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Wastewater Quality Index – A Tool for Categorization of the Wastewater and Its Influence on the Performance of Sequencing Batch Reactor

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Abstract

Wastewater treatment using Sequencing Batch Reactor (SBR) technology is one of the state-of-the art wastewater management systems. In SBR equalization, biological treatment and secondary clarification are performed in a single tank in a timed control sequence. SBR system is more idle for the areas where the available land is limited, since it operates in less space and very cost effective even on small scales.The concept of Water Quality Index (WQI) has been developed by representing it as numeric value for easy and quick understanding of quality of the water. It provides a convenient means of summarizing complex water quality data for easy communication to common people and it is considered as an important decision making tool for the authorities. Global Environmental Monitoring System (GEMS) studied different models and found that the Canadian Water Quality Index (CWQI) or Canadian Council of Ministers of the Environment (CCME) Water Quality Index is suitable model for this task. Similarly, the wastewater quality index (WWQI) may be considered as a useful tool to provide insight into the degree to which the wastewater is polluted by human activity and the requirements of treatment to meet the relevant objectives. The wastewater quality index of the influent wastewater in the existing treatment plant site at Puducherry was evaluated. The parameters considered for this study were pH, TDS, TSS, BOD, COD, N as NO_3 and P as PO_4., which were used for the determination of WWQI and statistical analysis. Multiple Linear Regression (MLR) and

Artificial Network Analysis (ANN) models were also developed for WWQI and compared.

Keywords: Sequencing Batch Reactor (SBR), Wastewater Quality Index (WWQI), Multiple Linear Regression (MLR), Artificial Neural Network (ANN).

1. INTRODUCTION

The SBR technology is known to be the pioneer of all activated sludge systems and the reactor functions as a fill - and – draw system. The unit processes of the SBR are similar to the conventional activated sludge systems. It is stated that "SBR is no more than an activated sludge system which operates in time rather than in space" [1]. In SBR system the process such as equalization, biological treatment, and secondary clarification are performed in a single tank with a time controlled sequence. In some cases, primary clarification is also performed. In the case of conventional activated sludge system, these unit processes are accomplished by using separate tanks.

Even though the SBR requires less volume, the reduction in size is not the main advantage of the SBR, but the inherent flexibility of operation offered by the SBR during the treatment process is much more important. The metabolic reactions, sedimentation and solid-liquid separation are carried out in one tank and in a well-defined and continuously repeated time sequence. It is advantageous in many aspects, as the duration of the process phases can be adjusted easily to any actual conditions without any need to structurally retrofit the existing tanks. When Biological Nutrient Removal (BNR) is considered in SBR plants, it eliminates the need for Return Activated Sludge (RAS) pumps and pipes [2].

1.1 SBR Technology

The SBR system may also described as Inter-Air system and its operation mode is based on the fill- and- draw principle involving the following five important steps namely, Fill, React, Settle Decant and Idle and is generally presented as "cycle"[3][4].

1.2 Fill

During the fill mode, the influent wastewater is let into the biomass that was already available in the tank during the previous cycle. The influent may be either primary effluent or the raw wastewater. During the fill mode it may be kept either aerated or non-aerated depending upon the characteristics of wastewater and the filling mode may be static, mixed or aerated [5].

1.3 React

During the react mode, wastewater flow to the tank is restricted while aeration and mixing continue. Reactions for substrate removal which were initiated during fill mode are completed during this react mode.

1.4 Settle

During this phase of settle mode, the entire aeration tank acts as a typical clarifier without any inflow or outflow of wastewater. The quiescent conditions developed give rise to the better separation of solids or sludge than that of conventional clarifiers.

1.5 Draw (Decant)

During the draw mode, the clarified supernatant liquid is discharged from the reactor as effluent after the settling mode. The excess waste activated sludge is also removed during this mode.

1.6 Idle

The period between the draw and fill mode is termed as idle mode. The purpose of this phase is to complete the fill cycle before switching to another unit.

2.0 STUDY AREA AND PRESENT SCENARIO

Puducherry is a coastal city, located at 11º 58’ 12” N, 79º 48’ 40” E and at 162 km south of Chennai, India (Figure 1). The urban population of Puducherry as per 2011 census is 6.54 lakhs. Puducherry town has been provided with underground sewerage facilities partially as early as 1980 and the municipal wastewater has been treated with an oxidation pond of 2.9 MLD capacity at Karuvadikuppam, in the north- western part of the Puducherry. Due to expansion of town areas the sewerage facilities were extended with three more oxidation ponds with treatment capacities of 2.9, 2.2, 4.8 MLD and all these four ponds were connected in series. Later on, two Upflow Anaerobic Sludge Blanket (UASB) reactors each have a capacity of 2.5 MLD, one at the Karuvadikuppam and another one at Dubrayapet. On the south-eastern part of the Puducherry town were installed. The treatment capacity of all the existing STPs is 17.8 MLD which covers about 30% of the urban areas only and the remaining 70 % area are being covered in a phased manner. Rapid urbanization and limitation of available space have necessitated adopting modern treatment methods. Accordingly, it was proposed to provide 3 Sequencing Batch Reactors (SBR) each having a capacity of 17 MLD. The SBR at Karuvadikuppam has been completed and commissioned. The other two SBRs at Dubrayapet and Kanaganeri are nearing completion.

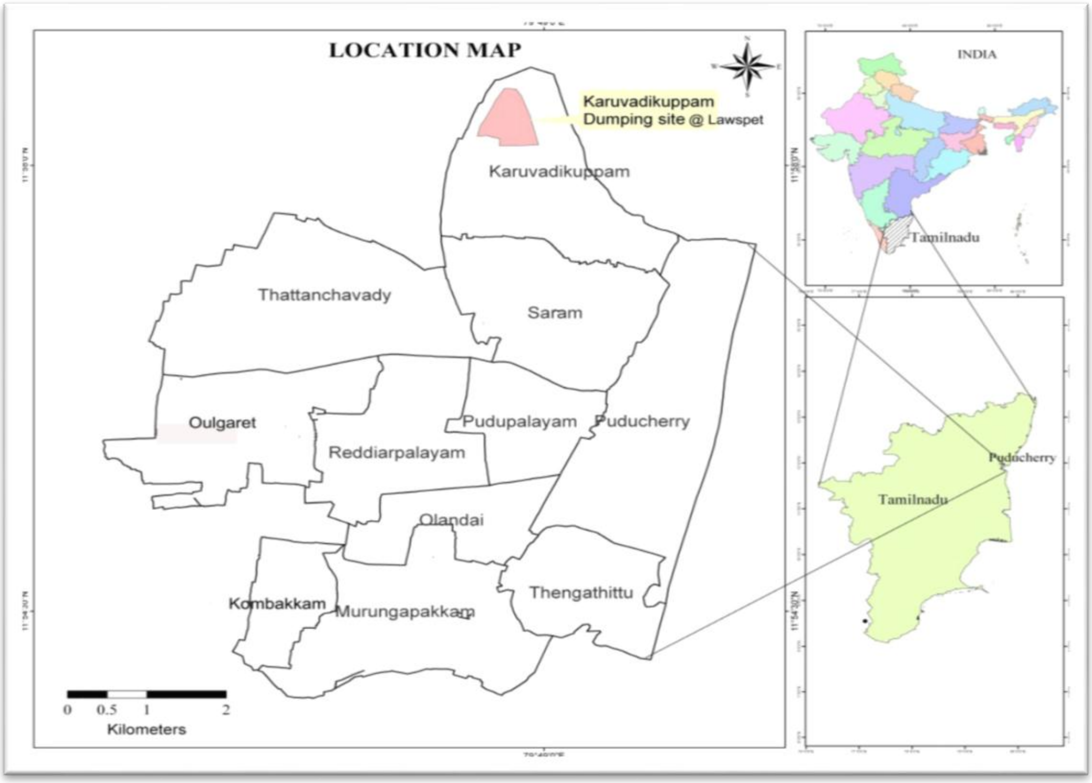

Figure 1: Plan showing the study Area

3.0 METHODLOGY

3.1Sequencing Batch Reactor (Pilot scale)

A pilot -scale SBR was installed at the treatment plant site at Dubrayapet, Puducherry to study and compare the performance of both pilot and real plant. The municipal wastewater generated in the Puducherry town and collected for treatment in the existing treatment plant was used in this study. A rectangular aerobic sequential batch reactor was designed and fabricated with a working volume of 60 L for this pilot study. The size of rectangular shaped acrylic sheet pilot reactor was 50cm x 30cm x 40cm height with a suspended growth system. The pumps, inlet and outlet pipelines were connected with the solenoid valves and an aquarium blower with air flow controller was used for aeration. The pumps, blower and the solenoid valves were controlled by a time controller. Automatic time control units were used in this pilot plant for proper operating and controlling of fill, react, settle and draw periods in the reactor. The materials and experimental setup are shown in Figures 2 and 3. The reactor was filled with raw sewage and seeded with the sludge collected from the existing oxidation pond at Karuvadikuppam. Digested cow dung was also mixed and aeration was done intermittently in order to ensure that sufficient quantity of active biomass was developed. The level of the MLSS was also monitored by periodically drawing the sludge. The pilot plant was put into operation during August 2014 and the same has been in continuous operation till October 2016.

3.2 Material and Experimental Set-Up

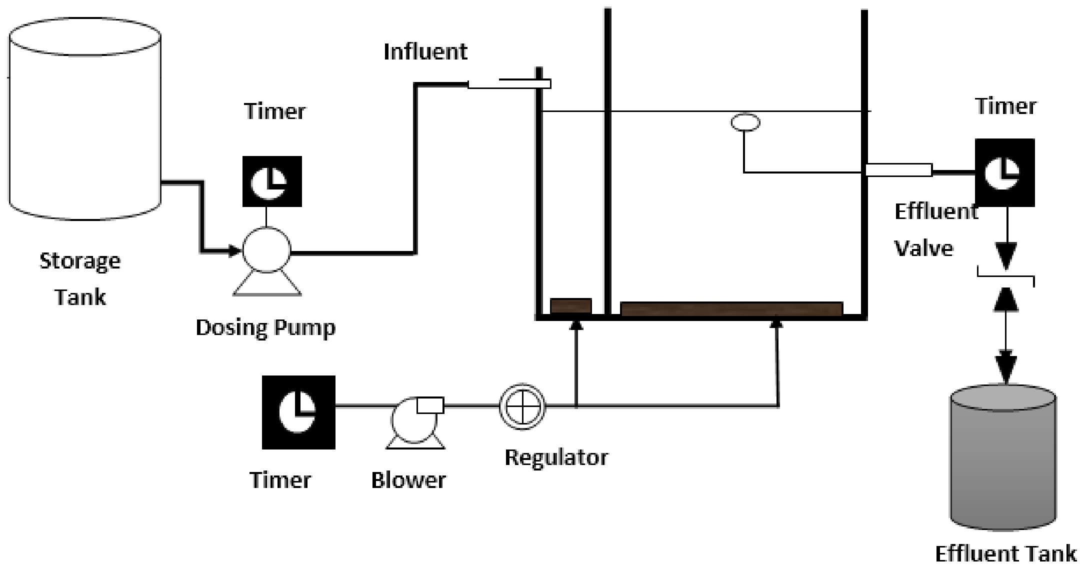

Figure 2 : Pilot Plant Experimental Set-up

3.3 Principles of the process

The process of wastewater treatment in SBR consists of complete–mix reactors, in which all the processes occur in the same reactor by way of establishment of operational cycles with defined duration [6]. The biomass is retained in the reactor during all the cycles, thus eliminating the need for separate sedimentation tanks and sludge recirculation pumping stations and thereby the sludge age becomes higher than the hydraulic detention time. The usual duration of each operational cycle may be altered depending upon the variations of the influent flow, the treatment requirements and the characteristics of the sewage and biomass in the system. Normally two or more SBRs run in parallel operations, each one in different stages of the operational cycle so that when a reactor in the sedimentation stage is unable to receive influent, the flow may be directed to the other reactor which is in the fill stage. Generally for domestic or municipal sewage, the degree of treatment is considered in terms of removal of BOD nutrients (nitrogen and phosphorous). It is often not enough to aim only at BOD removal and leaving other items unspecified.

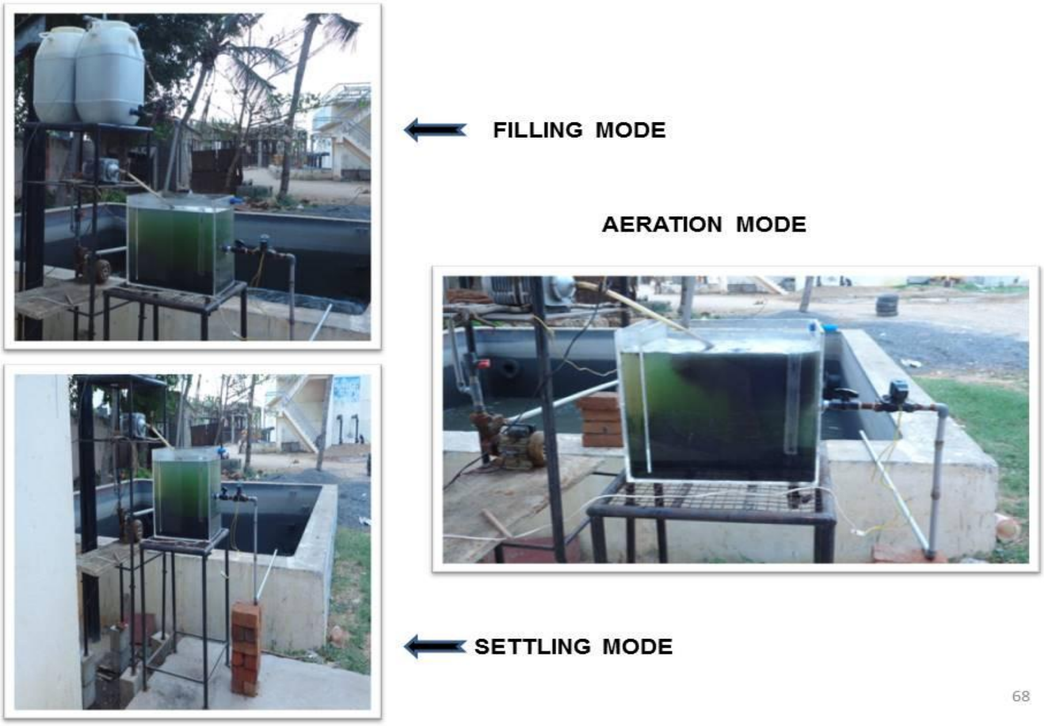

Figure 3 : Pilot Plant (Field Level)

Figure 4: Sequencing Batch Reactor (17 MLD) at Puducherry

3.4 SBR Real Plant

In the SBR plant at Karuvadikuppam (Figure 4), two operating C-Tech basins have been provided. These C-Tech basins work in sequence and the influent flow is distributed using automatic gates provided at the inlet chamber of C-Tech basins. The C-Tech basins are equipped with air blowers, diffusers, return activated sludge (RAS) pumps, surplus activated sludge (SAS) pumps, decanters, auto valves, programmable logic controller (PLC) etc. All cycles are automatically controlled using PLC. The size of each basin of the SBR in this location is 48m x 24 m x 5m.

3.5 Sample Collection and Testing

The pilot plant has been put into continuous operation for the past 27 months, since August 2014. The samples of both the influent and effluent were collected three days in a week and the samples were tested as per the standard testing methods [7]. During the study period, 159 samples for 53 weeks were regularly collected and tested. The physio - chemical and biological parameters like pH, EC, TDS, TSS, BOD, COD, N as NO_3 and P as PO_4 were tested for both the influent and effluent. The descriptive statistics of the influent parameters are listed in Table 1.

Table 1: Descriptive Statistics of the Influent parameters

	Mean	Min	Max	Median	Std. Dev	Kurtosis	Skewness
pH	7.00	6.60	7.50	7.10	0.17	0.23	-0.22
TDS	1111	725	1531	1140	181	-0.47	-0.27
TSS	238	71	398	209	112	-1.52	0.06
BOD	166	117	252	161	28	1.11	0.77
COD	278	191	431	263	58	0.48	0.97
N as NO_3	2.50	1.30	4.00	2.30	0.69	-0.14	0.71
P as PO_4	2.50	1.10	4.80	2.20	0.97	0.32	0.95

Note: All units are in mg/l except pH

3.6 Water Quality Index (WQI) and Wastewater Quality Index (WWQI).

The concept of Water Quality Index (WQI) has been developed as early as 1970 by representing it as numeric value for easy and quick understanding of quality of the water, for easy communication to common people and it is considered as an important decision making tool for the authorities [8][9]. A committee of water quality experts from across Canada developed the Canadian Water Quality Index known as CWQI. The CWQI is a tool for simplifying the reporting of water quality data. Traditional reports on water quality trends typically consisted of variable-by variable, whereas the CWQI provides a broad overview of environmental performance.

The wastewater quality index, which is a comprehensive representative of the said parameters, may be considered as a useful tool to provide insight into the degree to which the wastewater is polluted by human activity and the requirements of treatment to meet relevant objectives. The parameters of the influent wastewater which include design flow, maximum daily flow, temperature, BOD,COD, TSS, pH, alkalinity, Total Kjeldahl nitrogen (TKN), Ammonia-Nitrogen (NH_3-N), and Total Phosphorus (TP) impact the operating sequence of the SBR.

3.6.1 Canadian Water Quality Index (CWQI)

The CWQI water quality index consists of three factors [10]:

Factor 1: Scope

F1 (**Scope**) represents the extent of water quality guideline non-compliance over the time period of interest. It has been adopted directly from the British Columbia Index:

$$F1 = \frac{\text{Number of failed variables}}{\text{Total number of variables}} X\ 100$$

Factor 2: Frequency

F2 (**Frequency**) represents the percentage of individual tests that do not meet objectives ("failed tests"):

$$F2 = \frac{\text{Number of failed tests}}{\text{Total number of tests}} \text{ X } 100$$

The formulation of this factor is drawn directly from the British Columbia Water Quality Index.

Factor 3: Amplitude

F3 (**Amplitude**) represents the amount by which failed test values do not meet their objectives. *F3* is calculated in three steps. The formulation of the third factor is drawn from work done under the auspices of the Alberta Agriculture, Food and Rural Development[15].

(i) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an "excursion" and is expressed as follows. When the test value must not exceed the objective:

(ii)

$$\text{excursion}_i = \frac{\text{Failed Test Value}_i}{\text{Objective}_j} - 1$$

For the cases in which the test value must not fall below the objective:

$$\text{excursion}_i = \frac{\text{Objective}_j}{\text{Failed Test Value}_i} - 1$$

i) The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or *nse*, is calculated as:

$$\text{nse} = \frac{\sum_{i=1}^{n} \text{excursion}_i}{\text{Total number of tests}}$$

ii) *F3* is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (*nse*) to yield a range between 0 and 100.

$$F3 = \frac{nse}{.01nse + 0.01}$$

The Water Quality Index (CWQI) is calculated as [R] :

$$CWQI = 100 - \frac{\sqrt{\left(F1^2 + F2^2 + F3^2\right)}}{1.732}$$

Once the CWQI value has been determined, water quality is categorised as Excellent, Good, Fair, Marginal and Poor.

3.6.2 Wastewater Quality Index (WWQI)

The wastewater quality can be defined as a numerical value, which is inherently related to its input constituent parameters. The CCME WQI comprises of two components viz., percentile100 and the other varying factor $((F1^2 + F2^2 + F3^2)$ ^0.5) / 1.732. This factor may be termed as Pollution Index (PI) and when the PI tends to 0, the CWQI tends to 100 and the quality of the water is termed as Excellent. On the other hand when the PI tends to 100 the CWQI tends to 0 and the quality of the water is termed as Poor. In other words the quantum of pollution is the governing factor in assessing the characteristics and quality of the water. This concept of water quality index is applied to wastewater and the quality of the wastewater may be determined based on the PI. Thus level of pollution in the wastewater shall be evaluated and termed as Wastewater Quality Index (WWQI). The increase in PI indicates the increase in the level of pollution in the wastewater and the required degree of treatment can be predicted. Based on the WWQI, treatment process can be modified by adjusting the number and duration of cycle and the aeration time can be regulated depending on the predicted organic load or any other constituent parameter.

Table 2: Mean values of parameters and Wastewater Quality Index (WWQI)

pH	TDS	TSS	BOD	COD	N as NO_3	P as PO_4	WWQI
7.0	1221	109	243	409	4.0	4.8	46.42
6.7	1061	335	175	293	4.0	4.5	45.84
6.6	1268	151	161	220	4.0	4.5	33.28
7.1	1122	155	122	199	2.7	4.5	30.54
7.3	800	161	179	228	2.0	4.8	34.62
7.2	1021	152	192	280	4.0	3.5	44.04
7.1	805	160	117	255	2.7	3.5	39.95

pH	TDS	TSS	BOD	COD	N as NO_3	P as PO_4	WWQI
7.1	840	362	117	265	3.0	4.2	43.35
7.0	1073	337	210	300	2.7	2.3	47.27
7.1	1070	301	153	315	2.3	2.5	44.53
6.8	899	333	135	211	2.3	1.7	35.12
7.0	1134	269	139	358	2.7	2.3	43.64
6.9	1394	283	154	219	2.3	2.0	35.35
6.8	1284	355	161	249	2.3	3.0	36.96
6.9	1209	398	137	418	2.3	1.3	45.66
7.1	1196	394	145	431	2.7	2.7	46.02
7.1	1339	392	252	388	2.3	1.2	49.58
7.1	1330	359	117	225	1.7	1.5	34.49
7.2	1531	251	121	248	2.2	2.5	32.58
7.2	1330	351	126	213	1.7	1.2	34.88
7.1	1045	358	136	191	2.0	2.0	35.62
7.2	1141	388	181	307	2.0	3.0	46.78
7.3	1209	273	133	227	2.0	2.2	33.82
7.2	1203	253	120	236	1.3	2.2	32.55
7.1	1255	156	208	346	1.7	2.2	45.20
7.1	1153	184	204	308	2.7	2.8	45.20
7.4	1142	198	152	264	1.3	2.2	42.63
7.2	1259	167	159	274	3.3	3.0	42.57
6.9	1204	153	151	255	3.5	2.5	41.79
7.2	1409	196	155	257	3.5	3.3	42.71
7.1	1365	171	151	263	2.5	1.8	42.14
7.2	1231	283	164	235	2.3	2.2	35.94
7.2	1404	378	179	257	2.0	3.3	46.34
7.1	911	323	151	220	2.0	2.0	35.88
7.1	855	379	161	231	2.3	2.3	37.38
7.1	1026	327	155	254	3.7	3.7	44.61
6.7	939	234	154	225	2.0	2.2	34.44
7.0	812	173	155	285	2.0	2.2	42.53
7.0	845	265	183	283	2.3	2.0	45.20
7.1	725	179	143	289	3.7	1.7	42.00
6.9	745	320	187	307	2.0	1.5	46.21
7.2	787	209	161	267	2.3	2.0	43.28
7.0	799	292	174	257	2.0	2.2	45.03
6.9	975	383	161	237	2.7	2.3	37.41
7.0	983	241	137	224	2.0	1.7	33.46

pH	TDS	TSS	BOD	COD	N as NO_3	P as PO_4	WWQI
7.1	875	351	144	229	2.0	1.3	35.96
7.0	1107	379	145	245	2.5	2.4	36.50
7.0	1096	382	165	260	2.9	2.6	45.83
7.0	1102	380	162	255	2.8	2.5	45.65
6.8	1213	364	165	267	3.0	1.7	45.65
6.7	1257	395	154	245	3.7	1.3	37.25
6.9	1043	351	139	225	2.3	1.4	35.65
6.9	1095	301	155	249	2.3	1.1	35.75

Note: All units are in mg/l except pH

The municipal wastewater has been classified based on the ratios between pollutant parameters viz. (i) COD/BOD, (ii) COD/TN, (iii) BOD/TN (iv) COD/VSS,(v) COD/TOC and (vi) VSS/TSS. Apart from these ratios the WWQI can also be considered as a comprehensive parameter for assessing the level of pollution in the wastewater as follows:

Classification of Wastewater	**WWQI**
Low strength wastewater	0 - 35
Medium strength wastewater	36 - 55
High Strength wastewater	56 - 100

The weekly mean value of the parameters and WWQI determined based on the above said, CWQI method are given in Table 2. Further correlation analysis has been done among the parameters and WWQI and the results are tabulated as follows:-

Table 3: Correlation among various parameters

	WWQI	pH	TDS	TSS	BOD	COD	N as NO_3	P as PO_4
WWQI	1							
pH	0.027	1						
TDS	-0.058	0.017	1					
TSS	0.092	-0.170	0.053	1				
BOD	0.614	-0.070	0.045	-0.104	1			
COD	0.735	-0.019	0.110	0.011	0.509	1		
N as NO_3	0.281	-0.375	0.045	-0.218	0.219	0.189	1	
P as PO_4	0.087	0.045	-0.010	-0.397	0.156	0.046	0.494	1

4.0 MODEL STUDIES

Two models viz., (i) Multiple Linear Regression (MLR) and (ii) Non-Linear models using Artificial Neural Network (ANN) were proposed for the prediction of WWQI. These models were developed using the influent wastewater parameters.

4.1 Multiple Linear Regression model (MLR)

MLR is one of the very important statistical tools which is used in almost all fields of sciences. In regression analysis there are two types of variables. The variable whose value is influenced is called dependent variable and the variables which influence the dependent variable are called explanatory variables.

MLR is an extension of simple linear regression analysis is used to assess the relation between two or more independent variables and dependent variable. The MLR equation is expressed as follows [11][12].

$$Y = b_0 + \Sigma\, b_i X_i$$

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + \ldots\ldots\ldots\ldots + e$$

where, Y is the predicted or expected value of the dependent variable
X_i is the independent variables,
b_0 is the intercept and b_1 coefficient
e is the error

The regression coefficient represents the change in Y relative to one unit change in the respective independent variable. In the multiple regression situations, b_1, for example, is the change in Y relative to one unit change in X_1, holding all other independent variables constant. In this study WWQI is considered as dependent variable and the polluting parameters are considered as explanatory variables. The coefficients of MLR model and statistics are given in Table 4.

Table 4: Multiple Regression model coefficients and statistics

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-28.460	22.046	-1.291	0.203	-72.86	15.94
pH	6.067	2.971	2.043	0.047	0.084	12.05
TDS	-0.004	0.002	-1.908	0.063	-0.008	0.000
TSS	0.012	0.005	2.169	0.035	0.001	0.022
BOD	0.060	0.017	3.443	0.001	0.025	0.095
COD	0.051	0.009	5.571	0.000	0.033	0.070
N as NO_3	1.867	0.810	2.303	0.026	0.234	3.499
P as PO_4	-0.236	0.541	-0.44	0.665	-1.33	0.854

The Multiple Linear Regression model developed for WWQI is as follows:

$$WWQI= -28.46 + 6.06(pH) - 0.005(TDS) + 0.012(TSS) + 0.06(BOD) + 0.051(COD) + 1.87(NO_3) - 0.24(PO_4)$$

4.2 Artificial Neural Network (ANN)

Artificial Neural Network (ANN) is a computational model based on the structure and functions of biological neural networks [13][14]. The ANN is used as a mathematical tool that has been successfully applied in various fields. ANN is considered as nonlinear statistical data modelling tool where the complex relationships between inputs and outputs are modelled or patterns are found.

The application of ANN to biological treatment of wastewater processes such as SBR is one of the new techniques in wastewater quality management, and the pilot plant test results indicate the promising start of the adoption of computational science in this domain of research. The problem of determining the level of pollution in the wastewater based on known level of concentration is a part of investigation using ANN. Based on WWQI determined and other parameters 5 ANN models were developed. ANN1, ANN2 and ANN3 models were developed using all 7 parameters viz pH, TDS, TSS, BOD, COD, N as NO_3 and P as PO_4, whereas, the ANN4 model was developed by excluding one parameter (pH) and the ANN5 model was developed by excluding two parameters (pH and TDS). The results of the predicted WWQI for 5 ANN models are given in Table 5.

The determined and predicted WWQI (MLR) values were plotted against time and shown in Figure.5. Similarly, determined WWQI and predicted WWQI (MLR) and predicted WWQI (ANN2) were plotted and shown in Figure.6 and 7. The R^2 values for MLR and ANN2 models were 0.706 and 0.976 thereby indicating very good and perfect correlation.

In similar lines the effluent characterises of the parameters of the wastewater in the pilot and real plants were also investigated. A comparative study on the performance of the pilot plant in relation with real plant is underway. Also, optimizing the operational parameters such as number of cycles, duration of cycles, organic loading rate, hydraulic and solids retention time etc., of real plant in comparison with the pilot plant is under study.

Table 5: Simulation by MLR and ANN models

Determined WWQI	Predicted Values					
	MLR	ANN1	ANN2	ANN3	ANN4	ANN5
46.42	52.00	46.52	46.04	43.72	44.95	45.14
45.84	43.60	44.87	46.01	45.63	46.7	47.44
33.28	35.26	33.13	32.97	33.16	33.63	34.84
30.54	33.26	32.31	32.88	30.48	31.04	31.35
34.62	39.52	37.45	35.84	35.54	35.46	35.46
44.04	45.43	44.09	43.6	44.19	44.9	45.81
39.95	37.46	40.09	39.23	39.06	38.22	37.9
43.35	40.71	41.98	42.98	43.62	42.15	42.95
47.27	46.07	47.58	48.33	47.92	47.41	47.76
44.53	42.76	44.46	44.89	45.99	44.73	45.91
35.12	35.79	32.56	33.83	34.14	34.62	33.61
43.64	43.58	44.03	43.46	44.59	44.12	45.27
35.35	35.18	32.99	34.95	34.6	34.25	34.72
36.96	37.57	36.73	37.71	40.04	40.23	41.63
45.66	46.57	45.39	46.06	45.83	43.32	45.32
46.02	49.45	45.78	46.63	44.57	44.21	45.36
49.58	52.75	48.8	48.59	48.56	47.79	47.3
34.49	34.73	32.68	34.57	34.63	34.07	34.66
32.58	35.31	34.48	33.86	35.61	34.33	37.81
34.88	35.31	32.75	35.12	34.62	34.75	33.45
35.62	35.83	32.7	35.25	34.49	35.53	32.39
46.78	44.77	47.26	48.23	48.19	47.25	47.38
33.82	36.97	33.18	33.86	34.17	33.05	34.75
32.55	34.40	32.8	33.4	33.87	32.82	34.53
45.20	43.99	45.86	46.35	44.55	45.44	44.91
45.20	44.40	45.26	45.83	44.88	45.94	45.93
42.63	38.65	42.39	42.95	41.29	41.28	40.66
42.57	41.06	43.75	43.45	44.64	43.29	43.68
41.79	38.23	41.86	40.04	41.07	41.44	40.54
42.71	39.99	42.96	42.9	43.08	42.4	41.8
42.14	37.71	42.16	41.29	41.85	41.81	41.17
35.94	39.21	36.6	36.86	35.76	35.59	37.99
46.34	40.80	44.33	46.33	44.13	44.89	43.99
35.88	38.35	33.31	35.17	34.21	35.15	34.95
37.38	40.94	36.11	38.11	35.68	36.25	37.92

Determined WWQI	Predicted Values					
	MLR	ANN1	ANN2	ANN3	ANN4	ANN5
44.61	42.72	43.22	44.35	44.24	43.54	42.75
34.44	34.88	32.77	33.4	33.25	33.43	34.83
42.53	39.73	43.69	43.23	44.03	43.49	43.4
45.20	42.96	44.8	45.79	45.8	46.14	45.76
42.00	43.74	43.73	43.19	44.02	43.04	44.58
43.28	41.68	43.62	43.49	43.44	43.41	42.69
45.03	41.00	42.93	44.68	43.31	43.51	42.85
37.41	40.25	36.6	37.95	37.05	36.94	39.44
33.46	35.80	32.76	33.35	33.35	32.74	34.06
35.96	39.05	33.88	35.4	34.63	35.6	36.42
36.50	39.30	36.61	37.71	37.57	37.06	40.35
45.83	42.08	44.01	46.83	45.41	45.02	44.29
45.65	41.43	42.61	45.36	43.26	43.04	43.28
45.65	40.83	43.99	46.18	46.22	46.03	45.17
37.25	40.05	38.13	37.91	37.97	38.85	41.36
35.65	37.07	33.04	34.75	34.62	35.18	35.68
35.75	38.49	37.8	36.59	37.75	37.97	40.72
R^2	0.706	0.934	0.976	0.931	0.95	0.851
RMSE	2.76	1.43	0.83	1.27	1.14	1.95

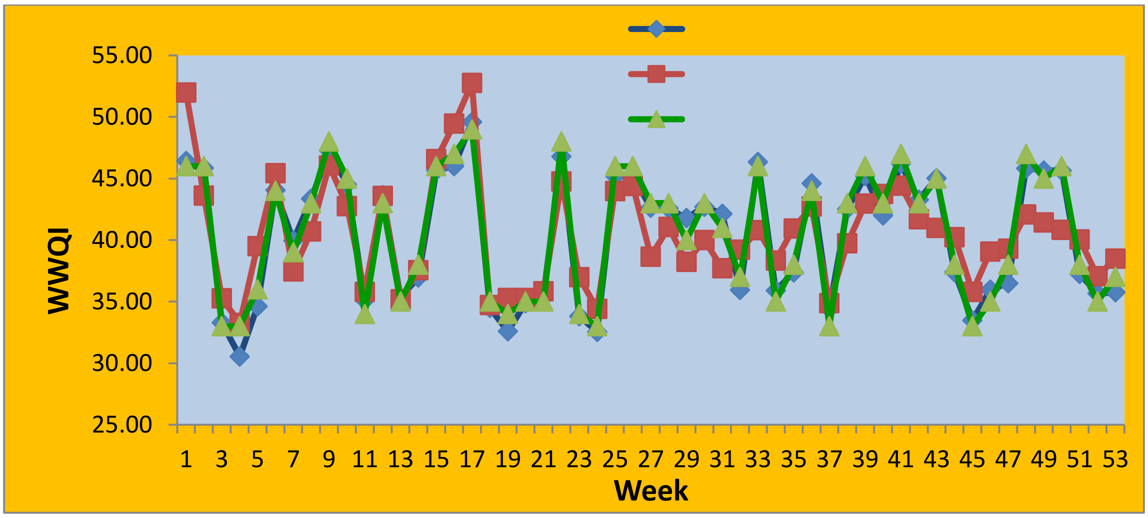

Figure 5: Variation of determined WWQI and predicted WWQI (MLR)

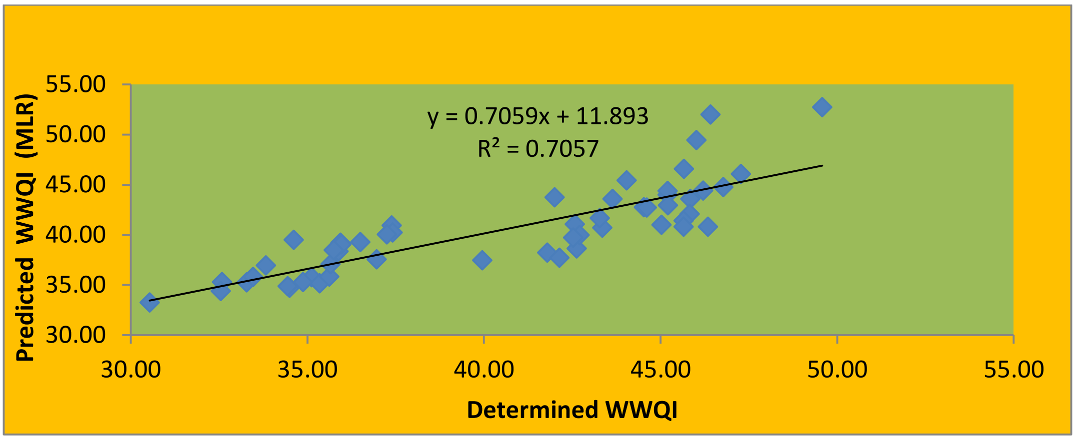

Figure 6: Correlation between determined and predicted WWQI (MLR)

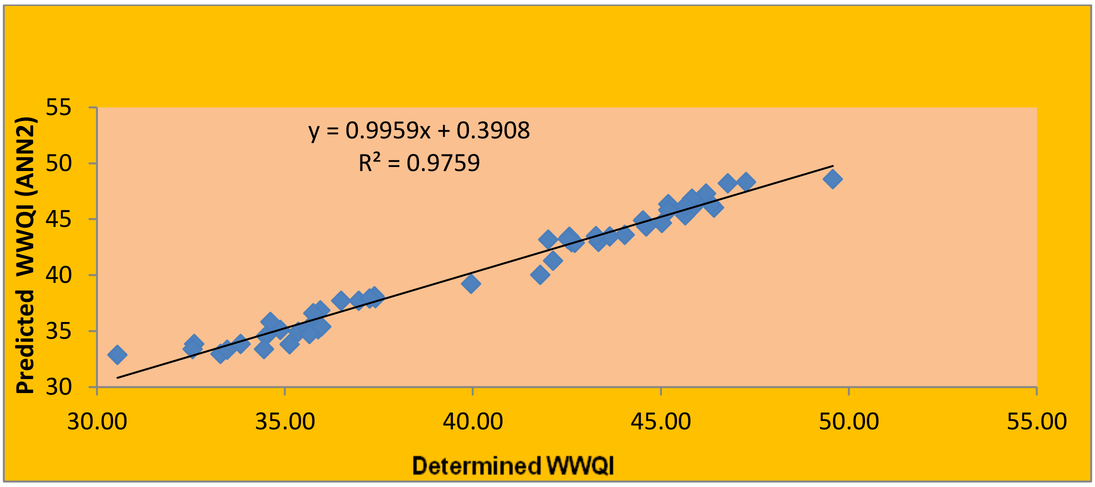

Figure 7: Correlation between determined and predicted WWQ (ANN2)

5. RESULTS AND DISCUSSION

In order to evaluate the characteristics of the domestic wastewater and to categorize the influent wastewater a pilot plant was installed to study and compare the performance of real SBR. In this study, 159 samples were collected and tested on weekly basis for 53 weeks for the assessment of the WWQI of the influent. The parameters such as pH, TDS, TSS, BOD, COD, N as NO_3 and P as PO_4 were tested and considered for the determination of the WWQI of the influent. Based on the weekly average values, the descriptive statistics like mean, minimum, maximum, median, standard deviation, kurtosis and skewness were evaluated.

The pH ranged from 6.5 to 7.4, TDS varied from 725 to 1531mg/l, and TSS showed the values from 109 to 398 mg/l. The level of BOD is found in varying amount from 117 to 252 mg/l and the COD ranges from 191 to 431 mg/l. The N as $NO_3$was found to vary from 1.33 to 4.1 mg/l and P as PO_4 ranged from 1.1 to 4.9. The ratios of COD / BOD were found between 1.63 and 1.71 and the WWQI so determined was found to vary from 30.54 to 49.58. Based on WWQI, the wastewater in Puducherry may be categorised as moderate strength owing to per capita water supply of more than 150 lpcd. Moreover there is no industrial or any other waste mixing with domestic wastewater.

Linear and Non-linear Model studies were carried out using Multiple Linear Regression and Artificial Neural Network models. In the MLR model, WWQI was treated as response variable and the other 7 variables as explanatory variables. The Coefficient of Determination (R^2) is 0.706, which indicates 70% of the total variance has been successfully explained by the explanatory variables. The Root Mean Square Error (RMSE) of the determined and predicted WWQI in MLR model was found to be 2.76.

Further, ANN models were developed with pH, TSS, TDS, BOD, COD, N as NO_3 and P as PO_4 as input parameters and WWQI as output parameter. Five ANN models viz., ANN1, ANN2, ANN3, ANN4 and ANN5 were chosen. ANN1, ANN2 and ANN3 models were developed with all the seven parameters. Sensitivity analysis was also carried out by excluding pH in ANN4 and pH & TDS in ANN5 model. Among these five models, ANN2 model was found to be more accurate with R^2 value of 0.976 with respect to WWQI. The RMSE values for all the ANN models were computed and value for the ANN2 model was found to be the least as 0.83 and consequently ANN2 model was chosen as best fit model and it explains 97.6% of the total variance.

A comparative study based on the operational parameters of the SBR and the characteristics of the influent and effluent between the pilot and the real plant is underway.

6. CONCLUSION

The studies of the characteristics of domestic wastewater and the determination of WWQI have shown that the wastewater in Puducherry can be categorized as moderate strength. The correlation analysis has revealed that there is good correlation between COD and WWQI and moderate correlation between BOD and WWQI. The values of R^2 and the RMSE between the determined WWQI and the predicted WWQI using MLR model were 0.706 and 2.86 respectively.

The studies on ANN models and their simulations illustrated that out of five ANN models viz., ANN1, ANN2, ANN3, ANN4 and ANN5, the ANN2 model has been found to be more accurate. The values of R^2 and RMSE between the determined WWQI and the predicted WWQI using ANN2 model were 0.976 and 0.83 respectively. Thus determination of WWQI gives an insight into the quality of the influent wastewater in Puducherry. From the WWQI, the duration of SBR cycle, the number of cycles and the required aeration for each cycle can be assessed. The WWQI may also be considered as one of the parameters for assessing the overall performance of the Sequencing Batch Reactor.

So far developing WWQI was not thought of in the domain of wastewater quality/treatment. A new approach based on CWQI has been developed to categorize domestic wastewater based on simple parameters. Keeping this as a basis, WWQI mapping can be formulated to study the influent characteristics of the urban and sub urban areas of Puducherry. On preparing such maps, WWQI values can easily be interpolated and interpreted so that suitable treatment process can be proposed. Further comparative studies between the pilot and real plants are under investigation.

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