Modeling The Factors Affecting Sizing of Attached Growth System of Wastewater Treatment Plant

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Abstract:

a computer program designed in Visual Basic Software 6.0 that used for designing attached growth system of wastewater treatment plants which are trickling filters, rotating biological contactor, and bio-towers. This program deals with the different environmental factors that affecting the design of wastewater treatment steps.

The verification between the results of the study with there results obtained from hand calculations procedures showed agood agrrement

The relationships between independent and dependent variables were determined by multiple non - linear regression analysis using statistical program "Data Fit version 8.0".

The population was found to be the most significant variable affecting the design of all wastewater units.

Keywords: Attached growth system of wastewater treatment plants.

العوامل البيئية المؤثرة على تصميم محطات معالجة مياه الصرف الصحي ذات النمو الملتصق

الخلاصة:

تُقدِم هذه الدراسة برنامج حاسوبي مصمم بلغةِ فيجوال بيسكِ 6.0. لتصميم محطات معالجة مياه الفضلات من نوع النمو الملتصق كذلك يهدف البرنامج إلى تحليلُ العواملَ البيئية المختلفة المؤثرة على مراحل تصميم محطات المعالجة.

المقارنة بين النَتائجِ المستحصلة من البرنامجَ مع النَتائِجِ الناتجة من الحساباتِ اليدويةِ أعطت نتائج جيدة.

تم استخدام طريقة التحليل الانحدار اللاخطّي المتعدّد بلستعمل برنامج الإحصائي "8" Data Fit لإيجاد العِلاقاتِ الإحصائية بين عدد من المتغيرات المستقِلة والمتغيرات المعتمدة

أظهرت الدراسة إن أكثر العوامل أهميه وتأثيراً على تصميم وحدات المعالجة لكل الأنواع المدروسة من المحطات هو عدد السكان.

Introduction:

The biological treatment unit is considered to be the most important unit in the wastewater treatment plant, and because of its important, the wastewater treatment plants were named after the biological treatment method employed. In attached growth system the microorganisms are attached to some inert medium such as rocks, slag, or plastic and also know as fixed – film process. The main types of this process are trickling filter and rotating biological contactor **(AL- Turaihy, 1993)**.

Wastewater Treatment Plant Layout

A typical wastewater treatment plant is accomplished by general steps which are:

1- Preliminary treatment
2- Primary treatment
3- Secondary treatment
4- Tertiary (advanced) treatment (if necessary) , and
5- Sludge treatment processes.

Types of attached growth units:

1- Trickling filter(TF): It consists of a shallow bed filled with crushed stones or synthetic media. Wastewater is applied on the surface by means of a self propelled rotary distribution system. The organics are removed by the attached layer of microorganism (slime layer) that develops over media.

2- Rotating Biological Contactors(RBC): It consists of a series of circular plates (discs) mounted over a shaft that rotates slowly. The discs are spaced so that wastewater and air can enter the space. The biological growth develops over the discs that receives alternating exposures to organics and air. **(Qasim, 1985)**.

3- Bio-towers(BT): Bio-towers are essentially deep trickling filter. In tower air and wastewater get thoroughly mixed while the wastewater trickles downward. The contact among the wastewater, microorganisms, and air is improved due to the increase in the length of travel. Moreover, the velocity of air and wastewater through the tower trickling filter is increased, causing higher oxygen transfer to the flocs. **(Peavy, 1985).**

The Studied Environmental Factors:

1) Population: The generated wastewater depends upon the population and per capita contribution of wastewater. **(Masten and Davis, 2004).**

2) Average and Maximum Per Capita Sewage Contribution: New wastewater systems should be designed on the basis of an average daily per capita (lpcd) flow of wastewater of not less than (270 liters) nor greater than (350 liters) **(WEF manual of Practice No.8 and ASCE Manual, 1992)**.

3) Organic Loadings and Total Solids Concentrations: The strength of a wastewater is usually measured as 5-days biochemical oxygen demand (BOD_5), and total suspended solids. In middle Euphrates reigns wastewater systems designed on the basis (70 l/d.c) for BOD production and for Tss production of wastewater of (90 l/d.c).

4) Variation of Temperature: The temperature of the sewage is primary factor in assessing the overall efficiency of a biological treatment process, the fermentation in the sludge layer in oxidation ponds depends very much on temperature **(AL- Turaihy, 1993)**. Temperature decreasing may result in a significant decreasing in the soluble (BOD) removing rate **(Davis, 1976)**.

5) Infiltration / Inflow (I / I):I/I is a part of every collection system and must be taken into account in the determination of an appropriate design flow.

6) Variation in Raw Waste Load: **Davies, 2005** stated that the increase in the concentration of substrate, the growth rate increases exponentially and then levels off. Therefore, with further increase in concentration of substrate in the medium, there is no further increase in growth. The bacteria are at their maximum growth rate.

7) Design Period: **Qasim, 1985** declared that the selection of design period depends on useful life of treatment units, future growth in population, service area, water demand

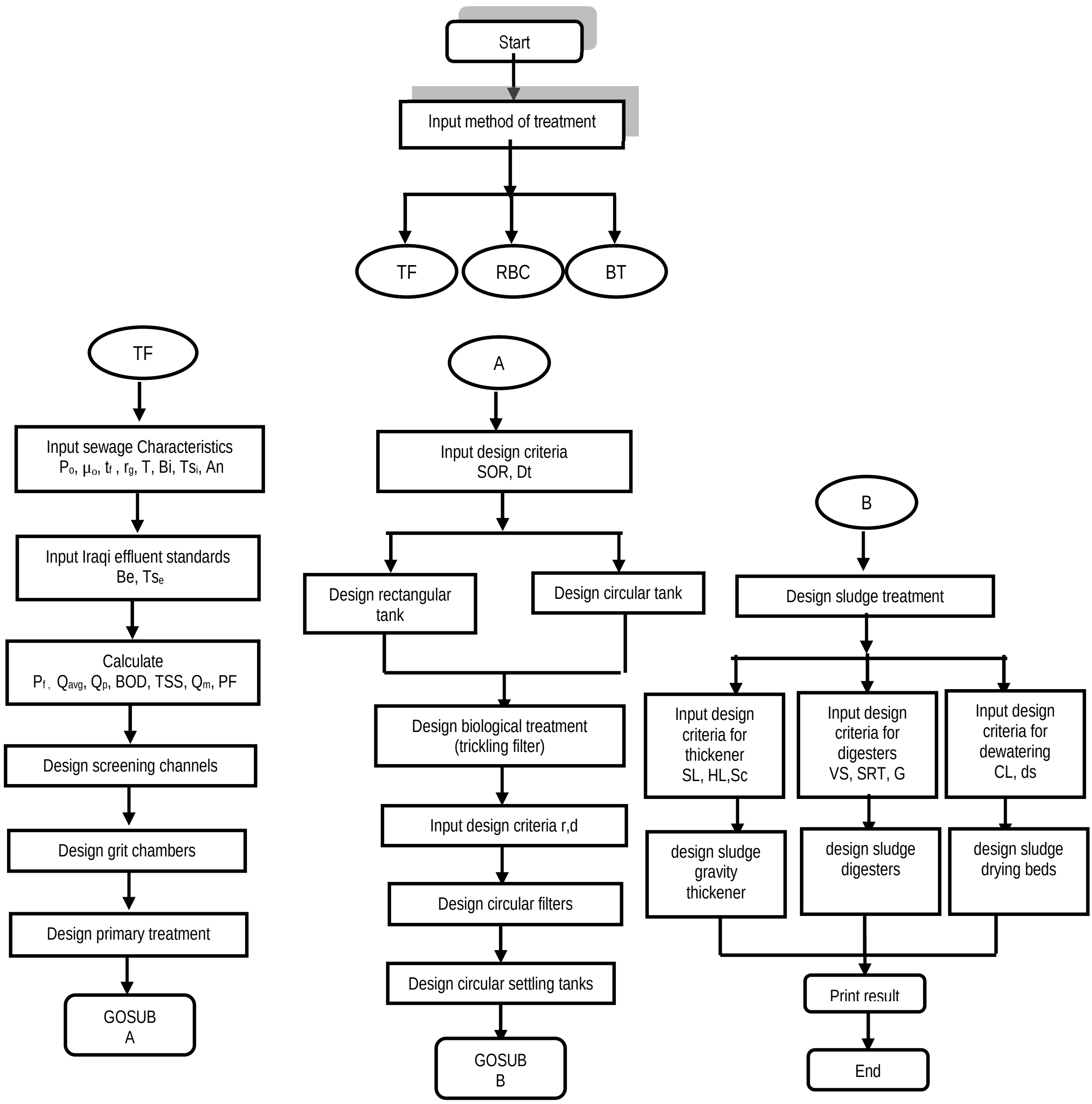
and wastewater characteristics and performance of treatment facility during the initial year when it's oversized this choice lies between (10-25) years.

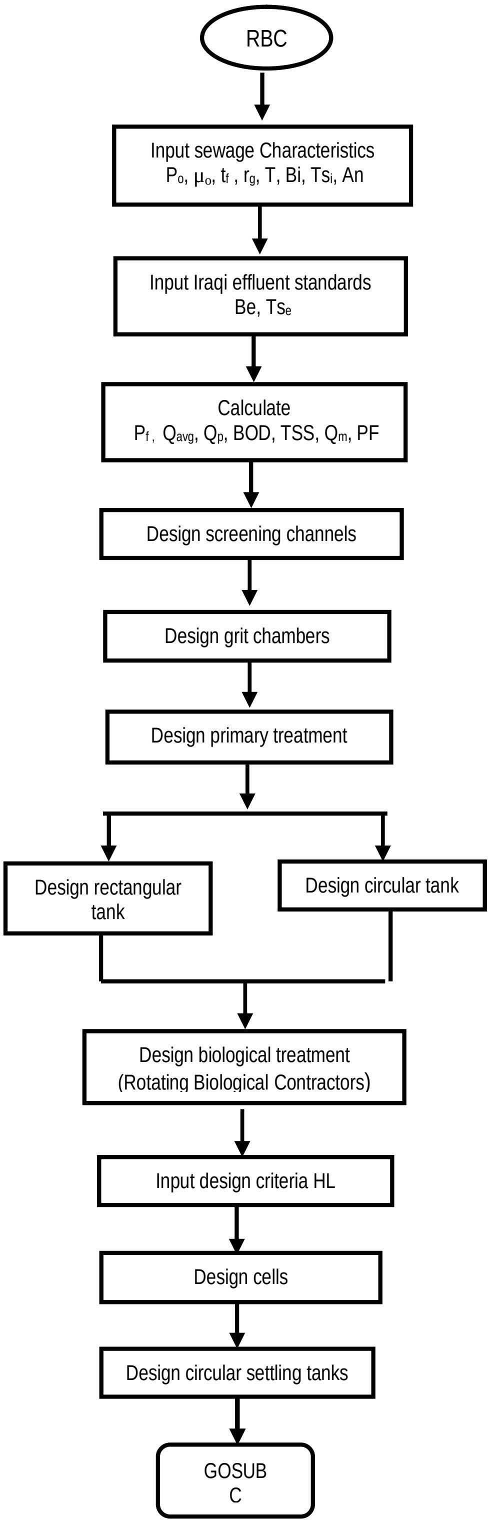
8) Recirculation Ratio: The ratio of the return flow, to the influent flow is called the recirculation ratio .

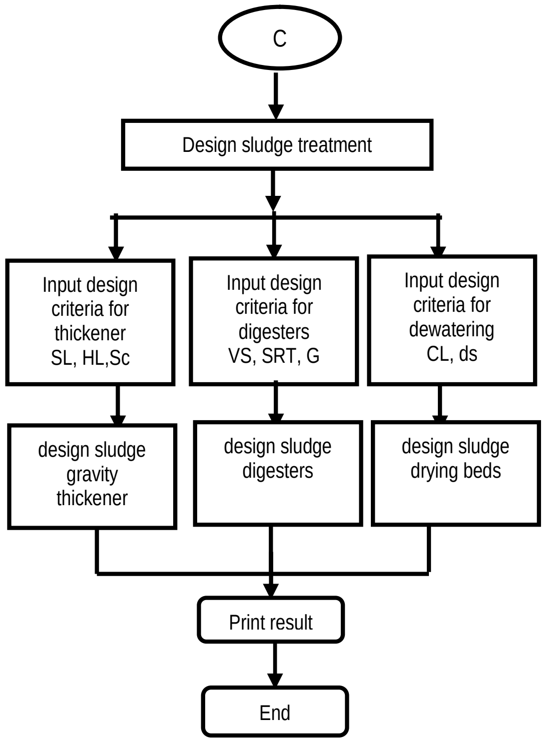
Description of Computer Program:

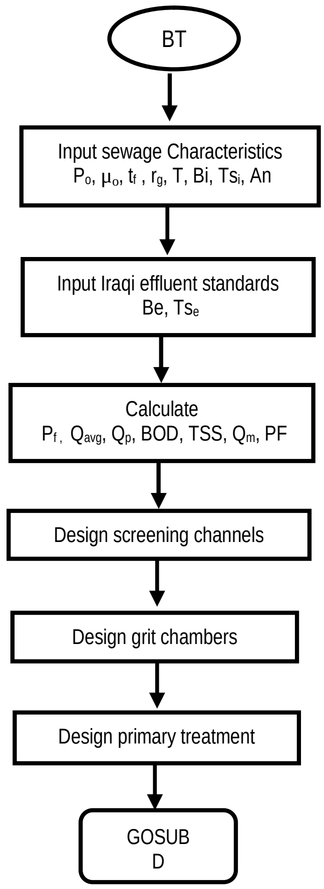
The program is written by using Visual Basic 6.0 language. The steps of the program are as follows:

1. The run of the computer program required the inputs data, these data are found in every type of treatment and assumed as follows (initial population,=100000 capita, specific sewage production= 270 l/c. d, design period= 25 year, growth rate= 3.8 %, the specific domestic BOD_5 in raw sewage flow= 70g/c.d, the specific domestic Tss in raw sewage flow= 90 g/c.d, the temperature= 20 ^oC, the area served by network= 400 hectare, and the infiltration rate= 0.1 l/s.ha).
2. The effluent concentration were kept constants values BOD = 40 mg/l, Tss=60mg/l.
3. Determination of the future population, peaking factor, total average flow rate, peak flow rate, minimum design flow rate, organic load and solids concentrations (BOD and TSS), then design preliminary treatments (screens and grit chamber).
4. Design primary sedimentation tanks (rectangular and circular basins)
5. Design a biological treatment according to its type as shown:
   - Design a trickling filter assuming that (recirculation ratio r and depth d),
   - Design a rotating biological contactors assuming that hydraulic loading HL, and
   - Design a bio-tower assuming that (recirculation ratio r and reaction coefficient k_{20}).
6. Design secondary sedimentation tanks (circular basins):
7. Design sludge treatment process as shown:
   - Design sludge thickner with design criteria (solid loading SL, hydraulic loading HL, Solid concentration S_c),
   - Design anaerobic digestion with design criteria (volatile solid loading VS, residence time SRT, gas density G), and
   - Design drying beds with design criteria (per capita loading CL, depth of applied sludge ds)


Start
Input method of treatment
TF
RBC
BT
TF
Input sewage Characteristics
Po, μo, tf, rg, T, Bi, Tsi, An
Input Iraqi effluent standards
Be, Tse
Calculate
Pf, Qavg, Qp, BOD, TSS, Qm, PF
Design screening channels
Design grit chambers
Design primary treatment
GOSUB
A
A
Input design criteria
SOR, Dt
Design rectangular
tank
Design circular tank
Design biological treatment
(trickling filter)
Input design criteria r,d
Design circular filters
Design circular settling tanks
GOSUB
B
B
Design sludge treatment
Input design
criteria for
thickener
SL, HL,Sc
Input design
criteria for
digesters
VS, SRT, G
Input design
criteria for
dewatering
CL, ds
design sludge
gravity
thickener
design sludge
digesters
design sludge
drying beds
Print result
End


RBC
Input sewage Characteristics
P_o, μ_o, t_f, r_g, T, Bi, Ts_i, An
Input Iraqi effluent standards
Be, Ts_e
Calculate
P_f, Q_{avg}, Q_p, BOD, TSS, Q_m, PF
Design screening channels
Design grit chambers
Design primary treatment
Design rectangular tank
Design circular tank
Design biological treatment
(Rotating Biological Contractors)
Input design criteria HL
Design cells
Design circular settling tanks
GOSUB
C


C
Design sludge treatment
Input design criteria for thickener
SL, HL,Sc
Input design criteria for digesters
VS, SRT, G
Input design criteria for dewatering
CL, ds
design sludge gravity thickener
design sludge digesters
design sludge drying beds
Print result
End


BT
Input sewage Characteristics
P_o, μ_o, t_f, r_g, T, Bi, Ts_i, An
Input Iraqi effluent standards
Be, Ts_e
Calculate
P_f, Q_{avg}, Q_p, BOD, TSS, Q_m, PF
Design screening channels
Design grit chambers
Design primary treatment
GOSUB
D

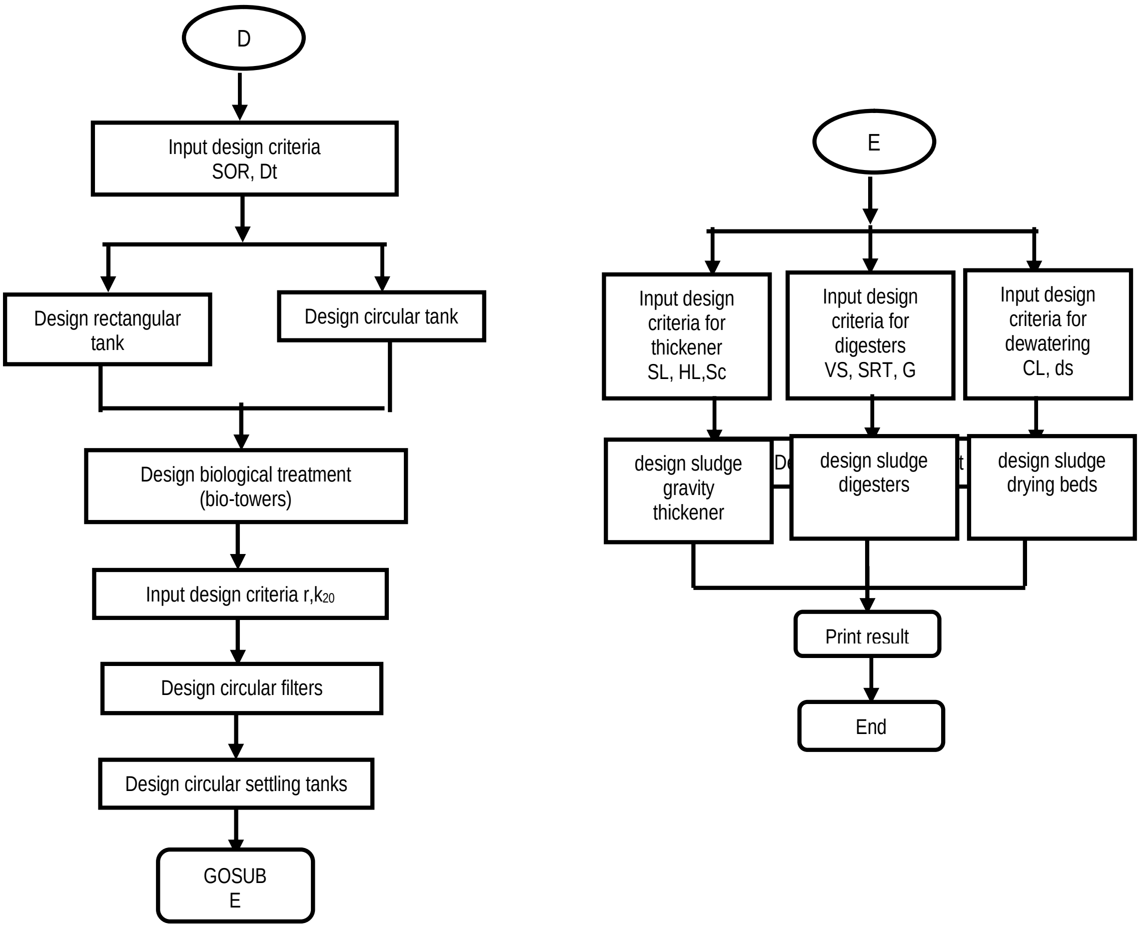


Fig.(1): Flowchart for Computer Program of Designing the Types of Wastewater Treatment Plant in The Present Study.

Application of Computer Program for Study Treatment Plant:

The computer program consists of three main parts, which are **(A)** The choice of biological treatment **(B)**The information base and **(C)** The design calculation modules which contain design requirement as shown in Figs. (2), (3), (4), and (5).

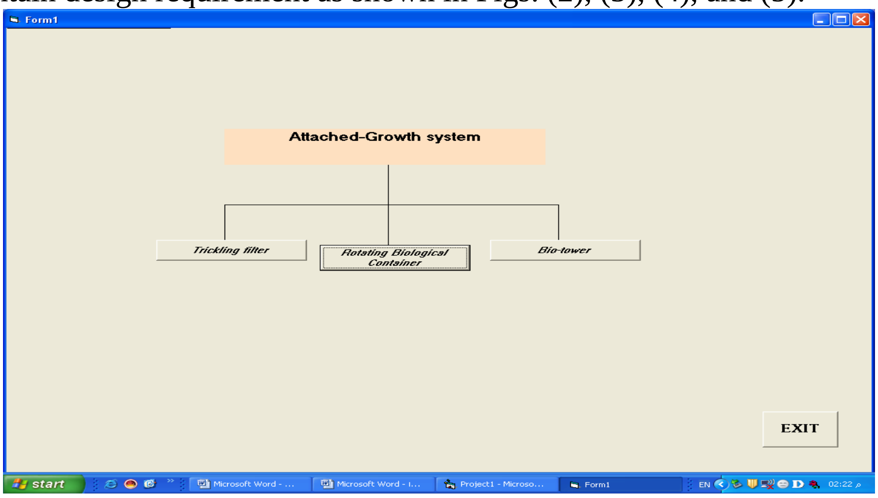


Fig.(2): Different types of Wastewater Treatment Plant of Present Study

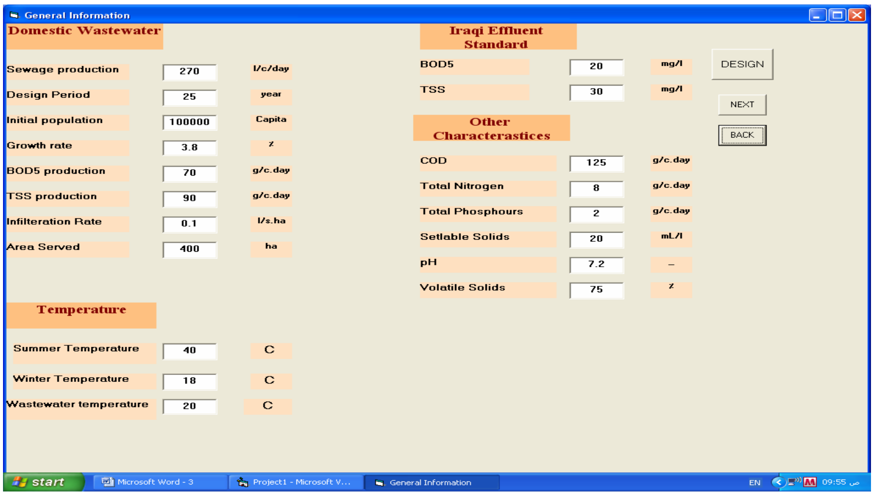


Fig.(3): General Information for Wastewater Treatment Plant

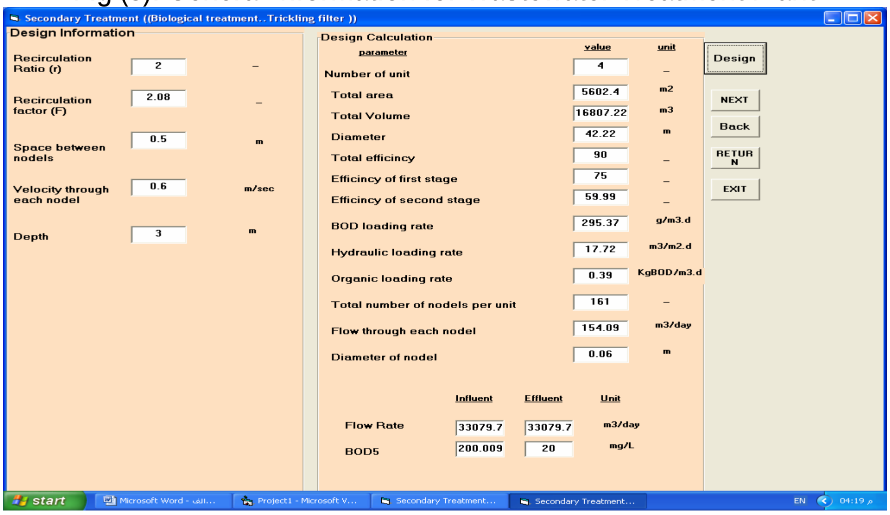


Fig. (4): Module for Design Trickling Filter

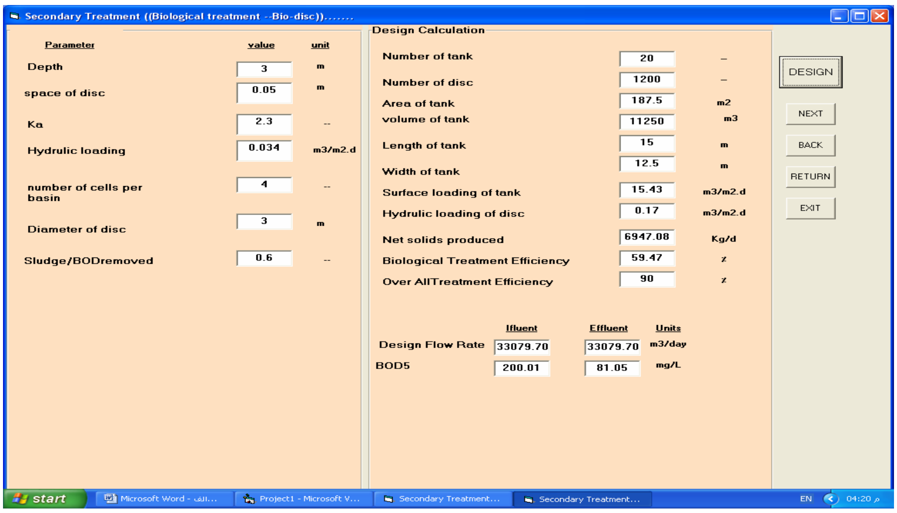


Fig. (5): Module for Design Rotating Biological Contactor

Verification of Computer Program Results

In the present work, a comparison was performed between the running of program results with these results of free hand calculations in order to get verification of the present models because the field data are not available. More than one factor could be taken for comparison but the population had been used because it is the most important factor. The results as follows in figs(6to13).

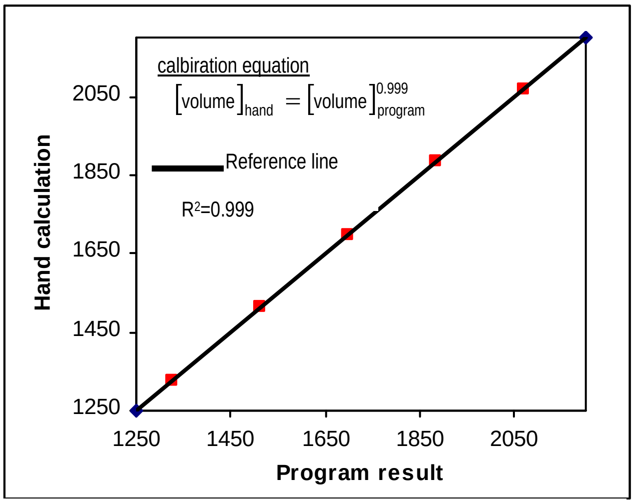


Fig. (6): Verification for Volume of Primary Clarifiar

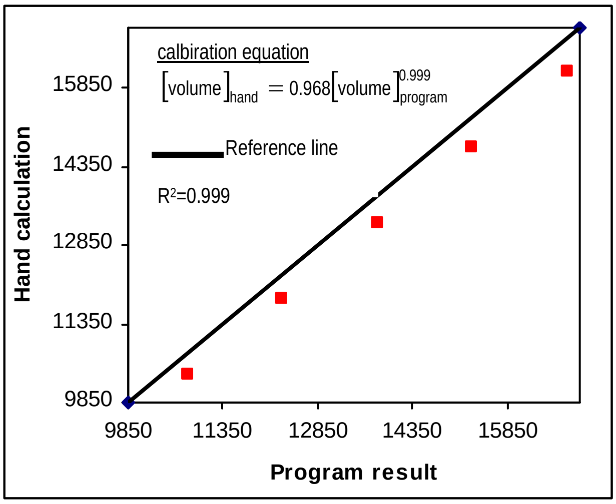


Fig. (7): Verification for Volume of Trickling Filter

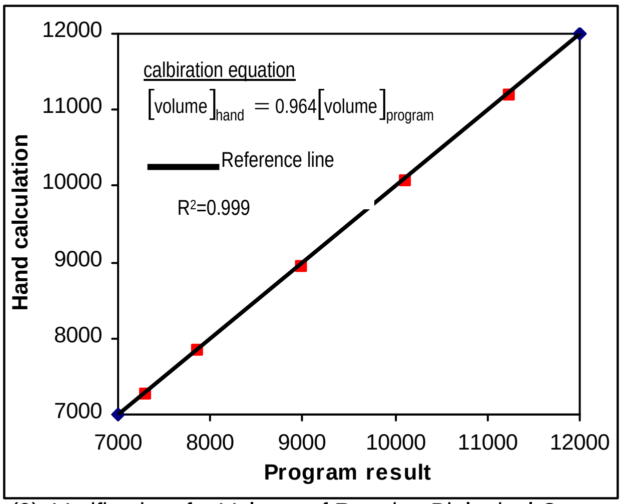


Fig. (8): Verification for Volume of Rotating Biological Contactor

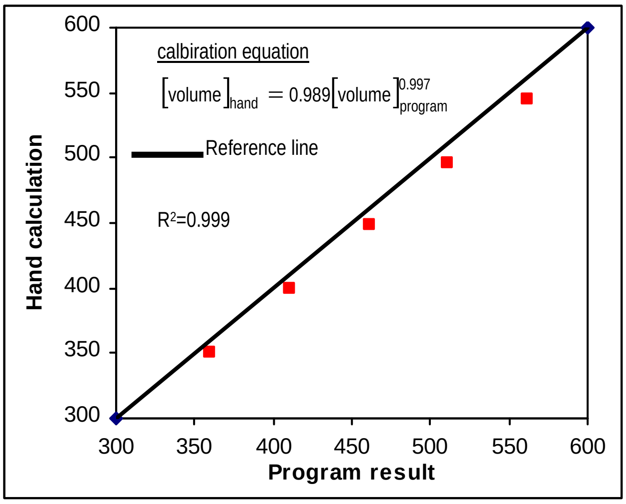


Fig. (9): Verification for Volume of Bio-Tower

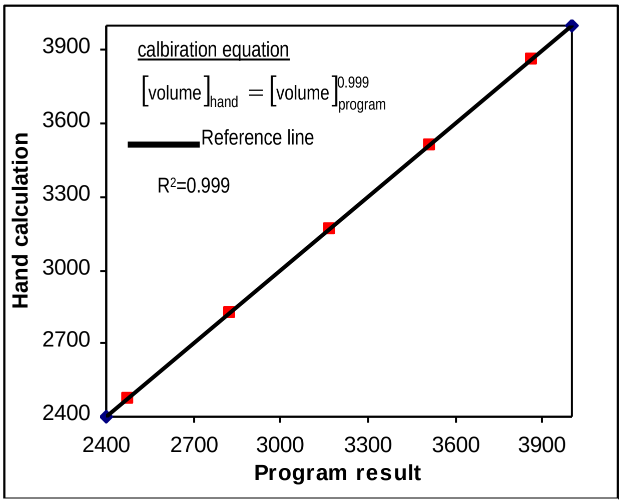


Fig. (10): Verification for Volume of Secondary Clarifier for Attach-Growth System

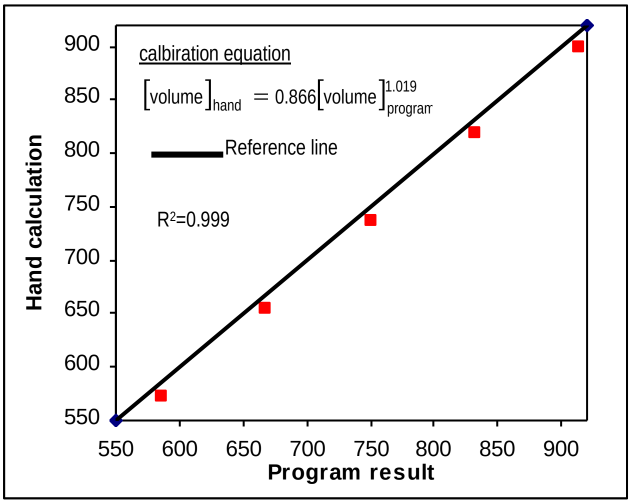


Fig. (11): Verification for Volume of Thickener for Attach-Growth System

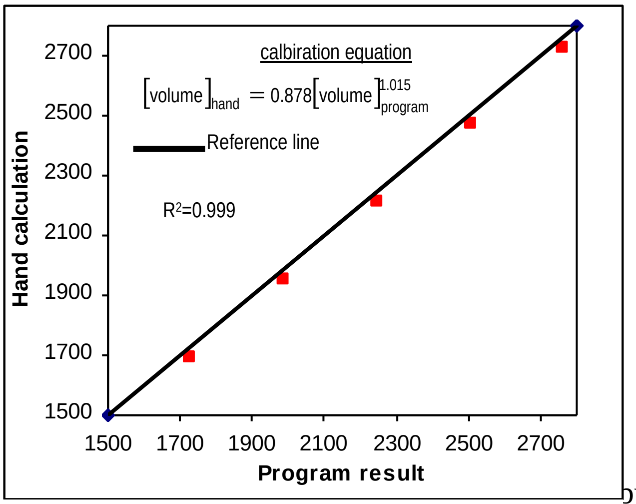


Fig. (12): Verification for Volume of Digester for Attach-Growth System

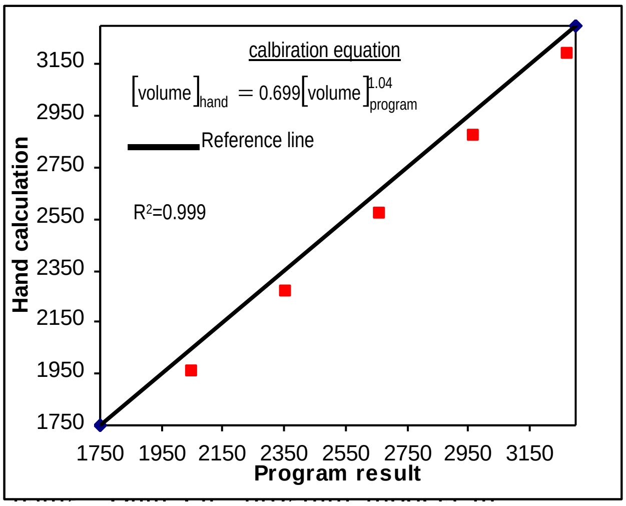


Fig. (13): Verification for Volume of Gas Produced for Attach-Growth System

that were proposed and investigated.

Table (2): The Proposed Models

symbol	description
A	$y=b_1x_1+b_2x_2+\ldots\ldots\ldots b_kx_k$
B	$y=\exp(b_1x_1+b_2x_2+\ldots\ldots.+b_kx_k)$
C	$y=b_1x_1+b_2x_2+\ldots\ldots\ldots b_kx_k+G$

Where;

y = dependent variables; $x_1, x_2, \ldots, x_k$ = the independent variables, and $b_1, b_2, b_3, \ldots b_k$ = are model coefficients, and G is model constant term.

<u>The Dependent Variables (y)</u>: The volume of each treatment unit, and the volume of gas production were assumed to be the dependent variables (y).

<u>The Independent Variables (x_k)</u>: Table (1) shows the independent variables.

Table (1): Independent variables for the present study

Variable	Description	Variable	Description
x_1	Population, capita	x_6	Area served by network, ha
x_2	Temperature, ^0C	x_7	Infiltration rate, l/s.ha
x_3	Specific sewage production,l/c.d	x_8	Design period, y
x_4	Tss production, g/c.d	x_9	Recirculation ratio
x_5	BOD_5 production, g/c.d		

Results and Discussions:

1) Volume of Primary Sedimentation Tank Model:

The value of R^2=0.999 and the value of the standard error of the estimate=1.307.

$$y = 0.019x_1 + 6.863x_3 + 0.539x_6 + 2157.51x_7 + 7.079x_8 - 2244.564$$

Where: y= volume of primary sedimentation tanks, m^3

The variation of the input and modeled values of the volume of primary sedimentation tanks can be seen in fig(14), which shows the adequacy of this model.

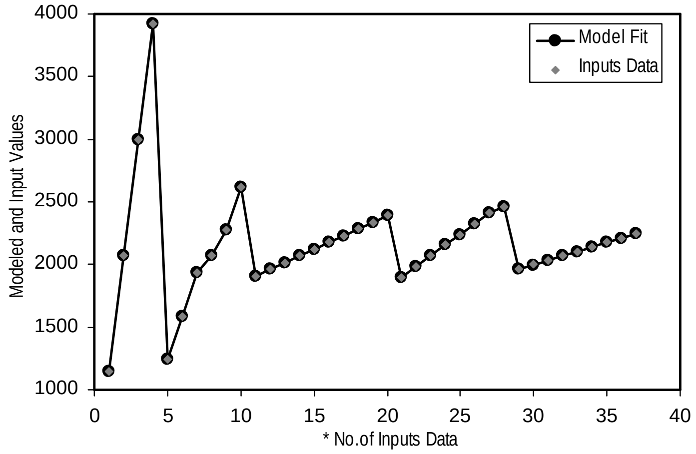


Fig (14): The Input Versus Modeled of Volume of Primary Sedimentation Tanks.

2) **Volume of trickling filter:**

The value of R^2=0.988 and the value of the standard error of the estimate=782.486.

$$y = \exp(6.733E-006x_1 + 0.032x_2 - 0.006x_3 + 0.0007x_4 + 0.025x_5 + 0.0003x_6 + 1.021x_7 + 0.004x_8 + 0.169x_9 + 7.473)$$

Where: y= volume of trickling filters, m^3.

The variation of the input and modeled values of the volume of trickling filter can be seen in fig(15), which shows the adequacy of this model.

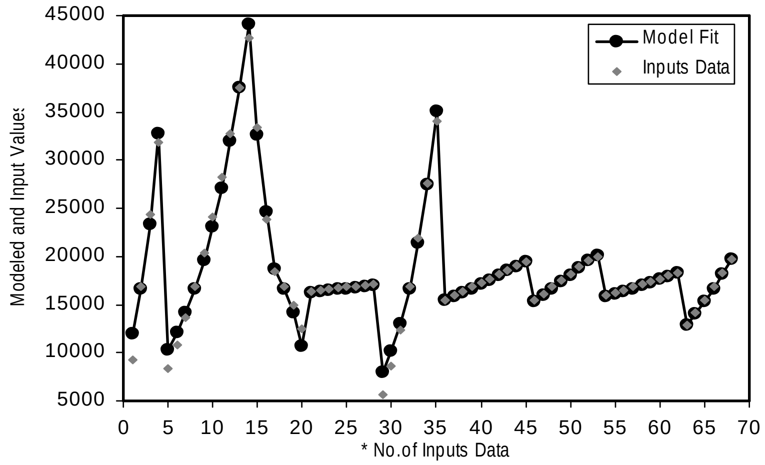


Fig. (15): The Input Versus Modeled of Volume of Trickling Filter.

3) **Volume of rotating biological contactor:**

The value of R^2=0.986 and the value of the standard error of the estimate=566.172.

$$y = \exp(6.621E-006x_1 + 0.033x_2 - 0.006x_3 + 0.001x_4 + 0.025x_5 + 0.0003x_6 + 0.956x_7 + 0.003x_8 + 7.417)$$

Where: y= volume of basins, m^3.

The variation of the input and modeled values of the volume of rotating biological contactor can be seen in fig(16), which shows the adequacy of this model.

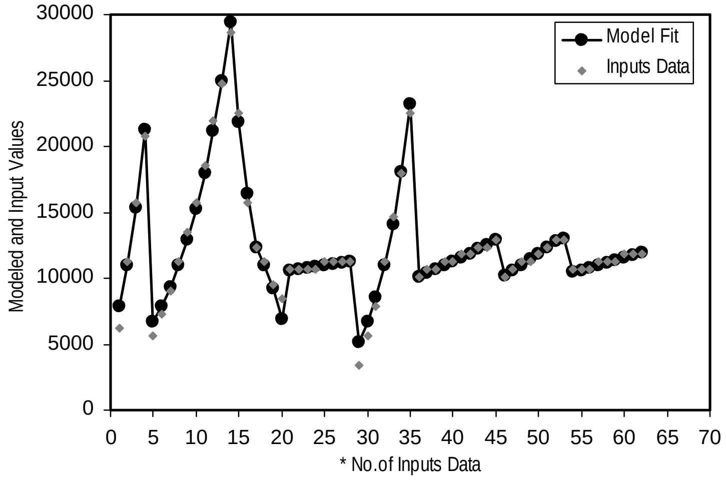


Fig. (16): The Input Versus Modeled of Volume of Rotating Biological Contactor.

4) **Volume of bio-tower**:

The value of R^2=0.994 and the value of the standard error of the estimate=30.036.

$$y = \exp(6.872E-006x_1 - 0.035x_2 - 0.003x_3 + 0.0004x_4 + 0.02x_5 + 0.0003x_6 + 1.101x_7 + 0.004x_8 - 1.13x_9 + 7.649)$$

Where: y= volume of towers, m^3.

The variation of the input and modeled values of the volume of bio-towers can be seen in fig(17), which shows the adequacy of this model.

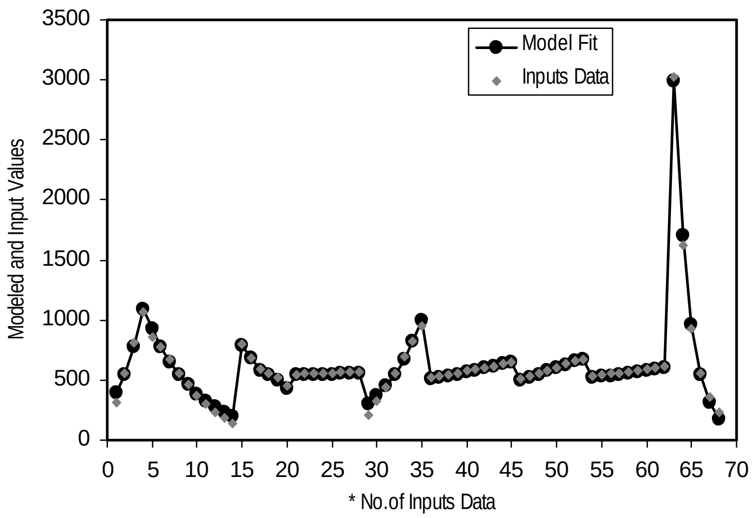


Fig. (17): The Input Versus Modeled of Volume of Bio-tower.

5) Volume of Final Settling Tanks Model:

The value of R^2=0.999 and the value of the standard error of the estimate=1.917.

$$y = 0.035x_1 - 0.01x_2 + 12.809x_3 - 0.016x_4 + 0.003x_5 + 1.007x_6 + 4027.56x_7 + 13.219x_8 - 4189.203$$

Where: y= volume of final settling tanks, m^3**.**

The variation of the input and modeled values of the volume of final settling tanks can be seen in fig(18), which shows the adequacy of this model.

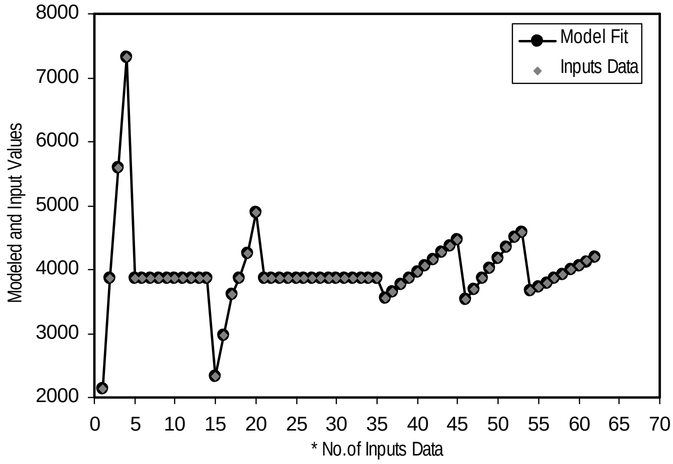


Fig. (18): The Input Versus Modeled of Volume of Settling Tanks for Attach Growth System.

6)Volume of Gravity Thickeners Model:

The value of R^2=0.999 and the value of the standard error of the estimate=3.646.

$$y = 0.008x_1 + 5.945x_2 - 0.648x_3 + 7.253x_4 + 4.245x_5 + 0.237x_6 + 949.561x_7 + 3.11x_8 - 1064.7$$

Where: y= volume of thickeners, m^3**.**

The variation of the input and modeled values of the volume of thickeners can be seen in fig(19), which shows the adequacy of this model.

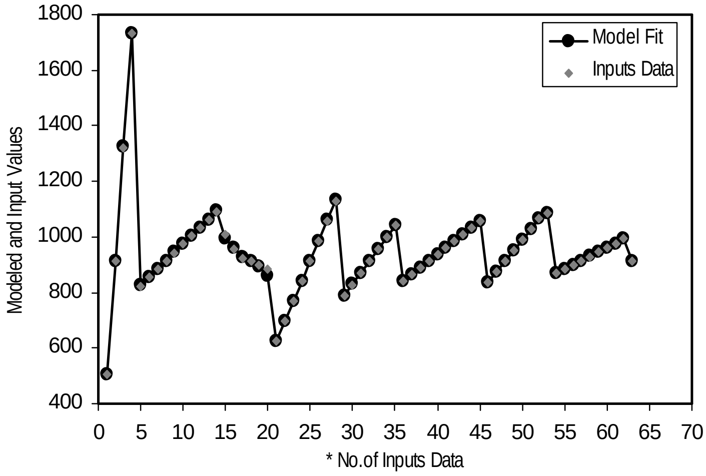


Fig. (19): The Input Versus Modeled of Volume of Sludge Thickener for Attached Growth System.

6) Volume of Anaerobic Digesters Model:

The value of R^2=0.999 and the value of the standard error of the estimate=6.577.

$$y = 0.026x_1 + 10.359x_2 - 1.191x_3 + 12.942x_4 + 7.406x_5 + 0.417x_6 + 1667.297x_7 + 9.895x_8 - 1979.069$$

Where: y= volume of digesters, m^3**.**

The variation of the input and modeled values of the volume of digesters can be seen in fig(20), which shows the adequacy of this model.

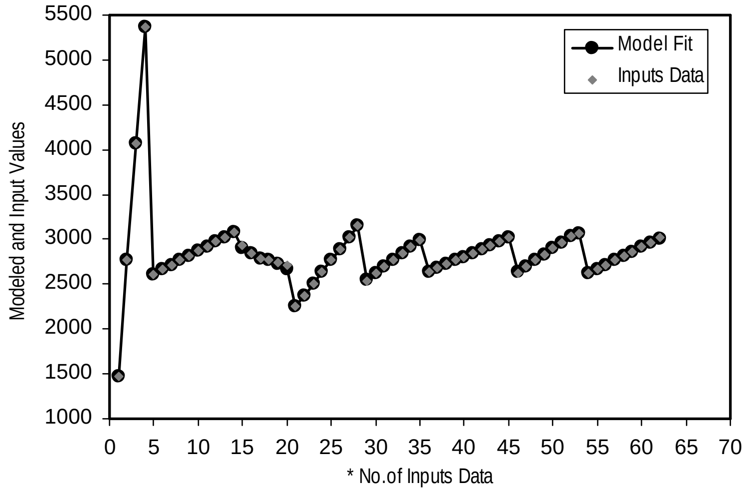


Fig. (20): The Input Versus Modeled of Volume of Sludge Digesters for Attached Growth System.

7) Quantity of Gas Produced Model:

The value of R^2=0.999 and the value of the standard error of the estimate=8.535.

$$y = 0.031x_1 + 13.678x_2 - 1.492x_3 + 16.699x_4 + 9.778x_5 + 0.546x_6 + 2184.79x_7 + 11.636x_8 - 2562.554$$

Where: y= quantity of gas produced, m^3/day**.**

The variation of the input and modeled values of the volume of the quantity of gas produced can be seen in fig(21), which shows the adequacy of this model.

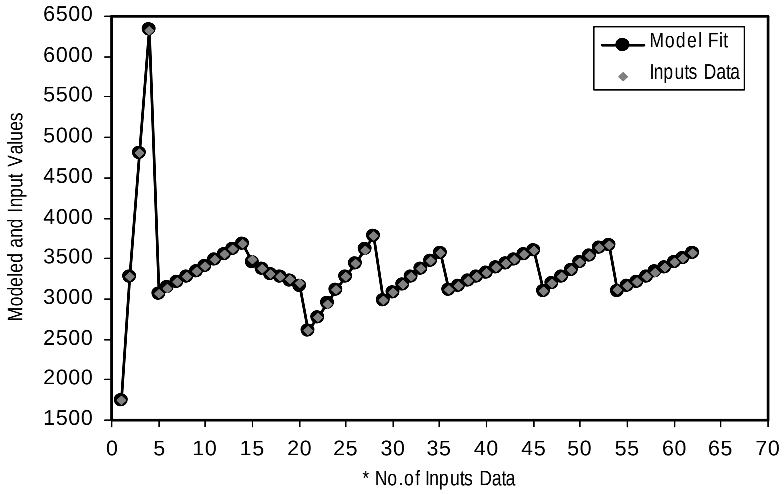


Fig. (21): The Input Versus Modeled of Quantity of Gas Produced for Attach Growth System.

Conclusions:

1. A computer program for the design of attached growth system of wastewater treatment plants which are trickling filters, rotating biological contactor, and

bio-towers was developed with considering the affect of the environmental factors.

2. The most appropriate significant independent variables are:

- **Population:** it is found to be the most significant variable affecting design of all wastewater treatment units for all types of present wastewater treatment plants.
- **Temperature:** it is found to be a significant variable that affecting on the models of volume of biological unit for trickling filters, rotating biological contactors, and bio-towers, quantity of gas produced, and volume of thickeners for trickling filters.
- **Sewage Contribution:** it significantly affects the models volume of final settling tanks for all types of present wastewater treatment plants.
- **Tss production:** it significantly affects the models (volume of thickeners, digesters volume, and quantity of gas generated) for all present wastewater treatment plants.
- **BOD production:** it reliably affects the volume of biological units for (trickling filters, rotating biological contactors, and bio-towers).
- **Area served by network:** it has a significance effects on design requirements.
- **Infiltration rate:** it increases the plant influent flow and decrease the concentration of BOD in the sewage because the infiltration caused by the high water table and defects in the network pipes.
- **Design period:** design periods have a significance effects on design requirements for all types of present wastewater treatment plants.
- **Recirculation ratio:** it is found to be a significant variable on the models of volume of biological units for trickling filters and bio-towers.

Recommendations:

1. Factors affecting the choice of industrial wastewater processes.
2. The environmental effects (gases emissions, insects, odor, pathogenic, noises and other nuisance effects) of each type of treatment.
3. Cost analysis (construction cost) for all units of treatment plant includes liquid system and sludge system with more details of estimating materials and equipments.

References:

1. AL- Turaihy. T.A, 1993 " Factors Affecting the Choice of Sewage Treatment Methods"., MSc. thesis, College of Engineering, Department of Civil Engineering, Baghdad University, April 1993.
2. American Society of Civil Engineers (ASCE) and Water Environment Federation (WEF). Manual of practice no. 8, 1992 "Design and Construction of Urban Storm Water Management Systems". New York: ASCE & WEF.
3. Davies P.S , 2005, "The Biological Basis of Wastewater Treatment", Ph.D. Published by Strathkelvin Ins. Ltd Emil: psd@ Strathkelvin.com.
4. Davis, L.F., 1976, " Factors Affecting Variability from Wastewater Treatment Plants" Progress in water technology, Vol.8, No.1.
5. L. Davis and Susan J. Masten, 2004 "Principles of Environmental Engineering and Science" , Mc Graw Hill, New York.

6. Peavy, Howard .S, Rowe, Donald. R and Techobanoglous G., 1985 "Environmental Engineering " McGraw-Hill, Inc.USA.
7. Qasim S.R., 1985 "Wastewater Treatment Plant, Design, and Operation", New York: Holt Rinehart & Winston.