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REVIEW OF PROCESS SIMULATION SOFTWARE FOR BIOLOGICAL WASTE WATER TREATMENT

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ABSTRACT
The efficiency of a Waste Water Treatment Plant (WWTP) can be estimated using process simulation. Process simulators (software) used for biological waste water treatment are Activated Sludge Simulation (ASIM), Sewage Treatment Operation and Analysis Over Time (STOAT), and GPS-X. A comparative chart on these software are assessed. Based on the ease-to-use, ASIM was selected to find out Chemical Oxygen Demand (COD) removal efficiency of a biological waste water treatment. This paper reviews the methodology utilized to find out the COD removal efficiency. The average COD removal efficiency of the treatment is found to be 62.734%. To further improve its efficiency, few suggestions were suggested. Instead of using a large volume of reactor, small number of reactors cascading its volume can be in use. Coupling membrane technology with activated sludge is an expensive method. Bardpheno process, where anoxic-aerobic stages are placed in an alternative manner, can also improve the COD removal efficiency of a biological waste water treatment.

KEYWORDS: ***ASIM, STOAT, GPS-X, Process Simulation, COD removal efficiency, Biological waste water treatment***

1. INTRODUCTION

Waste water treatment processes are mandatory in industries due to the implementation of stringent laws. In waste water treatment, the composition of the influent keeps on changing on a daily basis. This requires the knowledge of process simulation and process modelling for graduate Chemical Engineers (Process Engineers). The complexity of dealing with mathematical models can make fresh graduates reluctant to simulate. Therefore a comparison of software for Activated Sludge Model (ASM) was made. A simulation software in perspective of a recent graduate was chosen to simulate petroleum process water. Parallel research between Activated Sludge Simulation (ASIM), Sewage Treatment Operation and Analysis Over Time (STOAT), and GPS-X was executed.

Activated Sludge Models (ASMs) are standard prototypes introduced by the International Water Agency (IWA). They are classified into four based on the mathematical method used to model activated sludge systems. ASM1 is the first basic model released in 1987 that could calculate Chemical Oxygen Demand (COD), bacterial growth, and degradation. It also laid the foundation for other models. ASM2 is an extended version of ASM1 where the relationship between biological phosphorous removal and prediction of nitrogen were presented well. In the late 1990s, anoxic and aerobic uptake of phosphorous was introduced in ASM2d.The latest ASM3 can find the oxygen consumption, sludge production, nitrification, and de-nitrification of activated sludge system.

2. SOFTWARE DESCRIPTION

2.1. Activated Sludge Simulation (ASIM)

Activated Sludge Simulation Programme is an open software to simulate biological waste water treatment, developed by the Swiss Federal Institute of Aquatic Science and Technology. It is user friendly and does not require any prior knowledge of programming. It can be easily understood by engineering graduates as well as non-graduates. The biological model is developed on biokinetic model. This software also have process control loops (diurnal or seasonal load variation, temperature variation, variation of operational parameters such as aeration, excess sludge, recycle rates, etc.) (Eawag). The programme has in-built IWA activated sludge model 1, IWA sludge model 2, and IWA activated sludge model 2 with ferrous oxidation.

2.2. Sewage Treatment, Operation, and Analysis over Time (STOAT)

STOAT is a non-commercial software developed by Water Research Centre (WRC). This user friendly software requires prior knowledge of waste water treatment plant. It has additional features, such as the availability of ASM3 and Activated Digester Model (ADM) in addition to ASM1, ASM2, ASM2d. Long term dynamic simulation can also be done with optimization suggestion. Detailed illustration and mass balance of all parameters are visible at each stage.

2.3. GPS-X

GPS-X is the first commercially used dynamic simulator in the waste water treatment plants. However, its free version is available as GPS-Lite with limited features. The programme is developed Hydromantis. It has the most advanced tools for the waste water treatment plant.

Sl. No	Features	ASIM	STOAT	GPS-X
1.	Software is used only for commercial purposes (closed) or whether can be used by students for study and research purposes (open).	Open	Open	Close
2.	Software may require the knowledge of programming language such as Python, C++ or MATLAB. Any prior knowledge of language required.	☒	☒	▯
3.	In ASM1, COD, bacterial growth, and degradation. Does the software have ASM1 model to work on?	▯	▯	▯
4.	Extended version, ASM2 gives us the relationship between phosphorous and nitrogen removal. Does the software have ASM2 model to work on?	▯	▯	▯
5.	ASM2d model have anoxic and aerobic uptake of phosphorous. Does the software have ASM2d model to work with?	▯	▯	▯
6.	ASM3 can find the oxygen consumption, sludge production, nitrification, and de-nitrification of activated sludge system.	☒	▯	▯
7.	Can values be exported/imported from a different file format such as excel? This gives us ease on working where the influent characteristics can easily be written down to the software.	▯	▯	▯
8.	A default flow sheet can help a student with no prior knowledge at ease. Does the software have a defined flow sheet?	▯	▯	☒
9.	Results are shown in charts to predict the future variation, as well as study in relationship to change in other variable. A visual representation is easily understandable by people.	▯	▯	▯
10.	The level of user required for using these software. Based on the previous knowledge required for the user, ease of availability of software. Beginner-B, Intermediate-I, Advanced-A	B	I	A

Table 1: Comparative chart of ASIM, STOAT, and GPS-X

From the comparative chart above, it can been seen that for a recent graduate with no prior knowledge on waste water treatment simulation can use ASIM as their medium. A student with basic knowledge in waste water treatment can use STOAT with much more flexibility. GPS-X is a commercially used software with advanced tools used in the industry. Experienced individuals with thorough knowledge can work with GPS-X.

Since the number of input variables available is less, ASIM is the relevant software. Chemical Oxygen Demand (COD) removal efficiency for a petroleum waste water treatment plant is found using the steps below in ASIM.

3. CASE STUDY

In this section, simulation of a biological waste water treatment in a Petroleum refining and petrochemical complex is done. As per the results of the comparative study, ASIM software is chosen as the simulator. The dynamic simulation is done on ASM1 to find out the COD removal efficiency of the biological waste water treatment plant. The influent characteristics of the process water is given below:

Process Waste Water Influent Characteristics	
Flow Rate (Instantaneous Max)	1250 m^3/hr
Flow Rate (Hourly Max)	834 m^3/hr
Temperature	40 °C
Pressure	0.7 kg/cm^2G
pH	5 - 9
COD	533 mg/L
BOD	279 mg/L
Kj-N	32 mg/L
NH_4-N	32 mg/L
Total-N	32 mg/L
Total Suspended Solids (TSS)	33 mg/L
Oil and Grease	133 mg/L

Table 2: Process Waste Water Infuent Characteristics

3.1. Outline of Industry

ASIM software is being selected as the simulator for the above mentioned reasons. This biological treatment involves a anoxic basin, aeration tank, and a final clarifier.

Anoxic basin purpose is to remove nitrate through de-nitrification. A part of the final sludge from final clarifier is also mixed in the anoxic basin. The waste water from anoxic basin moves to aeration tank through gravity. This tank removes biodegradable matter and nitrify ammonia to nitrate. Aeration blower feeds dissolved oxygen in the range 1 mg/L to 4 mg/L. Finally, activated sludge with biologically treated waste water flows into the final clarifier with gravity, where sludge and supernatant is separated. The settled down sludge is scraped by final clarifier mechanism, and it is drawn out and sent to anoxic basin and/or sludge thickener basin by recycle pump.

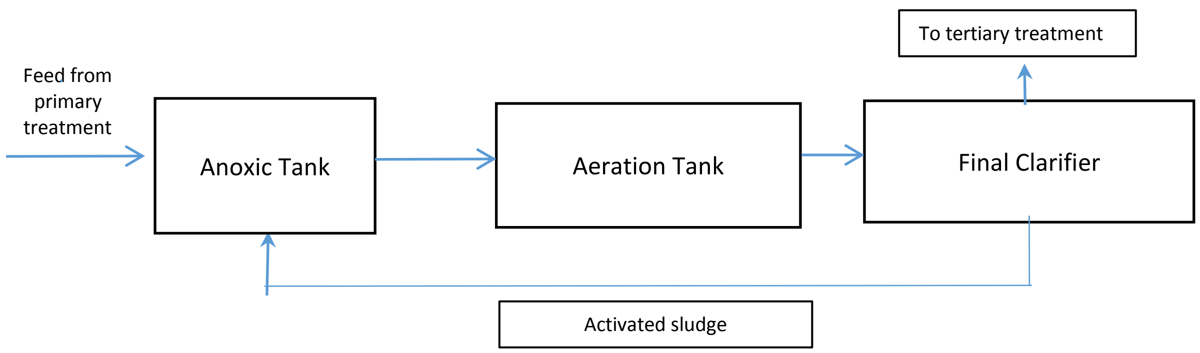

Fig 1: Flowchart of the biological waste water treatment.

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3.2. Steps for Simulation

3.2.1. Simulating Environment

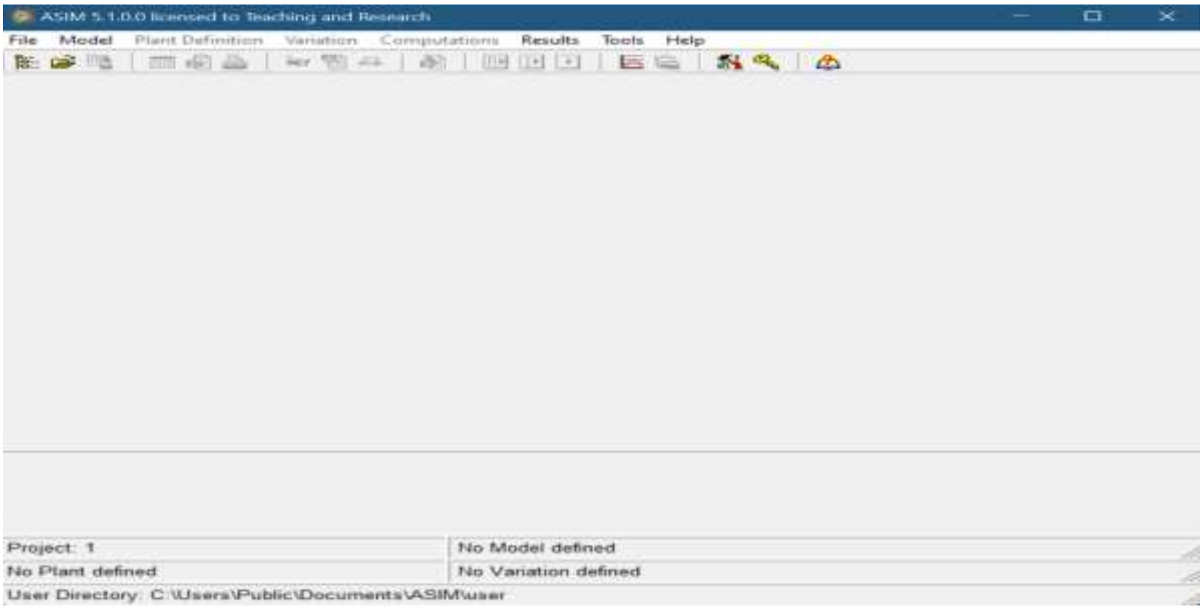

Fig 2: Simulating Environment of ASIM

The simulation environment contains the main flow sheet area where majority of the work (installing and defining plant model, plant definition) is done. The flow sheet area shows various tabs needed to simulate the waste water treatment.

3.2.2. Procedure

Step 1: While starting ASM, create a new project, and choose a name of the project. The files are saved in a project file directory 'User'. For eg. "'C:\\Program Files\ASIM\User''.
Step 2: Choose a model file for the biological waste water treatment. An already existing Activated Sludge Model has been selected.
Step 3: Select a plant file that defines the flow scheme, the concentration of the first and second influent and control loops. A plant file is created based on the characteristics of the influent. Here, biologically treatment simulation is done on the characteristics based on process waste water. For steady state simulation the COD variation is followed according to the standard various fraction as per ASM3 (Koch et al, 2000).

	Dissolved		Particulate			
Fraction	**Inert**	**Substrate**	**Inert**	**Substrate**	**Heterotroph**	**Total**
Share	6%	10%	20%	55%	9%	100%

Table 3: Standard fraction of COD variation

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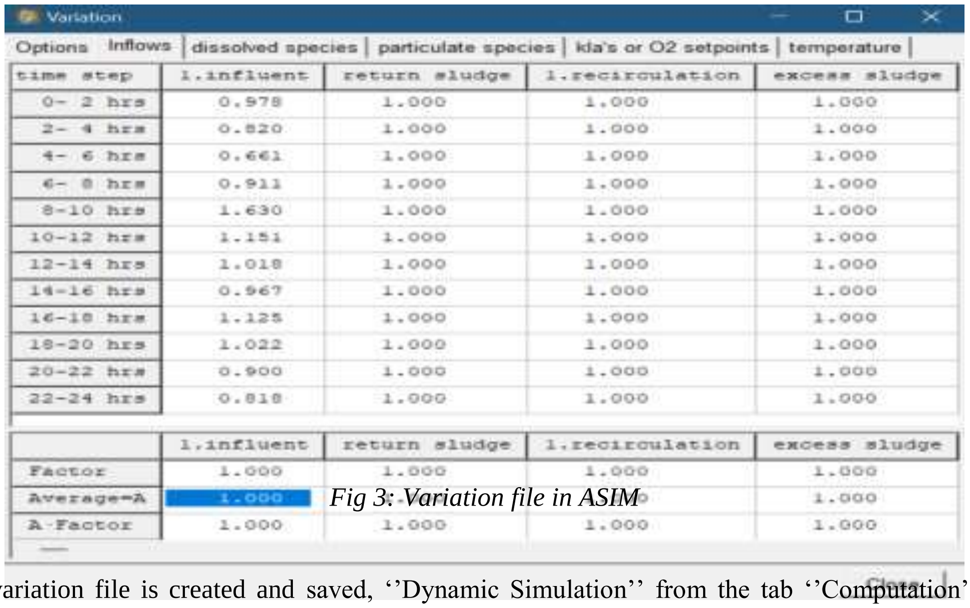
Step 4: For a dynamic simulation a variation file is created. The values are standardised according to the mean value 1.



time step	1.influent	return sludge	1.recirculation	excess sludge
0- 2 hrs	0.978	1.000	1.000	1.000
2- 4 hrs	0.820	1.000	1.000	1.000
4- 6 hrs	0.661	1.000	1.000	1.000
6- 8 hrs	0.911	1.000	1.000	1.000
8-10 hrs	1.630	1.000	1.000	1.000
10-12 hrs	1.151	1.000	1.000	1.000
12-14 hrs	1.018	1.000	1.000	1.000
14-16 hrs	0.967	1.000	1.000	1.000
16-18 hrs	1.125	1.000	1.000	1.000
18-20 hrs	1.022	1.000	1.000	1.000
20-22 hrs	0.900	1.000	1.000	1.000
22-24 hrs	0.818	1.000	1.000	1.000

	1.influent	return sludge	1.recirculation	excess sludge
Factor	1.000	1.000	1.000	1.000
Average=A	1.000			1.000
A·Factor	1.000	1.000	1.000	1.000

Fig 3: Variation file in ASIM

Step 5: After the variation file is created and saved, ''Dynamic Simulation'' from the tab ''Computation''. This will lead to simulation and results are available in chart form.

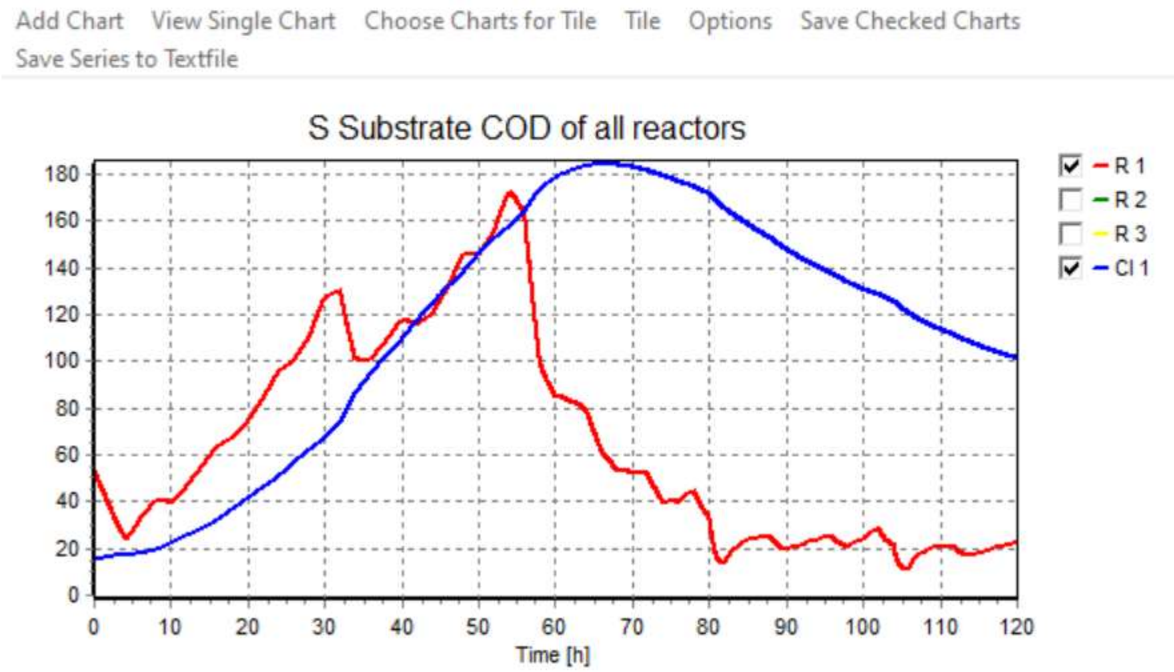


Fig 4: Result of simulation

4. RESULTS AND SUGGESTIONS

4.1. Results

Based on the COD graph, COD efficiency can be calculated:

$$\text{COD removal efficiency} = (CODinlet - CODoutlet) / CODinlet \times 100$$

Here outlet concentration is taken based on the mean COD concentration,

COD removal efficiency(average) = 172.676 - 64.333 / 172.676 × 100

= 62.743%

Title	Maximum	Minimum	Mean
R 1: S Substrate COD	172.676	11.493	64.333

Fig 5: Result of COD variation from ASIM in tabular form

4.2. Suggestions to improve COD removal efficiency

1. Instead of using a single stirred tank bioreactor, it is advisable to use a number of small size stirred tanks in series with the total volume of the cascade remaining the same as the single reactor (Narayanan 2019). Similar to tanks in series, it can also be made into parallel form to improve its efficiency. However, in both the cases the single stirred tank is divided into compartments.
2. Coupling Membrane Based Technology with activated sludge process is often advisable. Here Reverse Osmosis (RO) has been introduced, where two-thirds of the waste water can be restored and the rest by biological treatment (Narayanan 2019).
3. The Bardenpho process, a modified activated sludge process, is a 5-staged treatment in an anaerobic - anoxic - aerobic - anoxic - aerobic manner. Here each stage has separate compartments improving BOD removal efficiency for higher capacities.

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