Impact of primary sedimentation tank on wastewater treatment plant units using computer simulation program

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Abstract:This study presents a computer program designed in Visual Basic 6 program. The capability of this program is to design wastewater treatment plant units and determination of its construction cost.

The program deals with two types of wasted sludge the first type is wasted sludge from the aeration basin, while the second system is wasted sludge from the secondary clarifier. Also, there is a detailed output shows the design flowrate, mass balance analysis and composition of each stream in and out of each treatment unit. Program results are verified with hand calculations within the allowable recommended values and they showed a good accuracy.

The volume of aeration basin and secondary sedimentation tank increased with the elimination of primary sedimentation tank from the design of the wastewater treatment plant. Generally, an increment of about (52 – 170) % for aeration basins and (58-185) % for secondary sedimentation tanks are observed in the present study. From other hand, gravity thickener volume is decreased by (29 - 42) %, anaerobic digester volume is decreased about (38 - 52) % and drying beds is decreased by (29 - 38) % approximately.

The cost analysis showed that the cost of a wastewater treatment plant is increased after a certain amount of influent. That amount is nearly (36,708.33) m^3/d when wasted sludge is taken from aeration basin and (24,833.33) m3/d when wasted sludge is taken from secondary clarifier.

***Keywords*:** Sedimentation tank, Wastewatertreatment,
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1.Introduction

The purpose of wastewater treatment is to prepare controlled conditions with comparatively small size to remove suspended and soluble materials, treatment biodegradable organics and elimination of pathogenic organisms [1]. Wastewater treatment plant contains various interacting unit processes. The design, operation, and control of these plants are not a simple task [2]. The control of the treatment process is very complex, because of the large number of variables that can affect it [3].

The primary sedimentation tank has great effect on the biological treatment, because, it has considerable roll on removing a great deal of BOD and TSS , in other words, the sedimentation tank facility reduces the organic load that will be processed in the biological unit earlier[4]. Many studies have been done to evaluate the effects of environmental factors on the performance of biological wastewater treatment plants :

AL- Turaihy, T.A, 1993 studied the factors affecting the choice of sewage treatment methods[5]; While Ujang, Z.andSairan, F.2006 designed a computer program in that field.[6] Also E. C. C. F., 2005 made studies on optimal design of wastewater treatment plant [7]; Xiaoyi Z., 2005used Poisson rectangular pulse model toestimate peaking factors[8]. There are also researches done by Arcadio P. S. S., 2003 to find the differences between chemical and physical treatments.[9]Donald. L. B.*et. al*., 2004 showed how domestic wastewater treatment is affected by many environmental factors.[10], Also Nikoletta K. and DespoF., 2004 showed how urban wastewater treatment is greatly changed by changing the environmental factors.[11]

2. Objective of the present paper are:

The main objectives of this study can be stated as:

1. Building a computer program that will design a wastewater treatment plant with completely mixed activated sludge method by using Visual Basic 6.0 software.
2. Making the program capable of doing the design job for a wastewater treatment plant with two options; the first is with primary sedimentation tank facility while the second option is without the primary sedimentation tank.
3. Discussing the results that will be revealed from these designs.

A typical wastewater treatment plant is accomplished by general steps which are shown in figure (1)[12]

3.Computer Program Construction

The program is designed to calculatewastewater treatment plant unitsdimensions. the program will focus on the design of the facilities that follows preliminary treatment, i.e., primary treatment, secondary treatment and sludge treatment facilities in two cases,the first case is the design of the treatment plant in presence of sedimentation tanks. While the second case is the design in absence of sedimentation tanks. Data that was used for design were obtained between minimum and maximum standard values used for design. [13][14][15]

The analysis of the two cases is based upon the analysis of cost as well as performance of the plant.A brief sample of the program forms is shown in Figure (2)

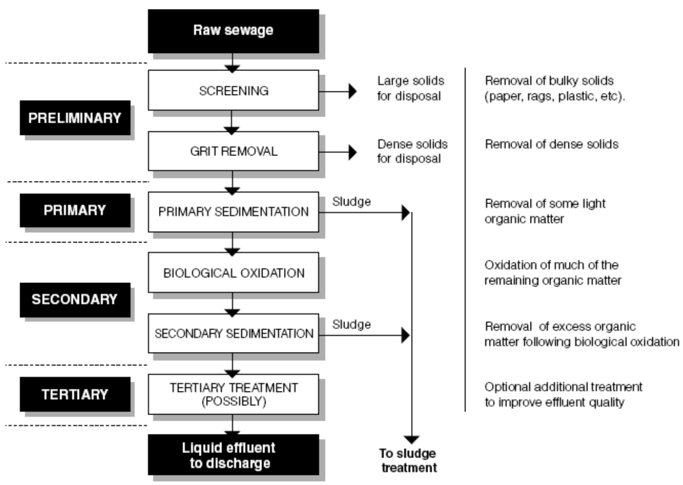

Figure (1) Typical Wastewater Treatment Plant Unit

4. Verification of Computer Program Results

It is necessary to check program results before depending on results in the final design of wastewater treatment plant.

Usually, any check is done by comparing the results that have been taken from the program with a standard formulas or equations, in the absence of such equations the program is to be checked with data that has been determined by hand calculation.

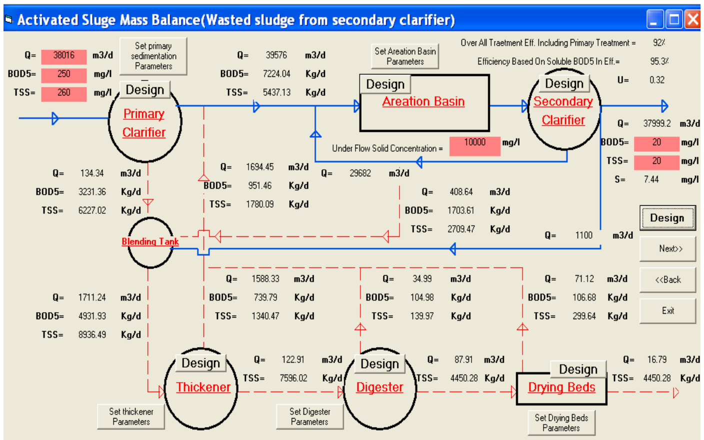

Figure (2) Wasted sludge from secondary clarifier mass balance window

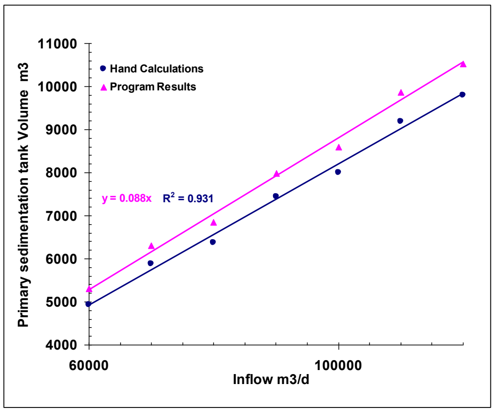

Figure (3) Verification between Hand Calculations and Program Results for Primary Sedimentation Tank Volume

The results obtained from verification are accepted as the program results show good convergence with that obtained by with hand calculation and a sample is shown inFigure (3)

5.Analysis of Data and Results

5.1 DATA

The flow rates and its characteristics used in the present study to obtain the data used in analysis are show in table (1). [13][14][15]. Additional two inflows (2500,5000)m /s was taken to enhance the regression analysis. The wastewater treatment plant units was designed for each of the mentioned (22) influents and this design was repeated (6) times, each time with different TSS and BOD ranging from (150)mg/l to (400)mg/l.

Table (1) Values of Characteristics of Sewage as used inthe program in the present study

Item	Units	Limits		
		Lower	Upper	Increment
Influent Flow Rate	m^3/d	10000	200000	10000
TSS In Influent	mg/l	150	400	50
BOD_5 In Influent	mg/l	150	400	50

5.2 Analysis

Multiple regression analysis were used in this study.In the present work, the volume of each treatment units is assumed to be the dependent variables (y) and the independent variables will be the influent to the wastewater treatment plant. Cost analysis was performed also for the designed plant. The construction costs of each unit for activated sludge treatment plant used in the present study are shown in Table(2). Single regression models in five forms are used for each one of design requirements to investigate which form gives the best fitting of data Table (3) shows these regression models.

Table (2) : Cost of Wastewater Treatment Plant units

Unit	**Cost %**
Inlet Pumping Station	6.75
Screening, Grit Removal and flow measurement	7.90
Primary Settlement	6.04
Biological Treatment	7.90
Final Settlement	6.22
Chlorination Plant	2.13
Sludge Treatment Plant	30.92
Recirculation or Sludge Return Pumps	1.33
Sludge Pumping Station	1.77
Electrical Works	5.34
Administration Block	2.33
Miscellaneous, Pipe work, Chambers, etc.	12.14
General Site Works, Roads, etc.	9.25
Total	100

5.3 Results

Single regression analysis is made to 22 models to find the relationship between independent variables (the influent flow rates, BOD_5 and TSS) and dependent variables (volume of each treatment unit) considering presence and absence of primary sedimentation tanks with different values of TSS_{inf} and BOD_{5inf}. Relationships between the influent and volume of each unit are found using (Microsoft Excel 2019) program for statistical calculations which showed a good degree of accuracy

Table (3): The Proposed Models in the Present Study

No.	**Equation**	**Description**
A	a_2	Linear
B	$_1\ln(\quad) \quad a_2$	logarithmic
C	$_2 \quad ^2 \quad _3 \quad ^3 \quad \ldots\ldots \quad _k X^n$	Polynomial
D	$_1X^{a_2}$	Power
E	$_1e^{\ _2X}$	Exponential

5.3.1 Volume of primary sedimentation tank

Model No. A was found to be the most suitable model for determining the volume of primary sedimentation tank. The predicted model can be written as:

$$y \quad 0.0874X$$

Where;

y= dependent variables, X = the independent variable, $a_1, a_2, a_3, \ldots a_k$ = are model coefficients

n = number refers to the polynomial degree

Figure (4) shows the primary sedimentation tank data fit model and its R^2 value.

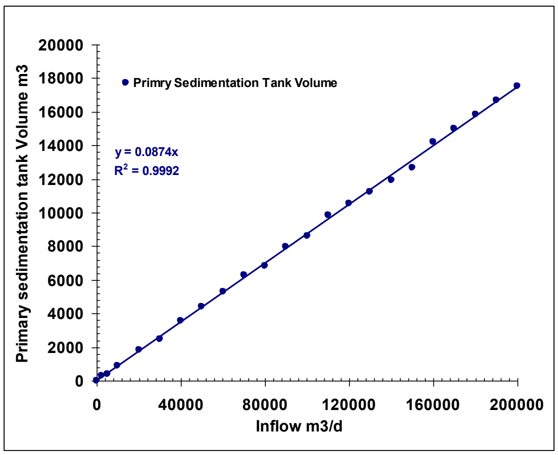

Figure (4): Primary Sedimentation Tank Regression Analysis

5.3.2 Volume of Aeration Basins Models

Table (4):Aeration Basin Models(WS From AB)

TSS_{inf} mg/l	BOD_{5inf} mg/l	Models			
		With PS	R^2	Without PS	R^2
150	150	y = 0.1338X	0.9997	y = 0.1861X	0.9998
200	200	y = 0.18X	0.9997	y = 0.2505X	0.9998
250	250	y = 0.2262X	0.9998	y = 0.3138X	0.9998
300	300	y = 0.2726X	0.9994	y = 0.3778X	0.9974
350	350	y = 0.3194X	0.9998	y = 0.3781X	0.9998
400	400	y = 0.3658X	0.9998	y = 0.506X	0.9998

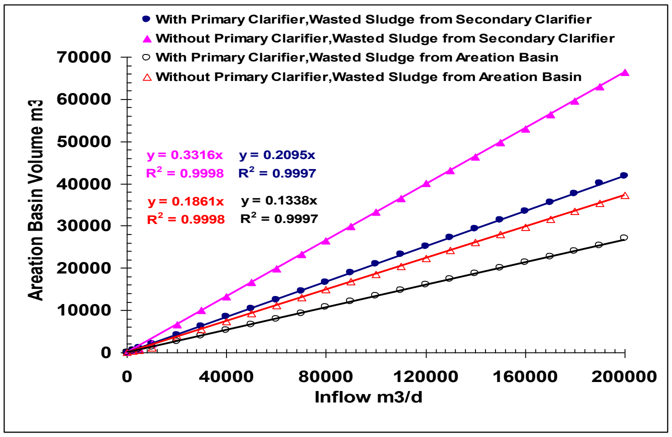

Figure (5): Aeration Basin Volume Data Fit (TSS_{inf} = 150 , BOD_{5inf} = 150) mg/l

5.3.3 Volume of Secondary clarifier Models

Table (5) Secondary clarifier Models (WS From AB)

TSS_{inf} mg/l	BOD_{5inf} mg/l	Models			
		With PS	R^2	Without PS	R^2
150	150	y = 0.2566X	0.9998	y = 0.3067	0.9998
200	200	y = 0.3008X	0.9998	y = 0.3675X	0.9998
250	250	y = 0.3448	0.9998	y = 0.4276	0.9985
300	300	y = 0.3888X	0.9998	y = 0.4876	0.9973
350	350	y = 0.4328X	0.9998	y = 0.488	0.9997
400	400	y = 0.4764X	0.9998	y = 0.6075	0.9997

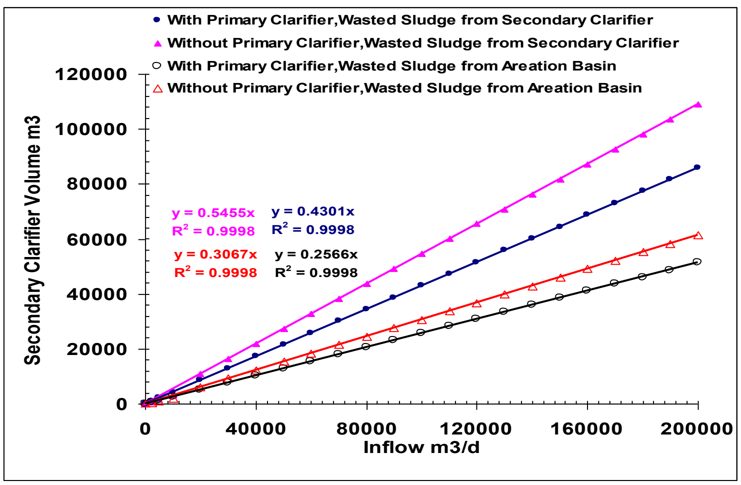

Figure (6):Final Clarifier Volume Data Fit (TSS_{inf}= 150 ,BOD_{5inf} = 150) mg/l

5.3.4 Volume of Gravity thickener Models

Table (6) Gravity thickener Models (WS From AB)

TSS_{inf} mg/l	BOD_{5inf} mg/l	Models			
		With PS	R^2	Without PS	R^2
150	150	y = 0.0104X	0.9986	y = 0.0033X	0.9981
200	200	y = 0.0147X	0.9995	y = 0.0053X	0.9986
250	250	y = 0.0191X	0.9996	y = 0.0074X	0.9981
300	300	y = 0.0235X	0.9994	y = 0.0094X	0.9977
350	350	y = 0.0278X	0.9996	y = 0.0095X	0.9993
400	400	y = 0.0322X	0.9997	y = 0.0136X	0.9993

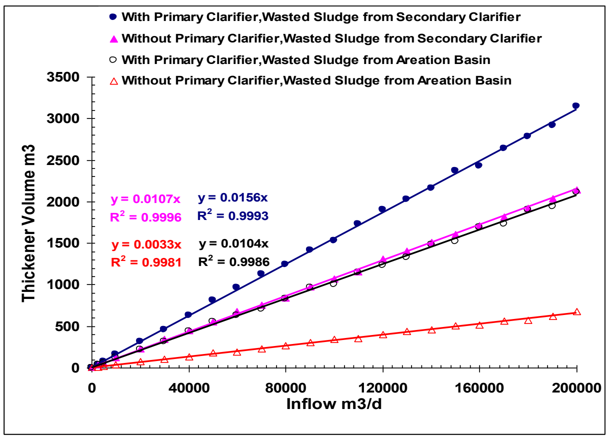

Figure (7): Gravity Thickener Volume Data Fit (TSS_{inf}= 150 ,BOD_{5inf} = 150)mg/l

5.3.5 Volume of Anaerobic digester Models

Table (7) Anaerobic Digester Models (WS From AB)

TSS_{inf} mg/l	BOD_{5inf} mg/l	Models			
		With PS	R^2	Without PS	R^2
150	150	y = 0.0894X	0.9948	y = 0.0613X	0.9927
200	200	y = 0.0894X	0.9950	y = 0.0613X	0.9927
250	250	y = 0.1067X	0.9995	y = 0.0414X	0.996
300	300	y = 0.1313X	0.9998	y = 0.0531X	0.9987
350	350	y = 0.1562X	0.9998	y = 0.0531X	0.9972
400	400	y = 0.1806X	0.9998	y = 0.0757X	0.9991

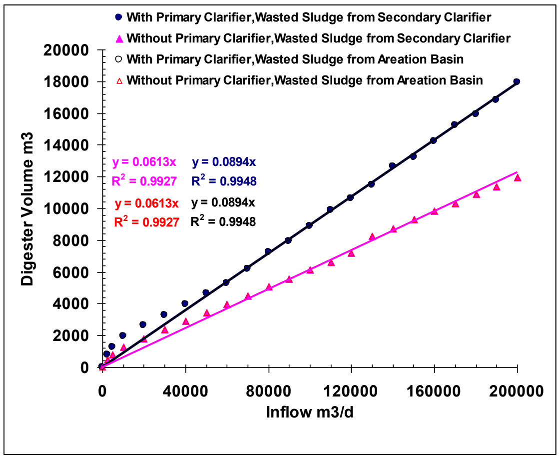

Figure (8): Anaerobic Digester Volume Data Fit (TSS_{inf}= 150 ,BOD_{5inf} = 150) mg/l

5.3.6 Volume of Drying bed Models

Table (8) Drying Bed Models (WS From AB)

TSS_{inf} mg/l	BOD_{5inf} mg/l	Models			
		With PS	R^2	Without PS	R^2
150	150	0.0007X	0.9998	y = 0.0002X	0.9998
200	200	y = 0.001X	0.9998	y = 0.0003X	0.9998
250	250	y = 0.0013X	0.9998	y = 0.0004X	0.9989
300	300	y = 0.0016X	0.9998	y = 0.0006X	0.9982
350	350	y = 0.0019X	0.9998	y = 0.0006X	0.9998
400	400	y = 0.0022X	0.9998	y = 0.0008X	0.9998

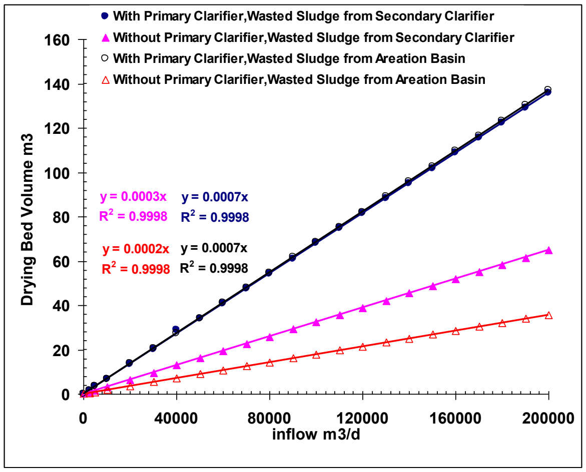

Figure (9): Drying Beds Volume Data Fit(TSS_{inf}= 150 ,BOD_{5inf} = 150)mg/l

5.3.7 Cost Estimation models

Table (9): Cost Analysis Models

TSS_{inf} mg/l	BOD_{5inf} mg/l	Equation	R^2
150	150	y = 3*10-24X5-2*10-18X4+4*10-13X3-3*10-8X2+0.0015X+81.075	0.9591
200	200	y =10-25X5-2*10-19X4+9*10-14X3-10-8X2+0.0009X+81.069	0.9017
250	250	y = 3*10-25X5-3*10-19X4+10-13X3-2*10-8X2+0.0011X+75.141	0.9006
300	300	y = 5*10-25X5-4*10-19X4+9*10-14X3-10-8X2+0.0007X+85.808	0.9064
350	350	y = -10-24X5+6*10-19X4-10-13X3+7*10-9X2+4*10-5X+91.044	0.9622
400	400	y = 2*10-24X5-10-18X4+3*10-13X3-3*10-8X2+0.0013X+79.553	0.9747

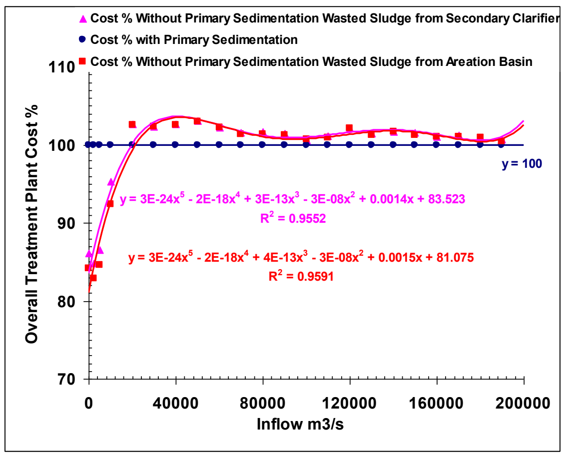

Figure (10): Cost Analysis of WWTP (TSS_{inf}= 150 ,BOD_{5inf} = 150) mg/l

6. Conclusions and Recommendations:

The present study has come out with the following conclusions:

1. It is more engineering convenient, much faster and accurate to builda computer programsoftware forwastewater treatment plantdesign.
2. Generally an increments about (52 – 170) % for aeration basins volume and (58-185) % for secondary sedimentation tanks were observed in the present study.
3. Approximately gravity thickener volume is decreased by about (29 - 42) %, anaerobic digester volume is decreased by (38 - 52) % and drying beds is decreased by (29 - 38) % if the design disregarded the presence of primary sedimentation in the present study.
4. The analysis showed that the usage of primary sedimentation tanks on a wastewater treatment plant is more economic when the influent is above (36,708.33) m /d when the wasted sludge from aeration basin, and (24,833.33)m /d if the wasted sludge from secondary clarifier.

The effect of altering in temperature, pH. Value and the presence of heavy metals in the effluent in the dimensional design of the treatment plant are recommended for practical future researches.

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