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Performance evaluation of existing ASP & SBR (30 MLD capacity) STP's at PCMC, Pune (MH) – A case study.

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ABSTRACT : *The present study was undertaken to evaluate performance of sewage treatment plants working on Activated Sludge process (ASP) and Sequencing Batch Reactor Process (SBR) of 30 MLD capacities each at Chinchwad, Pimpri Chinchwad Municipal Corporation, Pune, Maharashtra, INDIA. To evaluate performance of ASP & SBR, both plants were monitored for normal operation, samples were collected and analyzed for the major water quality parameters, such as pH, Colour, Temperature, Conductivity, Total solids, TSS, TDS, DO, BOD, COD, Chlorides, Alkalinity, Total Hardness, Nitrogen(Nitrates), Phosphates and Total Organic Carbon. The % Variations, % parameter removal efficiency, Effluent water quality indexes in terms of CCMEWQI, statistical co-relations between parameters of inlet, outlet, and % parameter removal efficiency were evaluated and based on these information performance of ASP & SBR had been compared. It was found out that ASP was working with average % removal efficiency for BOD & suspended solids as 83.59% & 75.55% respectively which were lower than design values whereas SBR was working with average % removal efficiency for BOD & suspended solids as 94.94% & 92.12% respectively which were higher than design values.*

Keywords- *% incremental efficiency, % removal efficiency, Activated Sludge Process (ASP), CCMEWQI, Sequencing Batch Reactor (SBR), Statistical co-relations*

I. INTRODUCTION

Pimpri Chinchwad Municipal Corporation (PCMC), Pune & Maharashtra Industrial Development Corporation (MIDC) lifts @435 MLD & supply @330 MLD raw water from Pavana River. As per Indian River Standards Pavana River was of Class C up to the raw water lifting point at Ravet but onwards it was Class D type and Non-Perennial River in the PCMC area. The industrial effluent was discharged through secondary and primary natural channels in to Pavana River. As well as treated water i.e. effluents from all STP's were also discharged in to Pavana River. As the effluents from all STP's were discharged into Pavana River it may be one of the reasons for Pavana River pollution. So it became necessary to check quality of effluents discharged into Pavana River as well as to evaluate the performance of the all STP's. For this purpose two STP's 1) 30 MLD STP at Bhatnagar, Pimpri-Chinchwad Link Road (ASP Process) and 2) 30 MLD STP at Laxminagar, Chinchwad (SBR Process) were taken for study of Performance evaluation of ASP & SBR for domestic sewage treatment as a case study. After treatment effluents were tested only for pH, BOD, COD, DO & TSS and maintained as per these parameters only. As per the Indian Effluent Standards laid by CPCB, effluent should be tested by using methodology specified in various parts in Indian Standards IS 3025 and compared with limits prescribed in the Indian Effluent Standards for parameters like pH, BOD, COD, DO, TSS, TDS, Nitrogen as Nitrates, Phosphates, Total Organic Carbon, Colour, Hardness and Chlorides. As effluents from all STP are wasted in river, the requirements of Indian River Standards laid for Class D River should be fulfilled by effluents. Parameters such as pH, Colour, Temperature, Conductivity, Total solids, TSS, TDS, DO, BOD, COD, Chlorides, Alkalinity, Total Hardness, Nitrogen (Nitrates), Phosphates and Total Organic Carbon were selected for present study. Samples were collected, analyzed and compared with limits prescribed in the Indian Effluent Standards & Indian River Standards. Based on this information % parameter removal efficiency, Effluent water quality indexes in terms of CCMEWQI, statistical co-relations between parameters of inlet, outlet, % removal efficiency & parameters were evaluated. Performance of ASP & SBR had been compared with design % removal efficiency and performance data prescribed in 'CPHEEO Manual', published by the Govt. of India.

II. DESCRIPTION OF WORK AREA

30 MLD STP at Bhatnagar, Pimpri-Chinchwad Link Road (ASP Process)

The sewage treatment plant was designed on Activated Sludge Process Technology popularly known ASP of capacity 30 MLD for purification of domestic sewage obtaining from the municipal corporation residential areas and constructed at Bhatnagar link road Chinchwad. The plant was designed in accordance with the characteristics of influent and effluent as provided and according to the guidelines set up by the 'CPHEEO Manual', published by the Govt. of India. The plant was designed for raw water characteristics as BOD_5 at 20°C – 350 mg/ltr, Suspended solids – 400 mg/ltr and effluent characteristics as BOD_5 at 20°C – 20 mg/ltr, Suspended solids – 30 mg/ltr with % removal efficiency for BOD & suspended solids as 94.29% & 92.50% respectively.

Location Coordinates: 18°37'39"N 73°47'44"E

30 MLD STP at Laxminagar, Chinchwad (SBR Process)

The sewage treatment plant was designed on Sequencing Batch Reactor Technology popularly known as SBR of capacity 30 MLD for purification of domestic sewage obtaining from the municipal corporation residential areas and constructed at Laxminagar, Chinchwad. The plant was designed in accordance with the characteristics of influent and effluent as provided and according to the guidelines set up by the 'CPHEEO Manual', published by the Govt. of India. The plant was designed for raw water characteristics as BOD_5 at 20°C – 250 mg/ltr, Suspended solids – 300 mg/ltr and effluent characteristics as BOD_5 at 20°C – 20 mg/ltr, Suspended solids – 30 mg/ltr with % removal efficiency for BOD & suspended solids as 92% & 90% respectively.

Location Coordinates: 18°37'51"N 73°47'32"E

III. METHODOLOGIES

1 Sample collection

Samples were collected at Parshall flume as inlet (influent) and after chlorination as outlet (effluent).

2 Experimental Methodologies

Samples were collected and analyzed for the major water quality parameters, such as pH, Colour, Temperature, Conductivity, Total solids, TSS, TDS, DO, BOD, COD, Chlorides, Alkalinity, Total Hardness, Nitrogen(Nitrates), Phosphates and Total Organic Carbon as per test procedure prescribed in Indian Standards IS:3025.

3 Computation Methodologies

Removal efficiencies were calculated by using formula % removal efficiency = (IC-EC) x100/IC which contains IC – Influent concentration, EC – Effluent concentration. Negative Removal efficiency shows that parameter had increased in effluent instead of decreasing so negative removal efficiency considered as incremental efficiency. Statistical co-relations were established by computing correlation coefficient (r) & coefficient of determination (r^2) by using eleven test data points. Computation of water quality indexes (WQI) done by using method prescribed by Canadian Council of Ministers of Environment (CCMEWQI) as per limits prescribed in Indian River Standards for Class D.

4 Result Comparison Methodologies

Test parameters were compared with limits prescribed for effluent characteristics in Indian Effluent Standards IS 2490:1982, limits prescribed for inland surface water class A to E in Indian River Standards IS 2296:1982 and design % removal efficiency along with average performance data of % removal efficiency of ASP & SBR prescribed in 'CPHEEO Manual', published by the Govt. of India.

IV. RESULTS & DISCUSSION

Samples were collected and analyzed for the major water quality parameters, such as pH, Colour, Temperature, Conductivity, Total solids, TSS, TDS, DO, BOD, COD, Chlorides, Alkalinity, Total Hardness, Nitrogen (Nitrates), Phosphates and Total Organic Carbon as per test procedure prescribed in Indian Standards IS:3025. The test results observed and noted in table no 1 along with calculated average & % variations & % parameter removal efficiency for each parameter.

Table no 1 Test Results

Sr.No.	Parameter	ASP			SBR		
		Inlet	Outlet	% Variations	Inlet	Outlet	% Variations
1	**pH**						
1	Min	6.84	6.93	1.11	6.70	7.10	4.41
2	Max	7.40	7.53	4.28	7.05	7.60	11.94
3	Average	7.22	7.40	2.40	6.89	7.46	8.25
2	**Temperature (°C max)**						
1	Min	24	22	0.00	26	26	0.00
2	Max	25	25	8.33	30	30	7.14
3	Average	24.36	23.36	4.15	27.91	27.45	1.62
3	**Dissolve oxygen (DO) recovery (mg/ltr min)**						
1	Min	0	2.7		0.0	5.5	
2	Max	0	4.7		0.0	5.9	
3	Average	0	3.91		0.00	5.79	
Sr.No.	**Parameter**	**ASP**			**SBR**		
		Inlet	**Outlet**	**% Removal Efficiency**	**Inlet**	**Outlet**	**% Removal Efficiency**
4	**Colour (Hazen units max)**						
1	Min	757	385	47.16	759	43	86.35
2	Max	1208	571	65.06	1172	160	94.33
3	Average	1051	463.55	55.67	1021.09	108.00	89.79
5	**Conductivity (µs max)**						
1	Min	236	261	-9.22	369	341	5.25
2	Max	465	577	-24.09	591	551	9.70
3	Average	412.27	469.91	-13.69	472.36	438.82	7.12
6	**Total solids (mg/ltr max)**						
1	Min	332	253	15.71	288	178	31.30
2	Max	471	322	35.03	488	285	43.55
3	Average	413.64	298	27.55	399.64	246.09	38.12
7	**TSS (mg/ltr max)**						
1	Min	138	25	71.18	102	6	88.78
2	Max	255	68	85.12	205	23	94.12
3	Average	193.9	48.09	75.55	147.55	11.82	92.12
8	**TDS (mg/ltr max)**						
1	Min	194	223	-9.25	186	172	4.78
2	Max	232	287	-23.71	295	276	9.89
3	Average	219.73	249.82	-13.64	252.09	234.27	7.08
9	**BOD (mg/ltr max)**						
1	Min	140	18	78.67	110	6	93.33
2	Max	190	32	88.00	160	8	96.25
3	Average	161.82	26.45	83.59	141.82	7	94.94

Sr.No.	Parameter	ASP			SBR		
		Inlet	Outlet	% Removal Efficiency	Inlet	Outlet	% Removal Efficiency
10	**COD (mg/ltr max)**						
1	Min	240	60	66.67	230	20	88.00
2	Max	320	100	76.00	340	30	94.12
3	Average	269.09	78.18	70.85	298.18	23.64	91.98
11	**Chloride (mg/ltr max)**						
1	Min	30	36	-9.68	56	42	10.00
2	Max	62	68	-23.81	78	66	15.38
3	Average	42.73	48.91	-14.83	61.45	53.09	13.52
12	**Alkalinity (mg/ltr max)**						
1	Min	241.20	247.60	-1.31	227.00	260.20	-13.62
2	Max	269.00	275.40	-4.78	267.40	317.20	-21.81
3	Average	252.22	258.43	-2.48	247.19	291.85	-17.99
13	**Total Hardness (mg/ltr max)**						
1	Min	84	96	-5.56	128	112	4.55
2	Max	160	192	-26.32	192	176	15.79
3	Average	138.55	155.64	-12.35	159.27	144.73	9.24
14	**Nitrogen(Nitrates) (mg/ltr max)**						
1	Min	24.60	18.30	25.61	24.00	5.70	76.25
2	Max	78.80	43.80	53.68	68.90	12.30	84.29
3	Average	60.25	34.66	41.10	47.35	8.70	81.15
15	**Phosphates (mg/ltr max)**						
1	Min	5.32	4.52	7.80	3.87	1.20	63.31
2	Max	5.87	5.20	18.41	6.38	2.20	79.66
3	Average	5.52	4.87	11.74	5.48	1.56	71.33
16	**Total Organic Carbon (mg/ltr max)**						
1	Min	46.00	38.80	11.56	55.56	31.37	39.43
2	Max	68.80	55.85	27.83	68.80	38.60	50.68
3	Average	58.17	48.93	15.74	61.42	34.18	44.26

Note: - Negative Values of % parameter removal efficiencies shows an increase in parameter in effluent than influent, hence considered as % parameter incremental efficiencies.

Parameters of Influents & Effluents

1) pH

pH of effluents from both plants were found within the limits prescribed in Indian Effluent Standards as 5.5 to 9. After treatment of sewage pH of effluents had increased in both process plants but increase in pH of effluent was higher in case of SBR plant than ASP plant. Fig no 1 shows graphs of % pH variations of both plants.

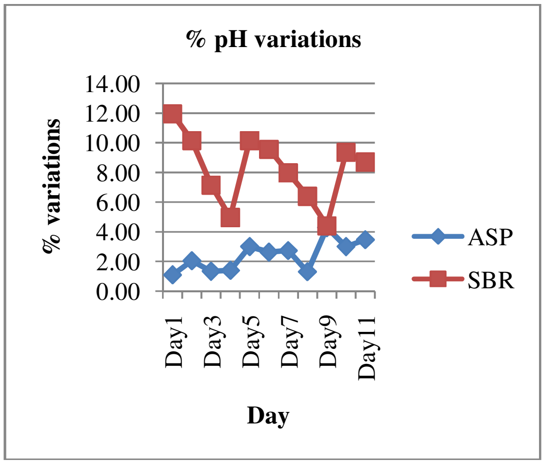

Fig no 1 % pH variations

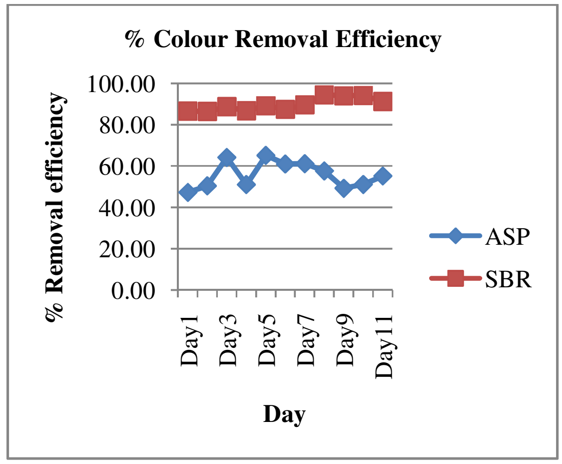

Fig no 2 % Colour removal efficiency

2) Colour
After treatment of sewage, Colour of treated water had decreased in both processes. It was observed that decrease in colour of effluent was higher in case of SBR than that of ASP. Limits for Colour of effluent were not prescribed in Indian Effluent Standards as well as Indian River Standards. Fig no 2 shows variations of % colour removal efficiency of both plants. SBR plant was working in range 86.35 to 94.33% colour removal efficiency with an average of 89.79%, whereas ASP plant was working in range 47.16 to 65.06% colour removal efficiency with an average of 55.67%. It was revealed that SBR plant was working at higher % colour removal efficiency than ASP plant.

3) Temperature
After treatment of sewage, Temperature of treated water was decreased most of the times in ASP but in case of SBR it was same and was found within the limits prescribed in Indian Effluent Standards as 40°C max. Fig no 3 shows % Temperature variations graphs of both plants. An average % Temperature variation of ASP plant was 4.15% which was higher than an average % Temperature variation of SBR plant as 1.62%.

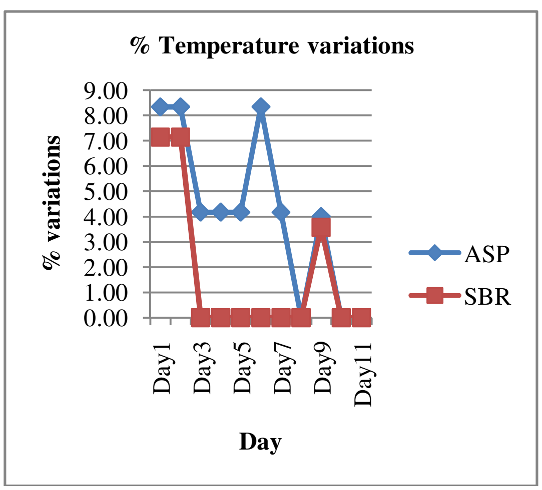

Fig no 3 % Temperature variations

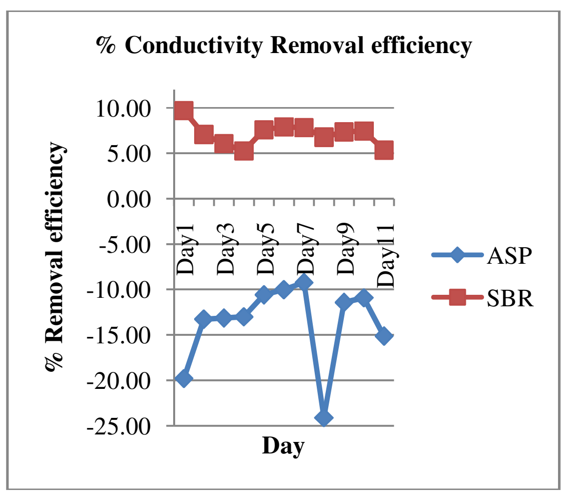

Fig no 4 % Conductivity removal efficiency

4) Conductivity
After treatment of sewage, Conductivity of effluent was augmented in ASP but in case of SBR it was lowered down. Limits for Conductivity of effluent were not prescribed in Indian Effluent Standards whereas Conductivity of effluent from ASP & SBR was found within the limits prescribed in Indian River Standards as 1000µs max. % Conductivity removal efficiency of both plants was plotted on graph as showed in fig no 4. SBR plant was working in range 5.25 to 9.70% conductivity removal efficiency whereas ASP plant was working in range -9.22 to -24.09% conductivity removal efficiency. ASP & SBR plants were working at -13.69% & 7.12%

average % conductivity removal efficiency respectively. Negative sign indicates an increase in conductivity of effluent than influent in case of ASP. SBR plant was working at higher % Conductivity removal efficiency than ASP plant.

5) Total Solids (TS)
Total solids in effluent were decreased in both plants after treatment of sewage. Limits for Total solids were not prescribed in Indian Effluent Standards as well as Indian River standards. Fig 5 describes variations in % Total solids removal efficiency of both plants. ASP plant was working in range 15.71 to 35.03% TS removal efficiency whereas SBR plant was working in range 31.30 to 43.55% TS removal efficiency. ASP & SBR plants were working at 27.55% & 38.12% average % TS removal efficiency respectively. ASP plant was running at lesser % Total solids removal efficiency than SBR plant.

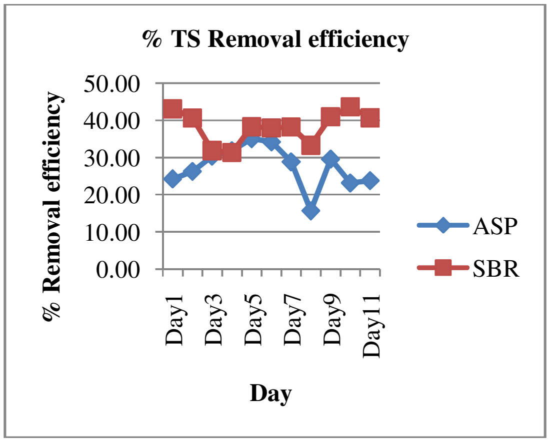

Fig no 5 % TS removal efficiency

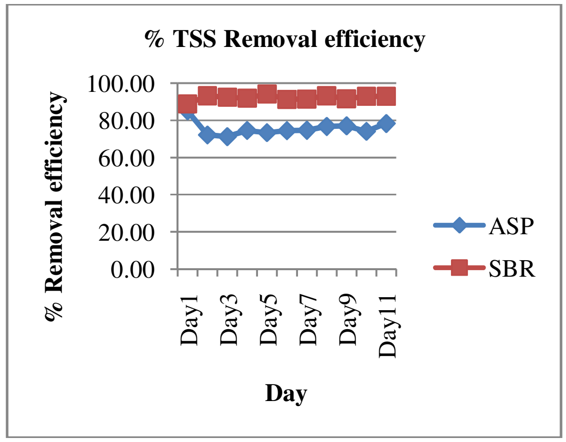

Fig no 6 % TSS removal efficiency

6) Total Suspended Solids (TSS)
After treatment of sewage, Total suspended solids in effluents from ASP & SBR were decreased & found within the limits prescribed in Indian Effluent Standards as 100 mg/litre max. ASP plant was operating in range 71.18 to 85.12% TSS removal efficiency whereas SBR plant was operating in range 88.78 to 94.12% TSS removal efficiency as plotted in Fig no 6. Both plants were working at 75.55% & 92.12% average % TSS removal efficiency respectively for ASP & SBR. It was observed that SBR was working at higher % Total suspended solids removal efficiency than ASP. Also it was discovered that ASP was designed for % TSS removal efficiency 92.50%, and it was working with average % TSS removal efficiency 75.55% which was lower than design value. SBR was designed for % TSS removal efficiency 90%, and it was working with average % TSS removal efficiency 92.12% which was higher than design values.

As per ‘CPHEEO Manual’, published by the Govt. of India performance of ASP & SBR as % TSS removal efficiency was 85 to 90% & 85 to 97% respectively. It was found that ASP plant was working with lesser efficiency than % TSS removal efficiency prescribed in CPHEEO manual on Day2 to Day11 and the design % TSS removal efficiency on all days. Whereas SBR plant was working within the range of % TSS removal efficiency prescribed in ‘CPHEEO Manual’, published by the Govt. of India on all days and the design % TSS removal efficiency on all days excluding day1.

ASP plants needs to provide efficient excess sludge removal system at secondary settling tank to enhance its % TSS removal efficiency and to reduce rising of sludge in secondary settling tank as it will also help to reduce total dissolved solids & conductivity in effluent.

7) Total Dissolved Solids (TDS)
TDS in effluent was increased in ASP but in case of SBR it was lowered down. Total Dissolved solids in effluent from ASP & SBR were found within the limits prescribed in Indian Effluent Standards as 2100 mg/litre max. ASP plant was working in range -9.25 to -23.71% TDS removal efficiency whereas SBR plant was working in range 4.78 to 9.89% TDS removal efficiency as drawn in fig no 7. ASP & SBR plants were working at -13.64% & 7.08% average % TDS removal efficiency respectively. Negative sign indicates increase in Total Dissolved Solids in case of ASP. ASP plants needs to provide efficient aeration & sludge removal system at secondary settling tank to enhance its % TDS removal efficiency and to reduce rising of sludge in secondary settling tank, it will also help to reduce total suspended solids & conductivity in effluent. % TDS removal efficiency was higher in case of SBR plant than ASP plant.

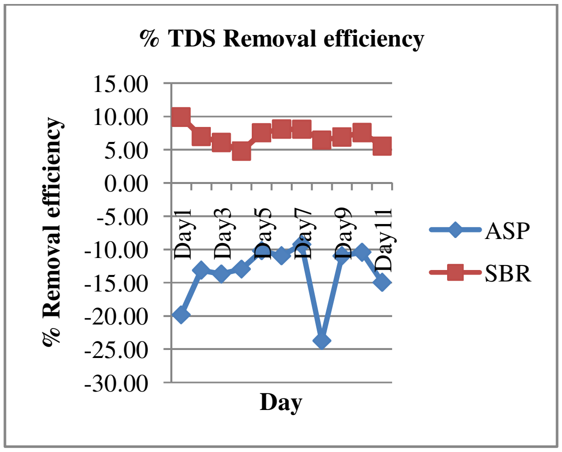

Fig no 7 % TDS removal efficiency

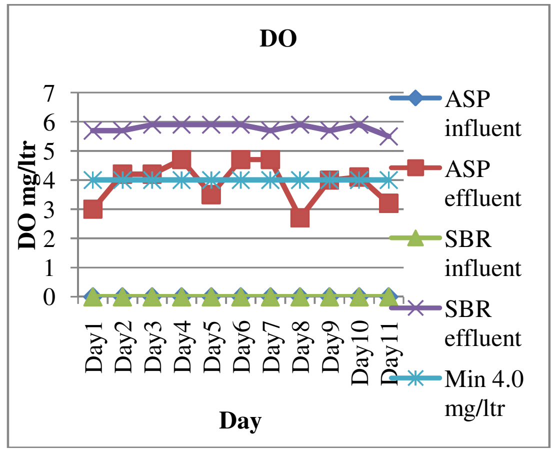

Fig no 8 DO in influents & effluents

8) Dissolved Oxygen (DO)

Limits for Dissolved Oxygen in effluents were not prescribed in Indian Effluent Standards whereas Dissolved oxygen in effluent from ASP was found less than the minimum limits prescribed in Indian River Standards for Class D as 4mg/litre min on Day1, Day5, Day8 & Day11 as 3, 3.5, 2.7 & 3.2 respectively. Dissolved oxygen in effluent from SBR was found within the limits prescribed in Indian River Standards for Class D as 4mg/litre min. DO in effluents was recovered in ASP & SBR plants with an average of 3.91 & 5.79 mg/litre respectively. DO in influents & effluents were showed in fig no 8. Higher and uniform DO recovery was observed in case of SBR plant than ASP plant because SBR plant was provided with Auto control of diffused aeration with the help of SCADA as compared to surface aerators used for aeration at ASP plant without SCADA.

9) Biochemical Oxygen Demand (BOD)

In ASP & SBR plants overall BOD of effluent was reduced after treatment of sewage. BOD of effluent from ASP was found higher than the limits prescribed in Indian Effluent Standards as 30 mg/litre max excluding Day2. Whereas BOD of effluent from SBR was within the limits prescribed in Indian Effluent Standards as 30 mg/litre max. ASP plant was running in range 78.67 to 88% BOD removal efficiency whereas SBR plant was running in range 93.33 to 96.25% BOD removal efficiency with an average of 83.59% & 94.94% BOD removal efficiency respectively. Fig no 9 shows the graphs of % BOD removal efficiency of both plants. It was found that ASP plant was working with lesser % BOD removal efficiency than SBR plant. In 'CPHEEO Manual', published by the Govt. of India performance of ASP & SBR for % BOD removal efficiency was prescribed as 85 to 95% & 89 to 98% respectively. ASP plant was working on lesser % BOD removal efficiency than % BOD removal efficiency prescribed in manual on Day1 to Day8 and the design % BOD removal efficiency on all days. ASP plants needs to provide efficient aeration system to enhance its % BOD removal efficiency. Whereas SBR plant was working within the range of % BOD removal efficiency prescribed in manual on all days and also it was working at higher % BOD removal efficiency than the design value on all days.

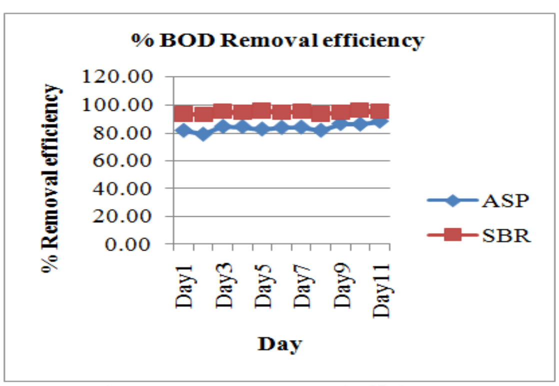

Fig no 9 % BOD removal efficiency

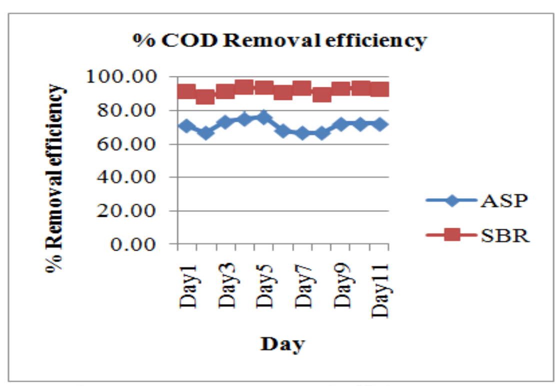

Fig no 10 % COD removal efficiency

10) Chemical Oxygen Demand (COD)

After treatment of sewage, COD of effluent was lowered down in both plants. COD of effluents from ASP & SBR were found within the limits prescribed in Indian Effluent Standards as 250 mg/litre max & % COD removal efficiency Graphs drawn as showed in Fig no 10. It was found that SBR had higher COD removal efficiency than ASP. ASP plant was operating in range 66.67 to 76% COD removal efficiency whereas SBR plant was operating in range 88 to 94.12% COD removal efficiency. ASP & SBR plant was working with an average of 70.85% & 91.98% COD removal efficiency respectively.

11) Chlorides

It was revealed that after treatment Chlorides in effluent were increased in ASP but decreased in effluent from SBR plant. Chlorides in effluent from ASP & SBR were found within the limits prescribed in Indian Effluent Standards as 1000 mg/litre max. SBR plant had higher and more uniform % Chlorides removal efficiency than ASP plant as showed in fig no 11. ASP plant was working in range -9.68 to -23.81% Chlorides removal efficiency whereas SBR plant was working in range 10 to 15.38% Chlorides removal efficiency. ASP & SBR plant was working with an average of -14.83% & 13.52% Chlorides removal efficiency respectively. Negative sign indicates increase in Chlorides in case of ASP plant which resulted in increase in Total hardness and Conductivity of effluent in case of ASP plant. ASP plants needs to provide efficient aeration system to enhance its % chlorides removal efficiency; it will also help to reduce total suspended solids, total hardness & conductivity in effluent.

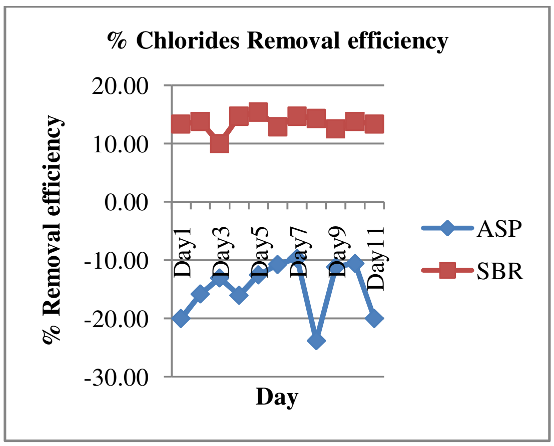

Fig no 11 % Chlorides removal efficiency

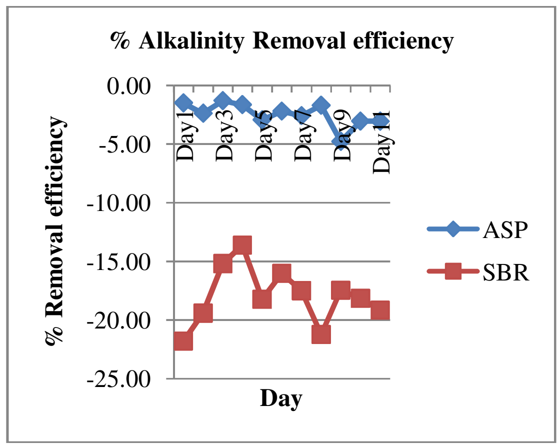

Fig no 12 % Alkalinity removal efficiency

12) Alkalinity

Alkalinity of effluent was increased after treatment in ASP & SBR plants. Limits for Alkalinity were not prescribed in Indian Effluents Standards & Indian River Standards. ASP plant was working in range -1.31 to -4.78% whereas SBR plant was working in range -13.62 to -21.81% Alkalinity removal efficiency as drawn in fig no 12. ASP & SBR plant was working with an average of -2.48% & -17.99% Alkalinity removal efficiency respectively. Negative sign indicates increase in Alkalinity in effluents from both plants. So % Alkalinity removal efficiency was considered as % incremental efficiency. SBR plant had higher % Alkalinity incremental efficiency than ASP plant.

13) Total Hardness

Total Hardness in effluent had increased in ASP but in case of SBR it was found decreased. Limits for Total Hardness were not prescribed in Indian Effluents Standards as well as in Indian River Standards for Class D. Fig no 13 shows graphs of % Total Hardness removal efficiency of both plants and it was observed that SBR plant was operating with higher % Total Hardness removal efficiency than ASP plant. ASP plant was operating in range -5.56 to -26.32% whereas SBR plant was operating in range 4.55 to 15.79% Total Hardness removal efficiency. ASP & SBR plant was working with an average of -12.35% & 9.24% Total Hardness removal efficiency respectively. Negative sign indicates an increase in Total Hardness in case of ASP plant resulted in an increase in Conductivity of effluent. ASP plants needs to provide efficient aeration system to enhance its % Total Hardness removal efficiency; it will also help to reduce total suspended solids, chlorides & conductivity in effluent.

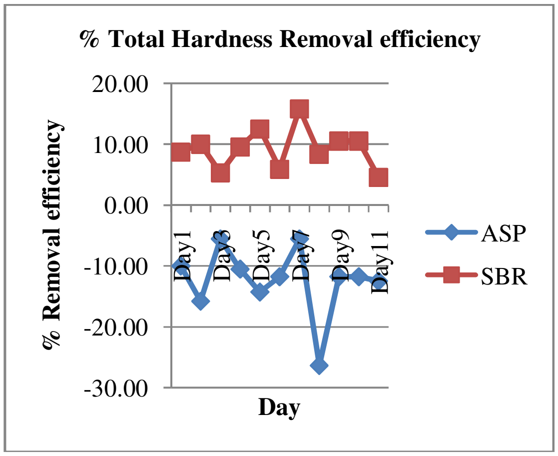

Fig no 13 % Total Hardness removal efficiency

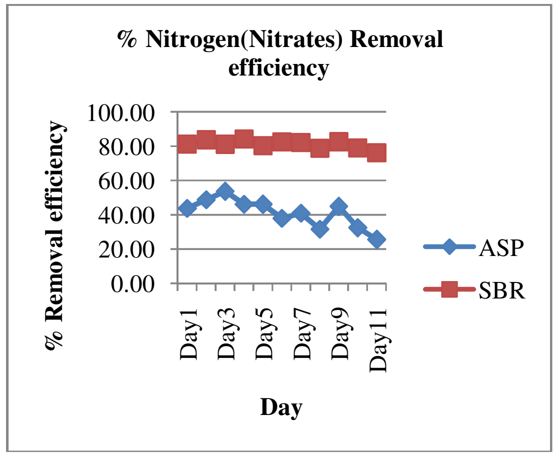

Fig no 14 % Nitrogen (Nitrates) removal efficiency

14) Nitrogen (Nitrates)

Nitrogen (Nitrates) in effluent was reduced after treatment in ASP & SBR plants. Limits for Nitrogen (Nitrates) in effluent were not prescribed in Indian Effluent Standards as well as Indian River Standards for Class D. In fig no 14 graphs of % Nitrogen (Nitrates) removal efficiency of both plants were plotted. SBR plant was working at very high % Nitrogen (Nitrates) removal efficiency than ASP plant. ASP & SBR plant was working with an average of 41.10% & 81.15% Nitrogen (Nitrates) removal efficiency respectively. Performance of SBR as % removal efficiency for Total nitrogen removal was >75% and no treatment in case of ASP plant was described in 'CPHEEO Manual', published by the Govt. of India . It was noticed that SBR plant & ASP plant was running at 76.25 to 84.29% & 25.61 to 53.68% Nitrogen (Nitrates) removal efficiency respectively.

15) Phosphates

It was observed that Phosphates in effluent reduced in both ASP & SBR plants. Phosphates in effluent from ASP were found higher on Day3 & Day8, whereas in case of SBR Phosphates in effluent were less than the limits prescribed in Indian Effluent Standards as 5 mg/litre max. In fig no 15 graphs of % Phosphates removal efficiency of both plants were plotted. From this graphs it was revealed that SBR plant was working with very high % Phosphates removal efficiency than ASP plant. No treatment & 57 to 69% efficiency range was described for Biological Phosphorus removal efficiency of ASP & SBR plants respectively in manual whereas it was discovered that ASP was working with 7.80 to 18.41% & SBR was working with 63.31 to 79.66% range of % Phosphates removal efficiency. ASP & SBR plant was working at 11.74% & 71.33% average % Phosphates removal efficiency respectively.

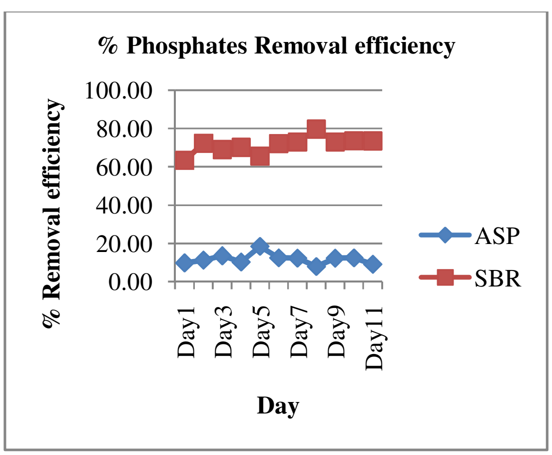

Fig no 15 % Phosphates removal efficiency

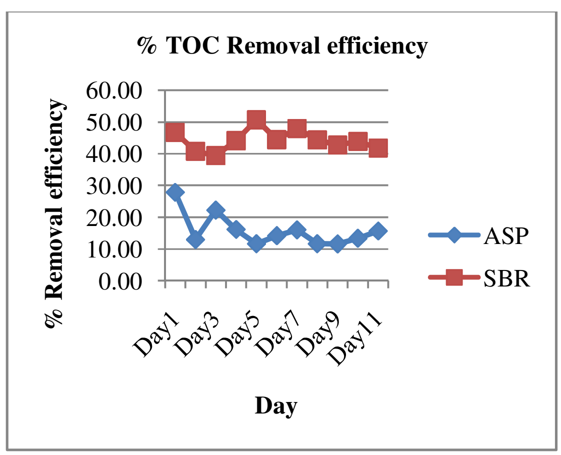

Fig no 16 % TOC removal efficiency

16) Total Organic Carbon (TOC)

After treatment of sewage, Total organic carbon in effluent had decreased in ASP & SBR plants. In Indian Effluent Standards & Indian River Standards for Class D no limits were prescribed for TOC. % TOC removal efficiency graphs were plotted as shown in fig no 16. It was found that SBR had higher % Total organic carbon removal efficiency than ASP plant. ASP plant was working in range 11.56 to 27.83% TOC removal efficiency whereas SBR plant was working in range 39.43 to 50.68% TOC removal efficiency. ASP & SBR plant was working at 15.74% & 44.26% average % TOC removal efficiency respectively.

Statistical co relations

Statistical co-relations between parameters of influents and effluents, % removal efficiency and parameters were evaluated by using eleven test data points and noted as in table no 2 of ASP and table no 3 for SBR. Statistical co-relations of very high degree between parameters such as TSS & Total solids, Total Hardness & Conductivity, TDS & Conductivity, Chlorides & Conductivity, Chlorides & TDS, Alkalinity & pH and Phosphates & Conductivity were detected in case of ASP. Statistical co-relations of very high degree between parameters such as TSS & Total solids, TDS & Conductivity, TDS & Total solids, Total Hardness & Conductivity, Total Hardness & TDS, Total solids & Conductivity, Total Hardness & Total solids, Phosphates & Total solids, Phosphates & TDS, COD & Alkalinity were detected in case of SBR.

Table no. 2 Statistical co-relations summary of ASP

Sr. No	Y			X			Co-relation Coefficient (r)	Coefficient of determination (r^2)	Slope (m)	Inter-cept (c)
	Inlet	Outlet	%RE/variations	Inlet	Outlet	%RE/variations				
					ASP					
1	TSS			Total solids			0.97	0.94	0.93	-192.58
2	Total Hardness			Conductivity			0.98	0.97	0.31	9.15
3		Total Hardness			Conductivity		0.97	0.95	0.29	18.91
4			TDS			Conductivity	1.00	0.99	0.98	-0.22
5			Chlorides			Conductivity	0.93	0.87	0.97	-1.57
6			Chlorides			TDS	0.92	0.85	0.98	-1.53
7			Alkalinity			pH	0.95	0.90	0.91	-0.28
8	TSS					Total Solids	0.89	0.78	6.56	13.10
9		Temperature				Temperature	-0.97	0.93	-0.36	24.86
10		BOD				BOD	-0.83	0.70	-1.27	132.94
11		Phosphates				Conductivity	-0.87	0.76	-25.76	772.22

Note: - Statistical co-relations were evaluated on the basis of test data for eleven data points. More accurate Statistical co-relations can be evaluated by using more data points.

Table no. 3 Statistical co-relations summary of SBR

Sr. No	Y			X			Co-relation Coefficient (r)	Coefficient of determination (r^2)	Slope (m)	Intercept (c)
	Inlet	Outlet	%RE/variations	Inlet	Outlet	%RE/variations				
					SBR					
1	TSS			Total solids			0.91	0.82	0.56	-75.88

Sr. No	Y			X			Co-relation Coefficient (r)	Coefficient of determination (r^2)	Slope (m)	Intercept (c)
	Inlet	Outlet	%RE/variations	Inlet	Outlet	%RE/variations				
2	TDS			Conductivity			0.92	0.85	0.39	67.25
3	TDS			Total solids			0.86	0.74	0.44	75.88
4	Total Hardness			Conductivity			0.98	0.97	0.27	30.24
5	Total Hardness			TDS			0.93	0.86	0.61	6.75
6		Total solids			Conductivity		0.91	0.83	0.42	62.10
7		TDS			Conductivity		0.92	0.85	0.39	61.42
8		TDS			Total solids		0.99	0.98	0.92	7.42
9		Total Hardness			Conductivity		0.98	0.97	0.30	14.50
10		Total Hardness			Total solids		0.90	0.82	0.59	-1.30
11		Total Hardness			TDS		0.91	0.82	0.64	-5.32
12		Phosphates			Total solids		-0.90	0.82	-0.01	3.43
13		Phosphates			TDS		-0.90	0.80	-0.01	3.46
14			TDS			Conductivity	0.99	0.97	1.08	-0.63
15	Colour					Colour	-0.91	0.82	-41.68	4763.07
16	BOD					BOD	0.91	0.82	18.63	-1627.36
17	COD					Alkalinity	0.84	0.70	12.14	516.59
18		Colour				Colour	-0.99	0.98	-14.07	1371.24

Note: - Statistical co-relations were evaluated on the basis of test data for eleven data points. More accurate Statistical co-relations can be evaluated by using more data points.

Water quality indexes

Water quality indexes in terms of CCMEWQI of influent and effluents were evaluated as per the method described by Canadian Council of Ministers of Environment (CCMEWQI) which was based on a formula developed by the British Columbia Ministry of Environment, Lands and Parks and modified by Alberta Environment. Daily water quality indexes were evaluated for influent and effluents as per Indian River Standards of Class D and showed on graph in fig no. 17.

CCMEWQI and its ranges of ASP influents & effluents were found 1) on daily basis between 14.36 to 14.44% & 14.48 to 21.05% respectively, 2) over total test period as 14.38 & 18.72% respectively and 3) average over total test period as 14.38 & 18.67% respectively, which was categorized as poor.

CCMEWQI and its ranges of SBR influents & effluents were found 1) on daily basis between 14.36 to 14.41% & 21.22 to 21.42% respectively, 2) over total test period as 14.38 & 21.31% respectively and 3) average over total test period as 14.38 & 21.32% respectively, which was categorized as poor.

It was revealed that the requirements of Indian Standards laid for Class D River IS 2296:1982 were not fulfilled by characteristics of effluent. Water quality of influent was improved after treatment in both process but in case of SBR quality of effluent was better & uniform than ASP.

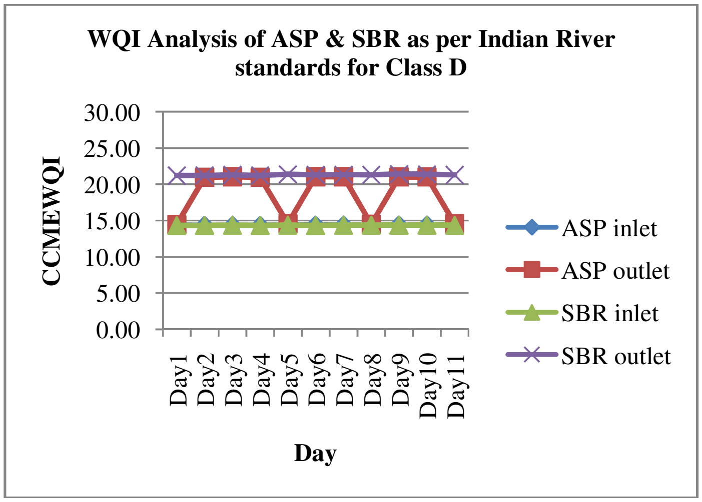

Fig no 17 CCMEWQI of ASP & SBR plants

Differentiation of ASP & SBR plants

Differentiation of ASP & SBR plants based on % parameter removal efficiency, Effluent water quality indexes in terms of CCMEWQI & statistical co-relations between parameters & % removal efficiency had been done and noted in table no 4.

Table no 4 Performance of ASP & SBR

Sr. No.	Parameters	Activated Sludge process STP			Sequencing Batch Reactor STP		
		Design	Range	Average	Design	Range	Average
1	Variations						
	pH		1.11% to 4.28%	2.40%		4.41% to 11.94%	8.25%
	Temperature		0 % to 8.33%	4.15%		0 % to 7.14%	1.62%
2	DO recovery		2.7 to 4.7 mg/liter	3.91 mg/liter		5.5 to 5.9 mg/liter	5.79 mg/liter
3	Removal efficiencies						
	Colour		47.16% to 65.06%	55.67%		86.35% to 94.33%	89.79%
	Conductivity		-24.09% to -9.22%	-13.69%		5.25% to 9.70%	7.12%
	Total solids		15.71% to 35.03%	27.55%		31.30% to 43.55%	38.12%
	TSS	92.50%	71.18% to 85.12%	75.55%	90%	88.78% to 94.12%	92.12%
	TDS		-23.71% to -9.25%	-13.64%		4.78% to 9.89%	7.08%
	BOD	94.29%	78.67% to 88%	83.59%	92%	93.33% to 96.25%	94.94%
	COD		66.67% to 76%	70.85%		88% to 94.12%	91.98%
	Chlorides		-9.68 % to -23.81%	-14.83%		10% to 15.38%	13.52%
	Alkalinity		-1.31% to -4.78%	-2.48%		-13.62% to -21.81%	-17.99%
	Total Hardness		-5.56% to -26.32%	-12.35%		4.55% to 15.79%	9.24%
	Nitrogen (Nitrates)		25.61% to 53.68%	41.10%		76.25% to 84.29%	81.15%
	Phosphates		7.80% to 18.41%	11.74%		63.31% to 79.66%	71.33%

Sr. No.	Parameters	Activated Sludge process STP			Sequencing Batch Reactor STP		
		Design	Range	Average	Design	Range	Average
	Total Organic Carbon		11.56% to 27.83%	15.74%		31.37% to 38.60%	44.26%
4	Performance (Design)	ASP plant was working with average % removal efficiency for BOD & suspended solids lower than design values.			SBR plant was working with average % removal efficiency for BOD & suspended solids higher than design values.		
5	Performance (CPHEEO manual range)	ASP plant was working with lesser % removal efficiency for BOD & suspended solids than the range prescribed in CPHEEO manual.			SBR plant was working within the range of % removal efficiency for BOD & suspended solids prescribed in CPHEEO manual.		
6	Statistical co-relations	Statistical co-relations between parameters such as TSS & Total solids, Total Hardness & Conductivity, TDS & Conductivity, Chlorides & Conductivity, Chlorides & TDS, Alkalinity & pH and Phosphates & Conductivity were detected in case of ASP.			Statistical co-relations between parameters such as TSS & Total solids, TDS & Conductivity, TDS & Total solids, Total Hardness & Conductivity, Total Hardness & TDS, Total solids & Conductivity, Total Hardness & Total solids, Phosphates & Total solids, Phosphates & TDS, COD & Alkalinity were detected.		
7	WQI(CCMEWQI) as per Indian River standards for Class D						
	Daily	14.48 to 21.05% Categorization- poor.			21.22 to 21.42% Categorization- poor.		
	Total test period	18.72% Categorization- poor.			21.31% Categorization- poor.		
	Average over Total test period	18.67% Categorization- poor.			21.32% Categorization- poor.		
	Quality	Less improved quality than SBR.			Better & uniform improved quality than ASP.		

Note: - 1. Negative (-) values of % parameter removal efficiencies shows an increase in parameter in effluent than influent, hence considered as % parameter incremental efficiencies.
2. Statistical co-relations were evaluated on the basis of eleven test data points. More accurate Statistical co-relations can be evaluated by using more data points.

V. CONCLUSIONS

- It was revealed that ASP plant was working at lesser efficiency of TSS & BOD removal than range prescribed in CPHEEO manual. For ASP plant No treatment was prescribed in manual for Nitrogen (Nitrates) and Phosphates but it was found that ASP was working in range of 25.61% to 53.68% & 7.80% to 18.41% removal efficiency respectively. In case of SBR plant, it was working within the ranges prescribed in CPHEEO manual for removal of TSS, BOD, Nitrogen (Nitrates) and Phosphates.
- It was found that ASP was working with average % removal efficiency for BOD & suspended solids as 83.59% & 75.55% respectively which were lower than design values.
- It was observed that SBR was working with average % removal efficiency for BOD & suspended solids as 94.94% & 92.12% respectively which were higher than design values.
- Average % Variations in pH and Temperature were noticed as 2.40% & 4.15% in case of ASP whereas 8.25% & 1.62% noticed in SBR.
- An average of 3.91 mg/liter & 5.79 mg/liter DO was recovered in treated effluents from ASP & SBR respectively.
- ASP was found working with average % removal efficiency for Colour, Conductivity, Total solids , TDS , COD, Chlorides, Alkalinity, Total Hardness , Nitrogen (Nitrates), Phosphates & Total Organic Carbon as 55.67%, -13.69%, 27.55%, -13.64 %, 70.85%, -14.83%, -2.48%, -12.35% , 41.10 %, 11.74 % & 15.74% respectively. Note:- Negative (-) sign shows an increase in parameter in effluent than in influent, hence considered as % parameter incremental efficiencies.
- SBR was observed working with average % removal efficiency for Colour, Conductivity, Total solids, TDS, COD ,Chlorides, Alkalinity, Total Hardness , Nitrogen (Nitrates), Phosphates & Total Organic Carbon as 89.79%, 7.12%, 38.12%, 7.08 %, 91.98 %, 13.52%, -17.99%, 9.24%, 81.15 %, 71.33% & 44.26% respectively. Note:- Negative (-) sign shows an increase in parameter in effluent than in influent, hence considered as % parameter incremental efficiencies.

- pH, Temperature, TSS, TDS, COD, Chlorides & Nitrogen (Nitrates) in effluents from ASP & SBR plants were found within limits prescribed in Indian Effluent Standards.
- DO in effluent from SBR found within limits but DO in effluent from ASP within limits excluding 4 days as per Indian River Standards for Class D as > 4 mg/litre.
- BOD found within limits excluding one day and Phosphates found within limits excluding two days in effluent from ASP as per Indian Effluent Standards. BOD & Phosphates in effluent from SBR were observed within the limits given in Indian Effluent Standards.
- Limits for Colour, Total solids, and Total organic carbon were not prescribed in Indian Effluent Standards but were found decreased in ASP & SBR. Colour of effluents found in range 385 to 571 hazen units & 43 to 160 hazen units in ASP & SBR respectively. Total solids in effluents detected in range 253 to 322 mg/liter & 178 to 285 mg/liter in ASP & SBR respectively. Total organic carbon in effluents observed in range 38.80 to 55.85 mg/liter & 31.37 to 38.60 mg/liter in ASP & SBR respectively.
- Limits for Conductivity & Total Hardness were not prescribed in Indian Effluent Standards but were found decreased in SBR and increased in ASP. Conductivity in effluents found in range 261 to 577 µs & 341 to 551 µs in ASP & SBR respectively. Total Hardness in effluents revealed in range 96 to 192 mg/liter & 112 to 176 mg/liter in ASP & SBR respectively.
- Limits for Alkalinity were not prescribed in Indian Effluent Standards but were found increased in both plants. Alkalinity in effluents found in range 247.60 to 275.40 mg/liter & 260.20 to 317.20 mg/liter in ASP & SBR respectively.
- It was revealed that the requirements of Indian River Standards for Class D IS 2296:1982 were not fulfilled by characteristics of treated effluents from ASP & SBR plants. Water quality of influent was improved after treatment in both plants but in case of SBR quality of effluent was better & uniform than ASP.
- Statistical co-relations between parameters such as TSS & Total solids, Total Hardness & Conductivity, TDS & Conductivity, Chlorides & Conductivity, Chlorides & TDS, Alkalinity & pH and Phosphates & Conductivity were detected in case of ASP. Statistical co-relations between parameters such as TSS & Total solids, TDS & Conductivity, TDS & Total solids, Total Hardness & Conductivity, Total Hardness & TDS, Total solids & Conductivity, Total Hardness & Total solids, Phosphates & Total solids, Phosphates & TDS, COD & Alkalinity were detected. <u>Note: - Statistical co-relations were evaluated on the basis of eleven test data points. More accurate Statistical co-relations can be evaluated by using more test data points.</u>
- It is recommended that the existing ASP plant can be modified by using SBR as a biological treatment of sewage which will help to upgrade quality of treated effluent.

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