Performance evaluation of sewage treatment plant at a residential building

Aishwarya JM

Department of Chemical Engineering, AC Tech,
Anna University,
Chennai 600 025, Tamilnadu, India
Email: jmaishaa67@gmail.com

Nilavunesan D

Department of Applied Science and Technology,
Anna University,
Chennai 600 025, Tamilnadu, India
Email: nilavunesand@gmail.com

Baskaralingam P

Department of Chemistry,
Anna University,
Chennai 600 025, Tamilnadu, India
Email: baskaralingam@gmail.com

Sivanesan S*

Department of Applied Science and Technology,
Anna University,
Chennai 600 025, Tamilnadu, India
Email: sivanesh1963@gmail.com
*Corresponding author

Abstract: In India, most residential sewage treatment plants are expected to have zero liquid discharge (ZLD). This study has been undertaken to evaluate the performance of 800 KLD residential sewage treatment plant (STP) located at Egattur, Uthandi, Kanchipuram District, Tamilnadu. It is based on fluidized bed aerobic bioreactor (FBR). This plant is designed and constructed with an aim to manage wastewater so as to minimize and remove organic matter, solids, nutrients, disease-causing organisms and other pollutants before it is reused. Sewage samples were collected from four different stages of the sewage treatment plant for 4 months and analysed for water quality parameters. From the analyses it is found that the maximum pH at inlet and outlet was 6.99 and 7.83, alkalinity was 248 and 136 mg/l, chloride was 194.25 and 82.14 mg/l, TSS was 165 and 31 mg/l, TDS 788 and 713 mg/l, BOD was 352.94 and 26.88 mg/l, COD was 463 and 27 mg/l and sulphate was 126.54 and 88.28 mg/l, respectively.

Keywords: BOD; COD; efficiency; FBR; sewage treatment plant; TSS.

Reference to this paper should be made as follows: Aishwarya, J.M., Nilavunesan, D. Baskaralingam, P. and Sivanesan, S. (2016) 'Performance evaluation of sewage treatment plant at a residential building', *Int. J. Environment and Sustainable Development*, Vol. 15, No. 3, pp.326–336.

Biographical notes: Aishwarya JM is working as Teaching Fellow in Department of Chemical Engineering, Anna University, Chennai. She has completed her Masters in Environmental Science and Technology.

Nilavunesan D is a Research Scholar in Department of Applied Science and Technology, Anna University, Chennai. He has completed his Masters in Environmental Science and Technology.

Baskaralingam P is working as an Assistant Professor in Department of Chemistry.

Sivanesan S is working as a Professor and Dean in Alagappa College of Technology, Anna University, Chennai. He has published more than 100 papers in International journals.

This paper is a revised and expanded version of a paper entitled 'Performance evaluation of sewage treatment plant at a residential building', presented at *BEST 2015*, Arunai College of Engineering, Tiruvannamalai, Tamilnadu, India.

1 Introduction

Pollution is one of the greatest abuses of our natural water resources. Water pollution is any chemical, physical or biological change in the quality of water that has a harmful effect on any living thing that drinks or uses or lives (in) it. All foreign material added to a natural body of water is considered pollution. Water quality issues arise when increasing amounts of treated wastewater are discharged to water bodies that are eventually used as water supplies [Metcalf & Eddy, Inc., 2003]. The waste water that flows after being used for domestic, industrial and other purposes is known as sewage. Sewage contains water as the main component, while other constituent, and include organic waste and chemical [Kushwah,Bajpai and Malik, (2011]. Municipal wastewater comes from residential and domestic sources. Wastewater, depending upon the sources, is broken into two categories: grey water and black water. Grey water is from showers, baths, whirlpool tubs, washing machines, dishwashers and sinks other than kitchen sink. Black water is from toilets and kitchen sinks. [Casanova, Gerba and Karpiscak, 2001]. Wastewater treatment is the method used to treat the wastewater by various physical, chemical and biological methods.

The basic function of the wastewater treatment plant is to speed up the natural processes by which water purifies itself [Office of Wastewater Management, Washington DC 20460, 2004]. Wastewater or sewage treatment is one such alternative, wherein many processes are designed and operated in order to mimic the natural treatment processes to reduce pollutant load to a level that nature can shandle [Kumar, Pinto and Somashekar, 2010]. Aims of wastewater treatment are, to convert the waste materials present in wastewater into stable oxidized end products that can be safely disposed of to inland waters without any adverse ecological effects and protect public health [Uzmajan Rafiq, 2012]. Using advanced technology, it is now possible to re-use sewage effluent. Zero liquid discharge is a process that is beneficial to industrial and municipal organizations as well as the environment because it saves money and no effluent, or discharge, is left over. The efficiency of sewage treatment plants can be illustrated by a study on the evaluation of pollutant levels of the influent and the effluent at the treatment plant of sewage treatment plants. In terms of water management, strict legislations are enforced to Reduce water consumption and waste water generation using water management practices [Sharda. Sharma and Kumar 2013].

Chennai is one of the four metropolitan cities in India with a population of about 1.2 billion. Due to urbanization, increase in population, changes in lifestyle and consumption pattern, the problem of wastewater management in Chennai has been rapidly increasing. The Chennai city sewerage system has been divided into five zones. Each zone has been provided with individual collection areas, pumping stations, force mains, etc.

[Sundarakumar, Sundarakumar and Ratnakanthbabu, 2010] have worked on a case study of Nesapakkam sewage treatment plant. Nesapakkam sewage treatment plant is located on the western part of city and receives the sewage collected from zone 4, covering the areas like Saidapet, West Mambalam, Ashoknagar, M.G.R Nagar, K.K. Nagar, Thirunagar, etc. The plant was commissioned in 1974, which is the first sewage treatment plant in Chennai. The plant is designed to provide for an average flow of 23 MLD. The overall performance of the existing plant was satisfactory. The removal efficiency of BOD was found to be 94.56% and that of TSS was 93.72%. The individual units are also performing well and their removal efficiencies are satisfactory. BOD and TSS removal efficiencies of the primary clarifier are 30.59% and 50.61%, respectively. BOD and TSS removal efficiencies of the activated sludge plant (aeration tank + secondary clarifier) are 91.27 and 86.76%, respectively. [Patil, Sawant and Deshmukh, 2012] have studied about the various physico-chemical parameters such as colour, temperature, hardness, pH, sulphate, chloride, DO, BOD, COD, alkalinity used for testing of water quality.

2 Description of sewage treatment plant

There is a rapid rise of multi-storey apartments rather than independent homes. Apart from common sewage treatment plant, each multi-storey building owns a sewage treatment plant, which treats and reuses the wastewater generated from the respective building without discharging it into natural water body. This project deals about such a sewage treatment plant operating at a residential building. The residential building consists of two BHK, three BHK, four BHK and five BHK houses and also a school and club house. The total occupancy of the building is 8841 and their total water requirement is 769355 lpcd (litre per capita per day). The proposed project site is located at Old Mahabalipuram Road in Chennai, which is known for many multi-storey buildings, IT sectors and many educational institutions.

3 Treatment process

Dissolved oxygen is a key element in water quality that is necessary to support aquatic life. A demand is placed on the natural supply of dissolved oxygen by many pollutants in wastewater. This is called biochemical oxygen demand, or BOD, and is used to measure how well a sewage treatment plant is working. If the effluent, the treated wastewater produced by a treatment plant, has a high content of organic pollutants or ammonia, it will demand more oxygen from the water and leave the water with less oxygen to support fish and other aquatic life. Organic matter and ammonia are 'oxygen-demanding' substances. Oxygen-demanding substances are contributed by domestic sewage and agricultural and industrial wastes of both plant and animal origin, such as those from food processing, paper mills, tanning and other manufacturing processes. These substances are usually destroyed or converted to other compounds by bacteria if there is sufficient oxygen present in the water, but the dissolved oxygen needed to sustain fish life is used up in this break down process.

The ongoing treatment process in the STP is 'modified activated sludge process' with attached and suspended growth biological system. The type of bioreactor is popularly known as fluidized bed aerobic bioreactor. This type of biological reactor has long sludge retention time since the packing media provide much larger surface area for biological growth and the bio-flock get attached to the packing media. The sludge produced in the conversion of dissolved organic matter in this process is comparatively lesser than the suspended growth due to the long sludge time and will not produce bad odour.

The wastewater from toilets, bathrooms and kitchens will be collected and made available by gravity sewer main to the STP. This will be stored in an UG RCC effluent collection tank. These tanks are mainly to take up the quality and quantity fluctuations and to average out the content and to provide the required volume for continuous operation of the plant when there is no inflow.

The effluent from the kitchen/pantry will be passed through oil/grease catcher and then mixed with the sewer. The raw sewage is screened for removal of floating matter and coarse solids/ garbage wastes.

To keep the effluent fresh and to get uniformity, air mixing is proposed. The air mixing will be through coarse bubble diffusers, and the required airline will be taken from the air blower main header.

The sewage received in the collection tank will be pumped to the biological reactor at a constant rate. The bioreactor is a fluidized bed aerobic reactor with a free-floating plastic media. The packing media is of very large area to volume ratio. The internal protected area of the packing is 400 m^2/m^3. The effluent from aeration is passed to clarification tank. The wastewater is finally passed through activated carbon filter and reused. The treated water is reused for gardening and flushing purposes.

Generally biological treatments are designed on the basis of hydraulic parameters, such as flow rate, HRT, solids loading rate, etc [Govindasamy et al., 2006]. Performance evaluation of existing treatment plant is required to assess the existing effluent quality and/or to meet higher treatment requirements and to know about the treatment plant whether it is possible to handle higher hydraulic and organic loadings. Performance appraisal practice of existing treatment plant units is effective in generation of additional data, which also can be used in the improvement in the design procedures to be followed for design of these units.

4 Materials and methodology

Sampling is a technique used to collect wastewater samples, which resembles the characteristics of the wastewater. There are different types of sampling techniques such as grab sampling and composite sampling used to collect samples.

Collection of samples at different units of unit operation gives the efficiency of plant more accurately and also the efficiency of the each and every unit of the sewage treatment plant. Hence, samples are to be collected at four different stages of STP. The different stages of the STP are as follows:

1 raw water sump (S1)
2 equalisation tank (S2)
3 after clarifier (S3)
4 outlet pipe (S4)

5 Sampling period

Thirty-two samples (i.e. eight sets of four samples) were collected from October 2014 to February 2015.

6 Laboratory analysis

Collected samples were tested by standard methods in the laboratory for the parameters. Chemical oxygen demand (COD) test is widely used as a means of measuring the pollutional strength of domestic and industrial wastewater. The test allows measurement of organic matter in terms of oxygen required for oxidation to CO_2 and water. This is a quickly measurable and more reliable parameter than BOD. It is based on the fact that almost all organic compounds can be oxidized by the action of strong oxidizing agents under acidic conditions. COD test is carried out by open reflux method. The purpose of running blank is to compensate for any error that may result because of the presence of organic matter in the reagents.

Biochemical oxygen demand (BOD) is defined as the amount of oxygen required by microorganisms, while stabilizing biologically decomposable organic matter in waste under aerobic conditions. Since the test is mainly a bio-assay procedure, involving the measurement of oxygen consumed by the bacteria while stabilizing the organic matter under aerobic conditions, it is necessary to provide standard conditions of nutrient supply, pH, absence of microbial growth inhibiting substances and temperature. Because of low solubility of oxygen in water, strong wastes are always diluted to ensure that the demand does not increase the available oxygen. A mixed group of organisms should be present in the sample; if not, the sample has to be seeded artificially. Temperature is controlled at 20°C. The test is conducted for 5 days, as 70–80% of the waste is oxidised during this period.

Sample 1: raw water sump: BOD, COD, pH, total suspended solids, total dissolved solids, chloride, sulphate and alkalinity.

Sample 2: equalisation tank: pH, total suspended solids, total dissolved solids, chloride, sulphate and alkalinity.

Sample 3: after clarifier: pH, total suspended solids, total dissolved solids, chloride, sulphate and alkalinity.

Sample 4: outlet pipe: BOD, COD, pH, total suspended solids, total dissolved solids, chloride, sulphate and alkalinity.

7 Observations and results

Table 1 BOD values observed during various periods at various sampling points

	BOD (mg/l)				
Date	S_1	S_2	S_3	S_4	*Efficiency (%)*
07.10.14	324.16	216.45	54.28	17.34	94.65
28.10.14	286.14	192.26	46.78	12.42	95.65
11.11.14	294.86	204.64	50.82	14.74	95
25.11.14	310.22	224.74	68.28	18.46	94.04
08.12.14	322.78	230.62	64.48	20.56	93.63
23.12.14	318.64	242.88	67.42	19.14	93.99
05.01.15	334.98	246.58	68.92	20.14	93.98
20.01.15	328.56	232.74	64.88	18.54	94.35
08.02.15	342.64	254.86	72.16	22.58	93.05
23.02.15	352.94	264.34	76.12	26.88	92.38

Table 2 Laboratory values of various water quality parameters at various sampling points during different sampling periods

		Parameters (mg/l)							
Date	*Sample*	*pH*	*BOD*	*COD*	*TSS*	*TDS*	*Chloride*	*Sulphate*	*Alkalinity*
1	2	3	4	5	6	7	8	9	10
07.10.14	S_1	6.56	324.16	437	146	775	179.94	114.64	234
	S_2	6.69	216.45	-	86	745	169.94	102.64	192
	S_3	7.23	54.28	-	40	722	89.97	96.16	156
	S_4	7.69	17.34	24	22	697	84.97	86.16	118
28.10.14	S_1	6.54	286.14	430	134	723	163.67	112.58	228
	S_2	6.79	192.26	-	76	711	151.67	96.58	188
	S_3	7.34	46.78	-	40	692	86.14	92.24	150
	S_4	7.7	12.42	21	18	667	78.14	86.24	112
11.11.14	S_1	6.34	294.86	410	130	718	161.97	98.42	220
	S_2	6.45	204.64	-	74	703	148.97	92.42	180

Table 2 Laboratory values of various water quality parameters at various sampling points during different sampling periods (continued)

		Parameters (mg/l)							
Date	*Sample*	*pH*	*BOD*	*COD*	*TSS*	*TDS*	*Chloride*	*Sulphate*	*Alkalinity*
	S_3	6.83	50.82	-	38	689	83.67	86.14	142
	S_4	7.01	14.74	18	14	663	75.67	78.14	104
25.11.14	S_1	6.42	310.22	402	136	776	177.94	102.46	216
	S_2	6.57	224.74	-	82	735	167.94	96.46	176
	S_3	6.92	68.28	-	46	719	87.97	88.58	132
	S_4	7.33	18.46	15	20	694	82.97	80.58	102
08.12.14	S_1	6.67	322.78	428	148	784	181.14	108.14	238
	S_2	6.82	230.62	-	90	753	171.14	98.14	198
	S_3	7.1	64.48	-	44	728	91.25	86.64	160
	S_4	7.23	20.56	21	22	695	86.25	80.64	122
23.12.14	S_1	6.81	318.64	440	153	787	176.67	116.24	224
	S_2	6.9	242.88	-	93	746	163.67	102.24	184
	S_3	7.21	67.42	-	47	718	84.97	92.14	146
	S_4	7.43	19.14	23	29	686	78.97	84.14	120
05.01.15	S_1	6.92	334.98	456	165	783	183.25	124.42	228
	S_2	7.03	246.58	-	95	745	169.25	112.42	192
	S_3	7.56	68.92	-	51	723	88.17	96.16	150
	S_4	7.64	20.14	25	31	705	77.17	88.16	124
20.01.15	S_1	6.84	328.56	445	130	788	187.67	118.46	234
	S_2	6.96	232.74	-	74	751	174.67	104.46	196
	S_3	7.23	64.88	-	42	729	93.14	86.24	158
	S_4	7.54	18.54	22	20	713	86.14	78.24	118
08.02.15	S_1	6.94	342.64	434	143	793	186.97	122.68	246
	S_2	7.12	254.86	-	83	765	172.97	110.68	198
	S_3	7.47	72.16	-	37	738	87.14	98.16	164
	S_4	7.81	22.58	24	19	711	78.14	90.16	128
23.02.15	S_1	6.99	352.94	463	150	784	194.25	126.54	248
	S_2	7.19	264.34	-	90	748	178.25	112.54	228
	S_3	7.52	76.12	-	44	721	91.14	96.28	172
	S_4	7.83	26.88	27	26	698	82.14	88.28	136

Figure 1 BOD values vs sampling points at various sampling periods (see online version for colours)

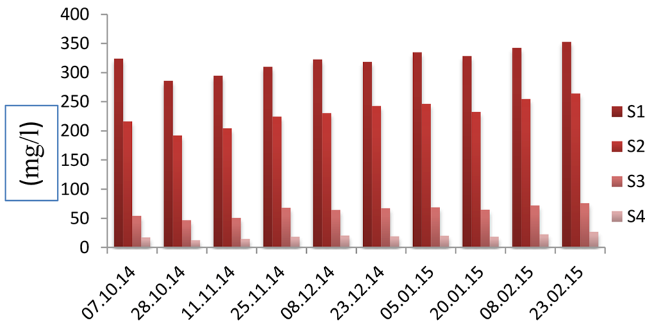


Table 3 COD values observed during various periods at various sampling points

	COD (mg/l)		
Date	*Inlet*	*Outlet*	*Efficiency (%)*
07.10.14	437	24	94.5
28.10.14	430	21	95.11
11.11.14	410	18	95.6
25.11.14	402	15	96.26
08.12.14	428	21	95.09
23.12.14	440	23	94.77
05.01.15	456	25	94.51
20.01.15	445	22	95.05
08.02.15	434	24	94.47
23.02.15	463	27	94.16

Figure 2 COD values vs sampling points at various sampling periods (see online version for colours)

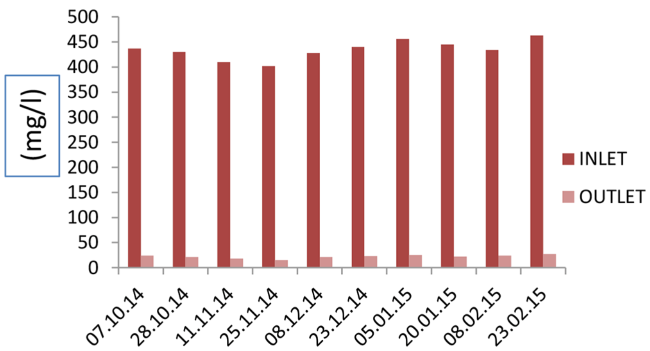


Table 4 TSS values observed during various periods at various sampling points

	TSS (mg/l)				
Date	S_1	S_2	S_3	S_4	*Efficiency (%)*
07.10.14	146	86	40	22	84.93
28.10.14	134	76	40	18	86.56
11.11.14	130	74	38	14	89.23
25.11.14	136	82	46	20	85.29
08.12.14	148	90	44	22	85.13
23.12.14	153	93	47	29	81.04
05.01.15	165	95	51	31	81.21
20.01.15	130	74	42	20	84.61
08.02.15	143	83	37	19	86.71
23.02.15	150	90	44	26	82.67

Figure 3 BOD values vs sampling points at various sampling periods (see online version for colours)

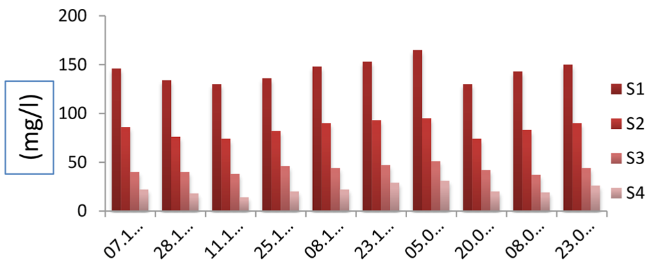
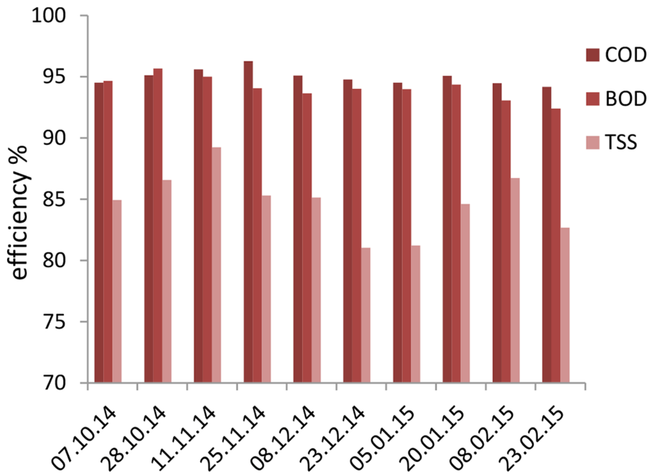


Table 5 Efficiency of COD, BOD, TSS during various sampling periods

	Efficiency (%)		
Date	*COD*	*BOD*	*TSS*
07.10.14	94.5	94.65	84.93
28.10.14	95.11	95.65	86.56
11.11.14	95.6	95	89.23
25.11.14	96.26	94.04	85.29
08.12.14	95.09	93.63	85.13
23.12.14	94.77	93.99	81.04
05.01.15	94.51	93.98	81.21
20.01.15	95.05	94.35	84.61
08.02.15	94.47	93.05	86.71
23.02.15	94.16	92.38	82.67

Figure 4 Efficiency of COD, BOD and TSS during various sampling periods (see online version for colours)



8 Results and discussion

Based on laboratory analysis, it is concluded that

1. From table 1, BOD values range from 286.14 to 352.94 mg/l at inlet and from 12.42 to 26.88 mg/l at outlet, respectively. The inlet value shows the higher organic loading rate at the inlet of the sewage treatment plant and after treatment it is considerably reduced [Figure 1]. This shows the efficient operation of the plant with the maximum efficiency of 95.65% [Figure 4]. While comparing Wakode and Sayyad (2014), they found BOD value was ranging from 113 to 151 mg/l at inlet and outlet ranging from 4 to 7 mg/l. Sequential batch reactor was used for treating the wastewater treatment in 25 MLD STP plants at Kalyan.
2. Average pH values at inlet are 6.85 and after treatment the value was raised to 7.73 [Table 2]. This shows the pH value is within permissible limits, which ranges from 5.5 to 9.0 (specified in the schedule of Environmental Protection Rule, 1989).
3. From Table 3, Concentration of COD at inlet (maximum value) was found to be 463 mg/l. The outlet value was found to be 27 mg/l [Figure 2]. Maximum efficiency of COD removal was 96.26 during sampling on 25 November 2014 [Table 5].
4. From Table 4, TSS values range from 130 to 165 mg/l at inlet of sewage treatment plant. After treatment at outlet, it was found to be 14–31 mg/l, respectively. The maximum TSS removal efficiency was 89.23% [Figure 3].

References

Awuah, E. and Abrokwa, K.A. (2008) 'Performance evaluation of UASB sewage treatment plant at James Town (Mudor), Accra' *33rd WEDC International conference*, Accra, Ghana.

Borkar, R.P., Gulhane, M.L. and Kotangale, A.J. (2006) 'Moving bed biofilm reactor – a new perspective in wastewater treatment', *IOSR International Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, Vol. 6, No. 6.

Casanova, L.M., Gerba, C.P. and Karpiscak, M. (2001) 'Chemical and microbial characterization of household graywater', *International journal of Environmental Science Health,* Vol. 36, No. 4, pp.395–401.

Fransisco, N. and Morell, M. (2007) 'Performance evaluation of on-site domestic STP for individual residencies'

Govindasamy, P., Madhavan, S.D., Revathi, S. and Shanmugam, P. (2006) 'Performance evaluation of common effluent treatment plant for Tanneries at Pallavaram CETP', *Journal of Environ. Science & Engg*, Vol. 47, No. 4, pp.326–335.

Kumar, R.P., Pinto, L.B. and Somashekar, R.K. (2010) 'Assessment of the efficiency of STPs: a comparative study between Nagasandra and Mailasandra STPs', *Kathmandu University Journal of Science, Engineering and Technology*, Vol. 06, No. II, pp.115–125.

Kushwah. R.K., Bajpai. A. and Malik, S. (2011) 'Wastewater Quality studies of influent and effluent water at municipal wastewater treatment plant, Bhopal (India)', *International Journal of Chemical, Environmental and Pharmaceutical Research (ijCEPR)*, Vol. 02, Nos. 2–3, pp.131–134.

Metcalf & Eddy, Inc. (2003) Wastewater Engineering Treatment and Reuse, 4th ed.

Office of Wastewater Management, Washington DC 20460, 2004, 'Primer for Municipal Wastewater Treatment Systems', EPA 832-R-04-001S

Patil, P.N., Sawant, D.V. and Deshmukh, R.N. (2012) 'Physico-chemical parameters for testing of water –a review', *International Journal of Environmental Sciences*, Vol. 3, No. 03.

Sharda. A.K., Sharma, M.P. and Kumar, S. (2013) 'Performance evaluation of Brewery wastewater treatment plant', *International Journal of Engineering Practical Research (IJEPR)*, Vol. 2, No. 3.

Sudhakar, M., Vijayalakshmi, P. and Sivanesan, S. (2014) 'Preventing membrane bio-fouling in a full-scale plant by textile effluent pre-treatment to produce near zero biological oxygen demand', R*esearch Journal of Chemistry and Environment.*

Sundarakumar, K., Sundarakumar, P. and Dr. Ratnakanthbabu, M.J. (2010) 'Performance evaluation of waste water treatment plant', *International Journal of Engineering Science and Technology*, Vol. 2, No. 12.

Uzmajan Rafiq, S.K. (2012) 'Efficiency of sewage treatment plant, Hazratbal, Srinagar,Jammu and Kashmir, India', *Journal of Nature and Science.*

Wakode, P.N. and Sayyad, S. U. (2014) 'Performance evaluation of 25MLD sewage treatment plant (STP) at Kalyan', *American Journal of Engineering Research*, Vol. 03, No. 03, pp.310–316.