PERFORMANCE EVALUATION OF STPs BASED ON DIFFERENT TECHNOLOGIES IN DELHI/NCR

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CERTIFICATE

It is certified that the work presented in this report entitled **"PERFORMANCE EVALUATION OF STPs BASED ON DIFFERENT TECHNOLOGIES IN DELHI/NCR"** by Ms. Charu Sharma, Roll No. 07/ENE/2010 in partial fulfillment of the requirement for the award of the degree of Master of Technology (M.Tech.) in Environmental Engineering, Delhi Technological University (Formerly Delhi College of Engineering), Delhi, is an authentic record. The work is being carried out by her under our guidance and supervision in the academic year 2013. This is to our knowledge has reached requisite standards.

The work embodied in this major project has not been submitted for the award of any other degree to the best of our knowledge.

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ACKNOWLEDGEMENT

It is a matter of great pleasure for me to present my thesis report on **"PERFORMANCE EVALUATION OF STPs BASED ON DIFFERENT TECHNOLOGIES IN DELHI/NCR"** First and foremost, I am profoundly grateful to my project guide **Dr. S. K. SINGH**, Professor & Head of Environmental Engineering Department for his expert guidance, patient reviews and continuous encouragement during all stages of this project. His help in the form of valuable information and research thoughts at proper time has brought life in this project. I am thankful to the kindness and generosity shown by him towards me, as it helped me morally to complete the project.

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DECLARATION

I, hereby declare that the work being presented in the Project Report entitled **"PERFORMANCE EVALUATION OF STPs BASED ON DIFFERENT TECHNOLOGIES IN DELHI/NCR"** is an original piece of work and an authentic report of our own work carried out during the period of 6th Semester as a part of my major project.

The data presented in this report was generated & collected from various sources during the above said period and is being utilized by the undersigned for the submission of our Major Project Report to complete the requirements of Master's Degree of Examination in Environmental Engineering, as per Delhi Technological University curriculum.

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ABSTRACT

India faces a number of water and wastewater issues and water related health hazards. These problems arise primarily due to the increasing level of qualitative and quantitative depletion of water resources owing to over-utilization and continuous discharge of wastewater. Sewage Treatment Plants (STPs) have been constructed in most places to reduce the degradation of water quality of the receiving water bodies by reducing the total pollution load on the same and to ensure a healthy environment both aesthetically along with preserving the ecosystem involved. However, the purpose of establishing the STPs is not met until their effectiveness in treating sewerage is ensured which has been observed as a major concern throughout the Country. In view of a varied experience with different technologies under the various river action plans that have been initiated from time to time, a need for a case study was perceived to assess technologically and financially suitable options for sewage treatment. Technologies which are being used in other parts of the world are being deployed in India on a large scale and it is well established that each technology has its own merits and demerits. Therefore, their techno-economic viability under Indian conditions needs to be proven and will depend on prevailing local conditions, urban settings, community acceptability, etc. The work carried out in this report presents the results of the evaluation carried out for the techno-economical and environmental performance with particular emphasis on six (6) STPs based on different treatment technologies such as Upflow Anaerobic Sludge Blanket (UASB), Sequential Batch Reactor (SBR), BIOFOR, Activated Sludge Process (ASP), Activated Sludge Process combined with BIOFOR (ASP + BIOFOR) and Oxidation ditch located in Delhi/NCR region for handling and treating the domestic wastewater generated from the designated localities under specific STPs. The parameters which were monitored under the study included pH, Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Mixed Liquor Suspended Solids (MLSS), Total Coliform (TC) and Fecal Coliform (FC). In addition to the evaluation of the performance of the STPs based on different treatment technologies, the same were also analyzed for the capital cost, operation and maintenance costs, energy requirements and land requirement, which is primarily based on the data as obtained from various STPs in the Ganga River Basin and information collected as well as compiled from various sewage treatment technology providers.

TABLE OF CONTENTS

CHAPTER -1 INTRODUCTION 1-3

1.1 Background 1

1.2 Objective of the Study 3

CHAPTER -2 LITERATURE REVIEW 4-11

2.1 Historical background on wastewater treatment 4

2.2 Wastewater Treatment in Developing Countries 5

2.2.1 Wastewater Treatment in India 6

2.3 Sewage Treatment Methods 7

2.3.1 Physical Unit Operations 7

2.3.2 Chemical Unit Processes 7

2.3.2 Biological Unit Processes 8

2.4 Waste water treatment process 9

2.4.1 Primary Treatment 9

2.4.2 Secondary Treatment 10

2.4.3 Tertiary Treatment 11

2.5 Selection of Appropriate Sewage Treatment Technology 11

CHAPTER- 3 METHODOLOGY & APPROACH 12-22

3.1 Plant Evaluation Procedure 12

3.2 Inventorization 13

3.3 Selection of Sampling Point 13

3.4 Analysis of Sample 13

3.4.1 pH measurement 14

3.4.2 Biochemical Oxygen Demand (BOD) 14

3.4.3 Chemical Oxygen Demand (COD) 16

3.4.4 Total Suspended Solids (TSS) 17

3.4.5 Total Colifom 18

3.4.6 Fecal Coliform 18

3.5 Qualitative & Quantitative O&M Assessment 22

  3.5.1 Qualitative O&M Performance Indicators 22

  3.5.2 Quantitative O&M Performance Indicators 22

CHAPTER-4 DETAILS OF SEWAGE TREATMENT TECHNOLOGIES 23-49

4.1 Biological Filtration and Oxygenated Reactor (BIOFOR) 23

  4.1.1 Introduction 23

  4.1.2 Process type 23

  4.1.3 BIOFOR working mechanism 23

  4.1.4 BIOFOR media description 25

  4.1.5 Advantages of BIOFOR Technology 25

  4.1.6 Disadvantages of BIOFOR Technology 25

4.2 Sequencing Batch Reactor (SBR) 26

  4.2.1 Introduction 26

  4.2.2 Process Type 26

  4.2.3 SBR working mechanism 26

  4.2.4 Nitrification & Denitrification in SBR 29

  4.2.5 Process design consideration of SBR 29

  4.2.6 Advantages of SBR Technology 30

  4.2.7 Disadvantages of SBR Technology 31

4.3 Up-Flow Anaerobic Sludge Blanket (UASB) 32

  4.3.1 Introduction 32

  4.3.2 Process type 32

  4.3.3 UASB working mechanism 32

  4.3.4 Anaerobic digestion stages in UASB 33

  4.3.5 Key features of UASB reactor. 34

  4.3.6 Process Design Considerations for UASB 35

  4.3.7 Problems associated with UASB Process Working 37

  4.3.8 Advantages of UASB Technology 38

  4.3.9 Disadvantages of UASB Technology 38

4.4 Activated Sludge Process (ASP) 39
  4.4.1 Introduction 39
  4.4.2 Process Type 39
  4.4.3 ASP working mechanism 39
  4.4.4 **Activated Sludge Process Variables** 41
  4.4.5 ASP Process control factors 43
  4.4.6 Advantages of ASP Plant 44
  4.4.7 Disadvantages of ASP Plant 44
4.5 Oxidation Ditch (OD) 45
  4.5.1 Introduction 45
  4.5.2 Process Type 45
  4.5.3 Oxidation Ditch working mechanism 45
  4.5.4 Nutrient removal in Oxidation Ditch 46
  4.5.5 Design criteria of Oxidation Ditch 47
  4.5.6 Advantages of Oxidation Ditch 49
  4.5.7 Disadvantages of Oxidation Ditch 49

CHAPTER -5 PERFORMANCE EVALUATION OF STPs WITH DIFFERENT TECHNOLOGIES IN DELHI/NCR- A CASE STUDY 51-104
5.1 BIOFOR based STP at Dr. Sen Nursing Home Drain, Delhi 51
  5.1.1 Introduction of the STP 51
  5.1.2 Process Description of STP based on BIOFOR Technology 52
  5.1.3 BIOFOR-STP Performance Evaluation & Analysis 58
5.2 SBR based STP at Indirapuram, Uttar Pradesh. 61
  5.2.1 Introduction of the STP 61
  5.2.2 Process Description of STP based on SBR Technology 62
  5.2.3 SBR-STP Performance Evaluation & Analysis 69
5.3 UASB based STP at Dhanwapur, Gurgaon, Haryana 72
  5.3.1 Introduction of the STP 72

5.3.2 Process Description of STP based on UASB Technology 73

5.3.3 UASB-STP Performance Evaluation & Analysis 77

5.4 ASP based STP –Phase-I at Rithala, Delhi 80

5.4.1 Introduction of the STP 80

5.4.2 Process Description of STP based on ASP Technology 81

5.4.3 ASP-STP Performance Evaluation & Analysis 86

5.5 ASP with BIOFOR based STP –Phase-II at Rithala, Delhi 89

5.5.1 Introduction of the STP 89

5.5.2 ASP+BIOFOR Technology Description 90

5.5.3 Process Description of STP based on ASP+BIOFOR Technology 90

5.5.4 ASP+BIOFOR -STP Performance Evaluation & Analysis 95

5.6 Oxidation Ditch based STP –Phase-I at Keshopur, Delhi 98

5.6.1 Introduction of the STP 98

5.6.2 Process Description of STP based on Oxidation Ditch Technology 99

5.6.3 OD-STP Performance Evaluation & Analysis 104

CHAPTER- 6 RESULTS AND DISCUSSION 107-120

6.1 Physico-Chemical Analysis of STPs based on different technologies 107

6.1.1 TSS removal Profile of STPs based on different technologies 108

6.1.2 pH Profile of STPs based on different technologies 109

6.1.3 BOD removal Profile of STPs based on different technologies 110

6.1.4 COD removal Profile of STPs based on different technologies 111

6.1.5 Overall removal efficiency for physico-chemical parameters 111

6.2 Biomass Analysis in Terms of MLSS 112

6.3 Microbial Analysis of different STPs for TC & FC. 113

6.4 Area and Cost comparison of different sewage treatment technologies 114

6.6 Performance Assessment of different technologies 119

6.6.1 Performance in terms of Quality of Treated Sewage 119

6.6.2 Performance in terms of Resource requirements 120

6.6.3 Performance in terms of Resource Generation & Recovery 120

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS 122-126

7.1 Conclusions 122

7.2 Recommendations 125

7.3 Scope for further Study 126

References 127

LIST OF TABLES

Table 2.1 : Unit Operations & Treatment Processes in Wastewater Treatment 8
Table 2.2 : Sewage Treatment Process Selection Considerations 11
Table 3.1 : Parameters measured for monitoring 14
Table 3.2 : MPN Index and 95 percent confidence limits for various combinations of positive results when five tubes are used per dilution (10 ml, 1.0 ml, 0.1 ml portions of sample) 21
Table 4.1 : Typical design parameters for SBR process 30
Table 4.2 : Typical design parameter for phosphorus-removal in SBR 30
Table 4.3 : Typical design parameter for nitrogen-removal in SBR 30
Table 4.4 : Design criteria summary of UASB 37
Table 4.5 : Typical design parameters for ASP process 43
Table 4.6 : Typical design parameters for Oxidation Ditch process 48
Table 4.7 : Typical design parameter for nitrogen-removal in Oxidation Ditch 48
Table 4.8 : Description of STPs selected for the study 50
Table 5.1 : Dimensional details of various units and facilities of the STP based on BIOFOR at Sen Nursing Home Drain, Delhi. 56
Table 5.2 : Physico-chemical analysis of STP based on BIOFOR technology 58
Table 5.3 : Microbial analysis of STP based on BIOFOR Technology 58
Table 5.4 : Dimensional details of various units and facilities of the STP based on SBR at Indirapuram, Uttar Pradesh 67
Table 5.5 : Physico-chemical analysis of STP based on SBR technology 69
Table 5.6 : Microbial analysis of STP based on SBR Technology 69
Table 5.7 : Dimensional details of various units and facilities of the STP based on UASB at Dhanwapur, Gurgaon, Haryana 75
Table 5.8 : Physico-chemical analysis of STP based on UASB technology 77
Table 5.9 : Microbial analysis of STP with UASB Technology 77
Table 5.10 : Dimensional details of various units and facilities of the STP based on ASP at Phase-I Rithala, Delhi 84
Table 5.11 : Physico-chemical analysis of STP based on ASP Technology 86
Table 5.12 : Microbial analysis of STP based on ASP Technology 86

Table 5.13 : Dimensional details of various units and facilities of the STP based on ASP+BIOFOR at Phase-II, Rithala, Delhi 93

Table 5.14 : Physico-chemical analysis of STP based on ASP+BIOFOR technology 95

Table 5.15 : Microbial analysis of STP based on ASP+BIOFOR technology 95

Table 5.16 : Dimensional details of various units and facilities of the STP based on Oxidation Ditch at Keshopur, Delhi 102

Table 5.17 : Physico-chemical analysis of STP based on OD technology 104

Table 5.18 : Microbial analysis of STP based on OD technology 104

Table 6.1 : Physicochemical Analysis of STPs with different treatment Technologies (Monthly Average) 107

Table 6.2 : Description and Causes of Activated Sludge Foams 108

Table 6.3 : Mixed Liquor Suspended Solids (MLSS) Levels in different STPs 112

Table 6.5 : Total Coliform and Fecal Coliform levels in different STPs 113

Table 6.6 : Resource Requirement Analysis in terms of Cost, Area & Energy Requirement 115

Table 6.7 : Performance Grading of Different Technologies w.r.t. Reduction Potential 119

Table 6.8 : Performance Grading of Different Technologies w.r.t. Resource Requirements 120

Table 6.9 : Performance Grading of Different Technologies w.r.t. Resource Generation and Recovery 121

LIST OF FIGURES

Figure No.	Figure Title	Page No
Figure 1.1:	Decadal Population Growth of Delhi	1
Figure 2.1:	Proportion of the population using improved sanitation in 2010 (UNICEF/WHO2012)	5
Figure 2.2:	Waste water treatment in India	6
Figure 4.1:	Schematic diagram of BIOFOR Tank	24
Figure 4.2:	BIOLITE media used in BIOFOR	25
Figure 4.3:	Phases of the SBR Operation cycle	27
Figure 4.4:	Decanting Process in SBR Tank	28
Figure 4.5:	Schematic diagram of UASB reactor	33
Figure 4.6:	Stages in UASB digestion	34
Figure 4.7:	ASP Process description	40
Figure 4.8:	Activated Sludge Process Variables	41
Figure 4.9:	Schematic diagram of Oxidation Ditch	46
Figure 5.1:	Satellite image of STP based on BIOFOR Technology at Sen Nursing Home, Delhi	52
Figure 5.2:	Fine Screens in BIOFOR based STP	53
Figure 5.3:	Grit and Grease removing unit	53
Figure 5.4:	Densadeg Clarifier	54
Figure 5.5:	BIOFOR Stage –I Filtration	55
Figure 5.6:	BIOFOR Stage – II Filtration	55
Figure 5.7:	Process Flow Diagram of STP based on BIOFOR at Sen Nursing Home Drain, Delhi	57
Figure 5.8:	pH variation in BIOFOR STP located at Sen Nursing Home Drain, Delhi	59
Figure 5.9:	TSS variation in BIOFOR STP located at Sen Nursing Home Drain, Delhi	59
Figure 5.10:	BOD variation in BIOFOR STP located at Sen Nursing Home Drain, Delhi	60
Figure 5.11:	COD variation in BIOFOR STP located at Sen Nursing Home Drain, Delhi	60
Figure 5.12:	Satellite image of STP based on SBR Technology at Indirapuram, Uttar Pradesh	62

Figure 5.13: Coarse Screen: 40mm at SBR based STP 62

Figure 5.14: SBR Tanks installed at Indirapuram, Uttar Pradesh 64

Figure 5.15: Fill-Aerate phase of SBR Cycle 64

Figure 5.16: React Phase of SBR Cycle 64

Figure 5.17: Settle Phase of SBR Cycle 65

Figure 5.18: Fixed Type Decanter in SBR Tank 65

Figure 5.19: Process flow diagram of STP based on SBR at Indirapuram, Uttar Pradesh 68

Figure 5.20: pH variation in SBR-STP located in Indirapuram, Uttar Pradesh 70

Figure 5.21: TSS variation in SBR-STP located in Indirapuram, Uttar Pradesh 70

Figure 5.22: BOD variation in SBR STP located in Indirapuram, Uttar Pradesh 71

Figure 5.23: COD variation in SBR STP located in Indirapuram, Uttar Pradesh 72

Figure 5.24: Satellite image of STP based on UASB at Dhanwapur, Gurgaon, Haryana 73

Figure 5.25: Distribution Chambers for UASB reactors 74

Figure 5.26: UASB Reactor installed at Dhanwapur, Gurgaon, Haryana 74

Figure 5.27: Final Polishing Unit after UASB Reactor 74

Figure 5.28: Process Flow Diagram of STP based on UASB at Dhanwapur, Gurgaon, Haryana 76

Figure 5.29: pH variation in UASB STP located in Dhanwapur, Gurgaon, Haryana 78

Figure 5.30: TSS variation in UASB STP located in Dhanwapur, Gurgaon, Haryana 78

Figure 5.31: BOD variation in UASB-STP located in Dhanwapur, Gurgaon, Haryana 79

Figure 5.32: COD variation in UASB-STP located in Dhanwapur, Gurgaon, Haryana 79

Figure 5.33: Satellite image of STP based on ASP at phase-I, Rithala, Delhi 81

Figure 5.34: 20mm Mechanical Bar screens at ASP Plant inlet 81

Figure 5.35: Aeration Tank of ASP Plant installed at Rithala, Delhi 82

Figure 5.36: Final Settling Tank of ASP Plant 82

Figure 5.37: Process Flow Diagram of STP based on ASP at Phase-I, Rithala Delhi 85

Figure 5.38: pH variation in ASP-STP Phase-I at Rithala, Delhi 87

Figure 5.39: TSS variation in ASP-STP -Phase-I at Rithala, Delhi 87

Figure 5.40: BOD variation in ASP-STP Phase-I at Rithala, Delhi 88

Figure 5.41: COD variation in ASP-STP Phase-I at Rithala, Delhi 88

Figure 5.42: Satellite image of STP based on ASP+BIOFOR technology at Phase-II, Rithala, Delhi 90

Figure 5.43: Grit Chamber Unit of ASP+BIOFOR Plant 91
Figure 5.44: Aeration Tank of ASP+BIOFOR Plant 91
Figure 5.45: BIO Filtration Tanks after ASP installed at Phase-II, Rithala, Delhi 92
Figure 5.46: Process Flow Diagram of STP based on ASP-BIOFOR at Phase-II, Rithala, Delhi. 94
Figure 5.47: pH variation in ASP+ BIOFOR STP Phase-I at Rithala, Delhi 96
Figure 5.48: TSS variation in ASP+ BIOFOR STP -Phase-I at Rithala, Delhi 96
Figure 5.49: BOD variation in ASP+ BIOFOR STP Phase-I at Rithala, Delhi 97
Figure 5.50: COD variation in ASP + BIOFOR STP Phase-I at Rithala, Delhi 97
Figure 5.51: Satellite image of STP based on Oxidation Ditch Technology at Keshopur, Delhi 99
Figure 5.52: Oxidation Ditch installed at Phase-II, Rithala, Delhi 100
Figure 5.53: Sludge Drying Beds at Oxidation Ditch based STP 101
Figure 5.54: Process Flow Diagram of STP based Oxidation Ditch at Keshopur, Delhi 103
Figure 5.55: pH variation in OD- STP at Keshopur, Delhi 105
Figure 5.56: TSS variation in OD- STP at Keshopur, Delhi 105
Figure 5.57: BOD variation in OD- STP at Keshopur, Delhi 106
Figure 5.58: COD variation in OD- STP at Keshopur, Delhi 106
Figure 6.1: TSS removal profile of STPs with different treatment technologies 109
Figure 6.2: pH value at Inlet and Outlet of STPs based on different treatment technologies 109
Figure 6.3: BOD removal Profile of STPs with different treatment technologies 110
Figure 6.4: COD removal Profile of STP with different treatment technologies 111
Figure 6.5: Percentage removal efficiency of STPs based on different treatment technologies 112
Figure 6.6: Total Capital Cost (Rs. Lacs/MLD) for STPs based on different technologies 117
Figure 6.7: Operation & Maintenance (O&M) Cost (Rs. Lacs/MLD) for STPs based on different technologies 117
Figure 6.8: Land Area Requirement (m^2/MLD) for STPs based on different technologies 118
Figure 6.9: Energy Requirement (kWh/d/MLD) for STPs based on different technologies 118

LIST OF ABBREVIATIONS

APHA	American Public Health Association
ASP	Activated Sludge Process
BGLB	Brilliant Green Lactose Bile
BIOFOR	Biological Filtration and Oxygenated Reactor
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organization
DJB	Delhi Jal Board
DO	Dissolved Oxygen
E&M	Electrical and Mechanical
FC	Fecal Coliform
F/M	Food to Micro-Organisms
FPU	Final Polishing Unit
GAP	Ganga Action Plan
GOI	Government of India
HRT	Hydraulic Retention Time
MGD	Millions Gallons Per Day
MLSS	Mixed Liquor Suspended Solids
MLD	Millions Liter Per Day
MOEF	Ministry of Environment And Forests.
MPN	Most Probable Number
NCR	National Capital Region
NCT	National Capital Territory
NRCD	National River Conservation Directorate
OD	Oxidation Ditch
O&M	Operation and Maintenance
PHED	Public Health Engineering Department
PET	Polyethylene Terephthalate
PLC	Programmable Logic Controller

PPCL	Pragati Power Corporation Ltd
PST	Primary Settling Tank
SBR	Sequencing Batch Reactor
SPCBs	State Pollution Control Boards
SRT	Solids Retention Time
SST	Secondary Settling Tank
STPs	Sewage Treatment Plants
TC	Total Coliform
TSS	Total Suspended Solids
UASB	Up flow Anaerobic Sludge Blanket
USEPA	United States Environmental Protection Agency
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organization
YAP	Yamuna Action Plan

CHAPTER 1

INTRODUCTION

1.1 Background

India’s fragile and finite water resources are depleting while the multi-sectoral demands for water for sustained economic growth is driving the increased demand for water through coupled dynamics between increased energy and consumption. Exponentially increasing demand for water due to population growth and agricultural use, coupled with a high degree of variability in the availability of water resources throughout the country, will drive per capita accessibility of water to under 1,000 cubic meters by 2020, if left unchecked. Climate change and extreme climate variability are further likely to accentuate these numbers.

Urbanization has encouraged the migration of people from villages to the urban areas in India. Delhi is the eighth largest metropolis in the world by population with 1, 67, 53, 235 inhabitants as per the 2011 Census. There are nearly 22.2 million residents in the greater National Capital Region (NCR) urban area (which also includes Noida, Greater Noida, Ghaziabad, Gurgaon and Faridabad along with other smaller nearby towns). The population of Delhi is expected to increase by 40% by the Year 2021. Decadal population growth of Delhi is depicted in Figure 1.1.

Figure 1.1: Decadal Population Growth of Delhi

With exponential growth in urbanization, a number of environmental problems have emerged. Since the commencement of the centrally sponsored programme on river pollution control in the Year 1985, more than 70 Sewage Treatment Plants (STPs) have been constructed under the Ganga Action Plan (GAP) and Yamuna Action Plan (YAP) so far. These plants are based on a range of technologies involving varying levels of mechanization, energy inputs, land requirements, costs, skilled manpower, etc. In the early stages of their inception, the selection of technology was based primarily on past experiences and its perceived performance efficiency. Moreover, at different stages of these Action Plans, a number of technologies have been tried out on pilot scale and some of them have been scaled up for larger capacity plants. Over last twenty (20) years, a considerable experience and expertise has been built up within the country in this sector. However, the level of performance of these plants with regard to effluent quality, energy consumption, process stability, resource recovery, sustainability of initial costs and subsequent Operation and Maintenance (O&M) costs has been varied.

There are three (3) main sources of river pollution, namely a) households and municipal disposal sites, b) soil erosion resulting from deforestation occurring to make way for agriculture along with resulting chemical wash-off from fertilizers, herbicides, and pesticides and c) run-off from commercial activity and industrial sites.

Discharge of untreated sewage is considered to be the single most important root cause for pollution of surface & ground water since there is a large gap between generation and treatment of domestic wastewater in India. The problem not only limits to the adequacy of treatment capacity but also extends to operation and maintenance of treatment plants. Several STPs are established under centrally funded National River Action Plan, however, their operation and maintenance is generally not satisfactory. If massive investment both in terms of planning and costs involved is done on establishing these STPs and not properly operated, the entire exercise of establishing the same becomes futile.

In order to ensure that these STPs function properly, it was felt necessary to carry out a field study to be aware of the treatment processes involved, evaluate the performance with regards to the treatment potential of the processes and identify core issues related to both technical and administrative aspects to rectify and mend the situation.

1.2 Objective of the Study

Objectives of the study are:

1) To study various treatment technologies in Delhi/NCR, especially for works implemented under River Action Plans mainly BIOFOR, SBR, UASB, ASP, ASP+BIOFOR and Oxidation ditch.

2) To assess the performance of the treatment units of STPs in relation to the removal of physico-chemical and microbial quality parameters in STPs at Dr. Sen Nursing Home drain, Rithala & Keshopur in Delhi, Dhanwapur in Gurgaon and Indirapuram in Uttar Pradesh.

3) To compare performance and treatment cost of various sewage treatment technologies.

4) To recommend strategy for optimizing the performance of the STPs.

CHAPTER 2

LITERATURE REVIEW

2.1 Historical Background on Wastewater Treatment

Municipal Wastewater is mainly generated from domestic sources and usually contains high content of various organic and inorganic compounds which are easily utilized by different types of microorganisms (Bentzen *et al.*, 1995).

Wastewater is a very complex microbiological system including a great number of microorganisms divided into specific classes that exist in bulk water phase, biofilms and sewer sediments (Hvitved-Jacobsen *et al.*, 1999).

Furthermore, a great number of different fractions of organic matters acting as substrates for these micro-organisms are found in wastewater. Therefore, the composition of "young" wastewater with an age of only minutes or a few hours may be quite different from wastewater that has been under transportation for 20 hours or more in sewers due to the interactions between micro-organisms and substrates (Nielsen *et al.*, 1992).

Wastewater is a source of serious public health problems because it contains pathogenic bacteria and toxic substances (Toroglu *et al.*, 2006).

A number of Parameters like temperature, pH and quality characteristics in terms of biodegradability of organic matters and amount of active biomass available are crucial for the outcome of transformations occur in sewer (Hvitved-Jacobsen, 2002).

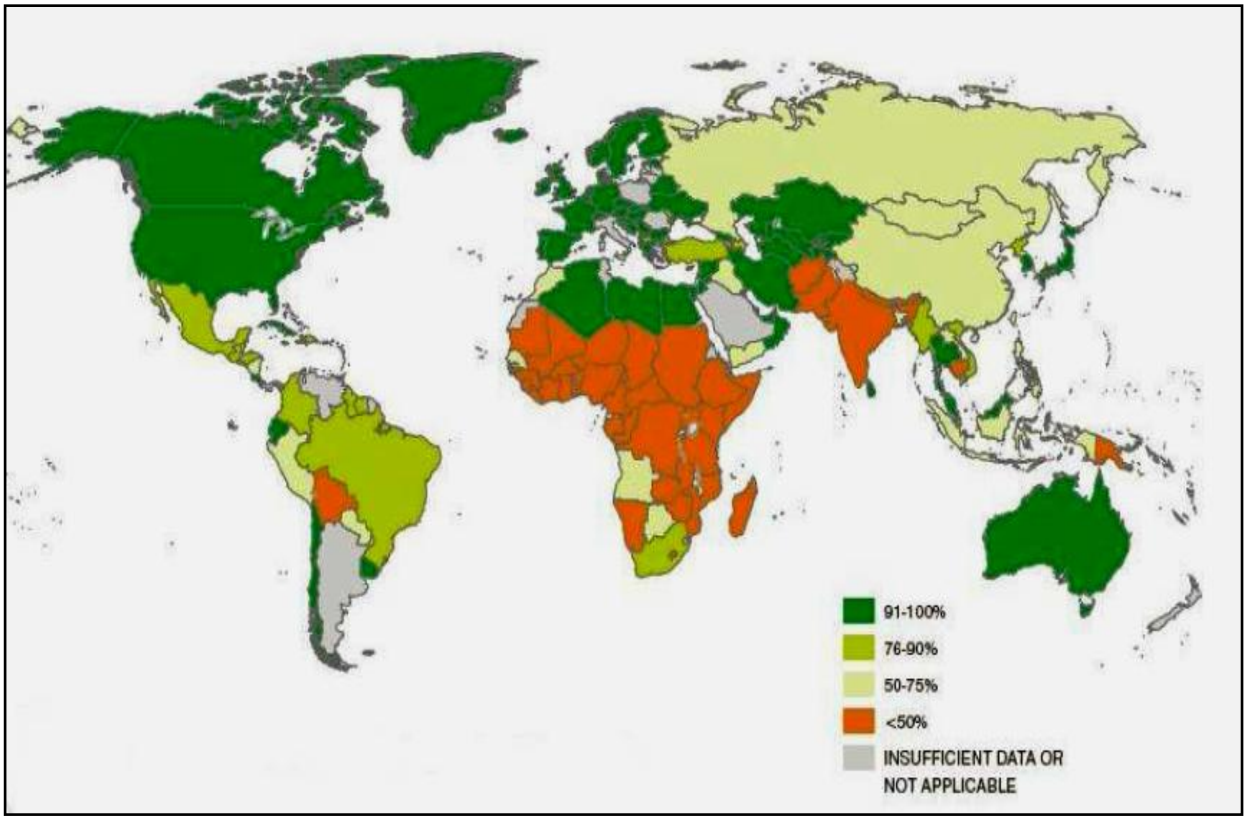
The problem of the contamination of water bodies through wastewater discharges was understood back in the time of the Romans. The first sewer in Rome was built about 400 BC under the name Cloaca Maxima (known as *'Great Sewer'*), a system mainly for transportation of drainage water. During the middle ages there was little progress in urban drainage and sewerage, until the introduction of water closets in the early 19th century. Another factor that attracted the attention to the need of wastewater collection and treatment was the global cholera outbreaks in the 19th century. On the other hand, the handling of one problem led to the introduction of another one i.e. pollution of surface waters.

The solution to this problem is through treatment of the raw wastewater. As an addition to collection and discharge of wastewater, physical, biological and chemical processes for the wastewater treatment were introduced, for the removal of pollutants. Through the 20th century, there was an increasing public concern for environmental issues, leading to a wider focus on wastewater disposal practices (*Britannica, 2012*). More advanced treatment techniques were developed, tailored for specific constituents in the wastewater. Treatment processes designed for different types of industrial wastewater has also been developed to a large extent. Today, most geographical areas have national regulations for maximum discharge values of different constituents, determining the scope of treatment necessary.

2.2 Wastewater Treatment in Developing Countries

According to the UNICEF/ WHO, only 30 % of the population in Sub-Saharan Africa has access to improved sanitation *(UNICEF/WHO 2012)*. Trends from the Year 1990 to 2010 show that increase in access to improved sanitation has been lowest in Sub-Saharan Africa at 4 % *(UNICEF/WHO 2012)*. Figure 2.1 gives a visual presentation of sanitation coverage in the countries of the world, and highlights the fact that the southern part of the world suffers from low sanitation coverage. Untreated wastewater generally contains high levels of organic material, numerous pathogenic micro-organisms, as well as nutrients and toxic compounds. It thus entails environmental and health hazards, which consequently must immediately be conveyed away from its generation sources and treated appropriately before final disposal. The ultimate goal of wastewater management is the protection of the environment in a manner commensurate with public health and socio-economic concerns.

Figure 2.1: **Proportion of the population using improved sanitation in 2010 (UNICEF/WHO2012)**



According to Vandeweerd *et al.* (1997), more than 90% of sewerage in the developing world is discharged directly into rivers, lakes, and coastal waters without any treatment. These reasons include lack of funds, ignorance of low-cost wastewater treatment processes and economic benefits of treated wastewater re-use, together with the tendency among decision-makers to accept the status quo: the continued discharge of untreated wastewater into the environment.

2.2.1 Wastewater Treatment in India

As per CPHEEO estimates about 70-80% of total water supplied for domestic use is being generated as wastewater. The per capita wastewater generation by the Class-I cities and Class-II towns, representing 72% of urban population in India, has been estimated to be around 98 lpcd while that from the National Capital Territory (NCT)-Delhi alone (discharging 3,663 Millions Liter per Day (MLD) of wastewaters, 61% of which is treated) is over 220 lpcd *(CPCB, 1999)*. As per CPCB estimates, the total wastewater generation from Class-I cities (498) and Class-II (410) towns in the country is around 35,558 and 2,696 MLD respectively. Moreover, the installed sewage treatment capacity is just 11,553 and 233.7 MLD for Class-I cities and Class-II towns respectively, thereby leading to a gap of 26,468 MLD in sewage treatment capacity. From 35 metropolitan cities (more than 10 Lac Population), 15,644 MLD of sewage is generated for which the treatment capacity exists for 8040 MLD i.e. 51% treatment capacity shown in Figure 2.2. Maharashtra, Delhi, Uttar Pradesh, West Bengal and Gujarat are the major contributors of wastewater with a contribution of almost 63% of the total wastewater generation *(CPCB, 2007a)*.

Among the Metropolitan cities, Delhi has the maximum treatment capacity i.e. 2330 MLD (30% of the total treatment capacity installed for all the metropolitan cities). Next to Delhi, Mumbai has the capacity of 2130 MLD, which is 26% of total capacity installed for all metropolitan cities.

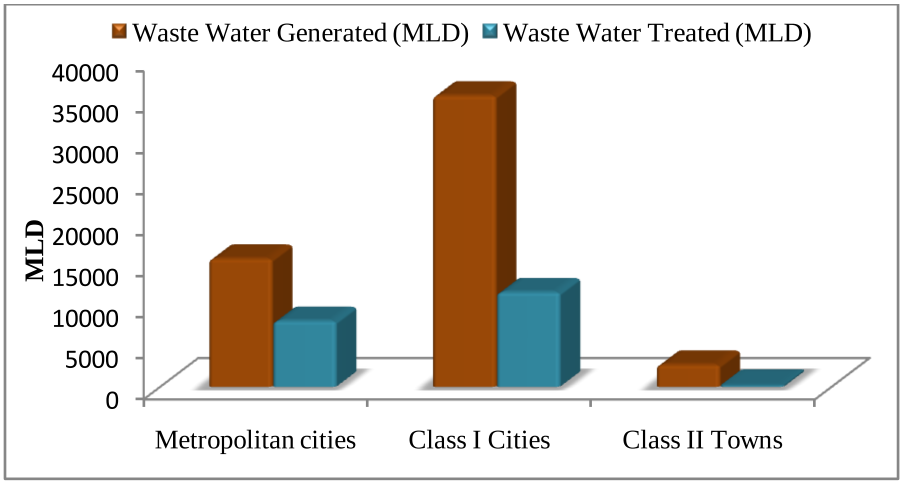


Figure 2.2: Wastewater treatment in India

2.3 Sewage Treatment Methods

Sewage treatment is the process of removing contaminants from wastewater and household sewage, both runoff (effluents) and domestic. The objective of the sewage treatment process is to produce an environmentally-safe fluid waste stream (or treated effluent) and a solid waste (or treated sludge) suitable for disposal or reuse. Treatment process includes physical, chemical, and biological processes to remove physical, chemical and biological contaminants.

The contaminants in wastewater are removed by physical, chemical, and biological means. The individual treatment methods are usually classified as:

- Physical unit operations
- Chemical unit processes
- Biological unit processes.

2.3.1 Physical Unit Operations

Treatment methods in which the application of physical forces predominates are known as physical unit operations. Screening, mixing, flocculation, sedimentation, floatation, filtration, and gas transfer are examples of physical unit operations. Villemonte *et al.* (1967) tested a prototype sedimentation basin characterizing the hydraulic flow regime and defined parameters such as short circuiting, stagnation, eddy diffusion, and recirculation eddy. Villemonte *et al.* (1967) showed that real basins are neither plug flow nor complete mixing. The effects of short circuiting can be minimized by covering the basin (eliminates the effect of wind or heat induced currents), adding stream deflecting baffles, influent dividing mechanisms, and velocity dispersing feed walls.

2.3.2 Chemical Unit Processes

Treatment methods in which the removal or conversion of contaminants is brought about by the addition of chemicals or by other chemical reactions are known as chemical unit processes. Precipitation and adsorption are the most common examples used in wastewater treatment. In chemical precipitation, treatment is accomplished by producing a chemical precipitate that will settle. In most cases, the settled precipitate will contain both the constituents that may have reacted with the added chemicals and the constituents that were swept out of the wastewater as the precipitate settled. Adsorption involves the removal of specific compounds from the wastewater on solid surfaces using the forces of attraction between bodies. Heukelekian and almat (1959) proposed that domestic wastewater contains more organic carbon in colloidal and suspended form than the dissolved form. Hunter and Heukelekian (1965) found that particulate fraction is 66% to 83% organic and contributes 58% and 63% of volatile solids for domestic wastewater. The COD to volatile solids ratio for the particulate fraction is approximately 1 .5 to 1 .0 while for the soluble fraction varies from 0 .6 to 0.8 to 1 .0.

2.3.3 Biological Unit Processes

Treatment methods in which the removal of contaminants is brought about by biological activity are known as biological unit processes. Biological treatment is used primarily to remove the biodegradable organic substances (colloidal or dissolved) in wastewater. Basically, these substances are converted into gases that can escape to the atmosphere and into biological cell tissue that can be removed by settling. Biological treatment is also used to remove nutrients (nitrogen and phosphorus) in wastewater. Erickson and Fan (1968), Naito *et al.* (1969), Fan *et al.* (1970, 1971), and McBeath and Eliassen (1966) conducted optimal design studies of the activated sludge subsystem (aeration tank and secondary clarifier). Parkin and Dague (1972) demonstrated that the most efficient individual units combined together may not produce an optimal system.

Adams and Asano (1978) estimated that approximately 60% of the total mass of sludge in a conventional plant can be considered biodegradable material, both cells and entrapped substrate. They have also suggested that the active fraction in sludge is between 0.2 to 0.3 at a sludge age of 10 days.

Unit operations & treatment processes used to remove constituents found in wastewater are listed in Table 2.1.

Table 2.1 Unit Operations & Treatment Processes in Wastewater Treatment

S. No.	Constituent	Unit Operation & Process
1	**Suspended solids**	Screening
		Grit Removal
		Sedimentation
		High Rate Clarification
		Floatation
		Chemical Precipitation
		Depth Filtration
		Surface Filtration
2	**Biodegradable organics**	Aerobic Suspended Growth variation
		Aerobic Attached Growth variation
		Anaerobic Suspended Growth variation
		Anaerobic Attached Growth variation
		Lagoon variation
		Physico-Chemical system
		Chemical Oxidation
		Advanced Oxidation
		Membrane Filtration

3	**Nutrients**	
3.1	Nitrogen	Chemical Oxidation (Break Point Chlorination)
		Suspended Growth Nitrification & De-Nitrification variation
		Fixed Film Nitrification & de-nitrification variation
		Air Stripping
		Ion Exchange
3.2	Phosphorus	Chemical Treatment
		Biological Phosphorus removal
3.3	Nitrogen & Phosphorus	Biological Nutrient Removal variation
4	**Pathogens**	Chlorine compounds
		Chlorine Di-oxide
		Ozone
		UV Radiations
5	**Colloidal & Dissolved Solids**	Membrane
		Chemical Treatment
		Carbon Adsorption
		Ion exchange
6	**Volatile Organic Compound**	Air stripping
		Carbon adsorption
		Advanced Oxidation
7	**Odors**	Chemical Scrubber
		Carbon Adsorption
		Biofilter
		Compost Filter
Source : Metcalf & Eddy, Fourth Edition, Wastewater Engineering Treatment and Reuse		

2.4 Wastewater Treatment Process

The unit operations and unit processes mentioned in Section 2.3 are grouped together to provide various levels of treatment described below:

2.4.1 Primary Treatment

Preliminary treatment by screens or grit chambers is usually followed by primary sedimentation. The main objective of this treatment step is to remove a large fraction (50-70%) of the total suspended solids in the wastewater. Since suspended solids also contribute to the content of Biochemical Oxygen Demand (BOD) in the wastewater, one should expect 25-40 % of the total

BOD to be removed in the process *(Metcalf & Eddy 2004)*. When followed by biological treatment, the primary sedimentation step contributes to improved conditions by lowering the oxygen demand and the rate of energy consumption as a result of BOD removal. Removal of suspended solids also reduces the risk of operational problems in the subsequent treatment processes.

2.4.2 Secondary Treatment

Biological wastewater treatment is based on the principle that microorganisms oxidize dissolved and particulate biodegradable matter into simple end products, which can be removed from the wastewater stream as sludge. Such processes can also remove suspended and non-settleable colloidal solids to a certain degree, as they are captured in biological flocs or biofilm. Nutrients such as nitrogen and phosphorus could also possibly be removed either as a part of the solids content or through biological decomposition. As an overview, the main purpose of secondary biological treatment is to remove readily biodegradable BOD that has escaped the primary treatment, in combination with further removal of suspended solids *(Davis 2011)*. Biological treatment can be achieved either in the presence of oxygen (aerobic processes) or in the absence of oxygen (anaerobic processes).

Two main types of biological treatment are common in wastewater treatment, one being suspended growth biological treatment, also known as Activated Sludge process, and the other being attached growth biological treatment, also known as Biofilter process.

i) Attached Growth Processes

In attached growth processes, the micro-organisms responsible for the conversion of organic material or nutrients are attached to an inert packing material. The organic material and nutrients are removed from the wastewater flowing past the attached growth also known as biofilm. Packing materials used in attached growth processes include rock, gravel, slag, sand, redwood, and a wide range of plastic and other synthetic materials. Attached growth processes can also be operated as aerobic or anaerobic processes. The packing can be submerged completely in liquid or not submerged, with air or gas space above the biofilm liquid layer.

ii) Suspended Growth Processes

In suspended growth processes, microorganisms responsible for treatment are maintained in liquid suspension by appropriate mixing methods. The most common suspended growth process used for municipal wastewater treatment is the activated sludge process.

2.4.3 Tertiary Treatment

These types of treatment steps, which also go under the term “advanced wastewater treatment” because of their generation of advanced techniques removes residual suspended solids (after secondary treatment), usually by granular medium filtration or micro screens. Pathogen removal is also typically a part of tertiary treatment.

2.5 Selection of Appropriate Sewage Treatment Technology

One of the most challenging aspects of a sustainable sewage treatment system design is the analysis and selection of the treatment processes and technologies capable of meeting the requirements. The process is to be selected based on required quality of treated water. While treatment costs are important, other factors should also be given due consideration. For instance, effluent quality, process complexity, process reliability, environmental issues and land requirements should be evaluated and weighted against cost considerations. Important considerations for selection of sewage treatment processes are given in Table 2.2.

Table 2.2: Sewage Treatment Process Selection Considerations

S.No.	Consideration	Goal
1	Quality of Treated Sewage	Production of treated water in line with the stipulated quality without interruption as regulated by the Central Pollution Control Board (CPCB) or State Pollution Control Boards (SPCBs)
2	Land required	Minimize land requirement
3	Capital cost of Project	Optimum utilization of the capital invested by selection of appropriate technologies
4	Operation & Maintenance Costs	Lower recurring expenditure during the operational phases of the STPs
5	Operator Training and Awareness	Easy to understand procedures and adequate training imparted to the personnel involved
6	Reliability	Consistent delivery of treated sewage with minimal shutdown of the STPs
7	Resource Recovery	Production of quality treated water and manure to be reused
8	Load Fluctuations	Withstand variations in organic and hydraulic loads
9	Power Requirement	Reduce energy consumption

Source : Protocol for the Verification of Wastewater Treatment Technologies, USEPA,2001

CHAPTER 3

METHODOLOGY & APPROACH

3.1 Plant Evaluation Procedure

The evaluation of a wastewater treatment plant consists of an in-depth analysis of the following basic elements:

- Plant Performance
- Sampling and Testing Program
- Operational Problems
- Operating Personnel
- Maintenance Data Program

Information and data for each element are gathered and analyzed in four (4) interrelated phases, namely

i) **Preparation of Site Visit**
Preparation for site visit includes compilation and review of information which provides a description of the plant's physical setting, previous records etc.

ii) **On-site Inspection**
On-site Inspection includes interaction with operating personnel, plant manager or chief operator and review of records & data.

iii) **Problem Identification**
The first step in problem identification and evaluation is to determine if the plant is meeting design performance standards by comparing its effluent quality and overall removal efficiencies with those specified standards.

iv) **Total Plant Evaluation**
In this evaluation, differences in existing plant performance and operational data with design and/or manual operational or performance data is carried out. This stage also includes identification of problem associated with maintenance system, laboratory equipments and plant machinery.

3.2 Inventorization

The methodology for the work comprised a combination of desk research, field visits to selected STPs, interaction with project implementing agencies, project management consultants and technology providers. Salient aspects of the methodology are as follows:

(i) Desk Inventory

To carry out the present study, dry inventory was conducted based on background information available. List of STPs having different treatment technologies was compiled.

Criteria for Site Selection:

a) STP should be fully commissioned
b) It should be easily approachable
c) Optimally utilized

(ii) Wet Inventory

The sampling and monitoring was conducted along with the officials of Central Pollution Control Board (CPCB). In this, STPs installed at Dhanwapur, Indirapuram, Rohini, Keshopur, and Sen Nursing Home drain were monitored. Samples of the treated/partially treated effluent from all the STPs during the period from January 2013 to June 2013 were collected, preserved and analyzed.

3.3 Selection of Sampling Point

For obtaining the required information about the qualities of the water, adequate selection of the sampling point is required and such a point should consider the following characteristics:

1. Representative sample should be collected.
2. Point should be easily approachable.
3. Sample must be collected from at least 6 inches depth.
4. Rinse the sampling container with the sampling water before taking the sample.
5. Sterilized glass bottle used for bacteriological samples

3.4 Analysis of Samples

All the precautions as per the standard procedures were followed in sampling and analysis. Analyses of most of the parameters have been carried out using Standard Method *(APHA, 2000)*. Details of frequency of monitoring, type and number of parameters studied are briefed in Table 3.1.

Table 3.1: Parameters measured for monitoring

S. No.	Parameter	Bottle Type	Preservation	Analysis Method	Reference
1.	pH	PET carboy	Ice	pH meter	APHA, 2000
2.	Total Suspended Solids	PET carboy	Ice	Gravimetric	APHA, 2000
3.	BOD	PET carboy	Ice	5 day BOD at 20^o C	APHA, 2000
4.	COD	PET carboy	Ice	Dichromate Reflux	APHA, 2000
5.	Total Coliform	Sterilized Glass bottle	Ice	MPN	APHA, 2000
6.	Fecal Coliform	Sterilized Glass bottle	Ice	MPN	APHA, 2000

3.4.1 pH measurement

The hydrogen-ion concentration is an important quality parameter for wastewater as well as natural water. The pH is defined as negative logarithm of H^+ ion

$$pH = -\log_{10}[H^+]$$

The concentration range suitable for the existence of most Biological life is quite narrow and critical which typically ranges from 6.0 – 9.0. The pH of various systems is measured via the means of a digital pH meter.

3.4.2 Biochemical Oxygen Demand (BOD)

BOD is a widely used parameter of organic pollution applied to both wastewater and surface water. The determination of this parameter involves the measurement of the Dissolved Oxygen (DO) used by micro-organisms in the biochemical oxidation of the organic matter present in the wastewater. The Biochemical Oxygen Demand (BOD) is an empirical standardized laboratory test which measures oxygen requirement for aerobic oxidation of decomposable organic matter and certain inorganic materials in water, polluted waters and wastewater under controlled conditions of temperature and incubation period. The quantity of oxygen required for above oxidation processes is a measure of the test. The test is applied for fresh water sources (rivers, lakes), wastewater (domestic, industrial), polluted receiving water bodies, marine water (estuaries, coastal water) and also for finding out the level of pollution, assimilative capacity of water body and also performance of wastewater treatment plants.

A. Equipment and Apparatus

a. BOD bottles 300mL capacity with a water seal.

b. Incubator or water-bath to be controlled at 20ºC or at any desired temperature 1ºC. All light excluded to prevent photosynthetic production of DO.

B. Reagents Used

- Phosphate Buffer Solution
- Magnesium Sulphate ($MgSO_4$) Solution
- Calcium Chloride ($CaCl_2$) Solution
- Ferric Chloride ($FeCl_3$) solution

C. BOD Test Procedure

1. In the standard BOD test a small sample of the wastewater is taken in the BOD Bottle [Vol = 300 ml].
2. The bottle is then filled with the dilution water saturated in oxygen and containing nutrients required for biological growth.
3. Then the seeding is done in the samples to seed the microbiological population in the samples .
4. Six Blanks are prepared by siphoning out dilution water directly into the bottles
5. Then the bottle is incubated for 3 days in the BOD Digester at 20º C.
6. After three (3) days of incubation, the dissolved oxygen concentration is measured.

D. Observations

S. No.	Sample Number	Initial DO	Final DO
1	Blank	IDOB	FDOB
2	Sample	IDOS	FDOS

E. Calculations

$$\text{BOD (mg /l)} = \frac{[(\text{IDOS} - \text{FDOS}) - (\text{IDOB} - \text{FDOB})]}{\text{Volume of Sample}} \text{ X } 100$$

Where, IDOS = Initial DO of Sample

FDOS = Final DO of Sample

IDOB= Initial DO of Blank

FDOB = Final DO of Blank

3.4.3 Chemical Oxygen Demand (COD)

COD is a parameter used to measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically. Chemical Oxygen Demand (COD) test determines the oxygen requirement equivalent of organic matter that is susceptible to oxidation with the help of a strong chemical oxidant. It is important, rapidly measured parameters as a means of measuring organic strength for streams and polluted water bodies. The test can be related empirically to BOD, organic carbon or organic matter in samples from a specific source taking into account its limitations. The test is useful in studying performance evaluation of wastewater treatment plants and monitoring relatively polluted water bodies. COD determination has advantage over BOD determination. COD results can be obtained in 3-4 hours as compared to 3-5 days required for BOD test. Further, the test is relatively easy, precise, and is unaffected by interferences as in the BOD test. The intrinsic limitation of the test lies in its inability to differentiate between the biologically oxidisable and biologically inert material and to find out the system rate constant of aerobic biological stabilization.

Interference: *Chlorides, Nitrates and iron are the main interfering radicals in wardly increasing COD. The interference of chlorides can be eliminated by sulphate.*

A. Open Reflux Method - Principle

The open reflux method is suitable for a wide range of wastes with a large sample size. The dichromate reflux method is preferred over procedures using other oxidants (e.g. potassium permanganate) because of its superior oxidizing ability, applicability to a wide variety of samples and ease of manipulation. Oxidation of most organic compounds is up to 95-100% of the theoretical value. The organic matter gets oxidised completely by potassium dichromate ($K_2Cr_2O_7$) with silver sulphate as catalyst in the presence of concentrated H_2SO_4 to produce CO_2 and H_2O. The excess $K_2Cr_2O_7$ remaining after the reaction is titrated with ferrous ammonium sulphate [$Fe\ (NH_4)_2(SO_4)_2$]. The dichromate consumed gives the oxygen (O_2) required for oxidation of the organic matter.

B. Apparatus and Equipment

a) 250 or 500mL Erlenmeyer flask with standard (24/40) tapered glass joints
b) Friedrich’s reflux condenser (12 inch) with standard (24/40) tapered glass joints
c) Electric hot plate or six-unit heating shelf
d) Volumetric pipettes (10, 25 and 50mL capacity)
e) Burette, 50mL with 0.1mL accuracy
f) Burette stand and clamp
g) Analytical balance, accuracy 0.001g
h) Spatula
i) Volumetric flasks (1000mL capacity)
j) Boiling beads, glass

C. Reagents Required

a) Standard Potassium Dichromate solution, 0.25 N
b) Mercuric Sulphate ($HgSO_4$)
c) Sulphuric Acid reagent (10g of Ag_2SO_4 to 1000 mL Conc. H_2SO_4)
d) Potassium Dichromate
e) Ferroin Indicator
f) Standard Ferrous Ammonium Sulphate (FAS - 0.02 N)

D. Procedure

1. In the COD test, 20 mL of the sample is taken in the testing tube and approximately 0.5 gm of the Mercuric Sulphate is added to it.
2. 10 mL of 0.25 N Potassium Dichromate is added to the sample.
3. 30 mL of the Sulphuric Acid reagent is then added to the sample.
4. The above sample is then kept in the COD digester for the duration of 2 hours.
5. After 2 hours of digestion, the sample is taken out of the digester and is allowed to cool for nearly an hour.
6. After the sample is cooled down, about 80 mL of Distilled water is added to the sample.
7. Lastly, to measure the COD in the sample, titration is conducted with Ferrous Ammonium Sulphate (FAS) of 0.02 N using ferroin as the indicator, till the end point is achieved and the readings are noted for the consumption of the FAS solution.

3.4.4 Total Suspended Solids (TSS)

Total Suspended Solids consist of the solid content which is composed of the floating matter, settleable matter, and colloidal matter present in the sample. TSS are separated by using Filter paper, hence the separation process is somewhat arbitrary, depending upon the pore size of the filter paper that have been used in the test, as more TSS will be measured if the pore size of the filter paper used is reduced.

Depending upon the sample size used for the determination of the TSS, auto-filtration, where the suspended solids that have been intercepted by the filter also serves as a filter performing the vital function of filtration.

A. Apparatus

a) Conical Flask
b) Filter Paper
c) Funnel

B. Reagent: No reagent required.

C. Procedure

1. Fold the filter paper and fix it in the funnel and put it on the funnel holder.
2. Take 50 mL of the sample in a measuring cylinder.
3. Slowly pour the sample in the funnel, having paper.
4. After complete filtration allow the filter paper to dry.
5. Now carefully remove the filter paper from the funnel, unfold it and observe for residue. Initial Weight and Final Weight with the residue is taken and difference of both provides for the TSS content in the wastewater sample.

3.4.5 Total Coliform (TC)

Coliform bacteria include all aerobic and facultative anaerobic gram negative, non-sore forming, rod shaped bacteria that produce gas upon fermentation in prescribed culture media within 48 hr at 35°C. The group includes thermotolerant coliforms and bacteria of fecal origin, as well as some bacteria that may be isolated from environmental sources.

Definition of coliform or fecal coliform basically relies on the activity of a single enzyme ß-*galactosidase*. The new enzymatic definition of TOTAL COLIFORM bacteria is based on the presence of ß-*galactosidase;* and that of E. *coli* is based on the enzymatic action of ß-*glucuronidase.*

3.4.6. Fecal Coliform (FC)

Fecal coliforms are a part of the total coliform group which are of fecal origin Fecal coliform live in the digestive tracks of warm-blooded animals, including humans, and are excreted in the feces. Although most of these bacteria are not harmful and are part of the normal digestive system, some are pathogenic to humans. Those that are pathogenic can cause disease such as gastroenteritis, ear infections, typhoid, dysentery, hepatitis A, and cholera. The presence of fecal coliform indicates the possible presence of organisms that can cause illness. Fecal coliform bacteria are differentiated in the laboratory by their ability to ferment lactose with production of acid and gas at 44.5ºC within 24 h. Fecal coliforms pose some of the same limitations as those posed by coliforms (Regrowth in distribution system, less resistance to water treatment than viruses and protozoa, etc.) Fecal coliforms are also detected by similar methods (MPN, MF and P/A) used for total coliforms.

Multiple tube fermentation technique for coliform bacteria (MPN test):

In the multiple-tube method, a series of tubes containing a suitable selective broth culture medium (lactose-containing broth, such as MacConkey broth) is inoculated with test portions of a water sample. After a specified incubation time at a given temperature, each tube showing gas formation is regarded as “presumptive positive” since the gas indicates the possible presence of coliforms. However, gas may also be produced by other organisms, and so a subsequent confirmatory test is essential. The two tests are known respectively as the presumptive test and the confirmatory test. For the confirmatory test, a more selective culture medium (brilliant green bile broth) is inoculated with material taken from the positive tubes. After an appropriate incubation time, the tubes are examined for gas formation as before. The most probable number (MPN) of bacteria present can then be estimated from the number of tubes inoculated and the number of positive tubes obtained in the confirmatory test. This technique is known as the MPN method.

A. Apparatus Required

a) Incubator(s) or water-baths capable of maintaining a temperature to within ± 0.5 ºC of 35 and 37 ºC and to within ± 0.25 ºC of 44 and 44.5 ºC. The choice of temperature depends on the indicator bacteria and the medium.
b) Autoclave for sterilizing glassware and culture media. The size required depends on the volume of work to be undertaken. A capacity of 100-150 litres would be required for a medium-size laboratory undertaking work on a routine basis.
c) Distillation apparatus, with storage capacity for at least 20 litres of distilled water.
d) Laboratory balance, accuracy ± 0.05 g, with weighing scoop. This may be omitted if culture media and potassium dihydrogen phosphate are available in pre-weighed packages of the proper size.
e) Racks for tubes and bottles of prepared culture media and dilution water. These must fit into the autoclave.
f) Pipettes, reusable, glass, 10 ml capacity graduated in 0.1 ml divisions, and 1.0 ml capacity graduated in 0.01 ml divisions.
g) Test-tubes, 20 × 150 mm for 10 ml of sample + 10 ml of culture medium, with metal slip-oncaps.
h) Bottles, with loose-fitting caps, calibrated at 50 and 100 ml, for 50 ml of sample + 50 ml of culture medium.
i) Measuring cylinders, unbreakable plastic or glass, capacity 100, 250, 500 and 1,000 ml.
j) Refrigerator for storage of prepared culture media.
k) Hot-air steriliser for sterilising pipettes.
l) Bunsen burner or alcohol lamp.
m) Durham tubes, 6 × 30 mm.
n) Flasks for preparation of culture media.
o) Wash-bottle/ Pipette bulbs.
p) Wire loops for inoculating media, and spare wire.

B. Consumables

a) Culture media: for example lauryl tryptose broth, Brilliant Green Lactose Bile (BGLB) broth, and *E. coli* medium.
b) Detergent for cleaning glassware and equipment.
c) Phosphate-buffered dilution water.

C. Procedure

1. Prepare the required number of tubes of culture medium. The volume and strength (single or double) of medium in the tubes will vary depending on the expected bacteriological density in the water and the dilution series planned.

2. Select and prepare a range of sample dilutions; these will normally be suggested by experience. Recommended dilutions for use when there is no experience with samples from that station are provided. To prepare a 1/10 dilution series, mix the sample bottle well. Pipette 10 ml of sample into a dilution bottle containing 90 ml of phosphate-buffered dilution water. To prepare a 1/100 dilution, mix the 1/10 dilution bottle well and pipette 10 ml of its contents into a bottle containing 90 ml of dilution water. Subsequent dilutions are made in a similar way. Alternatively, 1 ml of sample may be added to a bottle containing 9 ml of dilution water.

3. Pipette the appropriate volumes of sample and diluted sample into the tubes of medium.

4. Label the tubes with the sample reference number, the dilution and the volume of sample (or dilution) added to the tube. Shake gently to mix the sample with the medium. Place the rack in an incubator or water-bath for 48 hours at 35 ± 0.5 ºC or 37 ± 0.5 ºC.

5. After 18 or 24 hours, note which tubes show growth. Tubes that show turbidity and gas production, or a colour change indicating the production of acid (if the medium contains a pH indicator), are regarded as positive. Record the number of positive tubes at each dilution. Return the tubes to the incubator and re-examine after a total of 48 hours of incubation. Continue with the next step of the procedure.

6. Prepare the required number of tubes of confirmation culture medium (BGLB broth for total coliforms and *E. coli* medium for fecal coliforms). Using a sterile wire loop, transfer inocula from positive tubes into the confirmation medium. Sterilise the loop between successive transfers by heating in a flame until it is red hot. Allow it to cool before use. If confirmation of both total and fecal coliforms is required, a BGLB and an *E. coli* medium tube should be inoculated from each presumptive positive. Label these tubes carefully with the same code used in the presumptive test and incubate them for 48 hours at 35 ± 0.5 °C or 37 ± 0.5 °C for total coliforms (BGLB broth) or for 24 hours at 44 ± 0.5 °C for fecal coliforms (*E. coli* medium).

7. After the prescribed incubation time, note which tubes show growth with the production of gas, and record the number of positives for each sample dilution. Compare the pattern of positive results with a most probable number table as shown in Table 3.2.

Table 3.2: MPN Index and 95 percent confidence limits for various combinations of positive results when five tubes are used per dilution (10 ml, 1.0 ml, 0.1 ml portions of sample)

Combination of positives	**MPN Index per 100ml**	**95% Confidence Limits**		**Combination of positives**	**MPN index per 100ml**	**95% confidence limits**	
		Upper	**Lower**			**Upper**	**Lower**
0-0-0	<2	-	-	4-2-0	22	9.0	56
0-0-1	2	1.0	10	4-2-1	26	12	65
0-1-0	2	1.0	10	4-3-0	27	12	67
0-2-0	4	1.0	13	4-3-1	33	15	77
				4-4-0	34	16	80
1-0-0	2	1.0	11	5-0-0	23	9.0	86
1-0-1	4	1.0	15	5-0-1	30	10	110
1-1-0	4	1.0	15	5-0-2	40	20	140
1-1-1	6	2.0	18	5-1-0	30	10	120
1-2-0	6	2.0	18	5-1-1	50	20	150
				5-1-2	60	30	180
2-0-0	4	1.0	17	5-2-0	50	20	170
2-0-1	7	2.0	20	5-2-1	70	30	210
2-1-0	7	2.0	21	5-2-2	90	40	250
2-1-1	9	3.0	24	5-3-0	80	30	250
2-2-0	9	3.0	25	5-3-1	110	40	300
2-3-0	12	5.0	29	5-3-2	140	60	360
3-0-0	8	3.0	24	5-3-3	170	80	410
3-0-1	11	4.0	29	5-4-0	130	50	390
3-1-0	11	4.0	29	5-4-1	170	70	480
3-1-1	14	6.0	35	5-4-2	220	100	580
3-2-0	14	6.0	35	5-4-3	280	120	690
3-2-1	17	7.0	40	5-4-4	350	160	820
4-0-0	13	5.0	38	5-5-0	240	100	940
4-0-1	17	7.0	45	5-5-1	300	100	1,300
4-1-0	17	7.0	46	5-5-2	500	200	2,000
4-1-1	21	9.0	55	5-5-3	900	300	2,900
4-1-2	26	12.0	63	5-5-4	1,600	600	5,300
				5-5-5	>1,600	-	-

Source : APHA,1992

3.5 Qualitative and Quantitative O&M Assessment

3.5.1 Qualitative O&M Performance Indicators

a. **Visual Observations:** Visual inspections of effluent quality (e.g., color, turbidity) and wastewater treatment technology conditions (e.g., foaming in reactor, floating solids) was performed during sampling period.
b. **Operability and Reliability:** Observations regarding the ease of start-up and operation during testing and the reliability of the technology was observed.
c. **O&M Manual:** The usefulness and quality of the Vendor-supplied O&M Manual was checked.
d. **Operator Skills:** The level of operator expertise required to operate and maintain the wastewater treatment technology has been noted.

3.5.2 Quantitative O&M Performance Indicators

a. **Time Demand:** The personnel time required to start-up, shutdown, and maintain the wastewater treatment technology be recorded.
b. **Residuals:** Residuals (e.g., waste sludge) volumes, mass generation rates and concentrations were observed
c. **Chemical Use:** Usage rates and concentrations of any chemicals used in conjunction with operation of the wastewater treatment technology were observed.
d. **Power Consumption:** The power consumed by the wastewater treatment technology was monitored.
e. **Other Consumables**: The use of any other consumables was monitored.

CHAPTER 4

DETAILS OF SEWAGE TREATMENT TECHNOLOGIES

4.1 Biological Filtration and Oxygenated Reactor (BIOFOR)

4.1.1 Introduction

BIOFOR Technology (Biological Filtration and Oxygenated Reactor) is a patented technology of Degremont includes Intensified Aerobic treatment with Dense-Deg & BIOFER**.** Even though BIOFOR is a relatively new technology, installations treating from 0.1 to 110 MGD are in operation at over 100 locations worldwide, thereby implying its increased usability in shorter span of its inception.

The first municipal installation for the same occurred in 1997 at the 1.7 MGD Woodstream-Evesham Wastewater Treatment Plant in Marlton, New Jersey.

4.1.2 Process Type

The treatment process involved in the BIOFOR technology is “Aerobic-attached growth process” having Physico-chemical and Biological treatment with up flow aerated filtration.

4.1.3 BIOFOR Working Mechanism

BIOFOR employs a proprietary dense granular support media that acts as a biological contactor as well as a filter, thus eliminating the need for a separate clarification step. Both the influent wastewater and process air required, flows into the system from the bottom of the unit in an upward direction. Process air provides the necessary oxygen for aerobic biological activity and is introduced in the media through a network of diffusers located at the base of the reactor. Exceptionally high oxygen transfer is achieved in the media due to the up-flow pattern of air bubbles. The biological filtration process is of the submerged bed type. The effluent to be treated enters continuously from the bottom of the reactor and is distributed over the entire filter surface area by the nozzle under drain. Co-current up-flows of air and water allow for the finest particles to pass to the upper reaches of the Biolite filter support media; suspended matter becomes attached through the full height of the media which allows for long filter runs. The influent must be screened to avoid clogging of the filter nozzles.

Carbonaceous and nitrogenous pollution is eliminated through the high concentration of fixed-film biomass which is retained on the filter media during the filtration cycle. Process air is introduced continuously into the lower part of the reactor by Oxazur air diffusers. According to the present full scale experiences the oxygen transfer in the BIOFOR is depending on the nature of the filter material. Schematic diagram of BIOFOR is shown in Figure 4.1**.**

During the treatment, the biomass accumulates in the support bed because of:

- the bacterial growth due to the elimination of dissolved pollution; and
- the retention of suspended solids in the raw water and of the biological flocs.

The use of a co-current upflow design helps to limit odor generation since the treated water is situated at the surface of the filter (in contact with the atmosphere), and the untreated water enters at the bottom of the filter. The number of filters in filtration service is according to the flow entering the plant. During low flow periods, off-duty filters are aerated periodically to maintain the biomass in optimum condition. Since filters can be taken out of service when not required, operating costs (due to process air production) can be reduced.

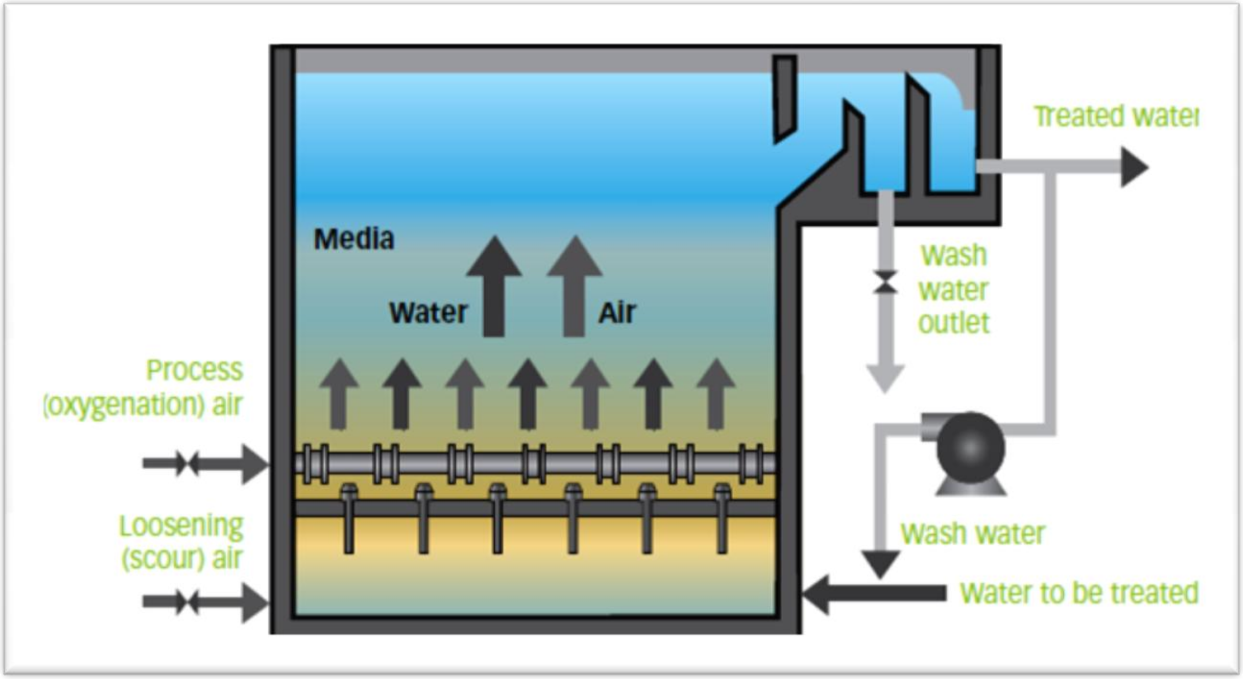


Figure 4.1: Schematic diagram of BIOFOR Tank

The Biological filtration can be described as a system of three phase with

i) A solid phase :- the filter material with attached biomass
ii) A liquid phase:- the wastewater that passes through filter material
iii) A gas phase:- the oxygen to assure oxidative process or the gaseous nitrogen at denitrification.

According to examinations of Richard Faup(1982) those process working with water and air in concurrent are particularly advantageous and clearly superior to process of counter current with regard to the nitrification capacity. The reason being that, in concurrent method the partial pressure of oxygen in the gaseous phase is higher in the filter areas of the highest oxygen demand then in the use of counter current and that the reduction of the oxygen concentration in the liquid film can be kept minor due to superior supply of oxygen from the gas phase.

4.1.4 BIOFOR Media Description

The filter material is chosen that way that a possibly high attached biomass concentration and a can have high retention of solids. BIOLITE filter material with rough & porous surface are particularly used in BIOFOR for treatment. BIOLITE filter media is shown in Figure 4.2.

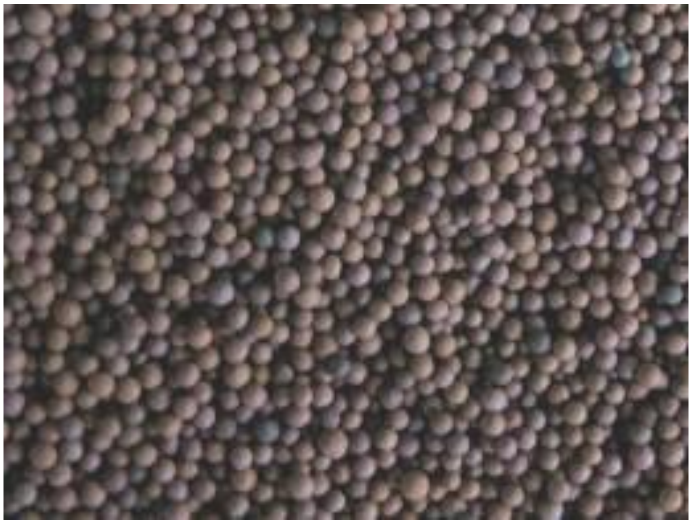


Figure 4.2: BIOLITE media used in BIOFOR

BIO-LITE is made from natural silicate at a higher temperature. Its stable chemical characteristics accord with the primitive living environment where micro-organisms live in. The space structure is optimal for micro-organisms colonization and growth. The multi-porous structure provides 6-8 times larger surface compared to other bio-media. Its highly penetrative porous structure enables the aerobic nitrifying bacteria's nitrification and anaerobic denitrifying bacteria's denitrification.

4.1.5 Advantages of BIOFOR technology

- Easily adapts to variable flows and pollution loads
- Modular construction allows for easy plant expansions in the future
- Elimination of secondary clarifiers removes all of the associated costs and operational problems that can accompany traditional treatment processes

4.1.6 Disadvantages of BIOFOR technology

- Continuous and high chemical dosing in primary clarification
- Undigested sludge from primary clarification requires post treatment.
- High Energy requirement

4.2 Sequencing Batch Reactor (SBR)

4.2.1 Introduction

The Sequencing Batch Reactor (SBR) is a fill-and draw cyclic activated sludge process. In this system, wastewater is added to a single “batch” reactor, treated to remove undesirable components, and then discharged. Equalization, aeration, and clarification can all be achieved using a single batch reactor. Interest in SBRs was revived in the late 1950s and early 1960s, with the development of new equipment and technology (USEPA, 1999).

The SBR has received considerable attention since Irvine and Davis described its operation (Irvine and Davis, 1971) and studies of SBR Process were originally conducted at the University of Notre Dame, Indiana (Irvine and Busch, 1979).

In recent year, sequencing batch reactor (SBR) has been employed as an efficient technology for wastewater treatment, especially for domestic wastewaters, because of its simple configuration (all necessary processes are taking place time-sequenced in a single basin) and high efficiency in BOD and suspended solids removal. SBRs could achieve nutrient removal using alteration of anoxic and aerobic periods (Rim *et al*., 1997)

4.2.2 Process Type

In SBR Technology, the process involved is aerobic treatment with suspended growth process.

4.2.3 SBR Working Mechanism

An SBR system may be designed as consisting of a single or multiple reactor tanks operating in parallel. The operation of an SBR is based on a fill-and-draw principle, which consists of five distinctive phases —FILL, REACT, SETTLE, DECANT and IDLE. These steps can be altered for different operational applications. The cyclic operation of the SBR is illustrated in Figure 4.3.

a) Fill phase

During the fill phase, the basin receives influent wastewater. The influent brings food to the microbes in the activated sludge, creating an environment for biochemical reactions to take place. Mixing and aeration can be varied during the fill phase to create the following three different scenarios:

Static Fill – Under a static-fill scenario, there is no mixing or aeration while the influent wastewater is entering the tank. Static fill is used during the initial start-up phase of a facility, at plants that do not need to nitrify or denitrify, and during low flow periods to save power.

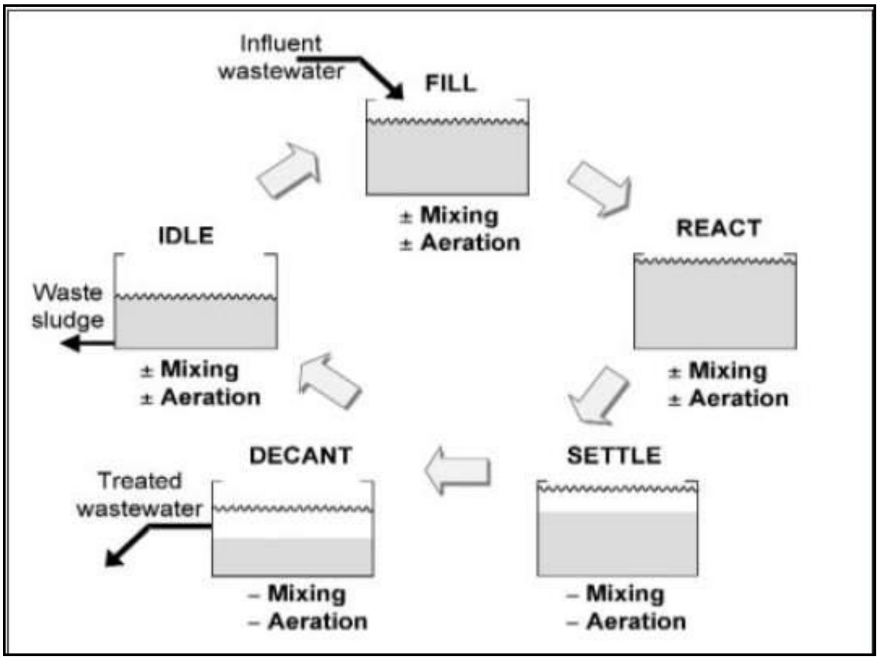


Figure 4.3: Phases of the SBR Operation cycle
Source: University of Florida TREEO Center's *Sequencing Batch Reactor Operations and Troubleshooting Manual*

Mixed Fill – Under a mixed-fill scenario, mechanical mixers are active, but the aerators remain off. The mixing action produces a uniform blend of influent wastewater and biomass. Because there is no aeration, an anoxic condition is present, which promotes denitrification. Anaerobic conditions can also be achieved during the mixed-fill phase. Under anaerobic conditions the biomass undergoes a release of phosphorous. This release is reabsorbed by the biomass once aerobic conditions are reestablished. This phosphorous release will not happen with anoxic conditions.

Aerated Fill – Under an aerated-fill scenario, both the aerators and the mechanical mixing unit are activated. The contents of the basin are aerated to convert the anoxic or anaerobic zone over to an aerobic zone. No adjustments to the aerated-fill cycle are needed to reduce organics and achieve nitrification. Dissolved oxygen (DO) should be monitored during this phase so it does not go over 0.2 mg/L. This ensures that an anoxic condition will occur during the idle phase.

Aeration in an SBR may be provided by time or coarse bubble diffusers, floating aerator/mixers or jet aeration devices. The SBR process is usually preceded by some type of preliminary treatment such as screening and grit removal. Because the SBR process operates in a series of timed steps, reaction and settling can occur in the same tank, eliminating the need for a final clarifier (USEPA, 1992)

b) React phase

During this phase, no wastewater enters the basin and the mechanical mixing and aeration units are on. Because there are no additional volume and organic loadings, the rate of organic removal increases dramatically. Most of the carbonaceous BOD removal occurs in the react phase. Further nitrification occurs by allowing the mixing and aeration to continue — the majority of denitrification takes place in the mixed-fill phase.

c) Settle phase

During this phase, activated sludge is allowed to settle under quiescent conditions—no flow enters the basin and no aeration and mixing takes place. The activated sludge tends to settle as a flocculent mass, forming a distinctive interface with the clear supernatant. This phase is a critical part of the cycle, because if the solids do not settle rapidly, some sludge can be drawn off during the subsequent decant phase and thereby degrade effluent quality.

d) Decant phase

During this phase, a decanter is used to remove the clear supernatant effluent as illustrated in Figure 4.4. Once the settle phase is complete, a signal is sent to the decanter to initiate the opening of an effluent-discharge valve. There are floating and fixed-arm decanters. Floating decanters maintain the inlet orifice slightly below the water surface to minimize the removal of solids in the effluent removed during the decant phase. Fixed-arm decanters are less expensive and can be designed to allow the operator to lower or raise the level of the decanter. It is important that no surface foam or scum is decanted. The vertical distance from the decanter to the bottom of the tank should be maximized to avoid disturbing the settled biomass.

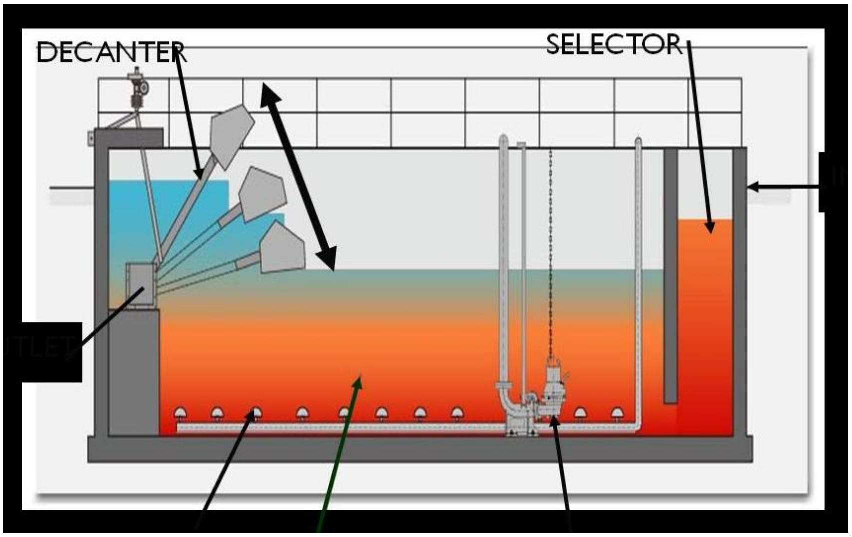


Figure 4.4: Decanting Process in SBR Tank

Idle

This step occurs between decant and fill phases. An Idle period is used in a multi-tank system to provide time for one reactor to complete its fill phase before switching to another unit. The time varies, based on the influent flow rate and the operating strategy. During this phase, a small amount of activated sludge at the bottom of the SBR basin is pumped out — a process called *wasting*. Because idle is not a necessary phase, it is sometimes omitted.

4.2.4 Nitrification & Denitrification in SBR

Removal about nutrient in SBR system was studied about nitrification, denitrification, biological phosphorous and monitoring and control. (Obaja et al., 2003; Akin et al., 2005; Ahmet, 2006). Nitrification is a two-step reaction: ammonium ($NH4^+$) is first oxidized to nitrite (NO_2^-) by autotrophic ammonia oxidizers, nitrite is then oxidized to nitrate (NO_3^-) by autotrophic nitrite-oxidizers (Reactions (I) and (II)). In anoxic denitrification, nitrite/nitrate is reduced to nitrogen gas (N_2) by heterotrophic denitrifiers with the presence of extra carbon source (acid) as electron donor (Reaction (III)). Nitrification can only be successfully operated under low chemical oxygen demand (COD), sufficient dissolved oxygen (DO) and long sludge retention time (SRT), while denitrification needs sufficient COD under anoxic condition. These different requirements pose challenges for nitrogen removal in sequencing batch reactor (SBR) systems, where nitrification and denitrification occur in the same tank (Le *et al.*, 2007)

- $2NH_4 + +3O_2 \rightarrow 2NO^{2-} + 4H^+ + 2H_2O$ (I)
- $2NO_2^- + O^2 \rightarrow 2NO_3^-$ (II)
- $5CH_3COOH + 8NO_3^- \rightarrow 4N_2 + 10CO_2 + 6H_2O + 8OH^-$ (III)

In working with initial concentrations of 1500 mg/l NH^+ 4 –N and 144 mg/l PO_3- 4–P, removal efficiency of 99.7% for nitrogen and 97.3% for phosphate was attained. The ratio C/N must be higher than 1.7 to obtain complete denitrification to molecular nitrogen during the denitrification stage. The SBR can also remove high concentrations of NH^+ 4–N even at temperatures as low as 16 °C. (Obaja *et al.*, 2003)

4.2.5 Process design consideration of SBR

The key design conditions selected are

i) The fraction of the tank contents removed during decanting
ii) The settle, decant, and aeration time.

Because the fill volume equals the decant volume, the fraction of decant volume equals the fraction of SBR tank volume used for the fill volume per cycle. Design parameters of SBR process is given in Table 4.1, design parameters for removal of phosphorus & nitrogen in SBR are given in Table 4.2 & Table 4.3 respectively.

Table 4.1: Typical design parameters for SBR process

Type of reactor	Batch
SRT, days	10-30
Volumetric loading (Kg BOD/m^3.d)	0.1-0.3
MLSS mg/L	2000-5000
F/M BOD/Kg, MLVSS.d	0.04-0.10

Table 4.2: Typical design parameter for phosphorus-removal in SBR

Type of reactor		Batch
SRT, days		20-40
MLSS mg/L		3000-4000
τ,*h*	Anaerobic zone	1.5-3
	Anoxic zone	1-3
	Aerobic zone	2-4

Table 4.3: Typical design parameter for nitrogen-removal in SBR

Type of reactor		Batch
SRT, days		10-30
MLSS mg/L		3000-5000
τ,*h*	Total	20-30
	Anoxic zone	Variable
	Aerobic zone	Variable

4.2.6 Advantages of SBR Technology

- High effluent quality; reduces main pollutants including ammonia by 96%, and reduces phosphates by 88%.

- SBR operates on storage and batching system – storing the effluent at peak times in the PST and treating it in small batches throughout the rest of the day – thereby ensuring that each batch receives the full treatment time. Batch system eliminates peak surges.

- There are no moving parts or electrical components within the tank. All functions within the tank are operated by air power generated by a small compressor/ blower.

- Process is simplified. Since all the unit processes are operated in a single tank; final sedimentation tank and return activated sludge pumping are not required, Compact facility; Operation is flexible; nutrient removal can be accomplished by operational changes, Quiescent settling enhances solid separation (low effluent SS), Systems require less space (small foot print) than extended aeration plants-of equal capacity. The system allows for automatic and positive control of mixed liquor suspended solids (MLSS) concentration and solids retention time (SRT) through the use of sludge wasting.

4.2.7 Disadvantages of SBR Technology

- High peal flow can disrupt operation unless accounted for in design.
- Batch discharge may require equalization prior to disinfection.
- Higher maintenance skills required for instruments, monitoring devices, and automatic valves.
- It is hard to adjust the cycle times for small communities.
- Sludge must be disposed frequently.
- Specific energy consumption is high.

4.3 Upflow Anaerobic Sludge Blanket (UASB)

4.3.1 Introduction

The Up-flow anaerobic sludge blanket (UASB) uses an anaerobic process whilst forming a blanket of granular sludge which suspends in the tank. The First UASB was developed by Dr. Gatze Lettinga and colleagues in the late 1970 at the Wagenigen University (Netherland) and was installed at Sugar beet refineries in Netherland.

UASB technology was adopted for the first time in India at Jajmau, Kanpur for the 5 MLD STP under Ganga Action Plan Phase-I in the year 1988-89.

The UASB reactor is mainly classified under the biological reactors, due to its biological treatment of wastewater. Recently, biological treatment has been majorly obtained a massive attention by the researchers due to its sustainability energy demand, simple construction, low cost effective, and high removal efficiency confirms its tolerance on treating high rate as well as low rate wastewater with various kind of pollutant (SHOW, K.-Y. *et al*).

4.3.2 Process type

In UASB Technology, the process involved is anaerobic treatment with suspended growth process, which is followed by aerobic treatment.

4.3.3 UASB Working Mechanism

UASB reactor operate as suspended growth system where wastewater is distributed at the bottom of the UASB reactor and travels in an up flow mode through sludge blanket as shown in Figure 4.5. In this, micro-organisms attached themselves to each other or small particles of suspended matter to form agglomerates of highly settleable granules that form an activated sludge blanket at the bottom of the reactor. The gas formed causes sufficient agitation to keep the bed fully mixed. The wastewater flows upward through a sludge blanket composed of biologically formed granules or particles. Treatment occurs as the waste comes in contact with the granules. The gas produced under anaerobic conditions cause internal circulation which helps in the formation and maintenance of biological granules. The free gas and the particles (attached with gas) rise to the top of the reactor. Particles that rise to the surface strike the bottom of the degassing baffles which releases attached gas bubbles. The degassed granules dropped back to the surface of the sludge blanket. The gas released from the granules is captured in the gas collection domes located in the top of the reactor.

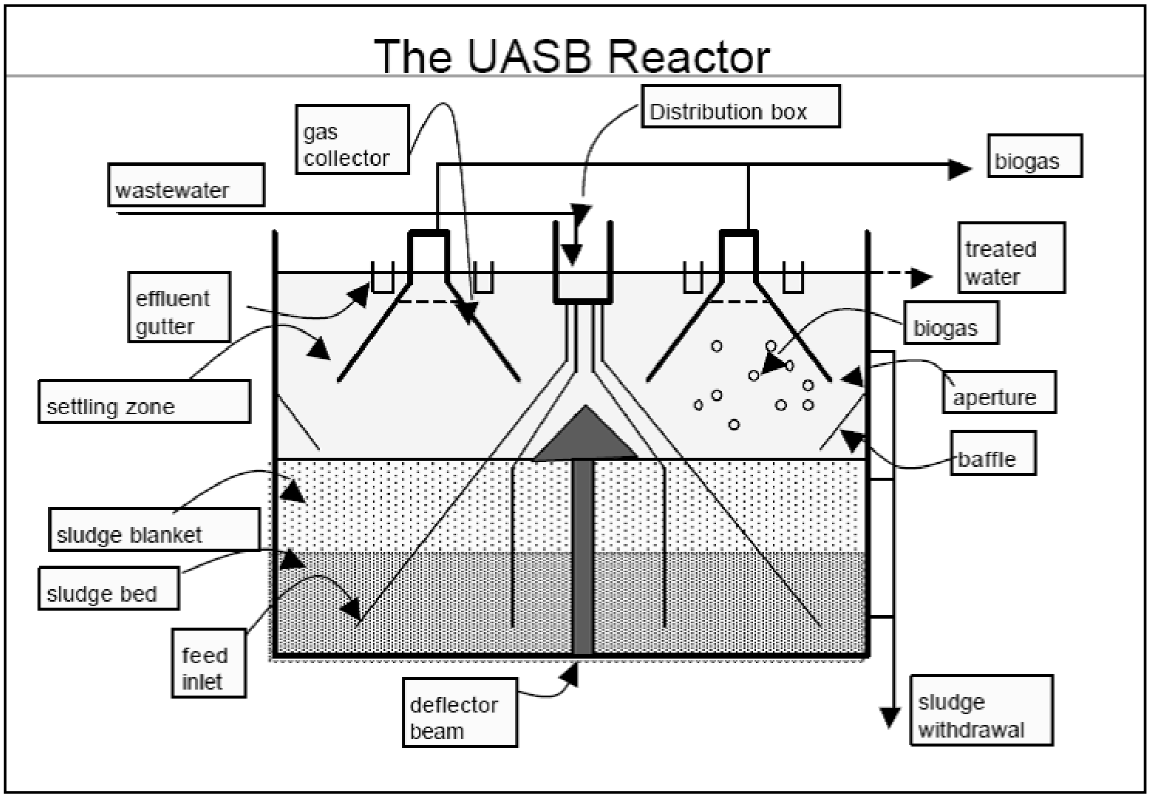


Figure 4.5 Schematic Diagram of UASB reactor

4.3.4 Anaerobic digestion stages in UASB

Anaerobic digestion indicates to various reactions and exchanges within microbial activities in a complex physio-chemical and biological process. i.e. complicated compositions of wastewater components as inputs in digester pass by many stages to be to be converted at the end to carbon dioxide (CO_2), and methane (CH_4). The process of anaerobic digestion involves many chemical exchanges affected by the physical changes as well as the environmental circumstances (Alimahmoodi M., 2004) .There are four (4) phases of anaerobic digestion in a UASB reactor as shown in Figure 4.6 and explained in the following sections.

i) **Hydrolysis**, where enzymes excreted by fermentative bacteria converts complex, heavy, un-dissolved materials (proteins, carbohydrates, fats) into less complex, lighter materials (amino-acids, sugar, alcohols).

ii) **Acidogenesis**, where dissolved compounds are converted into simple compounds (volatile fatty acids, alcohols, lactic acids, CO_2, H_2S, H_2, NH_3) and new cell matter.

iii) **Acetogenesis**, where digestion products are converted into acetates, CO_2, H_2 and new cell-matter.

iv) **Methanogenesis**, where acetate, hydrogen plus carbonate, formate, or methanol are converted into CH_4, CO_2 and new cell- matter.

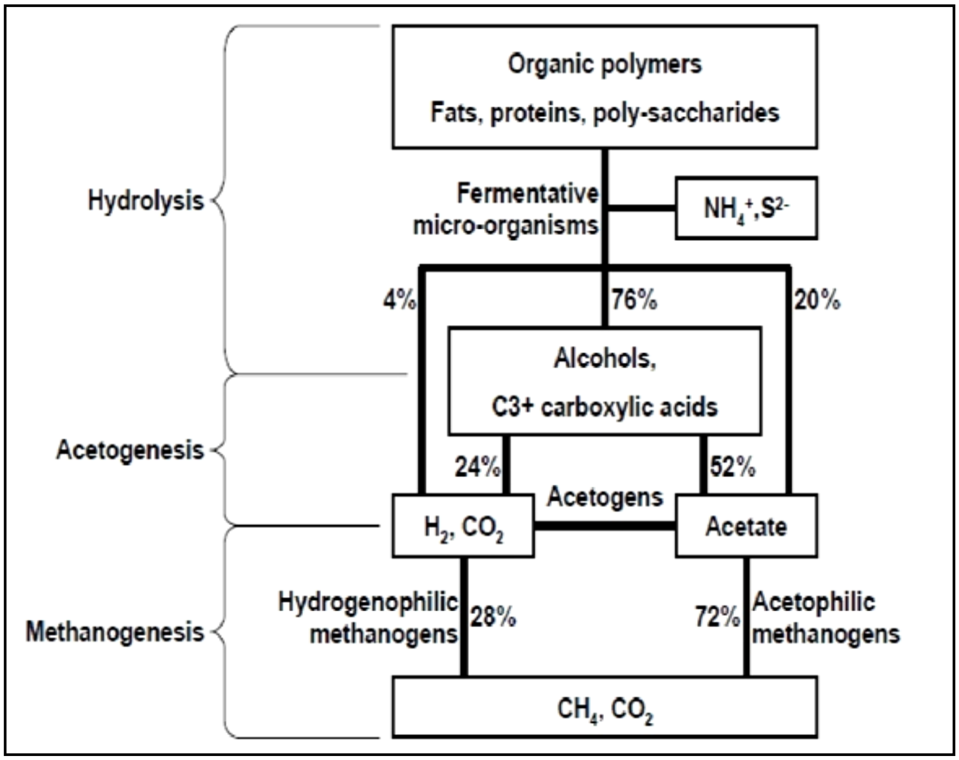


Figure 4.6 Stages in UASB Digestion

4.3.5 Key features of UASB reactor

The key features of the UASB process that allows the use of high volumetric COD loading as compared to the other anaerobic processes is the development of the dense granulated sludge. Because of the granulated sludge floc formation, the solids concentration can range from 50 to 100 g/l at the bottom of the reactor and 5 to 40 g/L in more diffuse zone at the top of the UASB sludge blanket. The granulated sludge particles have a size range of 1.0 to 3.0 mm and result in excellent sludge thickening property. The successful treatment in UASB reactor is mainly attributed to the formation of anaerobic granular in sludge bed. Where by the microbial communities is playing a very important role on digesting the substrates to biogas. Various theories have been explained the role and the behaviors of microbial communities inside UASB reactor. However, most of the theories have been indicated that acetotrophic methanogen Methanosaeta plays a key role in granulation growing.

On the other hand, some of them have been believed that Methanosarcina aggregations are enhanced granule formation. The granulation theories are in agreement with the sludge granules initiation considering that bacterial adhesion is the initial stage which can be described as (a physical-chemical process). The growth process of the particles required stabilizing operation, avoiding the particles washout which is mainly considered as the main concern of granules growing. However granulation development is totally depending on the effect of pH and temperature.

4.3.6 Process Design Considerations for UASB

Important design considerations are:

(1) Wastewater characteristics in terms of composition and solids content,
(2) Volumetric Organic Load,
(3) Upflow Velocity,
(4) Reactor Volume,
(5) Physical features including the influent distribution system, and
(6) Gas Collection System.

(i) Wastewater Characteristics. Wastewaters that contain substances that can adversely affect the sludge granulation, which can cause foaming, or cause scum formation are of concern in this particular technology. The fraction of particulate versus soluble COD is important in determining the design loadings for UASB reactors as well as determining the applicability of the process. As the fraction of solids in the wastewater increases, the ability to form a dense granulated sludge decreases. At a certain solids concentration (greater than 6 g TSS/L) anaerobic digestion and anaerobic contact processes may be more appropriate.

(ii) Volumetric Organic Loadings. Removal efficiencies of 90 to 95 percent for COD have been achieved at COD loadings ranging from 12 to 20 kg COD/m^3-d on a variety of wastes at 30 to 35°C with UASB reactors.

(iii) Upflow velocity. Temporary peak superficial velocities of 6 m/h and 2 m/h can be allowed for soluble and partially soluble wastewater respectively and is kept at 0.7 m/h typically for domestic wastewater. For stronger wastewater it will be determined by the volumetric COD loading. The upflow velocity is equal to the feed rate divided by the reactor cross-section area:

$$\mathbf{v = Q/A}$$

v= Design upflow superficial velocity, m/h
Q = influent flowrate, m^3/h
A = Reactor cross-section area, m^2

(iv) Reactor Volume and Dimensions. The effective treatment volume is that volume occupied by the sludge blanket and active biomass. An additional volume exists between the effective volume and he gad collection unit where some additional solids separation occurs and the biomass is dilute. The nominal liquid volume of the reactor based on using an acceptable organic loading is given by

$$\mathbf{V_n = Q\ S_o/L_{org}}$$

Where V_n = nominal (effective liquid volume of reactor, m^3
Q= initial flowrate, $m^{3/}h$
S_o = influent COD, Kg COD/m^3
L_{org} = organic loading rate, kg COD/m^3.d

To determine the total liquid volume below the gas collectors, an effectiveness factor is used, which is the fraction occupied by the sludge blanket.

$$\mathbf{V_L = V_{n/}E}$$

Where, V_L= Total liquid volume of reactor, m^3
V_n = Nominal liquid volume of reactor, m^3
E = effectiveness factor, unitless (0.8-0.9)

$$\mathbf{H_L = V_{L/}A}$$

Where, H_L= Reactor height based on liquid volume, m
V_L= Total liquid reactor volume, m^3
A= Cross sectional area (A= Q/v)

The gas collection volume is in addition to the reactor volume and adds an additional height of 2.5 – 3.0 m.

HT= HL+ HG

HT= Total reactor height, m
HL= reactor heights based on liquid volume, m
HG = reactor height to accommodate gas collection and storage, m

Physical Features: The main physical features requiring careful consideration are the feed inlet, gas separation, gas collection and effluent withdrawal.

(v) Gas Collection and Solid Separation: The gas solids separator (GSS) is designed to collect the biogas, prevent washout of solids, encourage separation of gas and solid particles, allow for solids to slide back into the sludge blanket zone and help to improve effluent solids removal.

Summary of UASB design parameters are shown in Table 4.4

Table 4.4: Design criteria summary of UASB

Up flow velocity	0.5 -0.9 m/h
Volumetric loading	6 – 20 kg COD /m^3.d (Depend on type of wastewater and its COD concentration)
Hydraulic retention time, HRT	6 - 48 h (depends on temperature)
MLSS concentration	At the bottom of reactor = 100000 – 150000 mg/L At the top of reactor = 5000 – 4000 mg/L
Reactor depth	3- 5 m (for domestic water) 3- 10 m (depending on COD suitability)
Biogas production	0.2 – 0.5 m^3/ kg of COD removed

4.3.7 Problems associated with UASB Process Working

(i) Shocks occurrence

The process of anaerobic digestion in UASB reactor is enormously affected by shocks occurrence. Whereby sudden change of organic loads as well as temperature happens, it can adversely affect the process [Veeresh, G. S *et al.*, 2005]. Successful operation mainly requires more understanding to the cause and influence of shocks in UASB reactor.

(ii) Loading shocks

Organic loading shocks occur as a result of organic increments of influent. Organic loading shock are extremely dropping the process efficiency by accumulating substrate in sludge bed, which is mainly caused inhibition, however, inhibition degree varies according to micro-organisms activities as well as loading shocks extent. An experiment by Hwang and Cheng have been investigated the influence of loading shocks on the performance of UASB reactor. Whereby it reported that two conditions on which inconsiderable effect may occur: (i) possible range of loading shocks does slightly affect the performance of UASB reactor i.e. negligible increase in organic loading rate of influent may not affect the process in steady-state condition. (ii) Stopping the loading shocks can accelerate the performance recovery only, whereas considerable shock may take a long time to recover a preceding performance. In other study by Fang, 1996 whereby Strong evidences have been practically presented that considerable decrease in COD removal efficiency from 83% to 52% was mainly attributed by raising the organic loading rate from 3 to 6 g COD/Litres/day (Fang, H. H. P. *et al.*, 1996).

(iii) Temperature Shocks

Temperature is the most significant parameter which is basically controlling the performance of UASB reactor. Temperature shocks usually occur in seasonal countries due to their temperatures varieties during the day. In one experiment the influence of temperature shocks has been studied by Huang and Cheng 1991, a decay rate of gas production to 40% while decreasing the temperature from 35 to 21^{o}C was reported. Another study by Fang 1996 reported that as a result of decreased temperature from 37 to 20^{o}C for about 48 hours, a considerable reduction in biogas production of 64% from the preceding production was registered. Subsequently, the partial recovery of biogas production took 5 day to reach 80% of original production whereas the full recovery has been achieved after 40 days.

4.3.8 Advantages of UASB Technology

- The system requires lesser and simpler electromagnetic parts as compared to the ones required in an Activated Sludge plant, leading to lower Operation and Maintenance Costs.
- Electricity consumption in this system, like all anaerobic system, is quite low, and the system is quite capable of withstanding long power failure.
- High reduction in organics.
- Can withstand high organic loading rates (up to 10kg BOD/m^3/day) and high hydraulic loading rates.
- Low production sludge leading to lesser cycles of de-sludging required.
- Biogas can be used for energy generation (which usually requires scrubbing prior to its usage)

4.3.9 Disadvantages of UASB Technology

- Difficult to maintain proper hydraulic conditions (upflow and settling rate must be balanced).
- Long start up time.

- Treatment may be unstable with variable hydraulic and organic loads.
- Constant source of electricity is required.
- Not all parts and materials may be available locally.
- Requires expert design and construction supervision

4.4 Activated Sludge Process (ASP)

4.4.1 Introduction

Activated Sludge Process, in which air or oxygen is forced into sewage liquor to develop a biological floc which reduces the organic content of the sewage. The activated sludge process was discovered in 1913 in the UK by two engineers, Edward Ardern and W.T. Lockett, who were conducting research for the Manchester Corporation Rivers Department at Davyhulme Sewage Works. Dr G Fowler, co-founder of the activated sludge process.

The process was named activated sludge by Arden and Lockett because it involved the production of an activated mass of microorganisms capable of aerobic stabilization of organic material in wastewater (Metcalf & Eddy, 1930)

Activated sludge system technology consists basically in the agitation of the effluent in the presence of aerobic bacteria, protozoa, metazoa and atmospheric oxygen for a sufficient period to metabolize and to flocculate a large part of the organic material (CETESB, 2000).

4.4.2 Process type

The process involved in Activated Sludge Process System is aerobic process having biological treatment with attached growth.

4.4.3 ASP working mechanism

The basic activated sludge treatment process, as illustrated in Figure 4.7, consists of the following three (3) basic components: (1) a reactor in which the microorganisms responsible for treatment are kept in suspension and aerated; (2) liquid-solid separation, usually in settling tank; and (3) a recycle system for returning solids removed from the liquid-solids separation usually in the reactor. Wastewater containing organic matter is aerated in an aeration basin in which micro-organisms metabolize the suspended and soluble organic matter. Part of organic matter is synthesized into new cells and part is oxidized to CO_2 and water to derive energy. The new cells formed in the reaction are removed from the liquid stream in the form of a flocculent sludge in settling tanks. A part of this settled biomass, described as activated sludge is returned to the aeration tank and the remaining forms waste or excess sludge.

An important feature of the activated-sludge process is the formation of flocculent settleable solids that can be removed by gravity settling in sedimentation tanks. The generation of activated sludge or floc in wastewater is a slow process and the amount so formed from any volume of wastewater during its period of treatment is small and inadequate for the rapid and effective treatment of the wastewater which requires large concentrations of activated sludge. Such concentrations are built up by collecting the sludge produced from each volume of wastewater treated and re-using it in the treatment of subsequent wastewater flows. The sludge so re-used in the process again is known as returned sludge which acts as a catalyst.

This is a cumulative process so that eventually more sludge has been produced and is available to maintain a viable biological population of organisms to treat the incoming wastes. The surplus, or excess activated sludge, is then permanently removed from the treatment process and conditioned for ultimate disposal.

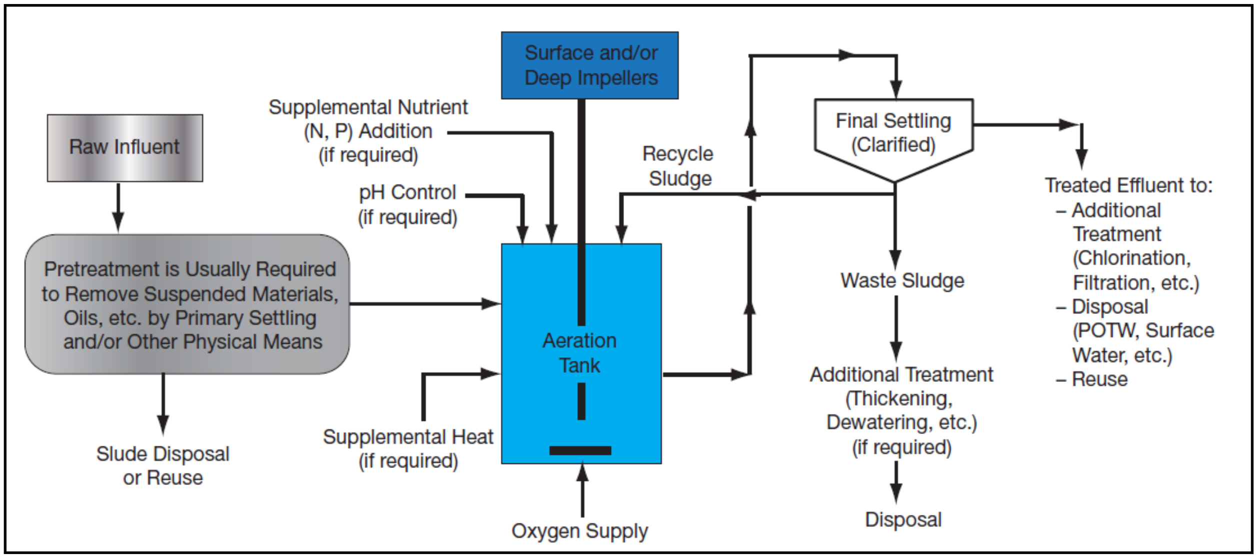


Figure 4.7 ASP Process description

Activated sludge plant involves:

1. Wastewater aeration in the presence of a microbial suspension,
2. Solid-liquid separation following aeration,
3. Discharge of clarified effluent,
4. Wasting of excess biomass, and
5. Return of remaining biomass to the aeration tank.

In activated sludge process, wastewater containing organic matter is aerated in an aeration basin in which micro-organisms metabolize the suspended and soluble organic matter. Part of organic matter is synthesized into new cells and part is oxidized to CO_2 and water to derive energy. In activated sludge systems the new cells formed in the reaction are removed from the liquid stream in the form of a flocculent sludge in settling tanks. A part of this settled biomass, described as activated sludge is returned to the aeration tank and the remaining forms waste or excess sludge.

4.4.4 Activated Sludge Process Variables

The main variables of activated sludge process are the mixing regime, loading rate, and the flow scheme which are shown if Figure 4.8

(i) Flow Scheme

The flow scheme involves:

- the pattern of sewage addition,
- the pattern of sludge return to the aeration tank, and
- the pattern of aeration.

Sewage addition may be at a single point at the inlet end or it may be at several points along the aeration tank. The sludge return may be directly from the settling tank to the aeration tank or through a sludge re-aeration tank. Aeration may be at a uniform rate or it may be varied from the head of the aeration tank to its end.

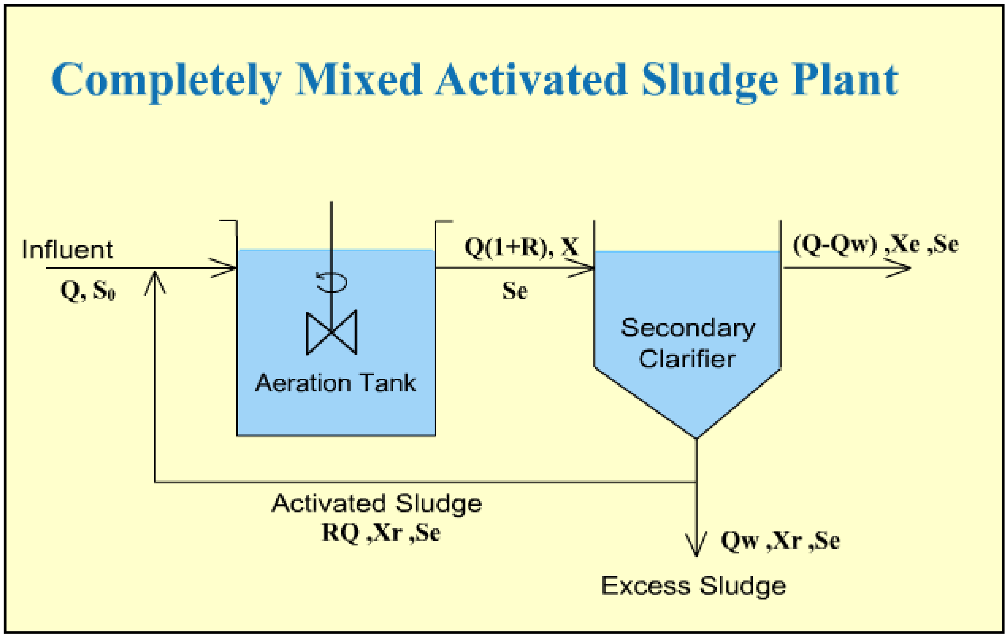


Figure 4.8 Activated Sludge Process Variables

Where,

Q = Flowrate , L^3/T

So, Se = S_O and S_e are influent and effluent organic matter concentration respectively, measured as BOD_5 (g/m^3)

X, X_e and X_r = MLSS concentration in aeration tank, effluent and return sludge, respectively

Q_w = Waste activated sludge rate

R = Oxygen supplied

(ii) Mixing Regime

Generally, two types of mixing regimes are of major interest in activated sludge process: ***plug flow*** and ***complete mixing***. In the first one, the regime is characterized by orderly flow of mixed liquor through the aeration tank with no element of mixed liquor overtaking or mixing with any other element.

There may be lateral mixing of mixed liquor but there must be no mixing along the path of flow.

In complete mixing, the contents of aeration tank are well stirred and uniform throughout. Thus, at steady state, the effluent from the aeration tank has the same composition as the aeration tank contents. The type of mixing regime is very important as it affects (1) oxygen transfer requirements in the aeration tank, (2) susceptibility of biomass to shock loads, (3) local environmental conditions in the aeration tank, and (4) the kinetics governing the treatment process.

(iii) Volumetric Organic Loading Rate

The volumetric organic loading rate is defined as the amount of BOD or COD applied ti the aeration tank volume per day and expressed in Kg BOD or COD/m^3.d, may vary from 0.3 to more than 3.0.

(iv) Sludge Retention Time

The SRT, in effect, represents the average period of time during which the sludge has remained in the system. SRT is the most critical parameter for activated-sludge design as SRT affects the treatment process performance, aeration tank volume, sludge production, and oxygen requirements. For BOD removal, SRT values may range from 3 to 5 days, depending on the mixed- liquor temperature.

Mean cell residence time or ***sludge retention time*** (SRT), θ_c, in days

$$\theta_c = \frac{V X}{Q_w X_r + (Q - Q_w) X_e}$$

Where, V is Volume in L^3, X, X_e and X_r are MLSS concentration in aeration tank, effluent and return sludge respectively, and Q_w= waste activated sludge rate.

Under steady state operation the mass of waste activated sludge is given by

$Q_w X_r = YQ\,(S_O - S_e) - k_d\,XV$

Where, Y= maximum yield coefficient (microbial mass synthesized / mass of substrate utilized) and k_d = endogenous decay rate (d^{-1}), S_O and S_e are influent and effluent organic matter concentration respectively, measured as BOD_5 (g/m^3)

From the above equation it is seen that $1/\theta_c = Yq - k_d$

(v) Food to Microorganism ratio

The food to microorganism (F/M) ratio is one of the significant design and operational parameters of activated sludge systems. A balance between substrate consumption and biomass generation helps in achieving system equilibrium. The F/M ratio is responsible for the decomposition of organic matter.

$F/M = Q(S_O - S_e) / XV = QS_O / XV$

The θ_c value adopted for design controls the effluent quality, and settleability and drainability of biomass, oxygen requirement and quantity of waste activated sludge. ASP process design parameters are shown in Table 4.5.

Table 4.5: Typical design parameters for ASP process

Type of reactor	**CMAS**
SRT, days	3-15
Volumetric loading (Kg BOD/m^3.d)	0.3-1.6
MLSS mg/L	1500-4000
F/M BOD/Kg, MLVSS.d	00.2-0.6

4.4.5 ASP Process Control Factors

Control of the activated-sludge process is important to maintain a high treatment performance level under a wide range of operating conditions. The principal factors in process control are the following:

- Maintenance of dissolved oxygen levels in the aeration tanks;
- Regulation of the amount of returning activated sludge;

- Control of the waste activated sludge.

(i) **Dissolved Oxygen Control**

Theoretically, the amount of oxygen that must be transferred in the aeration tank equals the amount of oxygen required by the microorganisms in the activated sludge system to oxidize the organic matter. In practice, the transfer efficiency for oxygen for gas to loquid is relatively low so that only a small amount of oxygen is used by the microorganisms. When oxygen limits the growth of microorganisms, filamentous organisms may predominate and the setteleability and quality of the ctivated sludge may be poor. In general, the dissolved oxygen concentration in the aeration tank should be maintained at about 1.5 to 2 mg/L in all areas of the aeration tank. Higher DO concentrations (>2.0mg/L) may improve nitrifications rates in reactors with high BOD loads. Values above 4 mg/L do not improve operations significantly though the same increases the aeration costs considerably.

(ii) Return Activated- Sludge Control

The purpose of return of activated sludge is to maintain a sufficient concentration of activated sludge in the aeration tank so that the required degree of treatment can be obtained in the time interval desired. The return of activated sludge from the final clarifier to the inlet of the aeration tank is the essential feature of the process. Ample return sludge pump capacity should be provided and is important to prevent the loss of sludge solids in the effluent. The solids form a sludge blanket in the bottom of the clarifier, which can vary in depth with flow and solids loadings variations to the clarifier. At transient peak flows, less time for sludge thickening is available so that the sludge blanket depth increases

(iii) Sludge Wasting Control

To maintain a given SRT, the excess activated sludge produced each day must be wasted. The waste sludge can be discharged to the primary sedimentation tanks for co-thkning, to thickening tanks, or to other sludge thickening facilities. An alternative method of wasting sometimes used is withdrawing mixed liquor directly from the aeration tank or the aeration tank effluent pipr where the concentration of solids is uniform. The waste mixed liquor can then be discharged to sludge –thickening tank or to primary sedimentation tanks where it mixes and settles with the untreated primary sludge

4.4.6 Advantages of ASP Plant

- Performance is not significantly affected due to normal variations in wastewater characteristics and seasona

4.4.7 Disadvantages of ASP Plant

- High recurring cost.

- Process requires high energy consumption.
- Performance is adversely affected due to interruption in power supply even for short period.
- Foaming, particularly in winter season, may adversely affect he oxygen transfer, and thus affect the performance of the plant.
- Requires elaborate sludge digestion/drying/disposal arrangement.

4.5 Oxidation Ditch

4.5.1 Introduction

An oxidation ditch is a modified activated sludge biological treatment process that uses long solids retention times (SRTs) to remove biodegradable organics. The typical oxidation ditch is equipped with aeration rotors or brushes that provide aeration and circulation. The wastewater moves through the ditch at 1 to 2 ft/s. The ditch may be designed for continuous or intermittent operation. Because of this feature, this process may be adaptable to the fluctuations in flows and loadings associated with recreation area wastewater production.

"Oxidation Ditch" or the oxidation process originated in the Netherlands, with the first full scale plant installed in Voorschoten, Holland, in 1954.

4.5.2 Process Type

The process involved in this technology is aerobic having biological treatment with suspended growth process.

4.5.3 Oxidation Ditch Working Mechanism

It is based on the principle of the Activated Sludge Process i.e. stabilization of biodegradable organic content of wastewater by the mixed population of micro-organisms. During the stabilization of organic content, biodegradable organic matter is oxidized or synthesized by microorganisms in aerobic conditions to produce new cell and other simple end products like CO_2 & H_2O etc. As shown in Figure 4.9, typical oxidation ditch treatment systems consist of a single or multichannel configuration within a ring, oval, or horseshoe-shaped basin. Surface aerators, such as brush rotors, disc aerators, draft tube aerators, or fine bubble diffusers are used to circulate the mixed liquor. The mixing process entrains oxygen into the mixed liquor to foster microbial growth and the motive velocity ensures contact of microorganisms with the incoming wastewater. The aeration sharply increases the dissolved oxygen (DO) concentration but decreases as biomass uptake oxygen as the mixed liquor travels through the ditch. Solids are maintained in suspension as the mixed liquor circulates around the ditch. Oxidation ditch effluent is usually settled in a separate secondary clarifier.

In the carousel arrangement, vertical shaft mechanical aerators are positioned in the oxidation ditch channel at the two ends of the race track configuration oxygen transfer and mixed liquor recirculation/mixing.

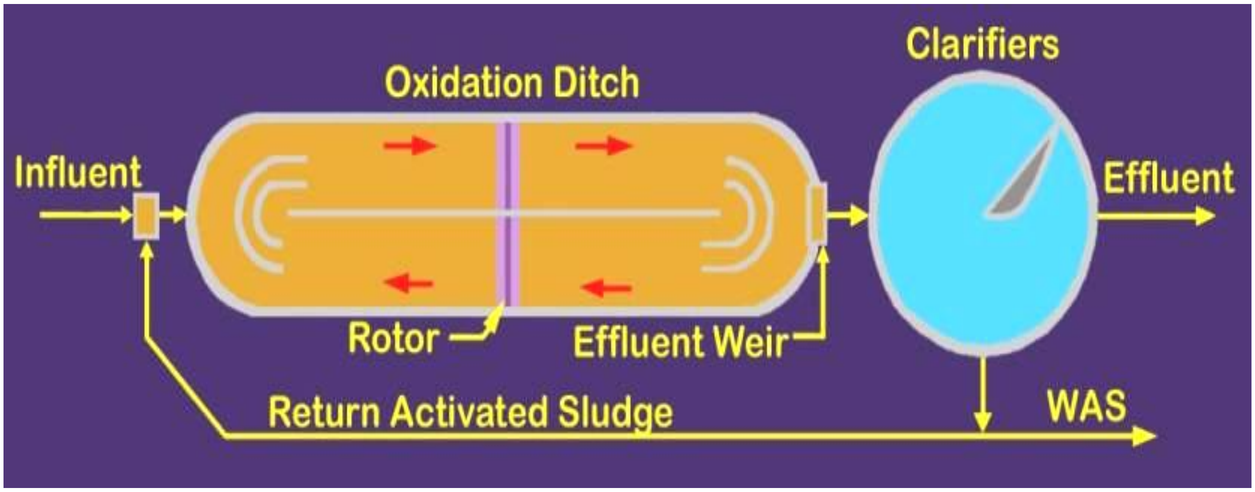


Figure 4.9: Schematic diagram of Oxidation Ditch

The ability to provide aerobic/anoxic/anaerobic conditions within an oxidation ditch allows a condition conducive for carbonaceous BOD removal, nitrification, and denitrification with a single sludge system. BOD removal or oxidation of organics is achieved in both the aerobic and anoxic zones of the channel. Nitrification or oxidation o f ammonia to Carbonaceous nitrate occurs only in the aerobic' portion of the channel. Denitrification or conversion o f nitrate to nitrogen gas occurs only in the anoxic portion of the channel.

4.5.4 Nutrient removal in Oxidation ditch

Carbonaceous BOD removal in the ditch process is achieved by facultative heterotrophic bacteria. The reaction occurs in two phases. The overall oxidation reactions are presented as Equation 1 and Equation 2.

1. Organics + O_2 + N + P $\longrightarrow$ New Cells + CO_2 + H_2O + Nondegradable Cellular Residue
2. Cells + O_2 $\longrightarrow$ CO_2 + H_2O + N + P + Nondegradable Cellular Residue

In the aerobic portion of the channel, organic materials (BOD, COD and TOC) are oxidized by the bacteria using oxygen as an electron acceptor. In the anoxic portions o f the basin, the organic materials are oxidized by the bacteria using nitrate (NO_3^-) as an electron acceptor. Consequently, the alternating aerobic/anoxic oxidation of organic materials results in reduced power requirements for aeration and a reduction in capital and operational cost.

Nitrification is the two-step biological oxidation of ammonia (NH_3) to nitrate (NO_3). The oxidation is performed by aerobic autotrophic bacteria frequently called nitrifiers. The predominant species responsible are nitrobacter and nitrosomonas. Equations describing the oxidation of amnonia to nitrite (NO_2) and oxidation of nitrite to nitrate are presented in Equations 3 and 4, respectively.

3. $2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 2H_2O + 4H^+$ + New Cells

4. $2NO_2^- + O_2 \rightarrow 2NO_3^-$ + New Cells

Nitrification occurs only under aerobic conditions. Temperature, pH, and alkalinity are primary factors in biological nitrification. Alkalinity is consumed at a rate of approximately 7.14 pounds per pound of ammonia nitrified. This alkalinity reduction causes the pH of the mixed liquor to drop. The rate of nitrification drops off rapidly at pH levels of less than 7. There is also a significant drop in nitrification rates at temperatures less than $15^{O}C$.

Denitrification or nitrogen removal is the biological reduction of nitrate (NO_3^-) ion to nitrogen gas (N_2). The process is performed under anoxic conditions by facultative heterotrophic bacteria. The formula which represents the chemical reaction is presented in Equation 5 as shown below.

5. $6NO_3- + 5CH_3OH \longrightarrow 3N2 + 5CO_2 + 7H_2O + 6OH^-$ + New Cells.

A carbon source (shown as CH_3OH in Equation 5) is required for denitrification to occur. In the oxidation ditch process, the carbonaceous BOD in the wastewater is utilized as the carbon source. Denitrification is an alkalinity producing process whereby approximately 3.57 pounds of alkalinity are released per pound of denitrified nitrate. Denitrification therefore slows the lowering of pH caused by nitrification in the mixed liquor.

4.5.5 Design Criteria of Oxidation ditch

Screened wastewater enters the ditch, is aerated, and circulates at about 0.25 to 0.35 m/s (0.8 to 1.2 ft/s) to maintain the solids in suspension (Metcalf & Eddy, 1991). The RAS recycle ratio is from 75 to 150 percent, and the Mixed Liquor Suspended Solids (MLSS) concentration ranges from 1,500 to 5,000 mg/L (0.01 to 0.04 lbs/gal) (Metcalf & Eddy, 1991).

The oxygen transfer efficiency of oxidation ditches ranges from 2.5 to 3.5 lb./Hp-hour (Baker Process, 1999). The design criteria are affected by the influent wastewater parameters and the required effluent characteristics, including the decision or requirement to achieve nitrification, denitrification, and/or biological phosphorus removal. Specific design parameters for oxidation ditches include:

(i) Solids Retention Time (SRT): Oxidation ditch volume is sized based on the required SRT to meet effluent quality requirements. The SRT is selected as a function of nitrification requirements and the minimum mixed liquor temperature. Design SRT values vary from 15 to 30 or more days.

(ii) BOD Loading: BOD loading rates vary from less than 160,000 mg/1000 liters (10 lb./1000 ft^3) to more than 4x107 mg/1000 liters (50 lb./1000 ft3). A BOD loading rate of 240,000 mg/1000 liters per day (15 lb./1000 ft^3/day) is commonly used as a design loading rate. However, the BOD loading rate is not typically used to determine whether or not nitrification occurs.

(iii) Hydraulic Retention Time: While rarely used as a basis for oxidation ditch design, Hydraulic Retention Times (HRTs) within the oxidation ditch range from 6 to 30 hours for most municipal wastewater treatment plants. Design parameters for Oxidation ditch process are shown in Table 4.6 and design parameter for removal of nitrogen in shown in Table 4.7

Table 4.6: Typical design parameters for Oxidation Ditch process

Type of reactor	**Plug flow**
SRT, days	15-30
Volumetric loading (Kg BOD/m^3.d)	0.1-0.3
MLSS mg/L	3000-5000
F/M BOD/Kg, MLVSS.d	0.04-0.10

Table 4.7 Typical design parameter for Nitrogen removal in Oxidation Ditch

Type of reactor		**Plug flow**
SRT, days		20-30
MLSS mg/L		2000-4000
τ,h	Total	18-30
	Anoxic zone	Variable
	Aerobic zone	Variable
RAS, % of influent		50-100

4.5.6 Advantages of Oxidation Ditch

The main advantage of the oxidation ditch is the ability to achieve removal performance objectives with low operational requirements and operation and maintenance costs. Some specific advantages of oxidation ditches include:

- An added measure of reliability and performance over other biological processes owing to a constant water level and continuous discharge which lowers the weir overflow rate and eliminates the periodic effluent surge common to other biological processes, such as SBRs.
- Long hydraulic retention time and complete mixing minimize the impact of a shock load or hydraulic surge.
- Produces less sludge than other biological treatment processes owing to extended biological activity during the activated sludge process.
- Energy efficient operations result in reduced energy costs compared with other biological treatment processes.

4.5.7 Disadvantages of Oxidation Ditch

- Effluent suspended solids concentrations are relatively high compared to other modifications of the activated sludge process.
- Requires a larger land area than other activated sludge treatment options. This can prove costly, limiting the feasibility of oxidation ditches in urban, suburban, or other areas where land acquisition costs are relatively high.

Description of the STPs with different technologies that were selected for the study is listed in Table 4.8 below.

Table 4.8: Description of STPs for selected for the study

S. No.	Name & Location of STP	Treatment Technology	Capacity	Year of Commissioning	Developed by	Maintained by	Treated water discharge/ disposal
1	**Sen Nursing Home STP, Delhi**	BIOFER	10 MLD	2003	DJB	M/s Degremont Pvt Ltd	To PPCL for Electricity generation.
2	**SBR Indirapuram, UP**	SBR	74 MLD	2012	UP Jal Nigam, Ghaziabad	M/s UEM India Pvt. Ltd	Hindon River
3	**UASB, Dhanwapur, Gurgaon**	UASB	30 MLD	1998	PHED	Some private agency	Najafgarh drain
4	**Phase-I, Rithala, Delhi**	ASP	182 MLD (40 MGD)	1990	DJB	Some private agency	Najafgarh drain
5	**Phase-II, Rithala, Delhi**	ASP-BIOFOR	182 MLD (40 MGD)	2001-2002	DJB	M/s Degremont Pvt Ltd	Najafgarh drain
6	**Phase-II, Keshopur, Delhi**	Oxidation Ditch	20 MGD	1975	DJB	M/s Va-Tech Wabag Ltd	Najafgarh drain

CHAPTER- 5

PERFORMANCE EVALUATION OF STPs WITH DIFFERENT TECHNOLOGIES IN DELHI/NCR- A CASE STUDY

5.1 BIOFOR Based STP at Dr. Sen Nursing Home Drain, Delhi

5.1.1 Introduction of the STP

The Sewage Treatment Plant established at Dr. SEN Nursing Home Nallah with a capacity of 10.0 MLD [2.2 MGD] of average flow. It is located on the north bank of the Dr. Sen Nursing Home Nallah, east of the Ring road. Details of the plants are as follows:

(i)	**Plant capacity**	10.0 MLD
(ii)	**Plant Location**	Installed at Dr. Sen Nursing Home drain, behind Indraprastha Metro Station.
(iii)	**Year of Commissioning**	The plant was commissioned during 2003
(iv)	**Developed & Maintained by**	Constructed by M/s Degremont Pvt Ltd for Delhi Jal Board under Yamuna Action Plan.
(v)	**Capital Cost**	6.21 Crores
(vi)	**Sewage intake**	From Dr. SEN Nursing home drain flowing adjacent to the plant, having flow of around 60-70 MLD.
(vii)	**Treatment Technology**	Intensified Aerobic treatment with Dense-Deg & BIOFER
(viii)	**Treatment Units**	Screening, aerated mechanical grit chamber with clarifier; Flash mixer, coagulation and flocculation chamber, clarifier cum thickener; Double stage fluidized bed BIOFOR tanks; Sludge pit, sludge recirculation, sludge press.
(ix)	**Biogas utilization**	Not applicable, no biogas is generated.
(x)	**Treated Water disposal**	Treated water is utilized by Pragati Power Corporation Ltd (PPCL) for cooling towers and in return PPCL provide electricity for operating the STP.

Figure 5.1 Satellite image of STP based on BIOFOR Technology at Sen Nursing Home, Delhi

A satellite imagery of the STP located near Indraprastha Metro Station taken from google earth is shown in the Figure 5.1.

5.1.2 Process Description of STP based on BIOFOR Technology

(i) Raw Sewage Sump and Bar Screens

Raw Sewage is passed through an Inlet channel and then two numbers of coarse screens (One working and one standby) equipped with 35mm opening for removing any floating material. These screens are cleaned manually with the help of rakes. The raw sewage from the raw sewage sump is pumped up to the elevated structures to allow gravity flow in the further treatment process. Six nos. of horizontal centrifugal non-clog pumps are provided to pump the sewage to the Elevated structures. Once the Raw Sewage is pumped to the Elevated Structures it undergoes medium screening by 20 mm screens and fine screening with 5 mm screens as shown in Figure 5.2. Then effluent flows to the grit and grease removal unit

(ii) Grit and Grease removing unit

The Grit and Scum Removal unit is an aerated chamber as shown in Figure 5.3. The grit extraction is carried out by the airlift mechanism. The scour air required for the lifting of the grit hoppers is supplied by the same blower, which is used for feeding the air diffusers in the Grit removal unit. The grit is then lifted up by the inclined Screw Conveyor and the Grit dropped into a trolley for further disposal. The scum steaming from the floating of grease is removed manually.

(iii) Flow measurement

The Sewage after undergoing Grit Removal flows through the Parshall Flume where the Flow is displayed by the Ultrasonic Flowmeter. The Parshall flume has a flow meter, recorder and indicator leads, etc.

Figure 5.2: Fine Screens in BIOFOR based STP

Figure 5.3: Grit and Grease removing unit

(iv) Physico Chemical Treatment

After pre-treatment, the effluent undergoes a Physico-Chemical treatment to remove most of suspended solids in the influent and thus reducing the BOD. The Physico-Chemical treatment comprises of flash mixing and flocculation followed by clarification. After the Parshall Flume, the Sewage flows into the Flash Mixer wherein commercial Alum is dosed for the coagulation of the Sewage. The Flash Mixer ensures a perfect mixing of the coagulating Alum with the Raw Sewage.

(v) Alum Preparation Tank and Dosing

Alum solution is dosed in the Flash Mixer at the inlet of densadeg. Two (2) nos. alum solution preparation tanks have been provided with agitators**.** Alum tanks are provided with overflow drain lines along with drain valves.

Alum solution preparation is carried out in one tank at a time while alum dosing will be carried out using the other. Two nos. reciprocating metering pumps are provided to transfer alum solution to Flash Mixer of densadeg. The pumps are designed to operate on one (1) working and one (1) standby basis.

(vi) DENSADEG Clarifier

The DENSADEG is a high performance clarifier developed by Degremont as shown in Figure 5.4. It consists of three (3) main technological modules:

a) **Reactor:** The reactor Module for flocculation, uses two successive zones with a variable flocculation Energy. It is designed for both rapid flocculation and slow flocculation for floc growth with Sludge recycling. The resultant floc has a high level density which is enhanced by using a Polymer.

b) **Pre – Settling – Thickening:** This Module leads to homogeneity to the Settling and Thickening of the Floc. Thickening is promoted by continuous scraping of the precipitated Sludge. Part of the Sludge (i.e. 30 m^3/hr.) is recirculated in the Reactor.

c) **Lamella Clarifier**: The lamella Clarifier features a rack of inclined metal plates, which cause flocculated material to precipitate from water that flows across the plates. The residual floc is removed in this module with tube modules for fast settling producing the final quality of Primary Treated Sewage.

Figure 5.4: DENSADEG Clarifier

(vii) Biological Filters / BIOFORS

The final stage of treatment is biological filtration. This stage reduces the content of Suspended Solids and the BOD in the effluent to the required levels. The biological filtration is carried out in two identical successive stages and each stage consists of a battery of four filters operating simultaneously. BIOFILTERATION stages are shown in Figure 5.5 and Figure 5.6.

Figure 5.5: BIOFOR Stage –I Filtration

Figure 5.6: BIOFOR Stage – II Filtration

Each filter has an RCC false floor cast near the bottom of filter media. The false floor is fitted with polypropylene Degremont-make UC25 nozzles. These nozzles are provided to allow passage of air/water as required. Each nozzle consists of a hollow stem approximately 30 cm long located below the false floor and a vertically slotted top above floor. The slot width at top is less than the media particle size ensuring that no media escape through the slots. The bottom of the nozzle stem contains a hole and vertical slot for air passage during backwash air scouring while backwash water enter the nozzle from the bottom of the scum. Thus during backwashing an air cushion is formed just below the false floor with the water layer below. The large number of nozzles provided ensures equal distribution of air/water throughout the filter without any short circuiting. Each filter has an up flow operation, through a layer of media in which pollution reduction is biologically. This treatment is an aerobic one in which process air is supplied to each unit by process air blowers, common to both batteries on a continuous basis

Periodic washing of the media is required to evacuate the sludge accumulated. Backwashing requirement arises due to the slow biological growth of bacteria in the filter media as well as retention of the suspended solids carried by the effluent. As media chock age increases, the head loss through the filter bed also increases resulting in water level in the inlet chamber to rise. Hence, backwashing is required to clean media at regular intervals.

(viii) Dewatering Unit

The excess sludge produced in the plant is mechanically dewatered by Degremont presssdeg to reduce the handling volume of Sludge. The PRESSDEG is designed to remove the water contained in the sludge of DENSADEG by continuous filtration of Sludge, under pressure. The Sludge Layer is placed between two (2) belts after appropriate Polyelectrolyte conditioning that promotes the formation of bulky floc well separated from water.

(ix) Treated Effluent Tank

An RCC treated effluent tank is provided to hold the final treated water from second stage filters. The capacity of tank is designed to retain about 300 m^3 of water, which is equivalent to one filter backwash requirement. The overflow from this tank returns by gravity to the downstream of nallah through an RCC channel / outfall or reused for other purpose.

(x) Treated Water Disposal

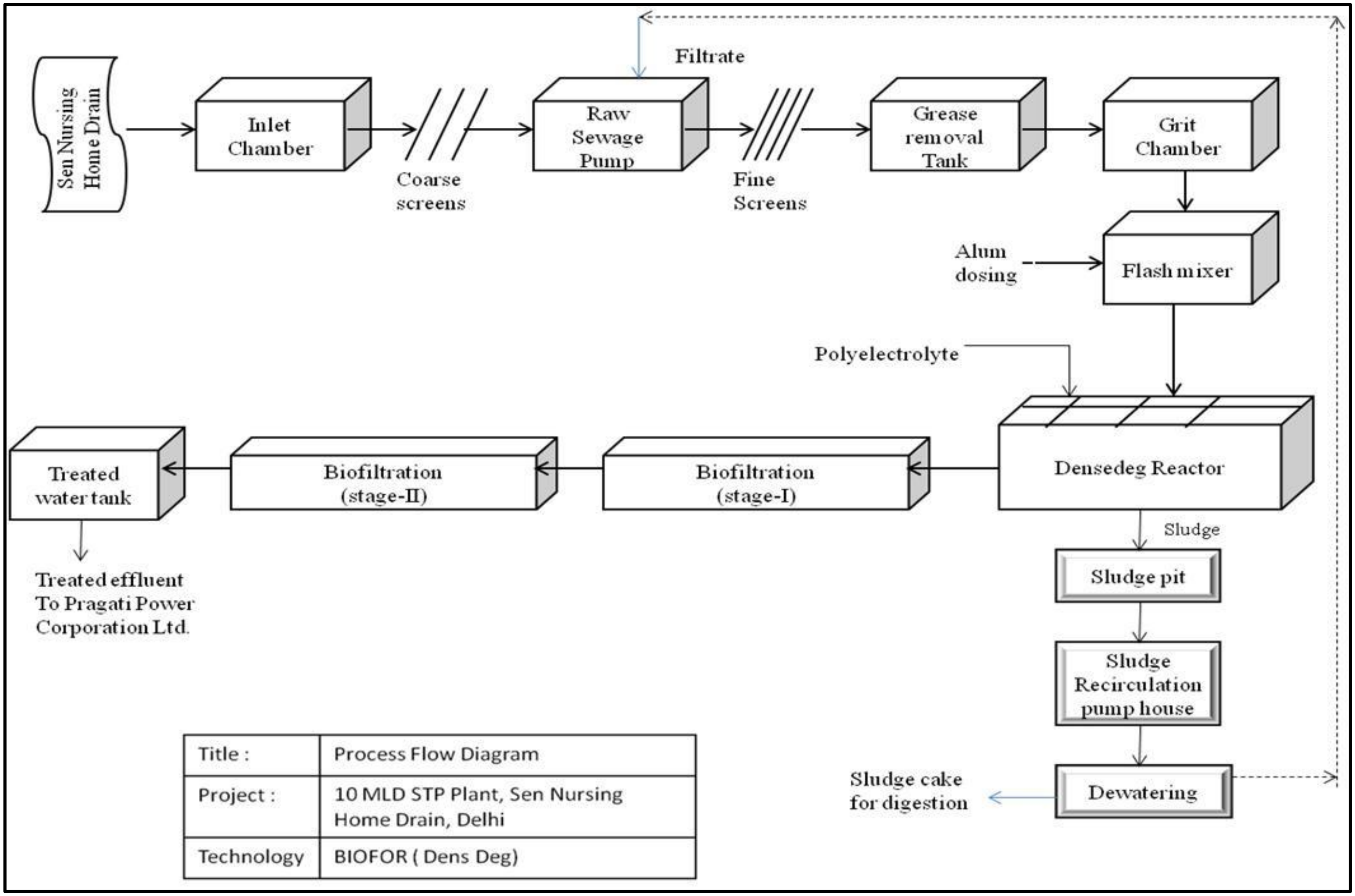
Treated water is utilized by Pragati Power Corporation Ltd (PPCL) for cooling towers and in return PPCL provide electricity for operating the STP.

Dimensional details of STP units and facilities installed at Dr. Sen Nursing Home drain are shown in Table 5.1, and Process Flow Diagram of STP is shown in Figure 5.7.

Table 5.1: Dimensional details of various units and facilities of the STP based on BIOFOR at Sen Nursing Home Drain, Delhi.

Unit	No.	Dimensions
Flow		**10 MLD**
Raw Sewage Sump	1	20m X 7.95m, Rectangular shape
Raw Sewage pump House	1	20m X 11.9m
Grit & grease removing Unit	1	7m X 4m X 3.5 m Surface Loading rate = $30m^3/m^2/d$ Settling Velocity = 0. 95m / Sec Grit Extraction: by air lift Blower = (1 duty / 1 standby) Roots type Capacity= 250 Nm^3 / hr @ 6 bar
Densadeg Reactor	1	Tube clarifier Flocculating Reagent = Polyelectrolyte Rising Velocity = 10 m^3/m^2/hr. at Avg.Flow 20 m^3/m^2/hr. at Peak Flow
Flocculent Chamber	1	1.5mX 1.5m, Rectangular with baffles
Clarifier	1	Type = Tube clarifier Capacity= 8.3mX 8.3m
Dewatering equipment	1+1	Continuous Belt press filter Belt width = 2m Cake dryness = 30 %
BIOFOR	2X4	Type = Fixed Film Biological Filter Surface flow rate = 7.1m/hr at peak flow. Filter Medium = Biolite Media level = 2.9 m(with gravel)
Treated effluent Tank	1	Flow-rate = $300m^3$

Figure 5.7: Process Flow Diagram of STP based on BIOFOR at Sen Nursing Home Drain, Delhi



Title :	Process Flow Diagram
Project :	10 MLD STP Plant, Sen Nursing Home Drain, Delhi
Technology	BIOFOR (Dens Deg)

5.1.3 BIOFOR-STP Performance Evaluation & Analysis

Samples were collected from the Inlet & Outlet point of the treatment plant to evaluate the overall performance of the treatment plant to reduce the pollution load on the receiving waters. Samples were collected once in a month for the period from January to May 2013 and the analytical results as obtained are summarized in Table 5.2 below. The variation in pH, TSS, BOD and COD in different months is shown in Figure 5.8, Figure 5.9, Figure 5.10 and Figure 5.11 respectively.

Table 5.2: Physico-chemical analysis of STP based on BIOFOR technology

Parameters	**pH**		**TSS**		**BOD**		**COD**	
Month- 2013	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
January	7.03	6.8	969	17	306	3	925	13
February	7.4	7.3	448	14	115	10	296	36
March	7.3	7.2	324	12	140	8	460	32
April	7.4	7.3	328	14	100	9	368	32
May	7.4	7.3	344	14	145	8	324	44
Maximum	7.4	7.3	969	17	306	10	925	44
Minimum	7.03	6.8	324	12	100	3	296	13
Average	**7.3**	**7.2**	**483**	**14.2**	**161.2**	**7.6**	**475**	**31.4**
Percentage Reduction	-		**97%**		**95.2%**		**93.4%**	

No disinfection of treated water is currently being practiced at STP of Dr. Sen Nursing Home drain**.** Samples at inlet and outlet of were examined for Fecal Coliform and Total Coliform parameter in order to assess microbial contamination removal. Results of the microbial analysis are summarized in Table 5.3.

Table 5.3: Microbial analysis of STP based on BIOFOR Technology

S. No.	**Parameter**	**Inlet**	**Outlet**
1.	**Total Coliform (MPN/100ml)**	$97 X10^6$	$42X10^5$
2.	**Fecal Coliform (MPN/100ml)**	$24 X10^7$	$23 X10^4$

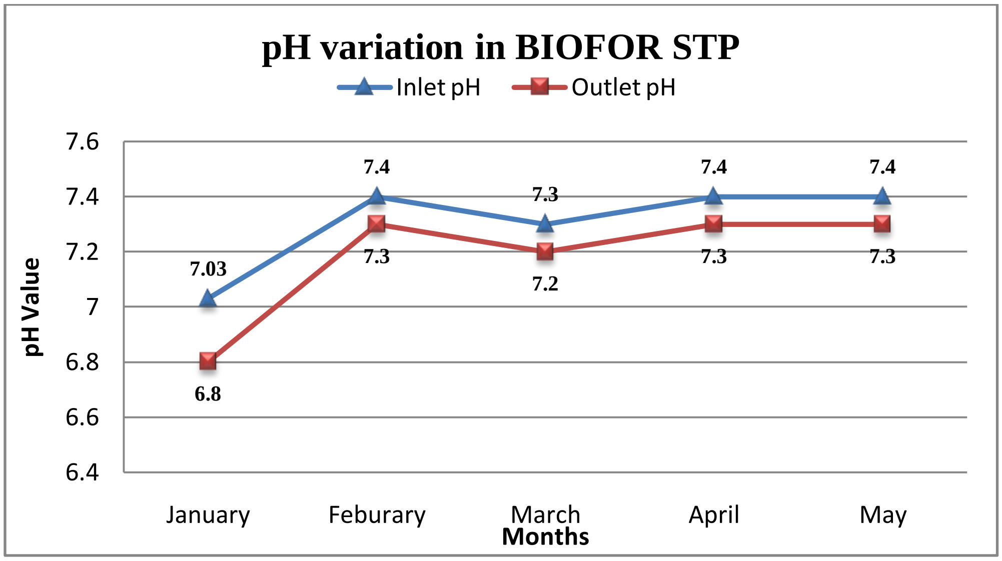


Figure 5.8: pH variation in BIOFOR STP located at Sen Nursing Home Drain, Delhi

From the Figure 5.8, it can be seen that pH value at the outlet of the plant is lowered as compared to the inlet of the plant. Throughout the study pH value at the outlet was almost consistent at the value range between 7.2-7.3. However, in the month of January it was found slightly varied upto 6.8 that created acidic conditions in the system. Bacteria that treat wastewater to reduce the COD and BOD, are extremely sensitive to pH. Therefore, pH can also have a huge effect on activated sludge COD and BOD reduction rates.

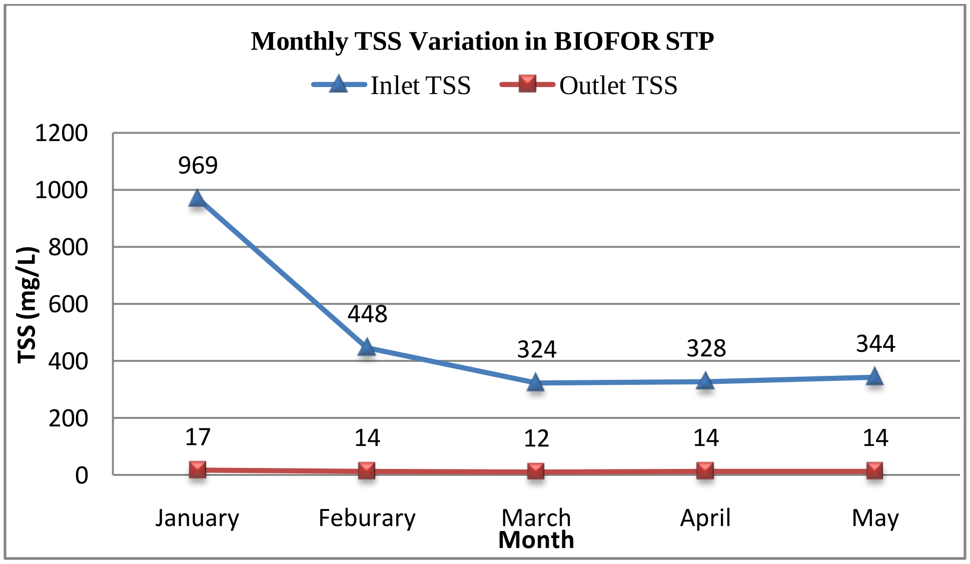


Figure 5.9 TSS variations in BIOFOR STP located at Sen Nursing Home Drain, Delhi

From Figure 5.9 above, it is depicted that, in the month of January, the value of TSS was found quite high at the inlet of the Plant which is 969 mg/L and at the outlet it was found 17 mg/L. Due to DENSADEG primary clarifier, the removal efficiency of TSS is very high in BIOFOR Plant.

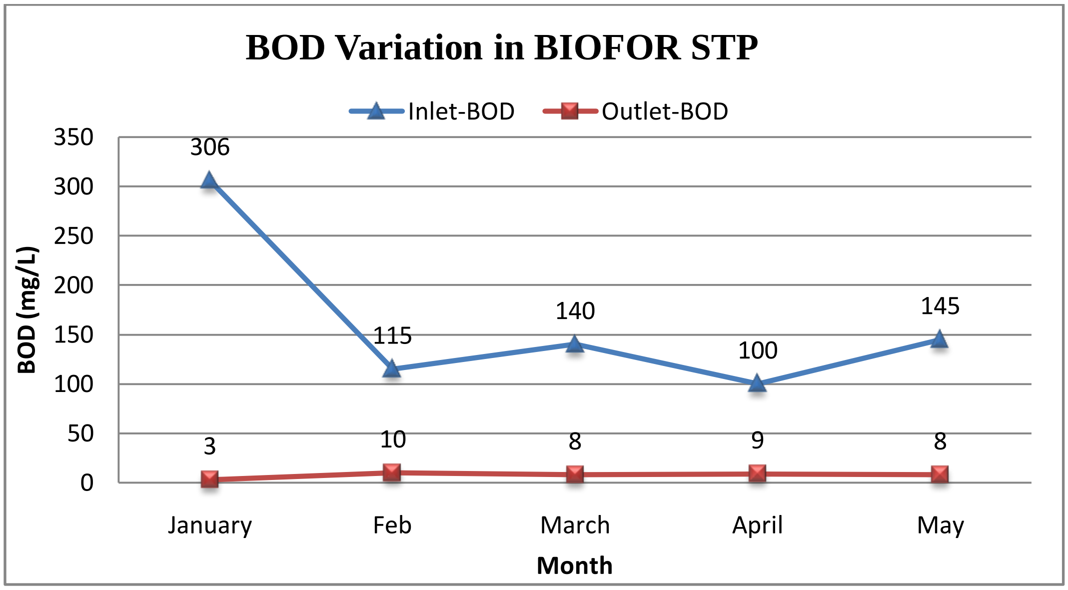


Figure 5.10 BOD variation in BIOFOR STP located at Sen Nursing Home Drain, Delhi

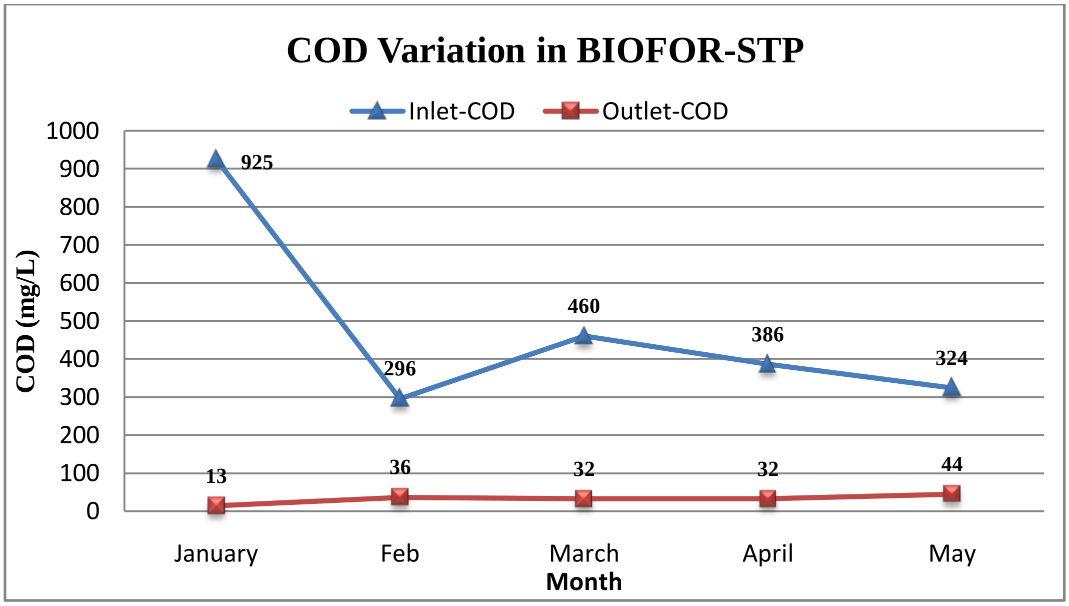


Figure 5.11 COD variation in BIOFOR STP located at Sen Nursing Home Drain, Delhi

Figure 5.10 & Figure 5.11 as shown above demonstrates the BOD & COD variation of BIOFOR plant respectively from the month of January to May. It can be seen that, in the month of January BOD & COD values are high with values as 306 mg/L and 925 mg/L respectively and throughout the study it ranges between 100mg/L to 145 mg/L for BOD and 296 mg/L to 460 mg/L except in the month of January. Due to advanced aerobic two-stage Biofiltration, BOD & COD removal rate is very high in BIOFOR Plant.

5.2 SBR Based STP at Indirapuram, Uttar Pradesh

5.2.1 Introduction of the STP

The Sewage Treatment Plant at Indirapuram, Ghaziabad, Uttar Pradesh has been designed to treat 74 MLD of raw sewage flowing in the Sahibabad drain. The plant was commissioned during 2012 and constructed by M/s UEM India Pvt. Ltd. (hereinafter referred to as UEM). Details of plant are as follows:

i)	**Plant capacity**	74 MLD
ii)	**Plant Location**	Installed at Shakti Khand, Indirapuram, Uttar Pradesh
iii)	**Year of Commissioning**	The plant was commissioned during 2012
iv)	**Developed & Maintained by**	Constructed by M/s UEM India Pvt. Ltd for UP Jal Nigam, Ghaziabad under Yamuna Pollution Control Unit - I.
v)	**Capital Cost**	100 Crores
vi)	**Sewage intake**	From Sahibabad drain
vii)	**Treatment Technology**	Sequencing batch reactor (SBR) is a fill-and draw process with returned activated sludge system.
viii)	**Treatment Units**	Inlet Chamber, Coarse Screen, Main Pumping Station, Stilling Chamber , Fine Screens, Grit Removal System, Distribution Chamber for Bioreactor, SBR Tank, Chlorination Contact Tank, Treated Effluent channel, sludge thickener, Centrifuge
ix)	**Biogas utilization**	Not applicable, no biogas is generated.
x)	**Treated Water disposal**	Treated water is discharged in to Hindon River and ultimately in to River Yamuna.

A satellite imagery of the STP located near Indirapuram, in the state of Uttar Pradesh is shown in the Figure 5.12.

Figure 5.12: Satellite image of STP based on SBR Technology at Indirapuram, Uttar Pradesh

5.2.2 Process Description of STP based on SBR Technology

(i) Overflow Weir

An overflow weir / flow diversion arrangement across the Sahibabad drain is provided, so as to impound the water flowing in the drain and divert it to the raw sewage sump cum pump house of the treatment plant.

(ii) Inlet Chamber/Coarse Screens

The sewage after screening is conveyed to the inlet chamber of main pumping station with hydraulic retention time as mentioned .Wastewater carries large objects such as wood, plastics, cloth etc that may damage or obstruct pumps and equipments or structures in subsequent stages of the treatment. To take care of such objectionable materials, as shown in Figure 5.13, coarse screens of size 40 mm are provided before the raw sewage is transferred to the main pumping station of the STP.

Figure 5.13: Coarse Screen: 40mm at SBR based STP

(iii) Stilling Chamber & Fine Screens

The sewage from main pumping station is pumped to the stilling chamber with hydraulic retention of 30 sec. There are two (2) Mechanical (working) and two (2) Manual (standby) i.e. mechanically cleaned screen of 6 mm clear opening and of manually cleaned fine screen of 10 mm clear opening.

(iv) Grit Removal Unit

The Screened sewage flows by gravity into Mechanical Grit Separators. Grit removal is necessary to protect the moving mechanical equipment and pump elements from abrasion and accompanying abnormal wear and tear. Also, removal of grit reduces the frequency of cleaning of SBR tanks.

Grit removal system with central scrapper mechanism, screw classifier and organic return pump has been provided. The solids are removed by a rotating scrapper mechanism to a sump at the side of the tank. Settled grit is removed by a reciprocating rake mechanism. Organic solids are separated from the grit by organic return pump, propeller type screw pump suitable for low lift and non-clog design.

(v) Flow Measurement

Flow measurement is being done through a Parshall Flume. An ultrasonic level measurement device measure sewage depth in the flume and the flow computation is through the dedicated digital display with integrator near the flume. The Parshall flume channel lead to the distribution chamber of the SBR Tank.

(vi) Sequential Batch Reactor

Screened and de-gritted sewage is introduced into SBR Process Units designed for the average flow of 74 MLD as shown in Figure 5.14. SBR is a fill-and-draw type of reactor system involving a single complete mix reactor in which all steps of the activated sludge process occur. Mixed liquor remains in the reactor during all cycles, thereby eliminating the need for separate sedimentation tanks. The complete operation is controlled automatically through Programmable Logic Controller (PLC) system.

a) Fill- Aerate

During the fill phase, the basin receives influent wastewater through distribution channel as shown in Figure 5.15. Under an aerated-fill scenario, both the aerators and the mechanical mixing unit are activated. The contents of the basin are aerated to convert the anoxic or anaerobic zone over to an aerobic zone.

Figure 5.14: SBR Tanks installed at Indirapuram, Uttar Pradesh

b) React

During this phase, no wastewater enters the basin and the mechanical mixing and aeration units are on as shown in Figure 5.16. Because there are no additional volume and organic loadings, the rate of organic removal increases dramatically. Most of the carbonaceous BOD removal occurs in the react phase

Figure 5.15 Fill Aerate phase of SBR Cycle

Figure 5.16 React phase of SBR Cycle

c) Settle

During this phase, activated sludge is allowed to settle under quiescent conditions—no flow enters the basin and no aeration and mixing takes place as shown in Figure 5.17. During the initial settling period, the sludge undergoes internal flocculation due to the residual mixing energy within the basin. As this energy dissipates the sludge interface forms and settles as a blanket. Dense solids fall through the formed mass to settle on the basin floor. The activated sludge solids form a sludge blanket which progressively falls towards the floor of the basin. There is an initial slow settling velocity which increases and then gradually decreases due to the compressive accumulation of solids on the basin floor. Zone settling velocity is a function of the initial solids concentration, basin depth, total area of the basin and nature of the biological solids. The flocs adhere together and the mass settles as a blanket leaving a layer of clear supernatant. At this point in the cycle, the preceding phases have accomplished all of the process objectives related to reduction of carbonaceous compounds, nitrification and de-nitrification and conditioning of biomass.

d) Decant

Decanter remove treated clarified effluent from the reactor without drawing floating scum or disturbing the settled sludge blanket. Once the settle phase is complete, a signal is sent to the decanter to initiate the opening of an effluent-discharge valve. A fixed type decanter is used for decanting purpose as shown in Figure 5.18. Excess Waste Activated Sludge (WAS) is also removed from the SBR during the DECANT phase influent. The IDLE period occurs when actual flows are less than design flows.

Figure 5.17: Settle Phase of SBR Cycle

Figure 5.18: Fixed Type Decanter in SBR Tank

(vii) Sludge Holding Tank & Sludge Dewatering

The excess aerobic sludge coming out of the SBR is being collected in sludge sump with blowers. Sludge from sludge holding tank is pumped by screw pumps to centrifuge for dewatering of sludge and to reduce it to spade-able concentration. A poly-electrolyte system dosing system is provided.

(viii) Disinfection

The treated water is undergoing disinfection using chlorine as a disinfectant. Two Vacuum type chlorinators have been provided. The chlorination system is based on chlorine being drawn off as a gas from containers located in container store area and taken to the chlorinator room where chlorinators and ancillary equipment.

(xi) Treated Effluent Channel

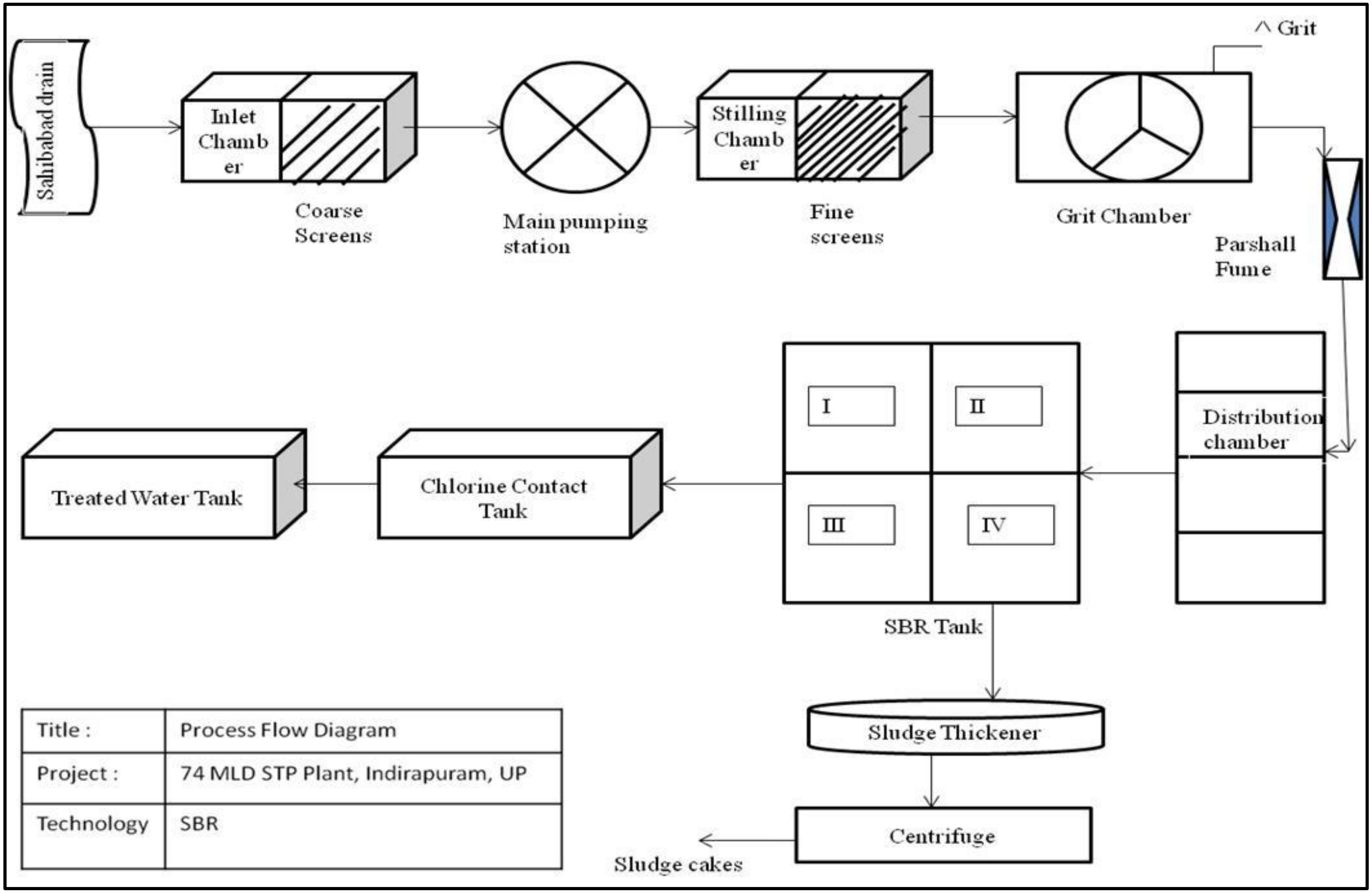
After chlorination the final treated effluent is conveyed to the existing final effluent channel. The length of the treated effluent channel is 10 m (approx.) and ultimately discharged into Hindon River

Dimensional details of STP units and facilities based on SBR Technology installed at Indirapuram, Uttar Pradesh are shown in Table 5.4 and Process Flow Diagram of STP is shown in Figure 5.19**.**

Table 5.4: Dimensional details of various units and facilities of the STP based on SBR at Indirapuram, Uttar Pradesh

Unit	No.	Dimensions
Flow		**70 MLD**
Inlet Chamber	1	Size=7.3m X 3.35m X 1.2 m Retention Time = 15 sec
Coarse Screen	2	Clear opening 40mm
Fine Screen	1	Clear opening 60mm
Main Pumping station	1	Diameter = 11.9 m SWD = 3.5m Retention Time = 650 Sec
Stilling Chamber	1	Size= 4.8m X 4.3m X 2m Retention Time = 30 sec (at peak flow)
Distribution Chamber	1	Size = 6m X 3m X 1 m
Grit Separator	3 (2W+1S)	Size = 8.7m X 8.7m X(0.9+0.4) m
SBR Tank	4	Shape= Trapezoidal bottom with rectangular top. At Top= 75m X 31 m At Bottom = 64.62 X20.62m Tapered angle = 30^{o} Liquid depth = 6m
Blower	6 (4W+ 2S)	Capacity = 5818.6 m^3/hr
Sludge Holding Tank	1	Diameter = 7.5m SWD = 3m
Centrifuge	2 (1W+1S)	Capacity = 20m^3/hr
Chlorine Contact tank	1	25m X 20.6m X 3m
Treated Effluent Channel	1	10m X 1.2mX1.1m

Figure 5.19: Process flow diagram of STP based on SBR at Indirapuram, Uttar Pradesh



Title :	Process Flow Diagram
Project :	74 MLD STP Plant, Indirapuram, UP
Technology	SBR

5.2.3 SBR-STP Performance Evaluation & Analysis

Samples were collected from the Inlet & Outlet point of the treatment plant for the period starting from January till May 2013. Analytical results as obtained are summarized in Table 5.5 that illustrates reduction efficiency to be 98%, 96% and 87.7% for TSS, BOD and COD removal, respectively. The variation in pH, TSS, BOD and COD in different months is shown in Figure 5.20, Figure 5.21, Figure 5.22 and Figure 5.23 respectively.

Table 5.5: Physico-chemical analysis of STP based on SBR technology

Parameters	**pH**		**TSS**		**BOD**		**COD**	
Month-2013	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**
January	6.54	7.26	602	9	210	9	756	74
February	7.48	8.14	844	22	179	6	788	57
March	6.91	7.19	699	8	210	8	610	81
April	6.57	7.37	458	9	180	9	431	83
May	6.90	7.21	449	10	170	6	490	81
Maximum	7.48	8.14	844	22	210	9	788	83
Minimum	6.54	7.19	449	8	170	6	431	57
Average	**6.88**	**7.40**	**610**	**11.6**	**190**	**7.6**	**615**	**75.2**
Percentage Reduction	-		**98%**		**96%**		**87.7%**	

Disinfection in the form of chlorination is being practiced in STP locate at Indirapuram, Uttar Pradesh, for pathogen removal. Samples at inlet and outlet of were examined for Fecal Coliform and Total Coliform parameter in order to assess microbial contamination removal. Results of analysis are summarized in Table 5.6.

Table 5.6: Microbial analysis of STP with SBR Technology

S. No.	**Parameter**	**Inlet**	**Outlet**
1.	**Total Coliform (MPN/100ml)**	15×10^7	93×10^2
2.	**Fecal Coliform (MPN/100ml)**	21×10^7	23×10^2

Table 5.6 reveals that, there is high reduction in TC & FC from 15 X 10^7 to 93 X 10^2 & 21 X 10^7 to 23 X 10^2 respectively due to chlorination is provided prior to the discharge of the treated effluent.

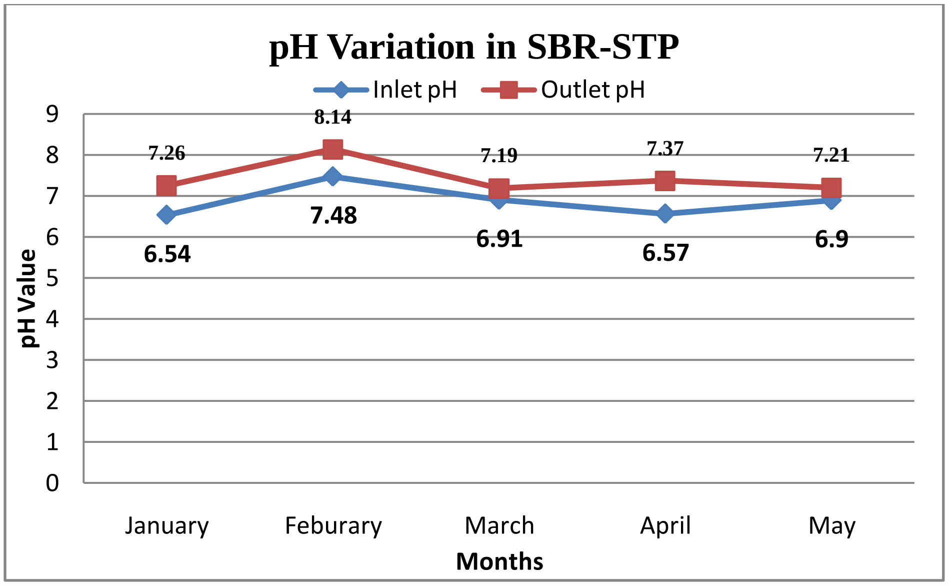


Figure 5.20: pH variation in SBR-STP located in Indirapuram, Uttar Pradesh

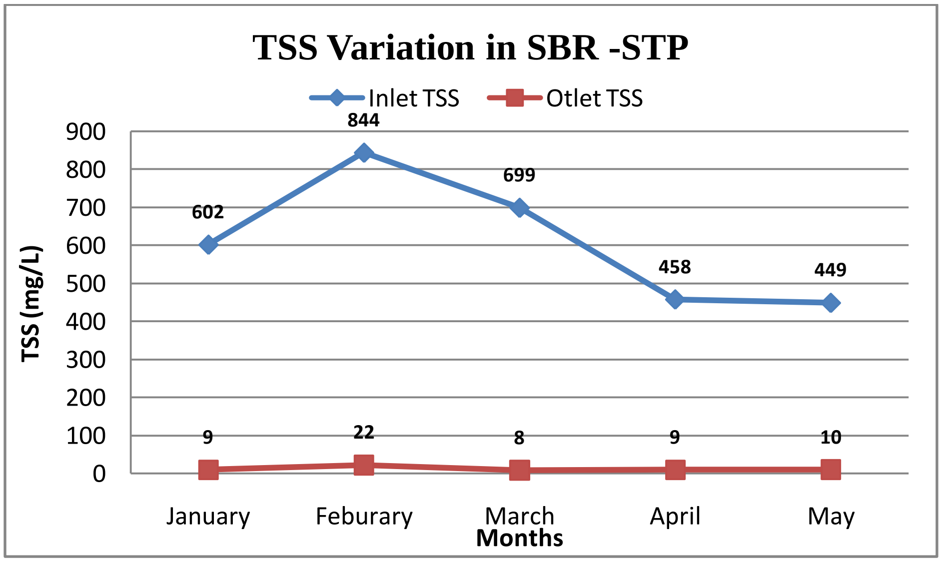


Figure 5.21 TSS variation in SBR-STP located in Indirapuram, Uttar Pradesh

Figure 5.20 & Figure 5.21 shows the variation in pH value and TSS value respectively for the SBR based STP for the month of January to May. It can be seen that, pH value in the month of February is 8.14 which needs to be monitored as pH range significantly affects the microbial activity and the pH control is an important operation parameter that needs to be checked. TSS variation also shows the maximum TSS value in the month of February only.

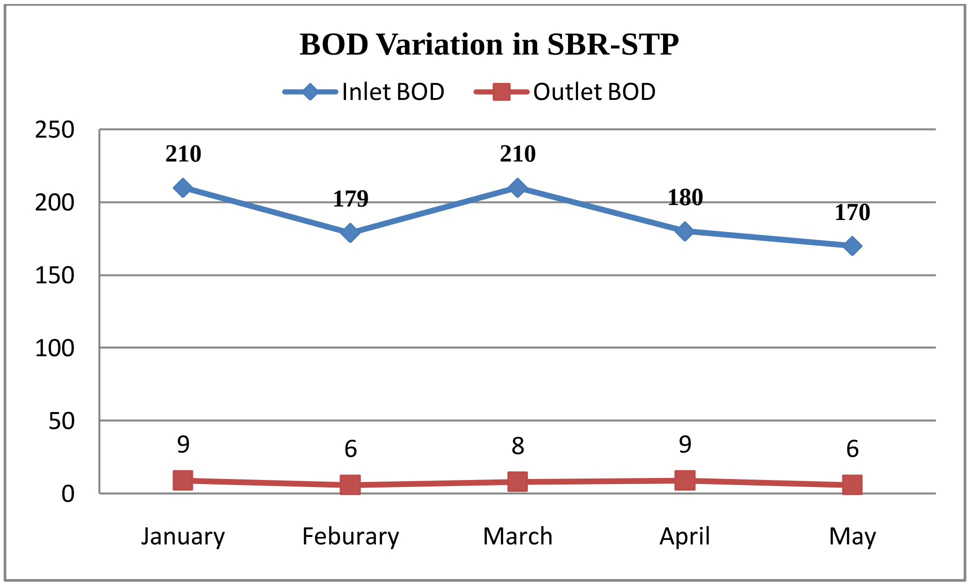


Figure 5.22: BOD variation in SBR STP located in Indirapuram, Uttar Pradesh

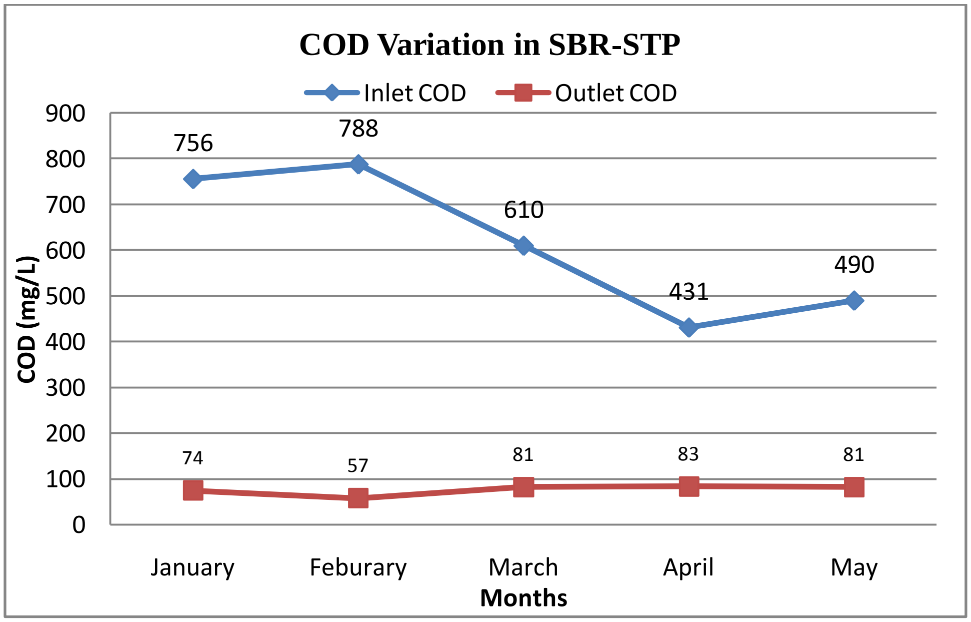


Figure 5.23 COD variation in SBR STP located in Indirapuram, Uttar Pradesh

Figure 5.22 & Figure 5.23 depicts the variation in BOD & COD respectively in SBR based STP in the month of January to May. BOD values at the inlet of STP are noted to be consistent and not much fluctuation was observed as it ranges from 210 mg/L to 170 mg/L throughout the study. BOD reduction in STP is observed to be very high. However, there is a wide fluctuation in the COD value at inlet of the STP with maximum value of 788 mg/L and minimum value of 431 mg/L. Intake of sewage is from Sahibabad drain and industrial area located near the drain is discharging its wastewater directly into the Sahibabad drain which leads to the fluctuation in values of pH, TSS, BOD & COD at the inlet of the STP and consequently affects the operation of the STP.

5.3 UASB Based STP at Dhanwapur, Gurgaon

5.3.1 Introduction of the STP

The STP of 30 MLD Capacity based on UASB has been designed at Dhanwapur, Gurgaon to treat the sewage generating from the Old Gurgaon area. The plant was commissioned in 1998 under Yamuna Action Plan-I. Details of Plant are given below:

i)	**Plant capacity**	**30 MLD**
ii)	**Plant Location**	Installed at Dhanwapur, Gurgaon, Haryana
iii)	**Year of Commissioning**	The plant was commissioned during 1998 under Yamuna Action Plan- I.
iv)	**Developed & Maintained by**	Municipal Corporation of Gurgaon.
v)	**Sewage intake**	From old Gurgaon region
vi)	**Treatment Technology**	**Up-flow anaerobic sludge blanket** (**UASB**), Anaerobic digestion process with Biogas generation.
vii)	**Treatment Units**	Inlet Chamber, Coarse Screen, Main Pumping Station,Grit Removal System, Distribution Chamber for Bioreactor, UASB Reactors, Final Polishing Unit, Treated Effluent channel, sludge, Gas holder, Sludge drying beds.
viii)	**Biogas utilization**	Biogas generated is being flared off in to the atmosphere.
ix)	**Treated Water disposal**	Treated water is discharged in to Najafgarh drain and ultimately in to River Yamuna.

A satellite imagery of the STP located at Dhanwapur, Gurgaon, in the state of Haryana, taken from google earth is shown in the Figure 5.24.

Figure 5.24: Satellite image of STP based on UASB at Dhanwapur, Gurgaon, Haryana

5.3.2 Process Description of STP based on UASB Technology

(i) Inlet Chamber

The inlet chamber is provided ahead of screen channel to receive the sewage from the rising mains. The incoming gravity sewer shall be connected to the inlet chamber in such a way that the invert levels of the pipe and chamber coincide.

(ii) Fine Screen (Manual) Channel

Wastewater from Inlet Chamber flows in to fine screen channel. Fine Screen channel has been provided. Velocity in the channel not exceeds 1.2 m/sec.

(iii) Grit Removal Chamber

Wastewater from screen channel flows into the grit chamber. Grit chamber of rectangular shape has been provided. The function of this unit is to remove inorganic grit from sewage after it gets screened in screening channel.

(iv) Distribution Chamber for UASB Reactor

An RCC distribution chamber as shown in Figure: 5.25, has been provided to equally divide the flow to three modules of UASB Reactor.

(v) UASB Reactor

The sewage from the distribution chamber enters the inlet chamber of the UASB Reactor of the present module. Three UASB Reactor each designed for handling 10 MLD flow working in parallel has been provided. UASB reactor is shown in Figure : 5.26.

Figure 5.25: Distribution Chambers for UASB reactor

Figure 5.26: UASB Reactor installed at Dhanwapur, Gurgaon, Haryana

(vi) Gas Holding Unit

Gas produced with in the UASB tank is taken into the gas holder. At present there is no utilization of biogas generated and gas is being flare off into the atmosphere.

(vii) Oxidation/ Polishing Pond

Aerobic treatment in the form of polishing pond has been provided in order to reduce the BOD level as shown in Figure 5.27. Oxygen from atmosphere is taken by the micro-organisms to degrade the organic matter into simpler form and settled at the bottom of the pond.

Figure 5.27: Final Polishing Unit after UASB Reactor

(viii) Sludge Disposal

Sludge generated from the digester is dried in Sludge drying beds. 22 nos. of Sludge drying beds having depth of 2ft each have been provided. Dried sludge is used as manure and taken by the farmers of nearby village area.

(ix) Treated Water Disposal

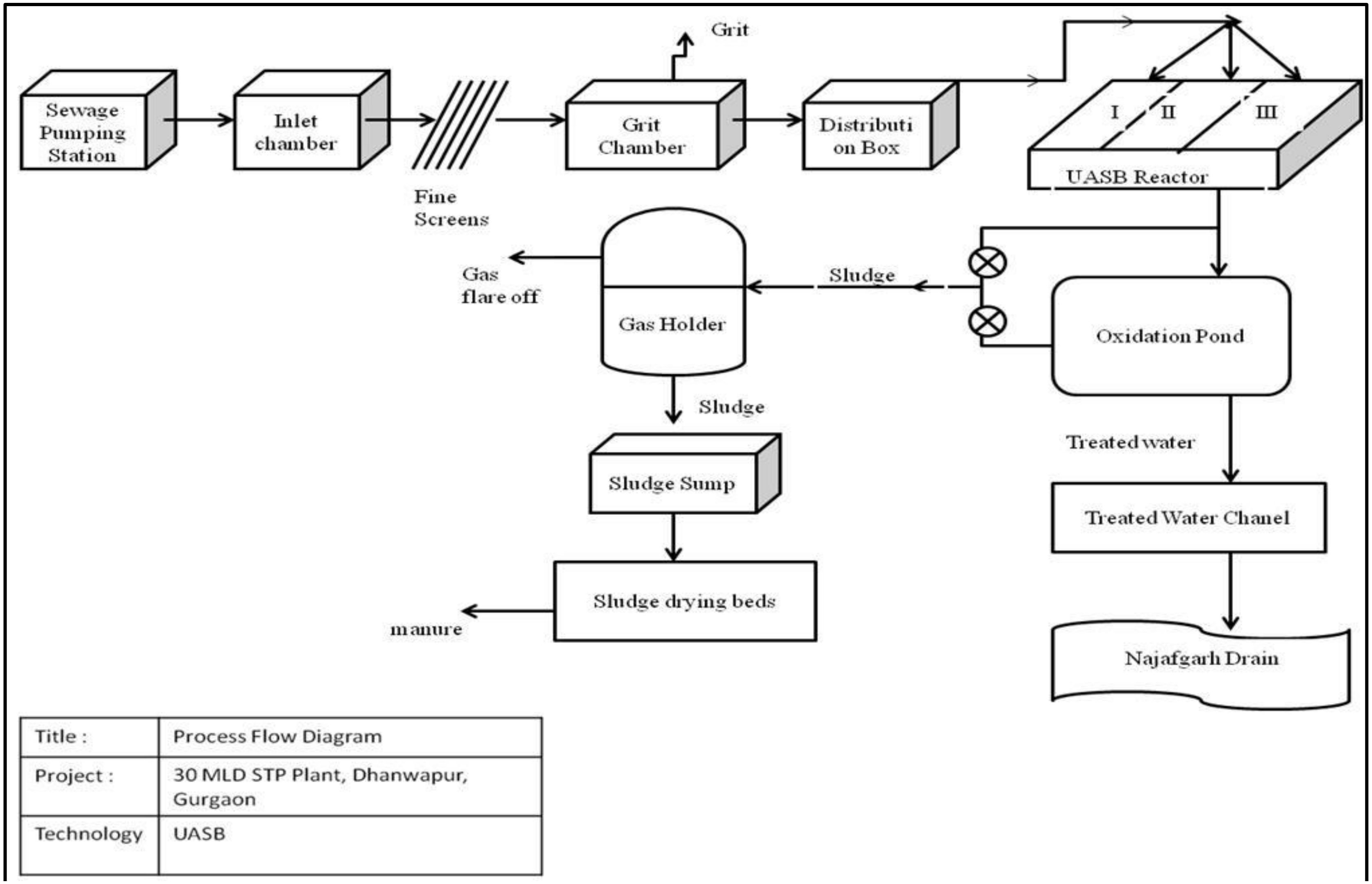
Treated effluent from polishing pond is being discharging into the Najafgarh Drain.

Dimensional details of STP units and facilities of UASB Plant are shown in Table 5.7 and Process Flow Diagram of STP based on UASB is shown in Figure 5.28

Table 5.7: Dimensional details of various units and facilities of the STP based on UASB at Dhanwapur, Gurgaon, Haryana

Unit	No.	Dimensions
Screen Channels	2	Clear spacing : 20 mm
Grit chamber		Size : Length =8 m Width = 8m Depth= 1.1m SWD Surface loading rate :960 m3/m2/d
UASB Reactor	3	10 MLD each Size : 40 m x 17 m x 5 m ht Retention Time = 8hr
Gas Holder	1	Gas quantity : 4500 m3/d Size : 15 m dia 6m height HRT- 6hrs
Oxidation/Polishing Pond	3	Size :Length = 30m Width= 100m Depth = 1.25m
Sludge Beds	22	Size : 11m X 11m Depth = 0.6m each

Figure 5.28: .Process Flow Diagram of STP based on UASB at Dhanwapur, Gurgaon, Haryana



5.3.3 UASB-STP Performance Evaluation & Analysis

Samples were collected from the Inlet & Outlet point of the plant for the period starting from the month of January to May 2013 in order to assess the efficiency of the treatment plant. Plant was niot found working in the month of February due to some maintenance work. Analytical results obtained for pH, TSS, BOD & COD are summarized in Table 5.8, Average values as well as maximum & minimum values also observed in order to characterize the raw/ Treated water. The variation in pH, TSS, BOD and COD in different months is shown in Figure 5.29, Figure 5.30, Figure 5.31 and Figure 5.32 respectively.

Table 5.8: Physico-chemical analysis of STP based on UASB technology

Parameters	**pH**		**TSS**		**BOD**		**COD**	
Month-2013	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**
January	7.4	7.6	434	62	225	92	520	198
February	Non Operational							
March	7.5	7.7	281	78	126	70	449	154
April	7.8	8.0	132	40	182	34	534	147
May	7.5	7.7	313	47	218	31	466	109
Maximum	7.8	8.0	434	78	225	92	534	198
Minimum	7.4	7.6	132	40	126	31	449	109
Average	7.5	7.75	290	57	188	58	492	152
Percentage Reduction	-		**80.3%**		**69%**		**69%**	

Samples at inlet and outlet of were examined for Fecal Coliform and Total Coliform parameter in order to asses microbial contamination removal. Results of microbial analysis are summarized in Table 5.9.

Table 5.9: Microbial analysis of STP based on UASB Technology

S. No.	**Parameter**	**Inlet**	**Outlet**
1.	**Total Coliform (MPN/100ml)**	$18 X 10^6$	$12 X 10^5$
2.	**Fecal Coliform (MPN/100ml)**	$38 X 10^6$	$89 X 10^4$

Table 5.9 reveals that there is poor removal of TC and FC in UASB+FPU treated effluent as no disinfection is being practiced in order to remove the pathogens from the treated water.

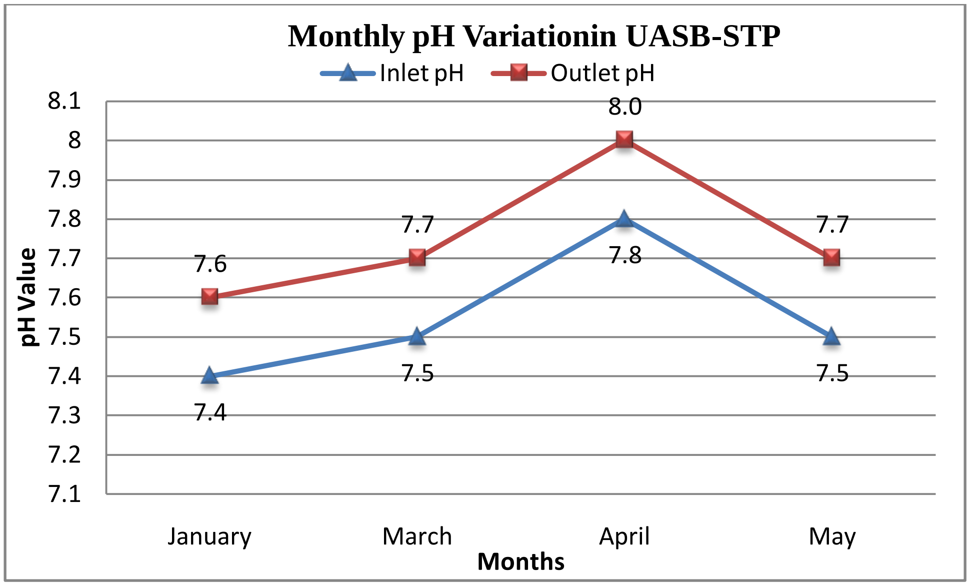


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Figure 5.29: pH Variation in UASB STP located in Dhanwapur, Gurgaon, Haryana

Figure 5.29 depicts the pH variation in UASB based STP. pH plays an important role in anaerobic digestion. UASB reactors are generally operated at pH 6.5 to 7.5. Maximum pH value at the inlet of UASB was 8.0 and minimum value was 7.6 during the assessment period of the study. Thus pH value of UASB rector does not shows any favorable conditions for methanogenesis and thus affects the performance of UASB reactor. Figure 5.30 shows the variation in COD value, where it is noted to be maximum in month of January i.e. 434 mg/L and minimum in the month of April i.e. 132 mg/L.

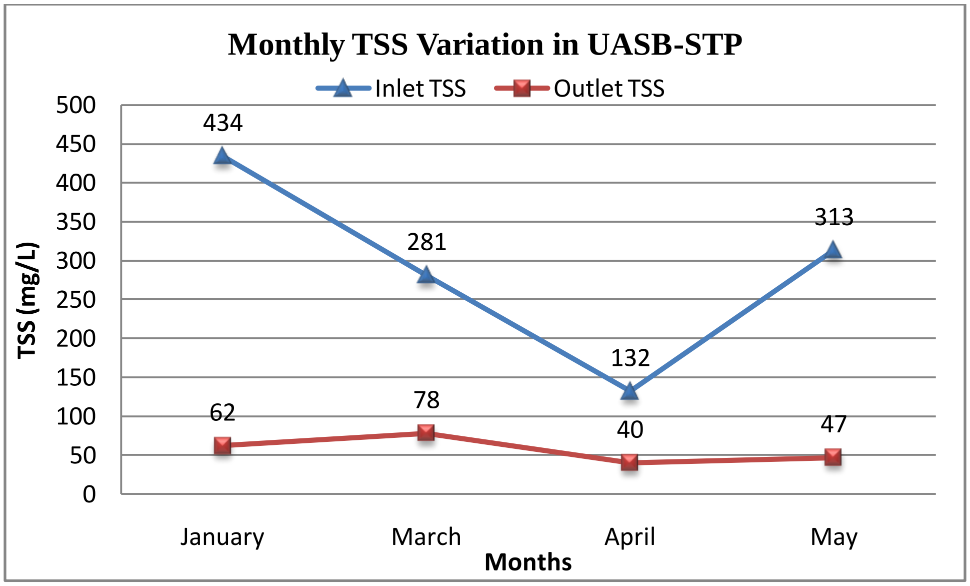


Figure 5.30: TSS variation in UASB STP located in Dhanwapur, Gurgaon, Haryana

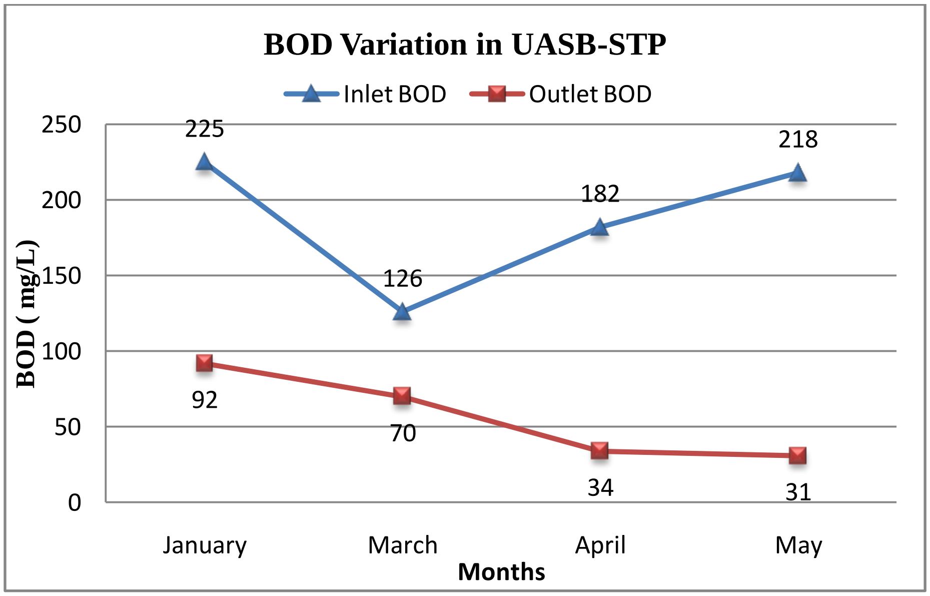


Figure 5.31: BOD Variation in UASB-STP located in Dhanwapur, Gurgaon, Haryana

Figure 5.31 depicts the BOD variation in UASB reactor with maximum value in the month of January which is 225 mg/l and minimum in March which is 126 mg/l. It can be seen that BOD value at the outlet of UASB is not meeting the stipulated discharge standard of 30 mg/L throughout the study, thereby need intervention in terms of evaluating the performance deterrent factors in detail. Figure 5.32 shows the variation in COD value which was in the range of 449 mg/L to 534 mg/L at the inlet and the range at the outlet is noted to be from 109 mg/L to 198 mg/L. Poor working of UASB rector was observed in terms of organic removal from the wastewater collected at the STP.

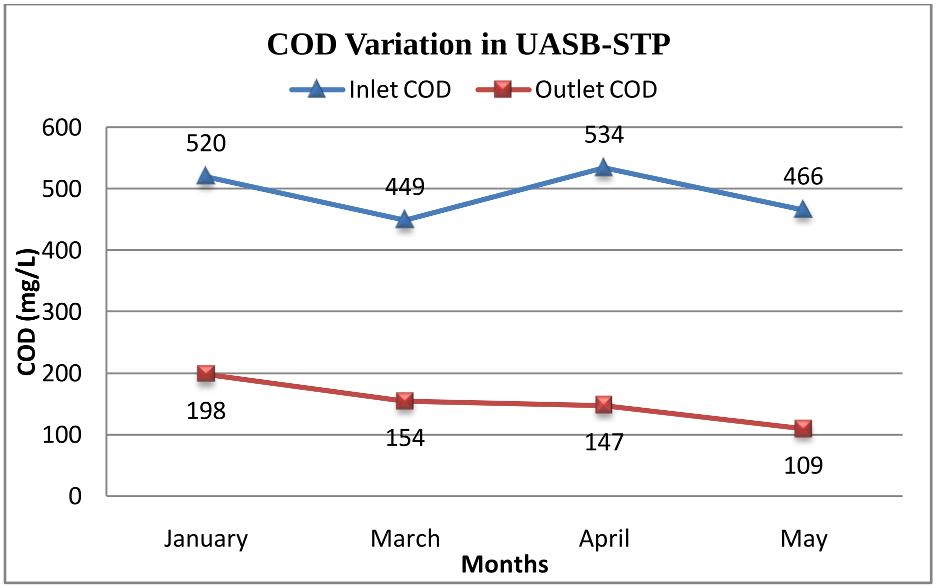


Figure 5.32: COD Variation in UASB-STP located in Dhanwapur, Gurgaon, Haryana

5.4 ASP based STP, Phase-I at Rithala, Delhi

5.4.1 Introduction of the STP

The Sewage Treatment Plant at Rohini, Delhi has the capacity of 40 MGD [181.6 MLD] of average flow. It is covering the sewerage from the Rohini region (North-West Delhi). The plant was commissioned during 1990 and constructed by Delhi Jal Board under Yamuna Action Plan. Details of Plant are given below:

i)	**Plant capacity**	**40 MGD**
ii)	**Plant Location**	Installed near Rithala metro station, Delhi
iii)	**Year of Commissioning**	The plant was commissioned during 1990
iv)	**Developed & Maintained by**	Constructed by Delhi Jal Board under Yamuna Action Plan.
v)	**Plant Cost**	1093 Lacs
vi)	**Sewage intake**	From eight different sewage pumping stations located in Rohini.
vii)	**Treatment Technology**	Activated Sludge Process, in which air or oxygen is forced into sewage liquor to develop a biological floc which reduces the organic content of the sewage
viii)	**Treatment Units**	Inlet Chamber, Fine Screen, ,Grit Chamber, Primary Setling Tank, Aeration tank, Final settling tank,Treated Effluent channel, sludge digestor, Gas holder, Sludge drying beds.
ix)	**Biogas utilization**	Biogas generated is being flared off in to the atmosphere.
x)	**Treated Water disposal**	Treated water is discharged in to Nangloi – Sultanpuri supplementary drain which ultimately drains into Najafgarh drain and then to River Yamuna.

A satellite imagery of the STP located near Rithala Metro Station, Delhi, taken from google earth is shown in the Figure 5.33.

Figure 5.33: Satellite image of STP based on ASP at phase-I, Rithala, Delhi

5.4.2 Process Description of STP based on ASP Technology

(i) Bar Screen

There are two no‘s of mechanical bar screen with a clear spacing of 20mm as shown in Figure-5.34. Debris and floating matter is removed here with rake mechanism, belt conveyors, trolleys and disposed off suitably.

Figure 5.34: 20mm Mechanical Bar screens at ASP Plant inlet

(ii) Grit Chambers

Two (2) numbers of grit chambers are provided with a detention period of 90 sec and velocity of 1.2m/sec. In this particular section, heavy organic matter of specific gravity more than 2.5 is allowed to settle down and then removed with the help of rake classifiers.

(iii) Primary Settling Tank

The sewage after removing the grit is taken to primary clarifiers by gravity. There are four (4) nos. of primary clarifiers of 10 MGD each having diameter of 29.4 meters and detention period of 2 hours. The raw sludge from the primary clarifiers is collected into the wet sump of raw sludge pump house.

(iv) Aeration Tanks

There are two (2) compartments with controlling gates each having four (4) nos. of mechanical surface aerators of 75 HP each. The effluent of primary clarifiers is taken into aeration tanks for aerobic treatment as shown in Figure 5.35. The process of treatment is achieved by activated sludge process with surface aeration. A part of activated sludge from the final clarifiers is also mixed to get the desired quality of treatment. The bacteria eat the organic matter present in the sewage and form the heavy flocks of organic matter.

(v) Final Settling Tank

The sewage from the aeration tanks is taken to final clarifiers where most of the organic matter settles down and form activated sludge. Final Settling tank is shown in Figure 5.36. The activated sludge is pumped back to aeration tank partly as per the requirement and rest before the primary clarifiers with the help of return sludge pumps. The final effluent (treated sewage) from the final clarifiers discharged into treated water channel.

Figure 5.35*: Aeration Tank of ASP Plant installed at Rithala, Delhi*

Figure 5.36: Final Settling Tank of ASP Plant

(vi) Return Sludge Pump House/Digester

Return sludge from the final settling tank is pumped back partly to aeration tank (upto 50-75 %) to maintain Mixed Liquor Suspended Solids (MLSS) and Food to Micro-organisms (F/M) ratio in the tank and rest to the distribution chamber before the primary clarifiers. Raw sludge from the primary clarifiers is pumped to digesters for digestion. Nine (9) nos. of fixed dome type digesters have been provided. The digestion period range from 25 to 30 days. Here the complex organic compounds decompose to form methane, carbon-dioxide, nitrogen, hydrogen sulphide gas, etc. This happen in the absence of air thus called anaerobic process. The digested mass (digested sludge) is drawn from the digesters to sludge drying beds by gravity.

(vii) Gas Holder

The gas produced in the digesters is collected in the floating dome type i.e. three (3) nos. of gas holder and recycled to digesters for mixing the digester contents with the help of compressors. The excess quantity of gas is being burnt in gas burners at present. Biogas generating can be utilized for electricity generation.

(viii) Sludge Drying Beds

The digested sludge is dried in the drying beds and forms the sludge manure which is being used for horticulture purposes and by farmers as manure.

(ix) Treated Water Disposal

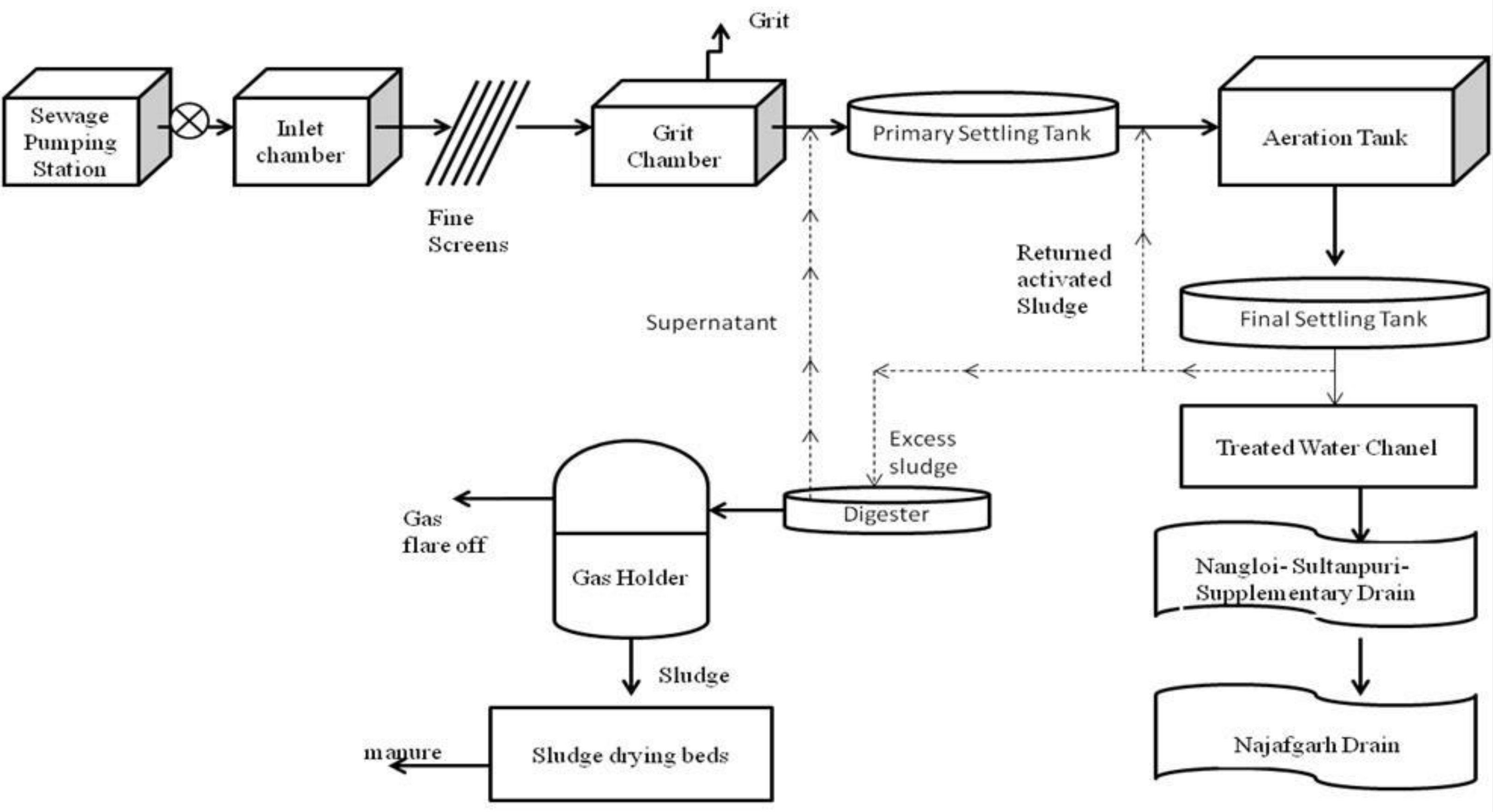
Treated water is discharging into Nangloi –Sultanpuri supplementary drain which ultimately drains into Najafgarh drain and then to River Yamuna.

Dimensional details of STP units and facilities of ASP Plant at Rithala, Delhi are shown in Table 5.10 and Process Flow Diagram of STP based on ASP at Rithala, Delhi is shown in Figure 5.37.

Table 5.10: Dimensional details of various units and facilities of the STP based on ASP at Phase-I Rithala, Delhi

Unit	No.	Dimensions
Flow		
Bar Screen	2	20 mm spacing
De-gritting	1	By rake classifier Retention time = 90 sec
Primary Settling tank	4	10 MGD each Diameter = 40m Depth = 3.12m Hydraulic Retention Time = 2.1 hr
Aeration Tank	4	Mechanical Surface Aerators 8 no= 75 HP 16 no- 14 HP Shape = Rectangular H.R.T = 6hrs.
Final Settling Tank	4	10 MGD each Diameter = 42m Depth = 4.2m H.R.T = 3 hr
Digester	9	Volume = 5660 m^3 Retention Time = 20-30 days Diameter = 25m Depth= 14m Fixed dome type
Gas Holder	3	Capacity = 5660 m^3 Liquid depth= 11.25 m
Gas Burners	2	For burning of gas
Sludge Drying Beds	48	Size = 30.5m X30.5m Sludge depth= 30 cm

Figure 5.37: Process Flow Diagram of STP based on ASP at Phase-I, Rithala Delhi



Title :	Process Flow Diagram
Project :	40 MGD STP Plant, Phase-I, Rithala,, Delhi
Technology	ASP

5.4.3 ASP-STP Performance Evaluation & Analysis

Samples were collected from the effluent Inlet & Outlet point of the treatment plant. Analytical results obtained for pH, TSS, BOD & COD are summarized in Table 5.11, Average values as well as maximum & minimum values also observed in order to characterize the raw/ Treated water. . The variation in pH, TSS, BOD and COD in different months is shown in Figure 5.38, Figure 5.39, Figure 5.40 and Figure 5.41 respectively.

Table 5.11: Physico chemical analysis of STP based on ASP Technology

Parameters	**pH**		**TSS**		**BOD**		**COD**	
Month	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**
January	8.0	7.9	100	20	90	22	384	74
February	7.9	7.7	116	16	110	20	296	84
March	7.8	7.9	364	34	185	18	588	72
April	7.3	7.7	484	09	270	14	607	52
May	7.8	7.9	252	32	105	29	312	80
Maximum	8.0	7.9	484	34	270	29	607	84
Minimum	7.3	7.7	100	09	90	14	296	52
Average	**7.8**	**7.8**	**264**	**22**	**152**	**21**	**437**	**72**
Percentage Reduction	**-**		**91.6%**		**86 %**		**83.5%**	

Fecal Coliform and Total Coliform parameter were analyzed in the samples obtained from the inlet as well as outlet of the plant so as to assess microbial contamination removal. Results of microbial analysis are summarized in Table 5.12.

Table 5.12: Microbial analysis of STP based on ASP Technology

S. No.	**Parameter**	**Inlet**	**Outlet**
1.	**Total Coliform (MPN/100ml)**	24×10^8	28×10^4
2.	**Fecal Coliform (MPN/100ml)**	15×10^7	15×10^4

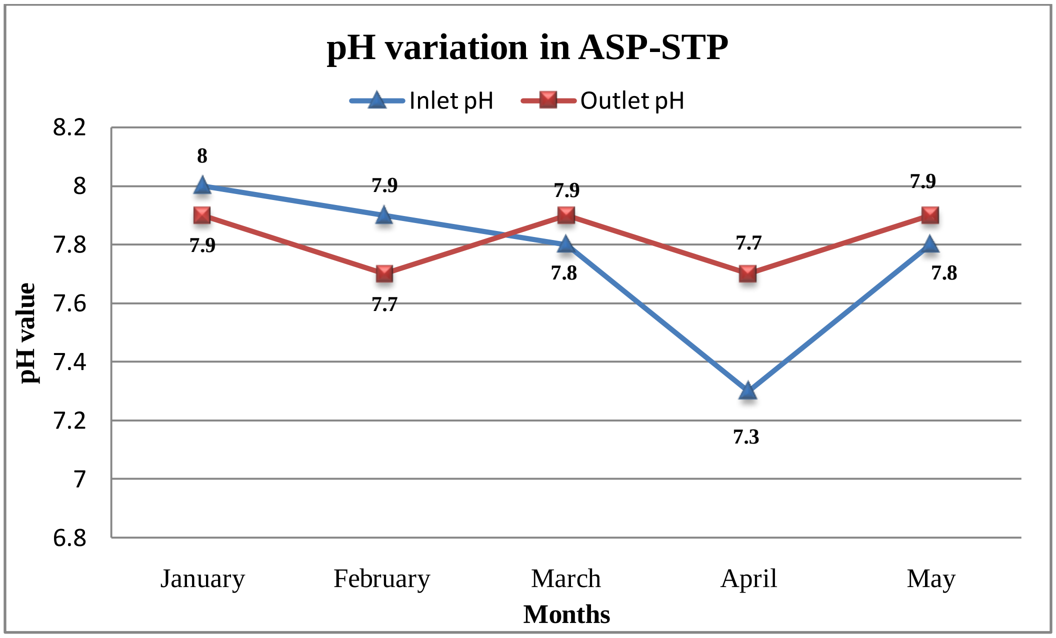


Figure 5.39: pH variation in ASP-STP Phase-I at Rithala, Delhi

Figure 5.39 & Figure 5.40 depicts the variation observed for the ASP based STP with regards to the pH value and TSS value respectively for the months of the assessment starting from January to May. At the inlet of the STP, pH value ranges from 7.7 – 8 which needs to be monitored in order to maintain the microbial activities, whereas at the Outlet the same varies in the range from 7.3 to 7.9. TSS variation depicts the maximum value at the inlet to be 484 mg/L and minimum to be 100mg/L. After the treatment, the treated effluent was noted to show TSS value in the range of 9 mg/L to 34 mg/L, thereby ensuring the stipulated standards as laid down by CPCB or SPCBs.

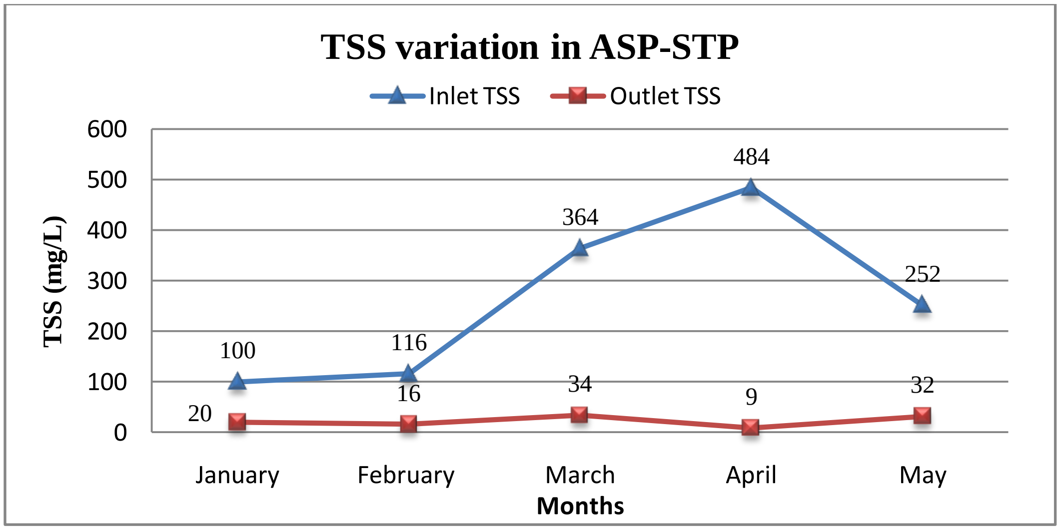


Figure 5.40: TSS variation in ASP-STP -Phase-I at Rithala, Delhi

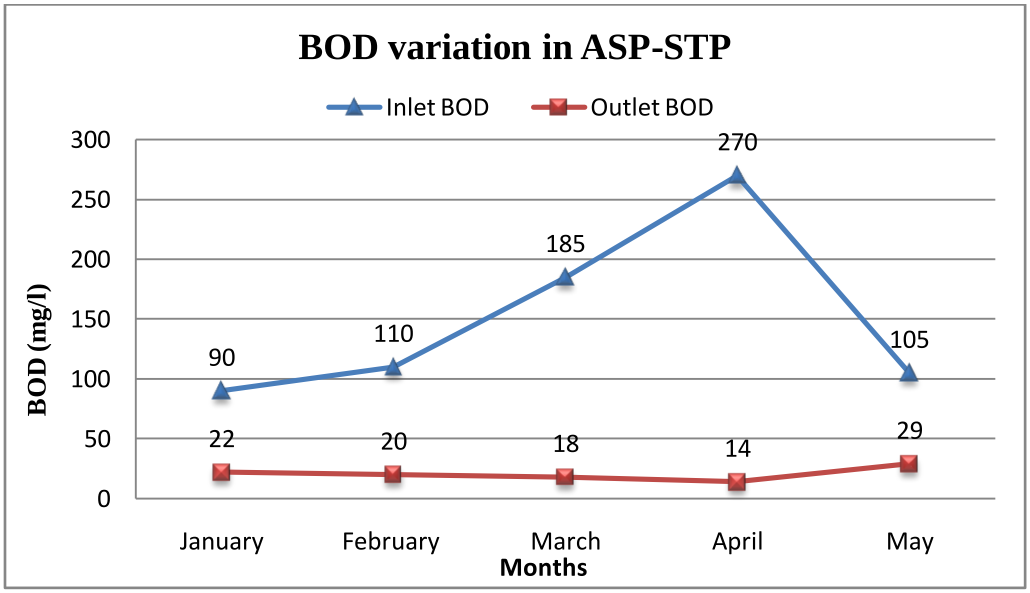


Figure 5.40: BOD variation in ASP-STP Phase-I at Rithala, Delhi

Figure 5.40 & Figure 5.41 shows the variation in BOD and COD respectively from the month of January to May in Activated Sludge Process Plant. Figures reveal that there is wide seasonal fluctuation the BOD & COD values. BOD value at the inlet ranges from 90 mg/L to 270 mg/L and after treatment its values is ranges from 14 mg/L to 29 mg/L, thereby ensuring that the stipulated standards are complied with. COD variation is from 296 mg/L to 607 mg/L and after treatment the value ranges from 52 mg/L to 84 mg/L.

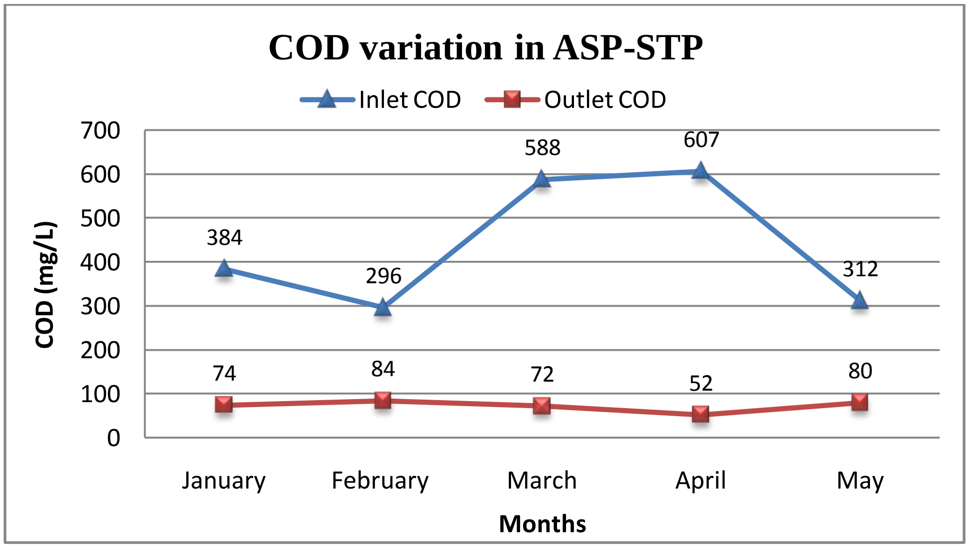


Figure 5.41 COD variation in ASP-STP Phase-I at Rithala, Delhi

5.5 ASP with BIOFOR Based STP at Phase-I, Rithala, Delhi

5.5.1 Introduction of the STP

The Sewage Treatment Plant located at Rithala, Delhi has the capacity of 40 MGD [181.6 MLD] of average flow. Sewerage from Rohini region (North-West Delhi) is being submitted to this STP. The plant was commissioned during 2001-2002 under Yamuna Action Plan. Details of plant are given below:

i)	**Plant capacity**	**40 MGD**
ii)	**Plant Location**	Installed near Rithala metro station, Delhi
iii)	**Year of Commissioning**	The plant was commissioned during 2001-2002
iv)	**Developed & Maintained by**	Constructed by Delhi Jal Board under Yamuna Action Plan.
v)	**Plant Cost**	8127 Lacs
vi)	**Sewage intake**	From eight different sewage pumping stations located in Rohini.
vii)	**Treatment Technology**	Activated Sludge Process followed by BIOFOR. Combination of conventional and advanced aerobic process.
viii)	**Treatment Units**	Inlet Chamber, Fine Screen, ,Grit Chamber, Aeration tank, Final settling tank, BIOFOR tanks, Polishing tank, Treated Effluent channel, sludge digestor, Gas holder, Sludge drying beds.
ix)	**Biogas utilization**	Biogas generated is being utilized to run the sewage treatment plant.
x)	**Treated Water disposal**	Treated water is discharged in to Nangloi – Sultanpuri supplementary drain which ultimately drains into Najafgarh drain and then to River Yamuna.

A satellite imagery of the STP located near Rithala Metro Station, Delhi is shown in the Figure 5.42.

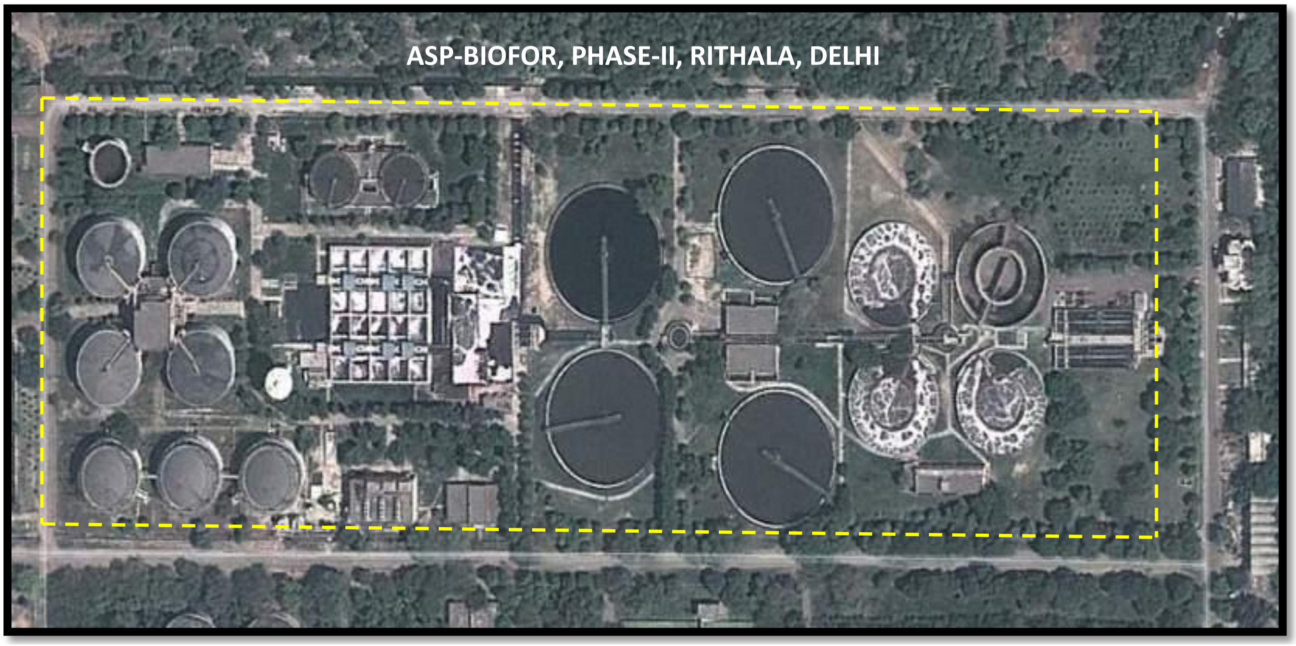


Figure 5.42 Satellite image of STP based on ASP+BIOFOR technology at Phase-II, Rithala

5.5.2 ASP+BIOFOR Technology Description

It is the combination of conventional Activated Sludge Process with the BIOFOR unit. Interlinking of ASP and BIOFOR eliminate the need of Primary settling tank and resultant effluent is of better quality as compared to ASP.

5.5.3 Process Description of STP based on ASP+BIOFOR Technology

(i) Bar Screen

Sewage is pumped though eight (8) nos. of sewage pumping stations and passed through bar screens. There are two (2) nos. of bar screen with a clear spacing of 10mm for mechanically operated screen and 20mm manual screen. Debris and floating matter is removed here with rake mechanism, belt conveyor, trolleys and disposed off suitably.

(ii) Grit Chamber

Two (2) nos. of grit chambers are provided with moving bridge in each as shown in Figure 5.43. Four (4) nos. of mixers and skimmers are also provided which serve the purpose of Oil & Grease removal as well. In this chamber, heavy organic matter of specific gravity more than 2.5 is allowed to settle down and then removed with the help of screw conveyer.

(iii) Aeration Tanks

Effluent from the grit chamber is directly taken into the aeration tank for aerobic treatment as shown in Figure 5.44. High rate aeration is provided through the four (4) nos. of diffusers provided at the bottom of the tank. Tank volume is 5675 m^3 and Hydraulic Retention Time is maintained for 1.5 hrs. A part of activated sludge from the final settling tanks is also mixed to get the desired quality of treatment. The bacteria eat the organic matter present in the sewage and form the heavy flocks of organic matter.

Figure 5.43: Grit Chamber Unit of ASP+BIOFOR Plant

Figure 5.44: Aeration Tank of ASP+BIOFOR Plant

(iv) Final Settling Tank

The sewage from the aeration tanks is taken to four (4) nos. of final settling tanks having Hydraulic Retention Time (HRT) of 2 hours where most of the organic matter settles down and form activated sludge. The activated sludge is pumped back to aeration tank partly as per the requirement and rest to the sludge thickener with the help of return sludge pumps. Sludge is collected by Siphon and bottom Scraper. Effluent from the final setting tank is further passing though the three (3) nos. of strainer of fine hole of 2.5 mm where floating material if present, swiped by brushing arm mechanism in order to protect the BIOFOR tanks.

(v) BIOFOR Tanks

Two (2) stage biofiltration process has been provided in BIOFOR tanks where intense aerobic treatment is provide and BOD levels reduced upto 98-99%. As shown in Figure 5.45, foaming was observed in the BIOFOR tanks for which the personnels involved in managing the same didn’t had any information regarding the reason of foaming. Filters are washed through backwash water systems

(vi) Polishing Tank

Effluent from the BIOFOR tanks is taken into polishing tank where chlorine is added as a disinfectant**.**

(vii) Return Sludge Pump House

Return sludge from the final settling tank is pumped back partly to aeration tank (upto 50-75 %) to maintain MLSS and F/M ration in the tank and rest pumped to Sludge thickening unit.

Figure 5.45: BIO Filtration Tanks after ASP installed at Phase-II, Rithala, Delhi

(viii) Sludge Thickener

A sludge thickener is an auxiliary unit with the specific objective to concentrate the excess sludge, before it is sent to the sludge digester. The supernatant from the thickeners is returned to the aeration tank, so that its quality in terms of suspended solids concentration is of little importance.

(ix) Digester

Four (4) nos. of sludge digester having Volume of 8000 m^3 has been provided**.** The digestion period range from 25 to 30 days. In the digester, the complex organic compounds decompose to form methane, carbon-dioxide, nitrogen, hydrogen sulphide gas etc. The digested mass (digested sludge) is drawn from the digesters to sludge drying beds by gravity.

(x) Gas Holder

The gas produced in the digesters is collected in the floating dome type three (3) nos. of gas holder and recycled to digesters for mixing the digester contents with the help of compressors. Biogas generating is being utilized for electricity generation and running of Plant.

(xi) Sludge Drying Beds

The digested sludge is dried in the 43 nos. of sludge drying beds and forms the sludge manure which is being used for horticulture purposes and by farmers as manure.

(xii) Treated Water Disposal

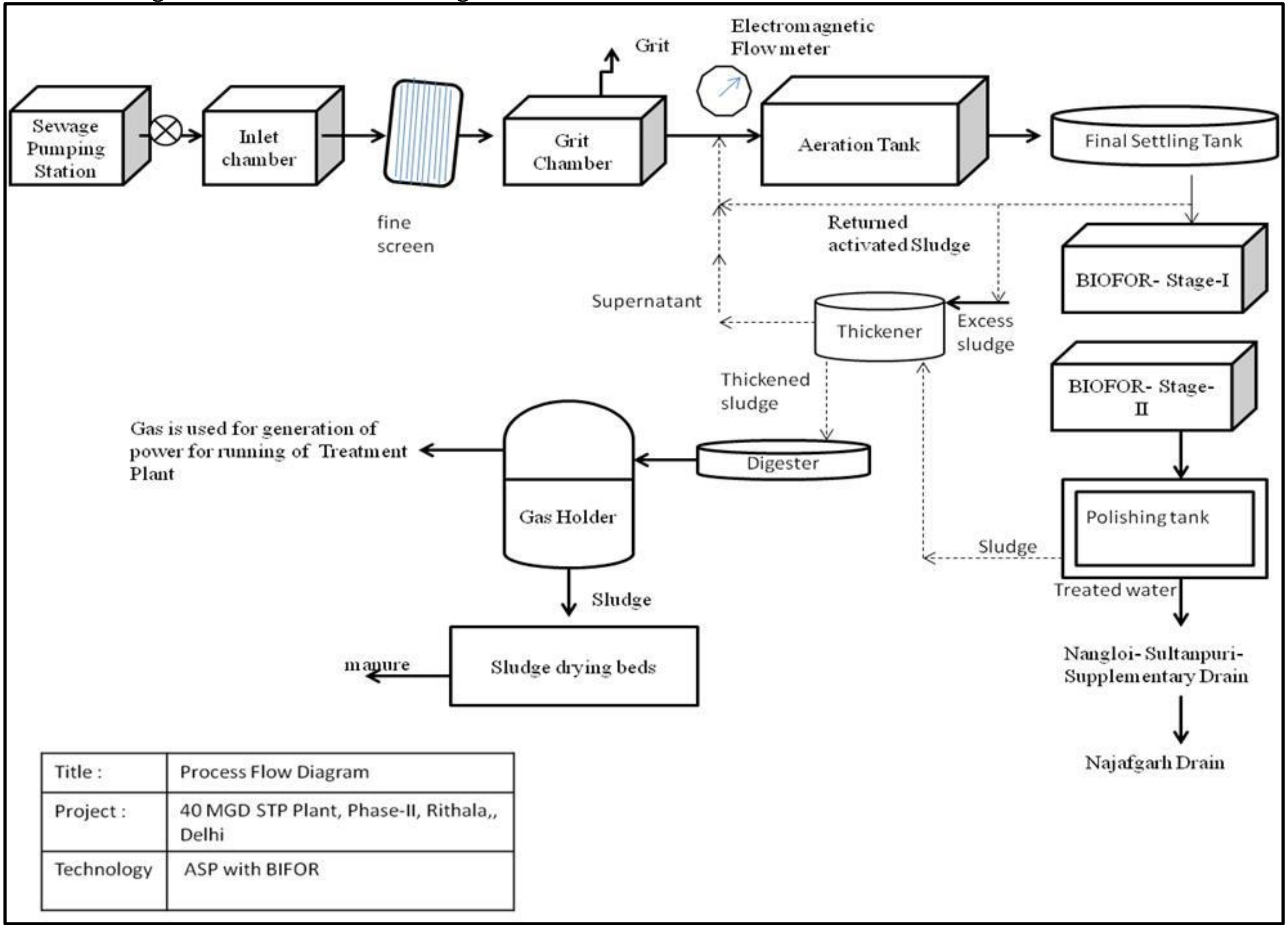
Treated water is discharging into Nangloi–Sultanpuri Supplementary drain which ultimately drains into Najafgarh drain and then to River Yamuna.

Dimensional details of STP units and facilities of ASP-BIOFOR Plant are shown in Table 5.13 and Process Flow Diagram of STP based on ASP+BIOFOR at Phase-II, Rithala, Delhi is shown in Figure 5.46.

Table 5.13: Dimensional details of various units and facilities of the STP based on ASP+BIOFOR at Phase-II, Rithala, Delhi.

Treatment Unit	No.	Size/ Dimensions
Bar Screen	3	20 mm Size = 8m X 1.6m X 1.05m each Volume = 40.32
De-gritting unit	4	Two cell with moving bridge Size= 30m X 4mX 3.9m Capacity = 1872 m^3 Retention Time = 15 min
Aeration Tank	4	Diameter =38m Depth = 5.5m H.R.T = 1.5 hr
Final Settling Tank	4	Diameter =49m Depth = 4.5m H.R.T = 2 hr
BIOFOR Filters	20 (10W+10S)	Unit filtration bed area = 62.64m^2 Filtration rate = 6m^3/m^2/hr
DAF Thickener	2	Diameter = 18m
Digester	4	Diameter = 26.8m Sludge Retention Time = 25 days
Gas Holder	3	Diameter =25m Liquid depth = 11.25m
Sludge Drying beds	43	30.5m X 30.5 m each Sludge depth = 30 cm.

Figure 5.46: Process Flow Diagram of STP based on ASP-BIOFOR at Phase-II, Rithala, Delhi



Title :	Process Flow Diagram
Project :	40 MGD STP Plant, Phase-II, Rithala,, Delhi
Technology	ASP with BIFOR

5.5.4 ASP+BIOFOR STP Performance Evaluation & Analysis

Samples were collected from the Inlet & Outlet point of the plant. In order to assess primary treatment units a sample was collected after Grit chamber and MLSS value of Biofiltration tank was assessed to estimate the biomass available in aeration tank for biological degradation of organic matter. Analytical results are summarized in Table 5.14 . The variation in pH, TSS, BOD and COD in different months is shown in Figure 5.47, Figure 5.48, Figure 5.49 and Figure 5..50 respectively.

Table 5.14: Physico-chemical analysis of STP based on ASP+BIOFOR technology

Parameters	**pH**		**TSS**		**BOD**		**COD**	
Month	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**
January	8.0	7.9	100	16	190	18	290	22
February	7.9	7.8	116	14	110	18	296	72
March	7.8	7.9	364	30	185	16	588	60
April	7.3	7.7	484	11	270	8	607	46
May	7.01	7.9	252	18	105	4	312	48
Maximum	8.0	7.9	484	30	270	18	607	72
Minimum	7.01	7.8	100	11	105	4	290	22
Average	**7.6**	**7.8**	**264**	**18**	**172**	**13**	**419**	**50**
Percentage Reduction	-		**93.1%**		**92.4%**		**88%**	

Disinfection in the form of chlorination is being practiced in Sewage treatment plant at Rithala based on ASP+BIOFOR, for pathogen removal Samples at inlet and outlet of were examined for Fecal coliform and Total coliform parameter in order to asses microbial contamination removal. Results of analysis are summarized in Table 5.15 that shows that this technology is also efficient to remove the Coliform bacteria from the wastewater.

Table 5.15: Microbial analysis of STP based on ASP+BIOFOR Technology

S. No.	**Parameter**	**Inlet**	**Outlet**
1.	**Total Coliform (MPN/100ml)**	$24 X 10^8$	$16 X 10^4$
2.	**Fecal Coliform (MPN/100ml)**	$15 X 10^7$	$85 X 10^3$

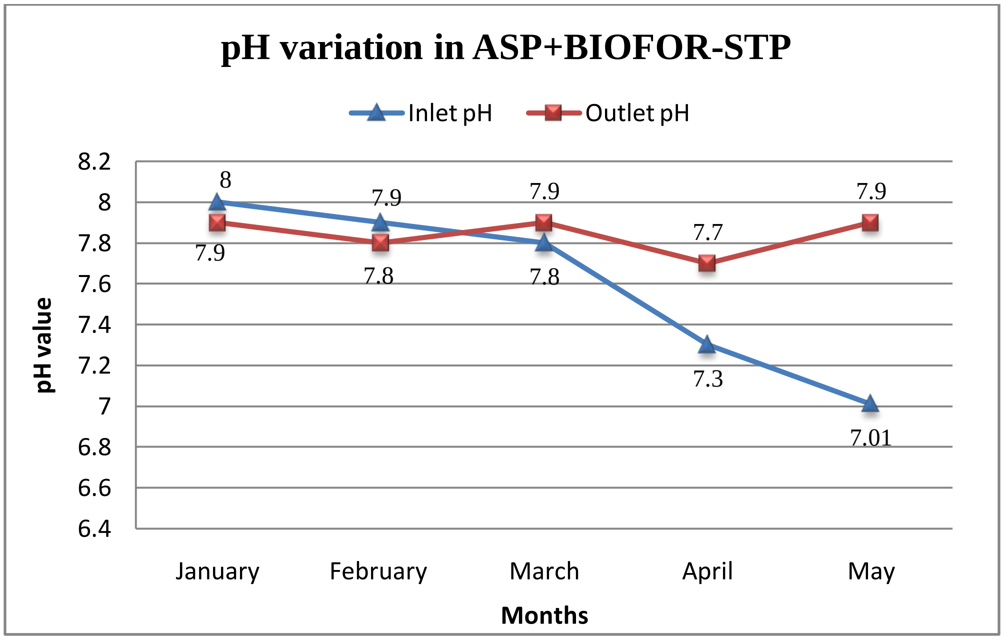


Figure 5.47 : pH variation in ASP+ BIOFOR STP Phase-I at Rithala, Delhi

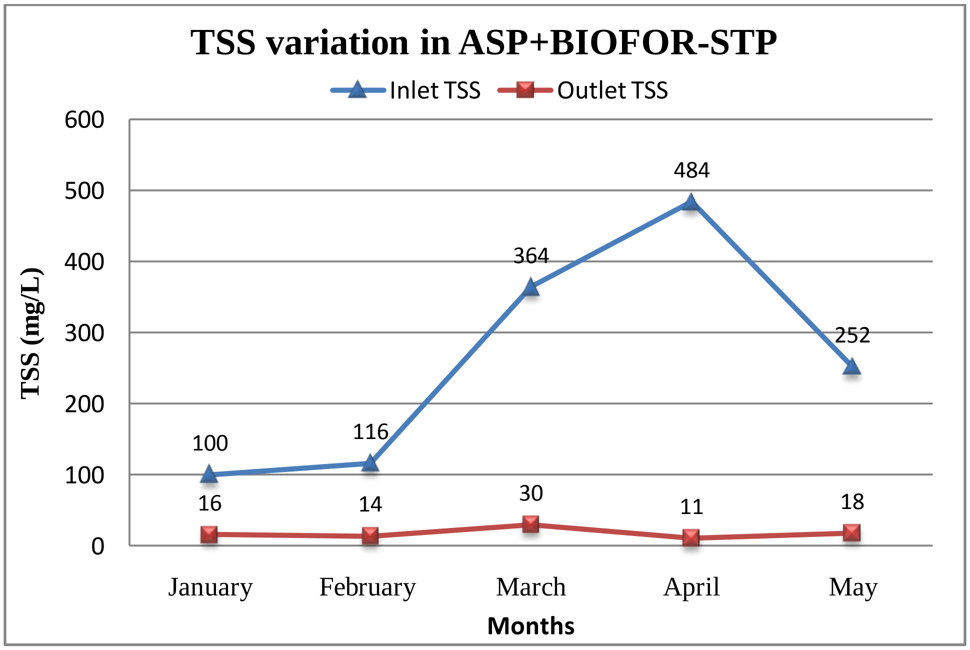


Figure 5.48: TSS variation in ASP+ BIOFOR STP -Phase-I at Rithala, Delhi

Figure 5.47 & Figure 5.48 shows the pH and TSS variation respectively in the months of January to May, for the ASP+BIOFOR Sewage Treatment Plant. pH value ranges from 7.01 to 8 at the inlet of STP and at the outlet his value is ranges between 7.7 to 7.9, which is noted to be controlled in this range for effective operation of the STP. TSS value at the inlet of STP ranges from 100 mg/L to 484 mg/L which at the outlet of STP after the treatment of the wastewater received was found ranging between 11 mg/L to 30 mg/L, thereby establishing the fact that the STP is efficient in Solids removal as High TSS removal was observed during the assessment.

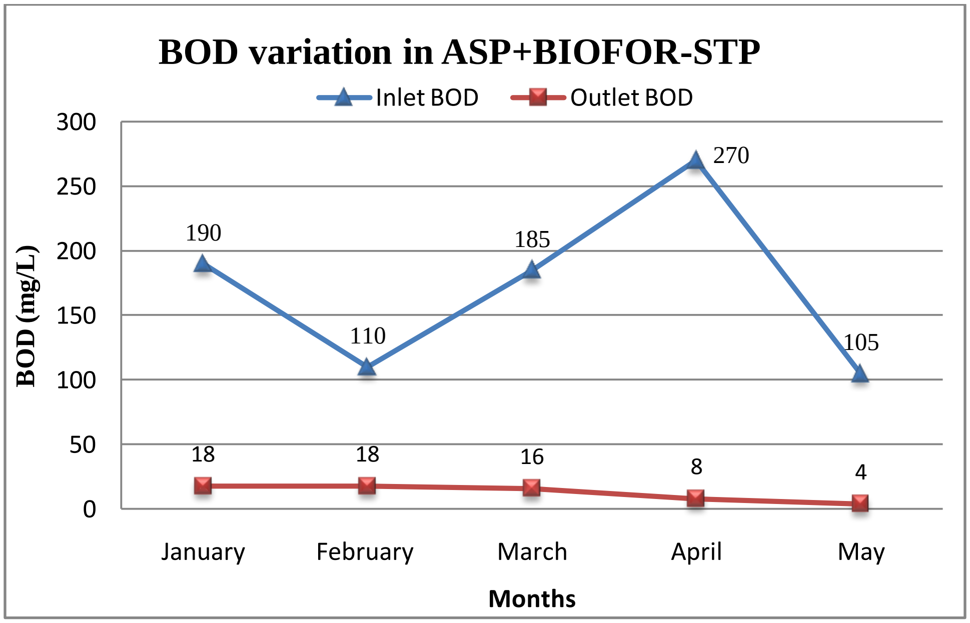


Figure 5.49: BOD variation in ASP+ BIOFOR STP Phase-I at Rithala, Delhi

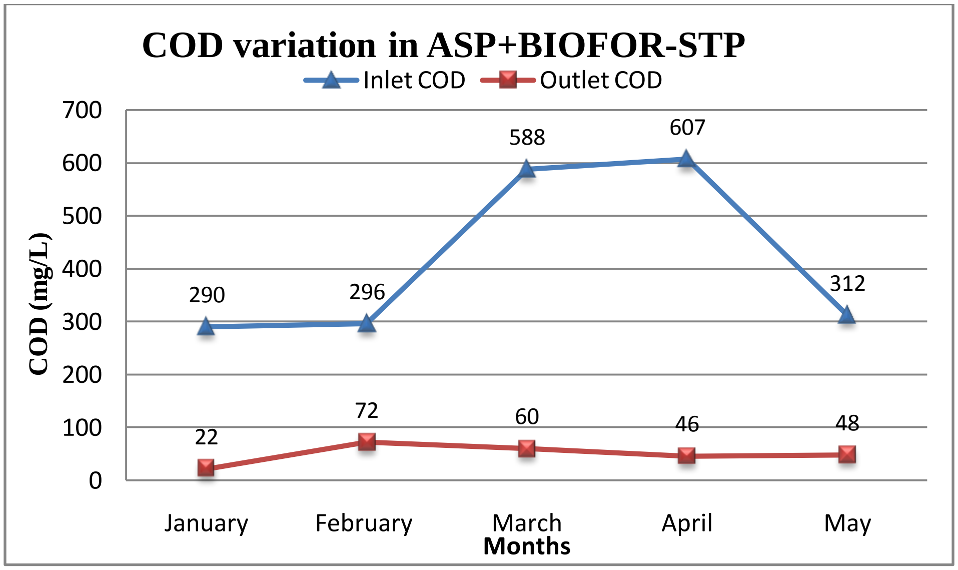


Figure 5.50: COD variation in ASP + BIOFOR STP Phase-I at Rithala, Delhi

Figure 5.49 & 5.50 depicts the BOD & COD variations respectively in the month January to May for STP based on ASP+BIOFOR Process. BOD value at the inlet was noted to be in between 110 mg/L to 270 mg/L and after treatment in the plant BOD value was brought down in the range starting from 4 mg/L to 18 mg/L, ensuring the compliance with the stipulated standards for effluent discharge. COD values throughout the study ranges between 290 mg/L to 607 mg/L at the inlet of the plant whereas after treatment the reduction of COD ranges in between 22 mg/L to 72 mg/L.

5.6 Oxidation Ditch Process Based STP at Phase-II, Keshopur, Delhi

5.6.1 Introduction of the STP

The Sewage Treatment Plant Phase-II, Keshopur, Outer Ring Road, Delhi is operating at the installed capacity of 20 MGD of average flow. The plant was constructed by the Delhi Jal Board under Yamuna Action Plan. Details of plant are given below:

i)	**Plant capacity**	20 MGD
ii)	**Plant Location**	Installed at Keshopur, Outer Ring Road, Delhi
iii)	**Developed by**	Constructed by Delhi Jal Board under Yamuna Action Plan.
iv)	**Maintained by**	M/s Va-Tech Wabag Ltd
v)	**Sewage intake**	From sewerage from localities of Patel Nagar, Naraina, Moti Nagar, Rajouri Garden, Janakpuri and Vikaspuri including Cantonment area
vi)	**Treatment Technology**	Oxidation Ditch
vii)	**Treatment Units**	Inlet Chamber, Bar Screen, ,Grit Chamber, Aeration tank-Oxidation Ditch, Final settling tank, Treated Effluent channel, sludge digestor, Gas holder, Sludge drying beds.
viii)	**Biogas utilization**	Biogas generated is being flared of into the atmosphere.
ix)	**Treated Water disposal**	Treated water is discharged in to Najafgarh drain and then to River Yamuna.

A satellite imagery of the STP located near Keshopur, Delhi taken from google earth is shown in the Figure 5.51.

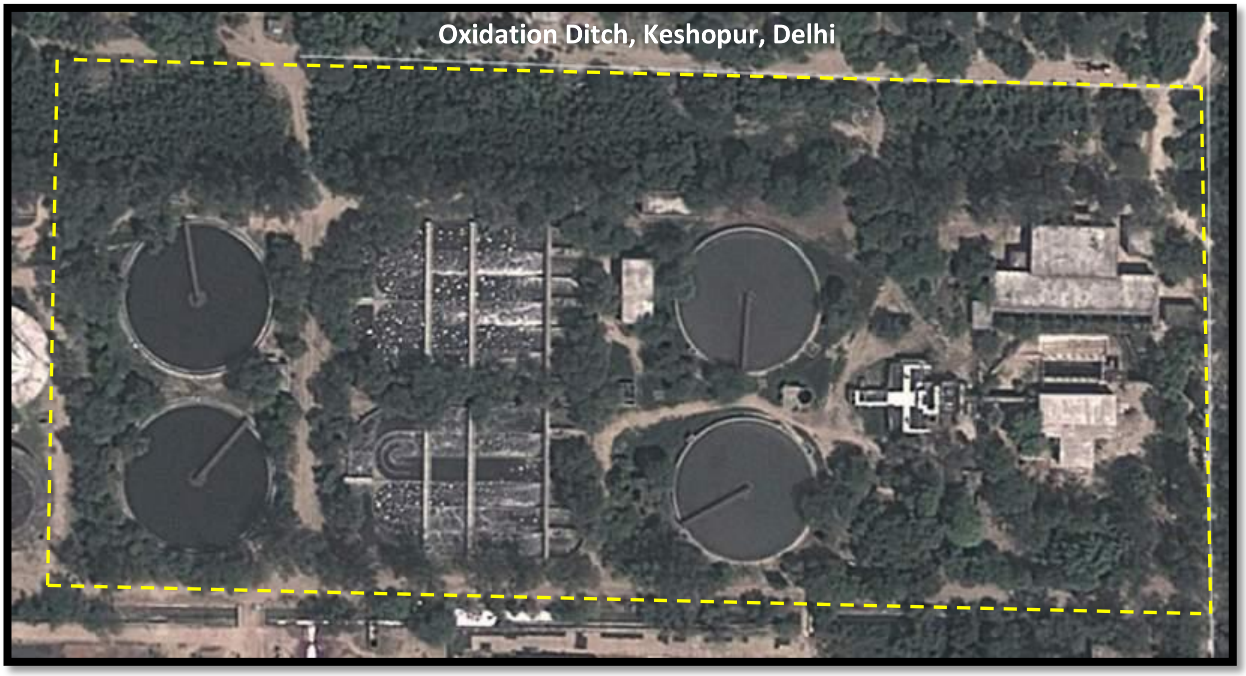


Figure 5.51: Satellite image of STP based on Oxidation Ditch Technology at Keshopur, Delhi

5.6.2 Process Description of STP based on Oxidation Ditch Technology

(i) Bar Screen

Sewage is conveyed from three (3) main trunk sewers namely West Delhi, Jail Road and Railway Wing trunk sewer and from sewage inlet chamber, the raw influent is passed through bar screens.

(ii) Grit Chambers

Grit chamber is provided where heavy organic matter of specific gravity more than 2.5 is allowed to settle down and then removed with the help of screw conveyer. From this section, sewage is pumped to primary clarifier.

(iii) Primary Settling Tank

The sewage after removing the grit is taken to primary settling tank by gravity. The raw sludge from the primary clarifiers is collected into the wet sump of raw sludge pump house.

(iv) Oxidation Ditch

Effluent form the primary settling tank is submitted to the Oxidation Ditch. As soon as the influent flow enters the ditch; it is subjected to heavy aeration and circulation (normally close to about 0.30 meters per second) thereby allowing long solid retention times. The mixing process entrains oxygen into the mixed liquor to foster microbial growth and the motive velocity ensures contact of microorganisms with the incoming wastewater. The aeration sharply increases the dissolved oxygen (DO) concentration but decreases as biomass uptake oxygen as the mixed liquor travels through the ditch. Solids are maintained in suspension as the mixed liquor circulates around the ditch. Oxidation ditch installed at Phase-II, Rithala is shown in Figure 5.52.

Figure 5.52: Oxidation Ditch installed at Phase-II, Rithala, Delhi

(v) Final Settling Tank

The effluent from the oxidation ditch is subsequently submitted to the Secondary Settling Tank (SST) or clarifier to separate the sludge, part of which is returned back to the ditch and remaining extra sludge is taken to the drying beds after passing through the digester.

(vi) Sludge Digester & Gas Holder

Sludge from the final settling tank is pumped to the sludge digester from where digested sludge is sent to sludge drying beds while the Supernatant is returned to the Primary Settling Tank (PST) and biogas generated is flared off into the atmosphere.

(vii) Sludge Drying Beds

Open Sludge drying beds have been provided in order to dewater the sludge as shown in Figure 4.39. Quality of sludge generated seems to be full of nutrients as plants were noted to be grown on the drying beds as depicted in the Figure 5.53.

Figure 5.53: Sludge Drying Beds at Oxidation Ditch based STP

(x) Treated Water Disposal

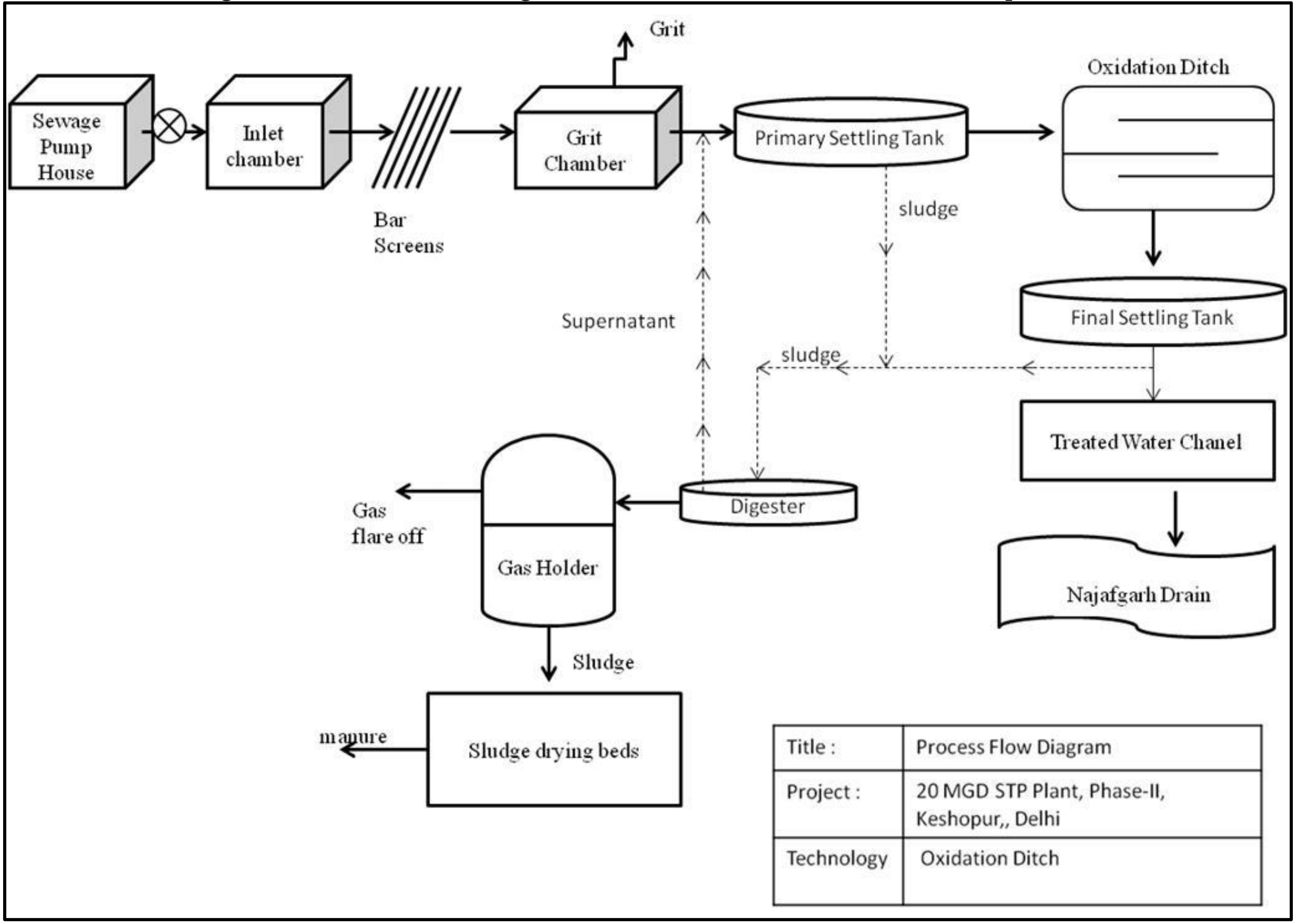
Treated water from the STP is discharging into the Najafgarh drain which ultimately drains into River Yamuna.

Dimensional details of STP units and facilities of Oxidation Ditch Plant are shown in Table 5.16 and Process Flow Diagram of STP based on Oxidation Ditch at Keshopur, Delhi is shown in Figure 5.54.

Table 5.16: Dimensional details of various units and facilities of the STP based on Oxidation Ditch at Keshopur, Delhi

Treatment Unit	Number	Size/Dimensions
Mechanical Bar Screens	2 Nos.	2.5 M x 1.5 M
Grit Chamber	2 Nos.	9.5 M x 9.5 M Water Depth:- 1.5 M
Primary Clarifiers	2 Nos.	Dia :- 42.0 M Depth :- 3.5 M Center Depth :- 5.0 M Retention time: - 1.5 Hrs to 2.0 Hrs. Sludge production rate:- 50% to 60%
Aeration Tank	1 No. 20 Nos. Aerator	Aeration tank volume - 88.0 m x 70.50 m Aeration Capacity - 16 MGD, HP- 40
Secondary Clarifier	2 Nos.	Dia :- 42.0 M Depth :- 3.5 M Center Depth :- 5.0 M Retention Time :- 2 Hrs to 4 Hrs
Raw Sludge Pump House (30 HP)	3 Sets.	LPS, Head
Return Pump House (30 HP)	4 Sets.	LPS, Head
Sludge Digester	6 Nos.	Capacity: - 36.0 Lac Cub. Feet
Gas Holder	2 Nos.	Capacity:- 10.0 Lac cub feet
Sludge Drying Beds	10 Nos.	Area :- 30.5 M x 30.5 M Depth :- 1.20 M

Figure 5.54: Process Flow Diagram of STP based Oxidation Ditch at Keshopur, Delhi



Title :	Process Flow Diagram
Project :	20 MGD STP Plant, Phase-II, Keshopur,, Delhi
Technology	Oxidation Ditch

5.6.3 Oxidation Ditch- STP Performance Evaluation & Analysis

Samples were collected from the Inlet & Outlet point of the plant and were analyzed for the parameters like pH, TSS, BOD and COD for the period starting from the month of January till May 2013. STP was not found operational in the Month of January and February due to plant rehabilitation work. Analytical results for the Oxidation Ditch are summarized in Table 5.17. The variation in pH, TSS, BOD and COD in different months is shown in Figure 5.55, Figure 5.56, Figure 5.57 and Figure 5.58 respectively.

Table 5.17: Physico chemical analysis of STP based on OD technology

Parameters	**pH**		**TSS**		**BOD**		**COD**	
Month	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**
January	Non operational due to plant rehabilitation work							
February								
March	7.4	7.4	464	18	180	36	688	156
April	7.6	7.8	332	28	120	18	420	56
May	7.48	7.87	73	25	163	30	344	160
Maximum	7.6	7.4	464	25	180	36	688	160
Minimum	7.48	7.87	73	18	120	18	344	56
Average	**7.49**	**7.69**	**290**	**24**	**154.3**	**28**	**484**	**124**
Percentage Reduction	**-**		**92%**		**81.8%**		**74.3 %**	

Samples at inlet and outlet of the STP were examined for Fecal Coliform and Total Coliform parameter in order to assess microbial contamination removal. Results of analysis are summarized in Table 5.18 as shown below.

Table 5.18: Microbial analysis of STP based on OD Technology

S. No.	**Parameter**	**Inlet**	**Outlet**
1.	**Total Coliform (MPN/100ml)**	$46 X 10^8$	$75 X 10^4$
2.	**Fecal Coliform (MPN/100ml)**	$15 X 10^8$	$23 X 10^4$

It can be seen from the Table 5.18 that TC & FC removal is in order from 10^8 to 10^4 irrespective of the fact that the technology is not a satisfactory performer in the removal of other parameters as discussed in the earlier section above.

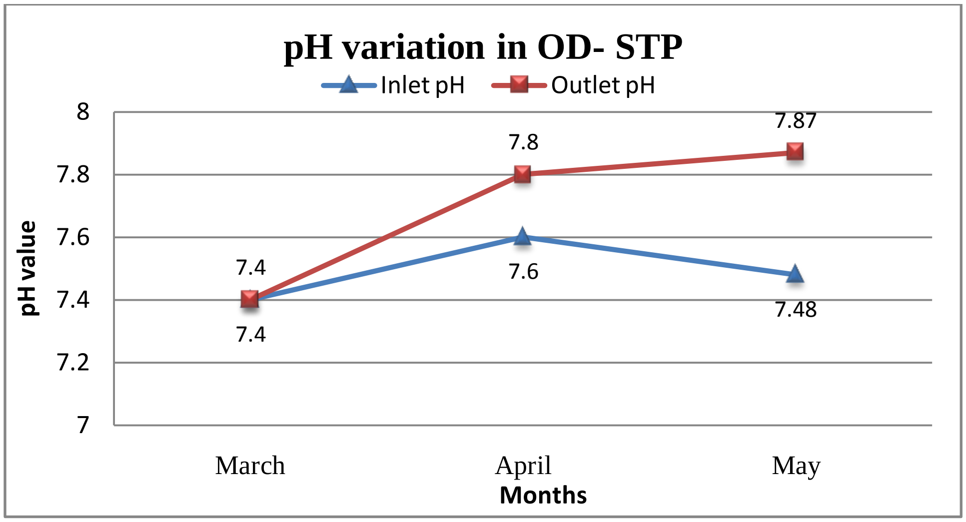


Figure 5.55: pH variation in OD- STP at Keshopur, Delhi

Figure 5.55 & Figure 5.56 represents the variation in pH and TSS respectively in the month March to May as the plant was non-operational in January and February months. pH value was found in range of 7.4 to 7.6 at the inlet and at the outlet ranges from 7.4 to 7.87, which is noted to be in controlled circumstances. However, there is wide fluctuation in TSS value and it can be understood from the fact that at the inlet it ranges from 73 mg/L to 464 mg/l, though after treatment TSS value was brought down in the range between 18 mg/L to 28 mg/L, which is noted to be within the stipulated standards for effluent discharge.

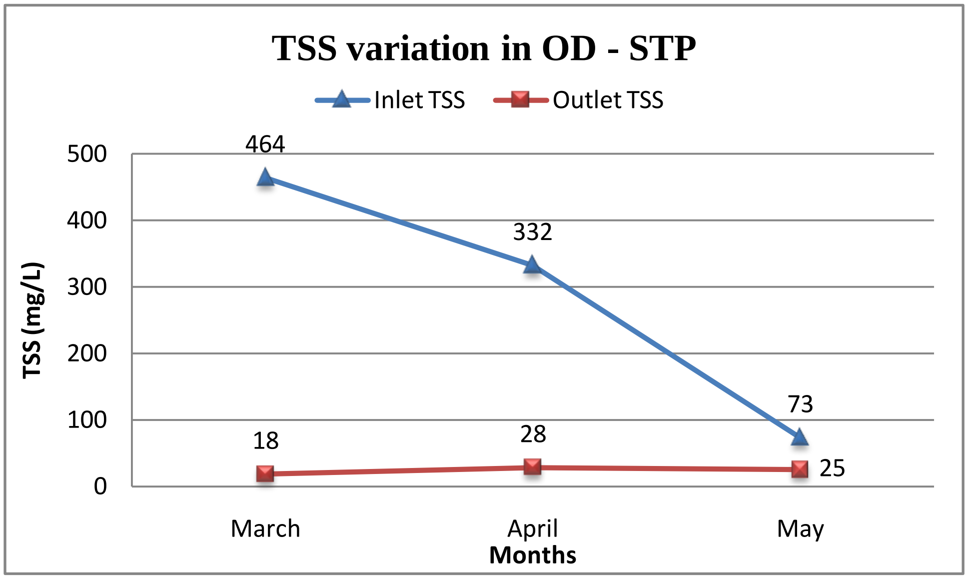


Figure 5.56: TSS variation in OD- STP at Keshopur, Delhi

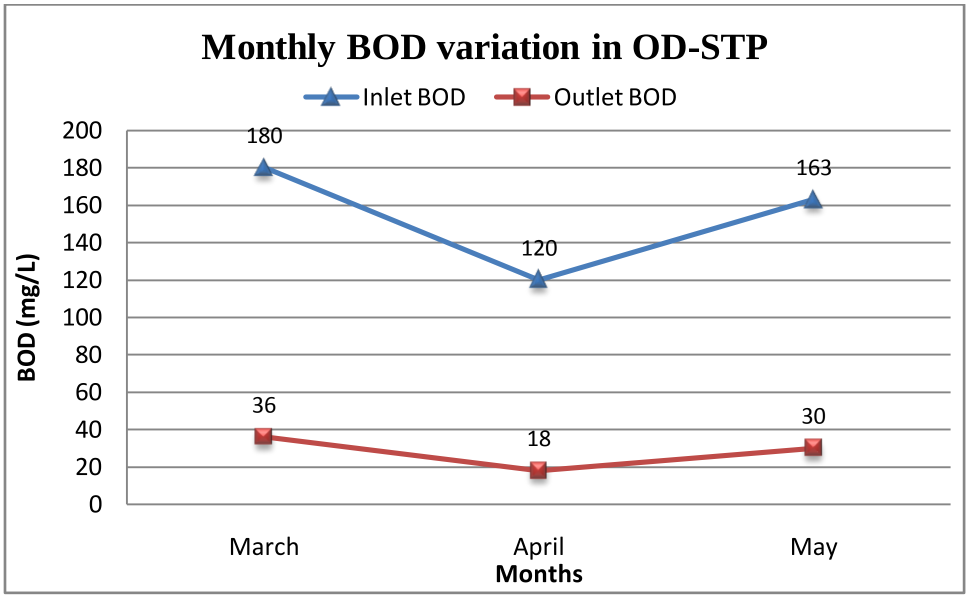


Figure 5.57: BOD variation in OD- STP at Keshopur, Delhi

Figure 5.57 & 5.58 represents the variation in BOD & COD respectively in STP based on Oxidation Ditch technology. BOD value at the inlet of the STP was found to range in between 120 mg/L to 180 mg/L and after treatment its vale is brought down in the ranges between 18mg/L to 36 mg/L, thereby pointing to non-compliance with the discharge limit of 30 mg/l at most of the months. COD value was determined to be in ranges varying from 344 mg/L to 688 mg/L at the inlet of STP and after treatment the value was found in the range of 56 mg/L to 160 mg/L.

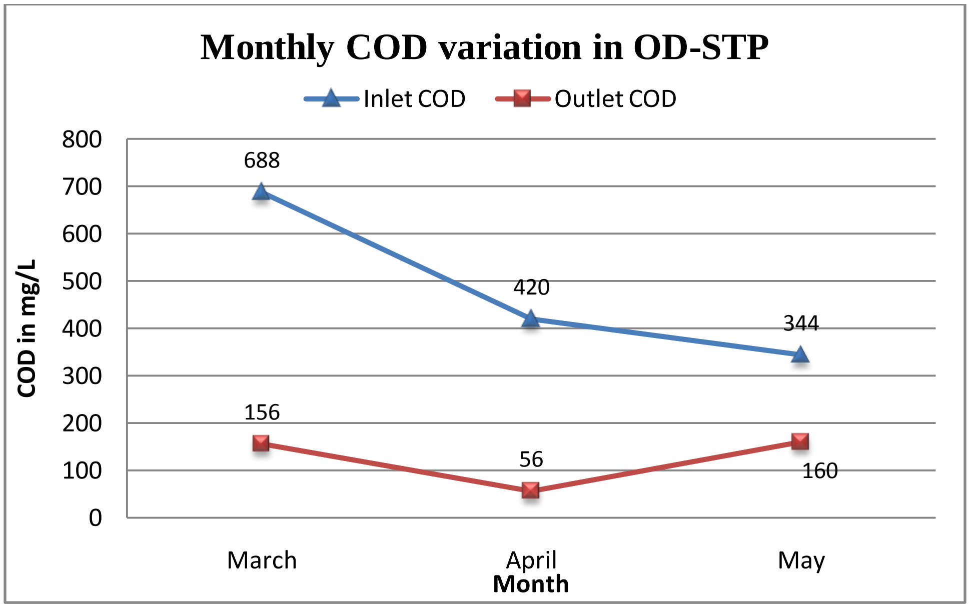


Figure 5.58: COD variation in OD- STP at Keshopur, Delhi

CHAPTER 6

RESULTS AND DISCUSSION

As a part of evaluation methodology for various technological options for sewage treatment, a number of parameters have been identified as a part of the study. These include performance efficiency with respect to removal of organics, suspended matter and enteric microbes; resource requirement along with associated cost and exploration of any possibility for resource recovery. Summary of the results of the physico-chemical analysis carried out during the course of the study is depicted in Table 6.1. The results of MLSS analysis of Bio-reactors, Microbial analysis and Resource requirement analysis in terms of Cost, Area and Energy is shown in Table 6.3, Table 6.4 and Table 6.5 respectively.

6.1 Physico-Chemical Analysis of STPs based on different technologies.

As evident from Table 6.1, it has been observed that except the STP based on UASB (located in Dhanwapur, Gurgaon, in the State of Haryana) all the technologies are capable of treating the effluent up to the effluent discharge standards as stipulated by the Central Pollution Control Board (CPCB). Moreover, BIOFOR & SBR are advanced aerobic treatment technologies which are theoretically designed for the removal of BOD <10 mg/l and TSS < 15 mg/l. BOD value after treatment from BIOFOR and SBR based STPs is 7.6 mg/L which corresponds to a removal efficiency of 95.2% and 96 % for BIOFOR and SBR treatment technologies, respectively. Sewage intake of both the STPs is from different drains.

Table 6.1 - Physicochemical Analysis of STPs with different treatment technologies (Monthly Average)

S. No.	Treatment Technology	pH		BOD			COD			TSS		
		Inlet	Outlet	Inlet	Outlet	% Removal	Inlet	Outlet	% Removal	Inlet	Outlet	% Removal
1	BIOFOR	7. 3	7.2	161	7.6	95.2%	475	31	93.4%	483	14	97%
2	SBR	6.8	7.4	190	7.6	96 %	615	75	87.7%	610	11.6	98 %
3	UASB	7.5	7.7	188	58	69 %	492	152	69%	290	5.7	80.3%
4	ASP	7.8	7.8	152	21	86 %	437	72	83.5%	264	22	91.6%
5	ASP-BIOFOR	7.6	7.8	172	13	92.4%	419	50	88 %	264	18	93.1%
6	Oxidation Ditch	7.5	7.7	154	28	81.8%	484	124	74.3%	290	24	91.7%

ASP-BIOFOR is a combination of conventional ASP technology with advanced aerobic treatment technology. From the Table 6.1, it can be seen BOD removal is from 172 mg/L to 13 mg/L, COD removal is from 419 mg/L to 50 mg/L and TSS removal is from 264 mg/L to 18 mg/L. However, white foams were observed in biofilter tanks. Foaming is related to the development of two bacteria genera *Nocardia* and *Micothrix* (Pitt and Jenkins, 1990), which have hydrophobic cell surfaces and attach to air bubble surfaces, where they stabilize the bubbles to cause foam. The organisms can be found in high concentrations in the foam above the activated sludge liquid. Foaming in activated sludge process can be of different types as listed in Table 6.2**.**

Table 6.2: Description and Causes of Activated Sludge Foams

Foam Description	Cause(s)
Thin, white to gray foam	Low cell residence time or “young” sludge (startup foam)
White, frothy, billowing foam	Once common due to non biodegradable detergents (now uncommon)
Pumice-like, grey foam (ashing)	Excessive fines recycle from other processes (eg. Anaerobic digesters)
Thick sludge blanket on the final clarifier(s)	Denitrification
Thick, pasty or slimy, grayish foam (industrial system only)	Nutrient-deficient foam; foam consists of polysaccharide material released from the floc
Thick, brown, stable foam enriched in filaments	Filament-induced foaming, caused by Nocardia, Microthrix or type.
Source: (Richard et al., 2003)	

6.1.1 TSS removal Profile of STPs based on different technologies

Viruses in waters are known to adsorb to solids which protect them from inactivation by biological, chemical and physical factors (USEPA 1985). TSS removal for BIOFOR & SBR based STPs is from 483 mg/l to 14 mg/l (97 % removal efficiency) and 610 mg/l to 11.6 mg/l (98 % removal efficiency) respectively. TSS removal for both the technologies is as per their theoretical removal efficiency which is <15 mg/l. TSS profile of different treatment technologies is shown in Figure 6.1.

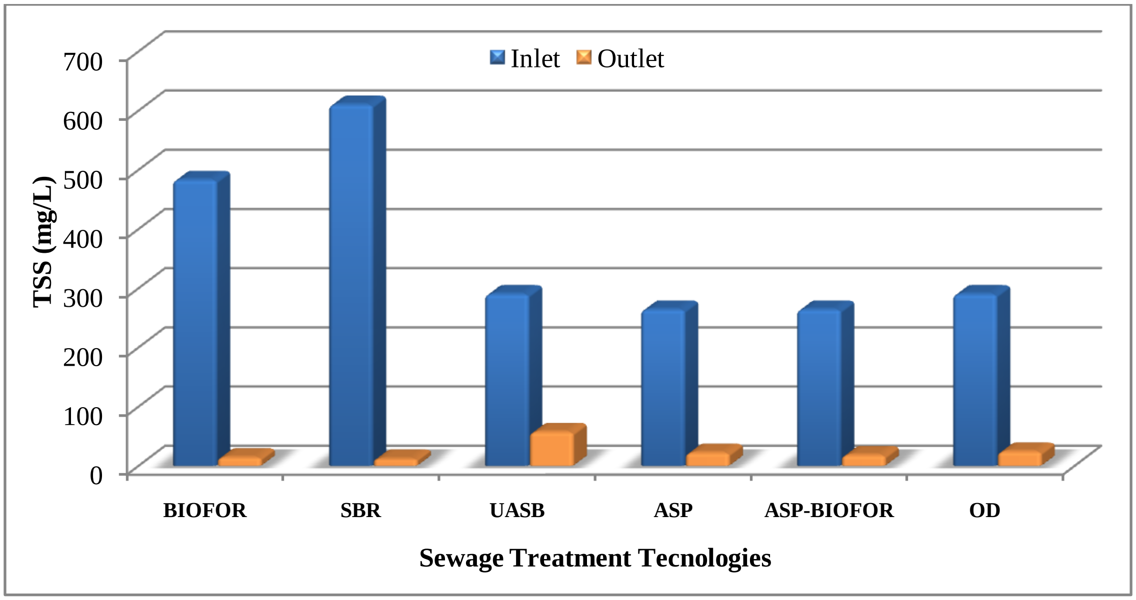


Figure 6.1: TSS removal profile of STPs with different treatment technologies

As observed from the Figure 6.1, except UASB all the treatment technologies such as BIOFOR, SBR, ASP, ASP+BIOFOR and OD are much more efficient in the removal of TSS.

6.1.2 pH Profile of STPs based on different technologies

Anaerobic wastewater treatment can proceed well at a pH range of 6.6 to 7.6 (McCarty & P. L, 1964). Reactor failure is often caused by decrease in pH (Huser *et al.*, 1982). UASB reactors are generally operated with pH value ranging from 6.9 to 7.5. pH value at the inlet of UASB based STP is 7.5 which required attention in order to preserve the microbial activities for organic stabilization through the sludge blanket. A comparative pH profile of UASB with other treatment technologies is shown in Figure 6.2 below.

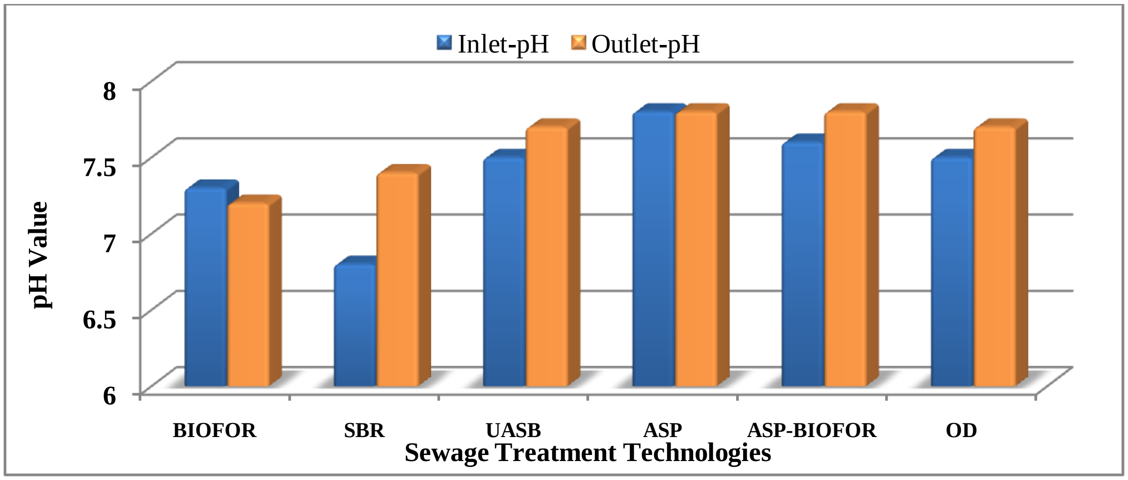


Figure 6.2: pH value at Inlet and Outlet of STPs based on different treatment technologies

6.1.3 BOD removal Profile of STPs based on different technologies

Reduction in BOD Levels is an important aspect to be considered while evaluating any treatment technology so as to ensure that minimal BOD load is imparted on the final receiving waters which is especially the rivers in the case of metropolitan cities such as Delhi-NCR and if not controlled will lead to destruction of the aquatic ecosystem altogether. ASP and Oxidation Ditch are conventional aerobic biological treatment technologies. STP based on ASP and OD are treating sewage received from different pumping stations located in Delhi region. The oxygen demand in both the technology is normally high and the process requires sufficient aeration and agitation for the effective oxygen transfer in the whole system. From the Table 6.1, it follows that the BOD removal is from 152 mg/l to 21 mg/l and 154 mg/l to 28 mg/l for ASP and Oxidation Ditch respectively which in turn corresponds to removal efficiency of BOD profile of different technologies is shown in Figure 6.3.

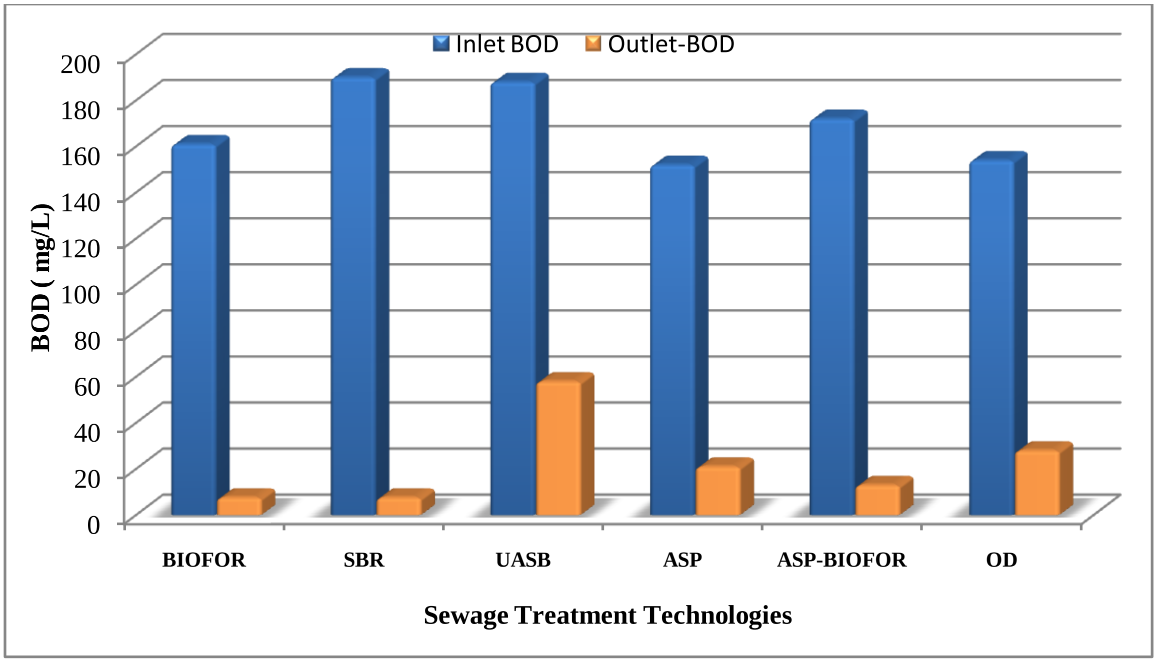


Figure 6.3: BOD removal Profile of STPs with different treatment technologies

UASB is a conventional treatment technology for the treatment of wastewater, with anaerobic decomposition of the same along with production of biogas. From the Figure 6.3, it can be seen that there is a minimal reduction in the BOD level which is brought down from 188 mg/l to 58 mg/l only in the final treated effluent that is being discharged into the Najafgarh drain. Final Polishing Unit (FPU) with retention time of only 24 hours is provided, which does not allow the growth of algal cells in FPU as it is noted to be too short for the minimum requirement of three (3) days.

6.1.4 COD removal Profile of STPs based on different technologies

A comparative profile for COD removal noted for different treatment technologies is depicted in Figure 6.4. It can be inferred from the figure below that being an anaerobic treatment method, UASB is not as effective in removal of organic matter as other treatment technologies, which indicate poor performance of Oxidation Ditch. This might be due to insufficient oxygen transfer in the ditch or due to less concentration of biomass as mixed liquor suspended solids generated in the system to enhance the removal rate. COD removal efficiency was observed to be maximum in case of STP based on BIOFOR technology which is from 475 mg/L to 31 mg/L while UASB was least efficient in removal of COD which is from 492 mg/L to 152 mg/L.

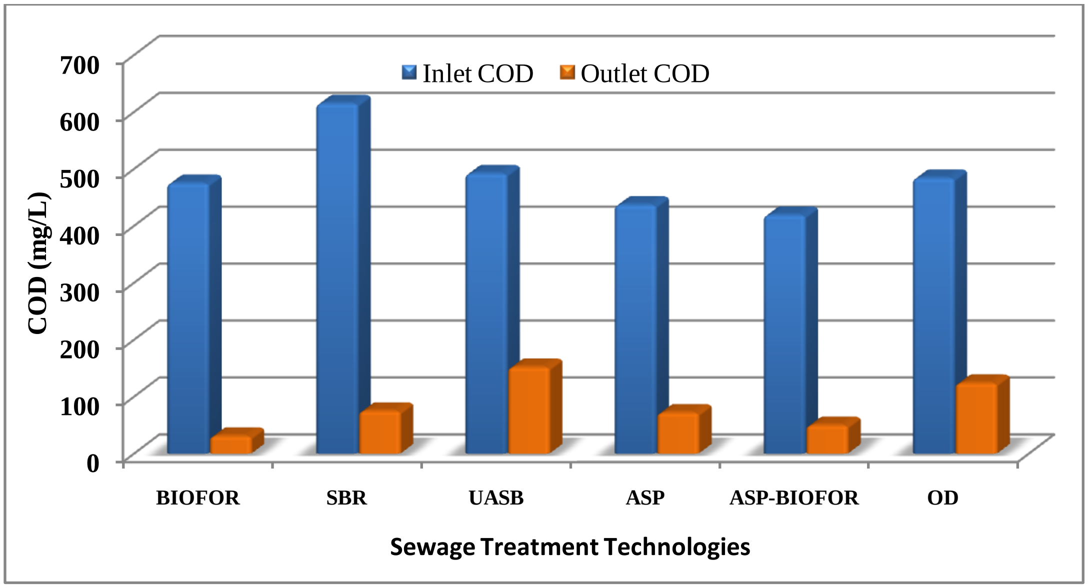


Figure 6.4: COD removal Profile of STP with different treatment technologies

6.1.5 Overall removal efficiency for physico-chemical parameters

Overall percentage removal of physico-chemical parameters namely BOD, COD and TSS of STPs based on different treatment technologies is shown in Figure 6.5**.** In terms of BOD removal, maximum removal efficiency was observed for STP based on SBR (96%) and minimum removal efficiency observed for UASB technology (69%). Order for overall BOD removal efficiencies as observed are **SBR (96%) > BIOFOR (95.2%) > ASP-BIOFOR (92.4%) > ASP (86%) > Oxidation Ditch (81.8%) > UASB (69%)**.

Removal Efficiencies of STPs in terms of COD removal were observed to be in the order as BIOFOR **(93.4%) > SBR (87.7 %) > ASP-BIOFOR (88%) > ASP (83.5%,) > Oxidation Ditch (74.3 %)> UASB (69%)**

However, in the case of TSS removal, the same were observed to be in the order as **SBR (98%)** > **BIOFOR (97%)** > **ASP-BIOFOR (93.1%)** > **OD (91.7%)** > **ASP (91.6)** > **UASB (80.3%).**

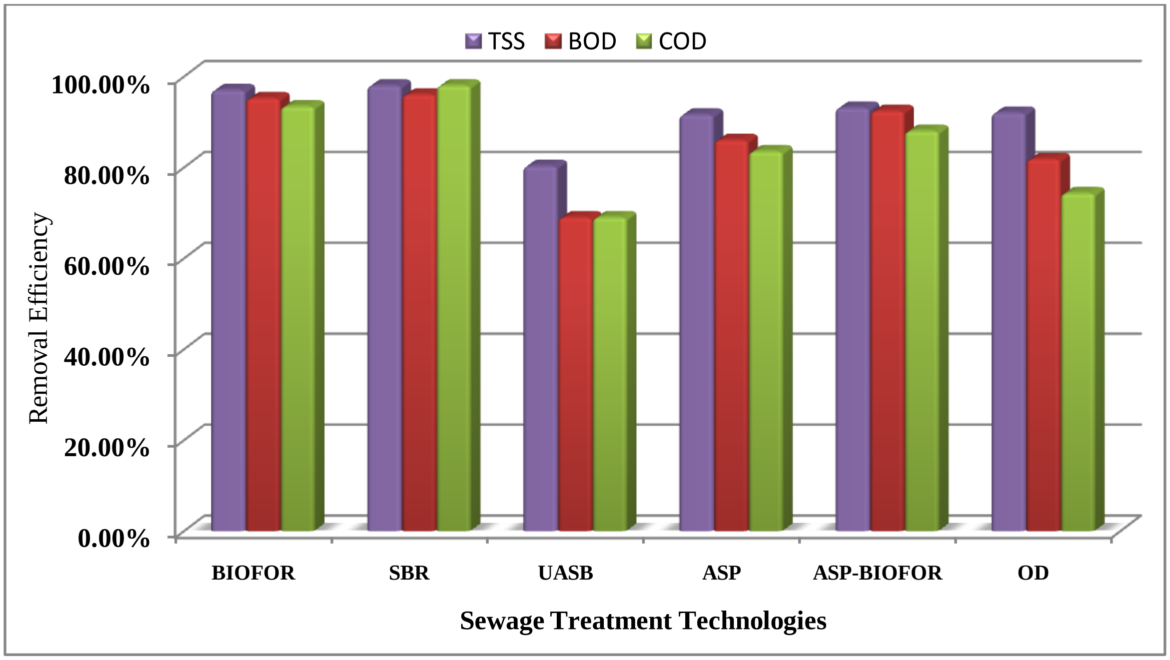


Figure 6.5: Percentage removal efficiency of STPs based on different treatment technologies

6.2 Biomass Analysis in Terms of MLSS

Mixed Liquor Suspended Solids (MLSS) is the concentration of suspended solids in the mixed liquor. If MLSS content is too high, the process is prone to bulking and the treatment system becomes overloaded which can cause the dissolved oxygen content to drop with the effect that organic matters are not fully degraded and biological ‘die off’. Also, excessive aeration is required in turn to maintain MLSS content in case it’s too high, which ultimately consumes more electricity and hence the O&M cost of the same increases. If MLSS content is too low, the process is not operating efficiently and again is consuming energy irrespective of the lower performance achieved. Values as observed during the analysis of the effluent for MLSS from the sections of the STPs where aeration is carried out are summarized in Table 6.3.

Table 6.3: Mixed Liquor Suspended Solids (MLSS) Levels in different STPs

S. No.	Technology	Tank Name	MLSS (mg/l)
1.	BIOFOR	Dens Deg Bio-reactor	2500
2.	SBR	SBR Tank	2700
3.	ASP	Aeration Tank	1956
4.	ASP+BIOFOR	Aeration Tank	1558
5.	Oxidation Ditch	Oxidation Ditch	1097

From the Table 6.3, biomass growth of BIOFOR & SBR based STP is noted to be sufficient for biological treatment as the same is meeting the primary requirement of 2200-2500 mg/l for

MLSS, which is an operational parameter that needs to be kept in the aforementioned range so as to ensure effective operation of the STP. However, biomass growth in ASP based STPs & OD is not sufficient for the biological treatment and thus affects the organic pollutant removal. MLSS level is observed to be least i.e. 1097 mg/l in the Oxidation Ditch that leads to overall poor performance of the same as noted from Table 6.1 as well.

6.3 Microbial Analysis of different STPs for TC & FC.

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 fecal origin, contaminate the environment and then gain access to new hosts through ingestion. (CPCB, 2008). Wastewater treatment plants discharge significant amounts of fecal pollution indicators and pathogenic micro-organisms leading to reduction in the water quality (Bahlaoui *et al.*, 1997). Fecal Coliforms (FC) are the indicator organisms used to evaluate the biological quality of surface waters for different purposes such as drinking, bathing, swimming, etc. High levels of FC indicate presence of pathogens, thus posing health implication. Composite samples give good results only for chemical analysis but not for bacteriological analysis of wastewater (CPHEEO, 1993). Raw influent and final effluent samples of STPs with different technologies were analyzed for the target micro-organisms using standard method of APHA and results are summarized in Table 6.4.

Table 6.4: Total Coliform and Fecal Coliform levels in different STPs

S. No	Treatment Technology	Total Coliform (MPN/100 ml)		Fecal Coliform (MPN/100 ml)	
		Inlet	Outlet	Inlet	Outlet
1	BIOFOR	$97 X10^6$	$42X10^5$	$24 X10^7$	$23 X10^4$
2	SBR	$15X10^7$	$93x10^2$	$21 X10^7$	$23X10^2$
3	UASB	$18X10^6$	$12X10^5$	$38 X10^6$	$89 X10^4$
4	ASP	$24X10^8$	$28X10^4$	$15 X10^7$	$15 X10^4$
5	ASP+BIOFOR	$24X10^8$	$16X10^4$	$15 X10^7$	$85 X10^3$
6	Oxidation Ditch	$46X10^8$	$75X10^4$	$15 X10^8$	$23 X10^4$

From the Table 6.4, it has been observed that Total Coliform (TC) and Fecal Coliform (FC) levels in the treated effluent from STPs employing different treatment technologies ranged from $93 X 10^2$ to $42 X 10^5$ MPN/100 ml and $23 X 10^2$ to $89 X 10^4$ MPN/ 100 ml. Removal of indicator organism by STPs depends on the type of technology employed and the influent sewage characteristics. High TC and FC levels were observed in the effluent from the STP based on BIOFOR (TC – $42 X 10^5$ & FC – $23 X 10^4$), UASB (TC – $12 X 10^5$ & FC – $89 X 10^4$) and

Oxidation Ditch (TC – 75 X 10^4 & FC – 23 X 10^4). On the other hand, a comparatively lower TC & FC levels i.e. 23 X 10^2 MPN/100 ml & 93 X 10^2 MPN/100 ml respectively were observed with regards to the STP based on SBR technology, as disinfection process in the form of chlorination is being practiced in this case.

Chlorination is also employed in ASP-BIOFOR based STP which leads to lower levels of TC & FC at the outlet i.e. 16 X 10^4 and 85 X 10^3 respectively, that are comparatively less than the values observed in the case of normal ASP process involved in one of the STPs without any chlorination being employed. TC and FC levels in all of the STPs except the one based on SBR, were observed to be on higher note than the effluent discharge standards as stipulated by National River Conservation Directorate (NRCD). The NRCD Committee recommended 10,000 MPN/100 ml as maximum discharge value and 1000 MPN/100 ml as desirable value for discharge of treated Sewage for all river bodies.

6.4 Area and Cost comparison of different sewage treatment technologies

In addition to the evaluation of the performance of the STPs based on different treatment technologies, the same were also analyzed for the capital cost, operation and maintenance costs, energy requirement and land requirement, which is primarily based on the data as obtained from various STPs in the Ganga river basin and information collected from various sewage treatment technology providers. This analysis has been summarized in Table 6.5.

Table 6.5: Resource Requirement Analysis in terms of Cost, Area & Energy Requirement

S.No.	Assessment Parameter	BIOFOR	SBR	UASB+PP	ASP	ASP+BIOFOR	OD
I	**Capital Cost**						
1.1	Avg. Capital Cost *(up to Secondary Treatment+ Sludge Handling)* Rs in *Lacs/MLD*	65	75	68	60	52	50
1.2	Avg. Capital Cost *(Tertiary Treatment+ Sludge Handling)* Rs in *Lacs/MLD*	40	40	40	40	40	40
1.3	**Total Capital Cost (Avg)** ***(Secondary + Tertiary Treatment units)*** Rs in *Lacs/MLD*	**105**	**115**	**108**	**100**	**92**	**90**
1.4	Civil Work *(% of Total Capital Cost)*	50	30	65	60	60	55
1.5	Electrical and Mechanical (E&M) Work *(% of Total Capital Cost)*	50	70	35	40	40	45
II	***Operational & Maintenance (O&M) Cost**						
2.1	**Total Annual O&M Costs** Rs in *Lacs/MLD of wastewater treated*	**8**	**9**	**5**	**12**	**5**	**8**
III	**Area Requirement**						
3.1	Avg. Area requirement, m^2/MLD *(up to Secondary Treatment + Sludge Treatment*[a]*)*	400	450	1000	900	800	800

3.2	Avg. Area requirement, m^2/MLD *(Tertiary Treatment)*	100	100	100	100	100	100
3.3	**Total Area, m^2/MLD** ***(Secondary + Tertiary Treatment)***	**500**	**550**	**1100**	**1000**	**900**	**900**
	[a] Sludge Treatment : Sludge Thickener+Digester, Sludge Drying Beds						
IV	****Energy Requirement**						
4.1	Average Daily Power Requirement,*kWh/d /MLD* *(up to Secondary Treatment)*	218.8	153.8	123.8	183.8	178.8	198.8
4.2	Average Daily Power Requirement , *kWh/d /MLD* *(Tertiary Treatment)*	1.20	1.20	1.20	1.20	1.20	1.20
4.3	**Total Daily Power Requirement (Avg.)**, *kWh/d /MLD* *(Secondary + Tertiary Treatment)*	**220**	**155**	**125**	**185**	**180**	**200**

***** *O & M cost includes: Cost of Energy requirement, repairing cost, cost of chemical required and cost for manpower. It is variable according to location, time and quality of treated effluent.*

****** *Energy Requirement includes : Avg. Technological power requirement and Avg. Non- Technological Power requirement for running of Plant*

Source : a) Compendium of Sewage Treatment Technologies, NRCD, MOEF,GOI-2009
b) CPCB report, Sewage Treatment in Class-I Town, December-2010
c) STP Technologies providers

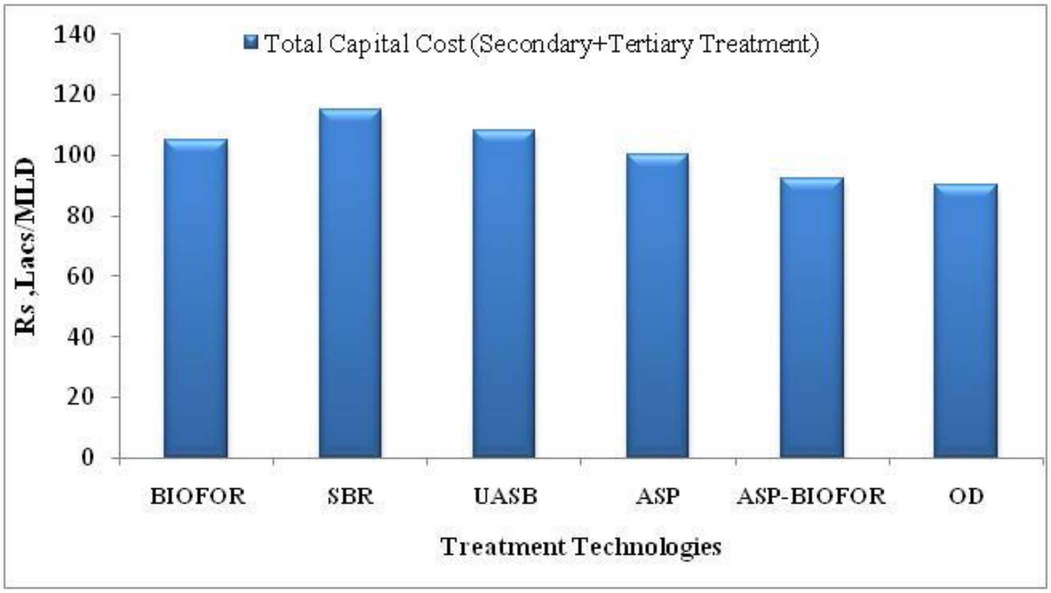


Figure 6.6 – Total Capital Cost (Rs. Lacs/MLD) for STPs based on different STPs

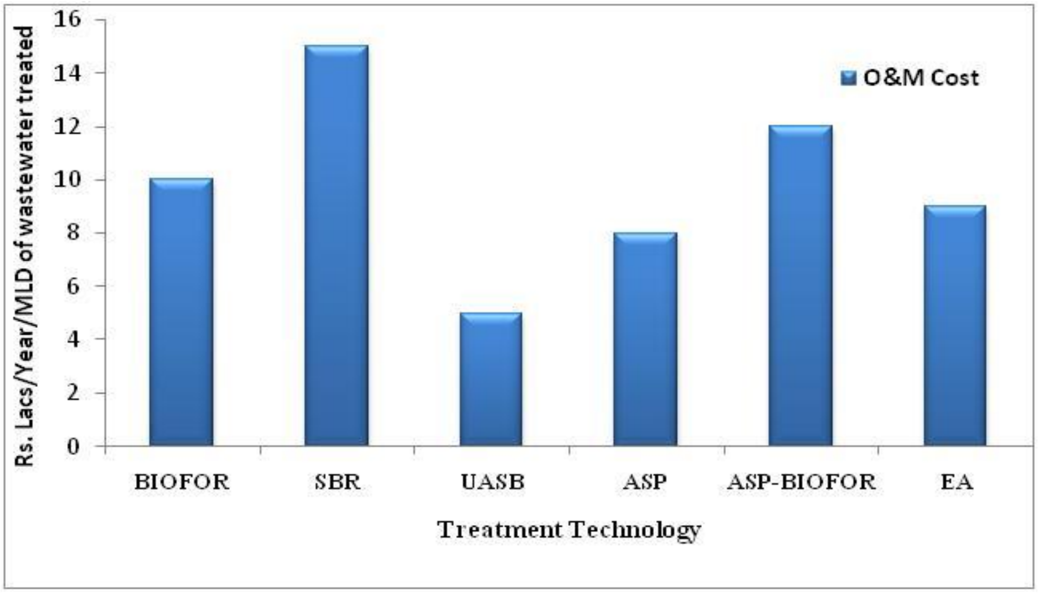


Figure 6.7: O&M Cost (Rs. Lacs/MLD) for STPs based on different technologies

As evident from the Figure 6.6 and 6.7, the total capital cost ranges from a minimum of 90 Lacs/MLD (Oxidation Ditch) to a maximum of 115 Lacs/MLD (Sequential Batch Reactor) while the annual O&M Costs varies from a minimum of 5 Lacs/MLD (UASB and ASP+BIOFOR) to a maximum of 12 Lacs/MLD (ASP). Therefore, it can be inferred that some of the technologies not only requires initial cost to establish the system but the O&M Cost plays an important role in selection of the technology in terms of evaluating the future prospects of the same. This will be of assistance to evaluate payback time in case there is an energy recovery involved such as in UASB system, which will again reduce the overall costs of the whole system installed.

Conventional Treatment technology such as ASP based STP not only involves higher initial investments but also incur higher O&M Costs to run the system based on the same.

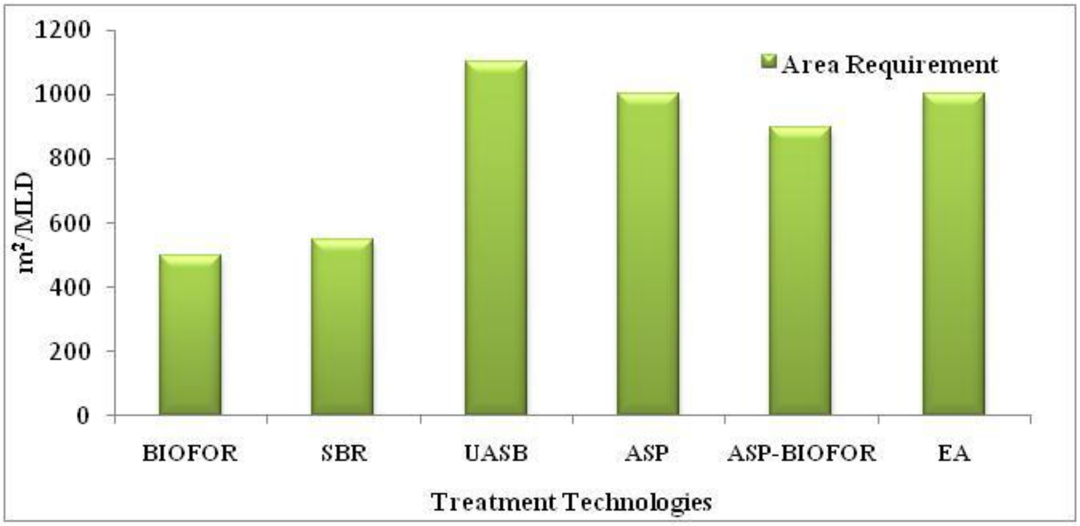


Figure 6.8: Land Area Requirement (m^2/MLD) for STPs based on different technologies

Land Area requirement for the different technologies differ as most of the advanced technologies such as BIOFOR and SBR requires minimal area with regards to the Process Units, however, conventional treatments would require higher land area, which is depicted in the Figure 6.9 as well. As per the Section III of Table 6.6 and Figure 6.8, treatment technologies such as UASB, ASP, ASP +BIOFOR and Oxidation Ditch require more land area as compared to BIOFOR and SBR systems.

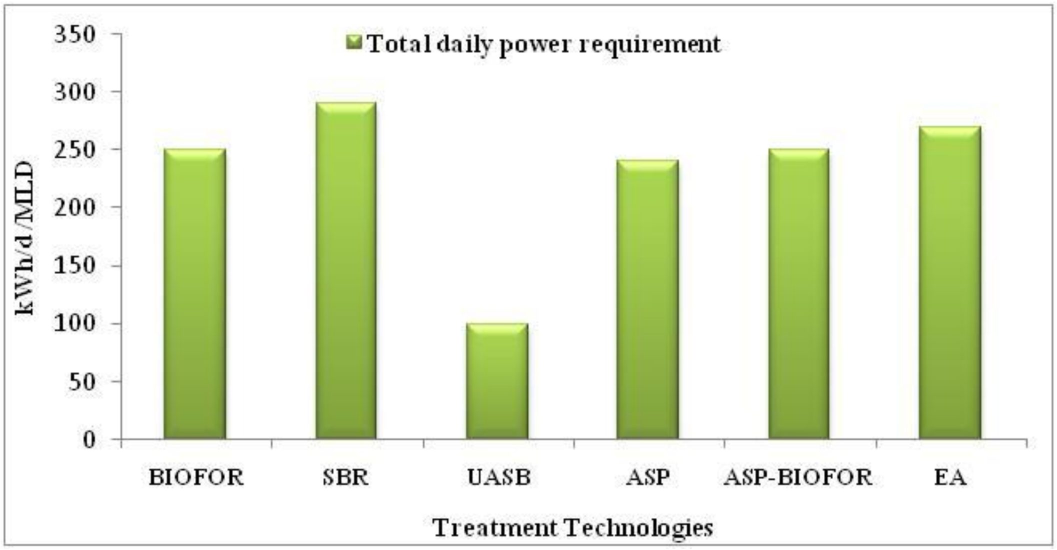


Figure 6.9: Energy Requirement (kWh/d/MLD) for STPs based on different technologies

Energy requirement to operate a wastewater treatment plant is an essential and integral part that accounts for a considerable portion of the costs involved. It also enables one to evaluate the performance of the system as it accounts for higher energy consumption when the system is old or is experiencing any technical issues, which in turn affects the overall performance and subsequently the treated water quality. As per the Section IV of Table 6.6 and Figure 6.9, it can be inferred that BIOFOR irrespective of being the advanced technology requires maximum energy (with daily power requirement of ~220 kWh/MLD) for daily functioning of the plant as compared to other technologies with UASB requiring the least amount of energy (with daily power requirement of 125 kWh/MLD). It can be contributed to the fact that UASB system also requires lesser land area for the installation of the system.

6.6 Performance Assessment of different technologies

Depending upon the assessment of different technologies, as per the appraisal scale, a technological option is rated as the following four (4) grades:

(i) Very High
(ii) High
(iii) Average
(iv) Low

6.6.1 Performance in terms of Quality of Treated Sewage

Conventionally, the major concern in terms of discharge of treated or untreated wastewater in water bodies has been the presence of organic matter and pathogens. These are responsible for (i) Spoiling aesthetics of water bodies, (ii) Depletion of dissolved oxygen resulting in adverse impact on aquatic ecosystem and (iii) spread of water-borne diseases. Any treatment technology must be selected in such a way so as to ensure that effluent discharge standards as stipulated by the Regulatory Bodies are being met on a continual basis.

Table 6.7: Performance Grading of Different Technologies w.r.t. Reduction Potential

S.No.	Treatment Technology	TSS Reduction Potential	BOD Reduction Potential	COD Reduction Potential	Coliform Reduction Potential
1	BIOFOR	Very High	Very High	Very High	Very High
2	UASB	Average	Low	Low	High
3	SBR	Very High	Very High	High	Very High
4	ASP	Very High	High	Average	Average
5	ASP with BIOFOR	Very High	Very High	High	Average
6	Oxidation Ditch	Very High	Average	Low	Average

It can be seen from the Table 6.7 that advanced treatment technologies such as BIOFOR and SBR have higher reduction potential for TSS, BOD, COD and Coliform as compared to other treatment technologies with Oxidation Ditch being the worst technology in terms of the reduction potential of these parameters.

6.6.2 Performance in terms of Resource Requirements

All the treatment technologies were reviewed against the following parameters in order to assess the performance of these technologies w.r.t. the resource requirements and also the associated costs with each of the resource:

1) Potential for Low Capital Cost in terms of the initial investments to establish a Treatment Plant
2) Potential for Low Energy Requirements with respect to usage of less energy intensive units and also the potential for a technology to produce returns in terms of energy recovery
3) Potential for Low Land requirement
4) Potential for low O&M cost during the operational phase of the Treatment Plant
5) Potential for low level of operator and skill determined by the type of technology which decides whether a skilled supervision is required for that particular technology or not.

Table 6.8 depict the performance of different sewage treatment technologies in terms of resource requirement.

Table 6.8: Performance Grading of Different Technologies w.r.t. Resource Requirements

S.No.	Treatment Technology	Capital Cost	Energy Requirements	Area Requirement	O&M Cost
1	BIOFOR	Very High	High	Low	High
2	UASB	Very High	Low	Very High	Low
3	SBR	Very High	Very High	Low	Very High
4	ASP	Average	High	High	Average
5	ASP-BIOFOR	High	High	High	Very High
6	Oxidation Ditch	Average	High	Average	Average

6.6.3 Performance in terms of Resource Generation & Recovery

Typically in a Sewage Treatment Plant, three (3) types of end products, which can be treated as resources are - (i) treated effluent, (ii) excess biomass or sludge, which can be used as manure or soil conditioner and (iii) biogas, which can be used as a fuel for power generation or other uses. In water scarce regions, the potential for recycling of the treated effluent for industrial, irrigation and other purpose is very high from the SBR, BIOFOR, ASP along with BIOFOR technology.

Sludge: Substantial quantity of sludge is produced from the technologies such as ASP, UASB and Oxidation Ditch that have a potential to be used as a resource on land acting like manure or soil conditioner. However, the information available on fate of sludge generated from such plants reveals that it contributes marginally in terms of resource generation. It was seen that sludge generated from Oxidation Ditch located in Rohini was so fertile that plants were found grown on sludge drying beds itself.

Biogas: Biogas is produced from Sludge Digestion and from the UASB Reactor. Biogas could be used as fuel or for generating electricity and can prove to be a useful resource. However, at most of the plants, biogas generated is being flared off into the atmosphere, except only in ASP with BIOFOR based STP, it is being used for operation of the plant itself and thereby conserving the energy. Performance of Different Technologies w.r.t. Resource Generation and Recovery is listed in Table 6.9.

Table 6.9: Performance Grading of Different Technologies w.r.t. Resource Generation and Recovery

S. No.	Treatment Technology	Potential of Water reuse	Potential of sludge application	Potential of Biogas generation and utilization
1	BIOFOR	Very High	Low	Low
2	UASB	Average	Average	Very High
3	SBR	Very High	Low	Low
4	ASP	High	High	High
5	ASP with BIOFOR	Very High	High	High
6	Oxidation Ditch	Low	High	Average

CHAPTER 7

CONCLUSIONS & RECOMMENDATIONS

7.1 Conclusions

It is estimated that about 38,254 million litres per day (MLD) of wastewater is being generated in urban centres comprising of Class-I Cities and Class-II towns housing a population of more than 50,000 (which accounts for more than 70 percent of the total urban population). Central Pollution Control Board (CPCB) carried out studies and collected data, which depicts that there are 269 Sewage Treatment Plants (STPs) in India, of which only 231 are operational showing the existing treatment capacity to be just 21 per cent of the present sewage generation. The remaining untreated sewage is the main cause of polluting our rivers and lakes. The large numbers of STPs created under Central Funding schemes such as the Ganga Action Plan (GAP) and Yamuna Action Plan (YAP) of National River Action Plan are not entirely functional.

As per the study carried out for evaluation of different sewage treatment technologies such as BIOFOR, SBR, UASB, ASP+BIOFOR & OD installed in Delhi/NCR for treatment of domestic wastewater, following conclusions are made:

1) BIOFOR Technology which is one of the patented techniques of M/s Degremont, is being used as an advanced aerobic method for sewage treatment as an alternative to conventional aerobic treatment technologies. This technology has an added advantage that it can be used individually or in combination with Activated Sludge Process. BOD, COD & Total Suspended Solids removal efficiencies for BIOFOR based STP was found to be 95.2%, 93.4% and 97% respectively. As compared to other treatment technologies, area requirement is lowest for BIOFOR which is around 500m^2/MLD. Energy requirement is 220 kWh/d/MLD which is noted to be very high, as continuous high rate aeration is required to be provided in Bio-filtration tank.

2) SBR Process is another advanced aerobic treatment method with compact and simplified operations. Since all the unit processes are operated in a single tank, the operation is flexible and nutrient removal can be accomplished by operational changes with quiescent settling enhances the solid separation thereby achieving TSS removal as observed to be up to 98 %. The Highest BOD removal efficiency for this technology is observed to be up to 96% and COD removal up to 87.7%. One of the main advantages of the technology is that it requires less space i.e. only 550 m^2/MLD. The system allows for automatic and positive control of Mixed Liquor Suspended Solids (MLSS) which was determined to be 2700 mg/L in SBR tanks. Capital Cost involved in establishing an STP based on SBR technology is Rs 115 Lacs per MLD treated, which is quite high as compared to other

technologies. With the disinfection process after SBR treated effluent, Fecal Coliform and Total Coliform was noted to be reduced from 21 X 10^7 MPN/100 ml to 23 X 10^2 MPN/100 ml and 15 X 10^7 MPN/100 ml to 93 X 10^2 MPN/100 ml respectively.

3) ASP along with BIOFOR technology is a combination of advanced and conventional treatment technology which was found effective enough to treat the domestic sewage and conforms to the discharge standards as stipulated by CPCB or SPCBs. BOD, COD & Total Suspended Solids removal efficiencies for ASP+BIOFOR based STP was found to be 92.4%, 88% and 93.1% respectively. Operation & Maintenance Cost of this combination of conventional along with an advanced technology is noted to be Rs 8 Lacs/ MLD of treated water, which is quite high as compared to other treatment technologies.

4) ASP is a conventional aerobic treatment technology which uses activated sludge from the secondary clarifier that acts as a catalyst in the treatment process. Reduction efficiencies with regards to BOD, COD & TSS were established to be 86%, 83.5% & 91.6% respectively. Average area requirement for Activated Sludge Process based STP up to the tertiary treatment is 1000 m^2/MLD and power consumption of ASP is i.e. 185 kWh/d/MLD.

5) Upflow Anaerobic Sludge Blanket (UASB) treatment method requires maximum land area and least energy requirement amongst the treatment technologies studied. BOD and TSS reduction is noted to be 69% and 80.3% respectively, thereby clearly specifying the need of providing a second stage aerobic treatment so as to enable the compliance with the stipulated standards and in retrospect the less ambitious conventional technologies e.g. Activated Sludge Process and Oxidation Ditch are still able to perform much better as compared to the UASB. Capital cost for the treatment of UASB plant with complete tertiary treatment is Rs. 108 Lacs/MLD, which is quite high as compared to other treatment technologies except SBR technology.

6) Oxidation Ditch is one of the conventional aerobic treatment technologies for sewage treatment. As there are various new and advanced treatment technologies are available, Oxidation ditches are not being installed with new plants as it is not much effective in removal of Organic matter and solids present in wastewater. Removal efficiencies for TSS, BOD & COD was found to be 91.7%, 81.8 % and 74. 3% respectively. Energy requirement is high which 200 kwh/d/MLD is. Capital cost is lowest which Rs 90 Lacs/MLD is and area requirement is in order of 900 m^2/MLD.

7) Overall BOD removal efficiencies as observed in the assessment of different STPs are in the order as SBR (96%) > BIOFOR (95.2%) > ASP-BIOFOR (92.4%) > ASP (86%) > Oxidation Ditch (81.8%) > UASB (69%). Removal Efficiencies of STPs in terms of COD removal were observed to be in the order as BIOFOR (93.4%) > SBR (87.7 %) > ASP-

BIOFOR (88%) > ASP (83.5 %,) > Oxidation Ditch (74.3 %)> UASB (69%) . However, in the case of TSS removal, the same were observed to be in the order as SBR (98%) >BIOFOR (97%) > ASP-BIOFOR (93.1%)> OD (91.7%) > ASP (91.6%) > UASB (80.3%). As per the results obtained, it can be inferred that UASB not only involves a high capital cost and land area but also is not able to perform well in terms of treatment of domestic wastewater. BIOFOR technology was noted to be the best performer amongst all the technologies assessed as a part of the study.

8) Capital Cost involved in establishing STPs with different technologies in Rs Lacs/MLD are in noted to be in the order as SBR > UASB+FPU > BIOFOR > ASP > ASP+BIOFOR > OD. For Operation & Maintenance Cost in Rs Lacs/MLD of treated water, it is in order of ASP > SBR > BIOFOR = OD > UASB+FPU= ASP+BIOFOR.

9) Requirement of Energy in kWh/d/MLD is observed to be maximum for BIOFOR and minimum for UASB technology. For different technologies the energy requirement is note be in the order as BIOFOR > OD > ASP > ASP+BIOFOR > SBR > UASB. In terms of requirement of land, UASB technology requires the maximum land area while BIOFOR technology requires least area amongst all the six treatment technologies based STPs. Order of land requirement for different technologies in m^2/ MLD is UASB > ASP > ASPBIOFOR = OD > SBR > BIOFOR.

7.2 Recommendations

Based on the the study carried out for evaluation of different sewage treatment technologies such as BIOFOR, SBR, UASB, ASP+BIOFOR & OD installed in Delhi/NCR for treatment of domestic wastewater, following recommendations are made:

1) Gas generated from the sludge digester should be used, wherever possible to generate electricity to meet the in-house power requirement of STPs rather than flaring it off and thereby losing an important share of energy than can be conserved and to create a possibility of reducing the overall energy consumption of the STPs.

2) Installation of disinfection units in all of the STPs where the practice is currently being employed, in order to reduce the Total Coliform & Fecal Coliform level.

3) STPs shall have an equalized flow so that they can be operated on a continuous basis with zero shutdowns and efficiently as well, in order to reduce the final load on the receiving waters. In view of non-perennial conditions of the river, augmentation of treatment technology for all STPs to meet BOD level to 10 mg/l should be expedited.

4) Agencies hired for operation and maintenance of the STPs should work appropriately and more diligence is required in terms of administering the STP operation. Many STPs have different units achieving different level of treatment and the treated effluent from the units achieving the standard should be considered for recycling and may be utilized in industrial sector wherever feasible.

5) The performance of the STPs is interlinked with the influent quality and operating parameters of the treatment process. A synergy between the two is essential for optimum performance of the STPs which was found lacking in most of the STPs as the operators do not possess the required experience and knowledge to operate such plants. An IT based system synergizing the operating parameters with the influent quality will help in improved and steady performance of STPs as it is currently being practiced in the SBR process based STP. In nearly all the plants, the sewage is generally pumped from intermediate pumping stations or through drains which are managed manually. For better management of flow into the STPs, incorporation of IT Technology needs to be probed and envisaged.
6) Re-use of treated wastewater to meet the demand of power plants, construction industry, Delhi Metro, Railways, Automobile workshops and DTC depots for cleaning of vehicles need to be explored along with meeting water requirement of horticulture, parks and

irrigation in cultivable land. The maximum re-use of treated wastewater will contribute in less abstraction of water from river Yamuna and controlled exploitation of ground water.

7) The treated and untreated Sewage discharged in River Yamuna from Delhi/NCR is being utilized traditionally for agriculture in several parts of Delhi, Haryana and Uttar Pradesh. Possibilities may be explored to use the treated sewage for non-edible agricultural products instead of mixing of treated and untreated sewage and utilizing for agricultural purposes.

8) There is a need of the development of microbial quality standards for urban wastewater and 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.

Technology can only serve as a means and other enabling factors play a far more critical role in usage of the technology.

7.3 Scope for further Study

In the present research work , six different Sewage Treatment Technologies namely BIOFOR, SBR, UASB, ASP, ASP + BIOFOR & OD were studied. As per the assessment carried out during the months starting from January to May 2013 which was comprehensive on one part that involves identification of initial root cause and operational parameters which were noted to be not efficiently controlled but it was noted that there is a scope of more detailed study which couldn’t be completed in the course of this thesis work due to limited resources and timeframe, however the findings as per the study carried out lays the foundation for further investigation. It is highly recommended that the Administration responsible for maintaining the STPs envisage alternative technological advancements, substitutions or enhancement options, wherever techno-economically feasible so as to ensure that the stipulated standards are being met and reduces the pollution load to our rivers and other water bodies to a level where the natural resources are conserved and replenished for the future generations to come. The study was able to demonstrate that even though technologies such as UASB is efficient enough to treat Industrial Wastewaters but was not able to perform well with regards to the treatment of Domestic Wastewaters. This points to the fact that selection of the technology is a critical factor prior to establishing a STP with a specific technology which further needs research and development prior to their start up.

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