ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013

Performance Evaluation Of Sewage Treatment Plant Based On Advanced Aerobic Biological Filtration And Oxygenated Reactor (BIOFOR) Technology- A Case Study Of Capital City -Delhi, India

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Abstract*— India faces a number of water and wastewater issues and water related health hazards. 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. The BIOFOR process is an emerging advanced wastewater treatment technology that has been successfully applied at an ever increasing number of locations around the world. The work carried out in this research presents the results of the evaluation carried out for the techno-economical and environmental performance of STP based on advanced aerobic BIOFOR technology located in Delhi for handling and treating the domestic wastewater. 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 STP, same was 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 River Action Plans and information collected as well as compiled from sewage treatment technology provider.

***Index Terms* —Wastewater, Performance Evaluation, STP, BIOFOR.**

I. INTRODUCTION

The typical domestic wastewater treatment system is a centralized municipal-sized facility that treats wastewater to specified discharge limits, to protect human health and the environment [1]. Treatment of any kind of wastewater to produce treated water of good quality is necessary. Treatment technologies are based on varying levels of mechanization, energy inputs, land requirements, costs, skilled manpower etc. Therefore, choice of an effective treatment system is important. Though well proven and reliable, conventional aerobic treatment processes usually require large surface areas and react slowly to high-load variations. In order to provide compact plants and to assure greater treatment efficiency and reliability, biological aerated filtration technique has been developed [2]. *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* [5]. The BIOFOR technology can be applied to aerobic carbonaceous BOD_5 removal and to nitrification and Denitrification. Aerated biological filtration combines in a single step both biological degradation of biodegradable soluble matter and solids retention by mechanical filtration of suspended solids. The biological filtration is achieved in up-flow filters loaded with a suitably sized granular supporting media, thus giving rise to an efficient filtration effect. The filter media provides adequate support for biomass attachment and a mechanical filtration capability. The processes 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

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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 [3].

II. STUDY AREA

In capital city of India, study area covers Sewage Treatment Plant (STP) based on BIOFOR technology and situated on the north bank of Dr. Sen Nursing Home drain, East of Ring Road, Delhi. Satellite image indicating Layout plan of the said Plant is shown in Fig. 1. Process Flow Diagram of Sewage Treatment Plant with BIOFOR Technology installed at Dr. Sen Nursing Home drain is given in Fig. 2. The STP is designed to handle an average flow of 10 MLD from Dr. Sen Nursing home drain flowing with average flow of 60-70 MLD. The plant was constructed by M/s Degremont Pvt Ltd for Delhi Jal Board under Yamuna Action Plan and was commissioned during the Year 2003. This research work evaluated the performance of the STP based on advanced aerobic BIOFOR technology in terms of wastewater characterization to derive a comparative account between the pollution load before and after the treatment processes, besides, discerning their efficiency.

Fig.1 Satellite image of STP based on BIOFOR Technology at Sen Nursing Home, Delhi (Acquired from Google Earth)

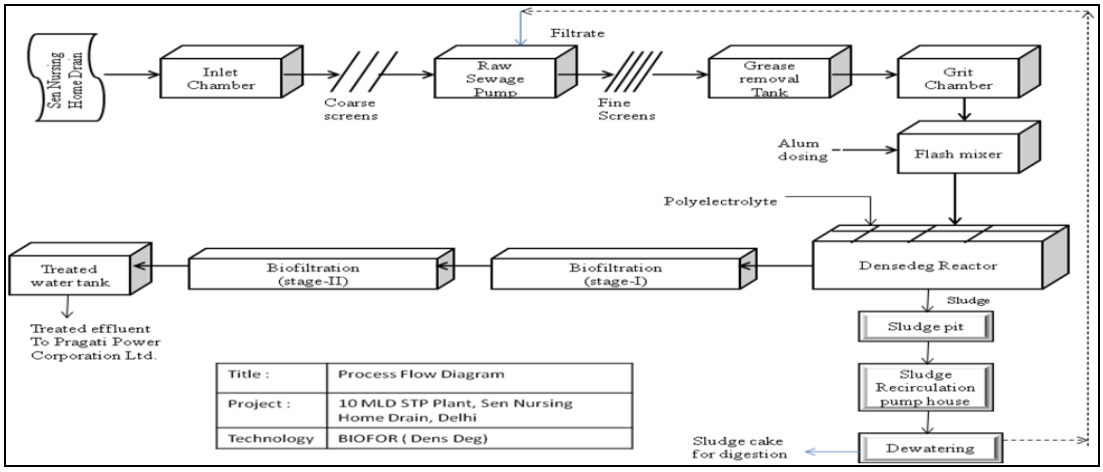

Fig.2 Process Flow Diagram of STP based on BIOFOR at Sen Nursing Home Drain, Delhi

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III. MATERIALS & METHODS

The experimental method for the work comprised a combination of desk research, field visits to the STP, Collection of grab samples, interaction with project implementing agency and technology provider. The source for the collection of wastewater samples throughout the present studies was the Sewage Treatment Plant based on BIOFOER Technology located at Dr. Sen Nursing Home, near Indraprastha Metro Station, Delhi. Samples of the treated/partially treated effluent from the STP during the period from January 2013 to May 2013 were collected, preserved and analyzed. All the precautions as per the standard procedures were followed in sampling and analysis. Samples were analyzed for various parameters like pH, BOD, COD & TSS and depending on the results, performance of STP was evaluated. Analysis of most of the parameters have been carried out using Standard Methods (APHA, 2000). Details of various parameters studied and the procedure adopted are briefed in Table 1.

Table 1: Parameters measured for monitoring

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

IV. BIOLOGICAL FILTRATION AND OXYGENATED REACTOR (BIOFOR)

A. Technology Description

Biological Filtration and Oxygenated Reactor is one of the patented technologies of M/s Degremont Ltd. which include Intensified Aerobic treatment with Dense-Deg & BIOFOR. BIOFOR filters are aerobic biological reactors that use attached growth technology. 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. 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 air diffusers. According to the present full scale experiences, the oxygen transfer in the BIOFOR depends on the nature of the filter material. Schematic Diagram of BIOFOR is shown in Fig.3. The Biological filtration can be described as a system of three phase with

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

B. 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 Fig. 4.

ISSN: 2319-5967
ISO 9001:2008 Certified
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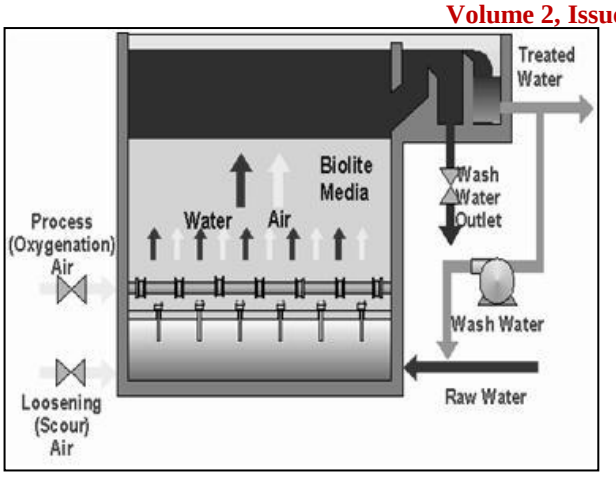

Fig. 3 Schematic Diagram of BIOFOR Tank

Fig. 4 BIOLITE media used in BIOFOR

BIOLITE 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 larges surface compared to other bio-media. Its highly penetrative porous structure enables the aerobic nitrifying bacteria's nitrification and anaerobic denitrifying bacteria's denitrification.

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

Disadvantages of BIOFOR technology

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

Dimensional details of various units and facilities of the STP based on BIOFOR at Dr. Sen Nursing Home Drain, Delhi are shown in Table 2.

Table 2: Dimensional Details of BIOFOR STP located at Dr. 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 %

ISSN: 2319-5967
ISO 9001:2008 Certified
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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

V. RESULTS & DISCUSSION

Colmenarejo *et al.*, (2006) determined the general efficiency indicator to compare overall performances of the different plants in terms of average TSS, COD, $BOD_{(5)}$ and ammonia removal efficiencies. Similarly, the efficiency of plants is generally measured in terms of removal of organic matter [4]. The pH directly affects the performance of a secondary treatment process [7] because the existence of most biological life is dependent upon narrow and critical range of pH. During the course of the study period, samples were collected from the Inlet & Outlet point of the treatment plant to evaluate the overall performance of the plant to reduce the pollution load on the receiving waters. Samples were collected once in a month for the period starting from January to May 2013 and the analytical results as obtained are summarized in Table 3.

Table 3: Physico-chemical analysis of STP with 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%**	

The variation in pH, TSS, BOD and COD in different months is shown in Fig. 5, Fig. 6, Fig. 7 and Fig. 8 respectively. Samples at inlet and outlet of were also examined for Fecal Coliform and Total Coliform parameter in order to assess microbial contamination removal once in a study period. Results of the microbial analysis are summarized in Table 4.

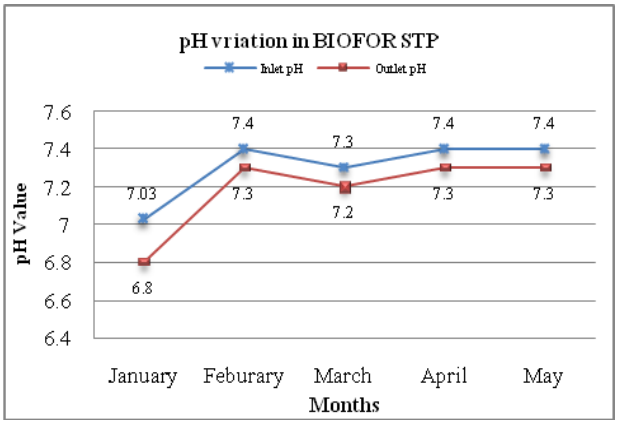

Fig. 5 pH variation in BIOFOR STP

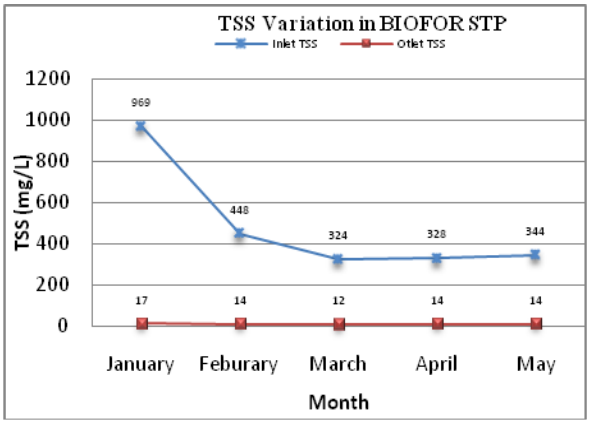

Fig. 6 TSS variation in BIOFOR STP

ISSN: 2319-5967
ISO 9001:2008 Certified
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Volume 2, Issue 4, July 2013

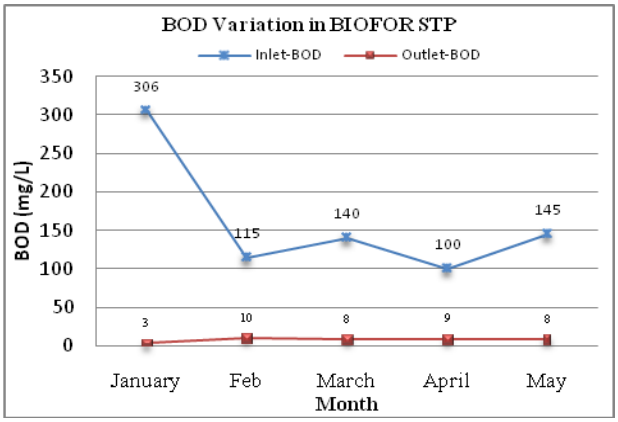

Fig. 7 BOD variation in BIOFOR STP

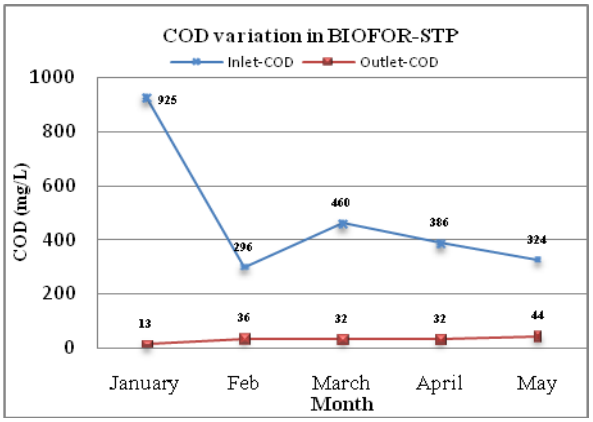

Fig. 8 COD variation in BIOFOR STP

Table 4: Microbial Analysis of BIOFOR based STP

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

As known, filtration or biological filtration can lead to reduction of pathogens. In a test conducted for BIOFOR STP at Dr. Sen Nursing Home Drain, it was found to eliminate the Total Coliform (TC) and Fecal Coliform (FC) values from the wastewater. From Table 4, it can be seen that, at the inlet of BIOFOR plant TC & FC value was found 97 X 10^6 and 24 $X10^7$ respectively. No disinfection was employed for pathogen removal. After Treatment High TC level was observed at the outlet which was in order of 42 X 10^5, however observed value of 23 X 10^4 for FC removal in the effluent from the STP represents better results in FC removal. From the Fig. 5, it can be seen that pH value at the outlet of the plant is lowered as compared to the inlet of the plant.

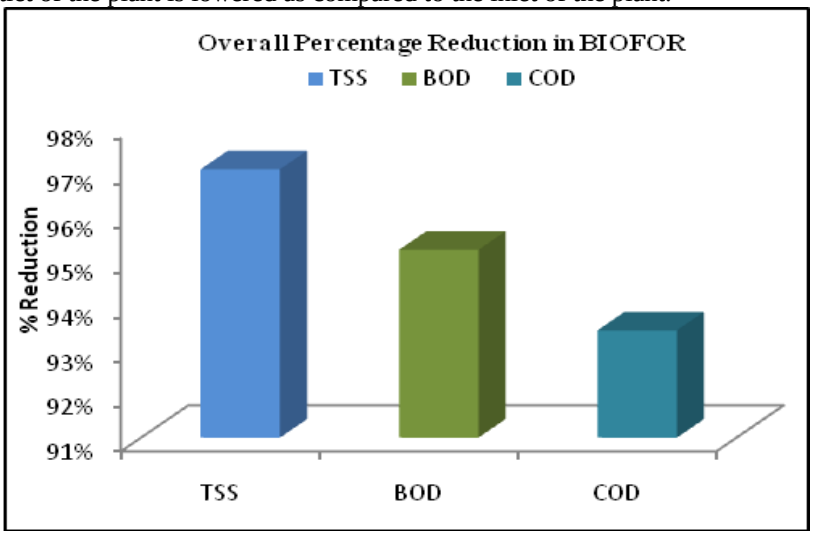

Fig. 9 Overall percentage removal efficiency of BIOFOR STP

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. From Fig. 6 above, it is depicted that, in the month of January, the value of TSS was quite high at the inlet of the Plant which is 969 mg/L and at the outlet it was found 17 mg/L, thereby pointing to efficient removal with regards to TSS. Due to DENSADEG primary clarifier, the removal efficiency of TSS is very high in BIOFOR Plant. Fig. 7 & Fig. 8 show the BOD & COD variation of

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013

BIOFOR plant respectively from the month of January to May 2013. It can be seen that, in the month of January BOD & COD values are high which 306 mg/L and 925 mg/L respectively and throughout the study it ranges between 100 mg/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 stages Biofiltration, BOD& COD removal rate is also noted to be very high in BIOFOR Plant. Overall percentage removal efficiency of BIOFOR based STP for TSS, BOD & COD removal is shown in Fig. 9.

VI. ECONOMICS OF BIOFOR

A. Space requirements

As compared to conventional Activated Sludge Process, Space requirement is very less. Space saving can upto 75% can be achieved if purely BIOFOR plant can be installed. Area Requirement in BIOFOR plant is 500 m^2/MLD. 40% space savings can also achieved when plant installed with in combination with the Activated Sludge Process for which area requirement is 900 m^2/MLD.

B. Cost

The economic efficiency of the process is reflected in capital cost of the installation and Operational & Maintenance (O&M) costs. Some of the technologies not only require initial cost to establish the system but the O&M Cost (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.) plays an important role in selection of the technology in terms of evaluating the future prospects of the same. Capital cost for BIOFOR plants upto Tertiary treatment ranges from Rs. 100-105 Lacs/MLD. Capital cost ranges between Rs 6-8 Lacs/MLD of treated water. The cost factor is also based on the local conditions, property prices and material availability, etc.

VII. CONCLUSIONS & RECOMMENDATIONS

The results from the study illustrates that BIOFOR technology which is patented technique of Degremont, is being used as an advanced aerobic method for sewage treatment as an alternative to conventional aerobic treatment technologies. Results of STPs based on BIOFOR Technology indicate that BOD, COD & Suspended Solids removal efficiencies were noted to be 95.2%, 93.4% and 97% respectively, that indicates efficient removal of the parameters. 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 high as continuous high rate aeration is required to be provided in Biofiltration tank. Also, the technology was found to be quite satisfactory in removal of Fecal Coliform from the wastewater though not efficient enough in removal of Total Coliform. However, after disinfection high quality of microbial population reduction can be achieved. Conventional Treatment technology such as ASP not only involves higher initial investments but also incur higher O&M Costs to run the system based on the same. Thus, BIOFOR systems open up further possibilities for a more economically and secure sewage treatment process in India.

ACKNOWLEDGMENT

The authors wish to acknowledge the Central Pollution Control Board, Government of India (GOI), India to facilitate and undertake this research work.

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AUTHOR BIOGRAPHY

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An Environmental Engineer by Profession, Ms. Charu Sharma has done her Masters in Environmental Engineering (M.Tech – Part Time) from Delhi Technological University (Formerly Delhi College of Engineering). Ms. Sharma has over four (5) years of diverse industrial, teaching as well as consultancy experience in both Government and Private Organizations located in Delhi, India. She has completed her Bachelors in Environmental Engineering (B.Tech) from Guru Gobind Singh Indraprastha University (GGSIPU) with distinction. She has also successfully completed Certificate Course in Disaster Management from Indira Gandhi National Open University (IGNOU). She has undergone Industrial Training on Air & Water Pollution Monitoring in Badarpur Thermal Power Station under the ownership of National Thermal Power Corporation (NTPC) and Civil Division of Bharat Sanchar Nigam Limited (BSNL) for dissertation work entitled "Wise Water Management and Solar Efficient Buildings", as a part of the successful completion of the B.Tech Degree. She has presented various review/research papers in National/International conferences on topics such as "Occupation Health and Hygiene Control Practices in Construction Sector" in National Conference organized by Indian Association of Occupational Health (IAOH) at Indian Habitat Center, Delhi; "Comparative study of Common Effluent Treatment Plants at Delhi- A Case Study" and "Disposal and Harmful Effects of Plastic Waste: An Overview" in 27th Indian Engineering Congress, organized by Institution of Engineers (India); "Bio-filtration: An Emerging Air Pollution Control Technology", "UASB Technology: An approach for Wastewater Treatment with Methane Recovery and Energy Conservation" and "Global Scenario and Economic Benefits of Carbon Sequestration Techniques" in proceedings of the International Conference on Civil Engineering-iSPACE 2013 organized by ITM University located in Gurgaon, Haryana. As a potential knowledge building prospect, she has participated in National Seminar on "Sustainable and Innovative Solutions for Water Woes", organized by DTU in association with Green Institute for Research and Development (GIRD). She has also attended Pre-conference National Workshop on "Office Ergonomics and Occupational Health", organized by IAOH. She has received positive reception for the term projects on topics such as "Different Wastewater Treatment Technologies", "Regenerative Breaking System in Delhi Metro for Greenhouse Gases (GHG) Emission reduction" and "Sustainable Development in Transportation Sector".

2. Dr. S. K. Singh

A renowned Professor, Dr. S. K. Singh has over 25 years of Academic Experience in the field of Civil and Environmental Engineering. He's at present endowed with the responsibility as Head of the Department of Environmental Engineering, Delhi Technological University with an additional responsibility of Dean, International Collaboration, Delhi Technological University. Dr. Singh is an elected Executive Member of Environmental Engineering Division of Delhi State Centre, Institution of Engineers (India) and has Professional Memberships of about 22 Institutions spread across the country. Dr. Singh has published about 75 Journal Papers in various Publications both at National and International Stages and about 49 Conference Papers have been presented under his able guidance. He has been a continuous mentor and a source of inspiration for his students which can be inferred from the fact that Dr. Singh has successfully guided many PhD students as well as M.Tech Students apart from guiding the B.Tech. Students in their Project Work. He has been conferred with Honourary appointment to MEMBER OF THE RESEARCH BOARD OF ADVISORS by the Board of Directors and Governing Board of editors of the American Biographical Institute, Inc., Raleigh, North Carolina, USA. In his earlier years in academic excellence, Dr. Singh was awarded International Felicitation and WEC-IIEE-IAEWP Environment Award-1997 for outstanding work done in the field of Environmental Engineering presented in the 6th World Environment Congress (New Delhi), 21-23 December 1997. The award was given by His Excellency Dr. Shankar Dayal Sharma, former President of India.