Simulation and Evaluation Factors Effecting Sizing of Different Types of Wastewater Treatment Plant

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Abstract

A computer program is designed using Visual Basic Software 6.0 for designing different types of wastewater treatment plants. This program deals with different environmental factors that affecting the design of wastewater steps.

The verification between the results of the program and that obtained from hand calculations showed agood agrrement

The relationships between independent and dependent variables are found by multiple non - linear regression analysis. The statistical program "Data Fit version 8.0" is used in the present study.

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

Keywords: Wastewater treatment plants, Biological wastewater treatment.

الخلاصة

تُقدِم هذه الدراسة برنامج حاسوبي مصمم بلغةِ فيجوال بيسكِ 6.0. لتصميم أنواع مختلفة من محطات معالجة مياه الفضلات كذلك يهدف البرنامج إلى تحليلُ العواملَ البيئيةَ المختلفةَ المؤثرة على مراحل تصميمِ محطات المعالجة.

المقارنة بين النَتائِج المستحصلة من البرنامجَ مع نتائج الحساباتِ اليدويةِ أعطت نتائج جيدة.

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

أظهرت الدراسة إن أكثر العوامل أهميه وتأثيراً على تصميمِ 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 **(AL- Turaihy T. A, 1993)**.

The Studied Wastewater Treatment Plants

1- Activated Sludge Process: In this process, wastewater is mixed with a concentrated bacterial biomass suspension (the activated sludge) which degrades the pollutants.

2- Extended aeration: It consists of an aeration with a longer detention time than the conventional activated-sludge process **(AL- layla,1981).**

3- Oxidation ditch: It is an earthen tank of special shape with arrangements for a sufficient supply of oxygen. Raw wastewater is aerated for an extended period of time.

4- Aerated lagoon: The aerated lagoons are suspended growth reactors in earthen basins with no sludge recycle. **(Metcalf and Eddy, 1979)**.

5- Anaerobic ponds: Anaerobic ponds are commonly 2 – 5 m deep and receive wastewater with high organic loads. They normally do not contain dissolved oxygen or algae.

6- Facultative ponds: Facultative ponds (1-2 m deep) are of two types: Primary and secondary facultative ponds. The process of oxidation of organic matter by aerobic bacteria is usually dominant in primary facultative ponds or secondary facultative ponds.

7- Aerobic Ponds: Aerobic ponds also referred to as high-rate aerobic ponds, are relatively shallow with usual depths ranging from 0.3 to 0.6 m allowing light to penetrate the full depth.. **(ASCE,1992)**

The Studied Environmental Factors

1) Population: The wastewater generated 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 in Temperature: The temperature of the sewage is very important 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 T. A, 1993)**. Temperature decreasing may result in a significant decreasing in the soluble (BOD) removing rate **(Davis, L.F., 1976)**.

5) Infiltration / Inflow (In/Iw):In/Iw 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: **S. Davies (2005),** stated that the increasing 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 Syed (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.

Description of Computer Program

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

1. Choose the type of wastewater treatment plant.
2. 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. day, design period= 25 year, growth rate= 3.8 %, the specific domestic BOD_5 in raw sewage flow= 70g/c.day, the specific domestic Tss in raw sewage flow= 90 g/c.day, the temperature= 20 ^oC, the area served by network= 400 hectare, and the infiltration rate= 0.1 l/s.ha).
3. The effluent standards were kept constants values = 40 mg/l, =60mg/l.
4. Determining of 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 (screening and grit chamber).

Note: the steps from(1 to 4) are found in every types of wastewater treatment.

4. Design primary sedimentation tanks (rectangular and circular basins)

Note: this step is found only for the type of treatment that need this treatment like (conventional activated sludge, and oxidation ponds).

5. Design a biological treatment according to it's type as follows:

- Design an aerobic reactors assuming (K_d, Y, θ_c, MLSS, X_r)
- Design an extended aeration assuming (K_d, Y, θ_c, MLSS, X_r)
- Design an oxidation ditch assuming (K_d, Y, θ_c, MLSS, X_r)
- Design an aerated lagoon assuming (K_d, Y, θ_c, X_r)
- Design an anaerobic pond by assuming (temperature T and hydraulic retention time HRT)
- Design an facultative pond by assuming (temperature T and dispersion factor D)
- Design an aerobic pond by assuming (elevation e and energy utilization efficiency E)

6. Design secondary sedimentation tanks (circular basins):
7. Design sludge treatment process

Application of Computer Program for Studying Treatment Plant

The computer program consists of three main parts, which are **(A)** The choice of biological treatment type **(B)** The information base and **(C)** The design calculation modules which contain design requirement as shown in Figs. (1) and (2).

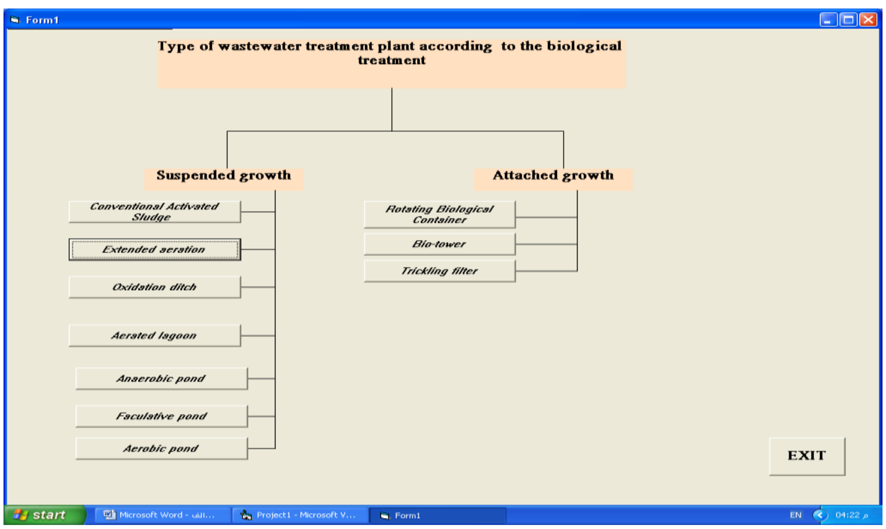

Fig.(1): Different types of Wastewater Treatment Plant of Present Study

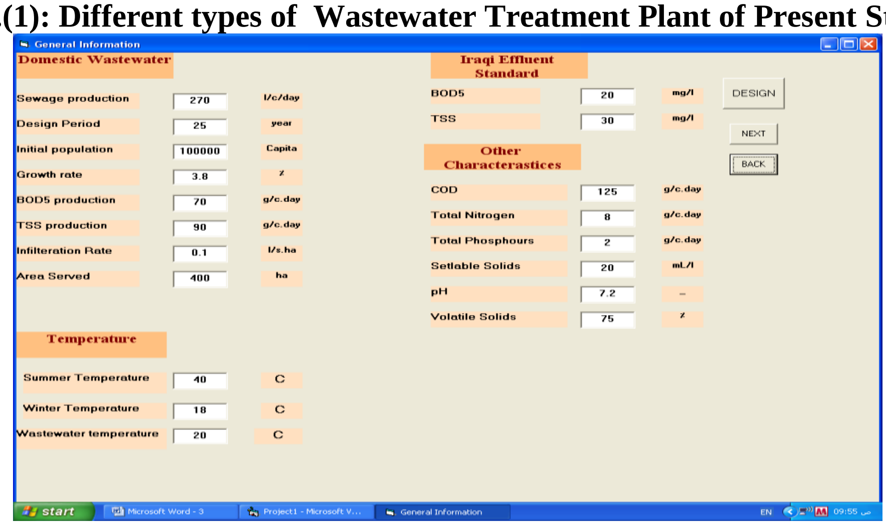

Fig.(2): General Information for Wastewater Treatment Plant

The Regression Analysis Technique

Regression were done by using "Data Fit" program models. The three forms were used for each one of design requirements to investigate which form gives the best fitting of data (i.e. appropriate model). Table (2) show regression models that were proposed and investigated.

Table (2): The Proposed Models

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

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, quantity of total air required for aerobic reactors, and volume of gas production were assumed to be the dependent variables (y).

<u>The Independent Variables (x_k):</u>

The independent variables can be seen in table (3).

Table (3): The Independent Variables

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

Results and Discussions

The result of present study can be seen in table (4).

Table (4): Reasults of Study.

Y	Models	R^2	Stand. Err	Relationship (Fig)
1-Volume (m^3) of:				
●Primary Sedimentation Tanks	$y=0.019x_1 +6.863x_3 +0.539x_6 +2157.51x_7 +7.079x_8 -2244.564$	0.999	1.307	3
●Biological unit for:				
* Conventional Activated Sludge	$y=0.085x_1 +388.671x_2 -8.177x_3 +18.563x_4 +125.306x_5 +2.381x_6 +9567.867x_7 +30.655x_8 -17542.249$	0.990	318.453	4
* Extended Aeration	$y=0.24x_1 +894.704x_2 -16.447x_3 +390.626x_6 +27283.591x_7 +88.24x_8 -45399.04$	0.990	318.453	5

* Oxidation Ditch	$y = 0.336x_1 + 751.73x_2 - 20.993x_3 + 535.716x_5 + 9.732x_6 + 38947.973x_7 + 127.509x_8 - 53857.893$	0.999	157.5 90	6
*Aerated Lagoon	$y = 2.593x_1 + 960.753x_3 + 75.504x_6 + 302051.494x_7 + 991.121x_8 - 314248.998$	0.999	183.0 25	7
* Aerobic Ponds	$y = 3.312x_1 - 367.97x_3 + 95.125x_4 + 95.94x_6 + 384023.99x_7 + 1256.31x_8 - 22109.74$	0.999	1799. 83	8
* Anaerobic Ponds	$y = 0.666x_1 + 247.08x_3 - 0.721x_4 + 19.4x_6 + 77609.607x_7 + 254.692x_8 - 80745.1$	0.999	43.04 6	9
* Facultative Ponds	$y = 8.211x_1 + 11761.05x_2 + 747.26x_3 + 2029.475x_4 + 8688.11x_5 + 259.625x_6 + 1030116.092x_7 + 3529.974x_8 + 249989.204x_{10}$ −158[illegible].247	0.912	63112 .57	10
● Final Settling Tanks for:				
* Conventional Activated Sludge	$y = \exp(1.06E-005x_1 + 0.021x_2 + 0.003x_3 + 0.001x_4 + 0.008x_5 + 0.0003x_6 + 1.474x_7 + 0.006x_8 + 6.982)$	0.971	1739. 669	11
* Extended Aeration	$y = \exp(1.166E-005x_1 + 0.017x_2 + 0.003x_3 + 0.009x_5 + 0.0005x_6 + 1.63x_7 + 0.008x_8 + 7.143)$	0.982	2549. 577	12
* Oxidation Ditch	$y = 0.166x_1 - 4.27x_2 + 58.937x_3 + 4.816x_5 + 5.057x_6 + 17888.42x_7 + 75.289x_8 - 21907.271$	0.991	336.7 95	13
*Aerated Lagoon	$y = 0.44x_1 + 405.068x_2 + 136.604x_3 + 235.451x_5 + 14.032x_6 + 56780.946x_7 + 263.88x_8 - 72377.566$	0.938	2499. 616	14
● Gravity Thickeners for:				
* Conventional Activated Sludge	$y = 0.008x_1 + 9.834x_2 - 0.96x_3 + 8.165x_4 + 3.449x_5 + 0.218x_6 + 872.306x_7 + 2.839x_8 - 1065.754$	0.997	8.954	15
* Stabilization ponds	$y = 0.006x_1 - 0.357x_3 + 7.146x_4 + 0.167x_6 + 666.502x_7 + 2.181x_8 - 666.04$	0.999	2.89	16
● Anaerobic Digesters for:				
* Conventional Activated Sludge	$y = 0.028x_1 + 21.362x_2 - 2.09x_3 + 17.849x_4 + 7.5x_5 + 0.475x_6 + 1904.150x_7 + 10.631x_8 - 2435.935$	0.999	19.45 9	17
* Stabilization ponds	$y = 0.021x_1 - 1.64x_3 + 6.786x_4 + 0.286x_6 + 1137.994x_7 + 8.245x_8 - 506.004$	0.954	92.877 2	18
● Holding Tank for:				
* Extended Aeration	$y = 0.004x_1 + 14.314x_2 - 0.263x_3 + 6.25x_5 + 0.109x_6 + 436.256x_7 + 1.41x_8 - 726.229$	0.997	7.282	19

* Oxidation Ditch	$y = 0.007x_1 + 15.034x_2 - 0.42x_3 + 10.714x_5 + 0.195x_6 + 778.914x_7 + 2.55x_8 - 1077.158$	0.999	3.151	20
*Aerated Lagoon	$y = 0.124x_1 + 46.12x_3 + 3.62x_6 + 14498.11x_7 + 47.57x_8 - 15083.68$	0.999	8.77	21
2- Total Air Required (m3/min) for:				
* Conventional Activated Sludge	$y = 0.005x_1 - 7x_2 - 0.526x_3 + 1.086x_4 + 7.712x_5 + 0.155x_6 + 621.325x_7 + 2.05x_8 - 471.144$	0.996	6.426	22
* Extended Aeration	$y = 0.011x_1 - 13.605x_2 - 0.768x_3 + 17.41x_5 + 0.317x_6 + 1265.802x_7 + 4.183x_8 - 814.638$	0.997	14.771	23
* Oxidation Ditch	$y = 0.021x_1 - 13.428x_2 - 1.352x_3 + 33.446x_5 + 0.623x_6 + 2489.264x_7 + 8.25x_8 - 2181.973$	0.994	39.268	24
*Aerated Lagoon	$y = 0.013x_1 - 21.168x_2 - 0.991x_3 + 21.133x_5 + 0.386x_6 + 1541.046x_7 + 5.124x_8 - 1086.653$	0.993	29.024	25
3- Quantity of Gas Produced (m^3/d) for:				
* Conventional Activated Sludge	$y = 0.027x_1 + 19.844x_2 - 1.937x_3 + 16.482x_4 + 6.963x_5 + 0.439x_6 + 1759.839x_7 + 10.208x_8 - 2262.922$	0.999	18.063	26
* Stabilization ponds	$y = 0.025x_1 - 0.821x_3 + 16.452x_4 + 0.383x_6 + 1533.029x_7 + 9.496x_8 - 1644.918$	0.999	6.733	27

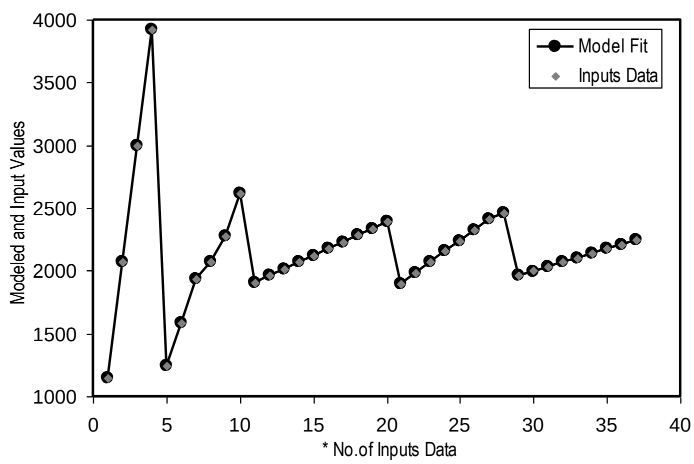

Fig (3): The Input Versus Modeled of Volume of Primary Sedimentation Tanks.

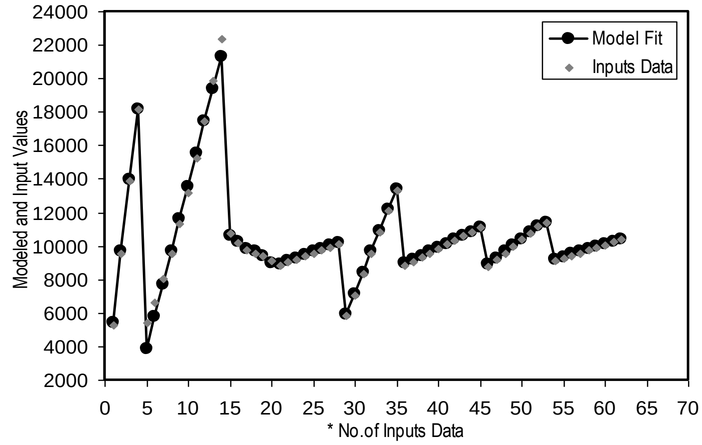

Fig. (4): The Input Versus Modeled of Volume of Aerobic Reactors Basins For Conventional Activated Sludge.

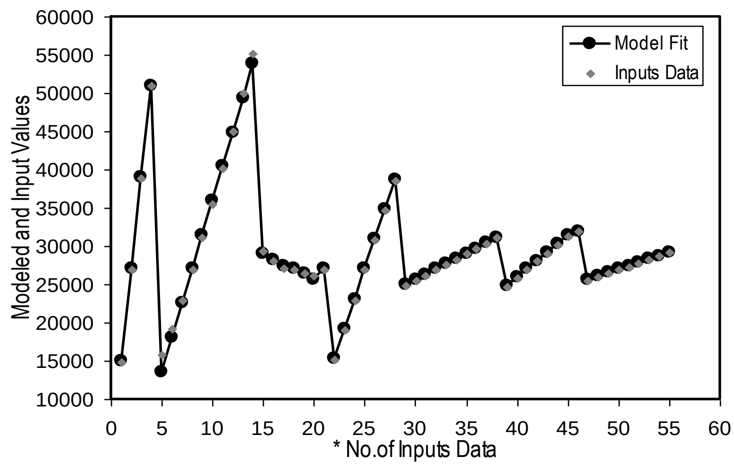

Fig. (5): The Input Versus Modeled of Volume of Extended Aeration Basins.

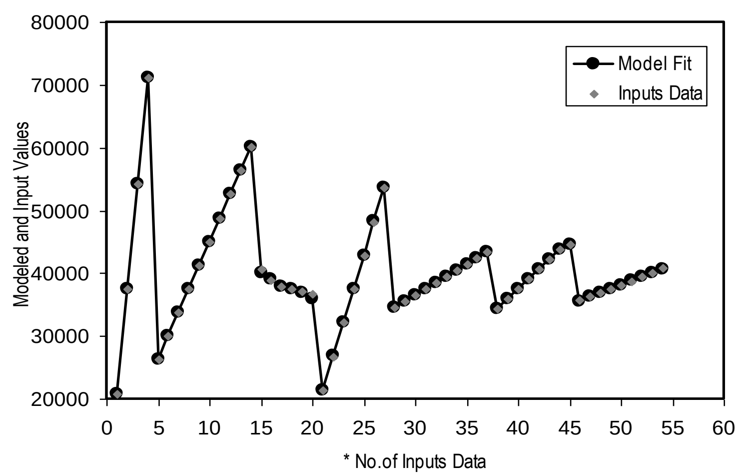

Fig. (6): The Input Versus Modeled of Volume of Oxidation Ditch.

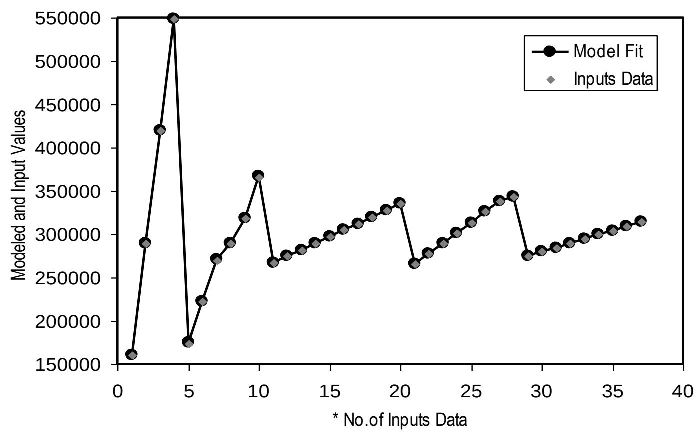

Fig. (7): The Input Versus Modeled of Volume of Aerated Lagoon.

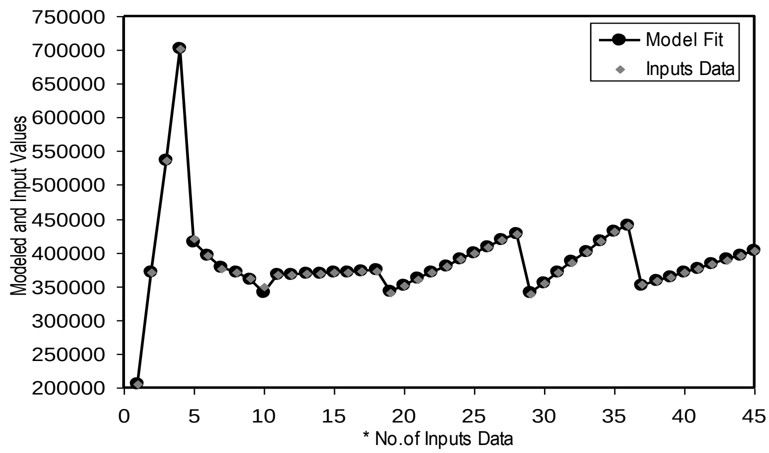

Fig. (8): The Input Versus Modeled of Volume of Aerobic Ponds.

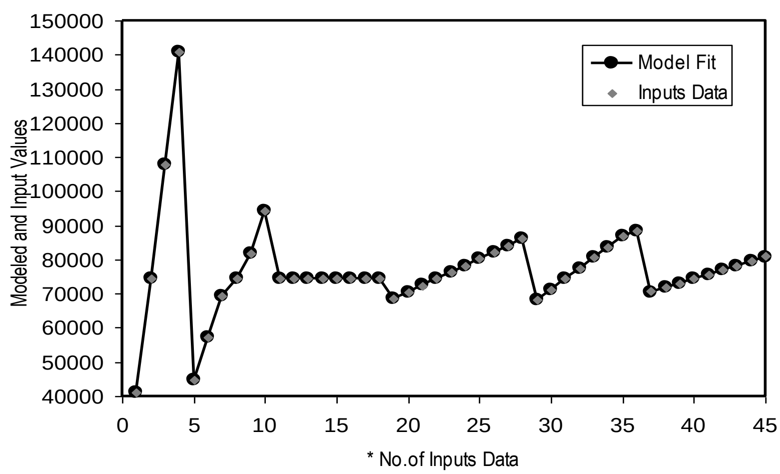

Fig. (9): The Input Versus Modeled of Volume of Anaerobic Pond.

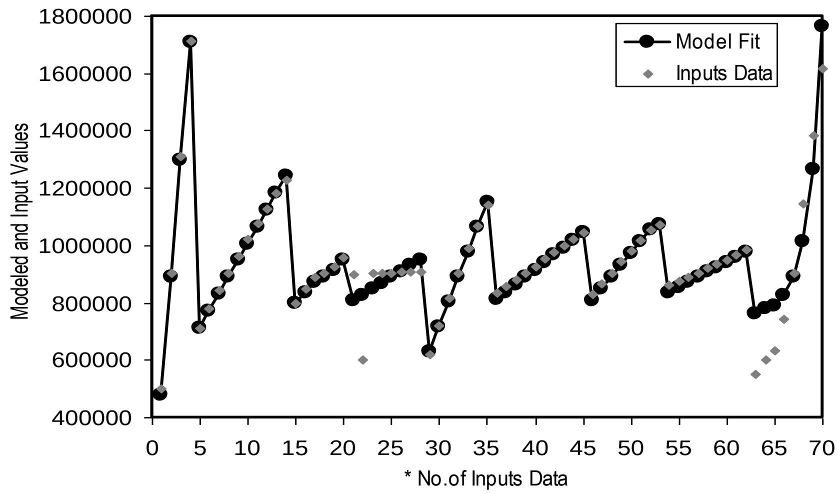

Fig. (10): The Input Versus Modeled of Volume of Facultative Pond.

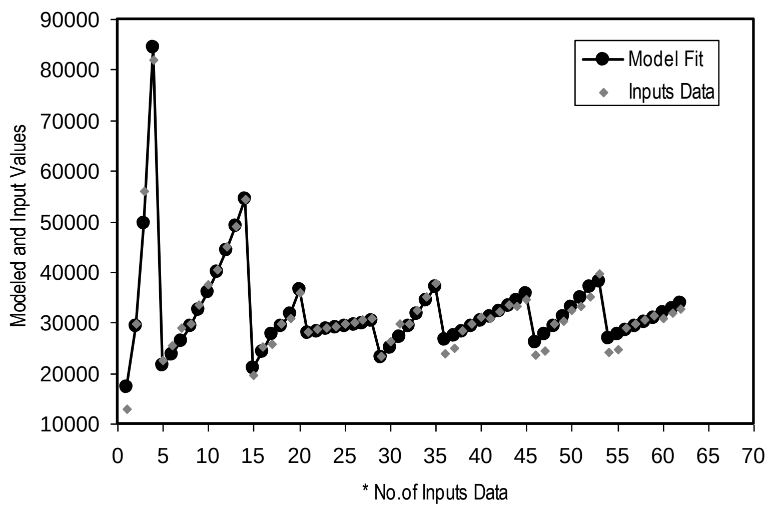

Fig. (11): The Input Versus Modeled of Volume of Settling Tanks for Conventional Activated Sludge.

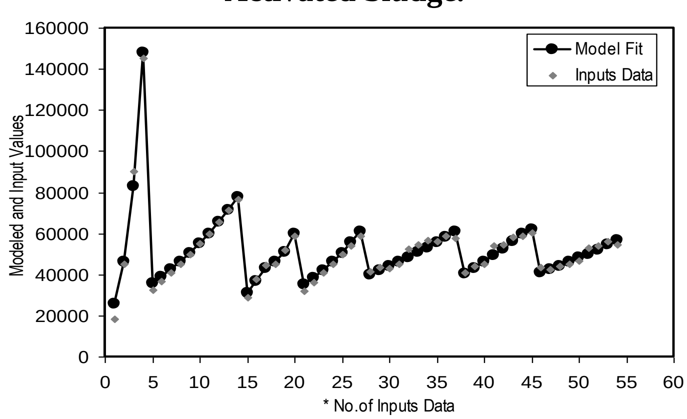

Fig. (12): The Input Versus Modeled of Volume of Settling Tanks for Extended Aeration.

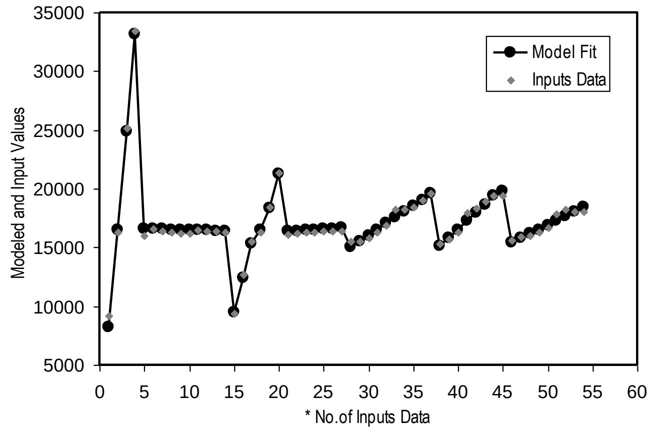

Fig. (13): The Input Versus Modeled of Volume of Settling Tanks for Oxidation ditch.

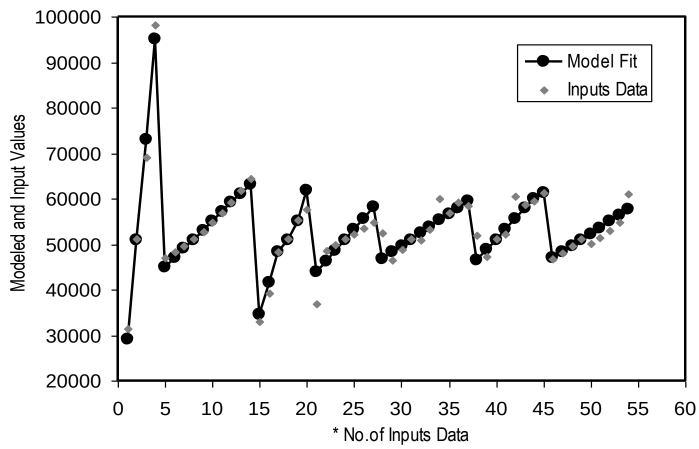

Fig. (14): The Input Versus Modeled of Volume of Settling Tanks for Aerated lagoon.

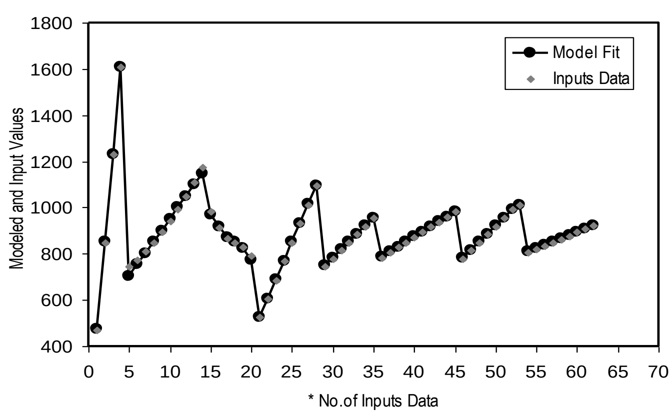

Fig. (15): The Input Versus Modeled of Volume of Sludge Thickeners For Conventional Activated Sludge.

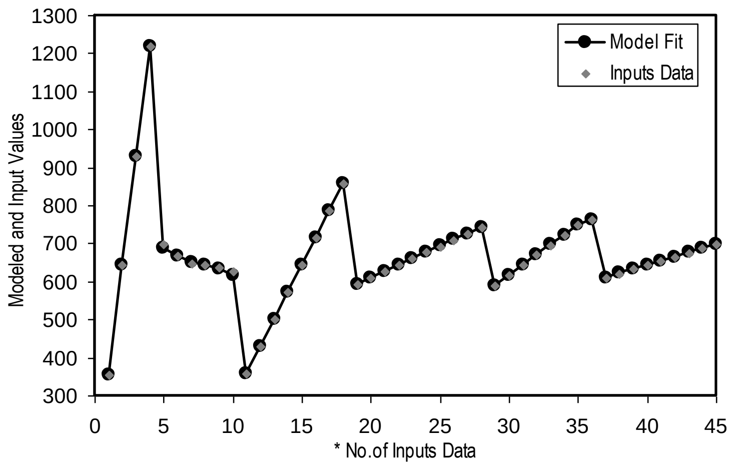

Fig. (16): The Input Versus Modeled of Volume of Sludge Thickeners for Stabilization Ponds.

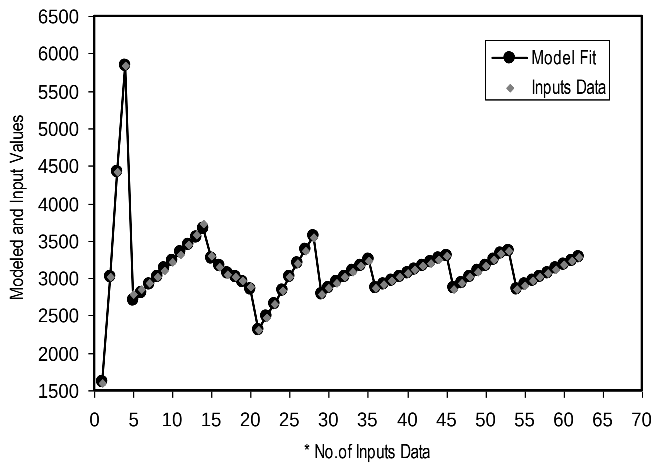

Fig. (17): The Input Versus Modeled of Volume of Sludge Digesters For Conventional Activated Sludge.

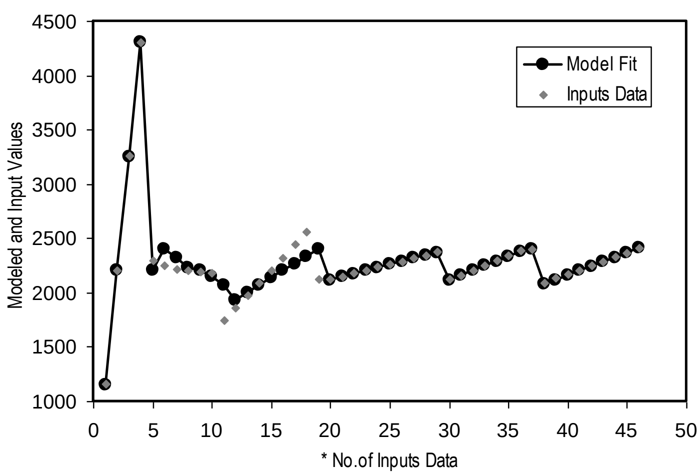

Fig. (18): The Input Versus Modeled of Volume of Sludge Digesters for Stabilization Ponds.

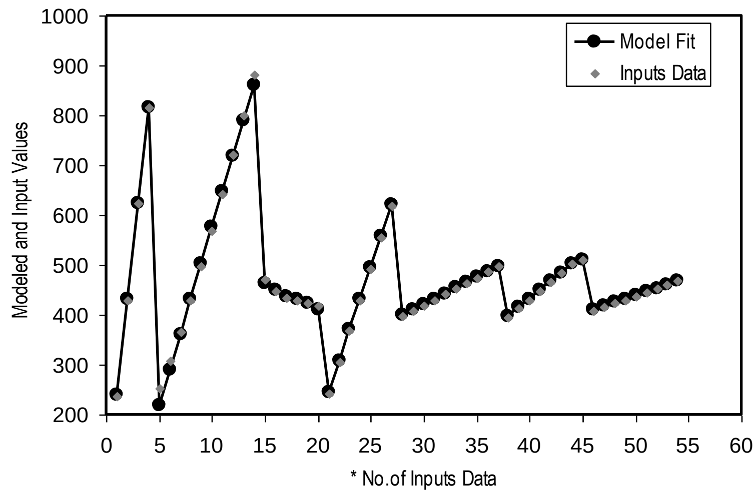

Fig. (19): The Input Versus Modeled of Volume of Sludge Holding Tank for Extended Aeration.

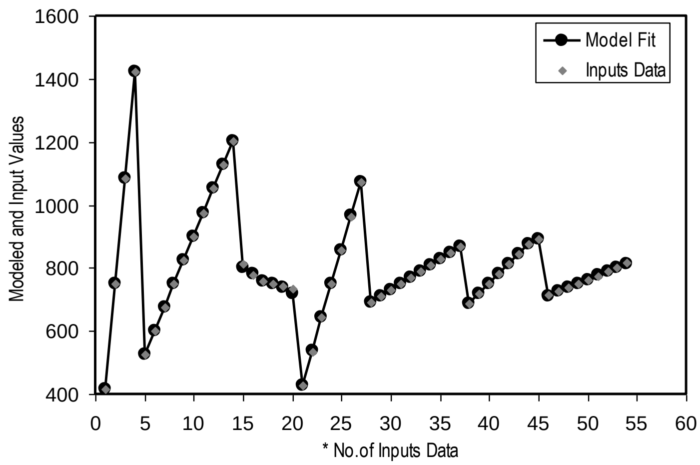

Fig. (20): The Input Versus Modeled of Volume of Sludge Holding Tank for Oxidation Ditch.

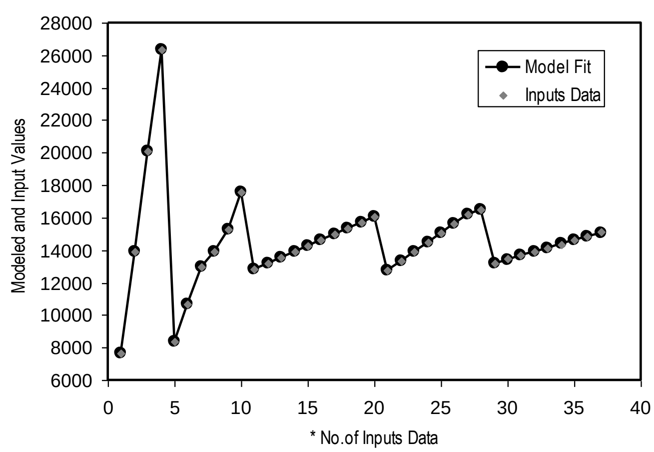

Fig. (21): The Input Versus Modeled of Volume of Sludge Holding Tank for Aerated lagoon.

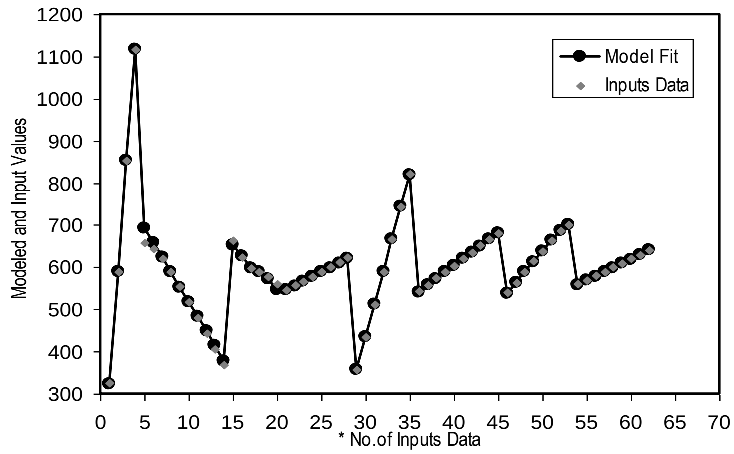

Fig. (22): The Input Versus Modeled of Volume of Total Air Required for Aeration Process for Conventional Activated Sludge.

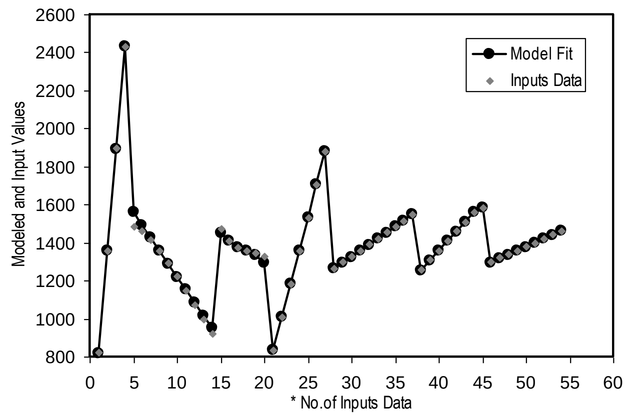

Fig. (23): The Input Versus Modeled of Volume of Total Air Required for Aeration Process for Extended Aeration.

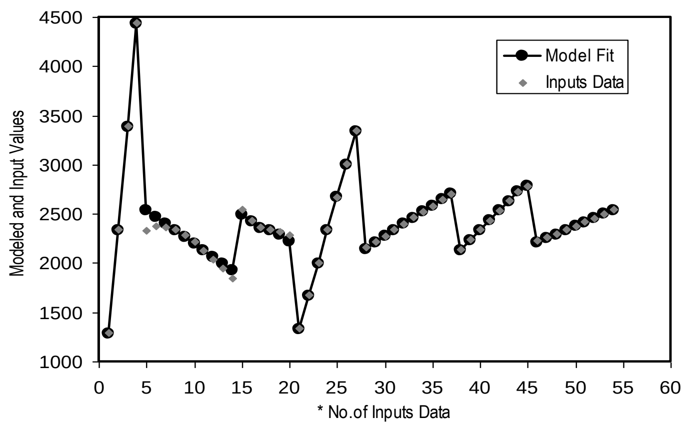

Fig. (24): The Input Versus Modeled of Volume of Total Air Required for Aeration Process for Oxidation Ditch.

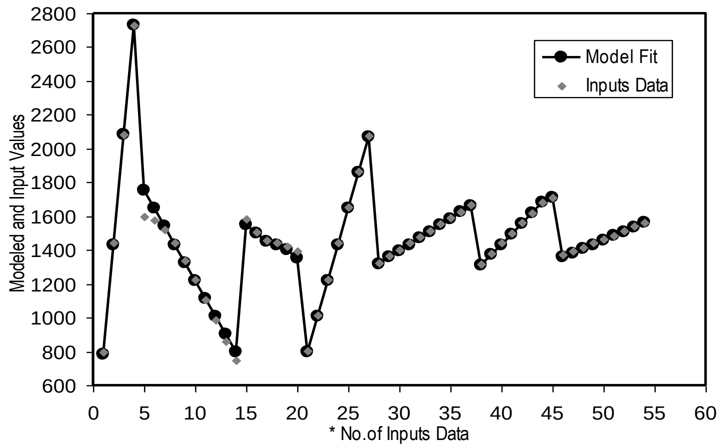

Fig. (25): The Input Versus Modeled of Volume of Total Air Required for Aeration Process for Aerated Lagoon.

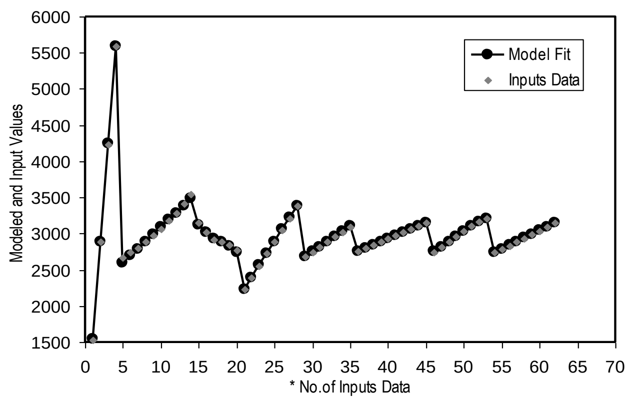

Fig. (26): The Input Versus Modeled of Quantity of Gas Produced for Conventional Activated Sludge.

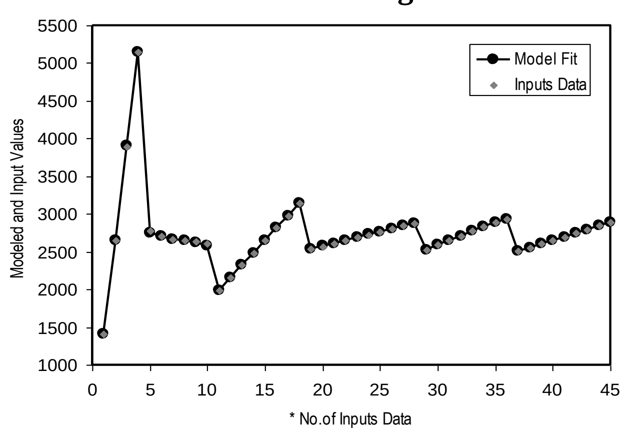

Fig. (27): The Input Versus Modeled of Quantity of Gas Produced for Stabilization ponds.

Conclusions

1. A computer program for the design of different types of wastewater treatment plants 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 (conventional activated sludge, extended aeration, oxidation ditches, and facultative ponds), quantity of total air required for aeration process for plants that need aeration, quantity of gas produced, and volume of thickeners for conventional activated sludge.
- **Sewage Contribution:** it significantly affects the models volume of settling tanks and volume of aeration basins 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 that found in it.
- **BOD production:** it reliably affects the volume of biological units for (conventional activated sludge, extended aeration, oxidation ditches, and facultative ponds), volume of total air required for all present wastewater treatment plants, and volume of holding tank for plants that need it.
- **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.

Recommendations

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

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