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Research Article

Segregation Tanks Suitability of Waste Water Equalization Systems for Multi Product Batch Plant

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Abstract

In this paper, an industrial case study to determine production possibility for the fixed volume segregation tanks and their structure is discussed. The generation rates of waste water from a batch plant causes significant variations in the flow rate as well as concentrations in the influent to effluent treatment plant. Flow equalization systems are used to reduce the shock loads. The present study deals with the suitability of two flow equalization schemes practiced in the industry with an objective of increasing production flexibility. Production schedule for each product is determined and represented in the form of Gantt chart. The waste water generated from each plant is connected to segregation tanks. Dynamic simulations are performed to identify time varying nature of the inlet streams and the height as well as concentration variation in each of these segregation tanks using MATLAB. The simulation study has conclusively established suitability of combined segregation tanks over distributed segregation tanks for a given production capacity. It is also shown that the production flexibility is more for combined scheme in comparison with the distributed scheme.

Keywords: *Segregation tanks, Production schedule, Flow equalization, waste water generation.*

1. Introduction

Batch processing plants are often classified as multi product batch plants, in which every product follows the same sequence through all the process steps. Quality and quantity of the effluent generated depend on the products produced and their quantities. Effluent generated from each one of these plants is discontinuous in nature. The effluent generated from these plants is treated in a continuously operated effluent treatment plant. Intermediated buffer tanks (Known as segregation tanks) are used to equalize the flow and concentration of the influent before treating in an effluent treatment plant.

Production planning, scheduling and prevention and control of waste water generated from batch plants have attracted considerable attention of the researchers in the recent past. Batch scheduling problems have been addressed in the frame work of State task networks or resource-task networks (Floudas, *et al*, 2008; Mockus, *et al*, 1999). The resulting mixed integer linear programming or mixed integer nonlinear programming problems are in general solved using Branch and bound algorithm. Optimization algorithms proposed for batch process in general considers planning, sequencing and scheduling problems (Nott *et. al*, 1999).

Methods are also proposed to incorporate features like various storage policies, resource constraints, variable batch sizes and processing times, batch mixing/splitting, and sequence-dependent changeover times (Janak *et al,* 2004; D. Wu, *et al*, 2004). These formulations are also being used for short-term scheduling of multi product batch plants (Winkel, *et al*, 1995). However, the variations in the flow of waste water generated for optimal product schedule has not received its due attention. The generation rates of waste water from a batch plant are strongly time dependent (Chang, *et al*, 2006). Peak flow rates significantly influences the capacity of equalization tank required.

It is known that the capital cost of a wastewater treatment operation is usually proportional to its capacity. In addition, since the biological-treatment unit is included in waste water treatment plant in most of the cases, the shock loads (mainly in concentration) must be avoided at all times so that the embedded bacteria can always be kept in an active state (McLaughlin, *et al*, 1992). Thus for both economic and process reasons, flow equalization is needed to reduce shock loads on the wastewater treatment system. Incorporation of wastewater equalization is a common practice in almost every industrial batch process (Nemerow, *et al*, 1971).

The problem of reducing the peak flow rates has been addressed by rescheduling the process and

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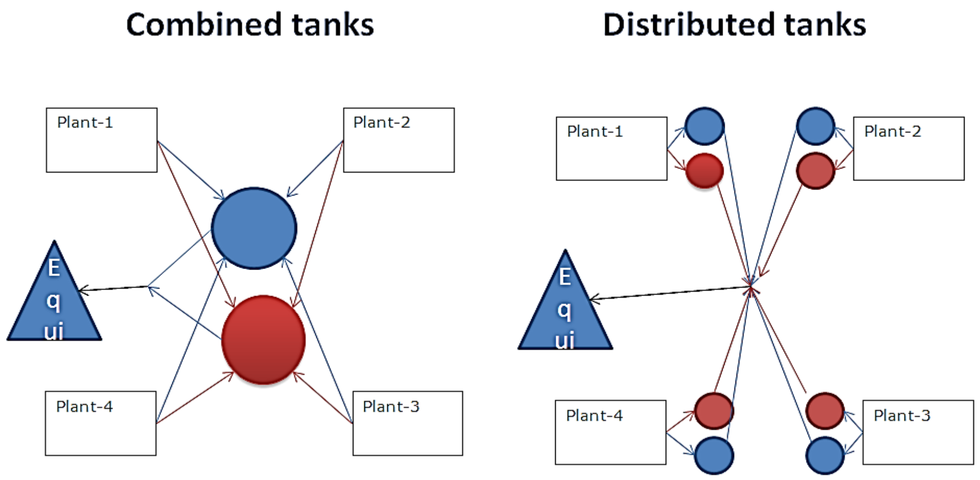

Figure 1 Combined and distributed segregation tank schemes under

adding new equipment (Tumsen, *et al*, 1996). A preliminary study on conceptual design and mathematical programming model also has been adapted to eliminate the possibility of producing an unnecessarily large combined water flow at any instance by using a buffer tank and by rescheduling the batch recipe (B.H. Li, *et al*, 2002). Most of the industries are adapting the approach of installation of a two - tanks configuration to remove peaks in the profile of total wastewater flow-rate and also in that of one pollutant concentration (R. Smith, *et al*, 2002). However, not enough emphasis is given to the variations in the waste water flow rates which are abrupt in some cases and gradual in other cases. Unless given due attention this draw back may lead to overflows from the segregation tanks especially when the output flow of these tanks are based on gravity. In this paper we have propose suitable waste water segregation scheme, for industrial complex consisting of multiple plants producing multiple products. An industrial case study to determine production possibility for the fixed volume segregation tanks and their structure is discussed. Production schedule for each product is determined and represented in the form of Gantt chart. The waste water generated from each plant is connected to segregation tanks. We have to evaluate the suitability of combined segregation tanks in comparison with the distributed segregation tanks for improved flexibility in production.

2. Problem statement

In the present work a comparative study is presented to evaluate the suitability of two industrially practiced waste water segregation schemes for an industrial complex. The industrial case study under consideration has twelve products produced in four plants located in a single complex. The waste water generated from entire complex is treated in a single waste water treatment facility consisting of physical, chemical treatment followed by secondary treatment (biological treatment) and tertiary treatment. To keep the biological treatment protected from the shock loads a suitable flow/concentration equalization system has to be designed. Fortunately for this existing production facility each product has dedicated equipment. Waste water is generated consists of process water, reactor washings, and water generated from various separation operations. The flow rate and characteristics of waste water generated depends on the product produced and the equipment used in individual process.

2.1 Proposed Method

The industry has four plants. Each Plant has three different Products. As mentioned above each plant has two segregation tanks for the collection of waste water of low concentration and high concentration. Waste water streams generated from individual plants are segregated as high and low COD streams. Waste water generate from each stage of the production is going to these two segregation tanks and higher limit for the concentration to enter into low concentration tank is taken as 5000 PPM. Two schemes for intermediate storage of these streams are considered for evaluation. The first scheme has two tanks 20 KL with height of 2m each (distributed) located at individual plants both for low COD and high COD streams. Each plant has two segregation tanks making the total number of small segregation tanks in the complex as eight. The second scheme has two tanks of 80 KL capacity (combined) with height of 4m each meant for Low COD and High COD respectively. Waste water contains high COD concentration goes in to high COD tank and lower concentration goes in to low COD tank. Details of smaller and bigger tanks are for both schemes are presented in Table 1and Table 2. Both combined and distributed segregation tank schemes are presented in Figure 1 and figure 2.

The process details of the products produced are of paramount importance while considering the scheduling process. Out of twelve products considered in the present case eleven of them are operated in

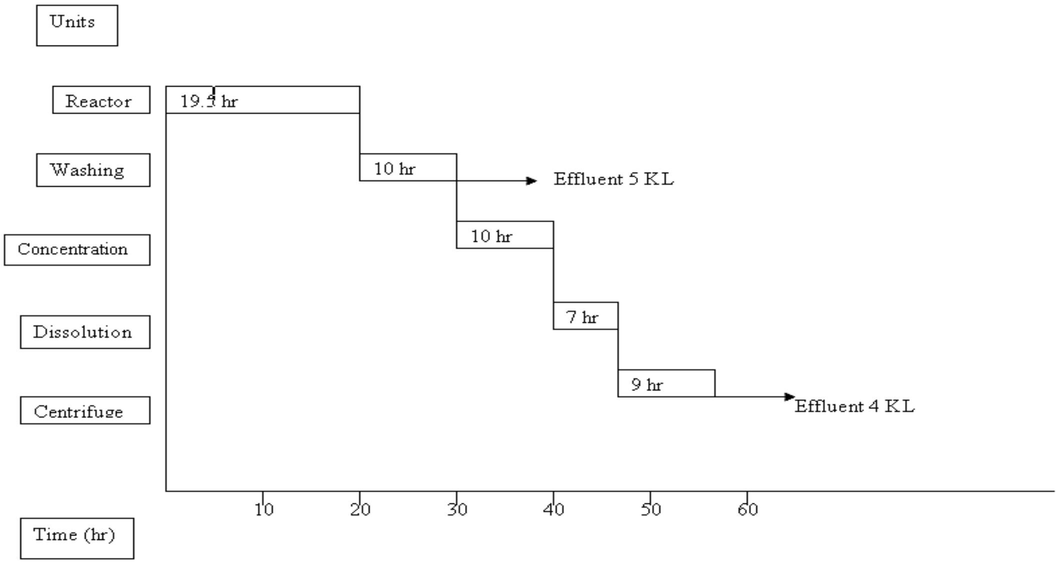

Figure 2: Gantt chart for Product A for single cycle

batch mode and remaining one is operated in continuous mode. Nominal values for production and corresponding waste water generated are presented in Table3 and Table 4.

Table 1: Dimensions of smaller segregation tanks placed in each plant

Sr. No	Parameter	Value(Units)
1	Height	2 (m)
2	Diameter	3.46(m)
3	Area	10(m^2)
4	Volume	20(m^3)

Table 2: Dimensions of bigger segregation tanks

Sr. No	Parameter	Value(Units)
1	Height	4 (m)
2	Diameter	7.136(m)
3	Area	40(m^2)
4	Volume	80(m^3)

Table 3: Nominal production target for each of the products considered

Sr.No	Plant where the product is produced	Product	Nominal Total production per month (MT)	Nominal production per batch (MT)
1	Plant 1	A	160	5.4
2	Plant 1	B	30	2.1
3	Plant 1	C	4	0.4
4	Plant 2	D	180	4
4	Plant 2	E	310	4
6	Plant 2	F	70	1
7	Plant 3	G	240	3.2
8	Plant 3	H	170	2.6
9	Plant 3	I	40	2
10	Plant 4	J	140	4
11	Plant 4	K	100	3
12	Plant 4	L	80	4

Table 4: Nominal waste water generated from each of the products

Sr.No	Plant where the product is produced	Product	Total Waste water generation (kl)
1	Plant 1	A	8
2	Plant 1	B	24
3	Plant 1	C	12
4	Plant 2	D	9.6
4	Plant 2	E	32
6	Plant 2	F	4
7	Plant 3	G	20.6
8	Plant 3	H	12.4
9	Plant 3	I	5.4
10	Plant 4	J	23.9
11	Plant 4	K	13.02
12	Plant 4	L	2.47

The process flow diagram, cycle time for each batch and waste water generation schedule from each unit operation involved in the respected process for each product under consideration are presented below.

3. Results and Discussion

Each product in the plant is produced in dedicated equipment. Discussion on a representative is presented here. The process consists of six different steps Reaction, Washing, Dissolution of Product, Crystallization, Centrifugation and Packing. The waste water is generated from three of the unit processes/operations. It is observed that the waste water generation is intermittent and discrete in nature.

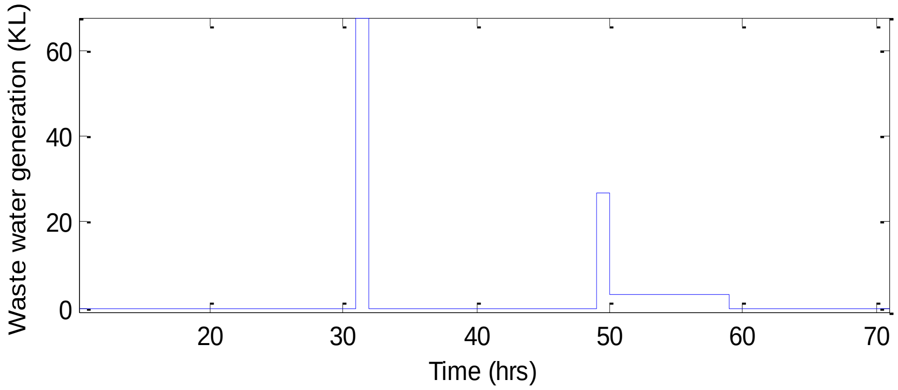

Figure 3: Waste water generation for product A for single cycle

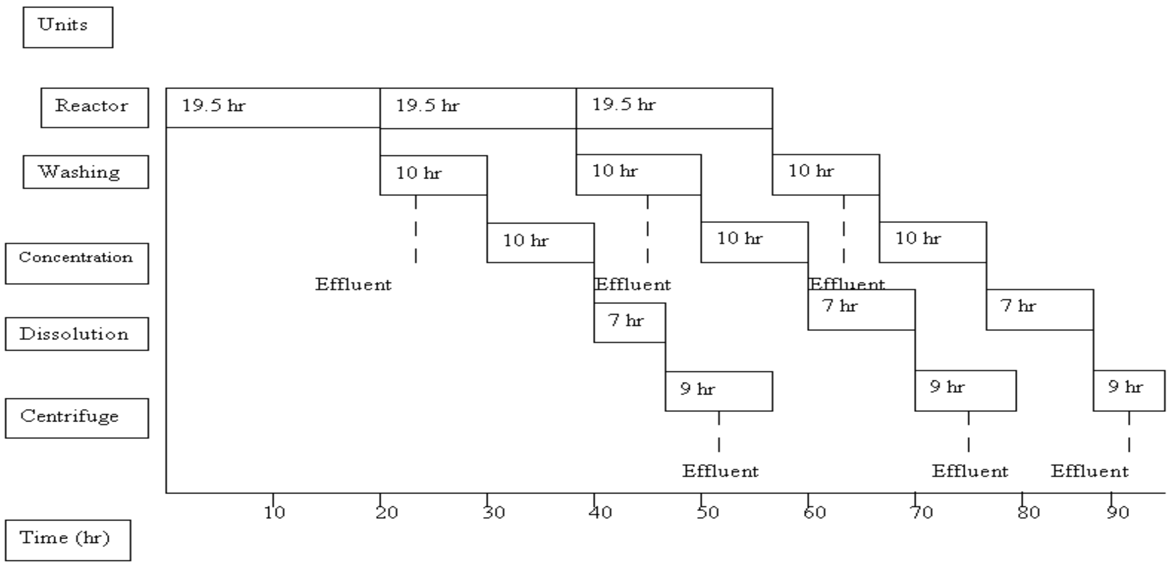

Figure 4: Gantt chart for product A for three cycles

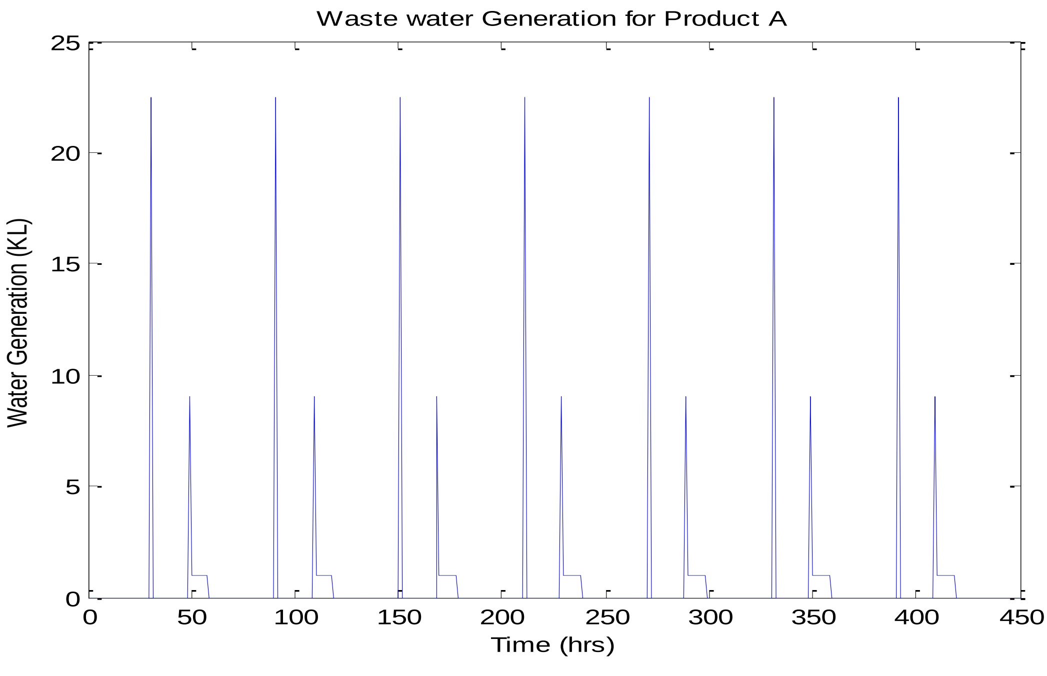

Figure 5: Waste water generation for product A for all three cycles

This implies that if waste water is allowed to flow into the final treatment it causes shock loads with respect to waste water flow as well as concentration depending on the amount of water discharged.

Scheduling of this process with an objective of maximizing/ achieving production target has been done using STN based formulation. The Short term scheduling for product A and the amount of waste water generated and time at which it is generated are presented in Figure 2.

However waste water is generated from several unit processes/operations. The waste water generated for single cycle batch operation is simulated in Matlab and presented in Figure 3.

From Figure 3 it can be seen that the waste water generation is intermittent and discrete in nature. This implies that if waste water is allowed to flow into the final treatment it causes shock loads with respect to waste water flow as well as concentration depending on the amount of water discharged.

The Short term scheduling for the Product A has been done for three cycles and presented in the form of Gantt chart shown in Figure 4.

The corresponding waste water generation with respect to time for all three cycles are simulated in Matlab and results are presented in Figure 5.

It is to be noted that the waste water generation for single product forms a cycle after a fixed period of time which can be observed from Figure 5. When multiple cycles are used the waste water peak flow gets altered. This leads to sever shock loads compared to the single cycle single product production. This problem becomes further sever when the plant is having more than one product and each product is operated at multiple cycles.

3.1 Waste water generation details for all four plants

Process and waste water generation details of remaining 11 products for their single and multiple cycle has also been done individually just similar to product A.

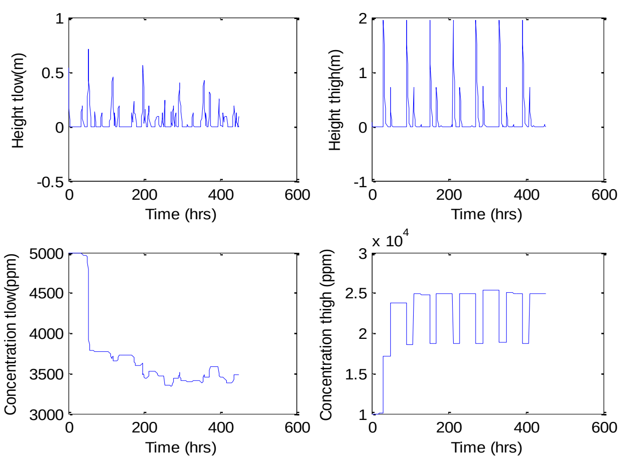

Figure 6: Height and Concentration for smaller segregation tanks of plant 1

The nominal simulation results for all four plants are also done. Figure 8 shows the height and concentration for smaller segregation tanks and Figure 9 shows the inlet flow of waste water and concentration of waste water for smaller segregation tanks for plant 1. The discharge waste water from each product is going to two segregation tanks one is lower holding concentration of waste water and other is higher holding concentration of waste water. If the concentration of waste water is below 5000 PPM, It is sent to low COD tank and above 5000 PPM, It is sent to high COD tank.

Waste water generation with respect to time and waste water concentration for three products produced for plant 1 is presented in Fig 7.

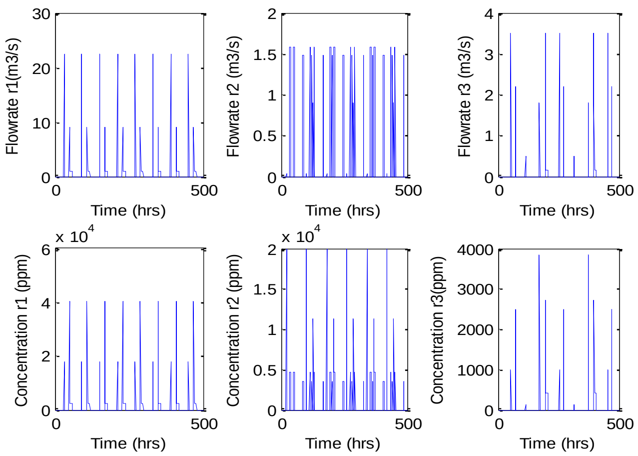

Figure 7: Inlet flow rate and concentration for smaller segregation tanks of plant 1

From the figure 6 and Figure 7 it has been evaluated that the height and concentration of low COD tank of plant 1 are 0.7 m and 3800 PPM and for high COD tank are 1.99 m and 25000 PPM.

The height and concentration for smaller segregation tanks and Inlet flow of waste water and concentration for smaller segregation tanks of plant 2 are shown in Figure 8 and Figure 9 respectively.

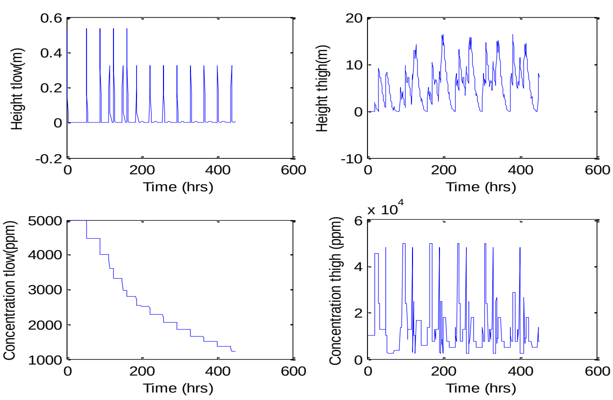

Figure 8: Height and Concentration for smaller segregation tanks of plant 2

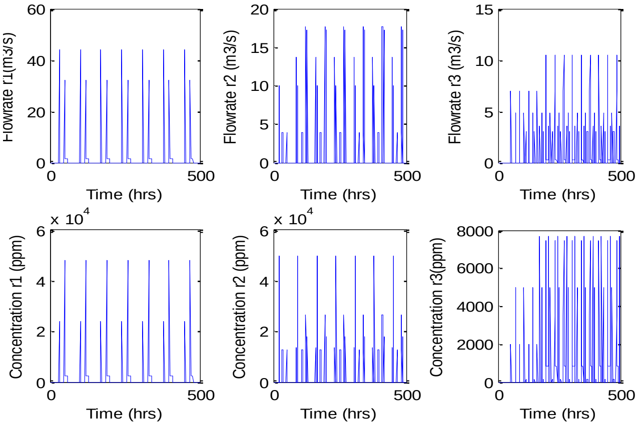

Figure 9: Inlet Flow rate and Concentration for smaller segregation tanks of plant 2

From the figure 8 and Figure 9 it has been evaluated that the height and concentration of low COD tank of plant 2 are 0.57 m and 4800 PPM and for high COD tank are 18 m and 50000 PPM.

The height and concentration for smaller segregation tanks and Inlet flow of waste water and concentration for smaller segregation tanks of plant 3 are shown in Figure10 and Figure11 respectively.

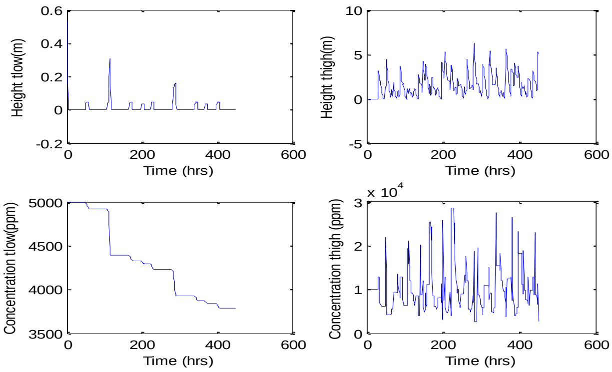

Figure 10: Height and Concentration for smaller segregation tanks of plant 3

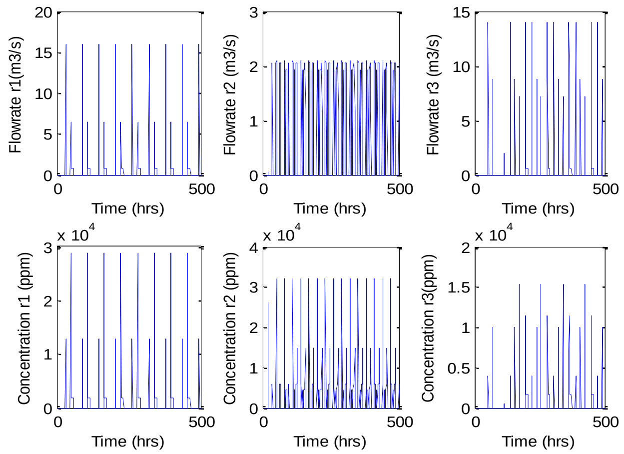

Figure 11: Inlet Flow rate and Concentration for smaller segregation tanks of Plant 3

From the figure 10 and Figure 11 it has been evaluated that the height and concentration of low COD tank of plant 3 are 0.3 m and 4300 PPM and for high COD tank are 6 m and 28000 PPM.

The height and concentration for smaller segregation tanks and Inlet flow of waste water and concentration for smaller segregation tanks of plant 4 are shown in Figure12 and Figure13 respectively.

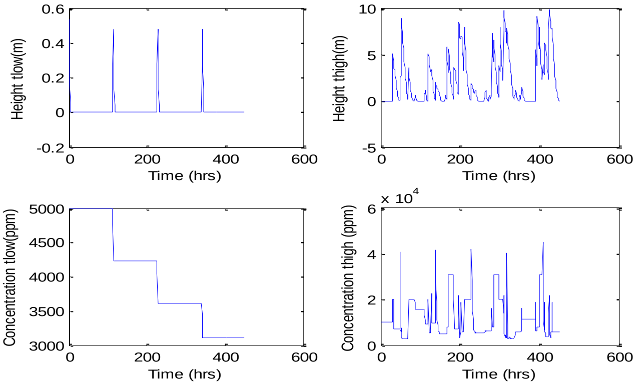

Figure 12: Height and Concentration for smaller segregation tanks of Plant 4

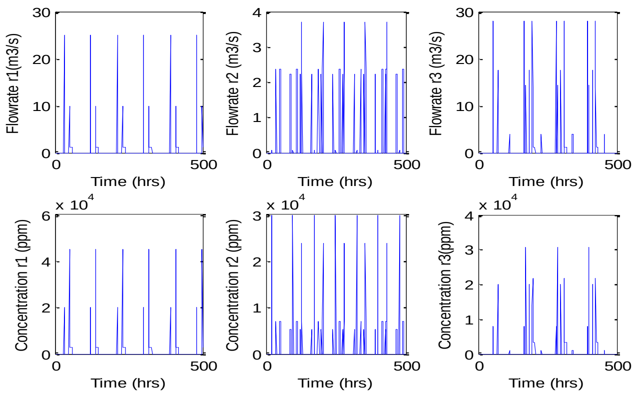

Figure 13: Inlet Flow rate and Concentration for smaller segregation tanks of Plant 4

From the figure 12 and Figure 13 it has been evaluated that the height and concentration of low COD tank for plant 4 are 0.5 m and 4200 PPM and for high COD tank are 10 m and 41000 PPM.

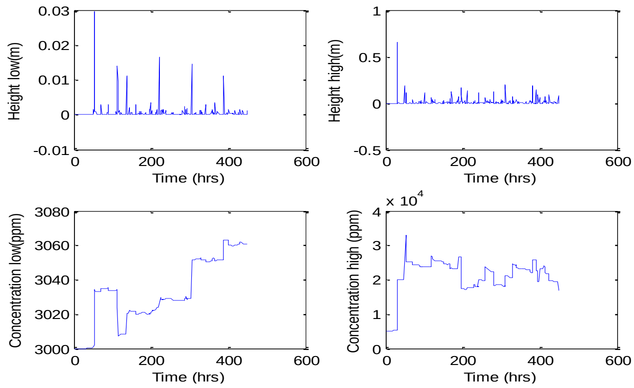

Figure 14: Height and Concentration for bigger segregation tanks of all four plants.

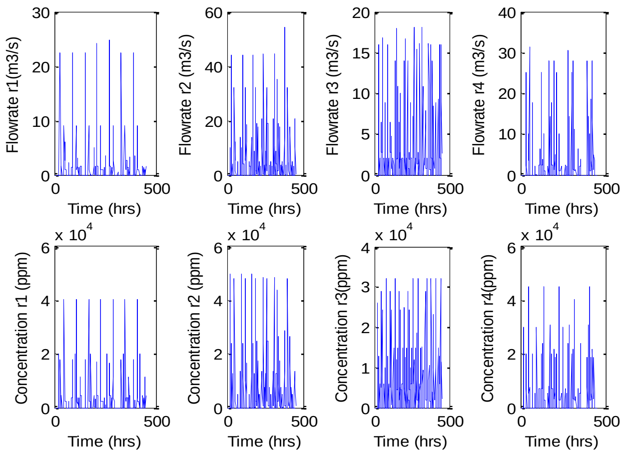

Figure 15: Inlet Flow rate and Concentration for bigger segregation tanks of all four plants

From the figure 14 and Figure 15 it has been evaluated that the height and concentration for bigger segregation tanks of all four Plants are: low COD tank 0.029 m and 3070 PPM and for high COD tank 0.7 m and 32000 PPM.

From Figures 8 to17 we observed that for nominal simulation, the overflow occurs from smaller segregation tanks of plant 2, 3 and 4 with significant margin but overflow does not occurred from bigger segregation tanks. So from this study we can avoid to have smaller segregation tanks.

Table 5: Representative results presenting the comparison of two segregation schemes

Plant	**Observation on Volume**	Lower Height (m)	Higher Height (m)
Plant-1 (Distributed tanks)	Sufficient	1.09	1.99
Plant-2 (Distributed tanks)	Overflows	0.48	18
Plant-3 (Distributed tanks)	Overflows	0.3	11
Plant-4 (Distributed tanks)	Overflows	0.4	16
Bigger segregation tanks for combine all plants	Sufficient	0.029	0.7

Conclusions

We propose suitable waste water segregation scheme, for industrial complex consisting of multiple plants producing multiple products. Simulation of waste water generation from each product and determine the combined waste water generated from each plant for optimized production schedule.

The waste water generated from each plant is connected to segregation tanks. Dynamic simulations are performed to identify time varying nature of the inlet streams and the height as well as concentration variation in each of these segregation tanks using MATLAB. The simulation study has conclusively established suitability of combined segregation tanks over distributed segregation tanks for a given production capacity. It is also shown that the production flexibility is more for combined scheme in comparison with the distributed scheme.

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