Effects of Non-Existence of Primary Sedimentation Tank on Wastewater Treatment Plant Units Design

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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 in two cases: the first case is with primary sedimentation tanks and the second case is without primary sedimentation tanks to assess primary sedimentation tanks effects on biological treatment

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.

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 2003) program for statistical calculations which showed a good degree of accuracy.

The volume of aeration basin and secondary sedimentation tank will increase if primary sedimentation tank is to be eliminated from the design of the wastewater treatment plant. This increment in volume varied according to the influent and effluent characteristics. Generally an increments about (52 – 170) % for aeration basins and (58-185) % for secondary sedimentation tanks are observed in the present study. Also, the volume of each sludge treatment unit is decreased when primary sedimentation is omitted in the design of plant. The amount of decreasing is also depending on influent, effluent characteristics. Approximately gravity thickener volume is decreased by (29-42) %, anaerobic digester volume is decreased about (38 - 52) % and drying beds is decreased by (29-38) %

Construction cost analysis is made to compare between the cost of a wastewater treatment plant design including primary sedimentation and another without primary sedimentation tank. 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, also, the above mentioned values depend on influent and effluent characteristics.

Finally it is found that the mixing of primary sludge with that of secondary sludge will give better results as compared with sludge treatment that obtained from secondary sludge only.

الخلاصة

تقدم هذه الدراسة برنامج مصمم ببرنامج (Visual Basic 6.0). لهذا البرنامج القدره على تصميم وحدات محطة لمعالجة المياه الثقيلة في حالتين الاولى بوجود احواض الترسيب الابتدائية والحالة الثانيه بعدم وجود احواض الترسيب الابتدائية لتقييم اثار احواض الترسيب الابتدائية على المعالجه الحيوية.

يتعامل البرنامج مع نوعين من طرق سحب الحمأة النوع الاول هو سحب الحمأه من حوض التهوية. النوع الثاني هو سحب الحمأة من حوض الترويق الثانوي. هنالك ايضا اخراج مفصل يظهر التصاريف التصميمي هو تحليل موازنة الكتله, و التراكيز لكل تصريف داخل وخارج من كل وحدة معالجه.تمت مقارنة نتائج البرنامج بالحسابات اليدويه ضمن القيم المسموحه و الموصى بها وقد اضهرت دقه جيده .

تم عمل طريقة تحليل الانحدار الاخطي المفرد لـ (22) نموذج لايجاد العلاقه بين المتغيرات الغير معتمده (التصاريف التصميميه) والمتغيرات المعتمده (حجوم وحدات المعالجه) مع الاخذ بنظر الاعتبار وجود او عدم وجود احواض الترسيب الابتدائيه لقيم مختلفه من (TSS) و (BOD_5).

تم ايجاد علاقات بين التصاريف الداخله للمحطه وحجم كل وحده من وحدات المعالجه باستخدام البرنامج (SPSS) للقيام بالحسابات الاحصائيه التي اضهرت مقدار جيد من الدقه.

وجدت الدراسه ان حجم احواض التهويه واحواض الترويق الثانويه سيزداد اذا ما تم استبعاد احواض الترسيب الابتدائيه من تصميم محطة معالجة المياه الثقيله.ان مقدار هذه الزياده متغير حسب خصائص التصاريف الداخله والخارجه من المحطه. عموما, هنالك زياده بمقدار (52–170) % لأحواض التهويه و(58–185) % لأحواض الترويق الثانويه قد لوحظت في البحث الحالي.

ان حجم وحدات معالجه الحمأه قد قل عندما تم استبعاد حوض الترسيب الابتدائي في التصميم. ان مقدار هذا النقصان يعتمد ايضا على خصائص التصاريف الداخله والخارجه من محطة المعالجه. قل حجم حوض المثخن بمقدار (29–42) % وحوض الهاضمه اللاهوائيه بمقدار (38–52) % كما و قد قل حجم حوض التجفيف بمقدار (29–38) %.

تم تحليل كلفة الانشاء للمقارنه بين كلفة محطة معالجة المياه الثقيله التي تتضمن حوض ترسيب ابتدائي ومحطه اخرى لا تحتوي على هذا الحوض. اظهرت تحاليل الكلفه ان كلفة محطة معالجة المياه الثقيله قد ازدادت اكثر من (100) % بعد تجاوز التصريف لمقدار محدد.

وجد ان هذا المقدار للتصريف هو (36,708.33) م^3/ يوم عند سحب الحمأه من حوض التهويه و (24,833.33) م^3/ يوم عند سحب الحمأه من حوض الترويق الثانوي وهذه المقادير ايضا تعتمد على خصائص التصاريف الداخله والخارجه من المحطه.

وأخيرا وجد ان خلط الحمأه الابتدائيه مع الحمأه الثانويه سوف يعطي نتائج افضل عندما يعالج هذا المزيج في وحدة معالجة الحمأه فيما لو عولجت الحمأه الثانويه لوحدها.

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.Wastewater treatment plant contains various interacting unit processes. The design, operation, and control of these plants are not a simple task. The control of the treatment process is very complex, because of the large number of variables that can affect it. (Frank, 2004 ; E.P.A., 2003).

The primary sedimentation tank is certainly has a 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(B. P. and J. Oleszkiewicz, 2006)

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; While Ujang, Z.and Sairan, F.2006 designed a computer program in that field. Also E. C. C. F., 2005 made studies on optimal design of wastewater treatment plant; Xiaoyi Z., 2005 used Poisson rectangular pulse model toestimate peaking factors. There are also researches done by Arcadio P. S. S., 2003 to find the differences between chemical and physical treatments. Donald. L. B. *et. al*., 2004 showed how domestic wastewater treatment is affected by many environmental factors. Also Nikoletta K. and Despo F., 2004 showed how urban wastewater treatment is greatly changed by changing the environmental factors.

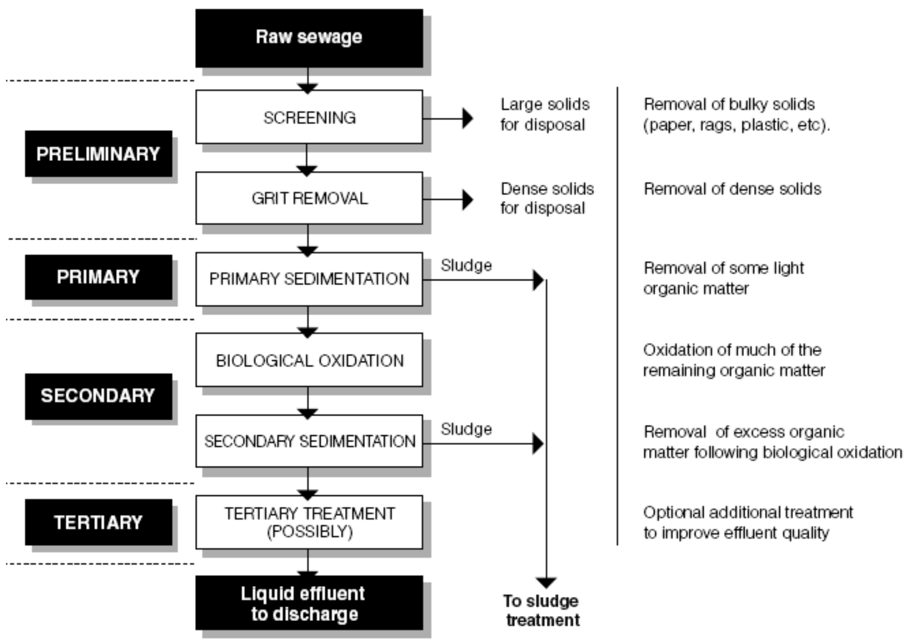
2. Objectives of the present paper :

The main objectives of this paper 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.

Standard wastewater treatment consists of a series of steps or unit processes tied together with the ultimate purpose of taking the raw sewage influent and turning it into an effluent that is often several times cleaner than the water in the outfalled water body.

A typical wastewater treatment plant is accomplished by general steps which are shown in figure (1) (WEF and American Society of Civil Engineers, 2008).



Figure(1): Typical Wastewater Treatment Plant Unit

3.Computer Program Construction:

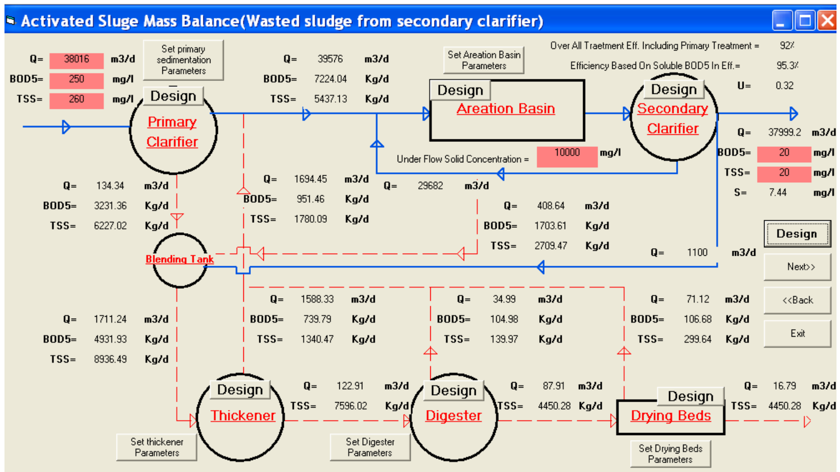
The program is designed to design wastewater treatment plant units. The treatment plant facility contains various units' processes that should be designed and sized, but the program will focus on the design of the facilities that follows preliminary treatment, i.e., primary treatment, secondary treatment and sludge treatment facilities.

In this study, a new program is build to design wastewater treatment plants with 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. 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).

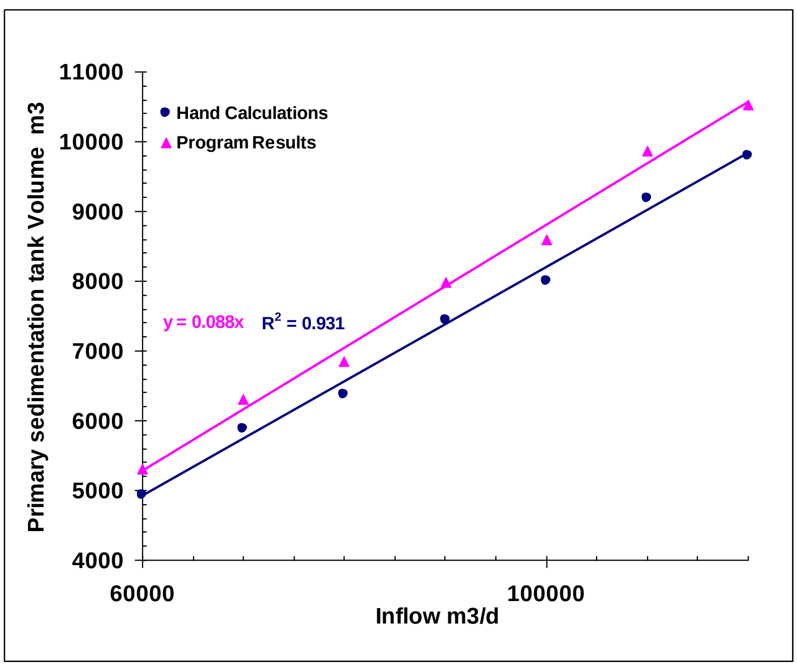
4. Verification of Computer Program Results

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

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 in Figure (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).

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

Table(1): Values of Characteristics of Sewage asUsed in the Program in the Present Study

Additional two inflows (2500,5000) m^3/d will also be taken to enhance the regression analysis. The wastewater treatment plant units will be designed for each of the mentioned (22) influents and this design will be repeated (6) times, each time with different TSS and BOD ranging from (150)mg/l to (400)mg/l.

5.2 Analysis

One of an important benefits of plotting data is to obtain results. Some simple models are considered in analysis which one variable (x) the independent variable is varied and the dependent variable (y) is obtained.

There is also the coefficient of determination (R2) which is a measure of how well your data fits an equation. The relationship between a single variable *y*, called dependent variable, and one or more independent variables, $x1$, … xk are explained or modeled by a multiple regression analysis. Where $k = 1$, it is called simple regression but when $k > 1$ it is called multiple regression.

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.

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Cost analysis is done by using the program to calculate the volumes of wastewater treatment plant units in two cases, the first case in presence of primary sedimentation tanks and the second case in absence of primary sedimentation tanks. 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 .It is worthy to note that the single regression is easy to use because it
Needs to simple efforts and it has quick calculations as compared with other types of statistical models.

Also the present study dose not used Excel Microsoft Program in analysis of data But it used only in drawing of analyzed data .In this study the resulted relations are obtained by using STISTICA program.

5.3 Results

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:

$$y = 0.0874X$$

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

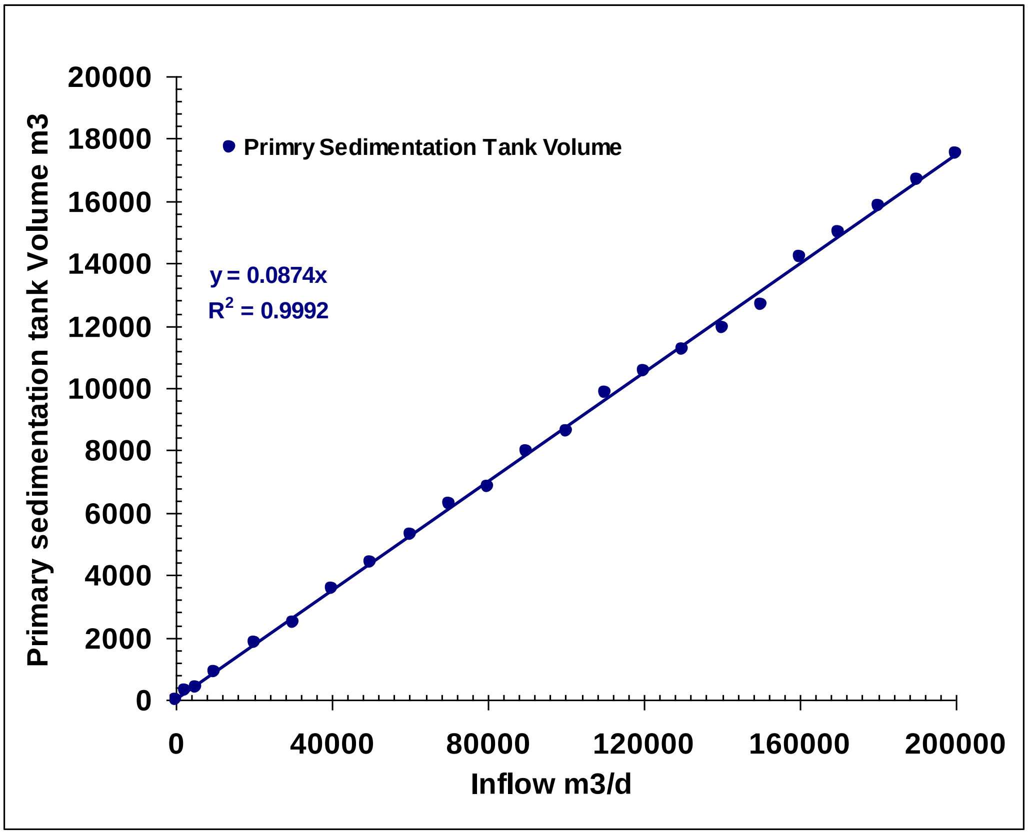
Table(2): Cost of Wastewater Treatment Plant units

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

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

o.	Equation	Description
A	$y = a_1 X + a_2$	Linear
B	$y = a_1 \ln(X) + a_2$	logarithmic
C	$y = a_1 X + a_2 X^2 + a_3 X^3 + ... + a_k X^n$	Polynomial
D	$y = a_1 X^{a_2}$	Power
E	$y = a_1 e^{a_2 X}$	Exponential

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

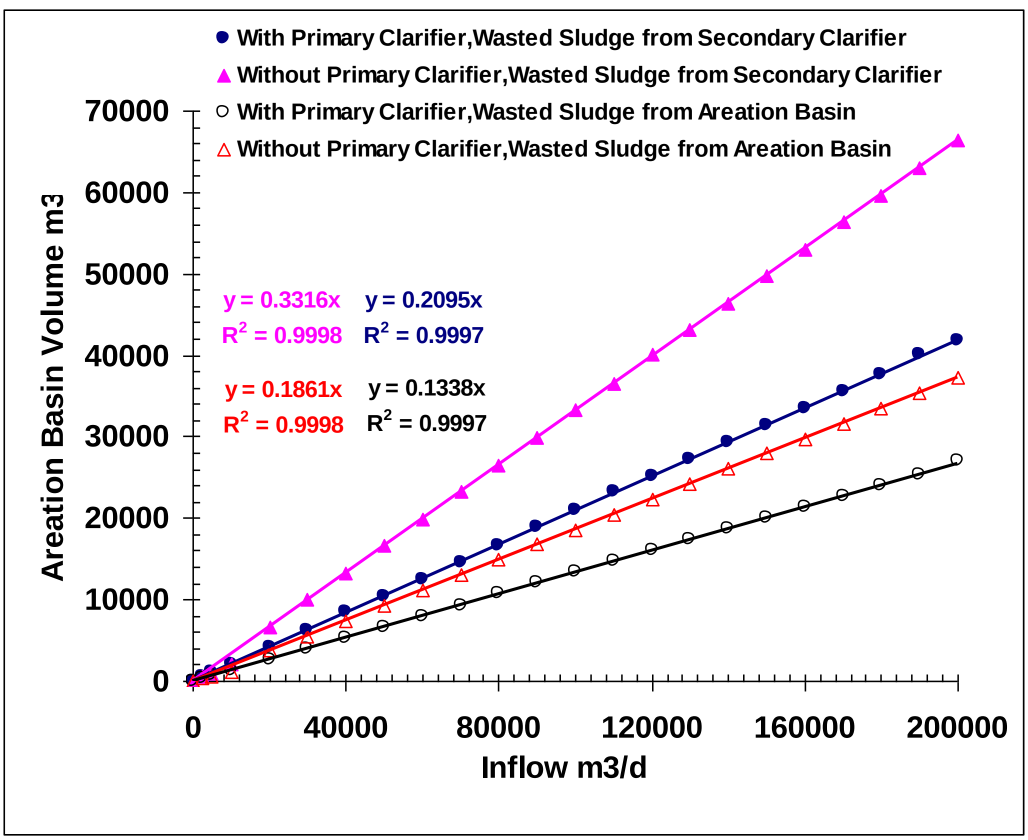


Figure(4): Primary Sedimentation Tank Regression Analysis

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

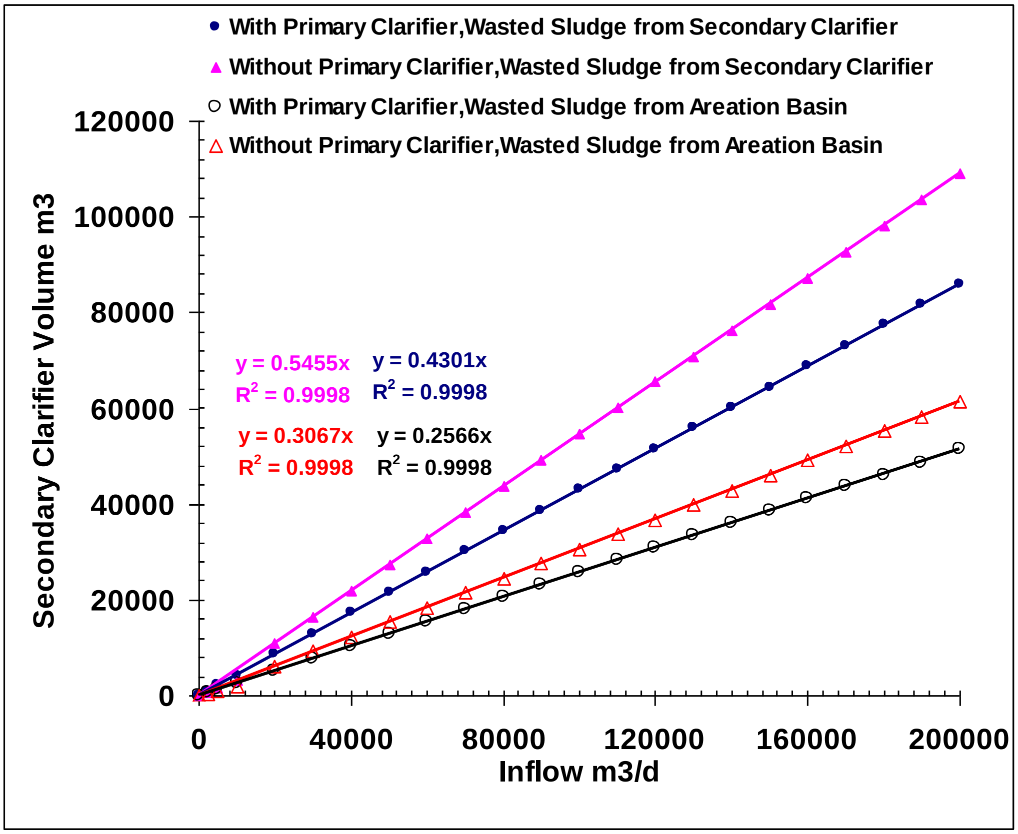


Figure(5):Aeration Basin Volume Data Fit(TSS_{inf} = 150 ,BOD_{5inf} = 150)mg/l

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

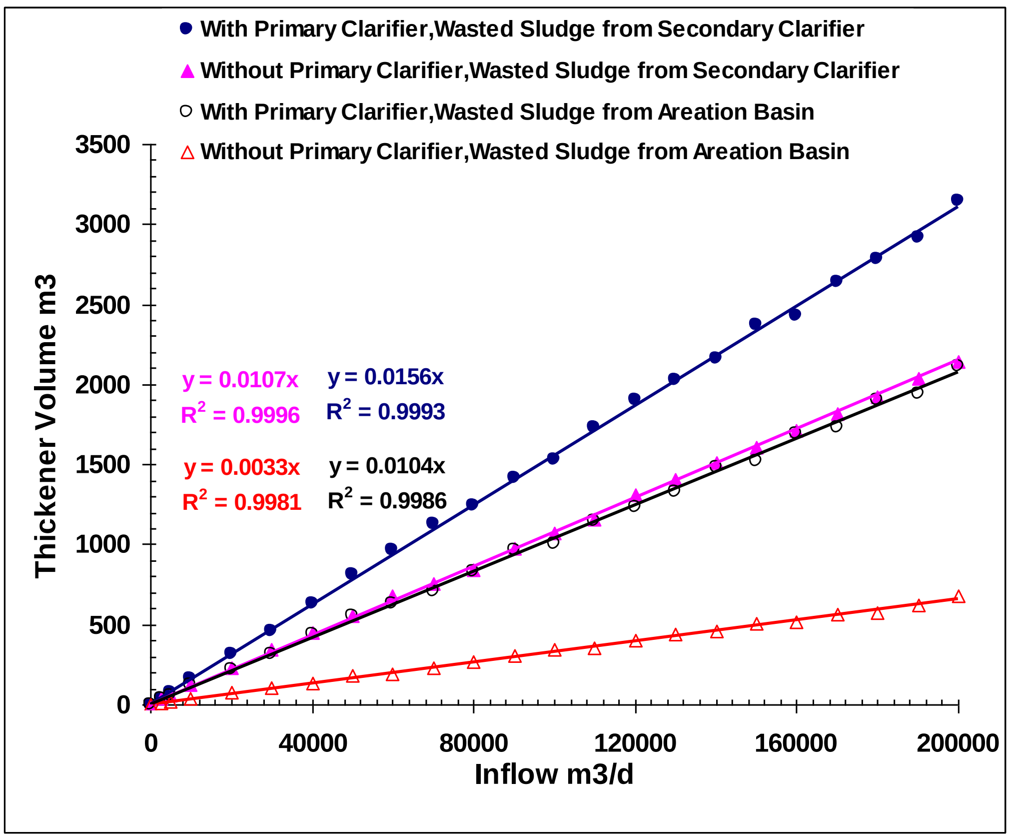


Figure(6):Final Clarifier Volume Data Fit(TSS_{inf} = 150 ,BOD_{5inf} = 150)mg/l

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

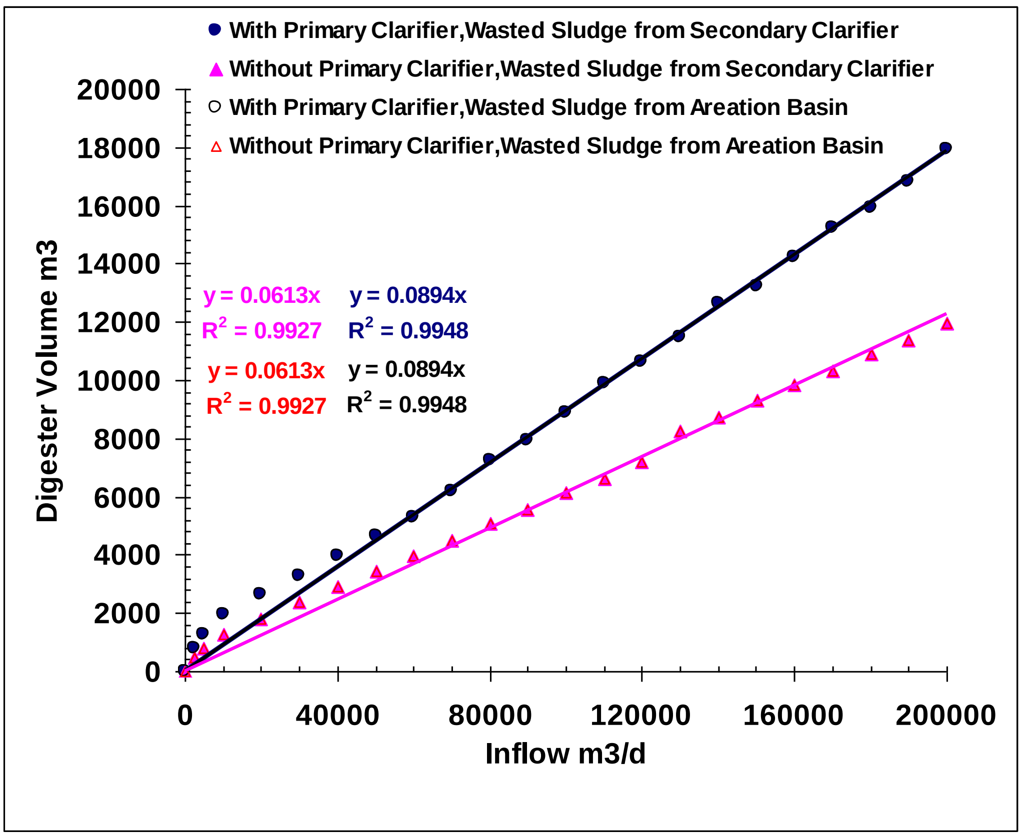


Figure(7): Gravity Thickener Volume Data Fit(TSS_{inf} = 150 ,BOD_{5inf} = 150)mg/l

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

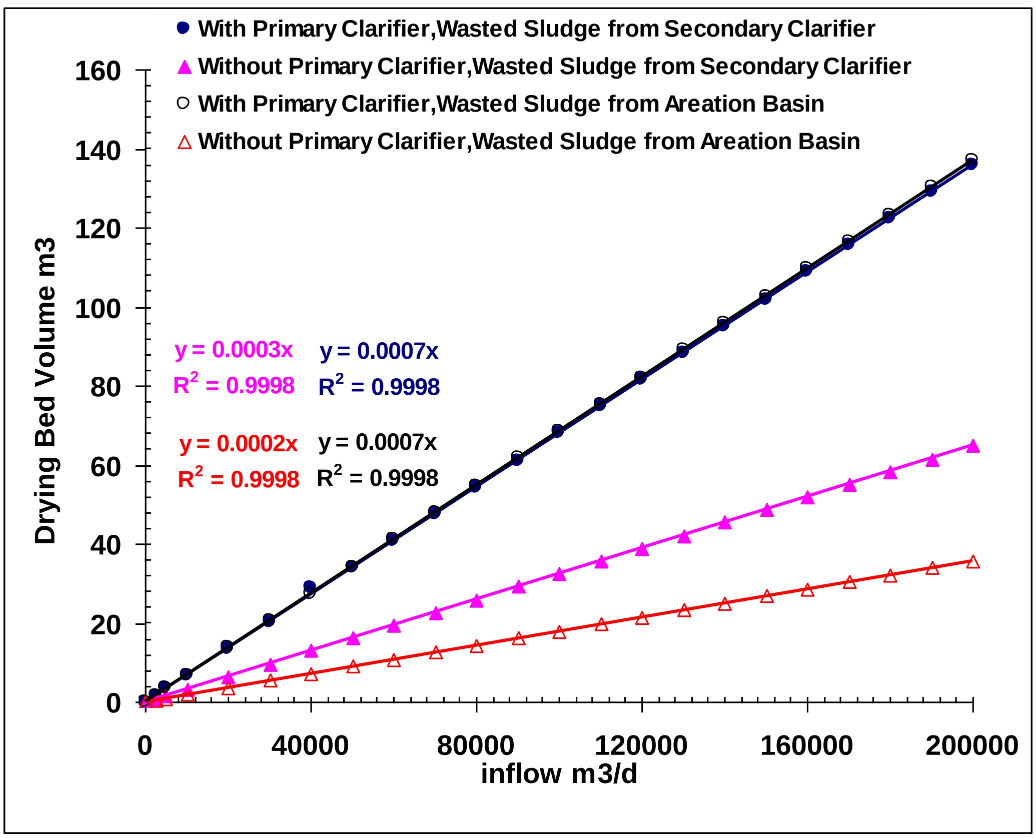


Figure(8): Anaerobic Digester Volume Data Fit(TSS_{inf} = 150 ,BOD_{5inf} = 150)mg/l

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

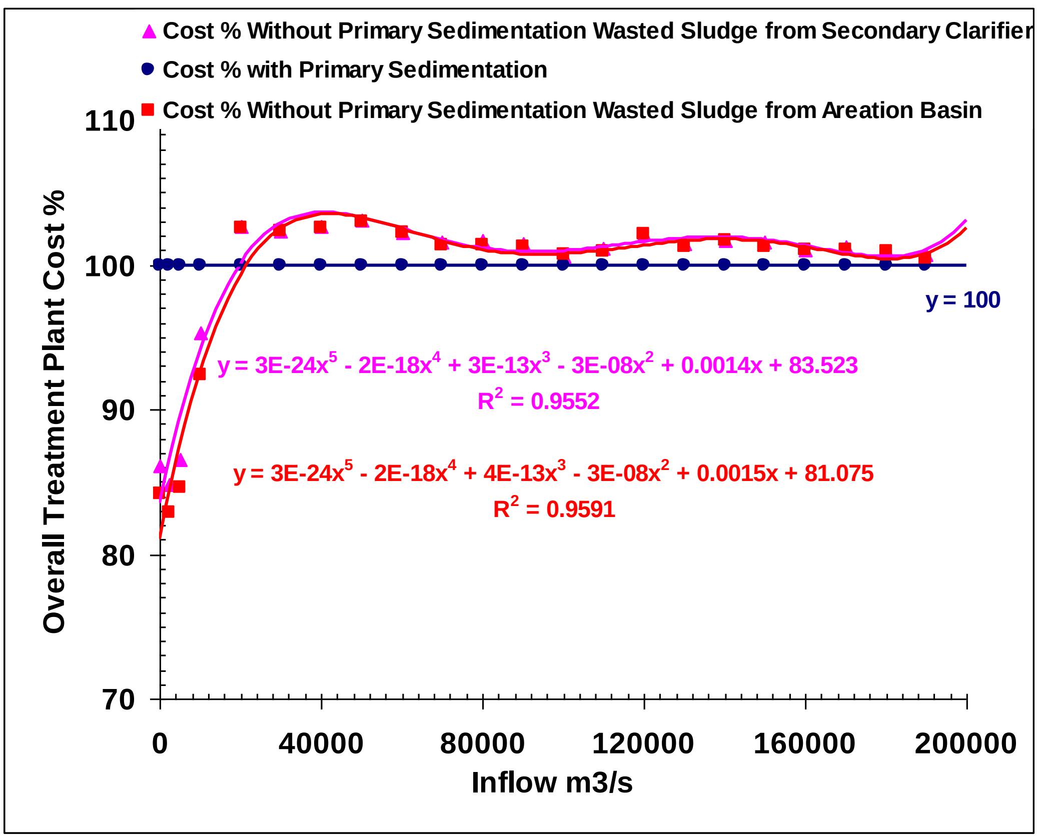


Figure(9): Drying Beds Volume Data Fit(TSS_{inf} = 150 ,BOD_{5inf} = 150)mg/l

5.3.7 Cost Estimation models

Table(9):Cost Analysis Models

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



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

6. Conclusions

The present study has come out with the following conclusions:

1. The analysis of results 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. That amount also depends on influent characteristics (TSS_{inf}, BOD_{5inf}), and effluent characteristics (TSS_{eff}, BOD_{5eff}).
2. Designing a computer program in Visual Basic 6.0 software to design wastewater treatment plant by using a conventional completely mixed activated sludge system with two types of sludge withdrawal one from aeration basin and the other from secondary clarifier.
3. The volume of aeration basin and secondary sedimentation tanks increase if primary sedimentation tank is to be omitted from the design of the wastewater treatment plant. This increment in volume varied according to the influent characteristics (TSS_{inf} , BOD_{5inf}), and effluent characteristics (TSS_{eff} , BOD_{5eff}). Generally an increments about (52 – 170) % for aeration basins and (58-185) % for secondary sedimentation tanks were observed in the present study.
4. The volume of each sludge treatment unit decreases when primary sedimentation is neglected in design. The amount of decreasing is also depending on influent characteristics (TSS_{inf}, BOD_{5inf}), and effluent characteristics (TSS_{eff}, BOD_{5eff}). 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.
5. If a completely mixed activated sludge method is used to design a wastewater treatment plant with small amount of influent, the design results may have some kind of disturbance, that what makes this method suitable for large amounts of influent.

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