet	7.2	28.4	4.8	540	27.5	31	415	75.63	26	$7.5x10^{4}$	$1.2x10^{4}$	$2.3x10^{3}$	-
	% removal	-	-	-	-	80.07	91.55	-	79.97	84.71	96.74	99.48	99.0	-

4.3.6.1 Impact of Seasonal Variations on the Physico- chemical and Microbiological Characteristics of Influent, Effluent and Removal Efficiency of Plant

The performance of UASB plant, Saharanpur w.r.t. organic as well as microbial pollutants removal were studied for all seasons i.e. summer, monsoon, winter and autumn. From the study work following results were obtained as depicted in Table 4.33

Table 4.33 Variations in the characteristics of Physico-Chemical and Microbial parameters and their removal during all the seasons

(A). Physico-Chemical Parameters

Seasons	TSS			BOD			COD		
	Inlet (mg/L)	Outlet (mg/L)	% R	Inlet (mg/L)	Outlet (mg/L)	% R	Inlet (mg/L)	Outlet (mg/L)	% R
Winter	258	38	79.3	164	27	83.0	308	91	68.13
Autumn	198	28	86.04	166	26	83.85	362	70	80.64
Summer	195	37	77.88	158	28	81.53	269	83	67.81
Monsoon	216	28	83.9	143	25	81.8	239	67	70.32
Mean	**215**	**32**	**81.72**	**157**	**27**	**82.54**	**291**	**77**	**71.54**

(B). Microbiological Parameters

Seasons	Total Coliforms			Fecal Coliforms			Fecal Streptococci		
	Inlet (MPN/ 100ml)	Outlet (MPN/ 100ml)	% R	Inlet (MPN/ 100ml)	Outlet (MPN/ 100ml)	% R	Inlet (MPN/ 100ml)	Outlet (MPN/ 100ml)	% R
Winter	4300000	61000	98.58	1200000	5000	99.6	136000	2200	98.4
Autumn	18000000	120000	99.33	3800000	8900	99.8	290000	2000	99.3
Summer	20600000	104000	99.50	5300000	15000	99.7	2300000	4200	99.8
Monsoon	25000000	150000	99.40	4300000	11000	99.7	410000	1400	99.7
Mean	**14000000**	**103000**	**99.26**	**3200000**	**9300**	**99.7**	**440000**	**2300**	**99.5**

% R= % Removal

As far as concerned about the impact of seasonal variation upon the plant efficiency following observations are made:

1. The effluent TSS was found little higher in winter and summer i.e. 38mg/L. Whereas high TSS removal was observed during autumn and monsoon i.e. 86 and 83% respectively (figure 4.87).

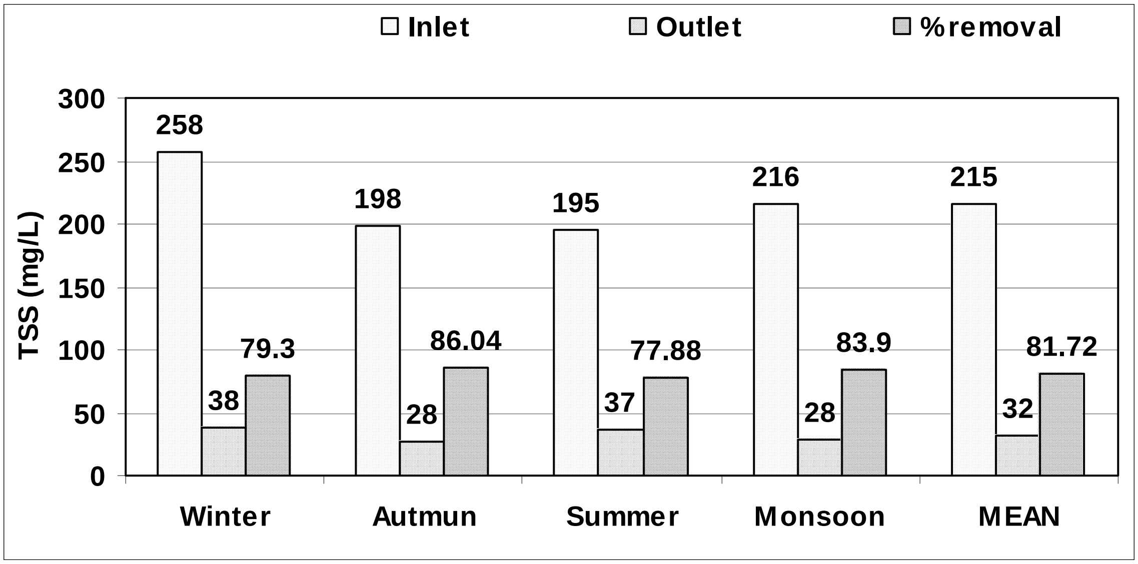


Fig 4.87 Impact of Seasonal variations on the TSS concentration of Influent, Effluent and percentage TSS removal efficiency of Plant

2. The effluent BOD (i.e. ≈27 mg/L) as well as BOD removal (i.e. ≈82.54%) during all the seasons were reported almost similar (Figure 4.88).

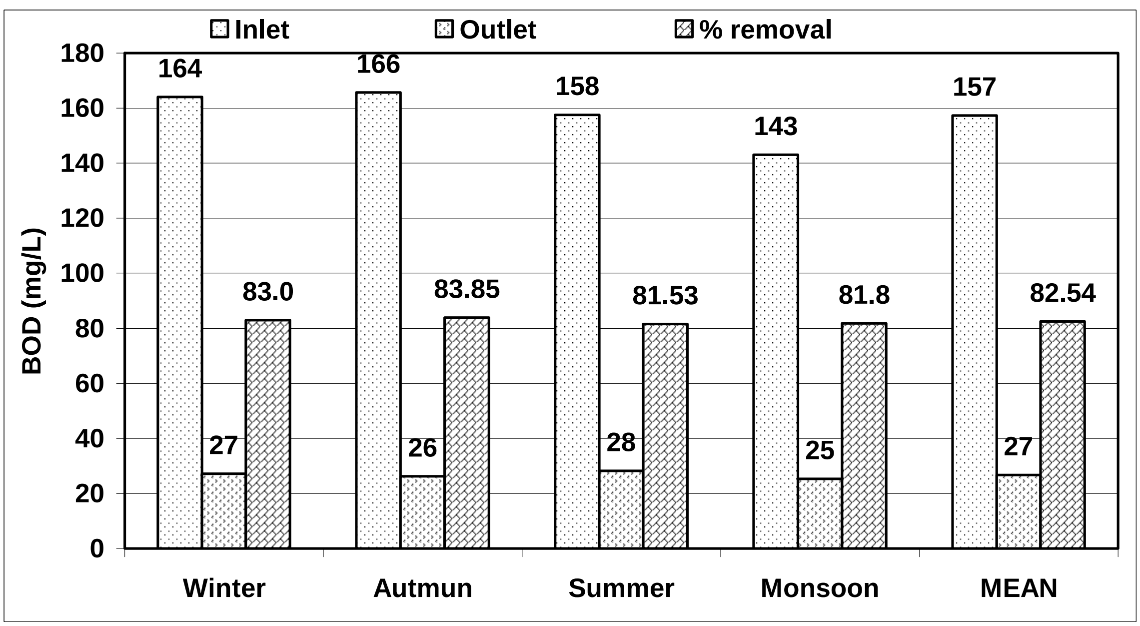


Fig. 4.88 Impact of Seasonal variations on the BOD concentration of Influent, Effluent and percentage BOD removal efficiency of Plant

2. The effluent COD was reported high during winter and summer period i.e. 91 and 83 mg/l respectively. Whereas the COD removal efficiency were found higher in autumn i.e. 80% (figure 4.89).

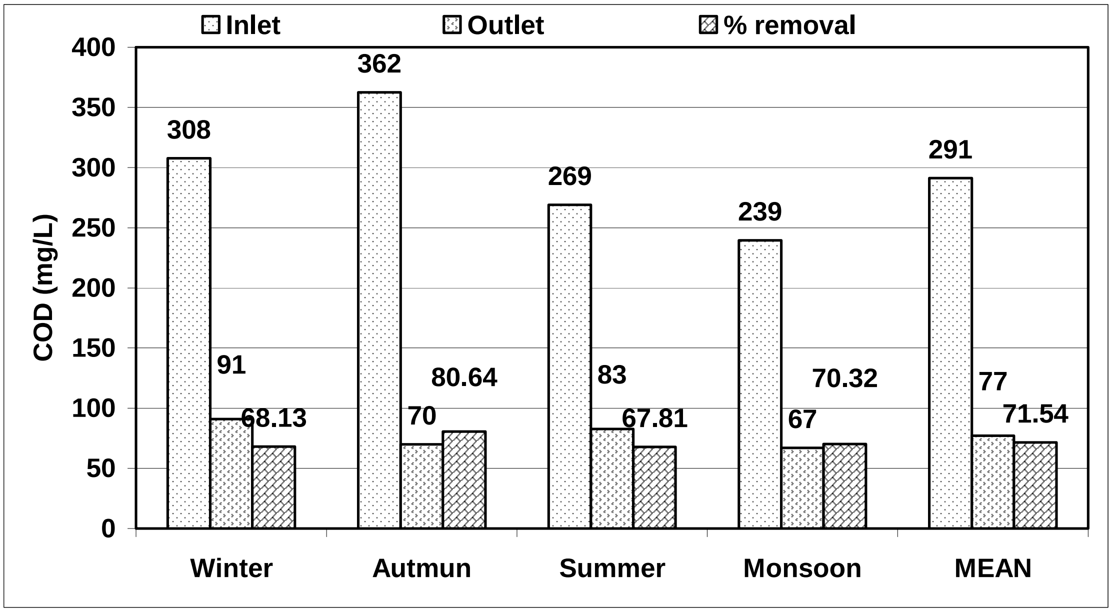
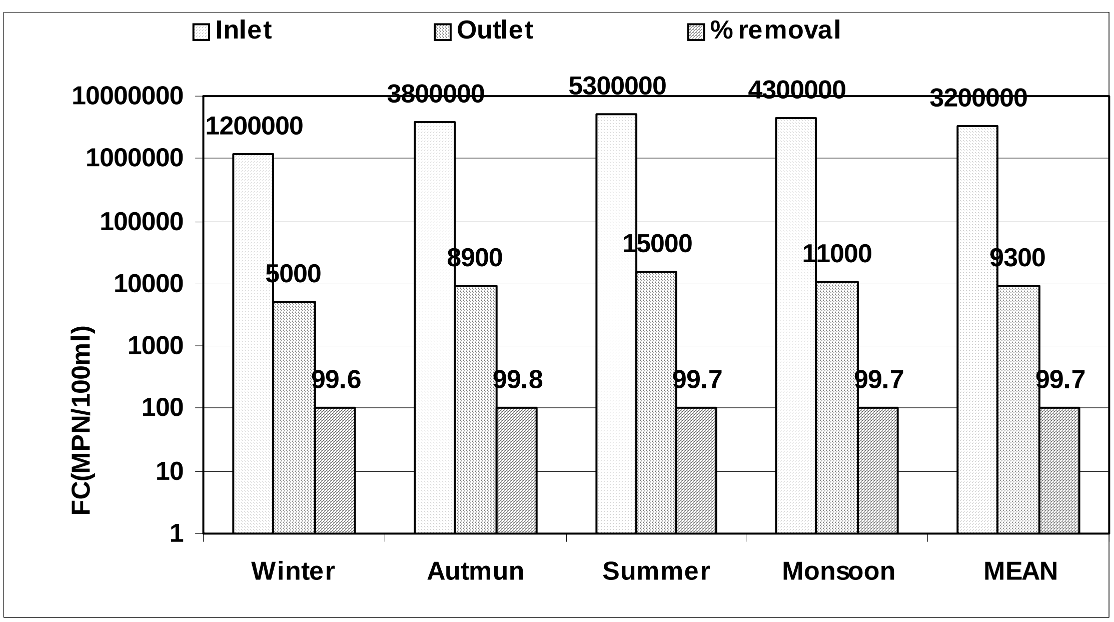


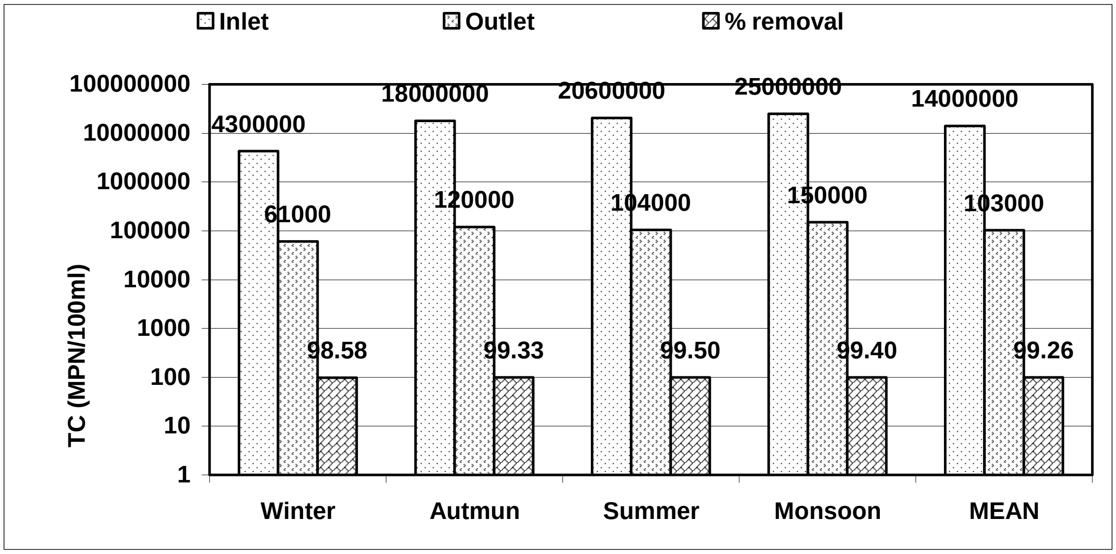
Fig. 4.89 Impact of Seasonal variations on the COD concentration of Influent, Effluent and percentage COD removal efficiency of Plant

4. The effluent concentration of Total Coliforms was observed lower in winters whereasthe highest effluent TC concentration was noted during monsoon period. More than 2 log removal was noted during all the seasons for total coliforms except winters (i.e. only 98.58%).

The effluent concentration of fecal coliforms was reported higher during summer and monsoon period whereas lowest in winters. Whereas the almost similar FC removal was reported during all the seasons (figure 4.90).



5. The effluent FS concentration was reported higher in summer and lower in monsoon period. Furthermore the similar FS removal observed during all the seasons except winters (figure 4.90).



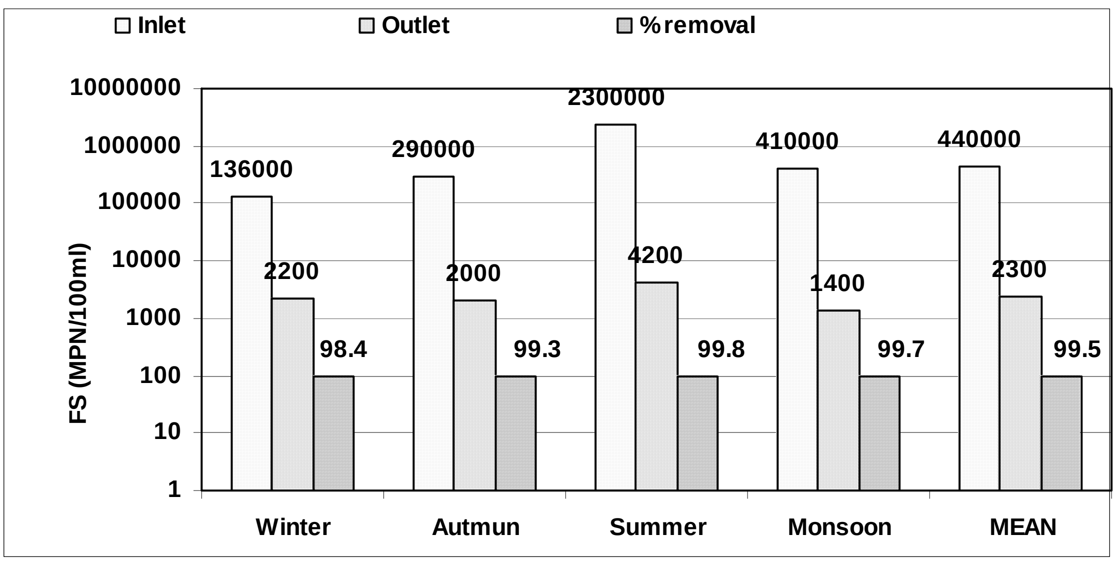


Fig 4.90 Impact of Seasonal variations on the Microbiological characteristics (TC FC and FS) of Influent, Effluent and TC and FC Removal efficiency of Plant

4.3.6.2 Estimation of Correlation between Physico-chemical and Indicator Microorganisms

On the basis of statistical analysis of data observed, we find out the relationship between key wastewater constituents i.e., Turbidity, TSS and BOD with Total Coliform, Fecal Coliform & Fecal Streptococci, discussed as follows:

The work presented here summarizes suspended particles and associated microbial indicators concentration at effluent of the plant. For Suspended Solids, there was a positive correlation between SS value and TC, FC, FS concentration (r^2 = 0.62, 0.66, 0.60 respectively) (fig.4.91 – fig 4.93). The value of r^2 in case of TC, FC and FS (0.69-0.72) shows that ≈ 65% variation in TC, FC and FS is influenced by SS changes. However, the remaining 35 % variations may be attributed to other factors.

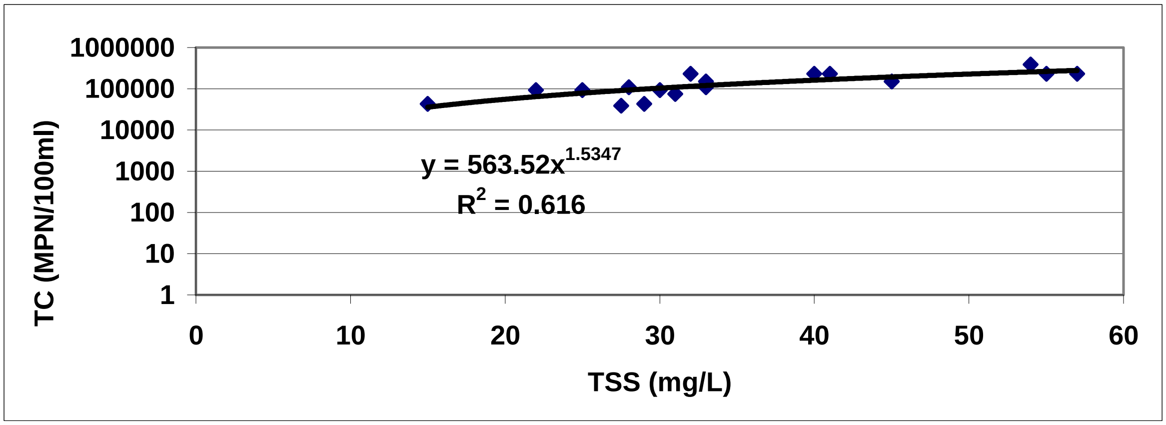


Fig.4.91 Correlation b/w Total Coliform and TSS at Outlet of UASB, Saharanpur

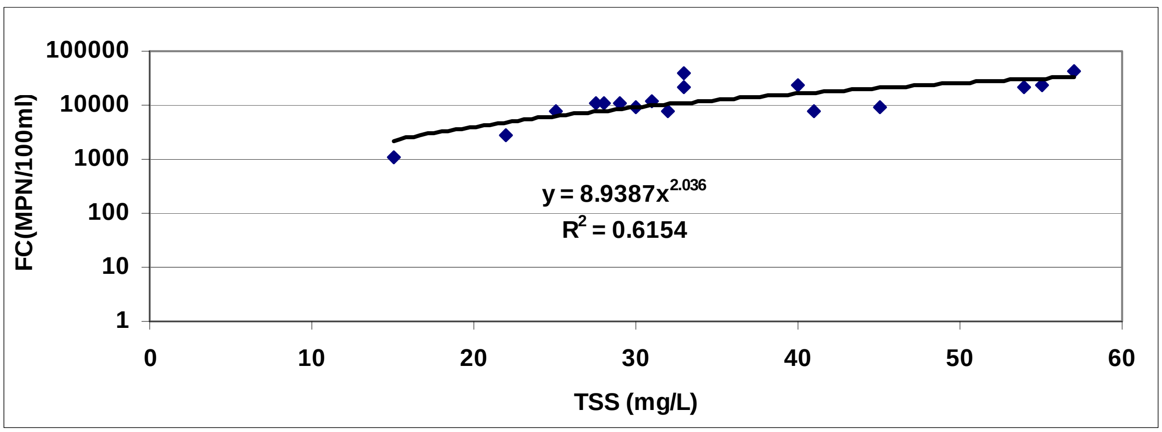


Fig. 4.92 Correlation b/w Fecal Coliform and TSS at Outlet of UASB, Saharanpur

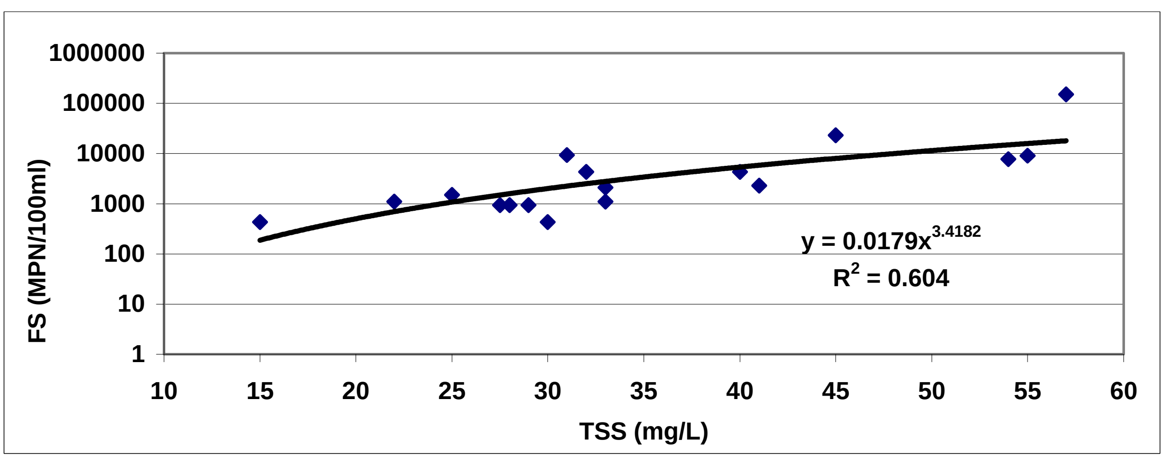


Fig. 4.93 Correlation b/w Fecal streptococci and TSS at Outlet of UASB, Saharanpur

The high concentration of turbidity was found to be associated with high number of indicator organisms at plant effluent. The statistical analysis of data shows less significant correlation between turbidity and TC, FC and FS values (r^2 = 0.58, 0.57, 0.50 respectively) (Fig.4.94- Fig 4.96) as compare to TSS. The value of r^2 in all cases (0.50- 0.58) shows that 53-58% variation in TC, FC and FS is influenced by turbidity changes. However, the remaining 40-50 % variations can be attributed to other factors.

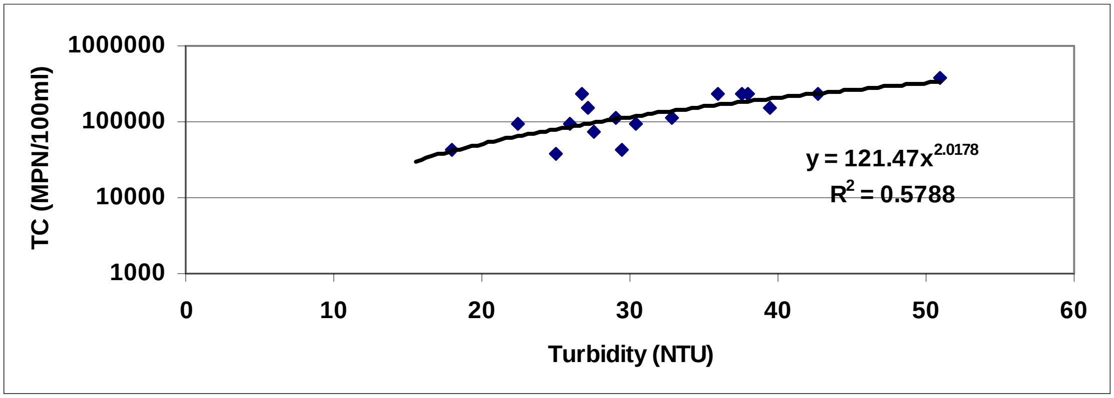


Fig.8.94 Correlation b/w Total Coliform and Turbidity at Outlet of UASB, Saharanpur

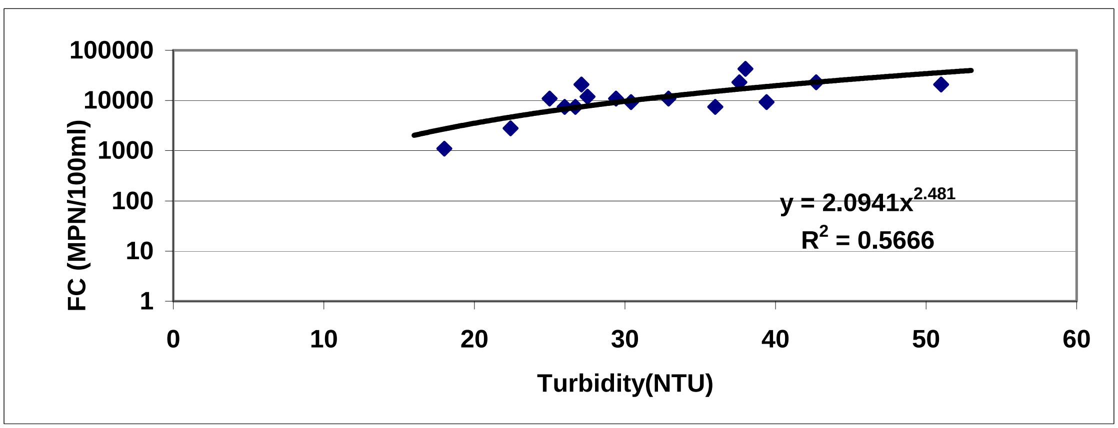


Fig. 4.95 Correlation b/w Fecal Coliform and Turbidity at Outlet of UASB, Saharanpur

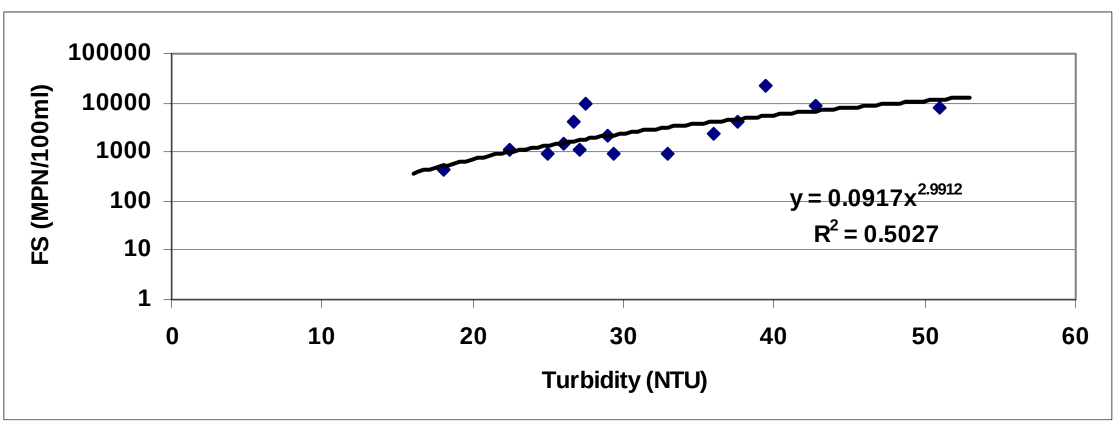


Fig. 4.96 Correlation b/w Fecal streptococci and Turbidity at Outlet of UASB, Saharanpur

The BOD concentration was also correlated to TC, FC and FS concentration at plant effluent (Fig.4.98). The results revealed that BOD show less significant correlation with microbial parameters (r^2 = 0.51, 0.43, 0.53 respectively) than SS and turbidity (Fig 4.97-Fig 4.99). Observation revealed that around 50% microbial fractions are influenced by BOD changes. However, the remaining 50 % variations can be attributed to other factors.

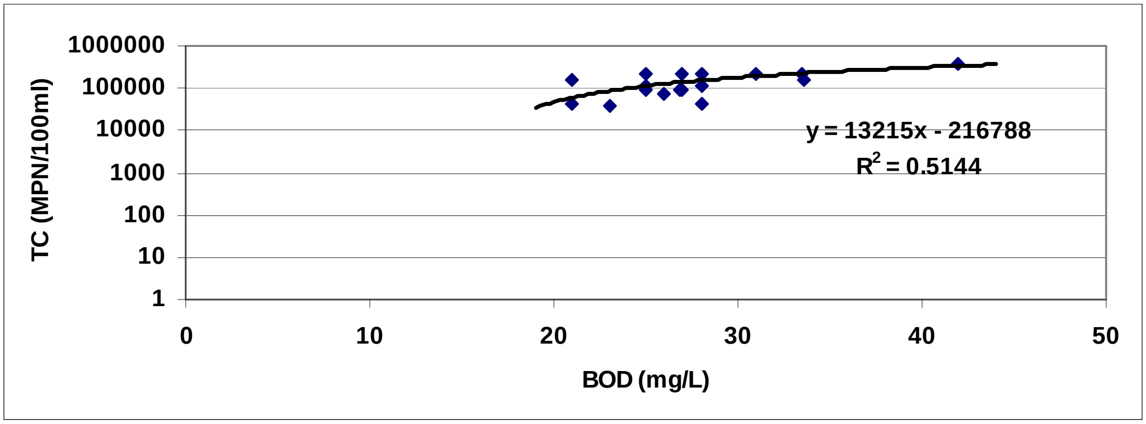


Fig. 4.97 Correlation b/w Total Coliform and BOD at Outlet of UASB, Saharanpur

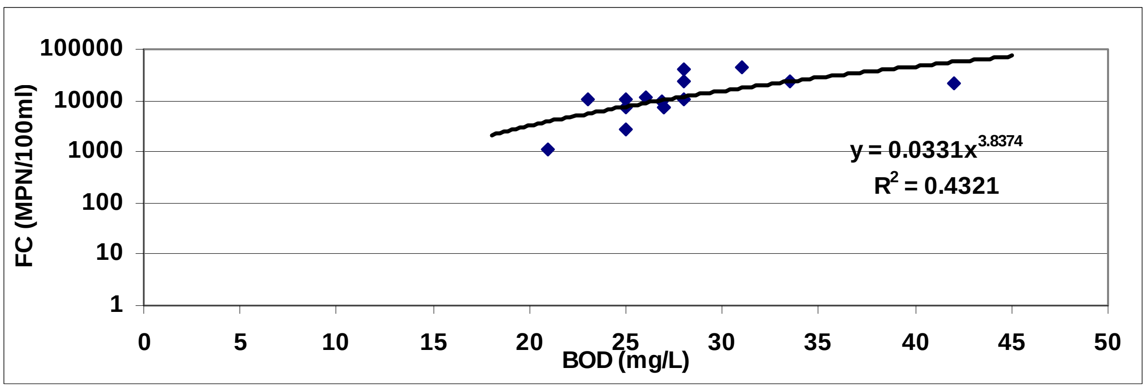


Fig. 4.98 . Correlation b/w Fecal Coliform and BOD at Outlet of UASB, Saharanpur

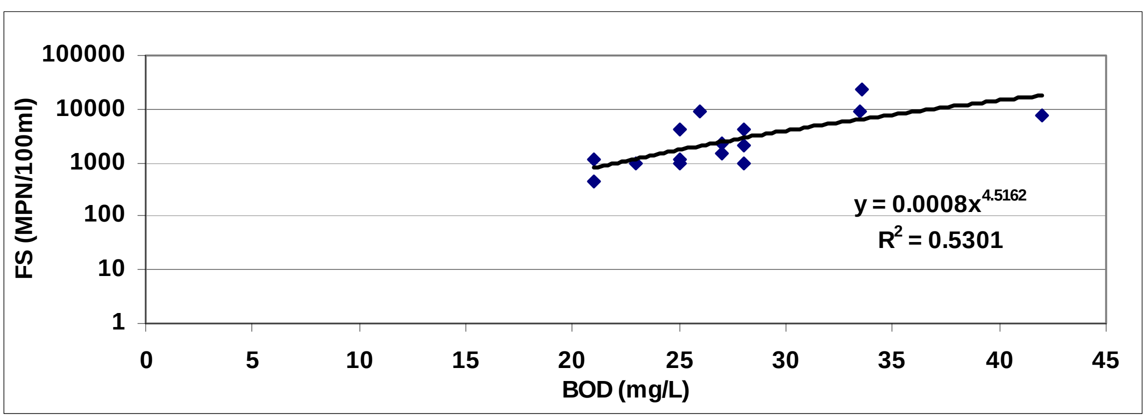


Fig. 4.99.Correlation b/w Fecal streptococci and BOD at Outlet of UASB, Saharanpur

4.3.7 6 MLD Oxidation (Facultative) Pond Plant Lakkarghat, Rishikesh (Uttrakhand)

4.3.7.1 Physico-Chemical and Microbiological Characteristic

Various Physico-Chemicals and microbiological parameters analyzed for the Influent and effluent of the plant as well as the derived efficiency of the plant with respect to these parameters are listed in Table 4.34.

Table 4.34: Descriptive Data and Removal Efficiency of Oxidation Pond Plant, Rishikesh.

Date	Sampling Point	Temp (°C)	TSS (mg/L)	Turbidity NTU	pH	TDS (mg/L	DO (mg/L)	COD (mg/L)	BOD (mg/L)	TC (MPN/ 100ml)	FC (MPN/ 100 ml)	FS MPN/ 100ml	Helminthes (eggs/L)
7/08/04	Inlet	25.2	390	224	7.0	350	0.0	298 (T) 210(S)	190(T) 140(S)	$2.8x10^7$	$9.3x10^6$	$3.9x10^5$	**26**
	Outlet	25.4	54	11.5	7.6	300	1.9	75(T) 45(S)	38(T) 29(S)	$1.5x10^5$	$9.3x10^4$	$1.5x10^3$	**0.2**
	% Removal	-	**86.2**	**94.9**	-	-	-	**74.8**	**80.0**	**99.5**	**99.0**	**99.6**	**100**
25/08/04	Inlet	30.5	310	201	7.1	335	0.0	322(T) 272(S)	180(T) 150(S)	$9.3x10^6$	$3.9x10^6$	$7.5x10^4$	**46**
	Outlet	31	47	8.7	7.7	310	1.8	70(T) 48.5(S)	35(T) 26(S)	$4.3x10^4$	$9.3x10^3$	$1.4x10^2$	**NIL**
	% Removal	-	**84.8**	**95.7**				**77.9**	**80.6**	**99.5**	**99.8**	**99.8**	**100**
13/09/04	Inlet	28.5	280	198	7.3	470	0.0	359(T) 203(S)	220(T) 190(S)	$2.3x10^7$	$9.3x10^6$	$4.3x10^5$	**22**
	Outlet	30	52	12	7.6	410	0.5	88(T) 47.4(S)	40(T) 32(S)	$2.3x10^5$	$7.5x10^4$	$9.3x10^2$	**NIL**
	% Removal	-	**81.4**	**93.9**	-	-	-	**75.5**	**81.8**	**99**	**99.2**	**99.8**	**100**
14/10/04	Inlet	27.2	350	261	7.4	375	0.0	350(T) 279(S)	195(T) 160(S)	$1.5x10^8$	$9.3x10^6$	$2.3x10^4$	16
	Outlet	29.3	54	14.1	7.7	365	2.1	79(T) 51(S)	45(T) 35(S)	$4.3x10^5$	$9.3x10^4$	$4.3x10^2$	Nil
	% Removal	-	**84.6**	**94.6**	-	-	-	**77.4**	**76.9**	**99.7**	**99**	**98.1**	**100**
5/11/04	Inlet	26.0	370	287	7.3	410	0.0	366(T) 208(S)	200(T) 165(S)	$9.3x10^8$	$2.3x10^8$	$9.3x10^6$	60
	Outlet	26.6	75	76	7.4	385	2.4	75(T) 64(S)	54(T) 48(S)	$4.3x10^6$	$2.1x10^6$	$4.3x10^4$	Nil
	% Removal	-	**79.7**	**73.5**	-	-	-	**79.5**	**73.0**	**99.5**	**99.1**	**99.5**	**100**
08/08/05	Inlet	27.5	254	236.9	7.6	480	1.8	312.28 (T) 154.46 (S)	195 (T)	$2.3x10^7$	$2.3x10^7$	$1.5x10^6$	45
	Outlet	28.8	55	24.9	7.9	415	1.1	53.98 (T) 33.78 (S)	36 (T)	$4.3x10^5$	$2.3x10^5$	$4.3x10^3$	NIL
	% Removal	**-**	**78.3**	**89.48**	**-**	**-**	**-**	**82.71**	**81.54**	**98.13**	**99.0**	**99.71**	**100**

(Table 4.34 Continued…)

Date	Sampling Point	Temp (ºC)	TSS (mg/L)	Turbi dity NTU	pH	TDS (mg/L)	DO (mg/L)	COD (mg/L)	BOD (mg/L)	TC MPN/ 100ml	FC MPN/ 100ml	FS MPN/ 100ml	Helmin-thes (eggs/L)
28/ 08/ 05	Inlet	27.8	218	258.3	7.5	430	1.4	363.26 (T) 157.53 (S)	160	$9.3x10^6$	$2.1x10^6$	$1.5x10^5$	67
	Outlet	28.7	47	18.6	7.8	359	1.6	81.21 (T) 51.63 (S)	35	$2.3x10^4$	$2.1x10^4$	$4.3x10^3$	NIL
	% Removal	-	**78.44**	**92.8**	-	-	-	**77.64**	**78.13**	**99.75**	**99.00**	**97.13**	**100**
08/ 09/ 05	Inlet	27.9	229	253	7.5	365	0.5	350.32 (T) 133.65 (S)	170	$9.3x10^6$	$2.1x10^6$	$9.3x10^5$	38
	Outlet	29.4	46.5	18.4	7.6	330	4.1	84.8 (T) 53.1 (S)	30	$2.3x10^4$	$2.1x10^4$	$7.5x10^2$	NIL
	% Removal	-	**79.69**	**92.7**	-	-	-	**75.79**	**82.35**	**99.75**	**99.0**	**99.92**	**100**
28/ 09/ 05	Inlet	28	262	210	7.4	385	0.5	442.36 (T) 107.20 (S)	195	$4.3x10^7$	$2.1x10^7$	$2.3x10^6$	88
	Outlet	28.4	52	18.8	7.8	375	6.4	84.18 (T) 50.82 (S)	30	$4.3x10^4$	$2.1x10^4$	$1.5x10^4$	0.5
	% Removal	-	**80**	**91.04**	-	-	-	**80.97**	**84.61**	**99.9**	**99.9**	**99.34**	**99.43**
10/ 10/ 05	Inlet	25.4	247	266	7.2	370	0.0	359(T) 126(S)	165(T) 115(S)	$7.5x10^6$	$2.1x10^6$	$2.1x10^4$	52
	Outlet	26.7	52.8	28.4	7.3	310	0.4	50(T) 34(S)	31(T) 27(S)	$9.3x10^4$	$4.3x10^4$	$1.4x10^3$	0.8
	% Removal	-	**78.6**	**89.3**	-	-	-	**86.1**	**81.2**	**98.8**	**98**	**93.3**	**98.5**
25/ 10/ 05	Inlet	26.1	250	190	7.4	384	0	355(T) 113(S)	125(T) 45(S)	$9.3x10^6$	$1.5x10^6$	$7.5x10^4$	32
	Outlet	26.3	46	16.8	7.3	340	4.4	40.4(T) 29.3(S)	21(T) 14.5(S)	$1.5x10^4$	$1.2x10^4$	$4.3x10^2$	Nil
	% Removal	-	**81.6**	**91.2**	-	-	-	**88.6**	**83.2**	**99.8**	**99.2**	**99.4**	**100**
08/ 11/ 05	Inlet	24.6	302	243	7.4	404	0	363(T) 93.6(S)	170(T) 110(S)	$9.3x10^6$	$9.3x10^6$	$2.3x10^4$	60
	Outlet	22.0	50	17.3	7.4	360	1.8	78.4(T) 63.5(S)	44(T) 18(S)	$2.3x10^4$	$1.5x10^4$	$7.5x10^2$	Nil
	% Removal	-	**83.4**	**92.88**	-	-	-	**78.4**	**74.1**	**99.8**	**99.8**	**96.7**	**100**
23/ 11/ 05	Inlet	21.5	302	249	7.4	480	0	333(T) 98.04(S)	153(T) (S)	$9.3x10^6$	$2.3x10^6$	$9.3x10^5$	48
	Outlet	21.5	48	23.4	7.2	399	0	60.43(T) 34.3(S)	34.1(T) (S)	$9.3x10^4$	$2.3x10^4$	$2.3x10^3$	Nil
	% Removal	-	**84.1**	**90.6**	-	-	-	**81.9**	**77.7**	**99**	**99**	**99.8**	**100**
07/ 12/ 05	**Inlet**	22.8	223	205	7.8	470	0	453.7(T) 168.8(S)	155(T)	1.5x107	2.3x106	4.3x105	56
	Outlet	18.8	53	20.9	7.8	410	3.3	101.9(T) 59.8(S)	25(T)	4.3x105	4.3x104	9.3x102	Nil
	% Removal	-	76.2	89.8	-	-	-	77.5	83.9	97.1	98.1	99.8	100

(Table 4.34 continued…)

Date	Sampling Point	Temp (ºC)	TSS (mg/L)	Turb-idity NTU	pH	TDS (mg/L)	DO (mg/L)	COD (mg/L)	BOD (mg/L)	TC MPN/ 100ml	FC MPN/ 100ml	FS MPN/ 100ml	Helmin-thes (eggs/L)
21/ 12/ 05	Inlet	20.8	389	294	7.2	452	0	414(T) 125.8(S)	171(T) 50(S)	$4.3x10^{6}$	$2.3x10^{5}$	$2.3x10^{6}$	39
	Outlet	21.2	57	**18**	7.0	419	0	102.6(T) 62.5(S)	28(T) 12(S)	$2.3x10^{4}$	$1.5x10^{3}$	$4.3x10^{3}$	0.8
	% Removal	**-**	**85.3**	**93.9**	**-**	**-**	**-**	**75.2**	**83.6**	**99.5**	**99.4**	**99.8**	**98**
04/ 01/ 06	Inlet	19.9	223	265	7.0	480	0	404.1(T) 156.4(S)	170(T) 115(S)	$2.3x10^{7}$	$9.3x10^{6}$	$4.3x10^{5}$	52
	Outlet	18.6	69	66	7.1	420	3.6	126.2(T) 97.5(S)	47(T) 29(S)	$1.5x10^{6}$	$4.3x10^{5}$	$9.3x10^{3}$	0.3
	% Removal	**-**	**69.1**	**75.1**	**-**	**-**	**-**	**68.8**	**72.4**	**93.5**	**95.4**	**97.8**	**99.4**
18/ 01/ 06	Inlet	20.6	388	344	7.5	449	0.0	412(T) 198(S)	180(T) (S)	$9.3x10^{6}$	$2.3x10^{6}$	$4.3x10^{5}$	62
	Outlet	19.8	48	43	7.5	427	0.0	115(T) 68(S)	34(T) (S)	$7.5x10^{4}$	$2.1x10^{4}$	$2.3x10^{3}$	Nil
	% Removal	**-**	**87.6**	**87.5**	**-**	**-**	**-**	**72.1**	**81.1**	**99.2**	**99.1**	**99.5**	**100**
08/ 02/ 06	Inlet	21.0	313	288	7.4	433	0.0	364(T)	164(T) 92(S)	$7.5x10^{7}$	$9.3x10^{6}$	$3.9x10^{5}$	42
	Outlet	19.8	57	28.6	7.6	392	0.0	80.2	35(T) 28(S)	$7.5x10^{5}$	$9.3x10^{4}$	$2.3x10^{3}$	0.5
	% Removal	**-**	**81.8**	**90.1**	**-**	**-**	**-**	**78.0**	**78.7**	**99**	**99**	**99.4**	**98.8**
28/ 02/ 06	Inlet	21.7	333	258	7.7	463	1.3	376.8(T) 149.5(S)	175	$2.3x10^{7}$	$2.1x10^{6}$	$4.3x10^{5}$	55
	Outlet	22.3	48.5	16.1	7.8	387	5.2	90.8(T) 53.7(S)	33.5	$9.3x10^{4}$	$9.3x10^{3}$	$2.3x10^{3}$	Nil
	% Removal	**-**	**85.4**	**93.8**	**-**	**-**	**-**	**75.9**	**80.9**	**99.6**	**99.6**	**99.5**	**100**
08/ 03/ 06	Inlet	28.4	242	175	7.4		0.7	438.14(T) 169.48 (S)	175 (T)	$4.3x10^{7}$	$9.3x10^{6}$	$2.3x10^{5}$	52
	Outlet	31.2	51	21.3	7.9		4.4	108.68 (T) 98.10 (S)	38 (T)	$2.3x10^{5}$	$9.3x10^{4}$	$1.1x10^{3}$	NIL
	% Removal	**-**	**78.8**	**87.82**	**-**	**-**	**-**	**75.19**	**78.3**	**99.46**	**99.0**	**99.52**	**100**

(Table 4.34 Continued…)

Date	Sampling Point	Temp (ºC)	TSS (mg/L)	Turbi-dity NTU	pH	TDS (mg/L)	DO (mg/L)	COD (mg/L)	BOD (mg/L)	TC (MPN/ 100ml)	FC (MPN/ 100ml)	FS (MPN/ 100ml)	Helmin-thes (eggs/L)
28/03/06	Inlet	28.1	265	234	7.5	-	0.6	461.39(T) 93.77(S)	165(T)	$4.3x10^7$	$1.5x10^7$	$2.3x10^5$	65
	Outlet	30.8	52	23	7.9	-	3.7	101.87(T) 64.3(S)	37 (T)	$2.3x10^5$	$1.1x10^5$	$2.1x10^3$	NIL
	% Removal	-	**80.4**	**90.17**	**-**	**-**	**-**	**77.92**	**77.6**	**99.46**	**99.26**	**99.08**	**100**
12/04/06	Inlet	25.3	257	162	7.3	511	0.4	416.3(T) 111.8(S)	210(T) 80 (S)	$2.3x10^7$	$2.1x10^6$	$4.3x10^6$	68
	Outlet	24.9	47	27.5	7.5	497	2.5	113(T) 52(S)	32(T) 22 (S)	$9.3x10^4$	$1.5x10^4$	$4.3x10^2$	NIL
	% Removal	-	**81.7**	**83.02**	**-**	**-**	**-**	**72.85**	**84.76**	**99.60**	**99.29**	**99.99**	**100**
26/04/06	Inlet	**28.4**	**222**	**188**	**7.6**	-	**0.1**	395.4(T) 155.31(S)	205(T) 101(S)	$7.5x10^7$	$4.3x10^7$	$2.3x10^6$	**72.2**
	Outlet	**29.8**	**54**	**30.3**	**7.8**	-	**3.4**	**88.9(T) 36.42(S)**	**26(T) 11.5(S)**	$4.3x10^5$	$9.3x10^4$	$2.1x10^3$	**0.5**
	% Removal	-	**75.67**	**83.88**	**-**	**-**	**-**	**77.51**	**87.31**	**99.42**	**99.78**	**99.90**	**99.30**
08/05/06	Inlet	**27.6**	**268.76**	**176**	**7.7**	-	**0.1**	401.26(T) 198.25(S)	212(T) 98.6(S)	$1.5x10^8$	$4.3x10^7$	$4.3x10^6$	**85**
	Outlet	**28.4**	**48**	**23**	**7.6**	-	**4.8**	**92.3(T) 52.1(S)**	**22.2(T) 15.2(S)**	$2.3x10^5$	$2.3x10^4$	$2.1x10^3$	**0**
	% Removal	-	**82.2**	**86.93**	**-**	**-**	**-**	**76.99**	**89.52**	**99.71**	**99.94**	**99.95**	**100**
28/05/06	Inlet	28.2	187	116	7.4	-	0.4	355.71(T) 119.69(S)	125(T)	$4.3x10^7$	$9.3x10^6$	$2.1x10^6$	44.5
	Outlet	30.1	50	15.2	8.0	-	3.1	91(T) 75.55(S)	37(T)	$2.3x10^5$	$9.3x10^3$	$1.1x10^3$	NIL
	% Removal	-	**73.3**	**86.89**	**-**	**-**	**-**	**74.41**	**70.4**	**99.46**	**99.9**	**99.94**	**100**
01/06/06	Inlet	32.1	366	228	7.1	446	0.1	395(T)	170(T) 30(S)	$2.3x10^7$	$4.3x10^6$	$9.3x10^6$	48.4
	Outlet	33.4	49	35.8	7.7	420	3.4	80(T)	16(T) 6(S)	$2.3x10^5$	$9.3x10^3$	$4.3x10^3$	1
	% Removal	-	**86.6**	**84.3**	**-**	**-**	**-**	**79.74**	**90.58**	**99.0**	**99.78**	**99.95**	**97.93**
16/06/06	Inlet	32.0	345	275	7.2	431	0.2	410(T) 125.6(S)	195(T) 89(S)	$7.5x10^7$	$3.9x10^5$	$7.5x10^5$	52
	Outlet	32.8	54	22	7.4	398	2.9	75(T) **32(S)**	25(T) **8(S)**	$2.1x10^5$	$1.1x10^4$	$2.1x10^3$	Nill
	% Removal	-	**84.3**	**92.0**	**-**	**-**	**-**	**81.7**	**87.2**	**99.72**	**99.72**	**99.72**	**100**

(Table 4.34 Continued…)

Date	Sampl-ing Point	Temp (°C)	TSS (mg/L)	Turbidity NTU	pH	TDS (mg/L)	DO (mg/L)	COD (mg/L)	BOD (mg/L)	TC MPN/ 100ml	FC MPN/ 100ml	FS MPN/ 100ml	Helmin-thes (eggs/L)
11/ 07/ 06	Inlet	28.5	325	190	7.4	449	1.1	405.29(T) 101.21(S)	185(T) 30(S)	$9.3x10^6$	$4.3x10^6$	$1.5x10^5$	45
	Outlet	30.6	77	36.9	7.8	369	5.0	85.89(T) 45.89(S)	33(T) 9(S)	$4.3x10^4$	$2.3x10^4$	$2.3x10^2$	0.5
	% Removal	-	**76.31**	**80.58**	-	-	-	**78.81**	**82.16**	**99.53**	**99.46**	**99.84**	**98.2**
27/ 07/ /06	Inlet	28.2	330	268	7.5	471	0.8	399.5(T) 158.1(S)	200(T) 168(S)	$1.1x10^7$	$1.5x10^6$	$4.3x10^5$	56
	Outlet	31.5	45	23.5	7.7	398	3.7	84.50(T) 47.2(S)	28(T) 12(S)	$2.1x10^4$	$9.3x10^3$	$1.1x10^3$	Nill
	% Removal	-	**86.36**	**91.2**	-	-	-	**78.85**	**86.0**	**99.8**	**99.38**	**99.74**	**100**
17/ 08/ /06	Inlet	28.6	236	111	7.3	551	-	382.19(T) 107.42(S)	175(T) 75(S)	$9.3x10^6$	$4.3x10^6$	$7.5x10^5$	61
	Outlet	30.4	16	29.6	8.2	478	-	98.11(T) 54.01(S)	15(T) 8(S)	$2.1x10^3$	$1.5x10^3$	$9.3x10^2$	0.5
	% Removal	-	**93.22**	**73.33**	-	-	-	**74.33**	**91.43**	**99.97**	**99.96**	**99.88**	**99.2**
30/ 08/ /06	Inlet	28.1	318	296	7.4	497	0.5	401.7(T) 112.3(S)	185(T) 40.(S)	$9.3x10^7$	$2.4x10^6$	$3.9x10^5$	55
	Outlet	30.8	33	30	7.7	419	1.9	87.9(T) 42.1(S)	18(T) 14.(S)	$4.3x10^4$	$2.3x10^3$	$1.5x10^3$	Nill
	% Removal	-	**89.62**	**89.9**	-	-	-	**78.12**	**90.3**	**99.95**	**99.90**	**99.62**	**100**
11/ 09/ 06	Inlet	30.1	339	190	6.9	369	0.4	409.53(T) (S)	255(T) (S)	$4.3x10^6$	$9.3x10^5$	$4.3x10^5$	56
	Outlet	30.4	43	21.9	7.6	374	3.7	50.11(T) **(S)**	24(T) **(S)**	$4.3x10^5$	$1.5x10^4$	$9.3x10^3$	Nill
	% Removal	-	**87.31**	**88.63**	-	-	-	**87.76**	**90.58**	**90.0**	**98.38**	**97.83**	**100**
26/ 09/ 06	Inlet	29.2	360	185	7.2	396	0.6	430(T) 131.2(S)	211(T) 78.(S)	$1.5x10^7$	$1.1x10^6$	$1.2x10^5$	72
	Outlet	29.8	58	18.9	7.3	379	4.3	95.45(T) 51.1(S)	26(T) 11(S)	$9.3x10^4$	$7.5x10^3$	$6.4x10^4$	0.8
	% Removal	-	**83.89**	**89.8**	-	-	-	**77.80**	**87.7**	**99.38**	**99.32**	**99.47**	**98.8**
05/ 10/ 06	Inlet	26.5	287	150	7.4	530	0.4	462.40(T)	230(T)	$2.3x10^7$	$4.3x10^6$	$4.3x10^4$	62
	Outlet	27.8	27	21.0	7.6	473	4.5	87.78(T)	38(T)	$9.3x10^4$	$1.5x10^4$	$4.3x10^2$	0.4
	% Removal	-	**90.59**	**86.0**	-	-	-	**81.01**	**83.47**	**99.59**	**99.65**	**99.0**	**99.35**
21/ 10/ 06	Inlet	26.4	313	210	7.2	418	0.0	415(T) 121(S)	235(T) 109(S)	$1.1x10^8$	$9.3x10^6$	$7.5x10^5$	41
	Outlet	26.9	35	23.5	7.4	372	3.5	88(T) 49.2(S)	40(T) 29.(S)	$7.5x10^5$	$6.4x10^4$	$4.3x10^3$	Nill
	% Removal		**8.82**	**88.8**	-	-	-	**78.80**	**83.0**	**99.32**	**99.3**	**99.43**	**100**

4.3.7.2 Impact of Seasonal Variations on the Physico-chemical and Microbiological Characteristics of Influent, Effluent and Removal Efficiency of Plant

The removal efficiency of Oxidation pond w.r.t. organic as well as microbial pollutants were studied for all seasons i.e. summer, monsoon, winter and autumn. From the study work following results was obtained as depicted in Table 4.35.

Table 4.35. Variations in the characteristics of Physico-Chemical and Microbial parameters and impact on their removal efficiency during all the seasons

(A)	Physico-Chemical Parameters								
Seasons	TSS			BOD			COD		
	Inlet (mg/L)	Outlet (mg/L)	% R	Inlet (mg/L)	Outlet (mg/L)	% R	Inlet (mg/L)	Outlet (mg/L)	% R
Winter	298.1	49.6	82.3	176.6	35.5	79.4	388.5	79.8	78.6
Autumn	285.93	52.09	81.58	169.67	35.83	78.83	407.81	94.76	76.72
Summer	267.01	50.26	80.49	183.21	25.48	84.67	395.11	89.27	77.15
Monsoon	291.7	45.7	83.4	192.6	28.0	84.7	372.4	82.1	77.8
Mean	285	49	82	180	31	82	390	86	78

(B)	Microbiological Parameters					
Seasons	Total Coliform			Fecal Coliforms		
	Inlet (MPN/ 100ml)	Outlet (MPN/ 100ml)	% Removal	Inlet (MPN/ 100ml)	Outlet (MPN/ 100ml)	% Removal
Winter	23000000	165000	98.70	4500000	40494	98.70
Autumn	42000000	250000	99.38	8200000	54539	99.30
Summer	51000000	216000	99.51	9200000	17678	99.74
Monsoon	15000000	53000	99.6	3900000	17193	99.3
Mean	30000000	150000	99.30	6000000	28000	99.27

% R= % Removal

As far as concerned about the impact of seasonal variation upon the plant efficiency, we make following observations given as:

1. The effluent TSS was found almost similar i.e. around 50 mg/L during all the seasons. While as no significant variation in TSS removal was observed throughout the seasons (Fig 4.100).

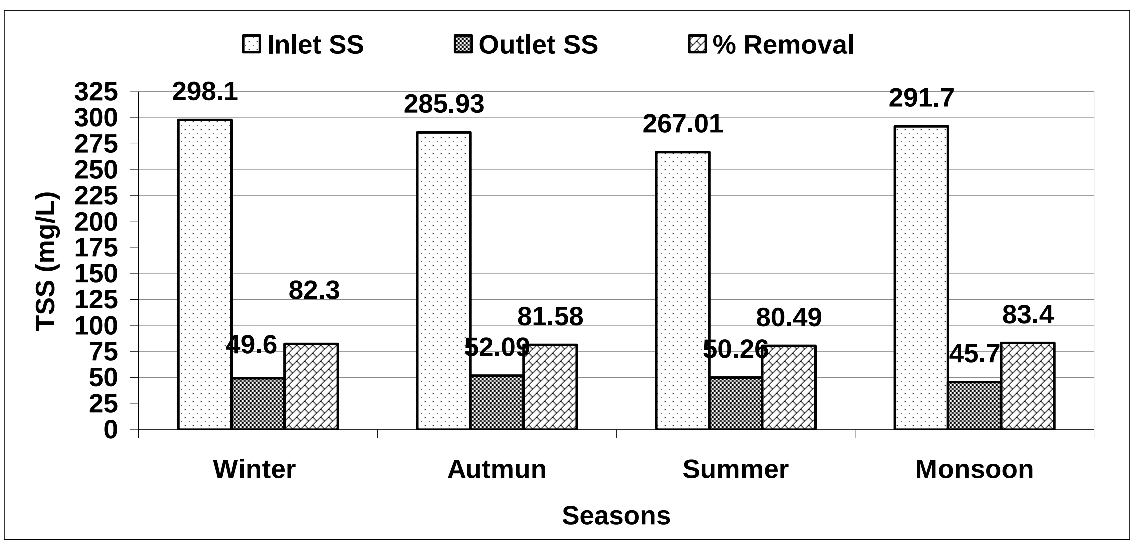


Fig 4.100. Impact of Seasonal variations on the TSS concentration of Influent, Effluent and percentage TSS removal efficiency of Plant

2. The maximum effluent BOD was reported during winter and autumn period. The maximum BOD removal was attained in summer and monsoon while lower in winters and autumn period (Fig 4.101).

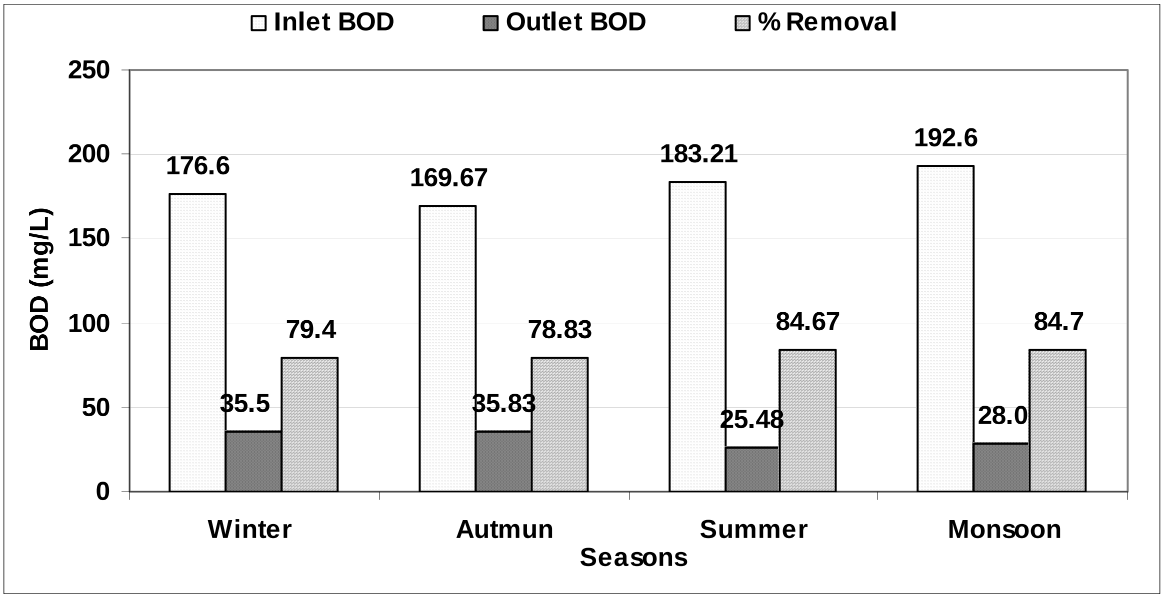


Fig 4.101 Impact of Seasonal variations on the BOD concentration of Influent, Effluent and percentage BOD removal efficiency of Plant

3. Almost similar COD removal efficiency of STP was observed during all the seasons (Fig 4.103).

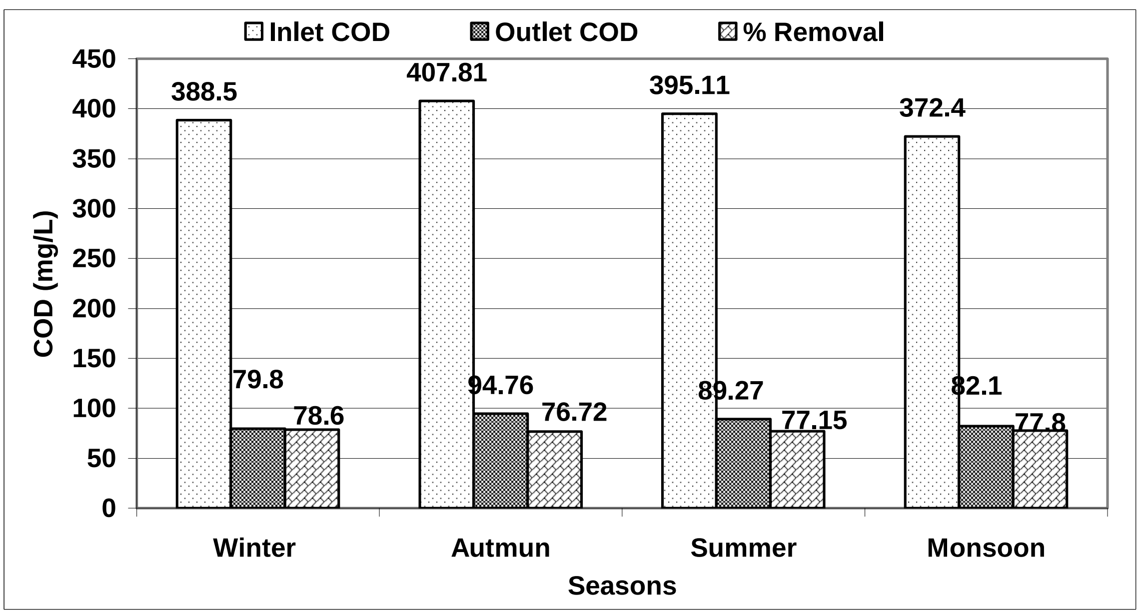
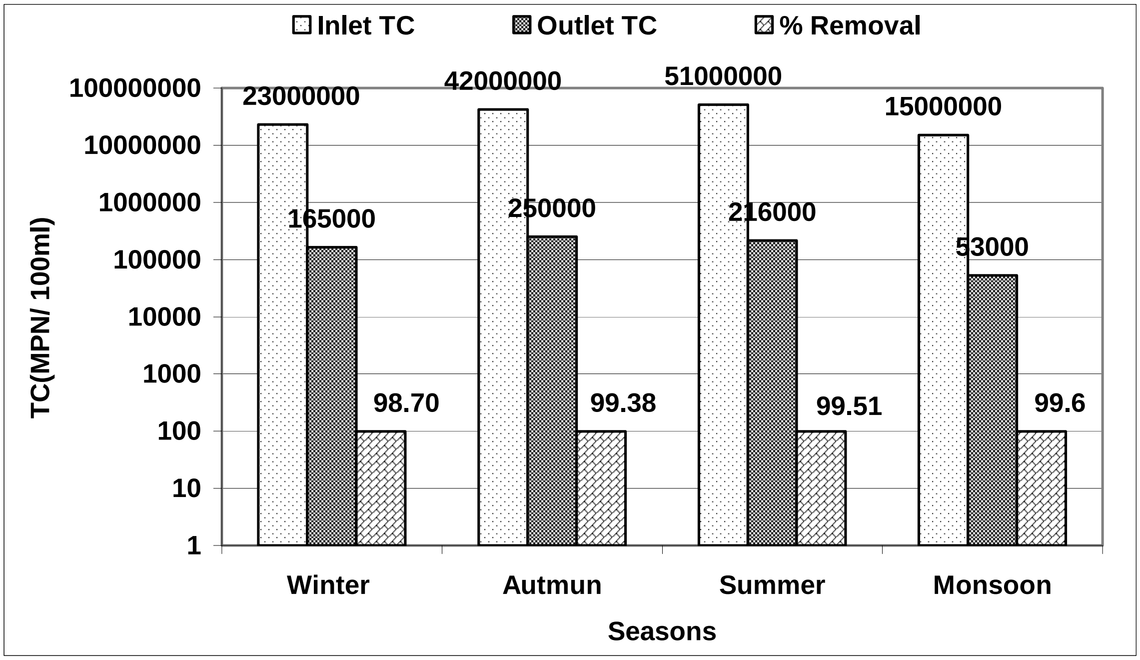


Fig.4.102 Impact of Seasonal variations on the COD concentration of Influent, Effluent and percentage COD removal efficiency of Plant

4. Similar effluent concentration of TC during all seasons except Monsoon period (53000 MPN/100 ml) while lower FC concentration during monsoon and summer period (17000 MPN/100 ml) were found. The STP removal efficiency w.r.t. TC and FC was higher during summer and autumn while lower in winter season **(Fig 4.103).**



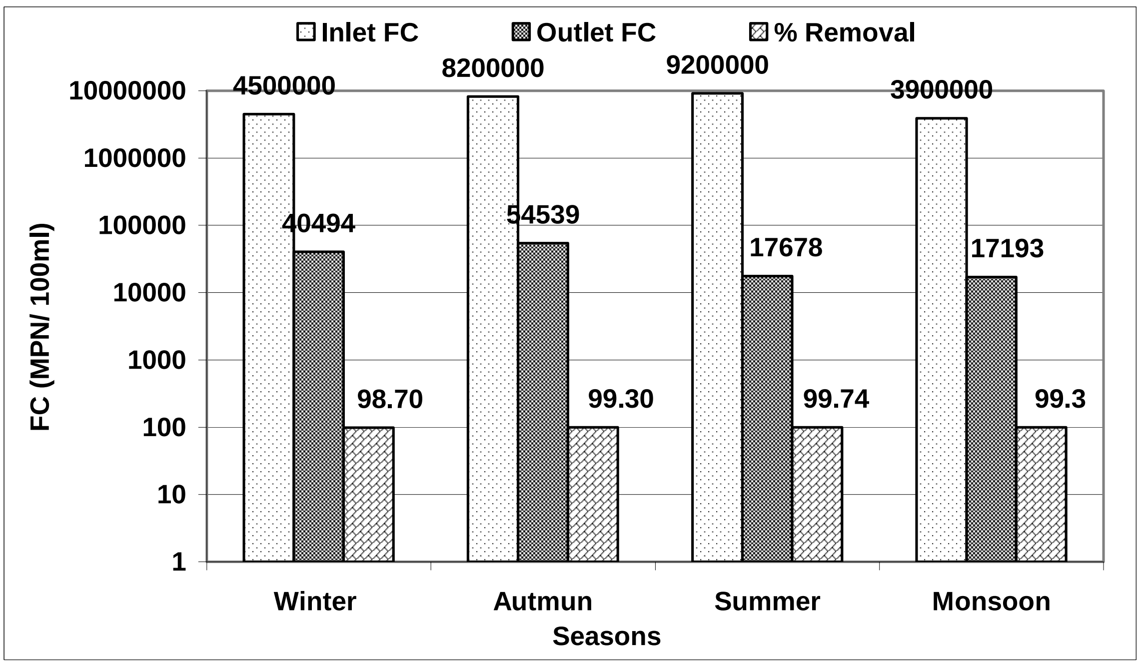
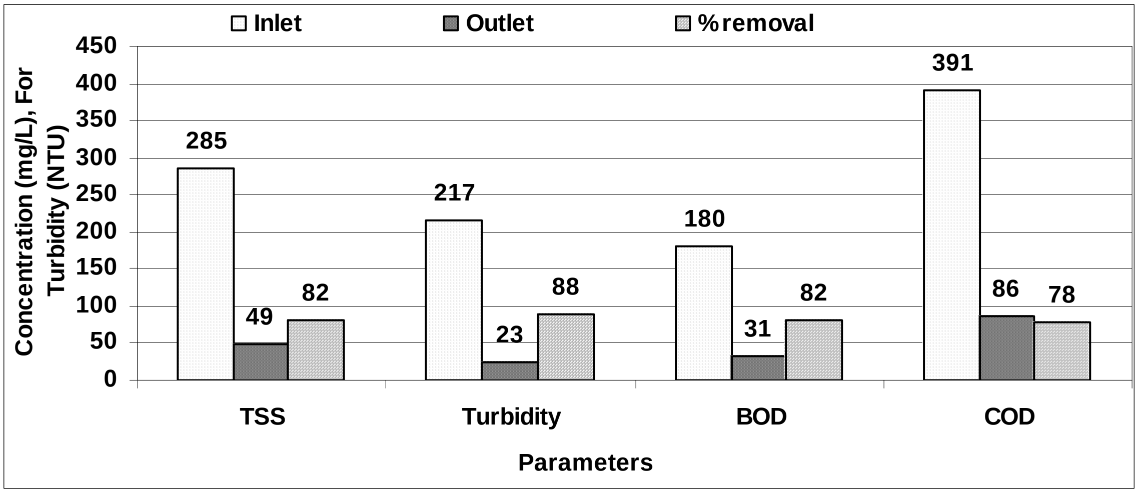


Fig 4.103 Impact of Seasonal variations on the Microbiological characteristics (TC and FC) of Influent, Effluent and TC and FC Removal efficiency of Plant

The mean concentration of all the analyzed parameters (i.e. physico-chemical and microbiological) as well as STP efficiency w.r.t. removal of theses pollutants during entire study period are shown in figure 4.104



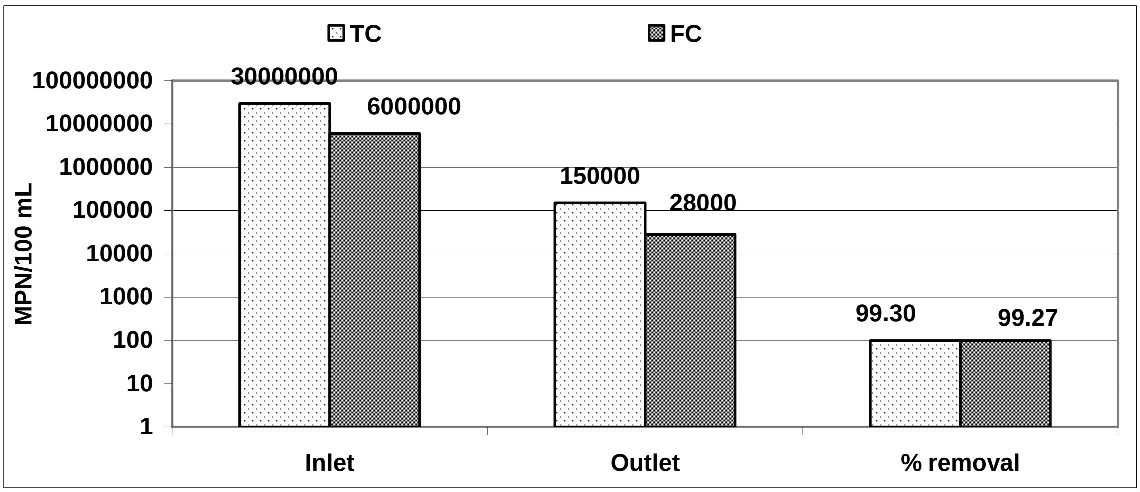


Fig.4.104 Mean concentration of Physico-Chemical and microbiological parameters as well as STP efficiency w.r.t. removal of these pollutants during all the study period

4.3.7.3 Estimation of Correlation Between Physico-Chemical and Indicator Microorganisms

Based on data observed, we tried to establish relationship between key wastewater constituents i.e., Turbidity, TSS and BOD with Total Coliform, Fecal Coliform & Fecal Streptococci. From figure 4.106 – figure 4.114 following relationships are obtained between key parameters.

1. TC = **115018** TSS **- 6E + 06** (**r^2 =** 0.79**)……………...**(i)
2. FC = **52767** TSS **- 3E + 06** (**r^2 =** 0.71**) …………….(**ii)
3. FS = **1033.1** TSS **- 50020** (**r^2** = 0.61**) …………….**(iii)
4. TC = **49216** Turbidity – **825795** (**r^2** = 0.75**)……………..**(iv)
5. FC = **22242** Turbidity – **383209** (**r^2** = 0.66**) …………….**(v)
6. FS = **425.59** Turbidity **– 6909.4** (**r^2** = 0.62**) …………….**(vi)
7. TC = **102304** BOD **- 3E+06** (**r^2** = 0.56**) …………….**(vii)
8. FC = **56403** BOD **- 2E+06** (**r^2** = 0.58**) …………….**(viii)
9. FS = **800.59** BOD **- 21816** (**r^2** = 0.42**) ……………..**(ix)

Our work presented here summaries suspended particles and associated microbial indicators concentration at effluent of the plant. For Suspended Solids, there was a positive correlation between SS value and TC, FC, FS concentration (r^2 = 0.79, 0.70, 0.61

respectively). The value of r^2 in case of TC and FC (0.79- 0.70) shows that 70-79% variation in TC and FC is influenced by SS changes. However, the remaining 20-30 % variations can be attributed to other factors.

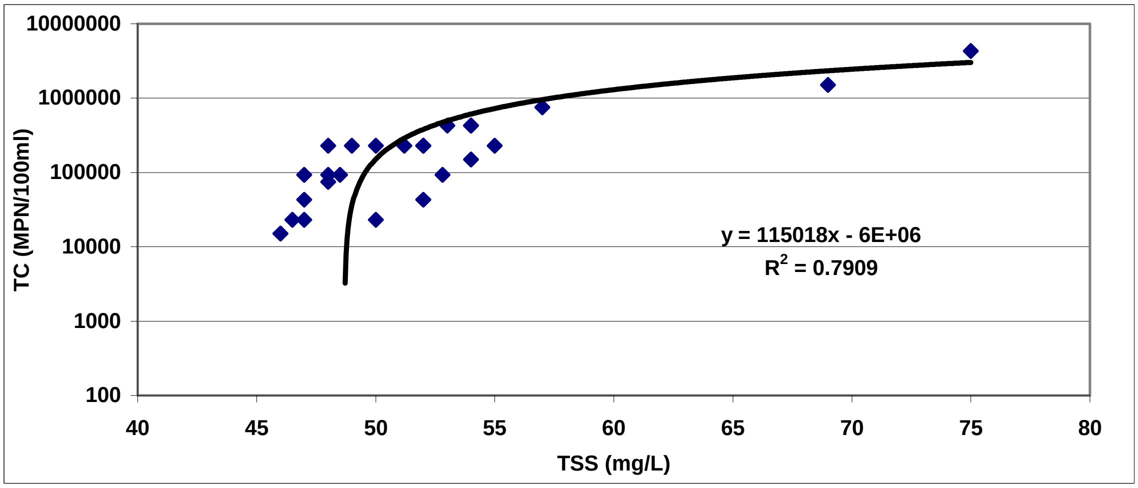


Fig 4.105 Correlation b/w TC and TSS at Outlet of Oxidation pond, Rishikesh

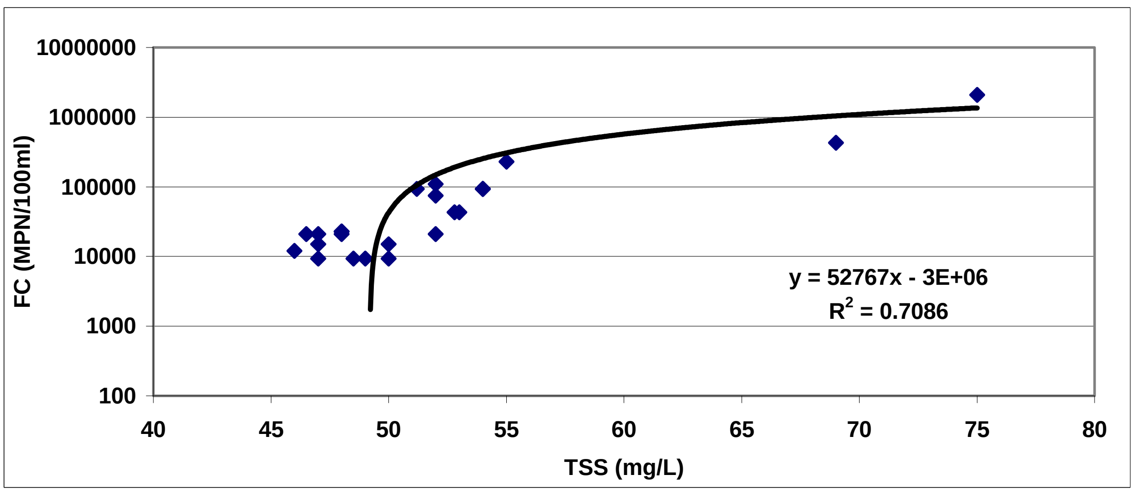


Fig. 4.106 Correlation b/w FC and TSS at Outlet of Oxidation pond, Rishikesh

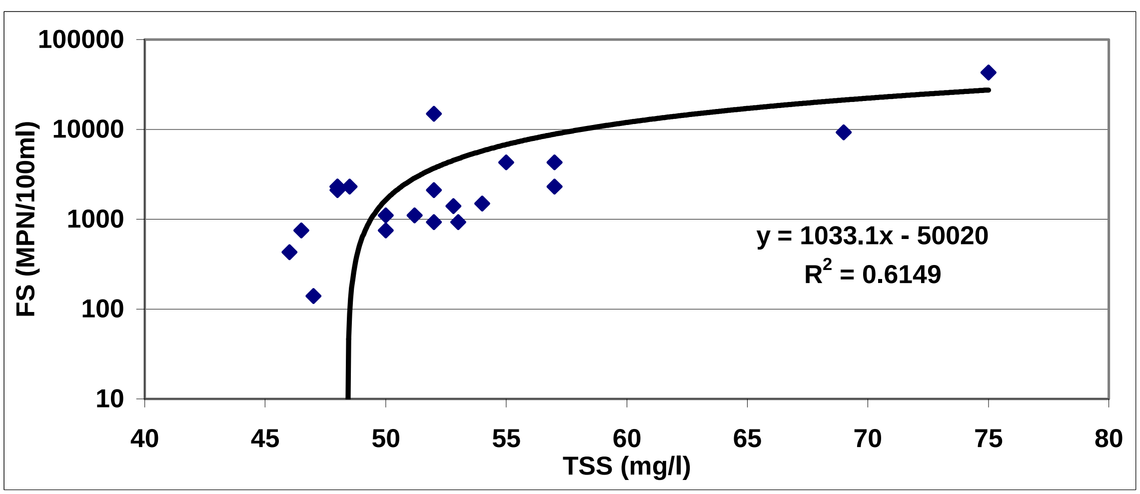


Fig. 4.107 Correlation b/w FS and TSS at Outlet of Oxidation pond, Rishikesh

The improvement of the microbiological quality of wastewater could be linked to the removal of other pollutant i.e. turbidity. The high concentration of turbidity was found to be associated with high number of indicator organisms at plant effluent. The statistical analysis of data shows significant correlation between turbidity and TC, FC, FS values (r^2 = 0.75, 0.66, 0.62 respectively). The value of r^2 in all cases (0.62- 0.75) shows that 62-75% variation in TC, FC and FS is influenced by turbidity changes. However, the remaining 25-40 % variations can be attributed to other factors.

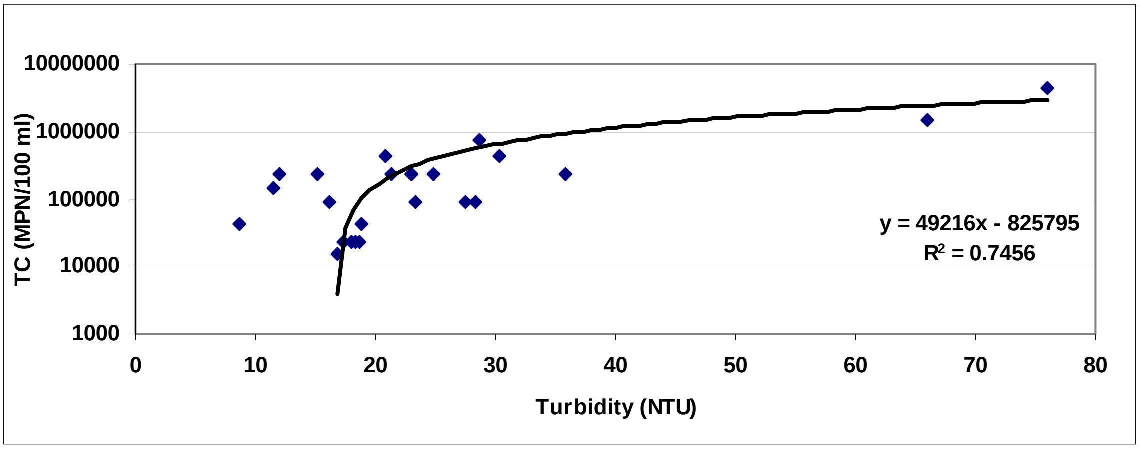


Fig.4.108 Correlation b/w TC and Turbidity at Outlet of Oxidation pond, Rishikesh

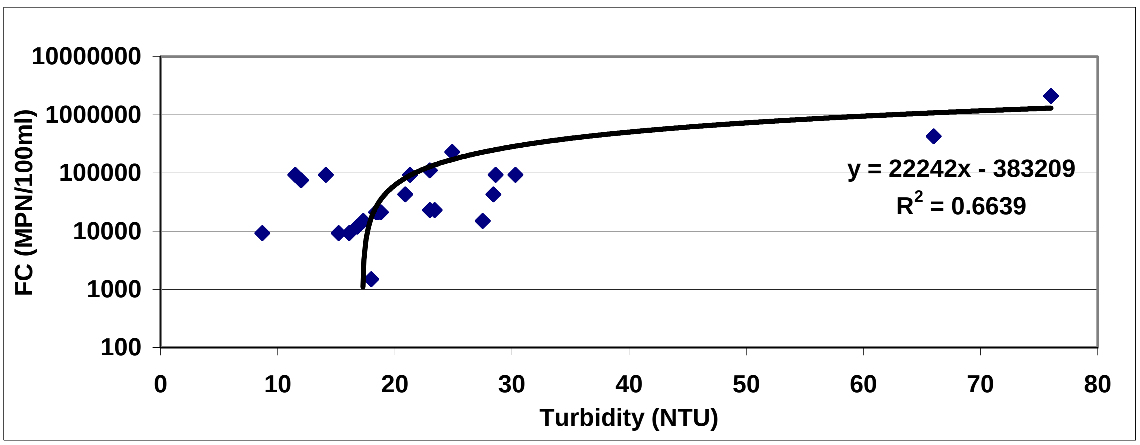


Fig.4.109 . Correlation b/w FC and Turbidity at Outlet of Oxidation pond, Rishikesh

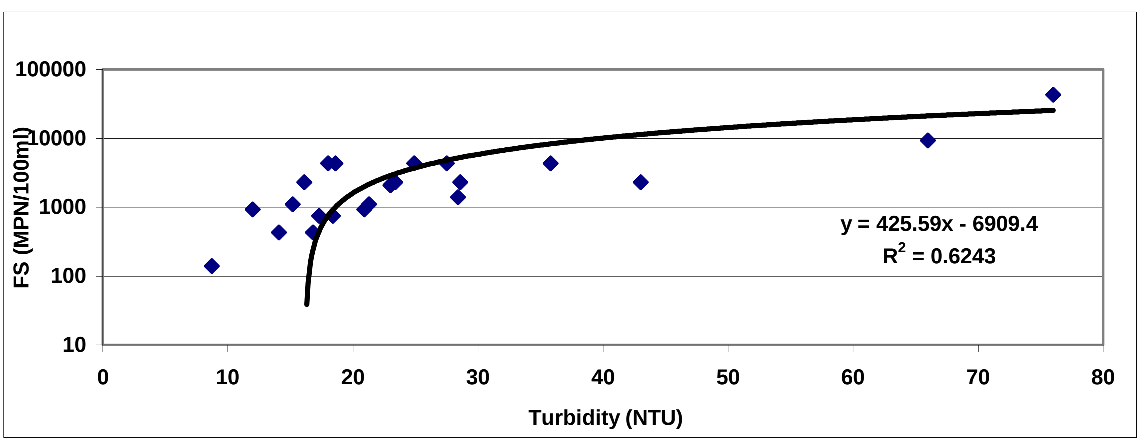


Fig.4.110. Correlation b/w FS and Turbidity at Outlet of Oxidation pond, Rishikesh

The BOD concentration was also correlated to TC, FC and FS concentration at plant effluent. The results revealed that BOD also have good correlations with microbial parameters (r^2 = 0.56, 0.58, 0.42 respectively) but it seems less significant as compare to SS and turbidity.

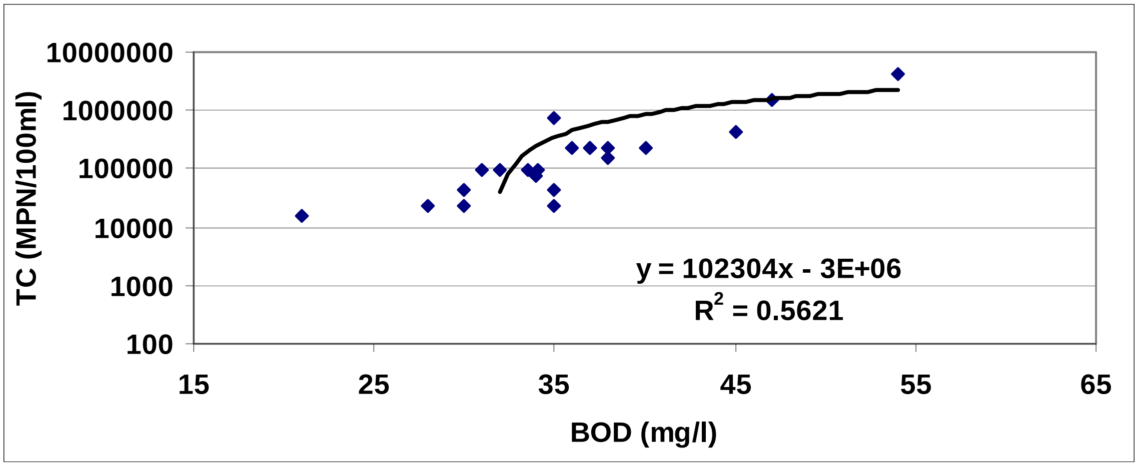


Fig.4.111 Correlation b/w TC and BOD at Outlet of Oxidation pond, Rishikesh

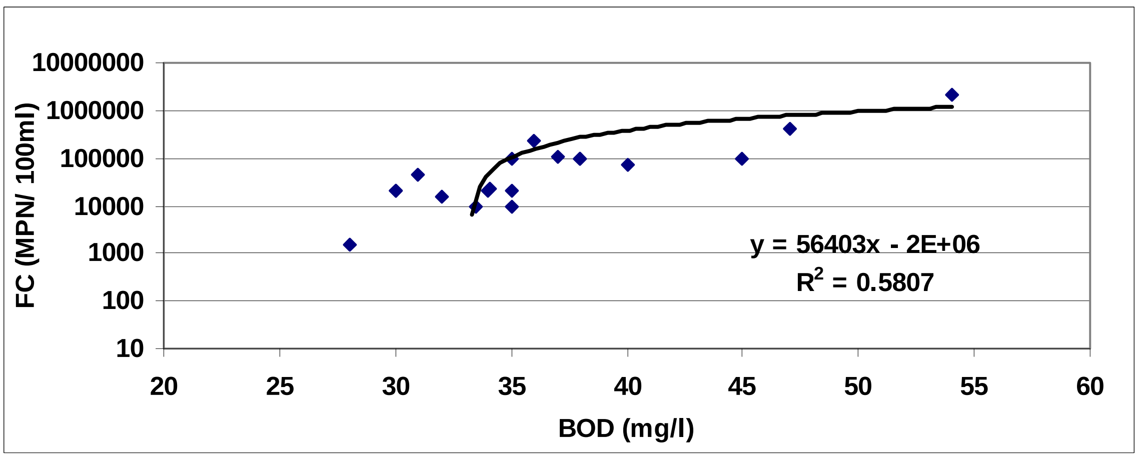


Fig. 4.112 Correlation b/w FC and BOD at Outlet of Oxidation pond, Rishikesh

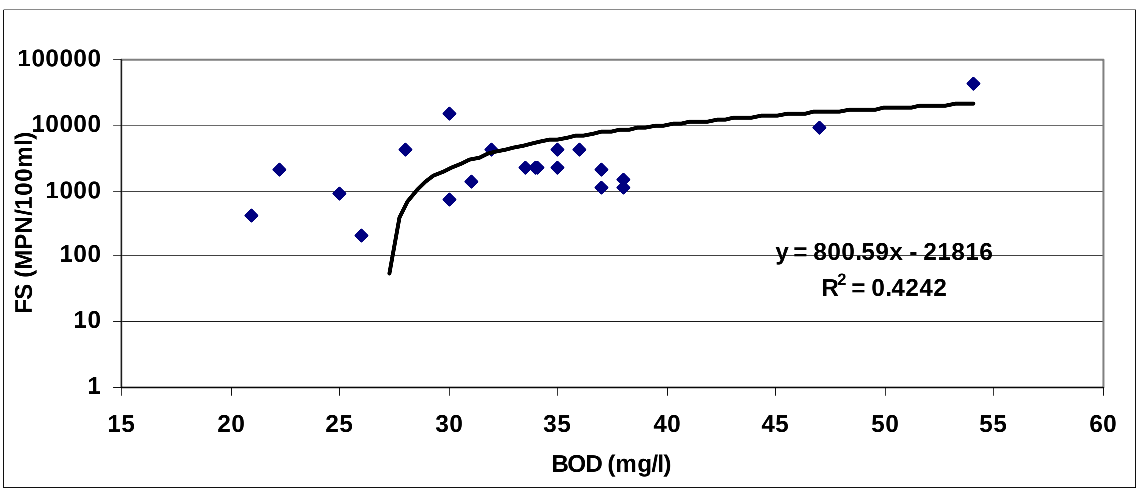


Fig. 4.113 Correlation b/w FS and BOD at Outlet of Oxidation pond, Rishikesh

4.3.7.4 18 MLD Activated Sludge Process Plant, Kankhal, Haridwar (Uttrakhand)

Various Physico-chemicals and microbiological parameters analyzed for the Influent and effluent of the plant as well as the derived efficiency of the plant with respect to these parameters are listed in Table 4.36.

Table 4.36 : Descriptive Data and Removal efficiency of Activated sludge plant, Kankhal, Haridwar

Date	Sampl-ing Point	Temp (ºC)	TSS (mg/L)	Turbidity NTU	pH	TDS (mg/L)	DO (mg/L)	COD (mg/L)	BOD (mg/L)	TC MPN/ 100ml	FC MPN/ 100ml	FS MPN/ 100ml	Helminthes (eggs/L)
07/08/04	Inlet	30.0	360	121	7.8	310	0.0	249.6(T) 142 (S)	125(T) 90(S)	$1.5x10^{8}$	$1.5x10^{8}$	2.1x104	42
	Outlet	30.0	25	3.5	8.0	285	4.8	44.3(T) 34.0(S)	20(T) 16(S)	$7.5x10^{5}$	$2.1x10^{4}$	6.4x102	0.8
	% Remove	-	93.1	97.1	-	-	-	82.3	84.0	99.5	99.99	96.95	98.1
25/08/04	Inlet	32	300	110	7.9	285	0.0	240.0(T) 86.6 (S)	95(T) 80(S)	$2.8x10^{7}$	$9.3x10^{6}$	$4.3x10^{5}$	62
	Outlet	32.5	21	2.7	7.5	185	4.5	28.8(T) 16.0(S)	12(T) 10(S)	$7.5x10^{4}$	$3.9x10^{4}$	$2.8x10^{3}$	1.2
	% Remove	-	93.0	97.5	-	-	-	88	87.4	99.7	99.6	99.4	98.06
13/09/04	Inlet	29.0	280	105	7.4	350	0.0	200(T) 150(S)	100(T) 70(S)	$4.3x10^{8}$	$2.1x10^{8}$	$4.3x10^{7}$	32
	Outlet	30.0	22.8	3.5	7.8	280	5.5	37 (T) 13(S)	18(T) 12 (S)	$3.9x10^{5}$	$9.3x10^{4}$	$9.3x10^{4}$	1.6
	% Remove	-	91.86	96.7	-	-	-	81.5	82	99.9	99.96	99.8	95
04/10/04	Inlet	26.3	325	111	7.4	325	0.0	200(T) 188(S)	120(T) 100(S)	$1.5x10^{8}$	$7.5x10^{6}$	$2.1x10^{5}$	34
	Outlet	26.1	18	3.2	7.6	290	4.7	49(T) 27(S)	22(T) 16(S)	$9.3x10^{4}$	$4.3x10^{4}$	$1.4x10^{3}$	2.2
	% Remove	-	94.46	97.1	-	-	-	75.5	81.7	99.94	99.43	99.33	93.52
05/11/04	Inlet	23.1	310	101	7.4	340	0.0	277.9(T) 126(S)	135 (T) 70(S)	$4.3x10^{12}$	$1.5x10^{10}$	$7.5x10^{7}$	38
	Outlet	22.5	30	3.7	7.6	310	1.5	42.5(T) 40(S)	19.5(T) 17.5(S)	$4.3x10^{8}$	$9.3x10^{6}$	$9.3x10^{4}$	2.4
	% Remove	-	90.32	96.3	-	-	-	84.7	85.6	99.99	99.9	99.9	93.7
08/08/05	Inlet	23.9	268	157	7.6	330	0.6	464.13(T) 105 (S)	175 (T)	$2.1x10^{7}$	$2.3x10^{6}$	$7.5x10^{5}$	33
	Outlet	24.1	40	18	7.7	321	6.2	56.52(T) 2.19(S)	41 (T)	$2.3x10^{5}$	$2.3x10^{4}$	$4.3x10^{3}$	1.2
	% Remove	-	85.07	88.53	-	-	-	87.82	76.57	98.90	99.0	99.42	96.36

(Table 4.36 Continued…)

Date	Sampling Point	Temp (ºC)	TSS (mg/L)	Turbidi-ty NTU	pH	TDS (mg/L)	DO (mg/L)	COD (mg/L)	BOD (mg/L)	TC MPN/ 100ml	FC MPN/ 100ml	FS MPN/ 100ml	Helminthes (eggs/L)
28/08/05	Inlet	24.1	240	112	7.5	383	0.4	385.84(T) 103.25 (S)	135 (T)	2.3x10^{6}	4.3x10^{5}	9.3x10^{4}	38
	Outlet	24.9	32	13.6	7.8	329	5.4	61.84(T) 36.75(S)	42(T)	2.3x10^{4}	2.1x10^{3}	2.1x10^{3}	3
	% Remove	-	86.66	87.85	-	-	-	83.97	68.88	99.0	99.51	97.74	92.10
08/09/05	Inlet	24.5	220	106	7.4	335	0.2	243(T) 109.94 (S)	125 (T)	2.3x10^{7}	2.3x10^{7}	2.3x10^{6}	65
	Outlet	24.7	21	7.8	7.7	302	5.2	26(T) 6.71(S)	14 (T)	2.3x10^{4}	9.3x10^{4}	4.3x10^{4}	1
	% Remove	-	90.45	92.64	-	-	-	89.30	88.8	99.59	99.59	98.13	98.46
28/09/05	Inlet	25.2	250	138	7.3	365	0.3	328(T) 154.81(S)	165 (T)	2.3x10^{8}	2.3x10^{8}	2.3x10^{6}	74
	Outlet	24.6	38	17.6	7.7	358	4.8	53.96(T) 28.92(S)	33(T)	9.3x10^{5}	4.3x10^{5}	2.1x10^{4}	1.8
	% Remove	-	84.8	57.24	-	-	-	83.54	80.0	99.59	99.81	99.08	97.56
10/10/05	Inlet	25.6	324	109	7.2	320	0.0	308(T) 180 (S)	150 (T) 95 (S)	2.3x10^{6}	1.5x10^{6}	2.3x10^{4}	50
	Outlet	26.3	12.5	1.8	7.4	295	4.7	36(T) 30 (S)	15 (T) 08 (S)	2.1x10^{4}	1.5x10^{4}	7.5x10^{2}	1.6
	% Remove	-	96.14	98.3	-	-	-	88.31	90.0	99.1	99	96.7	96.8
25/10/05	Inlet	24.7	369	101	7.5	310	0.0	254(T) 104(S)	136 (T) 81(S)	4.6x10^{6}	1.5x10^{6}	2.3x10^{4}	42
	Outlet	24.7	11	1.7	7.4	278	2.5	37(T) 17(S)	18 (T) 7.5 (S)	2.3x10^{4}	1.1x10^{4}	1.5x10^{2}	2.4
	% Remove	-	97.02	98.3	-	-	-	85.43	86.8	99.5	99.3	99.4	94.2
08/11/05	Inlet	26.0	350	112	7.4	298	0.0	299(T) 112(S)	160 (T) 100(S)	2.3x10^{6}	2.3x10^{6}	4.3x10^{4}	60
	Outlet	26.5	27	3.6	7.3	245	4.5	30(T) 15(S)	15(T) 12 (S)	1.5x10^{5}	2.3x10^{4}	2.3x10^{3}	2.6
	% Remove	-	92.29	96.8	-	-	-	90	90.63	93.48	99	94.7	95.7
23/11/05	Inlet	22.5	295	102	7.4	372	0	305.5 (T) 1033 (S)	145	3.9 x10^{6}	2.3x10^{6}	9.3x10^{4}	38
	Outlet	21.8	18	2.6	7.5	320	4.9	50.2 (T) 44.7 (S)	24	2.3x10^{4}	2.3x10^{4}	2.3x10^{3}	1.2
	% Remove	-	93.90	97.4	-	-	-	83.6	83.4	99.4	99	97.5	94.7
07/12/05	Inlet	20.5	335	101	7.6	374	0	330.7(T) 100.6(S)	160(T) (S)	2.3x10^{7}	2.1x10^{7}	1.5x10^{6}	65
	Outlet	20.3	11	2.1	7.7	320	4.8	39.04(T) 27.86(S)	12.5(T) (S)	2.3x10^{5}	1.5x10^{5}	9.3x10^{3}	2.2
	% Remove	-	96.72	97.9	-	-	-	88.18	92.2	99	99.3	99.4	96.6

(Table 4.36 Continued…)

Date	Sampling Point	Temp (ºC)	TSS (mg/L)	Turbi-dity NTU	pH	TDS (mg/L)	DO (mg/L)	COD (mg/L)	BOD (mg/L)	TC MPN/100ml	FC MPN/ 100ml	FS MPN/ 100ml	Helminthes (eggs/L)
21/12/05	Inlet	19.6	360	117	7.2	388	0	292.3 (T) 78.3 (S)	140 (T) 50 (S)	$1.5x10^{6}$	$9.3x10^{5}$	$2.3x10^{5}$	48
	Outlet	18.4	12	2.5	7.3	365	4.3	31.3 (T) 13.1(S)	11 (T) 8 (S)	$1.1x10^{4}$	$4.3x10^{3}$	$2.3x10^{3}$	1.4
	% Remove	-	96.67	97.9	-	-	-	89.3	92.1	99.3	99.5	99	97.8
04/01/06	Inlet	19.8	350	113	7.0	316	0	281.8(T) 91.4(S)	145(T) (S)	$2.3x10^{8}$	$2.3x10^{8}$	$2.3x10^{5}$	44
	Outlet	16.5	23	3.5	7.3	304	3.6	34.1(T) 19.7(S)	15(T) (S)	$2.3x10^{6}$	$2.3x10^{6}$	$7.5x10^{3}$	3.0
	% Remove	-	93.43	96.9	-	-	-	87.9	89.7	99	99	96.7	93.2
18/01/06	Inlet	21.5	313	126	7.1	332	0.0	348(T) 131(S)	147(T) (S)	$4.3x10^{6}$	$4.3x10^{6}$	$9.3x10^{5}$	40
	Outlet	19.6	10	1.6	8.1	307	5.6	36(T) 28(S)	12(T) (S)	$9.3x10^{3}$	$9.3x10^{3}$	$2.3x10^{4}$	1.4
	% Remove	-	96.81	98.7	-	-	-	89.7	91.8	99.78	99.78	97.53	96.5
08/02/06	Inlet	22.8	373	114	7.2	328	0.0	312(T) (S)	160(T) (S)	$7.5x10^{7}$	$2.3x10^{7}$	$2.3x10^{6}$	66.6
	Outlet	21.8	8	1.7	7.8	301	4.8	31.2(T) (S)	9.6(T) (S)	$2.3x10^{5}$	$1.5x10^{5}$	$2.3x10^{4}$	2.1
	% Remove	-	97.86	98.5	-	-	-	90	94	99.7	99.35	99	96.8
28/02/06	Inlet	21.3	363	121	7.4	357	0.2	295.7(T) 105.3(S)	135	$2.3x10^{7}$	$2.1x10^{5}$	$2.3x10^{5}$	50
	Outlet	20.7	11	2.8	7.6	322	4.5	33.4(T) 22(S)	14	$2.3x10^{4}$	$1.5x10^{3}$	$2.3x10^{3}$	2
	% Remove	-	96.97	97.7	-	-	-	88.8	89.6	99.9	99.29	99.0	96
08/03/06	Inlet	24.7	210	93.5	7.4	401	0.6	286.24 (T) 76.47 (S)	125(T)	$9.3x10^{6}$	$2.1x10^{6}$	$9.3x10^{5}$	42
	Outlet	24.5	19	6.77	7.8	392	4.9	45 (T) 12.24 (S)	30(T)	$4.3x10^{4}$	$2.1x10^{4}$	$1.1x10^{3}$	2
	% Remove	-	90.95	92.8	-	-		81	76	99.54	99	99.88	95.23
28/03/06	Inlet	24.4	190	79.8	7.3	396	0.4	209.5 (T) 77.96 (S)	115(T)	$9.3x10^{8}$	$7.5x10^{7}$	$4.3x10^{6}$	51
	Outlet	24.4	17	5.23	7.7	375	4.9	27.35 (T) 16.56 (S)	23(T)	$9.3x10^{5}$	$2.3x10^{4}$	$7.5x10^{3}$	1
	% Remove	-	91.1	93.4	-	-	-	87	80	99.9	98.65	99.82	98.03
08/04/06	Inlet	24.3	110	111	7.4	451	0.0	193 (T)	102(T)	$9.3x10^{6}$	$2.3x10^{6}$	$2.3x10^{6}$	23
	Outlet	24.1	11	2.7	7.6	398	4.5	26 (T)	17(T	$2.3x10^{4}$	$1.1x10^{4}$	$9.3x10^{3}$	1.5
	% Remove	-	90.0	97.5	-	-	-	86.4	83.3	99.75	99.52	99.60	93.47
28/04/06	Inlet	23.8	115	126	7.6	398	0.0	216 (T)	117 (T)	$9.3X10^{6}$	$2.3X10^{6}$	$7.5x10^{5}$	56
	Outlet	**24.0**	13	2.8	**7.7**	**375**	**4.4**	47(T)	24(T)	$2.3X10^{4}$	$1.1X10^{4}$	$4.3x10^{3}$	2.4
	% Remove	-	88.7	97.7	-	-	-	78.2	79.5	99.75	99.52	99.43	95.71

(Table 4.36 Continued…)

Date	Sampling Point	Temp (ºC)	TSS (mg/L)	Turbid i-ty NTU	pH	TDS (mg/ L)	DO (mg/ L)	COD (mg/L)	BOD (mg/L)	TC MPN/ 100ml	FC MPN/ 100ml	FS MPN/ 100ml	Helmi-nthes (eggs/ L)
12/ 04/ 06	Inlet	23.1	254	136	7.6	404	0.2	335.39 (T) 98.5 (S)	165(T) 105(S)	4.3x10^6	4.3x10^6	2.3x10^6	23
	Outlet	24.0	18	1.4	7.9	354	5.7	52.8 (T) 37.43 (S)	19(T) 14(S)	2.3x10^4	9.3x10^3	9.3x10^3	1.5
	% Remove	-	92.9	99	-	-	-	84.3	88.5	99.47	99.78	99.6	93.47
26/ 04/ 06	Inlet	24.2	110	40.2	7.4	412	0.3	193.43 (T) 104.49 (S)	102(T)	4.3X10^6	2.3X10^6	7.5x10^5	56
	Outlet	24.2	11	2.5	7.7	376	5.0	26.31 (T) 11.14 (S)	17(T)	4.3X10^3	2.3X10^3	4.3x10^3	2.4
	% Remove	-	90	93.8	-	-	-	86.4	83.3	99.9	99.9	99.42	95.71
19/ 05 06	Inlet	25.6	200	145	7.6	398	0.8	278.97 (T) 106.46 (S)	120(T)	9.3x10^6	4.3x10^6	4.3x10^5	44
	Outlet	26.6	21	2.4	7.8	368	4.9	36.02 (T) 10.22 (S)	14 (T)	9.3x10^4	2.3x10^4	2.3x10^4	1.6
	% Remove	-	89.5	98.3	-	-	-	87.1	88.33	99	99.47	94.65	96.36
30/ 05/ 06	Inlet	27	220	138	7.5	383	0.0	306 (T) 60 (S)	150(T) 100(S)	2.3x10^7	9.3x10^6	9.3x10^5	12
	Outlet	28	12	1.6	7.8	355	4.6	40 (T) 20 (S)	9(T) 7(S)	2.3x10^4	9.3x10^3	4.3x10^3	1.1
	% Remove	-	94.5	98.8	-	-	-	84.6	94	99.9	99.9	99.54	90.83
14/ 06/ 06	Inlet	28	195	119	7.0	395	0.0	259(T) 86(S)	135 (T) 105(S)	9.3x10^6	9.3x10^6	2.3x10^6	67
	Outlet	28.5	18	2.1	7.5	329	4.5	32 (T) 25(S)	17(T) 4(S)	4.3x10^4	2.3x10^3	2.3x10^3	2.0
	% Remove	-	90.76	98.2	-	-	-	87.64	87.40	99.53	99.97	99.9	97.01
29/ 06/ 06	Inlet	28	198	99.2	7.4	332	0	191.63(T) 69.30(S)	160 (T) 85 (S)	9.3x10^6	2.3x10^6	9.3x10^5	-
	Outlet	28.5	8	1.06	7.7	318	4.5	17.07(T) 9.23(S)	18(T) 10(S)	9.3x10^4	4.3x10^4	2.3x10^4	-
	% Remove	-	95.95	98.9	-	-	-	91.09	88.75	99.0	98.13	97.52	-
10/ 07/ 06	Inlet	28.6	199	118	7.5	365	0.5	244(T)	135(T)	4.3x10^6	2.3x10^6	4.3x10^5	-
	Outlet	28.8	4	1.84	7.8	312	3.5	8.5(T)	4(T)	2.3x10^5	9.3x10^4	4.3x10^3	-
	% Remove	-	97.99	98.4	-	-	-	88.3	89.6	94.65	95.96	99.0	-
31/ 07/ **06**	Inlet	28	220	124	7.5	387	0.0	290.23(T) 71.58(S)	105 (T) 65(S)	4.3x10^7	4.3x10^6	1.5x10^5	-
	Outlet	28.8	10	2.6	7.8	361	4.5	17.24(T) (S)	13(T) 4(S)	7.5x10^5	2.3x10^4	1.1x10^3	-
	% Remove	-	95.45	97.9	-	-	-	94.1	87.62	98.25	99.46	99.27	-
11/ 08/ **06**	Inlet	27.8	225	108	7.4	375	0.0	275(T)	125(T)	6.4x10^7	9.3x10^6	4.6x10^5	-
	Outlet	27.6	11	2.8	7.6	310	5.1	30(T)	13(T)	3.9x10^5	2.3x10^4	2.1x10^3	-
	% Remove	-	95.11	97.4	-	-	-	89.1	89.1	99.39	99.75	99.54	-

(Table 4.36 Continued…)

Date	Sampling Point	Temp (ºC)	TSS (mg/L)	Turbid i-ty NTU	pH	TDS (mg/ L)	DO (mg/L)	COD (mg/L)	BOD (mg/L)	TC MPN/ 100ml	FC MPN/ 100ml	FS MPN/ 100ml	Helmi nthes (eggs/ L)
21/ 08/ **06**	**Inlet**	28	263	139	7.4	385	0.0	324.92(T) 94.62 (S)	215 (T) 125 (S)	4.3x 10^7	$4.3x10^6$	$7.5x10^5$	-
	Outlet	28.5	15	4.3	7.8	424	5.3	33.60**(S)** 12.64(S)	23(T) 10(S)	$9.3x10^4$	$4.3x10^4$	$4.3x10^{-3}$	-
	% Remove	-	94.3	96.9	-	-	-	89.66	89.30	99.78	99.0	99.43	-
07/ 09/ **06**	**Inlet**	27.7	125	67.5	7.7	371	0.0	221.68(T)	145(T)	2.3x 10^6	$4.3x10^5$	$2.3x10^5$	-
	Outlet	27.7	7	3.01	7.7	411	4.7	20.85(T)	19(T)	$9.3x10^4$	$4.3x10^4$	$2.1x10^3$	-
	% Remove	-	94.4	95.5	-	-	-	90.59	86.89	95.95	90.0	99.08	-
25/ 09/ **06**	**Inlet**	30.0	87	73.7	6.9	341	0.5	211(T) 88.14(S)	105 (T) (S)	$9.3x10^6$	$1.5x10^6$	$2.1x10^7$	-
	Outlet	29.6	10	5.31	7.3	377	5.4	25.83(T) 29.17(S)	33(T) (S)	$2.3x10^5$	$2.3x10^4$	$4.3x10^5$	-
	% Remove	-	88.50	92.7	-	-	-	87.78	68.57	97.52	98.46	97.95	-
16/ 10/ **06**	**Inlet**	25.0	132	102	7.2	445	0.0	320.40(T) **(S)**	255(T) **(S)**	1.5x 10^7	$9.3x10^5$	$4.3x10^3$	-
	Outlet	25.0	9	2.18	7.7	351	4.8	21.34(T) (S)	41.0(T) (S)	$2.3x10^5$	$9.3x10^4$	$2.3x10^2$	-
	% Remove	-	93.18	95.9	-	-	-	93.33	83.92	98.46	90.0	94.65	-
31/ 10/ **06**	**Inlet**	24.7	265	115	7.5	395	0.6	335(T) (S)	215(T) (S)	$1.2x10^8$	$9.3x10^6$	$1.2x10^5$	-
	Outlet	25.1	12	2.1	**7.7**	**330**	**5.1**	35(T) (S)	16(T) (S)	$7.5x10^5$	$2.3x10^4$	$3.9x10^2$	-
	% Remove	-	**95.47**	**98.1**	-	-	-	89.55	92.56	99.38	99.75	99.68	-

4.3.8.1 Observations and Discussion

On the basis of the observed data at Activated Sludge Process, Kankhal (Haridwar) following observations are made:

1. In the **Raw sewage** BOD, COD and TSS was found vary from 95- 230 mg/L (Mean 141.1mg/L), 192- 464 mg/L (Mean 270mg/L) and 87-373 mg/L (Mean 243mg/L) respectively. As per Metcalf & Eddy (1995) Typical COD concentration in the Untreated Domestic sewage ranges from 250-1000 mg/L.
2. The BOD, COD and TSS concentration in **Effluent** ranges from 9- 42mg/L (Mean 17.7 mg/L), 25.8 - 62 mg/L (Mean 36.2 mg/L) and 4- 40 mg/l (Mean 14.3 mg/L) respectively.
3. The **mean removal efficiency** of BOD, COD and TSS were found to be 86.65, 86.2 and 93.2 respectively. Most of the researchers have mentioned the removal efficiency of BOD for ASP in the range of 85-93%.

4. TC, FC and FS concentrations in the system **influent** was varied from $1.5x10^6$ – $4.3x\ 10^{12}$ MPN/100mL (Mean 50000000 MPN/100mL) , $2.1\ x10^5$ – $1.5x\ 10^{10}$ MPN/100mL (Mean 17750000 MPN/100mL) and $4.3x10^3$ – $7.5x\ 10^7$ MPN/100mL (Mean 760000 MPN/100mL).

Observations revealed that the **effluent** concentration of TC, FC and FS was ranges from $9.3x10^3$- $4.3x\ 10^8$ MPN/100mL (Mean 250000 MPN/100mL), $1.5\ x10^3$ –$9.3x\ 10^6$ MPN/100mL (Mean 91500 MPN/100mL) and $2.3x10^2$- $9.3x\ 10^5$ MPN/100 ml (Mean 6800 MPN /100mL).

The percentages mean removal efficiency of TC, FC and FS was found 99.3, 99.32 and 98.80. As per Metcalf & Eddy (2003), reduction of bacteria in ASP is 90-98%. Earlier studies in activated sludge plants have usually showed similar 90-99% enteric bacteria reduction (Koivunen et. al, 2003).The mean value of FC in treated effluent (91500 MPN/100mL) greater than the permissible limits i.e. 1000 MPN/100mL, as specified by WHO (1989) for unrestricted irrigation.

The Helminthes Eggs concentration in the system influent was varied from 32- 66.6 eggs/ L. whereas the effluent concentration of ranges from 0.8-3 eggs/ L (Mean 1.9 eggs /L). The percentages mean removal efficiency Helminthes eggs was found 95.8. Even such a good eggs removal efficiency the effluent still contain the helminthes eggs concentration (1.9 eggs /L) more than the permissible limit (<1 eggs/L) for unrestricted irrigation as suggested by WHO (1989).

4.3.8.2 Impact of Seasonal Variations on the Physico-chemical and Microbiological Characteristics of Influent, Effluent and Removal Efficiency of Plant

The removal efficiency of Oxidation pond w.r.t. organic as well as microbial pollutants were studied for all seasons i.e. summer, monsoon, winter and autumn. From the study work following results was obtained as depicted in Table 4.37

Table 4.37 Variations in the characteristics of Physico-Chemical and Microbial parameters and impact on their removal efficiency during all the seasons

(A) Physico-Chemical Parameters									
Seasons	**TSS**			**BOD**			**COD**		
	Inlet (mg/L)	**Outlet (mg/L)**	**% R**	**Inlet (mg/L)**	**Outlet (mg/L)**	**% R**	**Inlet (mg/L)**	**Outlet (mg/L)**	**% R**
Winter	313.9	15.1	94.83	155.6	16.8	88.62	293.2	38	86.51
Autumn	284.0	13.8	94.21	133.8	19.2	84.91	263.4	34.2	86.65
Summer	177.1	12.3	92.28	133.7	15.6	87.43	243.2	36.2	84.82
Monsoon	221.1	16.3	91.50	142.5	19.6	85.68	283.2	36.3	86.83
Mean	243	14.3	93.19	141.1	17.6	86.65	270	36.2	86.20

(B). Microbiological Parameters									
Seasons	**Total Coliforms**			**Fecal Coliforms**			**Fecal Streptococci**		
	Inlet (MPN/ 100ml)	**Outlet (MPN/ 100ml)**	**% R**	**Inlet (MPN/ 100ml)**	**Outlet (MPN/ 100ml)**	**% R**	**Inlet (MPN/ 100ml)**	**Outlet (MPN/ 100ml)**	**% R**
Winter	35000000	170000	99.4	8800000	47000	99.32	180000	2500	97.85
Autumn	270000000	915000	99.6	166000000	620000	99.40	1940000	8500	99.4
Summer	9500000	37000	99.5	3750000	16000	99.41	1300000	15000	98.85
Monsoon	60000000	715000	98.8	18100000	150000	99.10	725000	6600	99.09
Mean	50000000	250000	99.3	17750000	91500	99.32	760000	6800	98.80

% R= % Removal

As far as concerned about the impact of seasonal variation upon the plant efficiency following observations are made:

1. The effluent TSS was found almost similar (Mean 14.3 mg/L) during all the seasons. While as no significant variation in TSS removal was observed throughout the seasons (Fig 4.114).

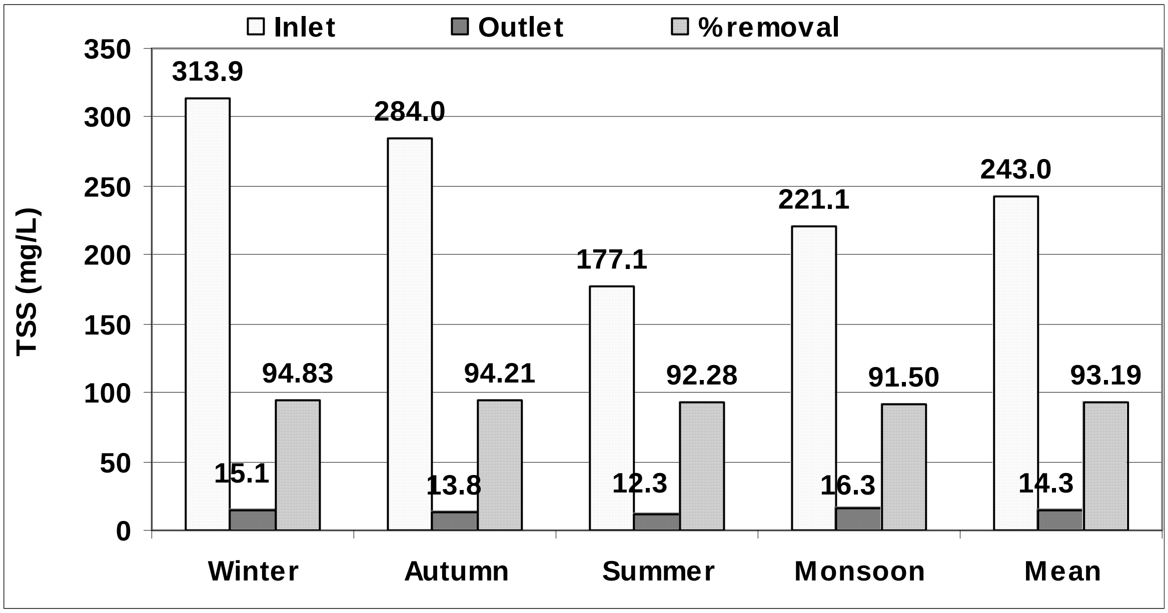


Fig.4.114 Impact of Seasonal variations on the TSS concentration of Influent, Effluent and percentage TSS removal efficiency of Plant

2. The effluent BOD was reported almost similar (Mean 17.7mg/L) during all the seasons. The BOD removal efficiency (Mean 86.65%) was also similar during entire study period (Fig 4.115).

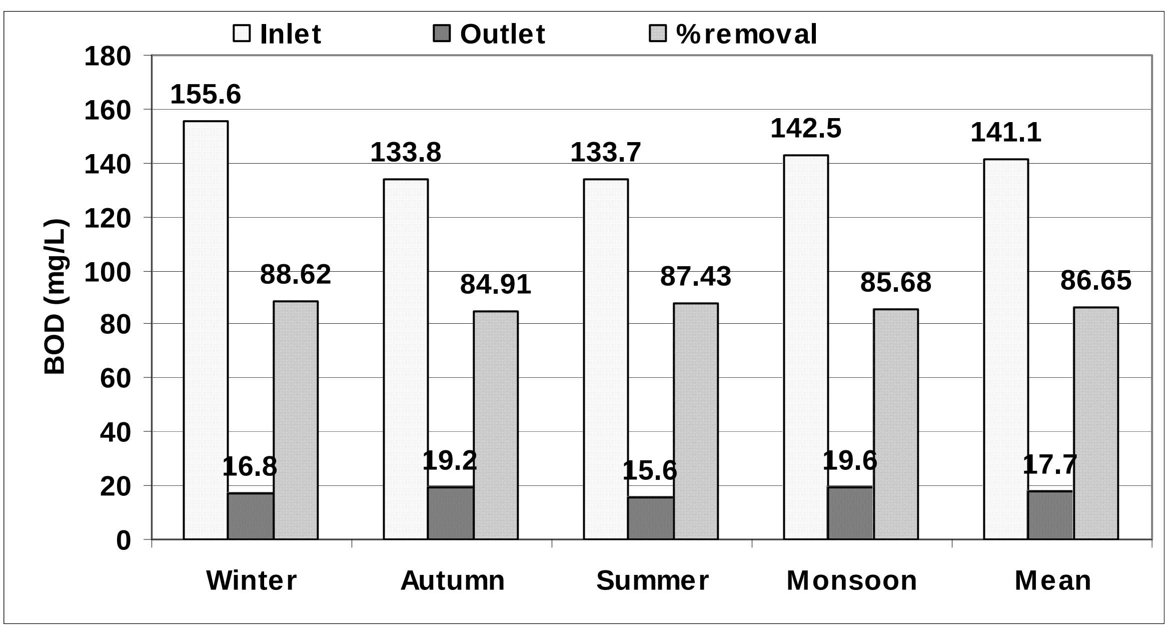


Fig. 4.115 Impact of Seasonal variations on the BOD concentration of Influent, Effluent and percentage BOD removal efficiency of Plant

3. Almost similar COD removal efficiency (Mean 86.20%) of STP was observed during all the seasons (Fig 4.116).

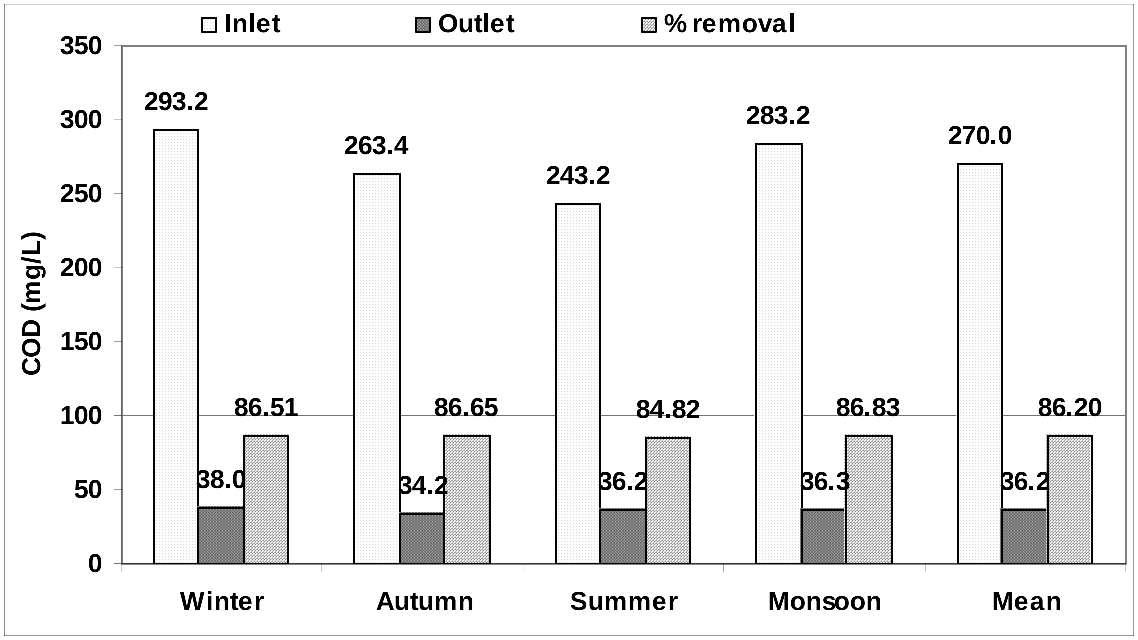
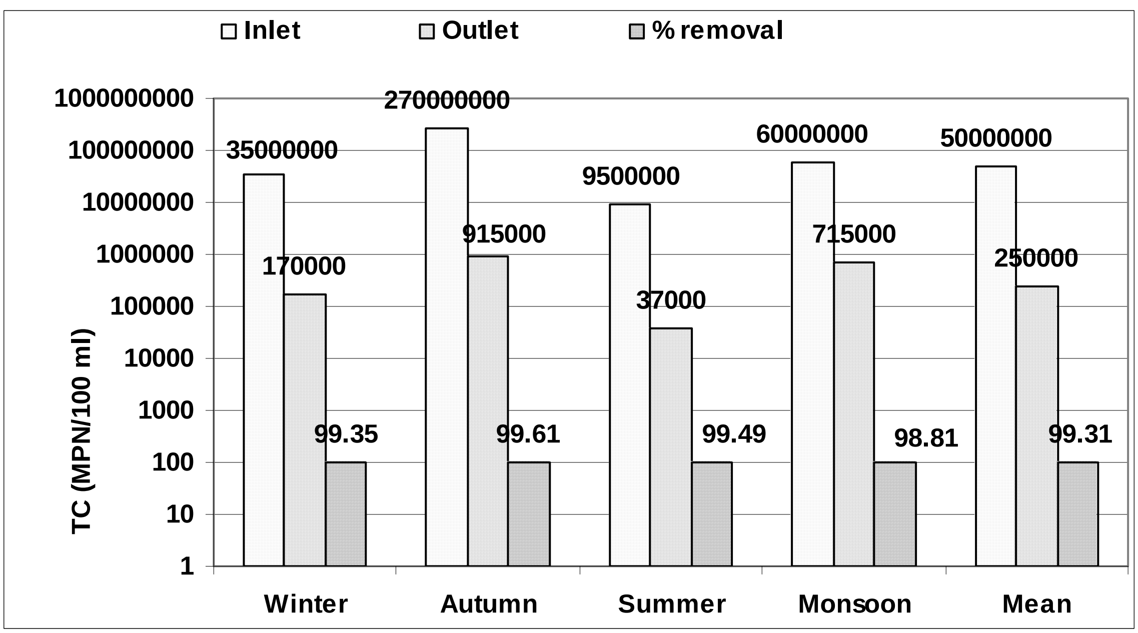


Fig. 4.116 Impact of Seasonal variations on the COD concentration of Influent, Effluent and percentage COD removal efficiency of Plant

4. We observed the maximum effluent concentration of TC and FC during monsoon and autumn period. While lower TC and FC concentration during summer and winter period. The STP removal efficiency w.r.t. TC and FC was found similar during all the seasons i.e. 2- 2.5 log (99%) removal (Fig 4.117).



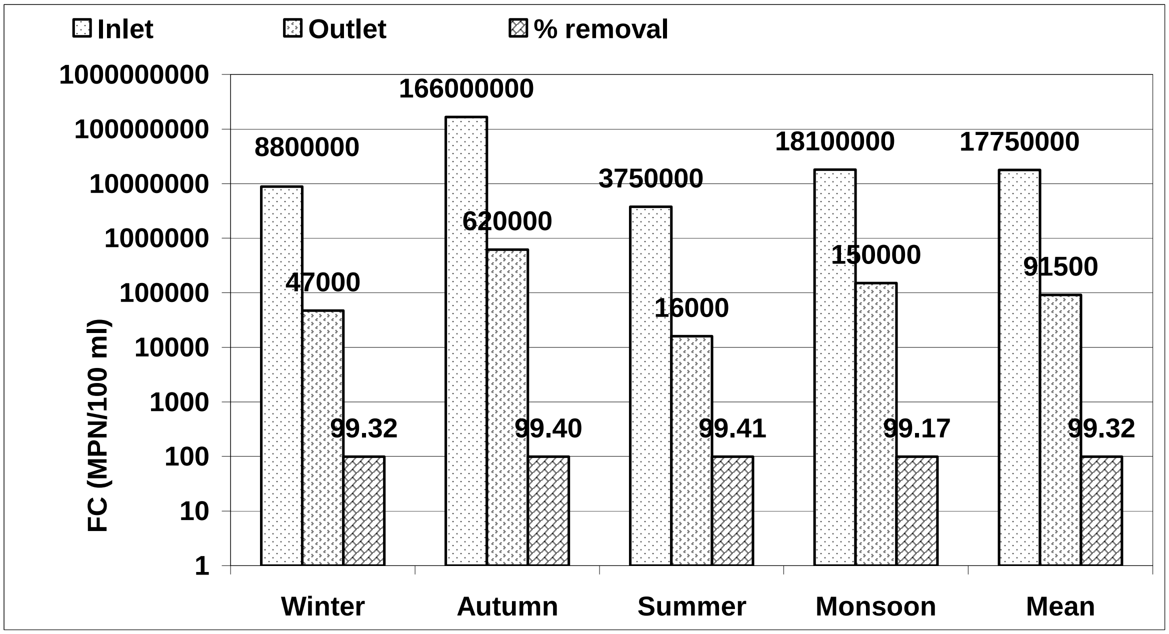


Fig 4.117. Impact of Seasonal variations on the Microbiological characteristics (TC and FC) of Influent, Effluent and their removal efficiency

5. The highest effluent concentration of fecal streptococci was noted in summer while lowest during winters. The maximum FS removal was observed in autumn and monsoon whereas minimum in winters and summers (Fig 4.118).

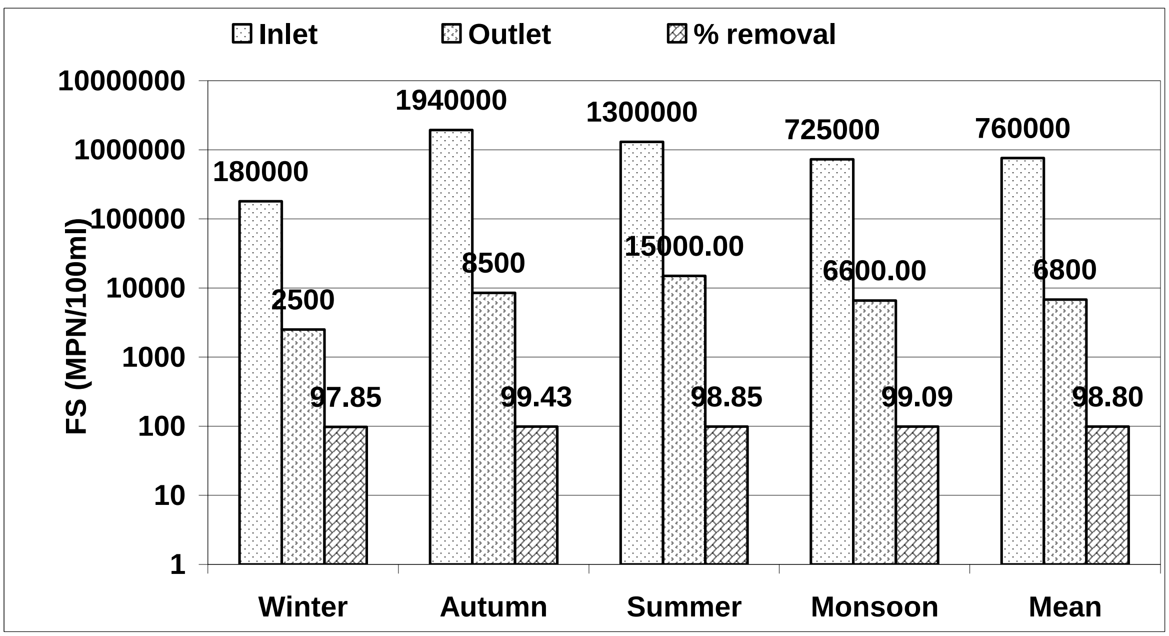


Fig 4.118 Impact of Seasonal variations on the fecal streptococci concentration of Influent, Effluent as well as their removal efficiency

4.8.3.3 Estimation of Correlation between Physico-Chemical Indicator Microorganisms

On the basis of data observed, we tried to establish relationship between key wastewater constituents i.e., Turbidity, TSS and BOD with Total Coliform, Fecal Coliform & Fecal Streptococci. From figures 4.119 – figure 4.127 following relationships are obtained between key parameters.

1. TC = 0.3133 $TSS^{4.6708}$ (r^2 = 0.70)…………(i)
2. FC = 0.0704 $TSS^{4.8844}$ (r^2 = 0.73) ………..(ii)
3. FS = 0.1046 $TSS^{3.9136}$ (r^2 = 0.66) ………..(iii)
4. TC = 5599.6 $Turbidity^{2.776}$ (r^2 = 0.74)………(iv)
5. FC = 2520.7 $Turbidity^{2.8109}$ (r^2 = 0.75) ………(v)
6. FS = 290.16 $Turbidity^{2.6882}$ (r^2 = 0.67) ……..(vi)
7. TC = 1.3155 $BOD^{4.0481}$ (r^2 = 0.59) ……..(vii)
8. FC = 0.0935 $BOD^{4.6808}$ (r^2 = 0.62) ………..(viii)
9. FS = 1.0829 $BOD^{3.2105}$ (r^2 = 0.50) ………...(ix)

Our work presented here summaries suspended particles and associated microbial indicators concentration at effluent of the plant. For Suspended Solids, there was a positive correlation between SS value and TC, FC, FS concentration (r^2 = 0.70, 0.73, 0.66 respectively). The value of r^2 in case of TC and FC (0.70- 0.73) shows that 70-73% variation in TC and FC is influenced by SS changes. However, the remaining 30 % variations can be attributed to other factors.

As suggested by Fecham et. al. (1981) removal of bacteria caused by settlement, as they adsorbed or interrupt within suspended solids. Drift et. al. (1977) reported that the bacterial removal could be achieved by sorption of bacteria to the sludge flocs. According to Mahler et. al. (2000) a significant proportion of bacteria were associated with suspended solids.

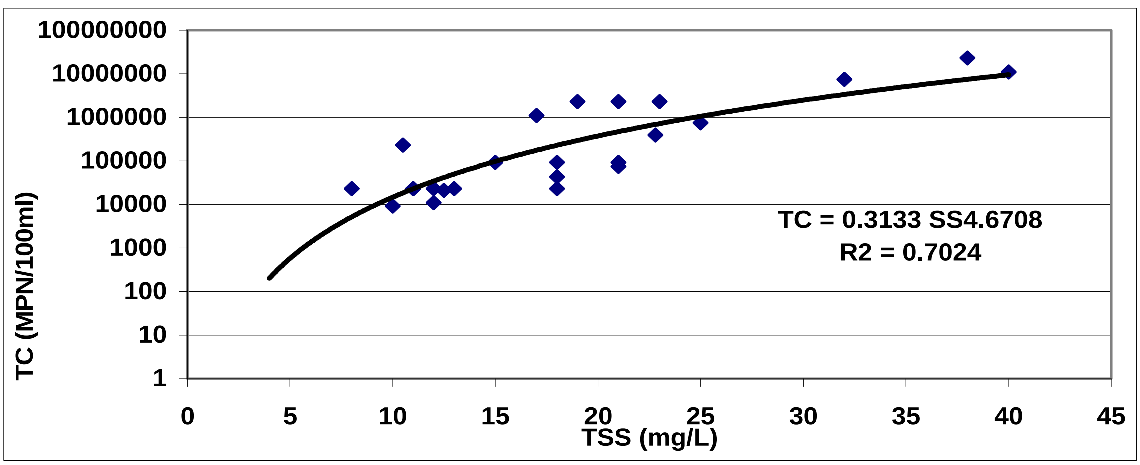


Fig.4.119. Correlation b/w TC and TSS at Outlet of ASP Haridwar

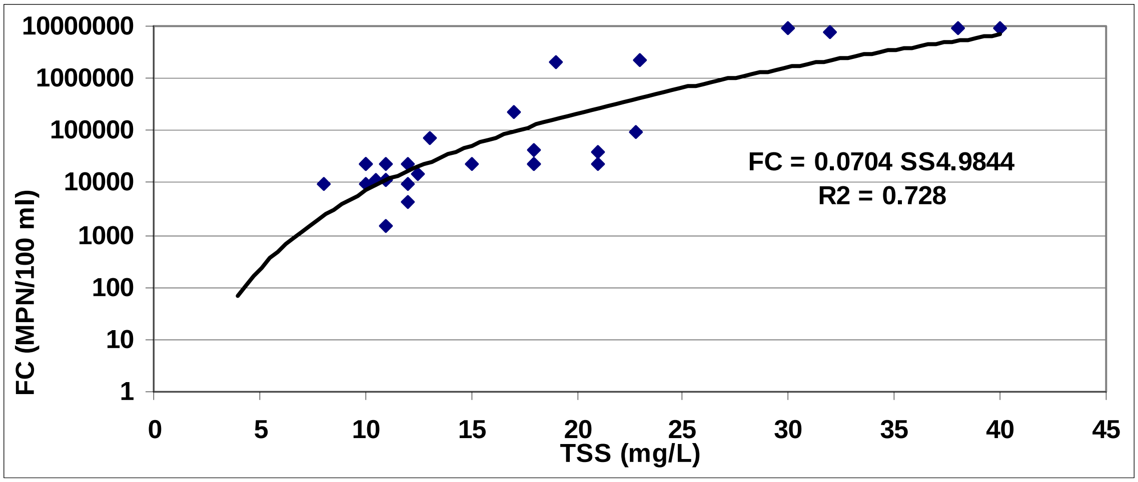


Fig. 4.120 Correlation b/w FC and TSS at Outlet of ASP Haridwar

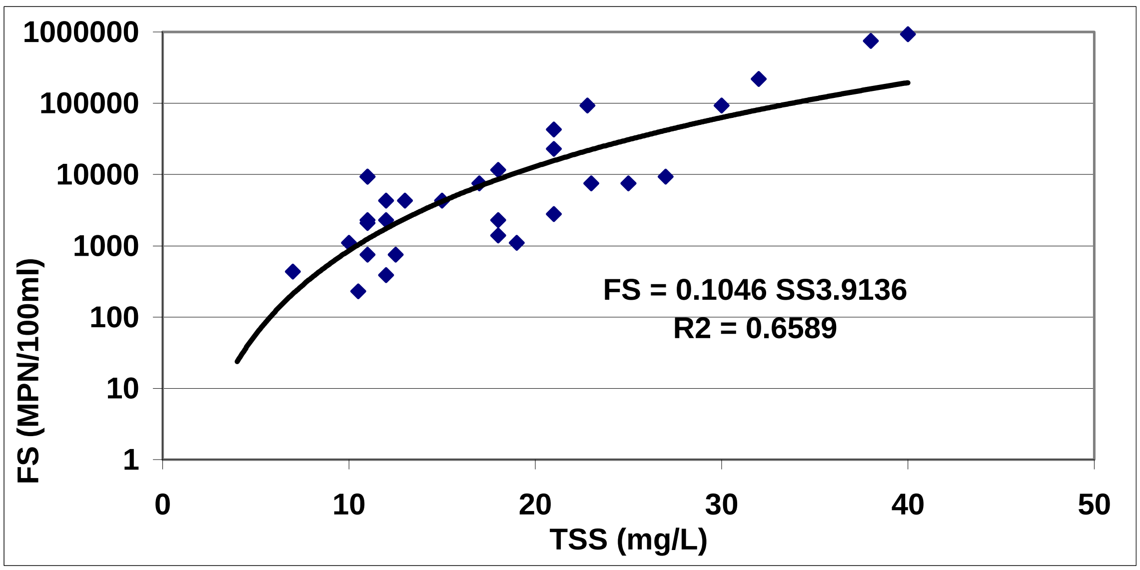


Fig. 4.121 Correlation b/w FS and TSS at Outlet of ASP Haridwar

The improvement of the microbiological quality of wastewater could be linked to the removal of other pollutant i.e. turbidity. The high concentration of turbidity was found to be associated with high number of indicator organisms at plant effluent. The statistical analysis of data shows significant correlation between turbidity and TC, FC, FS values (r^2 = 0.74, 0.75, 0.67 respectively). The value of r^2 in all cases (0.67- 0.75) shows that 67-75% variation in TC, FC and FS is influenced by turbidity changes. However, the remaining 25- 30% variations can be attributed to other factors. Haas et. al. (1983) noted that increased values of turbidity were associated with increased concentration of microorganism. Studies have showed a correlation between decreased turbidity and reduced bacterial counts. Cinque et. al. (2004) stated that high turbidity is currently used as a surrogate of pathogens and harvesting of water is based on its measurement. Mallin et. al. (2000), Nagels et. al. (2002) & Muirhead et. al. (2004) stated that there was a correlation between turbidity and indicator bacteria concentrations (Nishida et. al, 2005)

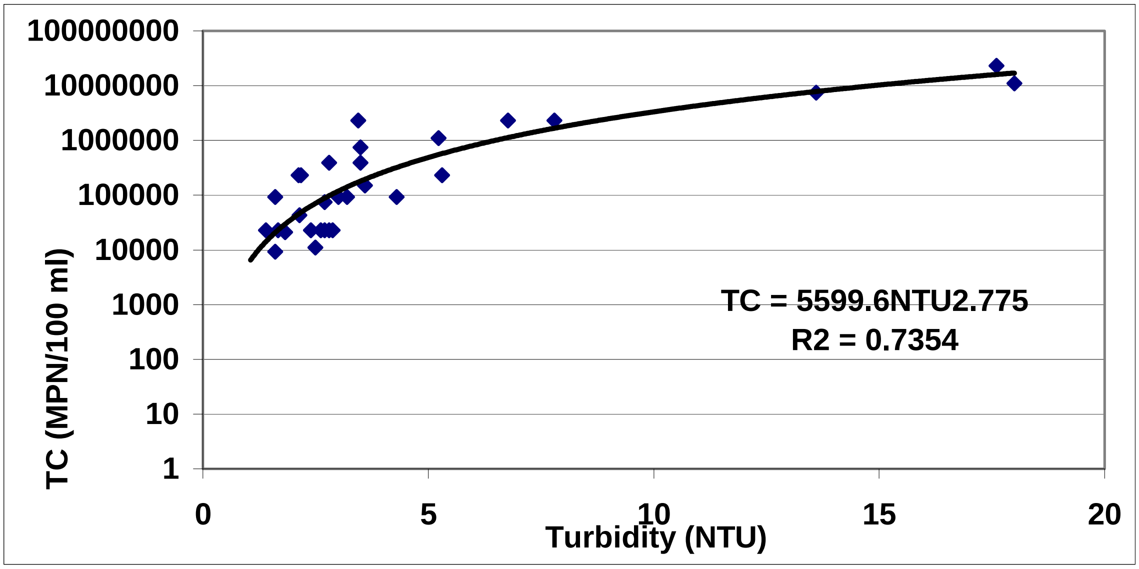


Fig.4.122 Correlation b/w TC and Turbidity at Outlet of ASP Haridwar

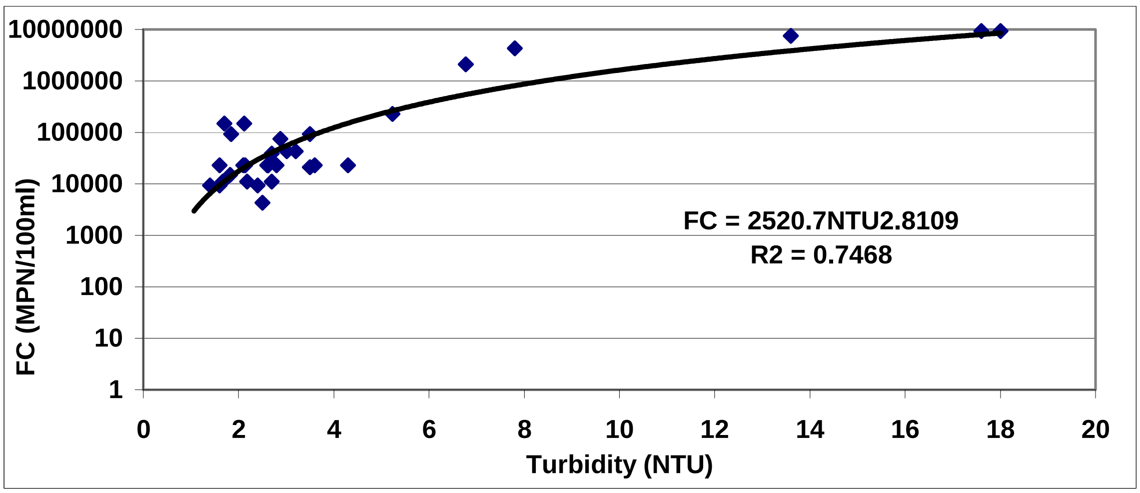


Fig. 4.123. Correlation b/w FC and Turbidity at Outlet of ASP Haridwar

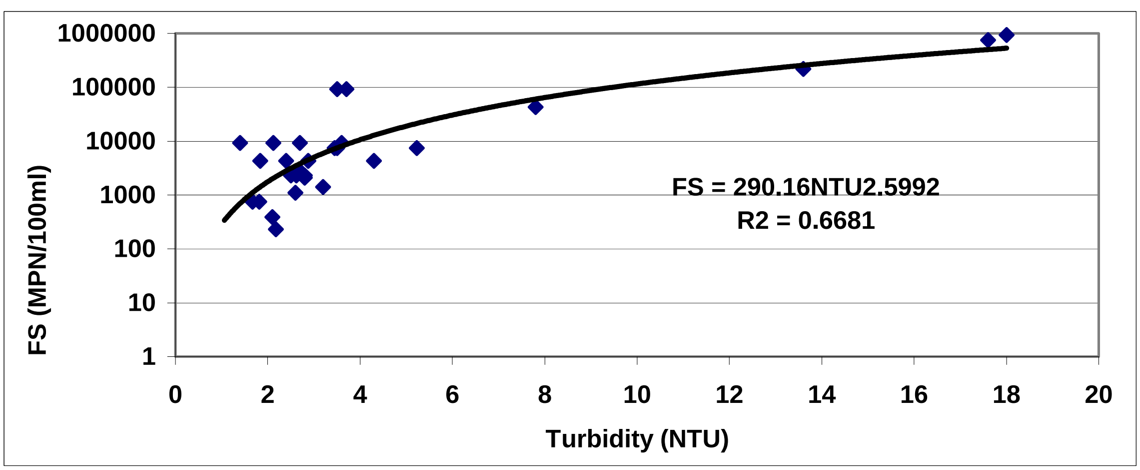


Fig. 4.124 Correlation b/w FS and Turbidity at Outlet of ASP Haridwar

The BOD concentration was also correlated to TC, FC and FS concentration at plant effluent. The results revealed that BOD also have good correlations with microbial parameters (r^2 = 0.56, 0.58, 0.42 respectively) but it shows less significant correlation as compare to SS and turbidity.

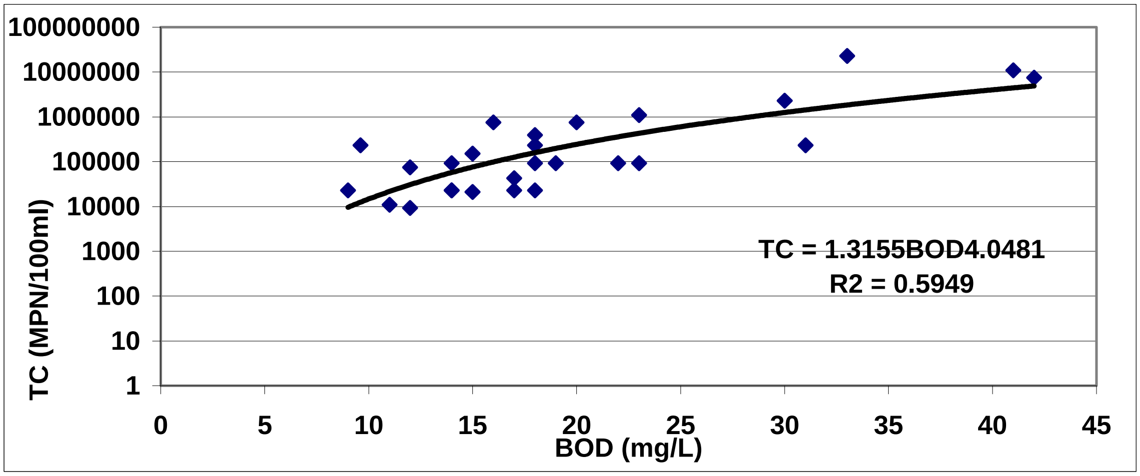


Fig. 4.125 Correlation b/w TC and BOD at Outlet of ASP Haridwar

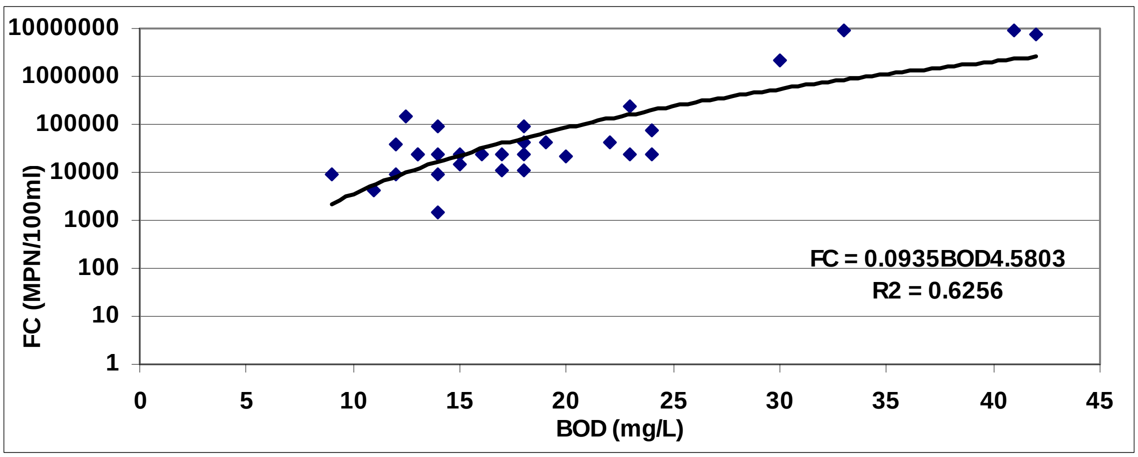


Fig.4.126 Correlation b/w FC and BOD at Outlet of ASP Haridwar

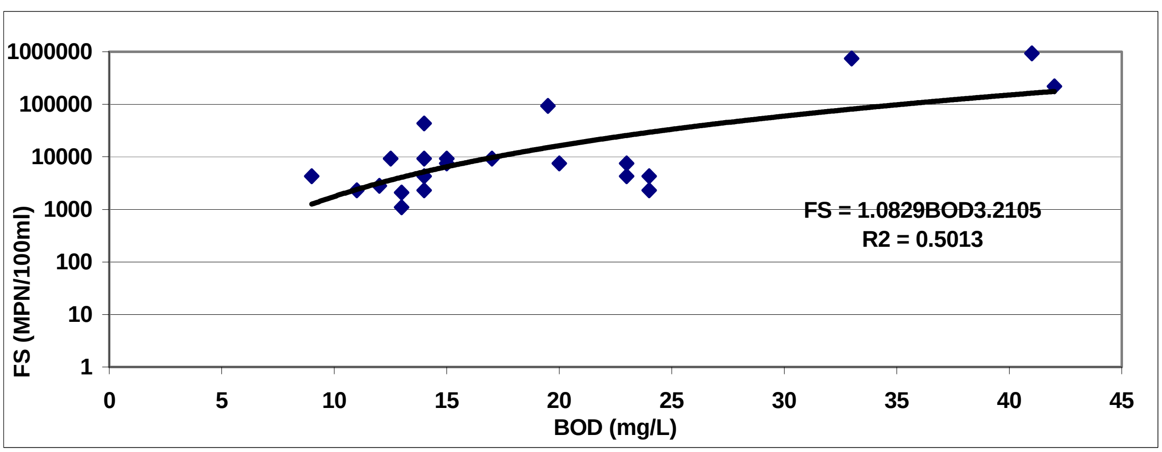


Fig. 4.127 Correlation b/w FS and BOD at Outlet of ASP Haridwar

4.8.3.4 Interrelationship between Process Parameters and Fecal Bio-Indicators

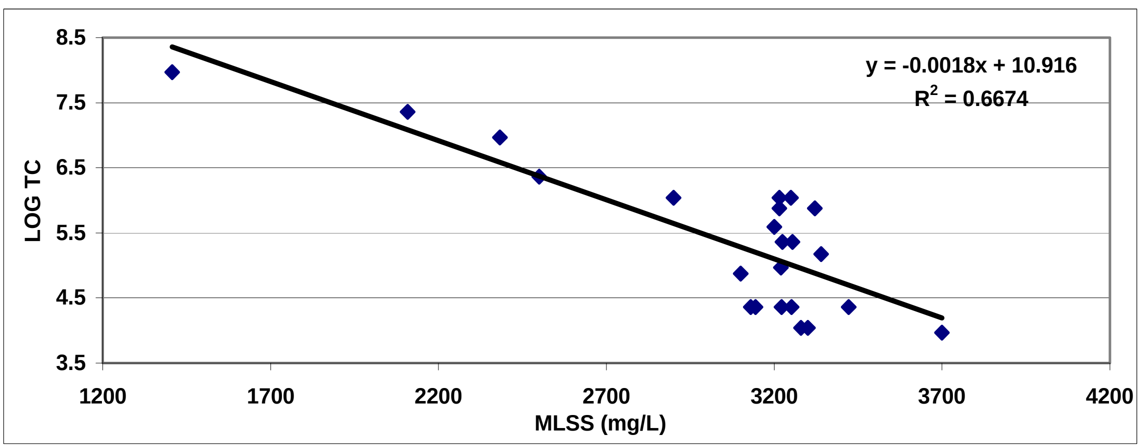
Operation parameters like MLSS, SVI and F/M ratio has been related with effluent TC, FC and FS and it was observed these operational parameters show the significant correlation with effluent TC, FC and FS.

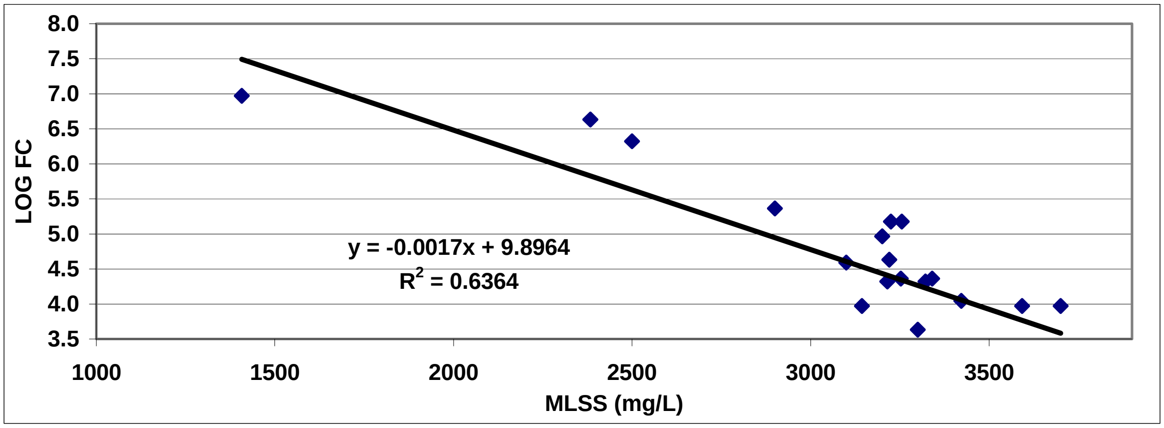
Table 4.38 Summarized Data on operational parameters

Process Parameters	Ranges	Mean
MLSS	2780-3600 mg/L	3500 mg/l
SVI	73- 299 ml/g	125 ml/g
HRT	2-4 hrs	-
SRT	8-10 days	-
F/M	0.16-0.46	0.3

4.3.8.5 Microbial Indicator removal efficiency of activated sludge process as a function of MLSS concentration in Aeration Tank

The relative influences of operating parameters i.e. Mixed Liquor Suspended Solids (MLSS) upon the removal of fecal biomarkers were assessed. A comparison of the secondary effluent concentrations of TC, FC and FS as a function of MLSS are shown in figure. Correlation coefficients were derived in between microbial variables in treated effluent and MLSS concentration in aeration tank at the same time. The correlation coefficient was 0.67, 0.64 and 0.66 for TC, FC and FS respectively (fig 4.128) In general, concentration of these indicators decreased with increasing MLSS, perhaps due to the increased potential for entrapment in biological flocs. We found our observations are consistent with those obtained by WERF (2004). They found almost similar correlation coefficient (r^2= 0.6) for fecal coliforms as a function of MLSS concentration in aeration tank. Further, suggest that higher levels of MLSS concentration and longer MCRT may play a significant role in increased removal of microbial indicators and pathogens. The less concentration of microbial indicators were noted in treated effluent within a MLSS range of 3000-3500 mg/l. An optimum MLSS range of 2000-5000 mg/l has been suggested by various researchers worldwide (Metcalf- Eddy, 2005; Rittmann & McCarty; 2005; Arcievala, 2005) for complete mix activated sludge process.





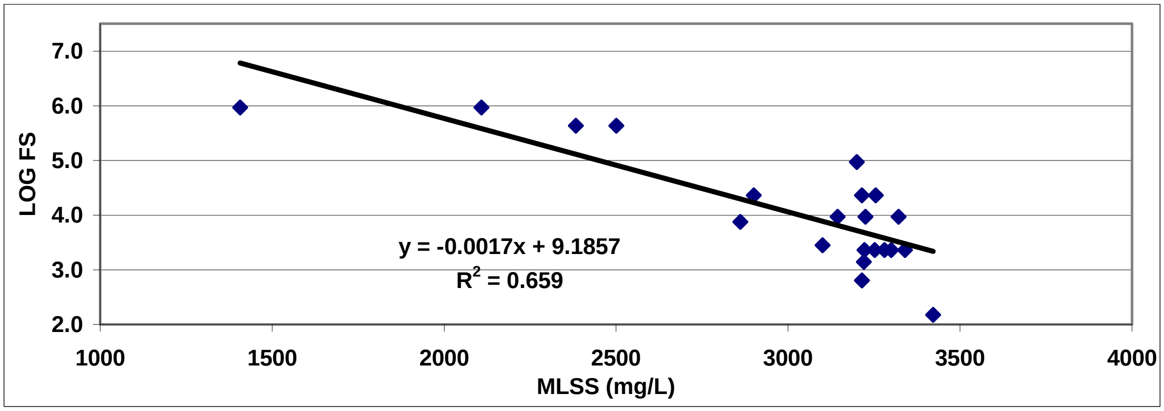
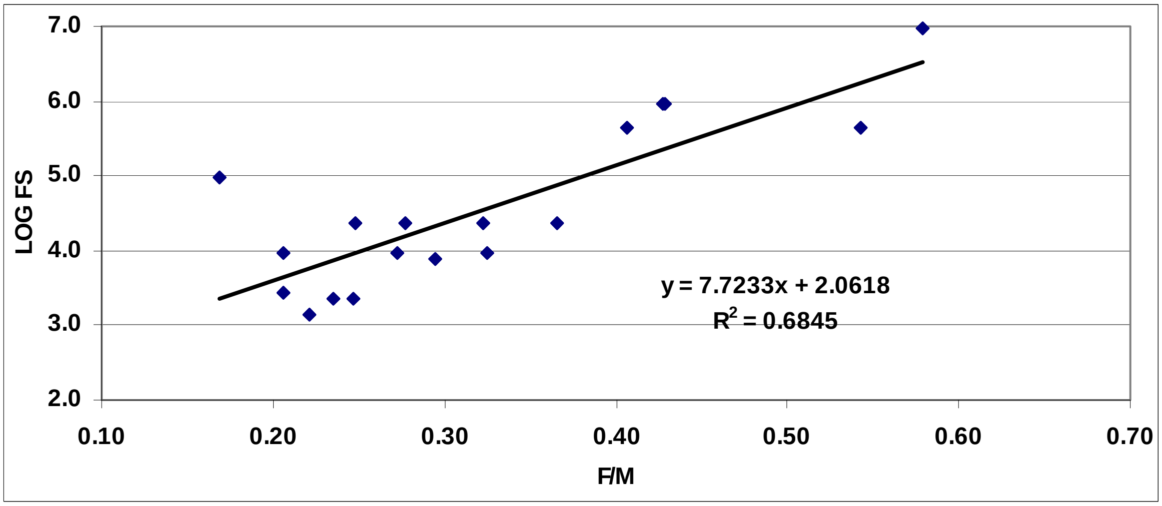


Fig.4.128 Correlation b/w MLSS and effluent concentrations of TC, FC and FS

4.3.8.6 Microbial Indicator removal efficiency of activated sludge process as a function of Food to Microorganisms (F/M) ratio in Aeration Tank

The optimum operating range of F/M helps to get the desired effluent concentration. It provides a means for maintaining the best effluent quality (Durbin, 2006). With this intent, we tried to find out the optimum F/M range for better coliforms removal. A significant correlation coefficient (r^2) was obtained i.e. 0.68 for TC, 0.63 for FC and 0.68 for FS as a function of F/M ratio applied to the system (fig.4.129). The higher microbial indicators removal was obtained at an optimum F/M range of 0.2- 0.35. A low F/M ratio will facilitate constant endogenous phase to the system. During this stage, bacteria begin to die-off or bacterial cell lyses will occur (McKinney, 1962). For a conventional design for the activated sludge treatment of domestic sewage, the F/M ratio has been suggested within a range of 0.25-0.5, a range that generally results in reliable operation with BOD removal efficiency of about 90-95% (Metcalf- Eddy, 2005; Rittmann & McCarty; 2005; Arcievala, 2005). If the F/M ratio is maintained at very high levels, the microorganisms will not floc but will be completely dispersed and the energy level of the system will be quite high at this non flocculent stage (Rittmann & McCarty, 2005).



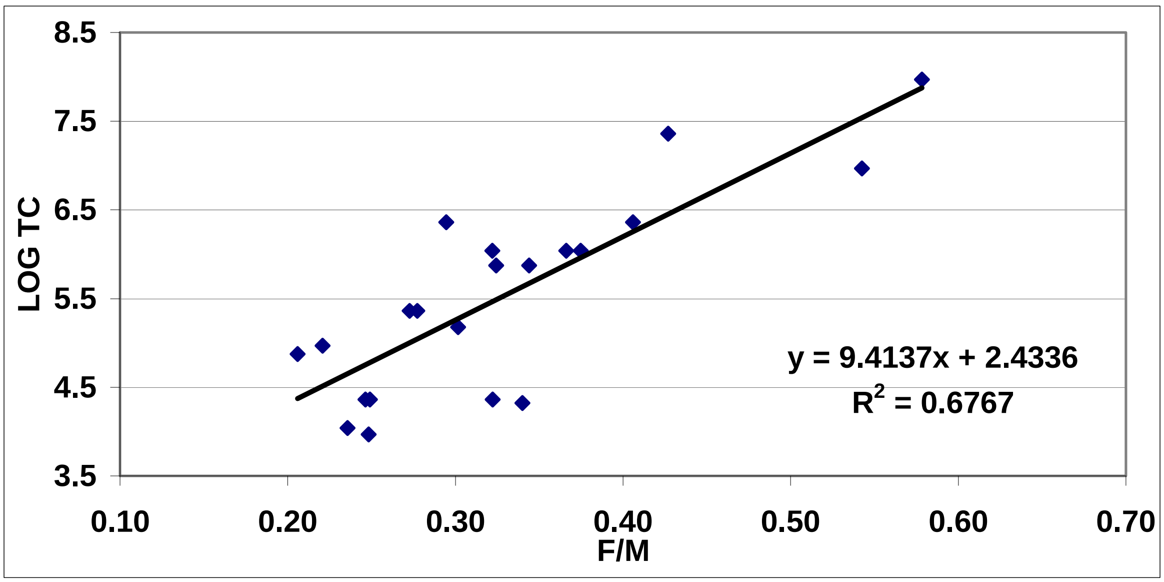


Fig.4.129 Correlation b/w F/M ratio and effluent concentrations of TC, FC and FS

(4.3.9) 0.5 MLD Swarg Ashram Sewage Treatment Plant, Rishikesh (Uttarakhand)

4.3.9.1 Physico-chemical and Microbiological Characteristic

The concentrations of physico-chemical and microbiological parameters of sewage samples were collected from the influent and effluent of Swarg Ashram STP are tabulated in Table 4.39.

Table 4.39 : Descriptive Data and Removal efficiency of STP Swarg Ashram

Date	Sampling Point	pH	Temp (°C)	DO (mg/L)	TDS (mg/L)	Turb-dity NTU	TSS (mg/L)	Alkali-nity (mg/L)	COD (mg/L)	BOD (mg/L)	TC	FC (MPN/ 100 ml)	FS (MPN/ 100 ml)
26/06/06	**Inlet**	7.2	30.2	0.5	477	123	156	370	393.02(T) 169.4(S)	190(T)	9.3×10^{6}	4.3×10^{6}	1.5×10^{6}
	Outlet	7.4	30.0	1.5	507	53.7	312	418	219.72(T) 165.2(S)	132(T)	4.3×10^{5}	4.3×10^{5}	1.5×10^{5}
	% removal	-	-	-	-	**56.34**	-	-	**44.09**	**30.53**	**95.37**	**90.00**	**90.00**
27/07/06	**Inlet**	6.8	28.0	0.0	214	100	284	152	278.81(T)	135(T) 90(S)	2.3×10^{7}	4.3×10^{6}	9.3×10^{5}
	Outlet	6.9	28.5	1.0	291	51.8	74	205	86.91(T)	69(T) 31(S)	4.3×10^{6}	2.3×10^{5}	4.3×10^{4}
	% removal	-	-	-	-	**48.2**	**73.9**	-	**69.82**	**48.8**	**81.3**	**94.65**	**95.37**
17/08/06	**Inlet**	6.9	28.0	0.0	749	219	436	356	579.53(T) 231.41(S	350(T) 180(S)	2.1×10^{7}	1.5×10^{7}	1.5×10^{5}
	Outlet	7.3	28.1	1.2	777	273	432	390	600.48(T) 135.2(S)	56(T) 20(S)	9.3×10^{6}	4.3×10^{6}	4.3×10^{4}
	% removal	-	-	-	-	-	**0.9**	-	-	**84.0**	**55.7**	**71.33**	**71.30**
11/09/06	**Inlet**	7.4	27.3	0.0	423	172	305	360	318.43(T)	134(T)	1.5×10^{7}	1.5×10^{6}	2.3×10^{5}
	Outlet	7.5	27.1	2.2	420	50.5	81	415	207.92(T)	85(T)	**4.3×10^{6}**	**9.3×10^{5}**	9.3×10^{4}
	% removal	-	-		-	**70.64**	**73.44**	-	**34.70**	**36.56**	71.33	38.0	**59.56**
25/10/06	**Inlet**	7.1	26.1	0.8	446	74.3	110	350	240.45(T) 151.8(S)	120(T)	7.5×10^{7}	9.3×10^{6}	9.3×10^{5}
	Outlet	7.0	26.6	1.2	494	53.9	69	400	295.72(T) 151.2(S)	85(T)	**4.3×10^{6}**	**7.5×10^{5}**	2.1×10^{4}
	% removal	-	-	-	-	**27.45**	**37.27**	-	-	**29.16**	**94.26**	**91.93**	**97.14**
Mean Raw Influent		**7.1**	-	-	-	**138**	**258**	-	**406**	**185.8**	**2.8×10^{7}**	**6.8×10^{6}**	**7.5×10^{5}**
Mean Treated Effluent		**7.2**				**96.6**	**193.6**	-	**282.4**	**85.4**	**4.5×10^{6}**	**1.3×10^{6}**	**7.0×10^{4}**
Mean % removal		-	-	-	-	**30.00**	**25.10**	-	**30.00**	**54.00**	**83.90**	**80.88**	**90.66**

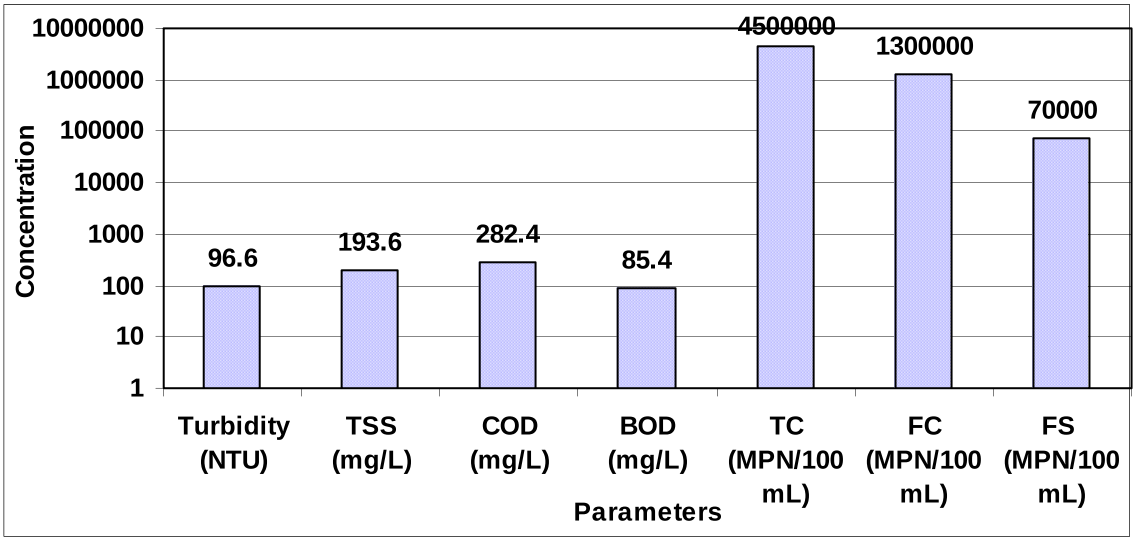


Fig. 4.130 Mean concentration of various pollutants in STP effluent

Therefore, the STP Swarg Ashram is incapable to remove the organic as well as microbial pollutants efficiently as shown in fig 4.131

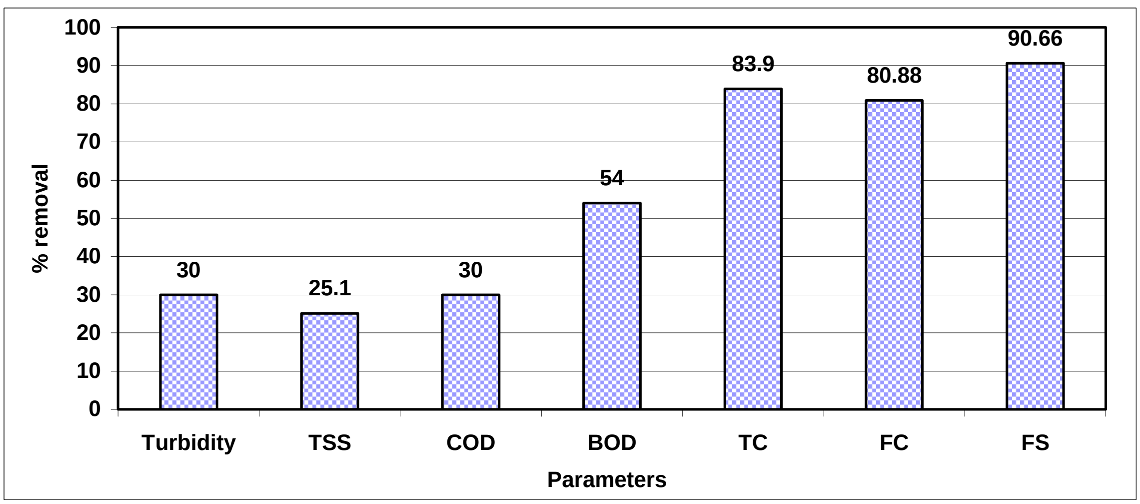


Fig. 4.131 Mean removal efficiency of various pollutants w.r.t. performance of STP Swarg Ashram

4.3.9.2 Conclusions

From the results of the present work following conclusions can be drawn.

1. The sewage treatment plant at Swarg Ashram has very poor performance in removal of organic, inorganic as well as microbial pollutants from the sewage.
2. Effluent characteristics of all most all the parameters of the sewage do not commensurate with effluent discharge standards.
3. By observing the concentrations of effluent parameters , the plant was abandoned and with the following suggestions :
    - **a)** Its performance should be upgraded like by cleaning filter beds and back washing etc.
    - **b)** Check the working of both the filters (Downflow and Upflow) and their filter media, with respect to its design, if not provide it according to its design size, shape, depth etc.
    - **c)** Clean up all the chambers of the plant like inlet, grit, and also primary sedimentation tank.

(4.3.10) 25 MLD Up-flow Anaerobic Sludge Blanket (UASB) Plant, Yamuna Nagar (Haryana)

4.3.10.1 Physico-Chemical and Microbiological Characteristic

The various Physico-chemical and microbiological tests were analyzed for the Influent and effluent of the plant and summarized in Table 4.40.

Table 4.40: Descriptive Data and Removal efficiency of UASB plant, Yamuna Nagar

Date	Sampling Point	Temp (ºC)	TSS (mg/L)	Turbidity NTU	pH	TDS (mg/L)	DO (mg/L))	COD (mg/L)	BOD (mg/L)	TC	FC 100 ml	FS 100 ml	Helminthes (eggs/L)
29/08/04	Inlet	31	230	385	7.1	530	1.5	330(T) 118(S)	250(T) 110(S)	$9.3x10^6$	$2.3x10^5$	$2.3x10^6$	60
	Outlet	31	40	118	7.3	500	0.5	67.4(T) 65.6(S)	32(T) 17(S)	$1.9x10^4$	$2.3x10^2$	$4.3x10^2$	1
	% Removal	-	82.6	69.4	-	-	-	79.6	87.2	99.8	99.9	99.9	98.3
05/11/04	Inlet	29	260	330	7.2	520	0.0	413.5(T) 189.4(S)	250(T) 150(S)	$4.3x10^6$	$9.3x10^5$	$4.3x10^6$	50
	Reactor Outlet	29	96	110	7.3	510	0.0	229.1(T) 124.9(S)	80(T) 70(S)	$1.1x10^5$	$1.0x10^4$	$6.4x10^4$	2.7
	% Removal	-	63	-	-	-	-	44.6	68	97.4	98.9	98.5	94.6

Remarks:

1. During the period between 29 August to 05 November 2004 , It is emphasized that inspite of best efforts, only limited visits and observations could be done because of continuous plant breakdown and oxidation pond repair work going on for long time.

2. Because of the first phase under review w.e.f. December 31,2004 the project was restarted only after review by June 2005.

Date	Sampling Point	Temp (ºC)	TSS (mg/L)	Turbidity NTU	pH	TDS (mg/L)	DO (mg/L))	COD (mg/L)	BOD (mg/L)	TC	FC 100 ml	FS 100 ml	Helminthes (eggs/L)
14/12/05	Inlet	22.7	330	401	6.9	616	0.0	360	150	$3.9x10^6$	$2.1x10^6$	$7.5x10^5$	72
	Reactor Outlet	22.8	205	298	6.8	589	0.0	290	100	$1.5x10^5$	$1.2x10^5$	$2.4x10^4$	-
	Outlet	21.5	97.5	118	7.0	575	0.5	101	36	$4.5x10^4$	$2.3x10^4$	$2.1x10^3$	1
	% Removal		70.5	70.6	-	-	-	71.9	76	98.85	98.90	99.7	98.6
30/12/05	Inlet	21.3	255	313	7.2	630	0.0	310	155	$7.5x10^6$	$2.3x10^6$	$2.3x10^5$	67
	Reactor Outlet	21.5	211	218	7.1	600	0.0	220	105	$2.3x10^5$	$1.5x10^5$	$2.1x10^4$	-
	Outlet	20.7	82	105	7.1	595	0.0	97	38	$3.9x10^4$	$2.1x10^4$	$2.1x10^3$	1.4
	% removal	-	67.8	66.5	-	-	-	68.7	75.5	99.5	99.1	99.1	97.9
07/01/06	Inlet	19.6	209	434	6.8	605	0.0	349(T) 150(S)	125(T) 90(S)	$1.5x10^7$	$1.5x10^7$	$4.3x10^5$	54
	Reactor Outlet	19.3	160	290	6.6	618	0.0	198.7(T) 107(S)	66(T) 56(S)	$2.3x10^6$	$2.3x10^6$	$2.3x10^5$	-
	Outlet	18.7	88	134	7.2	509	0.0	98.6(T) 82.3(S)	39(T) 35(S)	$2.3x10^5$	$2.3x10^5$	$2.3x10^4$	2
	% removal	-	57.89	69.1	-	-	-	71.9	68.8	98.5	98.5	94.65	96.3
22/01/06	Inlet	21.1	201	355	7.4	510	0.0	424.76	110	$2.3x10^6$	$2.3x10^6$	$2.3x10^6$	44.5
	Reactor Outlet	21.0	147	300	7.2	530	0.0	212.48	45	$2.3x10^5$	$9.3x10^4$	$9.3x10^4$	-
	Outlet	20.2	76.5	135	7.2	515	0.0	107.38	24	$4.3x10^4$	$2.3x10^4$	$1.1x10^4$	1.7
	% Removal	-	61.9	61.9	-	-	-	74.8	78	98.13	99	99.5	96.2

(Table 4.40 Continued…)

07/ 02/ 06	**Inlet**	22.0	278	296	7.1	684	0.0	428.3	122	$2.1x10^{7}$	$9.3x10^{6}$	$1.5x10^{6}$	57
	Reactor Outlet	22.1	165	262	6.6	626	0.0	204.6	48	$7.5x10^{6}$	$2.3x10^{5}$	$9.3x10^{4}$	-
	Outlet	19.8	88	104	6.8	652	0.0	105.4	27	$2.3x10^{5}$	$9.3x10^{4}$	$2.3x10^{4}$	1.2
	% removal	-	68.3	64.8	-	-	-	75.4	77.8	98.90	99	98.4	97.9
22/ 02/ 06	**Inlet**	21.7	203	273	6.6	675	1.7	412.4(T) 212.6(S)	145	$7.5x10^{6}$	$4.3x10^{6}$	$9.3x10^{5}$	64
	Reactor Outlet	23.8	159	197	6.7	630	0.1	276.2(T) 184.7(S)	88	$9.3x10^{5}$	$2.3x10^{5}$	$4.3x10^{4}$	-
	Outlet	21.3	78.5	115.8	7.2	660	1.5	101(T) 74.1(S)	28	$9.3x10^{4}$	$7.5x10^{4}$	$9.3x10^{3}$	1.1
	% removal	-	61.3	57	-	-	-	75.5	80.7	98.76	98.25	99	98.3
Remarks: Due to poor efficiency of Yamuna Nagar STP , it was decided to replace the same plant by 38 MLD UASB STP, Saharanpur in CPCB Meeting on 3rd April 2006.													

4.3.10.2 Observations and Discussion

From the above experimental results following observations are made:

(i) There were no significant variations observed in effluent pH and TDS values after treatment during all the study period.

(ii) In the raw sewage BOD, COD, TSS were found vary from 110-250 mg/L, 310- 428 mg/L and 201- 303 mg/L respectively.

(iii) The Plant effluent BOD, COD & TSS were found 25- 39 mg/L (Avg.31mg/L), 67- 107 mg/L (96 mg/L) & 40-97 mg/L (Avg. 76 mg/L) respectively. The observations revealed that the effluent BOD is more than the permissible limit i.e. 30 mg/L for discharge the effluent into surface waters.

(iv) The mean removal efficiency of BOD, COD and TSS were found to be 77.14, 73.87 and 66.8 respectively. Which is not satisfactory while as the two polishing pond are provided as a post treatment unit for UASB reactor outlet.

(v) Observations revealed that the influent has concentration of TC, FC and FS varied from $2.3x\ 10^{6} – 2.3x10^{7}$ MPN/100 ml, $2.3x\ 10^{5} – 1.5\ x10^{7}$ MPN/100 ml and $2.3x\ 10^{5} – 4.3x10^{6}$ MPN/100 ml. and for Helminthes eggs it varied from 44.5- 72 eggs/ L.. The effluent has concentration of TC, FC and FS varied from $1.9x\ 10^{4} – 2.3x10^{5}$ MPN/100 ml (Avg. $4.6x\ 10^{4}$ MPN/100 ml), $2.3x\ 10^{2} – 2.3\ x10^{5}$ MPN/100 ml (Avg. $1.8x\ 10^{4}$ MPN/100 ml) and $4.3x\ 10^{2} – 2.3x10^{4}$ MPN/100 ml (Avg. $5.2x\ 10^{3}$ MPN/100 ml) and for Helminthes eggs it varied from 1- 2 eggs/ L (Avg. 1.3 eggs/L).

(vi) It was found that the removal efficiency w.r.t. TC, FC, FS and Helminthes eggs are 98.91, 98.94, 98.62 and 97.64 respectively. The mean value of FC in final treated effluent is 2.3×10^{4}MPN/100 ml, which is more than the permissible limit (i.e. 1000 MPN/ 100ml) specified by WHO (1989) for unrestricted irrigation. The Mean concentration of helminthes eggs in effluent was found 1.3 eggs/ L. It is also above the permissible limit (< 1 eggs/L) as recommended by WHO for unrestricted irrigation.

(4.3.11) 14 MLD Extended Aeration Plant, Vasant Kunj, Delhi

4.3.11.1 Physico-Chemical and Microbiological Characteristic

Various physico-chemicals and microbiological parameters analyzed for the Influent and effluent of the plant as well as the derived efficiency of the plant with respect to these parameters are listed in Table 4.41.

Table 4.41: Descriptive Data and Removal efficiency of extended aeration plant Vasant Kunj, Delhi

Date	Sampling Point	Temp (ºC)	TSS mg/L	Turbi-dity NTU	pH	TDS (mg/L	DO (mg/L)	COD (mg/L)	BOD (mg/L)	TC MPN/ 100ml	FC MPN/	FS MPN/ 100ml
11/11/05	Inlet	25.8	465	366	7.0	570	0.0	658	265	$4.3x10^7$	$9.3x10^6$	$3.9x10^5$
	Outlet	26.5	79	10.8	7.4	760	1.5	57	23	$1.1x10^5$	$2.1x10^4$	$2.1x10^3$
	% Removal	-	**83**	**97.0**	-	-	-	**91.3**	**91.3**	**99.74**	**99.77**	**99.46**
22/11/05	Inlet	23.1	398	275	7.1	686	0.0	712(T)	284	$7.5x10^7$	$2.3x10^7$	$4.3x10^6$
	Outlet	22.5	80	10.8	7.7	564	3.9	60	20	$9.3x10^4$	$1.1x10^4$	$9.3x10^3$
	% Removal	-	**79.9**	**96.1**	-	-	-	**91.6**	**93.0**	**99.88**	**99.95**	**99.78**
22/12/05	Inlet	22.5	401	311	7.8	711	0.0	746.2	280	$2.3x10^7$	$2.3x10^7$	$2.3x10^6$
	Outlet	21.8	88	11.5	8.0	**684**	4.5	66.9	18	$6.9x10^4$	$2.3x10^4$	$7.5x10^3$
	% Removal	-	**78.1**	**96.3**	-	-	-	**91.0**	**93.6**	**99.70**	**99.90**	**99.67**
29/12/05	Inlet	20.5	412	392	7.2	818	0.0	525.4	216	$2.3x10^8$	$9.3x10^7$	$4.3x10^5$
	Outlet	20.3	107	17.1	7.3	**672**	4.3	80.1	29	$2.3x10^4$	$9.3x10^3$	$1.5x10^3$
	% Removal	-	**74.0**	**95.6**	-	-	-	**84.8**	**86.6**	**99.99**	**99.99**	**99.65**
12/01/06	Inlet	19.8	393	288	7.0	716	0	685.4	270	$9.5x10^6$	$2.3x10^6$	$2.1x10^5$
	Outlet	16.5	72	11.7	7.3	604	4.5	60.94	17	$2.3x10^4$	$2.1x10^4$	$1.5x10^3$
	% Removal	-	**81.7**	**95.6**	-	-	-	**91.1**	**93.7**	**9.76**	**99.09**	**99.29**
27/01/06	Inlet	21.5	414	375	7.1	632	0.9	624	277	$7.5x10^7$	$3.5x10^7$	$4.3x10^5$
	Outlet	19.6	77.8	11.6	8.1	507	5.2	67	18	$2.3x10^4$	$1.1x10^4$	$2.1x10^3$
	% Removal	-	**81.2**	**96.9**	-	-	-	**89.3**	**93.5**	**99.97**	**99.97**	**99.51**
11/02/06	Inlet	22.7	397	331	7.1	628	0.0	698	245	$1.4x10^7$	$9.3x10^6$	$4.3x10^5$
	Outlet	21.6	67.2	8.5	7.6	501	4.8	68	18.5	$7.5x10^3$	$2.1x10^3$	$1.1x10^3$
	% Removal	-	**83.1**	**97.4**	-	-	-	**90.3**	**92.4**	**99.95**	99.98	**99.74**
26/02/06	Inlet	21.3	443	256	7.4	657	0.2	635	267	$9.3x10^7$	$4.3x10^7$	$3.9x10^6$
	Outlet	20.7	87.8	12.2	7.6	522	4.5	78	21	$3.9x10^4$	$1.5x10^4$	$9.3x10^3$
	% Removal	-	**80.2**	**95.2**	-	-	-	**87.7**	**92.1**	**99.96**	**99.97**	**99.76**

(Table 4.41 Continued…)

Date	Sampling Point	Temp (ºC)	TSS mg/L	Turbi-dity NTU	pH	TDS (mg/L	DO (mg/L)	COD (mg/L)	BOD (mg/L)	TC MPN/ 100ml	FC MPN/ 100ml	FS MPN/ 100ml
11/ 03/ 06	Inlet	24.7	399	351	7.4	701	0.6	717	250	$9.3x10^6$	$7.5x10^6$	$9.3x10^5$
	Outlet	24.5	75	12.6	7.8	692	4.9	61	25	$2.3x10^4$	$1.2x10^4$	$2.1x10^3$
	% Removal	-	**81.2**	**96.4**	-	-		**91.5**	**90.0**	**99.75**	**99.84**	**99.77**
22/ 03/ 06	Inlet	22.4	445	332	7.5	696	0.4	663	242	$9.3x10^7$	$6.4x10^7$	$3.9x10^6$
	Outlet	22.1	67.8	11.3	7.7	575	4.9	54	21.6	$2.3x10^4$	$2.3x10^4$	$1.1x10^3$
	% Removal	-	**84.8**	**96.6**	-	-	-	**91.9**	**91.1**	**99.98**	**99.96**	**99.97**
03/ 04/ 06	Inlet	23.1	301	174	7.4	751	0.0	622	250	$2.3x10^7$	$2.3x10^7$	$9.3x10^5$
	Outlet	24.0	100	16.7	7.6	598	4.5	86	39	$2.3x10^5$	$9.3x10^4$	$2.3x10^4$
	% Removal	-	**66.8**	**90.4**	-	-	-	**86.2**	**84.4**	**99**	**99.60**	**97.53**
18/ 04/ 06	Inlet	24.3	444	285	7.6	798	0.0	680.5	235	$3.9x10^7$	$2.3x10^7$	$4.6x10^6$
	Outlet	24.1	63.7	9.4	**7.7**	**675**	**4.4**	75.4	24.1	$9.3x10^3$	$7.5x10^3$	$2.1x10^3$
	% Removal	-	**85.7**	**96.7**	-	-	-	**88.9**	**89.7**	**99.98**	**99.97**	**99.95**
04/ 05/ 06	Inlet	25.8	407.5	192	7.4	604	0.2	546	205	$4.3x10^7$	$2.3x10^7$	$1.2x10^6$
	Outlet	26.6	76.55	10.5	7.9	554	5.7	54.32	22	$4.3x10^4$	$2.3x10^4$	$3.9x10^3$
	% Removal	-	**81.2**	**94.5**	-	-	-	**90.1**	**89.3**	**99.90**	**99.90**	**99.68**
22/ 05/ 06	Inlet	27.6	468	313	7.4	612	0.3	730	265	$9.3x10^6$	$7.5x10^6$	$6.3x10^5$
	Outlet	28.1	**76.4**	**10.4**	7.6	576	5.0	**66.1**	**21**	$7.3x10^3$	$4.6x10^3$	$1.1x10^3$
	% Removal	-	**83.7**	**96.7**	-	-	-	**90.9**	**92.1**	**99.92**	**99.94**	**99.8**
07/ 06/ 06	Inlet	28.1	416	285	7.5	698	0.8	730	213	$9.3x10^6$	$2.3x10^6$	$6.4x10^5$
	Outlet	28.3	**75**	**9**	7.7	568	4.9	89	25	$2.3x10^4$	$9.3x10^3$	$7.5x10^2$
	% Removal	-	**82.0**	**96.8**	-	-	-	**87.8**	**88.3**	**99.75**	**99.60**	**99.88**
26/ 06/ 06	Inlet	28.2	400	290	7.2	695	0.0	589	202	$1.1x10^7$	$6.4x10^6$	$7.5x10^5$
	Outlet	28.5	**56**	**5.4**	7.5	529	4.5	67.8	**22.6**	$2.4x10^3$	$1.1x10^3$	$2.3x10^2$
	% Removal	-	86.0	98.1	-	-	-	88.5	**88.8**	99.98	99.98	99.97
12/ 07/ 06	Inlet	28.4	464	321	7.4	732	0	606	223	$6.4x10^7$	$7.5x10^6$	$6.4x10^5$
	Outlet	28.3	**83**	**12.7**	7.5	618	4.5	101	**31**	$3.9x10^4$	$9.3x10^3$	$2.1x10^3$
	% Removal	-	82.1	96.0	-	-	-	83.3	**86.1**	99.94	99.88	99.67

(Table 4.41 Continued…)

Date	Sampling Point	Temp (ºC)	TSS mg/L	Turbi-dity NTU	pH	TDS (mg/L	DO (mg/L)	COD (mg/L)	BOD (mg/L)	TC MPN/ 100ml	FC MPN/ 100ml	FS MPN/ 100ml
26/ 07/ 06	Inlet	28.2	430	310	7.2	765	0.5	612	211	$1.2x10^7$	$9.3x10^6$	$9.3x10^5$
	Outlet	28.4	**76.5**	**11.4**	7.5	612	3.5	69.6	**22**	$7.5x10^3$	$9.3x10^3$	$1.1x10^3$
	% Removal	-	82.2	96.3	-	-	-	88.6	**89.6**	99.94	99.90	99.88
14/ 08/ 06	Inlet	27.4	421	303	7.2	675	0.0	712	232	$2.4x10^7$	$4.3x10^6$	$2.3x10^5$
	Outlet	27.1	**69**	**10**	7.4	510	4.1	59.6	**18**	$4.3x10^3$	$3.9x10^3$	$9.3x10^2$
	% Removal	-	83.6	96.7	-	-	-	91.6	**92.2**	99.98	99.01	99.60
29/ 08/ 06	Inlet	27.9	469	330	7.4	785	0.0	644	212	$7.5x10^7$	$9.3x10^6$	$6.4x10^5$
	Outlet	28.1	**83.86**	**13**	7.8	624	4.3	65.58	**21**	$6.4x10^4$	$9.3x10^3$	$1.1x10^3$
	% Removal	-	82.1	96.1	-	-	-	90.7	**90.1**	99.91	99.90	99.83
14/ 09/ 06	Inlet	27.5	**412**	**295**	7.5	671	**0.0**	680	245	$1.2x10^7$	$7.5x10^6$	$7.5x10^5$
	Outlet	27.6	**72.43**	**10**	7.7	511	3.7	83.45	25	$7.5x10^3$	$7.5x10^3$	$7.5x10^2$
	% Removal	-	**82.4**	**96.6**	-	-	-	**87.7**	**89.8**	**99.94**	**99.90**	**99.90**
29/ 09/ 06	Inlet	28.0	**389**	**168**	7.3	341	0.5	565	238	$9.3x10^6$	$2.4x10^6$	$6.4x10^5$
	Outlet	27.6	**65**	**8.8**	7.3	377	4.4	88.1	22.4	$2.3x10^3$	$2.3x10^3$	$7.5x10^2$
	% Removal	-	**83.3**	**94.8**	-	-	-	**84.4**	**90.6**	**99.98**	**99.90**	**99.88**
10/ 10/ 06	Inlet	24.8	**400**	**210**	7.2	645	0.0	673.85	260	$9.3x10^6$	$4.3x10^6$	$1.1x10^5$
	Outlet	25.0	**55**	**4.9**	7.7	551	4.5	50	16	$1.5x10^3$	$1.1x10^3$	$2.1x10^2$
	% Removal	-	**86.3**	**97.7**	-	-	-	**92.6**	**93.8**	**99.98**	**99.97**	**99.81**
25/ 10/ 06	Inlet	24.7	**409**	**315**	7.4	695	0.6	690.47	259	$2.3x10^7$	$9.3x10^6$	$3.9x10^5$
	Outlet	25.1	**63**	**8.3**	**7.6**	**630**	**4.8**	93	31	$1.1x10^4$	$9.3x10^3$	$6.4x10^2$
	% Removal	-	**84.6**	**97.4**	-	-	-	**86.5**	**88.0**	99.95	**99.90**	99.84

4.3.11.2 Impact of Seasonal Variations on the Physico-Chemical and Microbiological Characteristics of Influent, Effluent and Removal Efficiency of Plant

The removal efficiency of Vasant Kunj extended aeration STP w.r.t. organic as well as microbial pollutants were studied for all seasons i.e. summer, monsoon, winter and autumn. From the study work following results was obtained as depicted in Table 4.42

Table 4.42 Variations in the characteristics of Physico-Chemical and Microbial parameters and impact on their removal efficiency during all the seasons

(A) Physico-Chemical Parameters

Seasons	TSS			BOD			COD		
	Inlet (mg/L)	Outlet (mg/L)	% R	Inlet (mg/L)	Outlet (mg/L)	% R	Inlet (mg/L)	Outlet (mg/L)	% R
Winter	411	76	81.0	263	21	91.6	661	66	89.7
Autumn	420	74	82.3	251	21	91.4	678	65	90.3
Summer	402	73	80.6	227	25	88.7	646	72	88.7
Monsoon	430	75	82.6	226	23	89.7	635	76	87.6
Mean	**416**	**75**	**82.0**	**241**	**23**	**90.5**	**655**	**70**	**89.1**

(B). Microbiological Parameters

Seasons	Total Coliforms			Fecal Coliforms			Fecal Streptococci		
	Inlet (MPN/ 100ml)	Outlet (MPN/ 100ml)	% R	Inlet (MPN/ 100ml)	Outlet (MPN/ 100ml)	% R	Inlet (MPN/ 100ml)	Outlet (MPN/ 100ml)	% R
Winter	36000000	25000	99.93	14000000	10200	99.93	530000	1700	99.68
Autumn	32600000	20000	99.91	21000000	10000	99.94	1570000	2200	99.86
Summer	18230000	18300	99.90	10500000	9500	99.91	1076000	1800	99.83
Monsoon	23200000	10500	99.95	6070000	6200	99.90	590000	1050	99.82
Mean	**26540000**	**17600**	**99.92**	**11700000**	**9000**	**99.92**	**852000**	**1600**	**99.80**

% R= % Removal

As far as concerned about the impact of seasonal variation upon the plant efficiency following observations are made:

1. The effluent TSS was found almost similar ranges i.e. 75mg/L during all the seasons. While as no significant variation in TSS removal was observed throughout the seasons (fig.4.132)

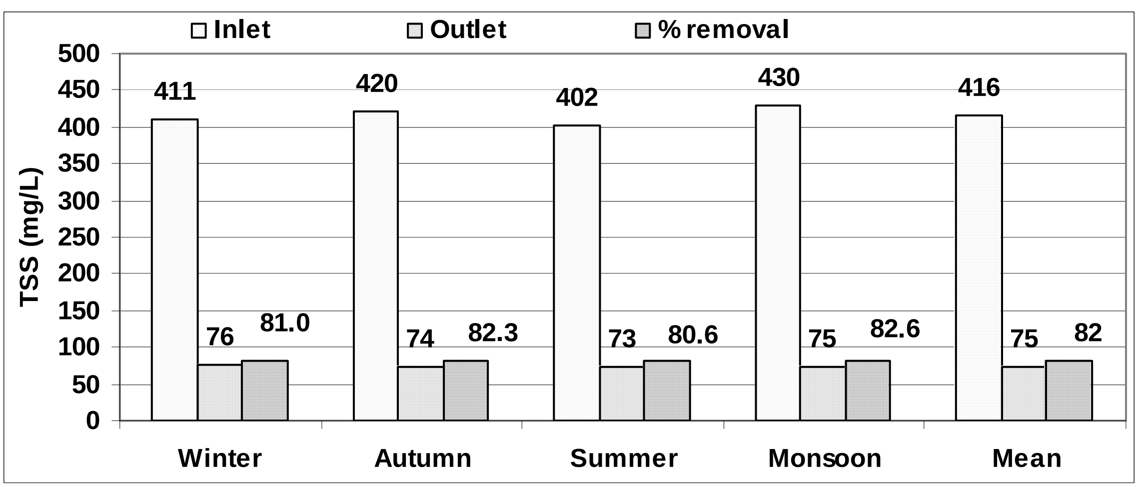


Fig.4.132 Impact of Seasonal variations on the TSS concentration of Influent, Effluent and percentage TSS removal efficiency of Plant

2. The effluent BOD (i.e. ≈23 mg/L) as well as BOD removal during all the seasons were reported almost similar (Fig 1.133).

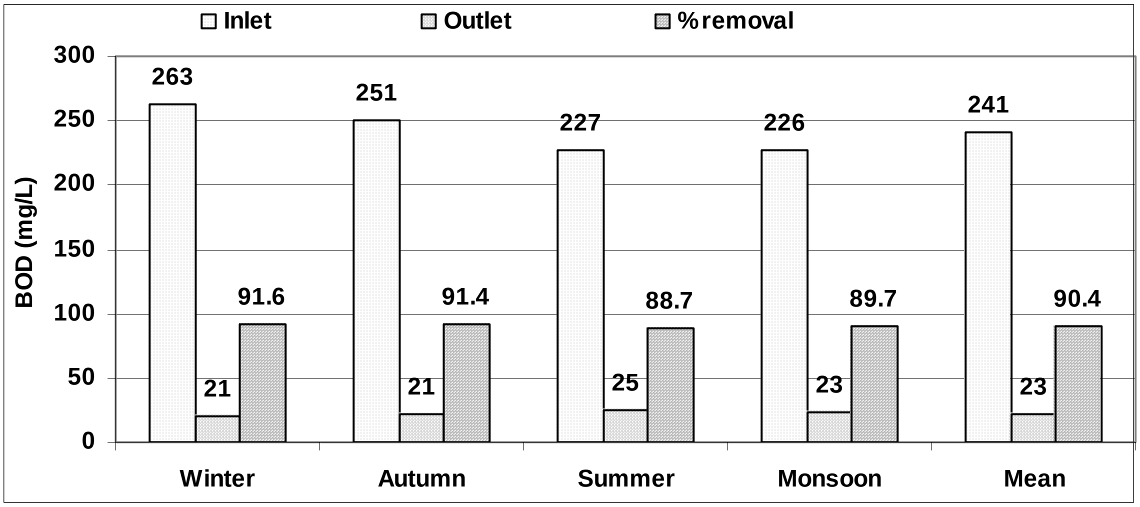


Fig.4.133 Impact of Seasonal variations on the BOD concentration of Influent, Effluent and percentage BOD removal efficiency of Plant

3. The little higher effluent COD was reported during summer and Monsoon period i.e. 72 and 76 mg/l respectively. Whereas the COD removal efficiency were similar i.e. ≈70 % during the entire study period.

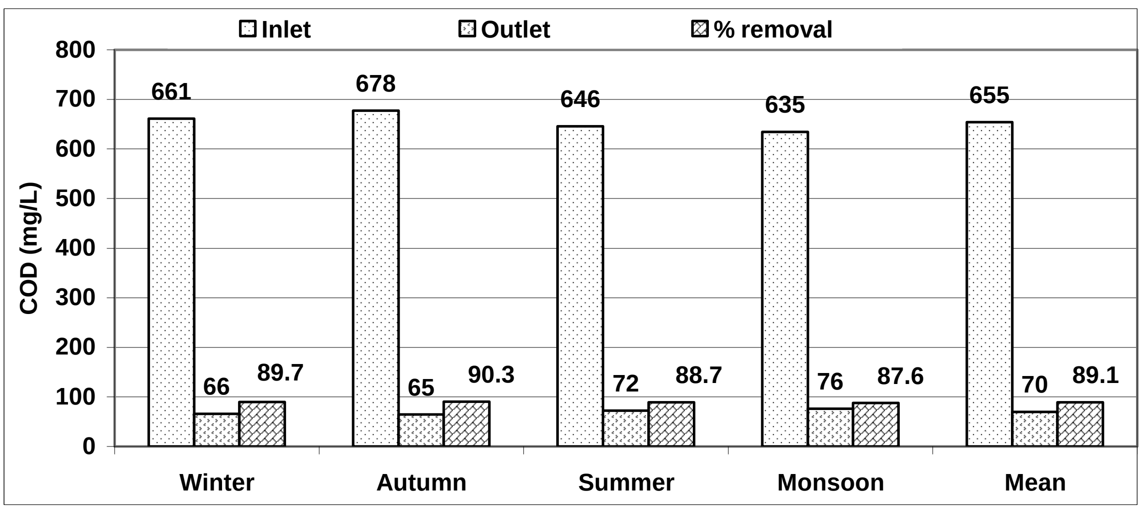
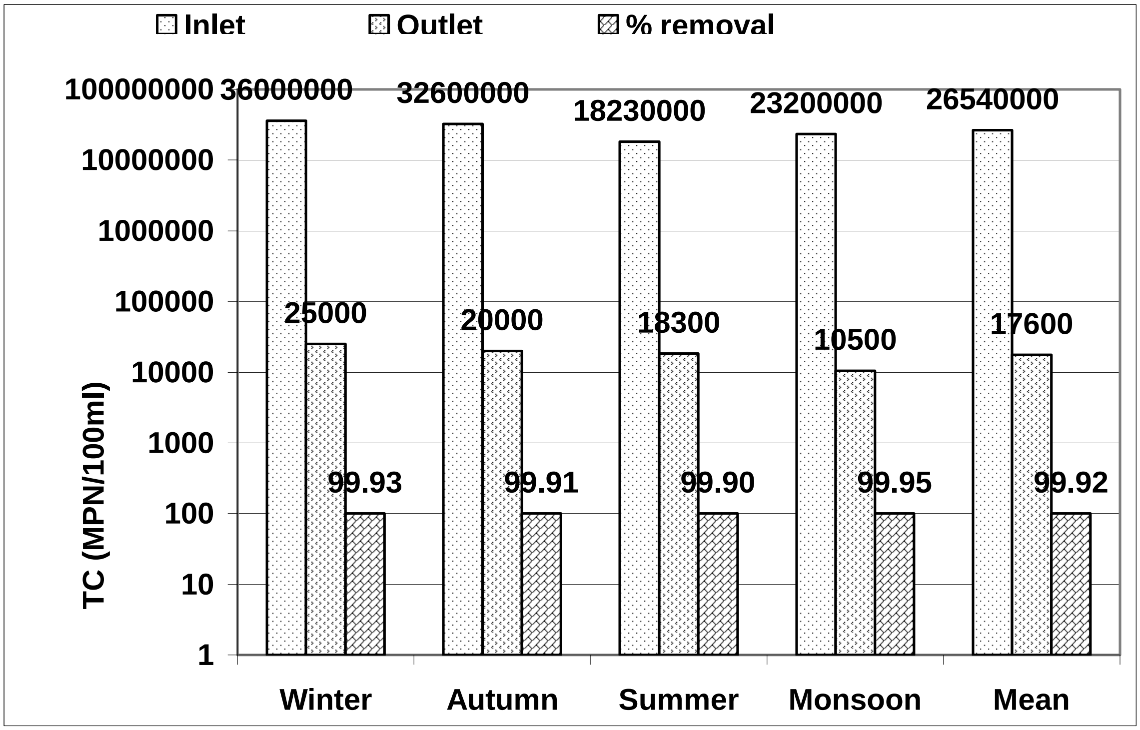


Fig.4.134 Impact of Seasonal variations on the COD concentration of Influent, Effluent and percentage COD removal efficiency of Plant

4. The lowest effluent concentration of Total Coliforms and fecal coliforms was observed during monsoon period whereas the highest effluent TC concentration was noted during winter period. The highest FC concentration in the effluent was noted during winters and autumn period. Almost 3 log removal was observed for TC and FC during entire study period.



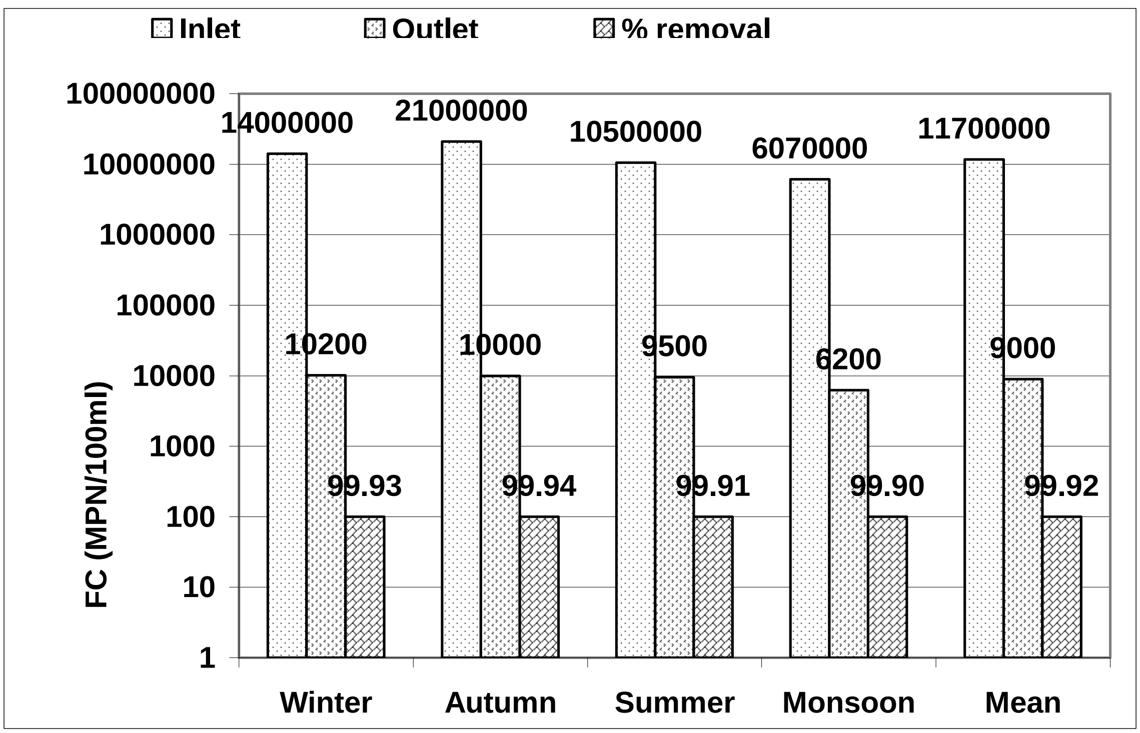


Fig 4.135 Impact of Seasonal variations on the Microbiological characteristics (TC and FC) of Influent, Effluent and their removal efficiency

5. The effluent FS concentration was reported highest in autumn and lowest in monsoon period. Furthermore the similar FS removal observed during entire study period.

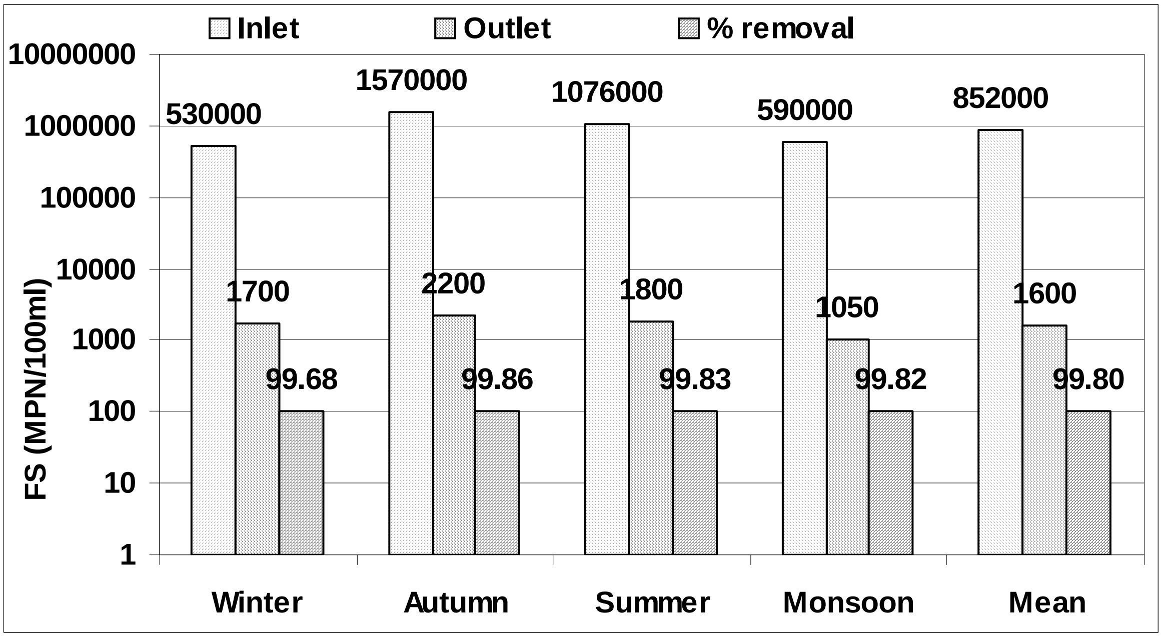


Fig 4.136 Impact of Seasonal variations on the fecal streptococci (FS) concentration of Influent, Effluent and FS removal efficiency

4.3.11.3 Estimation of Correlation between Physico-Chemical and Indicator Microorganisms

On the basis of statistical analysis of data observed, we tried to find out the relationship between key wastewater constituents i.e., Turbidity, TSS and BOD with Total Coliform, Fecal Coliform & Fecal Streptococci, discussed as follows:

The work presented here summarizes suspended particles and associated microbial indicators concentration at effluent of the plant. For Suspended Solids, there was a positive correlation between SS value and TC, FC, FS concentration (r^2 = 0.72, 0.69, 0.71 respectively) (fig.4.137 - fig 4.139). The value of r^2 in case of TC, FC and FS (0.69- 0.72) shows that ≈ 70% variation in TC, FC and FS is influenced by SS changes. However, the remaining 30 % variations may be attributed to other factors.

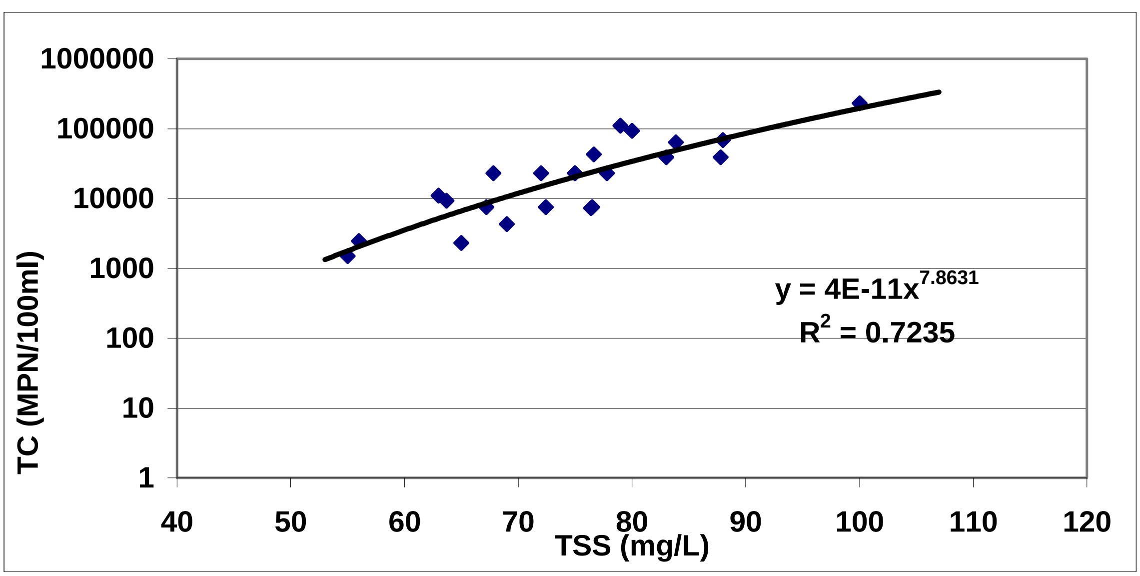


Fig.4.137. Correlation b/w TC and TSS at Outlet of EA, Delhi

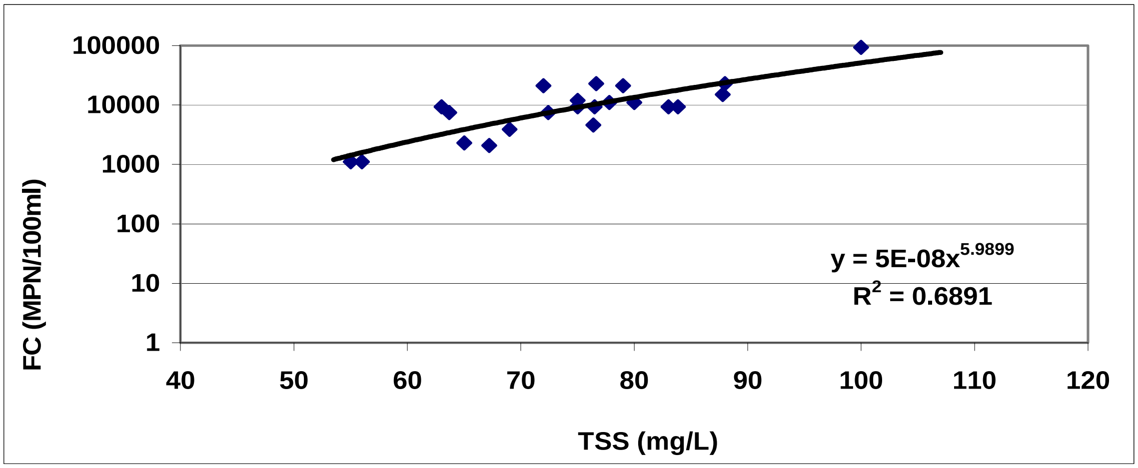


Fig.4.138.Correlation b/w FC and TSS at Outlet of EA, Delhi

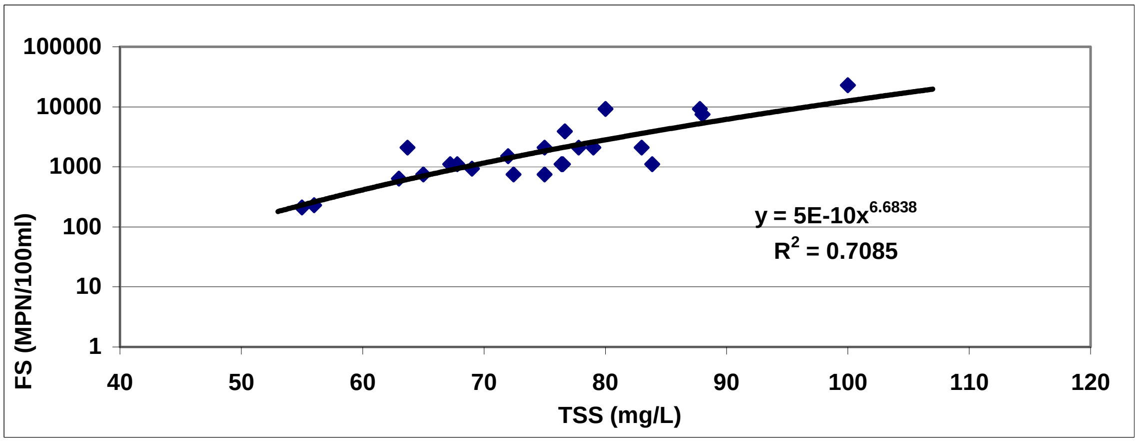


Fig.4.139 Correlation b/w FS and TSS at Outlet of EA, Delhi

The high concentration of turbidity was found to be associated with high number of indicator organisms at plant effluent. The statistical analysis of data shows significant correlation between turbidity and TC, FC and FS values (r^2 = 0.68, 0.69, 0.64 respectively) (fig.4.140- fig 4.142). The value of r^2 in all cases (0.64- 0.69) shows that 64-69% variation in TC, FC and FS is influenced by turbidity changes. However, the remaining 25-40 % variations can be attributed to other factors.

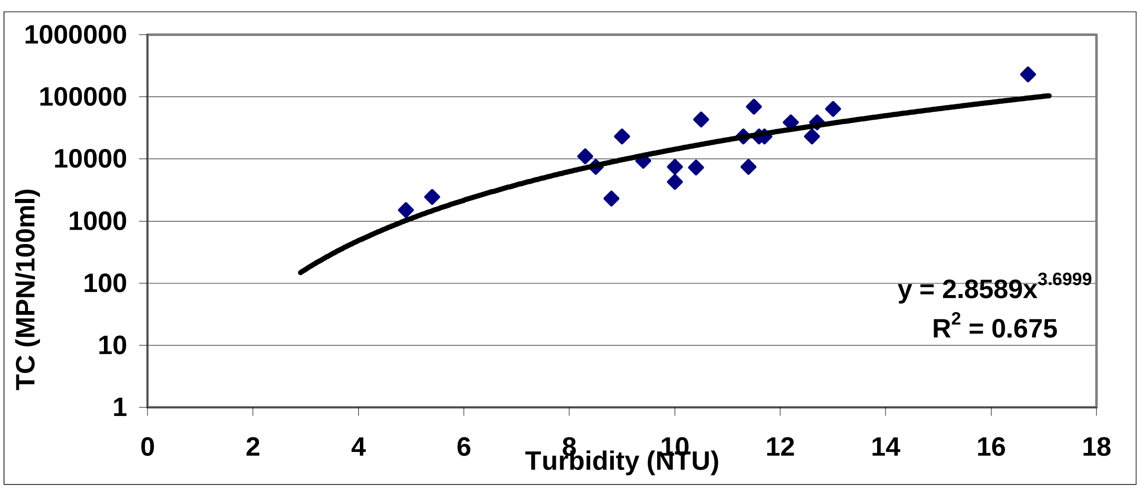


Fig.4.140 Correlation b/w TC and Turbidity at Outlet of EA, Delhi

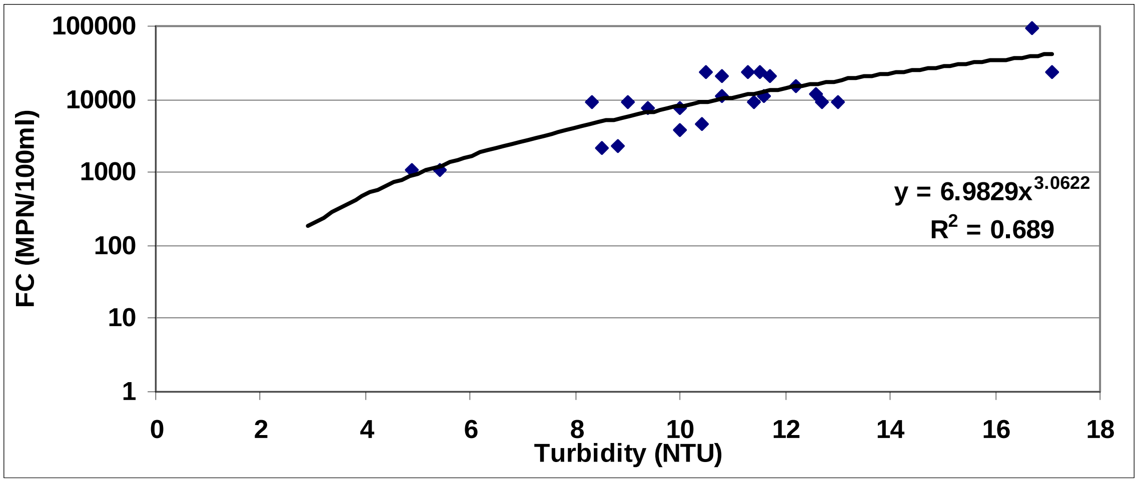


Fig. 4.141 Correlation b/w FC and Turbidity at Outlet of EA, Delhi

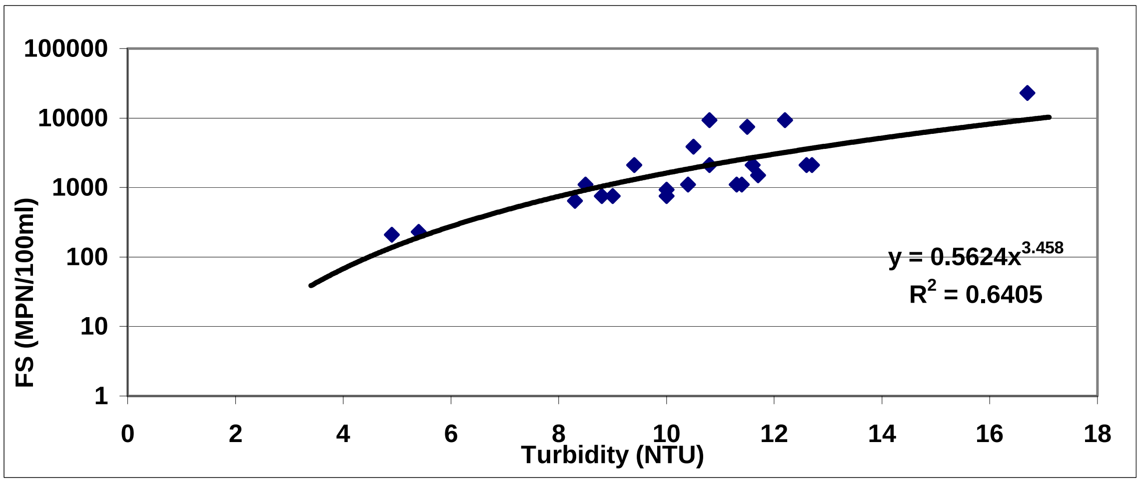


Fig. 4.142 Correlation b/w FS and Turbidity at Outlet of EA, Delhi

The BOD concentration was also correlated to TC, FC and FS concentration at plant effluent (fig.4.143 – fig 4.145). The results revealed that BOD show less significant correlation with microbial parameters (r^2 = 0.46, 0.48, 0.58 respectively) as compare to SS and turbidity. Around 50% microbial fraction is influenced by BOD changes. However, the remaining 50 % variations can be attributed to other factors.

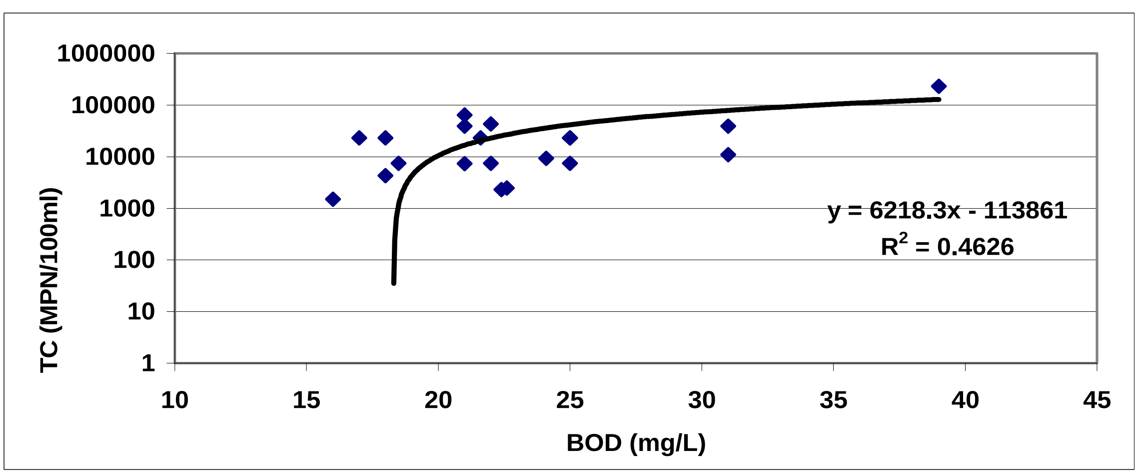


Fig. 4.143. Correlation b/w TC and BOD at Outlet of EA, Delhi

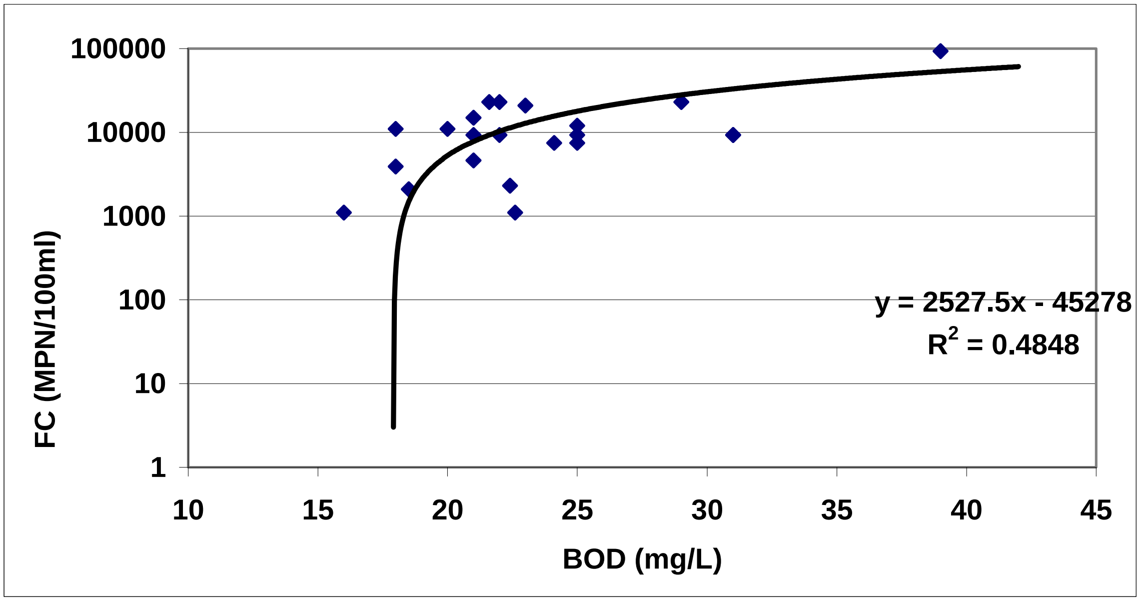


Fig. 4.144. Correlation b/w FC and BOD at Outlet of EA, Delhi

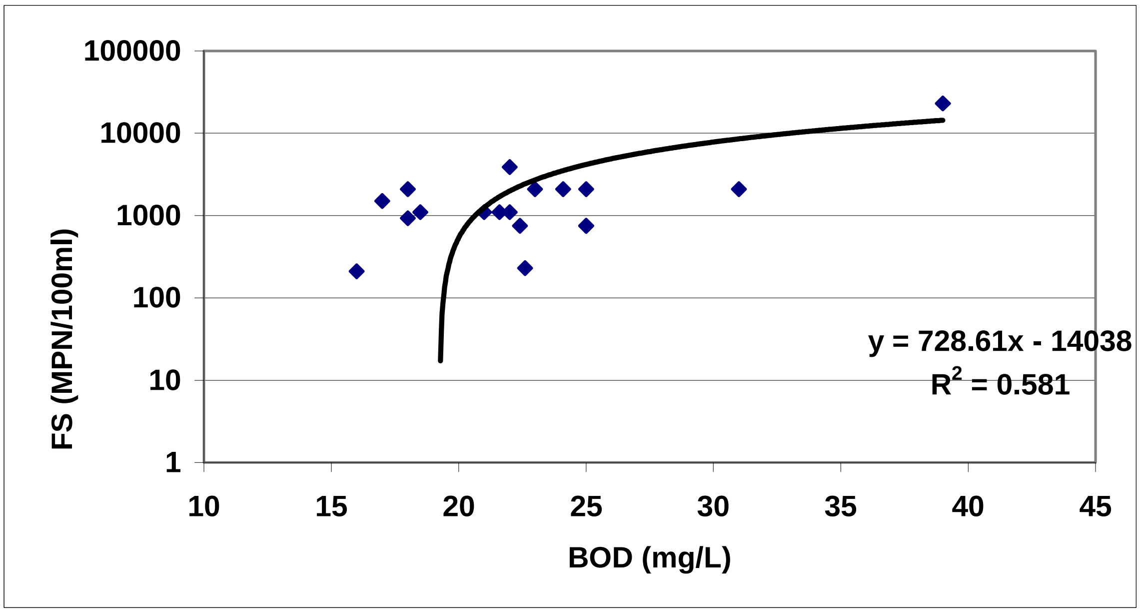


Fig. 4.145. Correlation b/w FS and BOD at Outlet of EA, Delhi

4.3.11.4 Impact of Protozoan Population on Coliforms Removal

More than 20 samples of activated sludge were investigated to detect the community structure of ciliated protozoa from Activated Sludge Process, Kankhal (Hardwar) and Extended Aeration Process, Vasant Kunj (Delhi). A wide range of species (21 sp.) have been observed in aeration tank (listed and classified in Table 4.38) which belong to three main groups namely: Ciliates, flagellates and amoeba. The mixed liquor fauna from the STP Vasant kunj were compared using Frequency distribution of bacterivorous ciliates.

Table 4.43 Frequency of occurrence of most predominant ciliated protozoan found at two sewage treatment plants

S.No.	Biota	Classification	Extended Aeration, Delhi
1	**Aspidisca**	crawling ciliates	++++
2	**Epistylis**	stalked ciliates	+
3	**Vorticella**	stalked ciliates	+
4	**Opercularia**	stalked ciliates	++
5	**Arcella**	Testae amoeba	+
6	**Zoothamnium**	stalked ciliates	+
7	**Chilodonella**	crawling ciliates	++++
8	**Blepharisma**	free swimming ciliates	+
9	**Carchesium**	stalked ciliates	+
10	**Rotatoria**	Rotifer	+
11	**Euplotes**	crawling ciliates	++
12	**Spirostomum**	free swimming ciliates	++
13	**Beggaitoa**	filamentous bacteria	+++++
14	**Spirillus**	filamentous bacteria	++++
15	**Paramecium**	free swimming ciliates	+++
16	**Metopus**	free swimming ciliates	+++
17	**Water flea (Cladocera)**	free swimming ciliates	+
18	**Colurella**	crawling ciliates	++
19	**Vahlkamphia limicola**	Amoeba	+
20	**Litonotus**	Free swimming Carnivores ciliates	+++
21	**Colpidium**	free swimming ciliates	++
+ = Extremely Low, ++ = Few, +++ = Average, ++++ = Many, +++++ = Extremely Many			

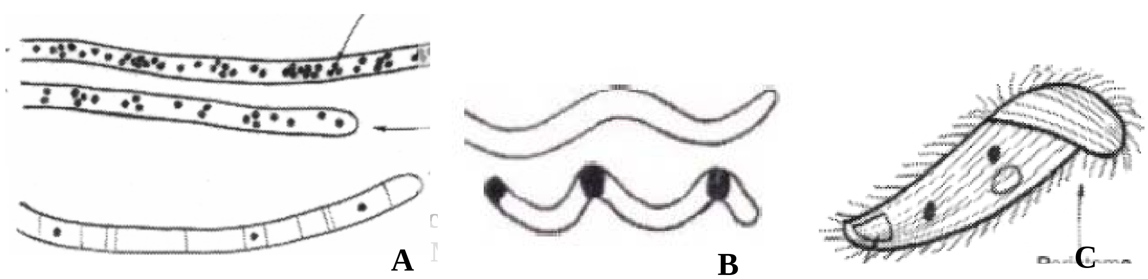
In the present study, an attempt was made to demonstrate whether any correlation is there between the existing protozoan population of extended aeration plant and the qualities of the effluents they delivered. The identification and enumeration of protozoa in activated sludge mixed liquor can provide rapid information on plant operating condition and performance (Al-Shahwani et. al, 1991). The effluent from Delhi plant were always very turbid and contained high concentration of SS, BOD, and COD. We found our observations more consistent to those obtained by Curds and Cockburn, 1970b. Plants which delivered turbid low- quality effluent either did not contain ciliated protozoa or contained only a few species in small numbers. Plants producing highly clarified, good quality effluent usually contained a large variety of ciliates species. The operational parameter values obtained for both of the treatment plant is shown in Table 4.44.

Table 4.44 : Data obtained from the aeration tank of STP Vasant Kunj

Parameters	Values
MLSS	4600 mg/L
SV30	≈800mg/L
DO (Aeration Tank)	<1 mg/L
F/M	0.6
HRT	10- 24 hrs
SRT	12- 15 days

A little lower density of ciliate protozoan community was found at Extended Aeration plant, Delhi. Ciliated protozoa improve the quality of the effluent have an elevated BOD and are highly turbid due to the presence of many dispersed bacteria (Madoni, 1994). An effluent BOD of 21 mg/l, Turbidity of 13 NTU and SS of 82 mg/l were reported at Vasant Kunj STP. Curds and Cockburn (1970a) found that Activated sludge plants which delivered turbid low-quality effluents either did not contain ciliated protozoa or contained only a few species in small numbers.

However, we observed higher coliform removal at EA plant, Delhi. The probable reason would be that filamentous bacteria feed on bacteria and they can play a significant role to remove the bacteria at maximum level. Two filamentous bacteria i.e. Beggiota & Spirillus found predominantly at Extended Aeration plant, Vasant Kunj, Delhi. The presence of filamentous bacteria in aeration tank also provides entrapment of bacteria onto and inside the filaments, resulting enhanced removal of microorganisms of interest by settling at sedimentation tank. Findings showed that more than 3 log Coliform removal at Vasant Kunj plant with a mean removal efficiency of 99.93%. Curds et. al. (1969) describe that Bacterivorous ciliates ingest large numbers of dispersed bacteria which are not associated with flocs and whose growth would generate high turbidity of the effluent. In the absence of ciliated protozoa, in fact, effluents have much higher BOD and are generally turbid because of the presence of many dispersed bacteria. As we observed, longer HRT, SRT and higher MLSS may be considered as significant factor responsible for higher coliforms removal at extended aeration plant Delhi. According to Ratsak et. al, 1996 at longer retention time some protozoan species would be able to remove practically all large bacteria, flagellates and small ciliates. Our findings are in good agreement with the observations reported by many researchers, as they revealed that higher MLSS and longer HRT and SRT tended to results in increased removal of indicator microorganisms (WERF, 2004; George, I., 2002; Loge et al, 2002; NG et al, 1993; Koivunen et. al, 2003).



Another major factor for higher coliform removal at Delhi plant may be due to segregation of sludge flocs (Poor settling, SV_{30}= 800mg/L) in aeration tank or small size flocs. Ratshak et. al. (1996) stated that smaller flocs have a relatively large grazing surface area. Bacterivorous ciliates ingest large numbers of dispersed bacteria which are not associated with flocs, remains in suspended forms. Ciliated protozoa have a strong affinity to feed upon suspended bacteria in lieu of those found attached to surface or inside the sludge flocs during activated sludge treatment Curds and Cockburn, 1970(b). Gurijala and Alexander (1990) found that less hydrophobic species (low density) only the non- growing species appeared to be eliminated by grazing (Ratsak et. al, 1996). As far as concerned the low ciliate population density at Delhi plant, we found the lack of aeration (<1mg/L DO in aeration tank) and high organic loading (BOD= > 275mg/L; Mean COD= 623 mg/L) at input. Curds & Cockburn (1970b) stated that crawling ciliates decrease with increasing loading. Madoni (2003) founds that degree of aeration, shock load of toxic discharge, under or over loading, excessive sludge wastage and lack of aeration affect ciliate population in aeration tank unfavorably. Like bacteria, protozoan must have oxygen to survive. Thus lack of DO will severely limit both the kind and number of protozoans.

4.3.11.5 Post Treatment of STP Effluent

It was observed that effluents from Extended Aeration Plant, Vasant Kunj have a FC concentration in the range of ≈10000 MPN/100mL. But for Unrestricted Irrigation itself the number of fecal coliforms should be less than 1000 MPN/100mL. Therefore Coagulation-Flocculation followed by Chlorination was done at lab scale as a post treatment of STP effluent to reduce the fecal coliforms concentration at desired level.

4.3.11.6 Coliform Removal by Coagulation- Flocculation

Coagulation-flocculation was done with alum dosage of 10,20,30,40, 50 and 60mg/L as Al_2O_3. Optimum alum dose was taken as 60mg/L because of minimum numbers of coliforms i.e. 750 MPN/100 mL for Total Coliforms and 230MPN/100mL for Fecal Coliforms were reported at this dose. These results are shown in Table 4.45.

Table 4.45 Effect of Coagulation- Flocculation upon Total and Fecal Coliform reduction

Alum Doses as Al_2O_3 (mg/L)	TC (MPN/100mL)	FC (MPN/100mL)
0	6400	2300
10	2300	2100
20	2100	1100
30	1100	1100
40	1100	930
50	930	750
60	750	230

4.3.11.7 BOD, TSS and Turbidity removal by coagulation- flocculation

At the optimum alum dose (60 mg/L) 50% of BOD, 59.47% of suspended solids and 76.02% of turbidity removal was obtained. Whereas the effluent BOD, TSS and turbidity was 26 mg/L, 35mg/l and 4.1 NTU respectively (Table 4.46).

Table 4.46 Effect of Coagulation- Flocculation upon the removal of BOD, TSS and Turbidity

Parameters	BOD (mg/L)	TSS (mg/L)	Turbidity (NTU)
STP Effluent	52	86.36	17.1
After Coagulation - Flocculation (60 mg/L for as Al_2O_3)	26	35	4.1
Removal (%)	50	59.47	76.02

4.3.11.8 Coagulation- flocculation of STP effluent followed by Chlorination

The chlorination was also done with same alum doses at two chlorine doses of 1 and 2 mg/L and a contact time of 30 minutes. The results are shown in Table 4.47

Table 4.47 : Descriptive data of the coliforms removal by chlorination of the samples obtained after coagulation-flocculation

Alum Doses as Al_2O_3 (mg/L)	TC (MPN/100mL)		FC (MPN/100mL)	
	1mg/L Cl_2	2mg/L Cl_2	1mg/L Cl_2	2mg/L Cl_2
0	11000	9300	11000	9300
10	9300	750	9300	750
20	7500	430	7500	430
30	1100	200	1100	200
40	200	80	200	80
50	80	40	80	40
60	40	20	20	20

The observations revealed that at an optimum alum dose of 60 mg/L as Al_2O_3 followed by a chlorine dose of 2 mg/L (contact time: 30 minutes) are sufficient to remove Total coliforms and Fecal coliforms significantly from the effluent of Vasant kunj STP.

The chlorination of the STP effluent was also practiced without its any pretreatment by coagulation- flocculation (Table 4.48).

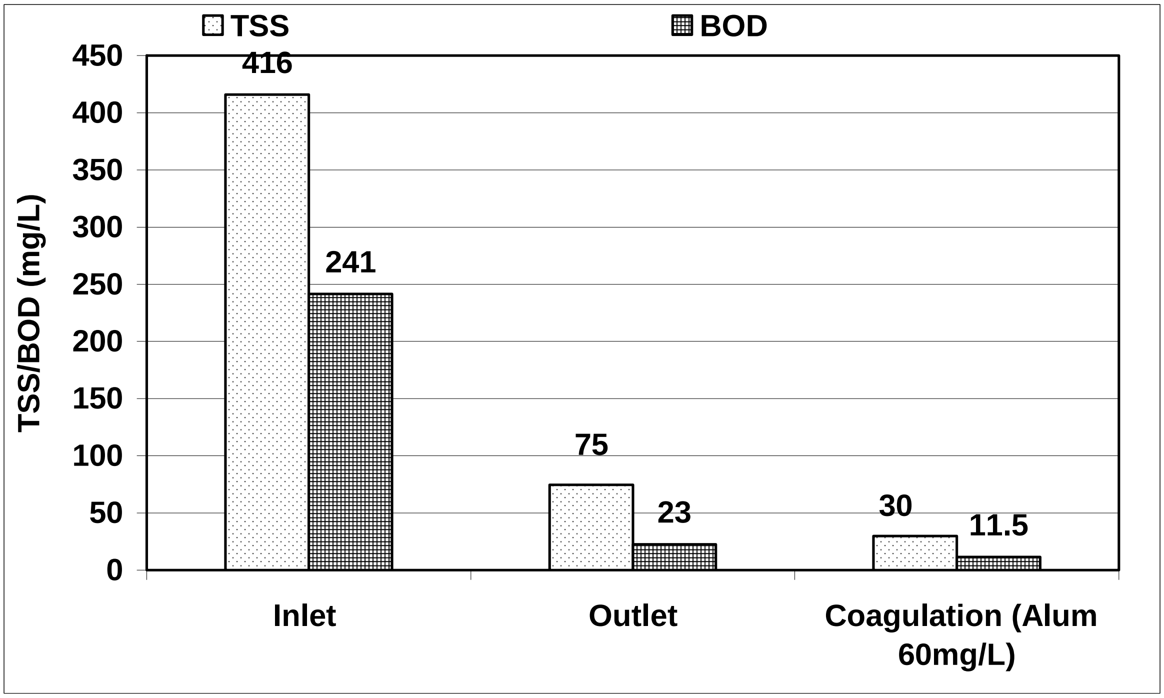
Table 4.48 Effect of Chlorine Doses on Total and Fecal Coliforms removal

Dose(mg/L Chlorine)	TC (MPN/100mL) [Contact time: 30 min]	FC (MPN/100mL) [Contact time: 30 min]
0	43000	21000
1	23000	1100
2	1100	230
3	230	230
4	230	80
5	80	20
6	20	2
7	2	NIL
8	NIL	NIL

It was observed that a chlorine dose of 8 mg/L with a contact time of 30 minutes is sufficient to kill all the coliforms present in the effluent sample.

4.3.11.9 Cumulative Efficiency of The Treatment System (Extended Aeration) Upto Augmentative Requirements

It can be seen that the normal treatment by Extended Aration system provides efficiencies upto 81.97% for TSS and 90.46% for BOD. However, with the augmentation through coagulation-flocculation the efficiency correspondingly increases to 92.79% and 95.23% respectively (Fig 4.146 & fig 4.147).



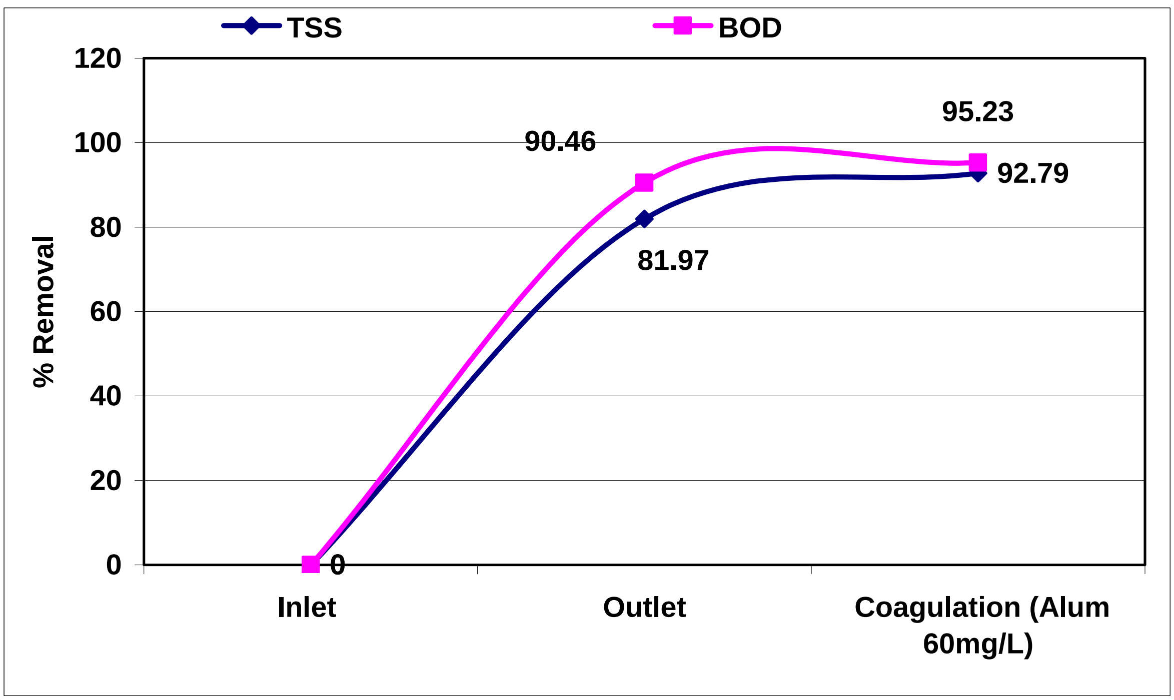


Figure 4.146 & Figure 4.147 : Cumulative efficiency of the EA system w.r.t. TSS and BOD removal upto augmentative requirement

Similarly the EA system removes TC and FC upto 99.93% and 99.93% respectively. Whereas, coagulation- flocculation with optimum alum dose, the efficiency increases to 99.992% and 99.9925% respectively. Further with additional chlorination the total TC and FC removal almost 100% have been possible. Therefore, these results points towards the augmentative requirements of existing treatment system for total removal of the pathogenic content of the water (fig 4.148 & fig 4.149).

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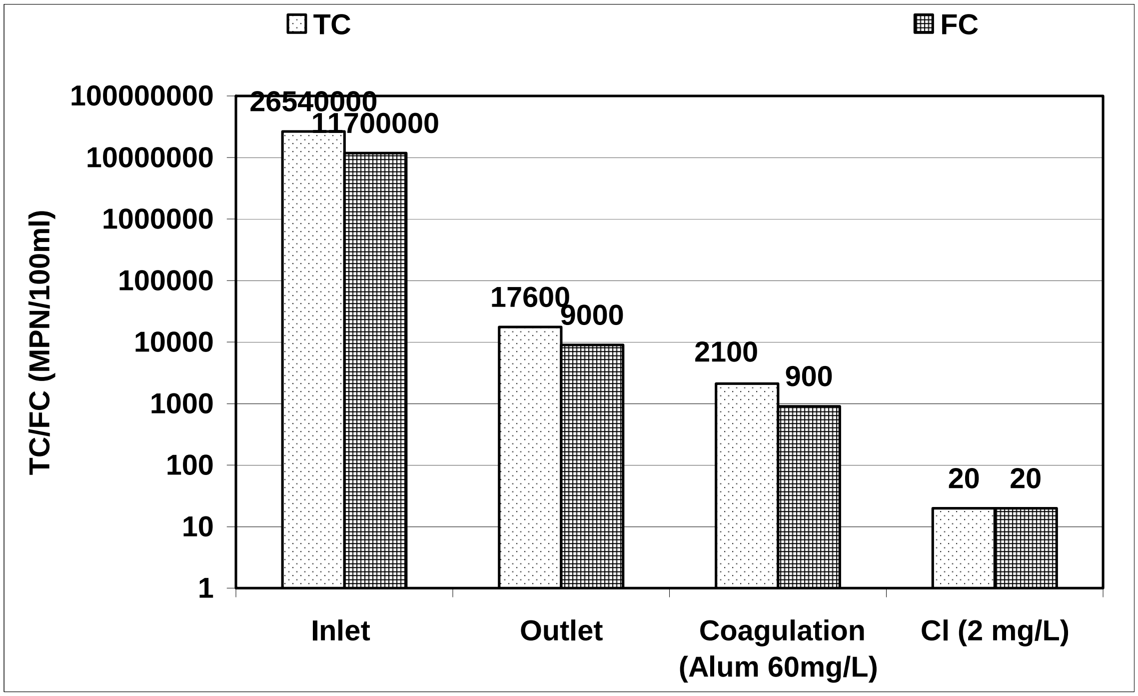

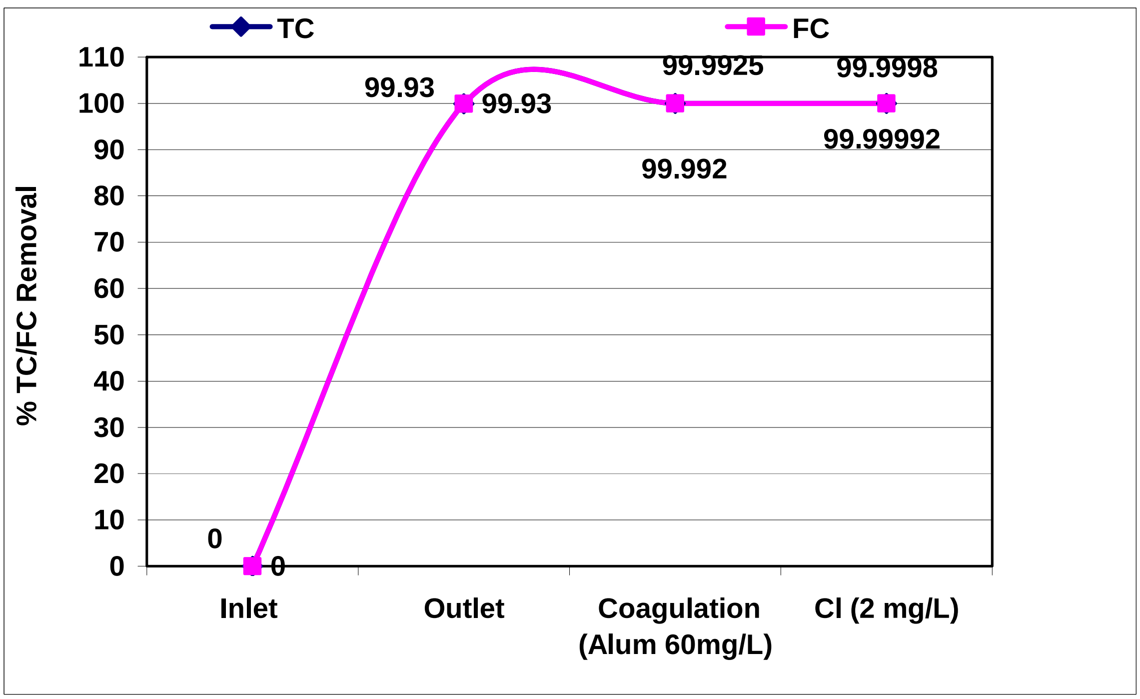

Figure 4.148 & Figure 4.149 : Cumulative efficiency of the EA system w.r.t. TSS and BOD removal upto augmentative requirement

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.0 Urban wastewater can be considered as a potential “resource” despite the fact that it is contaminated with pathogens, heavy metals, toxic chemicals and other substances, if industrial wastewater is mixed with it. There are public health concerns regarding the reuse of treated wastewater. According to current World Bank estimates, the wastewater from more than 4,000 million people worldwide does not receive any form of treatment. In India, the total wastewater generation from domestic sources in Class I towns is 33 billion litres and of this, a mere 25% is treated (CPCB, 2006). The current state of infrastructure marked with inadequate collection networks and treatment capacities forces discharge of untreated or partly treated wastewater into natural drains joining the rivers, lakes, and sea. The water pollutants, which are of most concern, are pathogenic organisms that cause waterborne diseases such as typhoid, cholera, bacterial and amoebic dysentery, enteritis, polio, infectious hepatitis and schistosomiasis. A properly developed framework policy and standard is essential for safe and efficient management of wastewater as a resource.

The Central Pollution Control Board of the Ministry of Environment and Forests, Government of India, is concerned with protecting India's scarce and rapidly diminishing national waters and aquifers from overexploitation and contamination, providing sufficient water for the needs of farmers and ensuring that standards are technically achievable and financially feasible. Local governments are generally more concerned about wastewater collection and rapid disposal - often into rivers or the sea. The rural areas however, see the wastewater as a valuable resource for crop irrigation, without overly worrying about the accompanying health risks under these circumstances the challenge confronting authorities in India, as in many developing countries, is to ensure that the set standards are realistic and promote efficient wastewater reuse. This may include wastewater treatment policies and health protection measures for users and consumers, a program of control and monitoring of treatment and other measures, and finally, adequate water for agriculture. All these need to be achieved notwithstanding the technological and financial restraints.

Based on the studies following major conclusions are drawn:

1. All the rivers within the country are polluted to such an extent that most of them carry water unfit for drinking or direct use. Microbial character of water is responsible for water borne diseases. Therefore, it is necessary to study the rising problem of microbial pollution of the inland water bodies.

2. The main cause of water pollution of inland water bodies is the disposal of urban wastewater into them without appropriate treatment. Various systems of treatment of urban wastewater need in depth study upto BOD and microbial level.

3. This work has reviewed the treatment efficiency attained with normal alternative wastewater treatment strategies. It has collected data of the average treatment

efficiencies attained with respect to various treatment systems. Further, in addition to study of normal treatment strategies, augmentative strategies have also been experimentally examined. Various pollution indicators have been correlated in terms of BOD, TSS, Turbidity, TC, FC and FS. Interesting interrelationship between TSS and Turbidity with TC, FC and FS have been found which will prove to be vital for quick evaluation of microbial removals.

4. Out of the six urban wastewater treatment system initially undertaken, four treatment systems ultimately could be successfully studied, which are being managed as per design. These are UASB followed by pond System, Activated sludge Process System, Stabilization Pond System and Extended Aeration System with proposed augmentative requirements by Coagulation- Flocculation followed by chlorination. The fifth plant as Upflow- Down flow anaerobic filter was studied only upto secondary level, and the study could not be concluded because of malfunctioning of the plant.

5. It is seen that all the existing treatment systems studied provide only BOD removal upto 90% while the maximum TC, FC removal could be attained upto the tune of 99%. However, the analysis of the results revealed that all urban wastewater treatment systems need to be upgraded upto tertiary level. It has been found that one of the best methods of achieving 100% fecal microbes removal is coagulation- flocculation followed by chlorination after secondary treatment. The cumulative microbial removal efficiencies attained with or without augmentative requirements of coagulation, flocculation followed by chlorination will go a long way in evolving the total treatment system configurations towards reducing 100% microbial content from urban wastewater.

5.1. Performance and Achievability of Sewage Treatment Plants

During the treatment of wastewater, in addition to the reduction of organic pollutant loading, the concentration of pathogenic and non-pathogenic microorganisms is lowered. Normal wastewater treatment plants employing the state-of-the-art mechanical-biological treatment methods are reported to be able to reduce the concentration of pathogenic bacteria at least by 2 $\log_{10}$ (i.e., by 99%). This means that for an untreated wastewater with a contamination 10^8 faecal coliform bacteria/100 mL, for example, the treated wastewater would contain 10^5 to 10^6 bacteria/100 mL.

It may be seen that there is a wide variation in the types and concentrations of indicator organisms of faecal origin in the influent depending on factors such as per capita water supply rate, connection of major sources such as hospitals, levels of disease in the community and other constituents of the wastewater including toxic chemicals. The results indicate that the conventional wastewater treatment systems (such as activated sludge, trickling filters) are not good at removing faecal bacteria; at best they achieved only a 2 $\log_{10}$ unit reduction of Faecal Coliforms. They do not meet the microbiological requirements as per WHO guidelines for agricultural reuse unless supplemented by tertiary treatment. Due to the retention time in primary and secondary sedimentation they are better at removing helminth eggs. A combination of tertiary treatment involving sand filtration and disinfection as in the case of the CPCL Plant is shown to achieve required Faecal Coliform standards.

In situations when land area is not constraint the wastewater treatment option of first choice is Waste Stabilization Ponds (WSP) as was the case in the Pondicherry Plant. The advantages of WSP are low cost, simplicity of construction, operation and maintenance, no energy costs, high ability to absorb organic and hydraulic loads and high efficiency especially with respect to the removal of nematode eggs and faecal bacteria. In tropical and subtropical regions, properly designed WSP can easily meet the WHO helminthological and bacteriological quality requirements for both restricted and unrestricted irrigation (Mara, 1997; Mara and Pearson, 1998). However, the Pondicherry plant did not achieve this. This may be due to factors such as improper design, overloading and poor maintenance. Low maintenance decentralized wastewater treatment also could not meet the microbiological requirements for agricultural reuse.

Pond systems incorporating anaerobic, facultative and maturation ponds, with an overall average retention time of 10-50 days (depending on the ambient temperature), can produce effluents in line with WHO guidelines. Maturation ponds (sometimes called "polishing" ponds) can be used to upgrade effluents from conventional treatment plants. Land availability or the cost of land can limit the use of WSP, especially when dealing with effluent from large cities (population > 1 million). In locations where temperatures are low, longer retention times and therefore larger land areas are required to meet the FC standards. For example, for a flow of 1000 m^3 per day of a wastewater with a BOD of 350mg/L and a faecal coliform count of $5x10^7$ FC/100mL, the total pond area required to produce an effluent containing < 1000 FC/100mL would be 8,000 m^2 at 25^oC, 13,700 m^2 at 20^oC, and 25,400 m^2at 15^0C.

Table 5.1 summarizes key faecal micro-organisms in sewage and their typical removals by various treatment processes

Table 5.1. Key Faecal Micro-Organisms in Sewage and their typical removals by various treatment processes

Source	***Escherichia coli***	***Salmonella / Campylobacter***	**Enteric Viruses**	***Giardia* Cysts**
Raw Sewage (L^{-1})	10^8-10^9	40,000	100-15,000	5,200-22,700
Removal (%) by:				
Primary treatment	50-90, 27-96	50-90, 15	0-30	55
Secondary treatment	91-99	96-99	30-75, 76-99	99
Tertiary (ponds/chlorine)	99.99-99.99999	99.99-100	99.8-99.99	99.8

Source: McNeill (1985), Höller (1988) and Yanko (1993) for bacteria and viruses; *Giardia* data unpublished (Ashbolt).

5.2 Improving Microbial Quality through Physical treatment and Disinfection

These include physical methods such as filtration through granulated media, membrane filtration, UV irradiation, high-temperature treatment and direct insolation using the thin-film method and chemical disinfection. Of these, only filtration and chlorination have so far gained substantial importance in practice.

The disinfectants that can be used in the removal of pathogens from wastewater are chlorine (Cl_2), ozone (O_3) and chlorine liberating substances such as chlorinated lime and sodium hypochlorite (NaOCl). The disinfectant effect of chlorine depends strongly on the pH. A pH between 6 and 8 is significantly better than more alkaline values. The actual disinfectant effect is provided by the hypochloric acid (HOCl) formed by the introduction of gaseous chlorine into water. The chlorine consumption of the wastewater must be determined by advanced tests. For a retention time of 15 to 30 minutes in a reaction tank, the amount of chlorine required is between 5 and 20 g/m³ of wastewater. There is growing criticism of the disinfection of wastewater with chlorine for reasons such as the formation of organics that are harmful.

Ozone is a highly reactive gas and cannot be stored or transported over long distances. It is produced directly at its place of intended use by silent electrical discharge in an ozone generator using dried air and pure oxygen. Substances in the water which consume ozone and those with catalytic effects which speed up the decomposition of ozone must be taken into consideration when estimating the amount of ozone necessary for disinfection. To ensure a sustained minimum concentration of 0.3 – 0.5 g of O_3/m^3 in municipal, biologically treated wastewater for approximately 10 minutes, the amount of ozone employed is usually 10 - 20 g/m³. Preliminary tests on ozone consumption are required to run an ozone plant to optimum effect. The power consumption for generating 1 g of ozone ranges from between 10 and 30 Wh if air is used to between 6 and 15 Wh if oxygen is used, depending on the size of the generator. The cost of wastewater disinfection with ozone is very high and may not be affordable at the current economic conditions.

5.3 Recommendations on Wastewater Reuse and Health

The reuse options may be divided into the following categories:

- Unrestricted urban reuse – irrigation of areas in which public access is not restricted, such as parks, playgrounds, school yards, and residences; toilet flushing, air conditioning, fire protection, construction, ornamental fountains, and aesthetic impoundments.
- Restricted urban reuse – irrigation of areas in which public access can be controlled, such as golf courses, cemeteries, and highway medians.
- Agricultural reuse on food crops – irrigation of food crops which are intended for direct human consumption, often further classified as to whether the food crop is to be processed or consumed raw.

- Agricultural reuse on non-food crops – irrigation of fodder, fiber, and seed crops, pasture land, commercial nurseries, and sod farms.
- Unrestricted recreational reuse – an impoundment of water in which no limitations are imposed on body-contact water recreation activities.
- Restricted recreational reuse – an impoundment of reclaimed water in which recreation is limited to fishing, boating, and other non-contact recreational activities.
- Environmental reuse – reclaimed water used to maintaining manmade wetlands, enhance natural wetlands, and sustain or augment stream flows.
- Industrial reuse – reclaimed water used in industrial facilities primarily for cooling system make-up water, boiler-feed water, process water, and general washdown.
- Groundwater recharge – using either infiltration basins, percolation ponds, or injection wells to recharge aquifers.
- Indirect potable reuse – the intentional discharge of highly treated reclaimed water into surface waters or groundwater that are or will be used as a source of potable water.

When wastewater is treated with the intention of reuse, the important quality criteria are those relevant to human health and needs of the exposed population rather than environmental criteria and those related to the well-being of aquatic life in receiving waters. The potential reuse options that are possible along with the health concerns under Indian conditions are categorized as listed in Table 5.2.

Water reclamation facilities must provide the required treatment to meet appropriate quality standards for the intended use. It shall be attained with wastewater treatment technologies that are widely practiced and readily available at an affordable cost. While discussing treatment for a reuse system, the overriding concern continues to be whether the quality of the reclaimed water is appropriate for the intended use. Higher level uses, such as irrigation of public-access lands or vegetables to be consumed without processing, require a higher level of wastewater treatment and reliability prior to reuse than will lower level uses, such as irrigation of forage crops and pasture. For example, in urban settings, where there is a high potential for human exposure to reclaimed water used for landscape irrigation, industrial purposes, and toilet flushing, the reclaimed water must be clear, colorless, and odorless to ensure that it is aesthetically acceptable to the users and the public at large, as well as to assure minimum health risk.

Table 5.2. Wastewater Reuse and Health Concerns

Sl. No.	Reuse options	Health Concerns
1.	Recreational and environmental reuse	- Body Contacts and aerosols
2.	Agricultural reuse / irrigation	- Worker's Health - Incorporation in irrigated crops (vegetable eaten raw) - Aerosol due to spray irrigation

[Table 5.2 Continued...]

3.	Pisciculture	- Transmission from fish eaten raw - Worker's health
4.	Surface water discharge	- Body contact during bathing - Infections through drinking water
5.	Industrial reuse	- Worker's health
6.	Groundwater recharge	- Contamination of drinking water sources

Development of microbial water quality requirements for direct or indirect reuse is difficult. The task involves a risk management process that entails evaluating, enumerating, and defining the risks and potential adverse health impacts that are avoided by breaking the life cycle of waterborne diseases and thereby preventing or reducing disease in the human population. As the physical proximity and perceived distance between reclaimed water and domestic water supply decrease, human contact with and consumption of reclaimed water become more certain, and the potential impacts to human health become harder to define.

5.4 Parameters for Microbiological Quality

Over 100 pathogens may be found in sewage, including viruses, parasites and bacteria. Viruses include enteroviruses such as poliovirus, hepatitis A virus and rotavirus. Parasites include helminths such as roundworms, and protozoa, such as *Giardia spp.,* and *Cryptosporidium spp.,* both of which cause diarrhoea. Bacteria include species of *Campylobacter, Salmonella, Shigella* and *Escherichia coli.* The coliform group consists of several genera of mostly harmless bacteria belonging to the family Enterobacteriaceae that live in soil and water as well as the gut of animals. Faecal coliforms are coliforms originating from the intestinal tract of warm blooded animals and passed through the faeces. While faecal coliforms are part of the normal intestinal flora and do not necessarily constitute a health risk by themselves, their presence is an indicator of contamination with faecal matter.

Detecting specific pathogens in water is difficult, time consuming and costly. Therefore, water is usually analyzed solely for the presence of "faecal coliforms". These are one of the many types of bacteria which live in human and animal intestines. A large number of faecal coliforms in water normally indicates recent contamination by untreated faeces and therefore the presence of infectious pathogens. As most of the microbial pathogens present in wastewaters are of faecal origin, the detection of indicator organisms of faecal origin like total coliforms, faecal coliforms, faecal streptococci etc., and their enumeration by MPN tests continue to be the most commonly monitored parameters. There is evidence to suggest that *E. coli* (a more specific sub-group of the coliform group) levels may not always be a reliable indicator of potential health risk to humans from other pathogens contained in wastewater. Coliform concentrations are used worldwide as a primary indicator of faecal microbiological contamination and thus health risk. Nevertheless, coliform concentrations do not, *ipso facto* serve as an indicator of pathogenicity.There are several reasons why there may not be a correlation between coliform and virus concentrations. These include the fact that enteric viruses persist significantly longer in the environment than bacterial indicators and the lack of a qualitative or statistical association between enteric viruses and bacterial indicators.

5.5 Coliform as Indicators

Monitoring the biological markers of a particular water source / treated sewage provides a means to determine the overall quality of the source water/ treated sewage without directly monitoring the infinite number of potential pathogens that may be present in the water. Internationally, bacterial indicators are used to monitor and predict microbiological water quality. Used since the 1920s, total and fecal coliforms are the standard microbial indicators of water quality. However, in recent times the use of bacteria to ensure the safety of water is being questioned because of their ability--or lack thereof--to accurately predict the presence of viral and protozoan pathogens. While bacterial indicators have been highly effective for indicating presence of disease-causing bacteria--such as those associated with typhoid, dysentery and cholera—they are known to be far less effective for determining presence of viral and protozoan pathogens. This may be due to a number of factors including different survival, transport and growth characteristics of viruses,bacteria and protozoa.

In the mid-80s research began to show that fecal coliforms did not correlate with swimming-associated gastrointestinal illness. Monitoring for bacterial indicators had a clear impact on incidence of bacterial disease caused by organisms such as *Vibrio cholerae* (cholera), *Yersinia entero-colitica* (gastroenteritis), *Shigella* (gastroenteritis), *Listeria* (flu-like symptoms), *Salmonella* (gastroenteritis, typhoid) and *Campylobacter* (gastroenteritis). Research supports use of *E. coli* and enterococci rather than the broader group of fecal coliforms as indicators of microbiological pollution.

E. coli is a member of the total coliform group and is always found in feces, providing a more direct indicator of fecal contamination and possible presence of enteric pathogens (i.e., viral, protozoan and bacterial pathogens of the gastrointestinal route). Certain strains of *E. coli* are directly pathogenic themselves--particularly, the serotype *E. coli* O:157-H7.

5.6 Shortcomings of Indicators

Microbiological water quality objectives are generally defined by indicators or treatment performance standards that do not measure the contaminant of concern, but nevertheless, provide some indication the treatment train is operating properly, and the product is of adequate quality. It is then assumed that under similar conditions of operation, the microbiological contaminant of concern is being removed concurrently. For example, coliforms are indicators of microbiological water quality. While there are documents discussing the criteria for an ideal surrogate, none meets every criterion. Hence, the shortcomings of the surrogate should be kept in mind while setting or implementing standards.

5.7 Importance of TSS Control

The removal of suspended matter is related to the virus. Many pathogens are particulate-associated and the particulate matter can shield both bacteria and viruses from disinfectants. Also, organic matter consumes chlorine, thus making less of the disinfectant available for disinfection. There is general agreement that particulate matter should be reduced to low levels, (10 mg/L TSS), prior to disinfection to ensure reliable destruction of pathogens.

Viruses in waters are known to adsorb to solids which protect them from inactivation by biological, chemical and physical factors (USEPA 1985). Sediments, for example can adsorb more than 99% of a poliovirus suspension (containing 108 plaque forming units per mL) and may contain 10-10, 000 times the concentration of viruses in overlying water (LaBelle and Gerba, 1979; Schaiberger et al., 1982). Hence, surface water sampling alone may not give a true indication of the potential viral hazard (Rao et al., 1984). Such sediment-bound viruses can also be taken up by other aquatic organisms, thus allowing their bio accumulation in animals life near sewage outfalls (Lewis et al., 1986).

WHO guidelines (1989) propose a nematode egg guideline of <1 nematode egg/L. Where crops have a short shelf life and where workers are not in direct contact with wastewater, a nematode egg standard of <1 nematode egg/L appears to be adequate. The review of literature during the study did not support the need for a separate guideline to specifically protect against viral and protozoal infection. Adoption of the WHO's guidelines is recommended as they are applicable world-wide, supported by the best available evidence based on scientific consensus and are achievable in the Indian context. These wastewater discharge standards can also be made location specific based on the carrying capacity approach for achieving the desirable water quality for designated best use. Fecal streptococci are used as indicators of fecal contamination. They are generally not harmful by themselves but are present, along with human pathogens, in the gut of humans and animals. Other bacteria under investigation as better indicators include species of Campylobacter and Clostridia.

5.8 WHO Guidelines on Microbiological Quality for Wastewater Reuse

One of the most critical objectives in any wastewater reuse program is to ensure that public health protection is not compromised through the use of reclaimed water. Other objectives, such as preventing environmental degradation, avoiding public nuisance, and meeting user requirements, must also be satisfied, but the starting point remains the safe delivery and use of properly treated reclaimed water. Protection of public health is achieved by: (1) reducing or eliminating concentrations of pathogenic bacteria, parasites, and enteric viruses in the reclaimed water, (2) controlling chemical constituents in reclaimed water, and/ or (3) limiting public exposure (contact, inhalation, ingestion) to reclaimed water. Reclaimed water projects may vary significantly in the level of human exposure incurred, with a corresponding variation in the potential for health risks. Where human exposure is likely in a reuse application, reclaimed water should be treated to a high degree prior to its use.

There is extensive literature on guidelines for reuse of wastewater in agriculture including the situation in developing countries (Peasey *et al*., 2000). There is also specific literature on standards, monitoring concerns and procedures for human health effects in regard to use in maintenance of recreational facilities.

The WHO Health Guidelines for the use of wastewater in agriculture and aquaculture published in 1989 propose different water qualities depending on the endpoint of discharge e.g., for restricted or unrestricted crop irrigation (WHO, 1989). The primary consideration of WHO's Guidelines is the health impacts. Guidelines are focused on preventing the spreading of disease. For disease to spread, water has to contain pathogens, these pathogens have to enter the human body, then they have to make people sick (infect), and finally they have to be transmitted to other humans. Therefore, the WHO Guidelines for water reuse issued in 1989 target the problem at the following levels:

- Wastewater treatment (limit the number of viable faecal intestinal nematode eggs and coliforms found in the water reused)
- Application procedures of reused water (some methods avoid disease transmission and protect field workers)
- Crop restrictions (some crops such as cotton are not ingested by humans) and good practices

Studies from Mexico, in an area where enteric infections are endemic, suggest that consumption of vegetables irrigated with 10^4-10^5 FC/100mL results in significant, but low, enteric infection risks for consumers (Blumenthal et al., 1998, Blumenthal et al., 2000b). Microbiological studies of Vargas et al., 1996 also suggest that a guideline of $<10^3$ FC/100mL is acceptable in hot climates. It was extrapolated from these data that use of water meeting the WHO guideline level of 1000 FC per 100 mL is likely to produce an annual risk of viral infection of less than 10^{-4}. Furthermore, additional treatment to a FC level more stringent than 1000 per 100 mL is not cost effective (Shuval et al.,1997). There are epidemiological and microbiological studies that suggest nematode egg standard of <1 Ovum/L is not adequate to protect the health of consumers (Peasey et al., 2000). As with all standards, authorities must decide the risk approach to be adopted i.e., whether their objective is to remove excess risk, reduce risk or minimise morbidity. For example, if the public health objective is to remove excess risk, a standard of <0.1 Ovum/L would be advisable.

The faecal coliform standard in most guidelines for wastewater reuse is intended to address the risks of enteric infections caused by both bacterial and viral pathogens; yet it may not provide adequate protection against viral infections because conventional treatment processes that use disinfection are much less efficient in removing viruses than in removing indicator bacteria.

5.9 Recommendations on Quality of Reclaimed Water

In order to put the concerns and issues discussed in the preceding chapters into perspective with respect to wastewater reclamation or disposal, it is important to consider the following questions.

- What is the intended use of the reclaimed water or wastewater after disposal

- Given the intended use of reclaimed water, what concentrations of microbiological organisms of concern are acceptable?
- Which treatment processes are needed to achieve the required reclaimed water quality?
- Which sampling/monitoring protocols are required to ensure that water quality objectives are being met?

Standards should be based on wastewater reuse experience in the country and elsewhere, technical material from the literature, performance of the STPs as monitored during the present study, attainability and best practicable treatment and management practices. They are intended to provide reasonable guidance for water reuse opportunities. These guidelines are principally directed at public health protection and generally are based on the control of pathogenic microorganisms for nonpotable reuse/ disposal applications. It would be impractical to monitor reclaimed water for all of the chemical constituents and pathogenic organisms of concern, and surrogate parameters are universally accepted.

Total and fecal coliforms are the most commonly used indicator organisms in treated wastewater. While coliforms are adequate indicator organisms for many bacterial pathogens, they are, by themselves, poor indicators of parasites and viruses. The total coliform analysis includes enumeration of organisms of both fecal and nonfecal origin, while the fecal coliform analysis is specific for coliform organisms of fecal origin. Therefore, fecal coliforms are better indicators of fecal contamination than total coliforms, and these guidelines use fecal coliform as the indicator organism. Either the multiple-tube fermentation technique or the membrane filter technique may be used to quantify the coliform levels in the reclaimed water.

Reclaimed water used for applications where no direct public or worker contact with the water is expected to achieve an average fecal coliform concentration not exceeding 1000/100 mL because:

- Most bacterial pathogens will be destroyed or reduced to low or insignificant levels in the water
- The concentration of viable viruses will be somewhat reduced
- Disinfection of secondary effluent to this level is achievable
- Significant health-related benefits associated with disinfection to lower, but not pathogen-free, levels are not obvious

5.10 Recommended Measures to Protect Public Health

While defining wastewater treatment policies it is important to remember that treatment is not the only measure available to protect health, crop selection and restriction. Wastewater irrigation techniques and human exposure control are equally important. These non-treatment options should be considered as part of the integrated approach to achieve the objective of health protection.

Crop selection and restriction may be employed in conjunction with wastewater treatment so that lower quality effluents can be used to irrigate non-edible crops. It can be effective only with a strong institutional framework controlling wastewater use and with the capacity to monitor and ensure compliance and where there is little market pressure in favour of excluded crops.

In general, health risks are greatest when spray or sprinkler irrigation is used as this distributes contamination over the surface of crops and exposes nearby population groups to aerosols containing bacteria and viruses. This technique should be avoided where possible, and if used, stricter effluent standards should be applied as suggested by WHO. Flood and furrow irrigation exposes field workers to the greatest risk, especially if earth moving is done by hand and without protection. Localised irrigation (drip, trickle and bubbler irrigation) can give the greatest degree of health protection by reducing the exposure of workers to the wastewater. A period of cessation of irrigation before harvest (at least a week) can allow die-off of bacteria and viruses such that the quality of irrigated crops improves. Farm workers and their families have higher potential risks of parasitic infections. Protection can be achieved by low-contaminating irrigation techniques together with protective clothing (e.g., footwear for farmers and gloves for crop handlers) and improved levels of hygiene both occupationally and in the home which help to control human exposure.

5.11 Recommendations on Operational Control and Maintenance

Microbial exposure through aerosols arising from use of reclaimed water can be limited through design or operational controls. Design features include:

- Setback distances, which are sometimes called buffer zones
- Windbreaks, such as trees or walls around irrigated areas
- Low pressure irrigation systems and/or spray nozzles with large orifices to reduce the formation of fine mist
- Low-profile sprinklers
- Surface or subsurface methods of irrigation Operational measures include:
- Spraying only during periods of low wind velocity
- Restriction of spraying when wind is blowing toward sensitive areas subject to aerosol drift or windblown spray
- Irrigating at off-hours, when the public or employees would not be in areas subject to aerosols or spray

The following points highlight more specific subjects for consideration in preparing specifications to help accomplish the above principles:

- Duplicate dual feed sources of electric power
- Standby onsite power for essential plant elements
- Multiple process units and equipment
- Flexibility of piping and pumping facilities to permit rerouting of flows under emergency conditions
- Operator certification to ensure that qualified personnel operate the water reclamation and reclaimed water distribution systems

A preventive maintenance program shall be provided at each reclamation plant to ensure that all equipment are kept in a reliable operating condition. Other measures may include,

- Instrumentation and control systems for on-line monitoring of treatment process performance and alarms for process malfunctions

- A comprehensive quality assurance program to ensure accurate sampling and laboratory analysis protocol
- Adequate emergency storage to retain reclaimed water of unacceptable quality for re-treatment or alternative disposal
- Quality assurance (QA) in monitoring
- Prevent improper or unintended use of nonpotable water through a proactive public information program

5.12 Recommendations on Effective Sampling and Monitoring

The purpose of sampling is to collect a portion of the wastewater, which is small enough to be conveniently handled in the laboratory and is still representative of wastewater. The sample must be collected in such a manner that nothing is added or lost in the portion taken and no change occurs between the time the sample is collected and the laboratory test is performed.

The location of sampling points and the collection of samples cannot be specified for all wastewater plants. Conditions vary in different plants and the sampling procedure must be adapted to each plant. Certain general sampling principles detailed in IS, (1981), Rao *et al.* (1997), APHA (1995) and (CPHEEO, 1993) are presented below:

- Raw sewage samples should be collected after screens or grit chambers.
- Samples of effluent from primary sedimentation or secondary sedimentation tanks should be taken from the effluent or ahead of discharge weirs.
- Influent to trickling filter should be collected below the distribution arm and the effluent from the filter outlet chamber or at the inlet to the secondary sedimentation tank.
- A point where there is good mixing should be selected for sampling of mixed liquor in aeration tanks in the activated sludge processes.
- Influent samples of septic tanks, imhoff tanks, clarigester and other sole treatment units such as oxidation ponds, oxidation ditches and aerated lagoons should be collected ahead of these tanks, in inlet chambers or channels leading to these units. Effluent samples should be collected outside the units in receiving wells or channels or chambers. Sampling within these tanks should be specified in terms of depth or distance or both.

5.13 Recommendations on Sampling Strategy

(a) BOD: Samples for BOD shall be 24-hour composite samples collected at least weekly.

(b) TSS: Samples for TSS shall be 24-hour composite samples collected daily. Reduced TSS sampling for those STPs that provide filtered reclaimed water may be allowed on a case by case basis.

(c) Coliform organisms: Grab samples for coliform organisms shall be collected daily and at a time when wastewater characteristics are most demanding on the treatment facilities and disinfection procedures. Compliance with the coliform requirements shall be determined daily, based on the median value determined from the bacteriological results of the last seven days for which analyses have been completed.

Samples collected for BOD, TSS and Coliforms determination shall be analyzed by standard methods, and in laboratories approved by the concerned local/regional/national authorities. These authorities may specify additional sampling parameters to satisfy existing regulatory requirements or to meet health regulations.

(d) Sampling Procedure

Sampling procedure involves collecting samples at the most representative points, using proper methods or techniques of collection and preserving the samples for transportation to the laboratories. The exact procedure used depends upon the type of water being sampled (river, lake, groundwater, wastewater etc), the variables measured and the type of analysis used in the laboratory.

There are two types of samples that may be collected, depending on the time available, the tests to be made and the object of the tests. One is called a "catch or grab" sample and the other is "composite samples". Grab samples (also known as catch samples) consist of samples that are collected all at one time. These samples are not completely representative of the total flow. These samples should be collected at that time of day when the treatment plant is operating at a representative loading, such as, at a flow rate near the average daily flow. If good operating efficiency is observed at average loadings, plant efficiency at lower loadings should be satisfactory. If grab samples are used to determine plant efficiency, the collection of the effluent should be delayed long enough after collection of the influent sample to allow for the influent sewage being tested to pass completely through the treatment process. By doing this, approximately the same sewage is being sampled at the end of treatment as at the beginning.

Composite or an integrated sample consisting of portions of wastewater taken at regular time intervals, the volume of each portion being proportional to the wastewater flow at the time it is collected. All the portions are mixed to produce a final sample. Composite samples give good results only for chemical analysis but not for bacteriological analysis of wastewater (CPHEEO, 1993). As the biological activity of microorganisms does not stop just because a sample has been collected, the longer it takes to perform these tests, the greater the chance that the pH will change or the dissolved oxygen level will be reduced.

Whenever possible, rubber gloves should be worn when sample collection requires contact with wastewater (including final effluent) and sludge. When finished, gloves should be washed thoroughly before removing them. After removing gloves, hands should be washed thoroughly using disinfectant type soap. Samples should never be collected without gloves if open sores or cuts are present. Sample poles and ropes should be used when necessary to safely collect samples. Samples for bacteriological examination should be collected in clean, sterilized, narrow mouthed neutral glass bottles of 250, 500 or 1000 mL capacity. The bottle should have a ground glass stopper, should be relaxed by an intervening strip of paper between the stopper and the neck of the bottles and should be protected by a paper or parchment cover. The bottles should be sterilized in hot air-oven at 160^{o}C for 1 hour or an autoclave at 1.02 ± 0.03 kg/cm^2 gauge pressure (15 lbs at 120^oC) for 15 minutes. The sampling bottle should not be opened except at the time of sampling. The container should not be rinsed before collecting the sample. When the sample is collected, ample air space in the bottle (at least 2.5 cm) should be ensured to facilitate mixing by shaking, before examination. Care should be taken to avoid entry of extraneous materials such as silt, scum and floating matters into sampling bottles (CPHEEO, 1993).

(e) Sample Volume

One to two litres of grab samples would be enough to perform all the physico-chemical and biological tests. For composite samples, a total quantity of 1 or 2 L collected over a 24 hours period is adequate. The actual volume of sample collected an any given time will depend on the volume of flow at that time, the total flow for the day, the total volume to be collected, and the number of individual samples to be collected.

(f) Transport, Preservation and Storage

Samples after collection should be immediately taken to the laboratory for examination. If the Processing is not possible within one hour, the samples should be transported in ice. In laboratory, if the immediate analysis is not possible, the samples p reserved at 4^oC up to 6 hrs, but in no case more than 24 hrs (WHO, 1976).

(g) Skills and Manpower

Laboratories of large plants should be under the charge of a qualified and experienced analyst supported by junior technical staff with a good background in the field of environmental sciences, chemistry, biology and bacteriology. The analyst should assimilate the details for functioning of the plants by experience and acquire the necessary preparedness for receiving further specialized training including performance interpretation and application of advanced techniques, which enable him to participate in the efficient operation of the treatment unit. In the case of small plants, the laboratory may be under the charge of person having some training in analysis of sewage (CPHEEO, 1993).

(h) Operating Records and Reports

Operating records shall be maintained at the STPs and pooled at a central depository within the operating agency. These shall include: all analyses specified in the regulations; records of operational problems, unit process and equipment breakdowns, and diversions to emergency storage or disposal; and all corrective or preventive action(s) taken. Any discharge of untreated or partially treated wastewater to the use area, and the cessation of same, shall be reported immediately to concerned authorities.

5.14 Recommendations to Improve the Microbiological Quality Status of Water Resources

The implementation of the suggested standards for wastewater reuse is to be complimented with several short term and long-term initiatives to improve the microbiological quality of water resources in the country. As a parallel or supplementary short-term activity, several low cost sanitary initiatives targeting site-specific rural and semi urban pockets taken up under different developmental schemes may be extended to potential urban areas. This would not only enhance the sanitary conditions of these environs but also control the diffused pollution of limited surface water resources and valuable arable lands.

The long-term objective should be to establish and operate appropriate STPs/sanitation systems in all the uncovered areas. As the cost for total coverage of the country by sewerage may be prohibitive, it is suggested that the Nullahs /drains to which the sewage is currently discharged may be intercepted at places before joining the major water bodies so that it could be pumped and treated in an STP. Of course, realization of this objective may require policy development and implementation of schemes at different levels – local, regional, national. Doubtless, insurmountable obstacles and constraints (technical, financial and others) will have to be encountered to cover the entire country under such a scheme.

5.15 Policy Frame Work

A policy for wastewater reuse must be clearly established prior to any development activity in this field. An obvious basis for such a policy should be to limit the use of treated effluent for purposes excluding potable uses, which-would avoid or minimize the risk of human contact. The necessary legislation must be enacted to promote and control related activities and to create an institutional set-up. The latter should be adequate to provide a framework for the allocation, use, quality and health and safety aspects, and there should be continuous coordination and cooperation between the agencies concerned. Thorough training of personnel is essential to make wastewater reuse a successful practice by maintaining safe and economic operations.

A national database of fecal indicator bacteria for water/ treated sewage could lead onto a better understanding of their distribution (seasonal trend and the impacts of rainfall events) and relevance in protecting public health. Additional data, such as time of sampling, state of receiving body, immediate use to which the water/ treated sewage is put to are also required along with financial resources to convert such data into useful information. Simultaneously, initiatives should be taken to gather epidemiological data by health departments and major pathology laboratories to identify likely water or fisheries exposure routes. Focused monitoring and quantitative risk assessment studies would help understand the role of the non-fecal pathogens. Until such a program is undertaken, little progress can be made on rationally setting national standards or using appropriate indicators/pathogens for environmental reporting.

Future indications are that water quality criteria will be developed for *Cryptosporidium* sp. and *Giardia* sp.-protozoan parasites associated with large and severe waterborne outbreaks. These two protozoa are often found in surface waters (the principle carriers of these organisms) contaminated by human sewage or wildlife. Numerous techniques have been developed for direct detection of viral and protozoan pathogens. No technique, however, has proven to be reliable, reproducible or economical enough to replace bacterial indicators.

Since microbial outbreaks are often acute and short-lived, it is not useful to labor over direct detection methods of pathogens that can frequently require days to weeks of analysis. Over 100 types of viruses are known to be transmitted by the fecal-oral route. For many, methods have not been developed for isolation and identification. Most researchers agree that total coliforms are a useful marker for non-health-related operational monitoring. In addition, turbidity of filtered drinking water and measures of disinfection such as contact time values are being increasingly used as indicators of microbial quality.

Looking back on the usefulness of coliforms count and the use of indicator bacteria for predicting treated sewage quality, one finds that not much has changed over the years. Even with the invention of rapid and cost effective approaches for direct monitoring of water/treated sewage for the presence of viral and protozoan pathogens, the technical difficulty of applying these methods for routine monitoring has prevented their widespread application. For effective water quality monitoring in the future, new indicators and improved methods for direct pathogen detection continue to evolve.

Where economic, technological and administrative constraints determine standards, alternative integrated approach to wastewater management and health protection measures must be implemented alongside partial treatment. Application of single or isolated measures will not provide full protection to all groups. For example, crop restriction as the only measure will only protect consumers; worker risks will remain unless supplementary measures to reduce worker exposure are taken. It is essential that all interested parties, the Central and State government, municipalities, service providers, farmers or the general population, evaluate current health protection measures, including wastewater treatment, crop restriction or irrigation systems, their effectiveness and their enforcement. It is also important for policy makers to consider all available health protection measures, not just wastewater treatment and create a realistic wastewater reuse policy that ensures genuine protection to people. Crop restriction, irrigation techniques, human exposure control and chemo-therapeutic intervention should all be considered as health protection measures to be used in conjunction with partial wastewater treatment. In some cases, community interventions using health promotion programmes and/or regular chemotherapy programmes could be considered, particularly where no wastewater treatment is provided or where there is a time delay before treatment plants can be built.

Where conventional treatment is opted for, treatment of the excess sludge must be considered. Organic and inorganic contaminants as well as pathogens are known to be concentrated in the excess sludge; helminth eggs can survive and remain viable for nearly 12 months in such sludges. Therefore, handling of the sludge requires care to protect both workers and consumers.

Once standards and accompanying health protection measures are established, two very important issues need to be addressed:
(1) Who is responsible for ensuring compliance?
(2) Who pays the cost of such policies?.
The question of who pays has long been an issue for considerations. However, it has now been generally accepted that the discharger pays the cost of treatment. Until this is can be achieved, the discharger and the user must share the burden of treatment.

The final outcome of the initiative, namely, '*SANITATION FOR ALL*' should outweigh all other considerations indeed!

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