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Prediction of Wastewater Fluctuations in Wastewater Treatment Plant by a System Dynamic Simulation Approach: a Projection Model of Surabaya's Mall

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Abstract: Wastewater quality and quantity fluctuations are the considered the essential component in installing a Wastewater Treatment Plant (WWTP). Therefore, this study aims to develop a representation model to give the projection of WWTP output. A data sampling collection was performed in D-Mall, which contains of waterflow, COD, BOD, TSS, NH3 and O&G parameters. The data then was simulated by using system dynamics for the 90% removal efficiency of anaerobic WWTP. The results ofthe simulation are able to project the current and future situation as well as able to detect the potential problem. The contribution of this research and the associated result can be used as a simulation model by Mall's owner as well as other Mall's owners to design the proper WWTP under the minimum threshold allowedand by policy maker to get a projection of the minimum quality standard required for every Mall in Surabaya by their own data simulation.
Keywords : Model, Wastewater, WWTP, Projection, System dynamics, Mall.

Introduction

Many cities all over the world are now facing inconvenience problem about their contamination of water river[1,2,3]. Many factors have contributed to this situation, including Indonesia with the untreated wastewater problem that flows into the river[4]. The untreated wastewater problem in Indonesia is commonly due to the inaccurate use of Wastewater Treatment Plant (WWTP), which resulted in a lot of leaks of pollutant in rivers. Designing a proper WWTP requires a good analysis on what kind of pollutant and how much it will flow from the wastewater. If the WWTP can be installed accurately, then its operation can prevent the leaking of pollutant to the river. While there are many types of anaerobic suspended and attached growth WWTP[5,6,7,8,9,10,11], a proper flow simulation will help the owner as well as the consultant to select the right WWTP. Thus, this research aims to provide a projection the wastewater with the system dynamics and D-Mall is used as a case study. System dynamics are selected because its approach and ability to simulate the model and it shows the effect of the system structure on policy intervention. The selected pollutant after WWTP process, wastewater removal, and wastewater in WWTP are being projected to 5 years future to see the output of the selected WWTP.

Experimental

Wastewater parameters of D-Mall in each hour

This research considers the selected parameters according to Governor of East Java of Indonesian regulation, which are BOD, COD, TSS, plus NH3, PO4, O&G (Oil & Grease) as parameter which related to restaurant liquid wastes in the Mall. A flow rate sampling is also recorded as a technical consideration for selecting the type of WWTP. To examine the parameter's concentration onquality and quantity fluctuations of wastewater D-Mall, a wastewater sampling was performed in April 2014 and it records every hour for 24 hours. The sampling parameter was then analyzed in the laboratory and the result is shown in Table 1.

Table 1. Concentration of fluctuation and flow rate of waste in D-Mall

Time (Hour)	BOD (mg/l)	COD (mg/l)	NH3 (mg/l)	O& G (mg/l)	PO4 (mg/l)	TSS (mg/l)	Flowrate (l/second)
12	144	236	105,1	18	3,09	236	4
13	192	314	103,19	24	3,97	214	4,05
14	146	236	117,54	18	5,83	120	3,75
15	204	326	87,33	36	3,16	480	2,28
16	148	236	147,76	17	5,64	140	3,21
17	144	225	134,77	17	5,17	148	2,42
18	112	180	135,24	14	5,44	142	3,76
19	151	236	124,24	20	6,33	172	3,54
20	184	292	136,19	22	4,01	268	4,08
21	178	281	155,01	21	6,95	138	3,92
22	166	270	170,04	20	20,16	144	1,52
23	488	764	145,4	84	12,28	852	0,39
24	436	752	120,42	82	21,25	950	0,39
1	344	584	103,33	64	13,12	772	0,51
2	370	629	174,83	70	37,09	660	0,48
3	356	595	157,06	66	25,75	676	0,53
4	338	584	209,28	62	35,27	662	0,42
5	332	550	28,06	60	17	706	0,15
6	346	561	157,33	62	15,32	660	0,19
7	274	450	150,9	34	17,19	346	1,31
8	256	415	135,45	30	8,26	360	1,31
9	178	292	157,06	22	19,7	166	1,02
10	220	348	99,36	26	4,75	232	1,81
11	352	606	74,05	68	5,79	638	3,73

Source: data sampling

From Table 1, a descriptive statistical analysis was performed and the result is shown in Table 2 (a), and 2 (b) below. The brief descriptions consist of mean, standard deviation, variance, coefficient variance, minimum value, quartile 1, median, quartile 3, maximum value and range of the data.

Table 2(a). Descriptive statistic result

Variable	N	Mean	StDev	Variance	CoeVar	Minimum	Q1
BOD	24	252,50	106,50	11346,3	42,19	112,00	154,80
COD	24	415,10	181,70	33011,9	43,77	180,00	244,50
NH3	24	130,37	37,56	1410,93	28,81	28;06	103,77
O & G	24	39,88	23,88	570,37	59,89	14,00	20,00
PO4	24	12,61	9,88	97,56	78,36	3,09	5,24
TSS	24	411,80	272,40	74226,90	66,17	120,0	152,50
Flowrate	24	2,03	1,51	2,291	74,48	0,150	0,49

Table 2(b). Descriptive statistic result 2

Variable	Median	Q3	Maximum	Range
BOD	212,00	345,50	488,00	376,00
COD	337,00	584,00	764,00	584,00
NH3	135,35	156,55	209,28	181,22
O & G	28,00	63,50	84,00	70,00
PO4	7,61	19,07	37,09	34,00
TSS	307,00	661,50	950,00	830,00
Flowrate	1,67	3,75	4,08	3,93

The 24 hours sampling data of mentioned parameters and flow rate represent how the condition of wastewater in D-mall on the day the data were taken. Because the total waste of the mall is relatively similar days after days, then the variation of every day data will not much different. The potential projection for the next analysis will be performed based on the descriptive statistics. Specifically, the minimum and maximum value will be used as an auxiliary variable n in the system dynamics.

The Selection of WWTP DED Plan

Mall D is selected due to the biggest wastewater concentration from ten Malls in Surabaya[12],it will be a good example for the representation case. As gathered in Table 1., the wastewater datahave some fluctuations. These data behavior are goodand similar enough to be treated by Sasseanaerobic WWTP[13,14].A DED plan of WWTP has been developed and shown in Figure 1. As it can see, the WWTP consists of four anaerobic layer filter below the basin and septic layer. The four layers and becomes the main process in filtering the parameters.

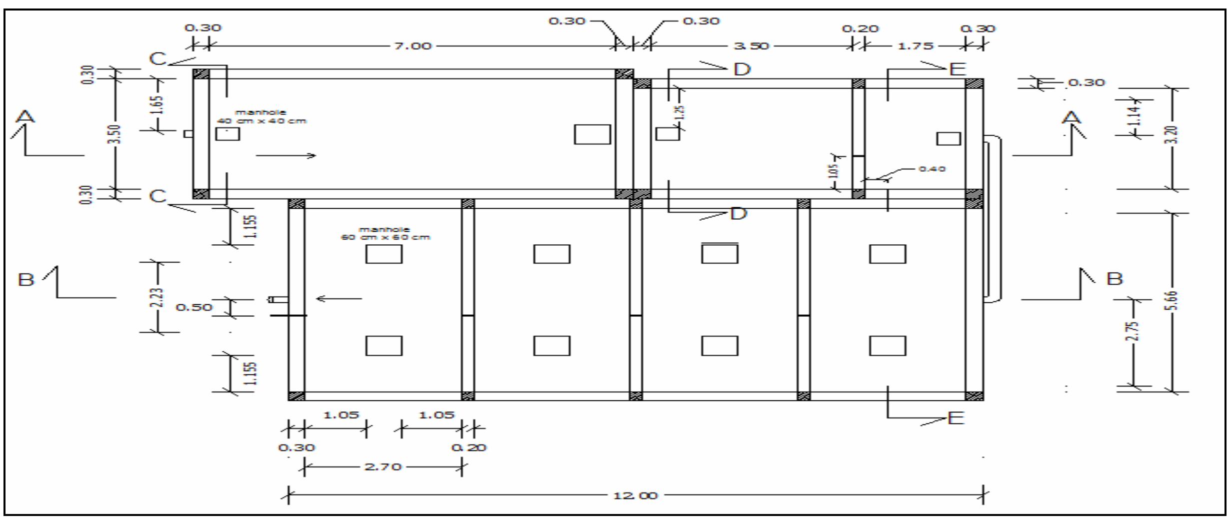

Figure 1. DED plan for WWTP in mall D

Based on the DED plan, a system dynamics model was developedby STELLA software for each variable and one of the representations is shown in Figure 2 below. In this figure, the rate variable contains of: “Produce Continuous Wastewater Parameters”, “Wastewater BOD”, and “WWTP Process”. The level of this model consists of: “Mall Wastewater BOD” and “WWTP”. The auxiliary variable in this model is: “Random Data Taken”, “WWTP Adjusted Coefficient Filter”, “Wastewater BOD Removal”, and “Wastewater BOD Flow to River”.

The flow of this projection model starting when the mall as a subject produce their wastewater from the regular mall’s activity, the values for these activities are denoted in random value between the minimum and maximum of parameters (function= Random (nMin,nMax)).The produced parameters then were recorded for the random data collection, the flow of parameter material then moves to selected WWTP. In WWTP tank, the parameter was processed through anaerobic process removal, which are 90%[13,15]. The processed wastewater then was recorded in variable wastewater parameter removal. The final parameter output consists of the calculation between the wastewater that is inside the WWTP tank and the process removal, resulted in the variable wastewater parameter to the river.

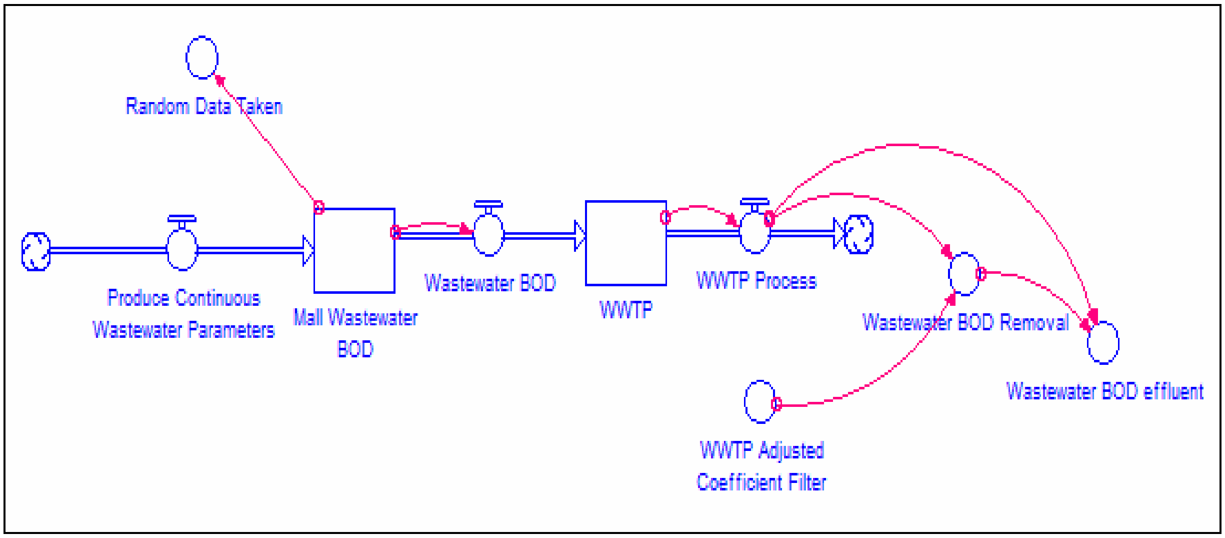

Figure 2.Example projection model: a case of BOD parameter.

Results and Discussion

The projection model was executed for each parameter, which are BOD, COD, NH3, PO4, O&Gand TSS for 5 years ahead as a period of EIA review. The unit of the resultis in a day, producing 365 times 5 that are 1825 days. All the variable value except for 90% “WWTP Adjusted Coefficient Filter”were treated uniquely for each parameter. For the first measurement, BOD, was simulated with the value of random between a minimum of 112 and maximum of 488 (see Table 1). The second measurement, COD, was simulated with a minimum of 180 and maximum of 764.The third measurement, NH3, was simulated with a minimum of 135,24 and maximum of 145,4. The fourth measurement, O&G, was simulated with a minimum of 14 and maximum of 84. The fifth measurement, PO4, was simulated with a minimum of 5,44 and maximum of 12,28. The last measurement, TSS, was simulated with a minimum of 142 and maximum of 852. The projection of 5 years WWTP produces several outputs as shown in Figure 3-8.

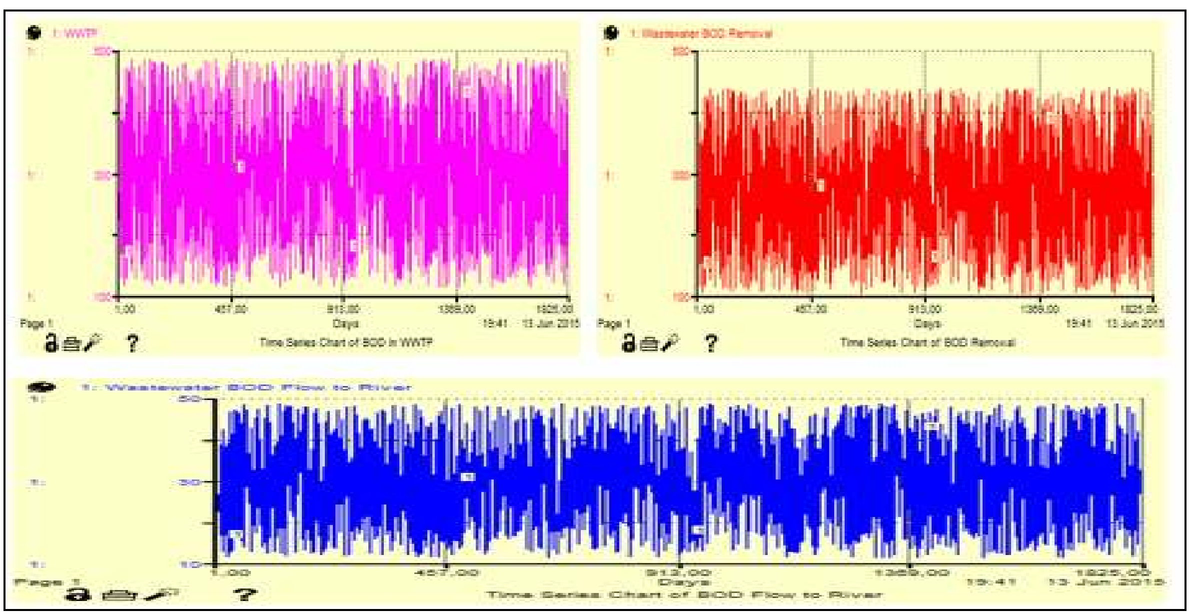

Figure 3.Five year projections of BOD parameter.

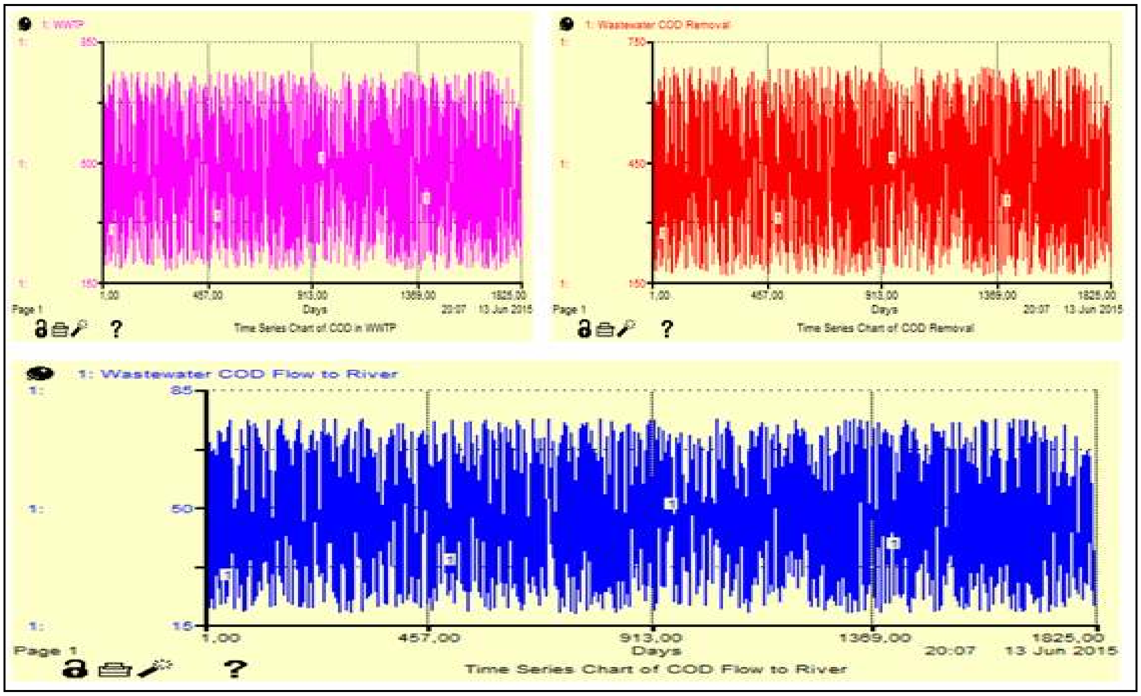

Figure 4.Five year projections of COD parameter.

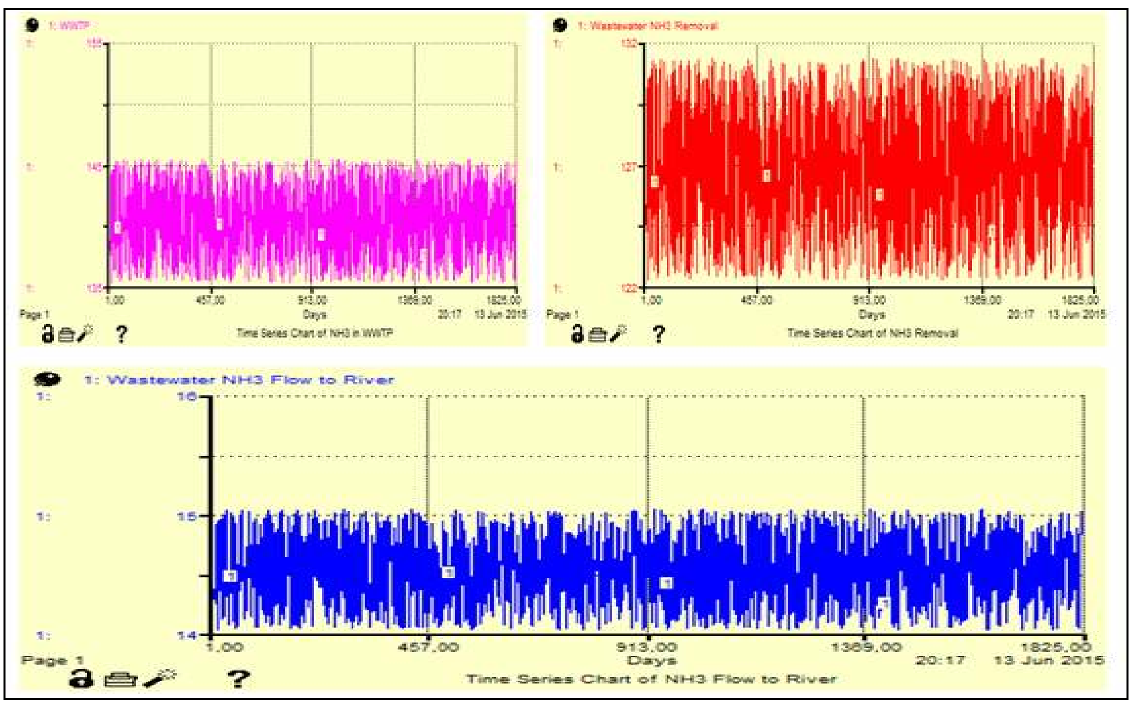

Figure 5.Five year projections of NH3 parameter.

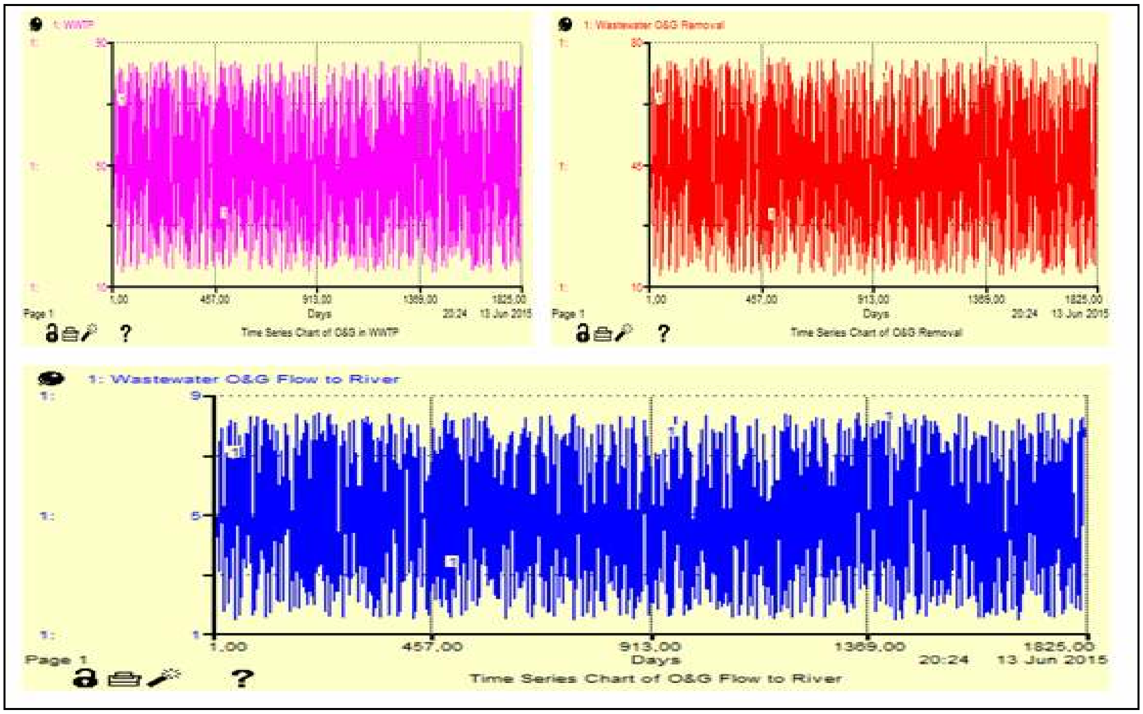

Figure 6.Five year projections of O&G parameter.

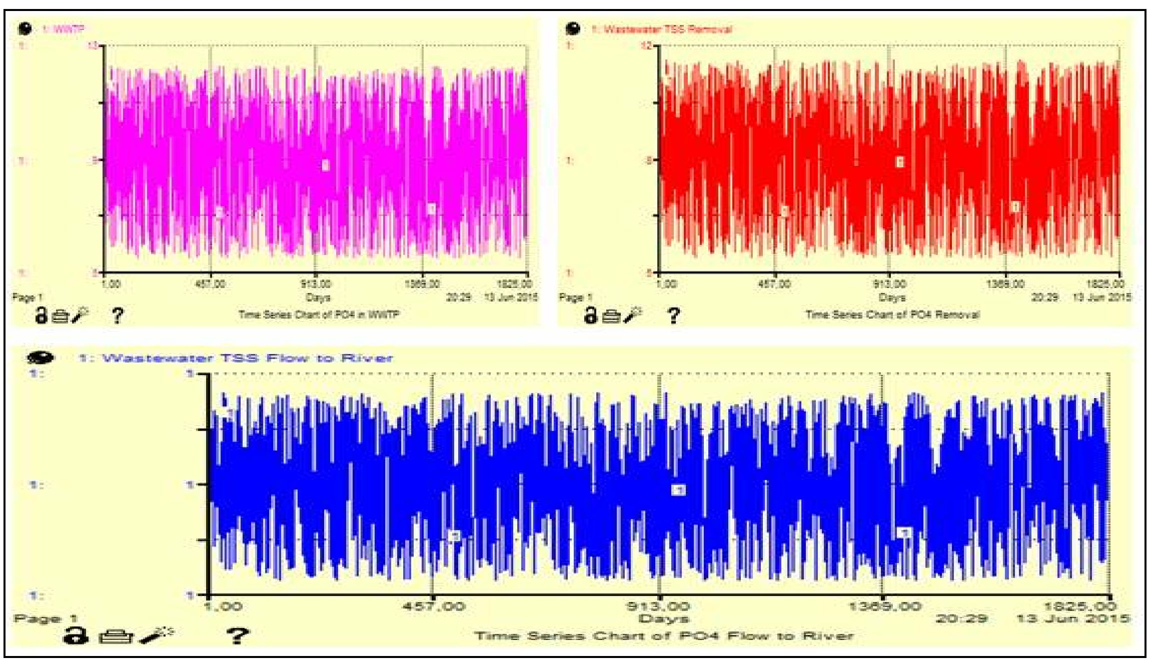

Figure 7.Five year projections of PO4 parameter.

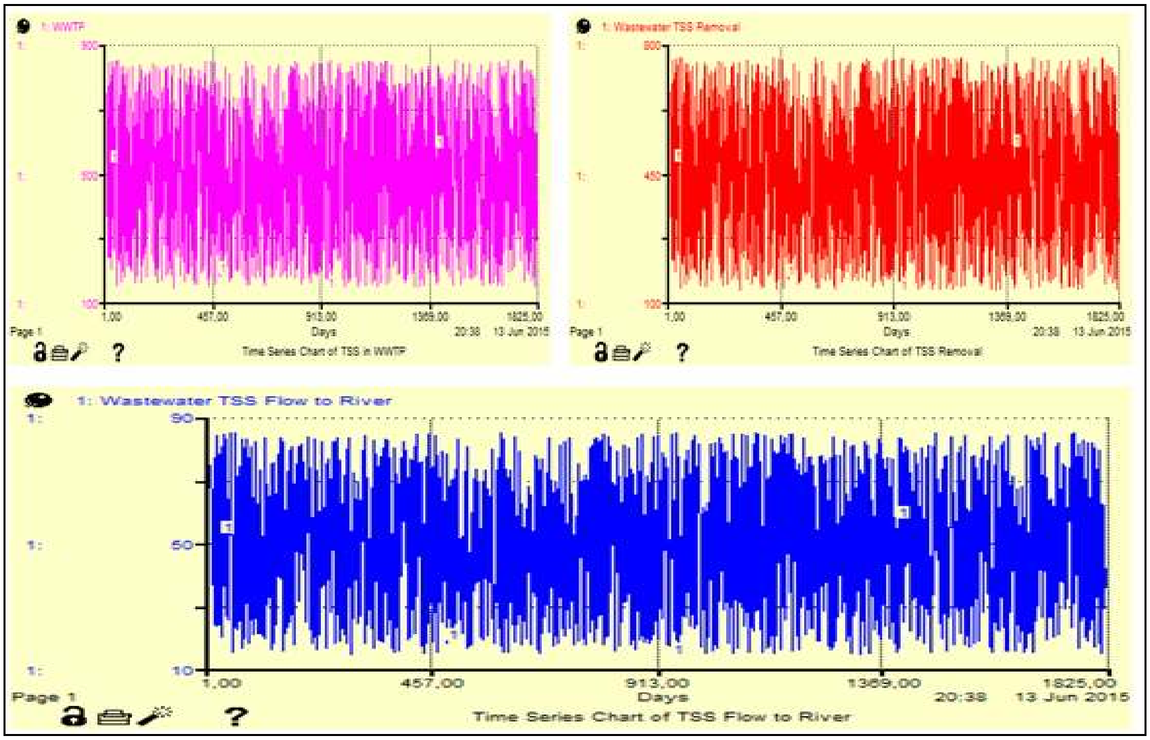

Figure 8.Five year projections of TSS parameter.

The information displayed from Figure 2-7 are consist of image information regarding WWTP, the removal process in WWTP and the reduced concentration on wastewater that will flow to the river. In this display information, four fractions were used to divide the information and to show each of the fraction's density.The brief details about the iteration for of each day for BOD, COD, NH3, PO4, O&G and TSS in five years are shown in the Table 3-5 below.

Table 3. Wastewater in WWTP

Time (days)	BOD (mg/l)	COD (mg/l)	NH3 (mg/l)	O& G (mg/l)	PO4 (mg/l)	TSS (mg/l)
1	223,87	693,95	138,68	47,03	10,98	719,01
2	223,87	693,95	138,68	47,03	10,98	719,01
3	265,79	197,32	138,12	42,23	8,32	746,5
4	238,46	502,17	137,48	56,19	11,65	602,57
5	331,87	665,53	144,08	74,48	10,95	458,09
6	167,1	225,29	138,37	34,94	11,18	367,27
7	387,78	357,32	142,1	30,68	6,7	572,83
8	262,81	195,16	144,47	78,96	9,5	537,11
9	127,87	355,68	142,7	64,74	10,16	773,09
10	282,28	672,28	140,5	52,43	11,44	237,67
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1820	144,58	311,38	143,33	49,06	9,39	332,21
1821	167,9	249,2	139,1	46,13	9,64	535,77
1822	387,74	538,14	141,34	82,24	6,21	288,6
1823	269,24	205,28	145,26	76,19	10,44	415,62
1824	397,66	554,57	136,03	45,66	7,15	840,04
1825	128,56	586,6	142,45	55,26	11,53	809,89

Table 4.Wastewater Parameter Removal

Time (days)	BOD (mg/l)	COD (mg/l)	NH3 (mg/l)	O& G (mg/l)	PO4 (mg/l)	TSS (mg/l)
1	201,48	624,56	124,81	42,33	9,88	647,11
2	201,48	624,56	124,81	42,33	9,88	647,11
3	239,21	177,59	124,31	38,01	7,49	671,85
4	214,61	451,96	123,73	50,57	10,48	542,31
5	298,68	598,98	129,67	67,04	9,85	412,28
6	150,39	202,76	124,53	31,45	10,06	330,55
7	349,01	321,59	127,89	27,62	6,03	515,55
8	236,53	175,64	130,02	71,06	8,55	483,4
9	115,08	320,11	128,43	58,27	9,14	695,78
10	254,05	605,05	126,45	47,18	10,3	213,9
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1820	130,12	280,25	128,99	44,16	8,45	298,99
1821	151,11	224,28	125,19	41,52	8,68	482,19
1822	348,97	484,33	127,21	74,01	5,59	259,74
1823	242,32	184,76	130,73	68,57	9,4	374,05
1824	357,9	499,11	122,43	41,09	6,44	756,04
1825	115,7	527,94	128,2	49,74	10,38	728,9

Table 5.Wastewater Effluent parameter

Time (days)	BOD (mg/l)	COD (mg/l)	NH3 (mg/l)	O& G (mg/l)	PO4 (mg/l)	TSS (mg/l)
1	22,39	69,4	13,87	4,7	1,1	71,9
2	22,39	69,4	13,87	4,7	1,1	71,9
3	26,58	19,73	13,81	4,22	0,83	74,65
4	23,85	50,22	13,75	5,62	1,16	60,26
5	33,19	66,55	14,41	7,45	1,09	45,81
6	16,71	22,53	13,84	3,49	1,12	36,73
7	38,78	35,73	14,21	3,07	0,67	57,28
8	26,28	19,52	14,45	7,9	0,95	53,71
9	12,79	35,57	14,27	6,47	1,02	77,31
10	28,23	67,23	14,05	5,24	1,14	23,77
::	::	::	::	::	::	::
1820	14,46	31,14	14,33	4,91	0,94	33,22
1821	16,79	24,92	13,91	4,61	0,96	53,58
1822	38,77	53,81	14,13	8,22	0,62	28,86
1823	26,92	20,53	14,53	7,62	1,04	41,56
1824	39,77	55,46	13,6	4,57	0,72	84
1825	12,86	58,66	14,24	5,53	1,15	80,99

As it can be seen from Table 3-5, the information give a projection on how the WWTP work in every day for five years. Based on the projection of Table 5, some of the parameters exceed the minimum standard as shown in Table 6 below. To overcome the situation that has been found by system dynamics simulation, two anaerobic filter tanks is added to reduce the half of the exceeding parameters and the result is shown in Table 7.

Table 6.The projection record of parameters that exceed the minimum standard quality

Parameter	Threshold	Highest value gathered	Total Exeeding Occurance (in days)	Percent over threshold
BOD	30	48,75	905	49,59%
COD	50	76,39	828	45,37%
NH3	-	14,54	-	-
O&G	10	8,4	-	0%
PO4	-	1,23	-	-
TSS	50	85,2	914	50,08%

Threshold source: Razifet al.[17]

Table 7. The projection record of parameters after two additional anaerobic filters

Parameter	Threshold	Highest value gathered	Total Exceeding Occurrence (in days)	Percent over threshold
BOD	30	24,38	-	0%
COD	50	38,20	-	0%
NH3	-	7,27	-	-
O&G	10	4,2	-	0%
PO4	-	0,62	-	-
TSS	50	42,6	-	0%

Threshold source: Razifet al.[17]

Thus, the system dynamics are conveniently able to detect the potential problem and provide the depiction to the mall's owner regarding the wastewater flow process as well as to other association of malls in Surabaya particularly, East Java generally.In addition, this model is dynamically able to be adjusted according to the coefficient threshold in each region by changing the auxiliary variable and it will help the responsible and related agencies to adapt with the new policy[16]. This model is also can be integrated with a control chart method to see the data deviation[17].

Conclusion

Understanding the problem of water pollutions becomes the job for every aspect of society in the cities including the mall's owner. This research provides the simulation of wastewater treatment of BOD, COD, NH3, PO4, O&G and TSS parameters. The model was developed and a data primer sampling was used as the test simulation. The result of the model is able to show the five year projection to the mall's owner and the association of environmental matters. This system dynamics model is also able to detect the problems that might happen in 5 years as it can see in Table 6. Thus, by detecting the problem, a further action can be performed. This model is conveniently able to be adjusted to new regulation and becomes the useful tool to select the proper WWTP and simulate it thoroughly. This model is also can be thrived for the future research as long as the explanations of regulations are clear and definite.

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