Effect of Environmental Factors on Design of Wastewater Treatment Plant

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Abstract

An interactive computer program by Visual Basic Language 6.0 has been written that using for designing conventional activated sludge wastewater treatment plants, also, this program deals with the different environmental factors that affecting the design of wastewater steps.

The results of the study were verified with there results obtained from hand calculations procedures. The verification showed agood agrrement between program results and hand calculation results.

Multiple non-linear regression analysis was employed by using "Data Fit" program to find the relationships between independent and dependent variables. Independent variables include population, temperature, sewage contribution per person, BOD and TSS concentrations, and area served by network. While dependent variables were considered as (volume of treatment units, volume of air required, quantity of sludge produces, and quantity of gas generated from digestion process).

The population was found to be the most significant variable affecting design of all wastewater units. The sewage contribution per capita was found to be the most significant variable in the following models (volume of settling tanks, volume of aeration basins, quantity of sludge produced). And the temperature was significantly affects the models of (volume of reactors, quantity of total air required for aeration, quantity of sludge produced, quantity of gas produced, and volume of thickener units).

The BOD concentration was found to have a reliable impact on the (volume of reactor units, volume of total air required, quantity of sludge produces, and quantity of gas generated from digestion process). While the TSS concentration was found to be significant variable on the models (quantity of sludge produces, quantity of gas generated, volume of thickeners, digesters volume). Finally, area served by network factor has a very small influence on design requirements.

Keywords: Wastewater treatment plant, Activated sludge process.

الخلاصة

إن الهدف منْ الأطروحةُ الحاليةُ هو بناء برنامجُ حاسبةٍ َبلغةِ فيجوال بيسكِ 6.0 والذي يُمْكِنُ المصممين من تَصميم محطةِ معالجة مياه الفضلاتِ باستخدام طريقة الحمأةِ المُنَشَّطةِ، كذلك يهدف البرنامج إلى تحليلُ العواملَ البيئيةَ المختلفةَ المؤثرة على تصميمِ محطةِ المعالجة ، والتي تَشْمُلُ على وحدات المعالجة التمهيدية, الابتدائية, الثانويةِ ، ومراحل معالجة الخبث الناتجِ.

تم اختبار صلاحيةِ النماذجَ المستخرجة بإجراء مقارنة بين نَتائِجِ البرنامجَ مع النَتائِجِ الناتجة من الحساباتِ اليدويةِ لأكثر عاملين أهمية وتأثيرا وهما (عدد السكانَ و مساهمة الشّخص الواحد لمياه الفضلات) باستعمال معادلةِ التحديدِ والتي أعطت نتائج جيدة.

تم استخدام طريقة التحليل الانحدار اللاخطّي المتعدّد باستعمال برنامج الإحصائي "Data Fit" (1995 – 1998) لإيجاد العِلاقاتِ الإحصائية بين عدد من المتغيرات المستقلةِ والمتغيرات المعتمدة. وتشمل المتغيرات المستقلة كل من (عدد السكان المنطقة المخدومةَ، درجة حرارة الفضلات، مساهمة الشّخص لمياه الفضلات الواحد، تركيز كل من and BOD TSS، ومساحة المنطقة المخدومة بالشبكة المجاري) بينما المتغيرات المعتمدة التي أخذت بعين الاعتبار هي (حجم وحداتِ المعالجةِ، حجم الهواءِ المطلوبَ، كمية الخبث الناتج، وكمية الغازِ المتولدة مِنْ عمليةِ الهضمِ). أظهرت الدراسة إن أكثر العوامل أهمية وتأثيرا على تصميمِ محطة معالجة مياه الفضلاتِ هو عدد السكان، أما مساهمة الشّخص لمياه الفضلات من المتغيّرَات المؤثرة على نماذجِ التاليةِ (حجم وحدات المعالجة الحياتية، كمية الهواء اللازم للتهويةِ، كمية الخبث الناتج). وكانت درجة الحرارة تؤثر بشكل ملحوظ على نماذجِ كل من (حجم وحدات المعالجة الحياتية، كمية الهواء اللازم للتهويةِ، كمية الخبث الناتج، كمية الغازِ المنبعث، وحجم وحداتِ مركزات الخبث). اما تركيز المواد العضوية أوBOD وُجِدَ انه يؤثر على (حجم وحدات المعالجة الحياتية، كمية الهواء اللازم للتهويةِ، كمية الخبث الناتج، كمية الغازِ المنبعث مِنْ عمليةِ الهضمِ). بينما تركيز المواد الصلبة او TSS فيؤثر على كل من نماذجِ (كمية الخبث الناتج، كمية الخبث الناتج، وحجم وحداتِ مركزات و هاضمات الخبث). أخيراً، عامل مساحة المنطقة المخدومة بشبكة المجاري وجد أن لَيْسَ لَها تأثير هام وان تأثيرها قليل جدا على متطلباتِ التصميمَ.

Introduction

The purpose of wastewater treatment plants is to prepare controlled conditions to remove suspended and soluble materials, treatment of biodegradable organic, separate pollutions such as solid particles, floating material, organic material from the wastewater before it is returned to the recipients (i.e. water resources), and elimination of pathogenic organisms.

Wastewater treatment plant is a complex dynamic process influenced by many uncertain factors, which are been complicate and extensive such as loading and biomass composition, population, organic loads, temperature, area served by network, pH, and others, thus the control of the treatment process is very complex, because of the large number of variables that can affect it. **(AL- Turaihy T. A, 1993)**.

Definition of Wastewater:

Wastewater may be defined as a combination of the liquid carrying wastes removed from residences, institutions, and commercial and industrial establishments, together with such groundwater, surface water, and storm water as may be present. Generally, wastewater comprises of 99.9 % water and 0.1 % solids and is organic because it consists of carbon compounds like human waste, paper, vegetable matter, etc. **(Qasim S., 1985)**.

The nature of wastewater includes physical, chemical, and biological characteristics which depend on the water usage in the community, the industrial and commercial contributions, weather, and infiltration/inflow. Table (1) shows typical concentration ranges for various constituents in untreated domestic wastewater **(Metcalf and Eddy, 2003)**.

Table (1): Typical Composition of Untreated Domestic Wastewater (After Metcalf and Eddy, 2003)

Contaminants	Unit	Concentration		
		Weak	Medium	Strong
Total solids (TS)	mg/L	350	720	1200
Total disolved solids (TDS)	mg/L	250	500	850
-Fixed	mg/L	145	300	525
-Volatile	mg/L	105	200	325
Suspended solids	mg/L	100	220	350
-Fixed	mg/L	20	55	75
-Volatile	mg/L	80	165	275
Settleable solids	mL/L	5	10	20
BOD_5, 20ºC	mg/L	110	220	400
TOC	mg/L	80	160	290
COD	mg/L	250	500	1000
Nitrogen (total as N)	mg/L	20	40	85
Organic	mg/L	8	15	35
Free ammonia	mg/L	12	25	50
Nitrites	mg/L	0	0	0
Nitrates	mg/L	0	0	0
Phosphorus (total as P)	mg/L	4	8	15
Organic	mg/L	1	3	5
Inorganic	mg/L	3	5	10
Chlorides	mg/L	30	50	100
Sulfate	mg/L	20	30	50
Alkalinity (as CaCO3)	mg/L	50	100	200
Grease	mg/L	50	100	150
Total coliforms	No/100 ml	10^6-10^7	10^7-10^8	10^7-10^9
Volatile organic compound	µg/L	<100	100-400	>400

The rates of sewage flow, the characteristics, and concentration of impurities in the wastewater vary widely throughout the day as shown in Fig. (1) **(Metcalf and Eddy, 1979)**.

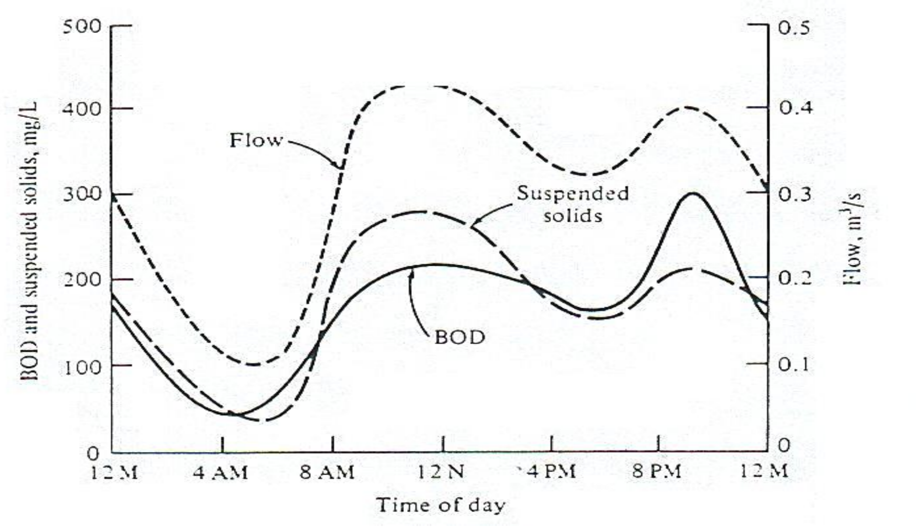


Fig. (1): The Relation between Flow Variation, BOD Variation and S.S Variation with Time (After Metcalf and Eddy, 1979)

Equations (1, 2 and 3) represents the peaking factor (M_1) (Harmon Formula) is the ratio of peak flow to average design flow ($Q_{avg.}$) which is calculated as Eq. (1) and Eq. (4) represents the ratio of and minimum to average flows (M_2) **(Metcalf and Eddy, 1979):**

$$Q_{avg} = P_f \times \mu_o \quad (1)$$

$$M_1 = 1 + \frac{14}{4 + \sqrt{P}} \quad (2)$$

And;

$$M_1 = \frac{4.0}{P^{1/6}}.n \quad (3)$$

Where;

n = factor depends on climate change, in normal conditions n values are (1.2 – 1.4), and *P* = population in thousands

Therefore Eq. (3) can arrange to:

$$M_1 = \frac{4.8}{P^{1/6}} \quad (4)$$

Also, ratio of minimum flow rate to average flow rate is calculated by equation:

$$M_2 = 0.2P^{1/6} \quad (5)$$

Where;

$Q_{avg.}$ = average design flow, m^3/d

P_f = future population, capita

μ_o = specific sewage production, l/c/d

M_1 = the ratios of peak flow to average flow

M_2 = ratio of minimum flow to average flow rate.

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 it is necessary) , and
5- Sludge treatment processes. As shown in Fig. (2):

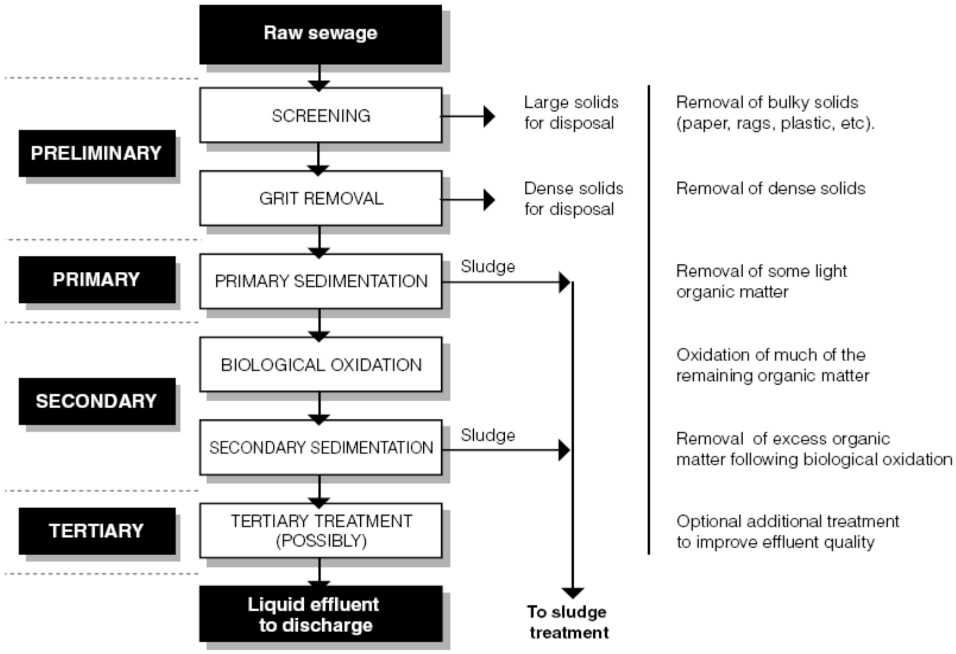


Fig. (2): Typical Stages in the Conventional Sewage Treatment Plant

The Studied Environmental Factors:

1) Variation in Raw Waste Load (RWL)

Variation in raw waste load, such as organic concentration and presence of toxic materials, may affects design of wastewater treatment works. **Robert and Stanley (1976)**; studied the response of activated sludge process to shock organic load. They found a quick response, quick increase in effluent (BOD_5) and (S.S) concentrations, of activated sludge process to input organic concentration changes. **James, (1998) and Pinheiro *et al.* (2002)**; showed that the effects of presence of toxic materials on performance of activated sludge process. These materials, even in low concentration, will kill the bacterial mass, which results in upset in the performance of activated sludge process.

2) Population

The wastewater generated depends upon the population and per capita contribution of wastewater. Predicting the dynamic of human population is important in design treatment works because it is the bases for the determination of deign capacity for municipal water and wastewater treatment systems and for waste reservoirs **(Masten and Davis, 2004).** The design population is multiplied by the appropriate capacity factor taken from Table (2) which is used to make allowances for population variation, changes in sewage characteristics, and unusual peak flows.

Table (2): Capacity Factors (After Donald L. Basham 2004)

Effective Population	Capacity factor
5000 or less	1.50
10000	1.25
20000	1.15
30000	1.10
40000	1.05
50000 or more	1.00

3) Per Capita Sewage Contribution

Unless satisfactory justification can be given for using a lower or higher per capita flow, 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)**.

4) Organic Loadings and Total Solids Concentrations

The strength (organic content) of a wastewater is usually measured as 5-days biochemical oxygen demand (BOD_5), and total suspended solids. The BOD_5 of raw domestic wastewater in the U.S is normally between 100 and 300 mg/L and the TSS of raw domestic wastewater in the U.S is normally between 200 and 400 mg/L. **Davis and Masten, (2004).**

5) Variation in Temperature

The temperature of the sewage is very important in assessing the overall efficiency of a biological treatment process. The activity of bacteria increases seven times for every 5^0 C rise in temperature. The time required for anaerobic stabilization depends on the temperature. Temperature with loading level below 0.23 kg BOD per day per 0.46 MLSS has no effect on process performance, increasing the loading, results in an increasing temperature effect on reaction rate. In addition, he reported that the required volume of reactor depends on temperature **DR. Holfeder (1980).**

6) Infiltration / Inflow (I / I)

Inflow means water other than wastewater that enters a sewer system from sources such as roof leaders, foundation drains, manhole covers, cross connections between storm sewers and sanitary sewers, and other drainage structures.

Infiltration means water other than wastewater that enters the sewer system from the ground through defective pipe, joints, and manholes.

Description of Computer Program:

The program is written by using Visual Basic 6.0 language. The flow chart of the program used is shown in Fig. (3). The steps of the program are as follows:

1- The input data that required running the computer program, these data are assumed as follows:

a- Initial Population, (P_o) : 100000 capita
b- Specific sewage production, (μ_o) : 270 l/c. day
c- Design period, (t_f) : 25 year
d- Growth rate, (r_g) : 3.8 %
e- The specific domestic BOD_5 in raw sewage flow, (B_i): 70 g/c.day
f- The specific domestic S.S in raw sewage flow, (S_i) : 90 g/c.day
g- The temperature, (T) : 20 ^oC

h- The area served by network, (A) : 400 hectare, and
i- The infiltration rate, (i) : 0.1 l/s.ha

2- The effluent standards were kept constants values B_e = 40 mg/l, and S_e = 60 mg/l.

3- Determining of future population (P_f), peaking factor (f), total average flow rate (Q_{avg}), peak flow rate (Q_p), minimum design flow rate (Q_m), organic load and solids concentrations (BOD and TSS), then design **STEP A** (Preliminary treatments).

4- **STEP A** Design screening chamber. Input data include maximum velocity through bar rack, bar spacing, bar width, and bar shape factor.

5- Design grit chamber to determine volume of grit chambers, dimensions, and quantity of theoretical air supply.

6- **STEP B** Design primary sedimentation tanks (rectangular and circular basins) by assuming values of surface overflow rate SOR, detention time, weir loading for determining volume of the basins, dimensions, actual SOR, primary sludge characteristics.

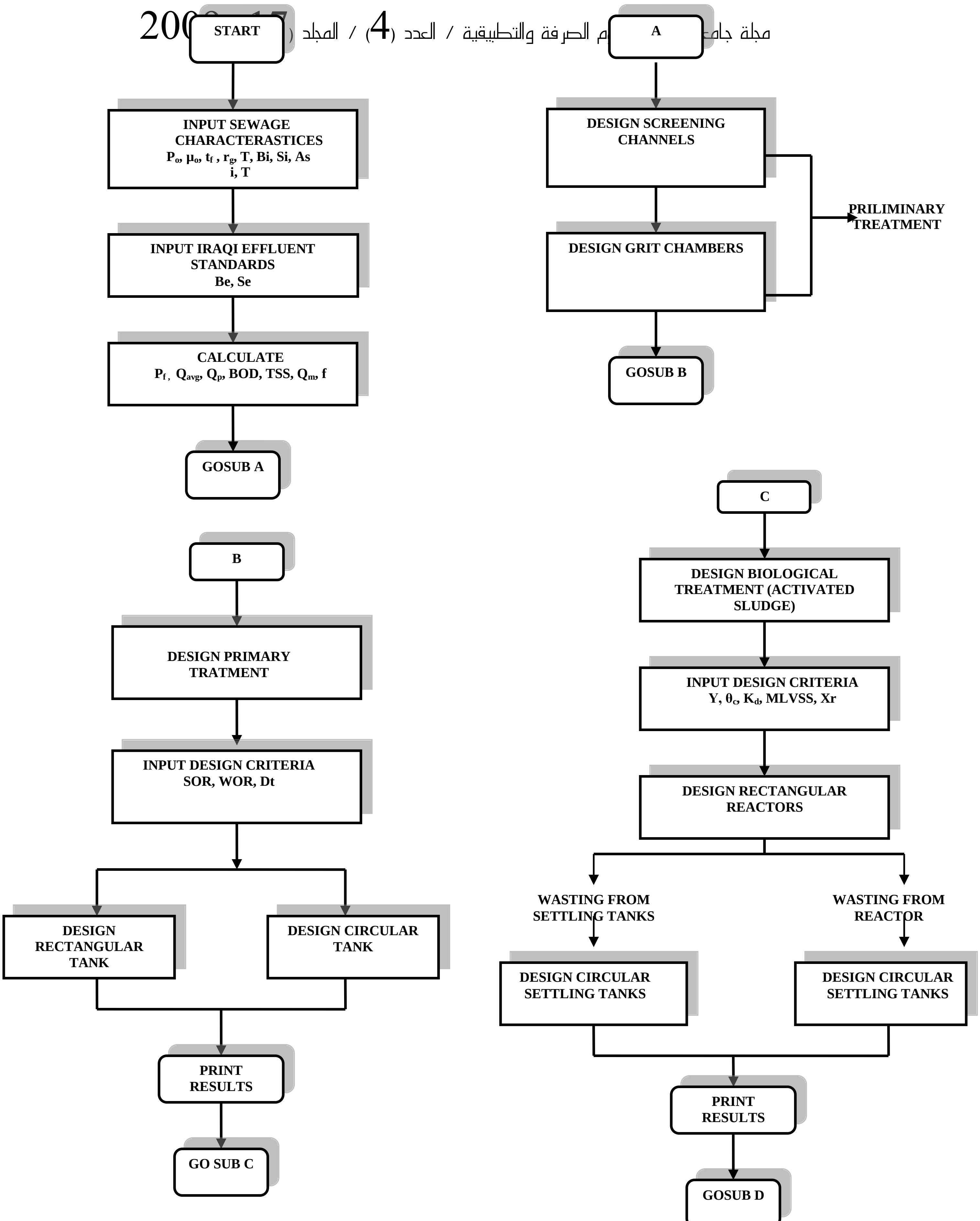
7- **STEP C** Design an aerobic reactors , assuming that tha values of (K_d, Y, $\theta_{c,}$ MLVSS, X_r).

8- **STEP D** Design sludge treatment process for treating (primary sludge and activated wasted sludge that wasting from settling tanks), these processes include sludge thickening, anaerobic digestion, and drying beds .

9- Repeat the design procedures from step No. 1 to step No. 8 for each different factors. These factors ranged between two limits (lower limit and upper limit) by a specific increment as shown in Table (3).

Table (3): Values of Characteristics of Sewage as used in program of Present Study

Characteristics	Units	Limits		
		Lower	Upper	Increment
Population	Capita	100000	200000	10000
Specific sewage production	L /c. day	150	350	20
Area served by network	Hectare	50	1000	100
Specified BOD production	g/c. day	40	90	10
Specific domestic S.S	g/c. day	50	100	10
Temperature	^{0}C	10	50	10


START
INPUT SEWAGE CHARACTERASTICES
Po, μo, tf , rg, T, Bi, Si, As
i, T
INPUT IRAQI EFFLUENT STANDARDS
Be, Se
CALCULATE
Pf , Qavg, Qp, BOD, TSS, Qm, f
GOSUB A
A
DESIGN SCREENING CHANNELS
DESIGN GRIT CHAMBERS
PRILIMINARY TREATMENT
GOSUB B
B
DESIGN PRIMARY TRATMENT
INPUT DESIGN CRITERIA
SOR, WOR, Dt
DESIGN RECTANGULAR TANK
DESIGN CIRCULAR TANK
PRINT RESULTS
GO SUB C
C
DESIGN BIOLOGICAL TREATMENT (ACTIVATED SLUDGE)
INPUT DESIGN CRITERIA
Y, θc, Kd, MLVSS, Xr
DESIGN RECTANGULAR REACTORS
WASTING FROM SETTLING TANKS
WASTING FROM REACTOR
DESIGN CIRCULAR SETTLING TANKS
DESIGN CIRCULAR SETTLING TANKS
PRINT RESULTS
GOSUB D

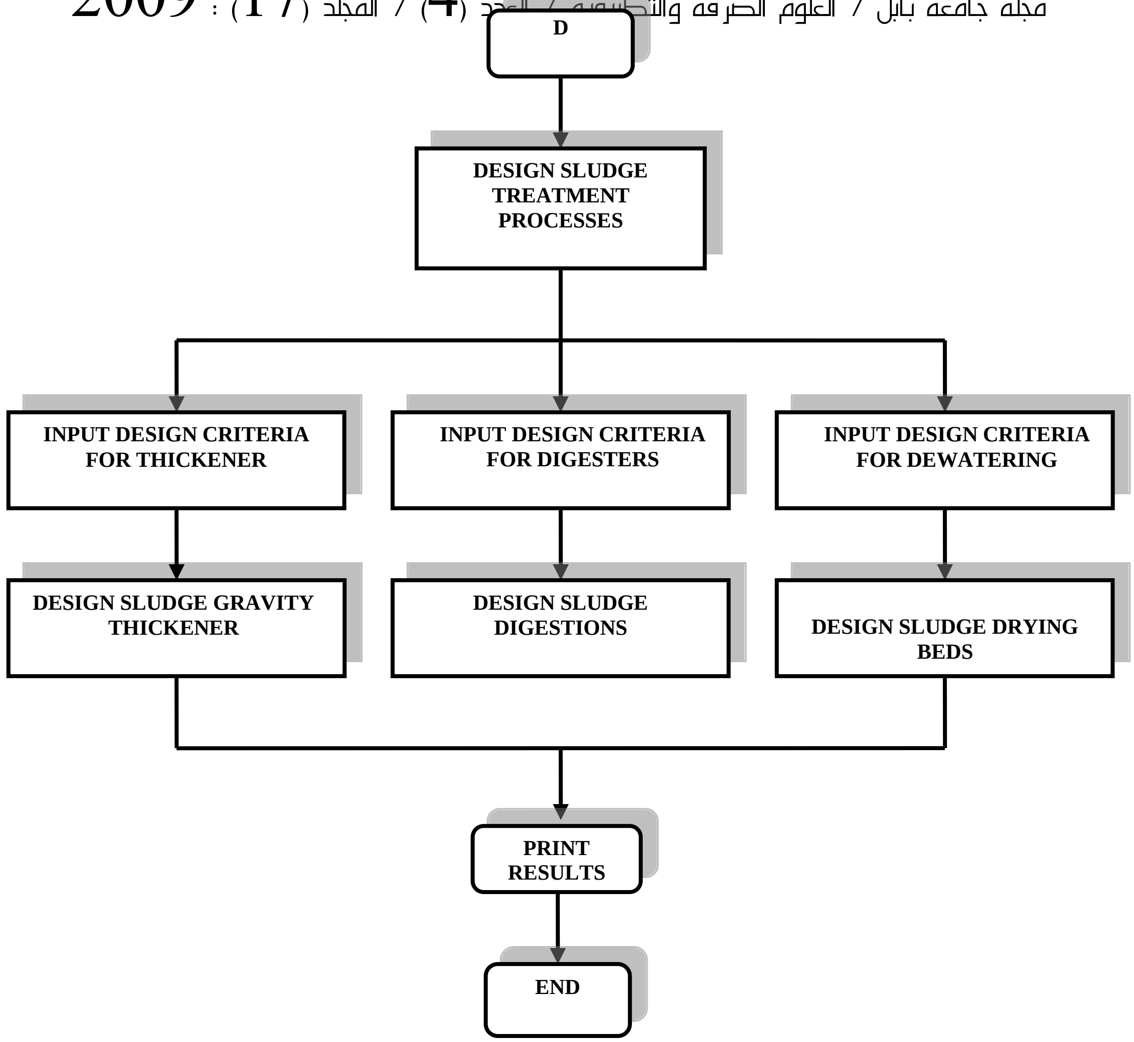


Fig.(3): Flowchart for Computer Program of Designing Conventional Activated Sludge Treatment Plant in The Present Study

Application of Computer Program for Study Treatment Plant:

The computer program is divided into two main parts, which are part **(A)**which is the information base which are include design period, growth rate, initial population, sewage characteristics as shown in Fig. (4). And part **(B).** The design calculation modules which contains design requirement as shown in Figs. (5), and (6).

Once all design data are entered, user can click the "DESIGN" button and the result automatically appeared. At the first page, the outputs are consisting of average and peak flow rate as shown in Fig. (3-3). Then, user can go to the next pages by clicking on the "Next" button. The steps should be followed for other pages similar with the first page until final design.

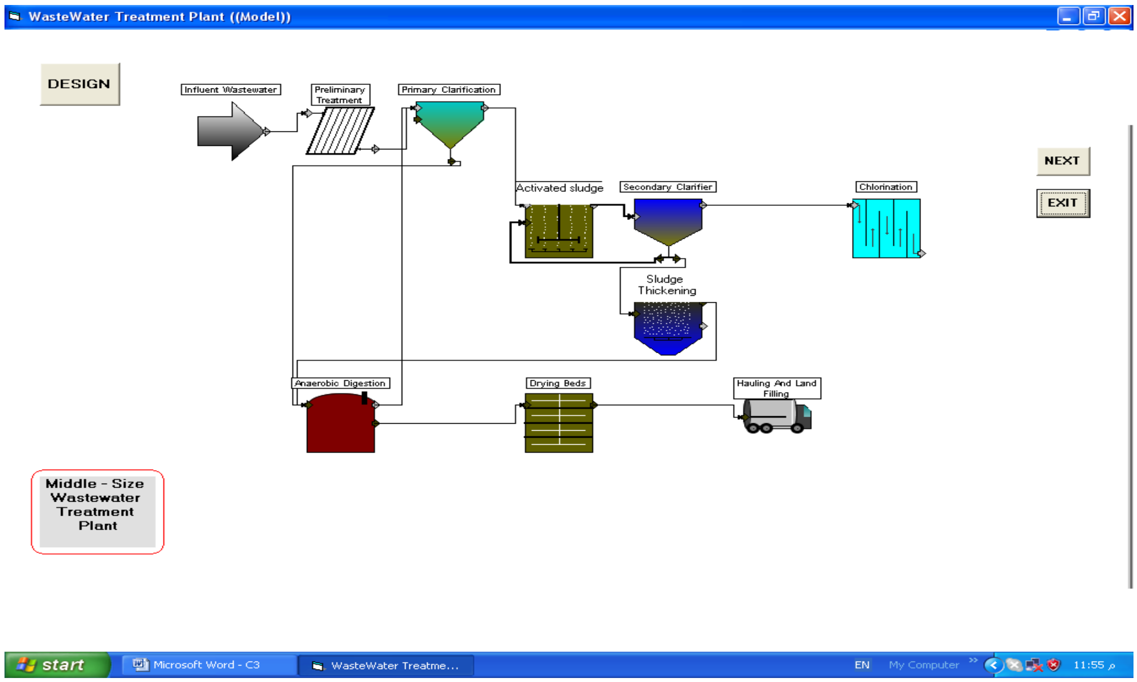


Fig. (4): Conventional Wastewater Treatment Plant of Present Study

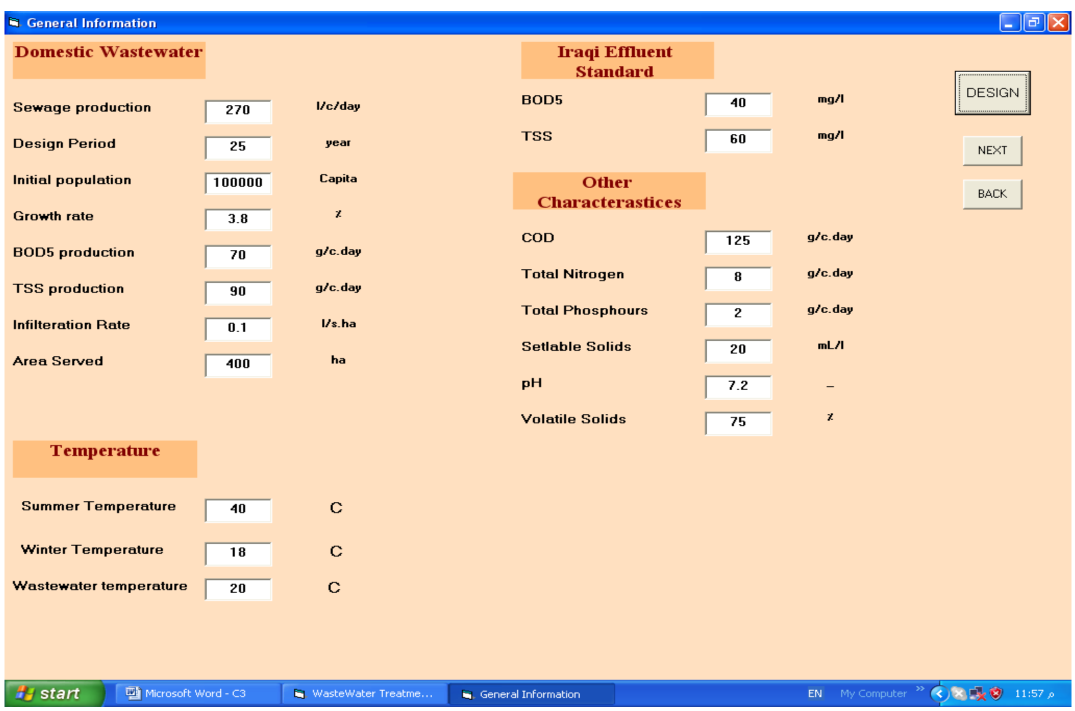


Fig. (5): General Information for Wastewater Treatment Plant

The Regression Analysis Technique:

Wastewater treatment plants are large non – linear systems subject to perturbations in flow and load, together with uncertainties concerning the composition of the incoming wastewater (Alex and Jeppsson 1999, and Yoo *et. al* 2000).

Multiple non-linear regression were done by using "Data Fit" program models in 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 (4) show regression models that were proposed and investigated.

Table (4): The Proposed Models

No.	Equation Description
A	$Y = b_1 X_1 + b_2 X_2 + ... + b_k X_k + G$
B	$Y = \exp(b_1 X_1 + b_2 X_2 + ... + b_k X_k + G)$
C	$Y = b_1 X_1 + b_2 X_2 + ... + b_k X_k$

Where;
Y = dependent variables; $X_1, X_2, ..., X_k$ = the independent variables, and $b_1, b_2, b_3, ...b_k$ = are model coefficients, and G is model constant term.

The Dependent Variables (Y_s)

Description
1- Volume of primary sedimentation tanks, m^3
2- Volume of aerobic reactors, m^3
3- Volume of total air required, m^3/min
4- Volume of final clarifiers, m^3
5- Volume of sludge gravity thickeners, m^3
6- Volume of sludge anaerobic digesters, m^3
7- Volume of sludge produced, kg/day
8- Quantity of gas produced, m^3/day

The Independent Variables (X_s)

Variables	Description
X_1	Population factor, capita
X_2	Temperature, ºC
X_3	Specific sewage production, l/c.d
X_4	BOD production, g/c.d
X_5	TSS production, g/c.d
X_6	Area served by network, ha

Results and Discussions

1) Volume of Primary Sedimentation Tank Model

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

$$Y = 0.017\ X_1 + 0.005 X_2 + 6.31\ X_3 + 2.56 X_4 - 0.003 X_5 + 0.54\ X_6 - 1703$$

Where;
Y= volume of primary sedimentation tank, m^3

The value of R^2 is the most important indication of the model accuracy, so the model has a high accuracy when R^2 is equal to 0.995. The adequacy of this model can be seen from Fig. (6), which shows the variation of the estimated and observed values of the volume of primary sedimentation tanks model.

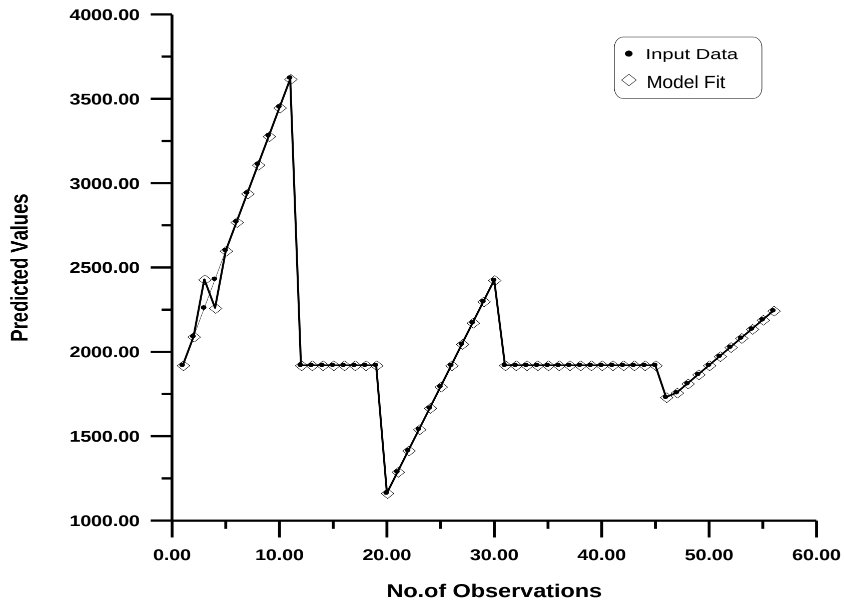


Fig. (6): The Estimated Versus Observed Values of Volume of Primary Sedimentation Tanks for Appropriate Model

2) Volume of Reactors Basins Model

The results of the non linear statistical regression analyses for selecting the most suitable model are Model No. A is selected to express volume of reactors basins:

$$Y = 0.052\,X_1 + 247.7X_2 - 3.14X_3 + 87.0X_4 + 0.28X_5 + 1.7X_6 - 10047.8$$

Where;

Y= volume of reactor basins, m^3.

As shown in the model, each of population, temperature, BOD production, TSS production, and total area served by network are the most significant variables which have a positive correlation between volume of reactors and independent variables while sewage contribution has a negative effect on reactors volume.

In addition to the high value of R^2 (0.988) which reflects the good prediction of model. The adequacy of this model can be seen from Fig. (7) which shows the variation of the estimated and observed values of the volume of reactors basins model.

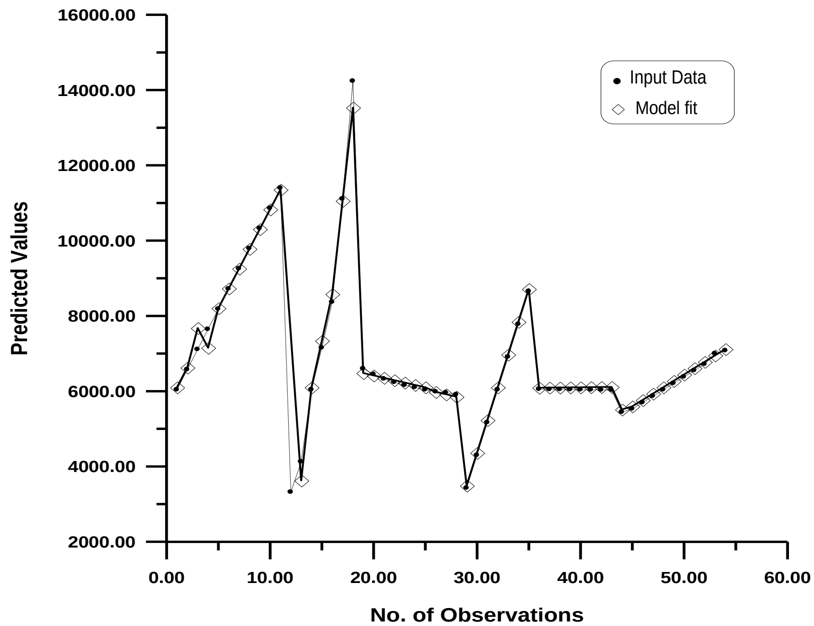


Fig. (7): The Estimated Versus Observed Values of Volume of Aerobic Reactors Basins

3) Volume of Total Air Required For Aeration Model

The final suitable model (Model No. A) was found to best model to determine the total air required for aeration. The predicted model as a function of:

$$Y = 0.0041\,X_1 - 5.14X_2 - 0.27X_3 + 6.7X_4 - 0.025X_5 + 0.13X_6 - 288.16$$

Where;

Y= volume of total air required, m^3/min

In above model, the independent variables which have a significant affect the volume of total air required are: population, temperature, sewage contribution, BOD concentration, and are served by network. It can be noticed from the above mentioned model that there is a positive correlation between the dependent variable and population, BOD concentration, and area served by network, in the other hand there is a negative correlation between dependent variable with temperature and sewage contribution.

The model gives a coefficient of determination of (R^2=0.990). The Fig. (8) shows the adequacy of this model when the variation of the estimated and observed values of the volume of air required. This figure indicates that the fitted model is a good predictor of total air required model.

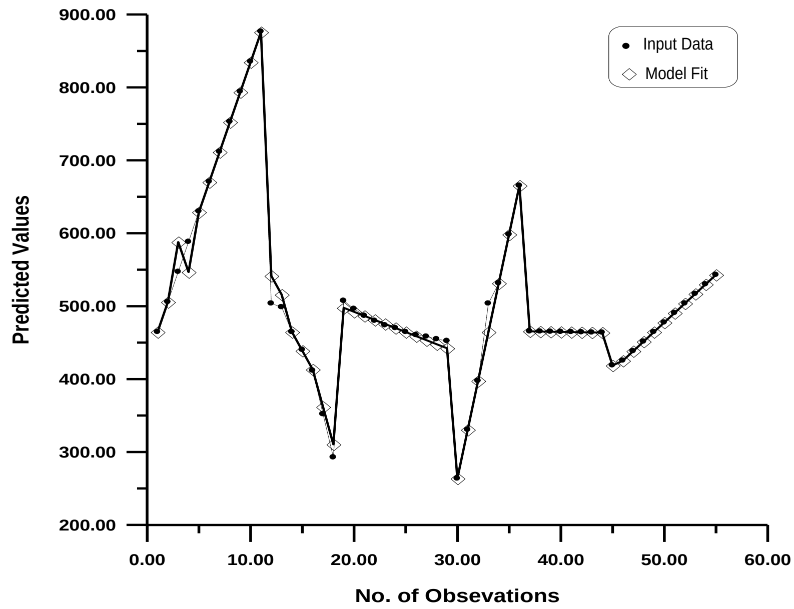


Fig. (8): The Estimated versus Observed Values of Volume of Total Air Required

4) Volume of Final Settling Tanks Model

The most suitable model that selected was model No. A, which is have a final form as:

$$Y = 0.104\,X_1 + 27.88X_2 + 28.77X_3 + 10.61X_4 + 0.63X_5 + 3.14X_6 - 9157$$

Where;

Y= volume of final settling tank, m^3

The explanatory power of the model R^2 indicates that the model has a high accuracy because of R^2 value is equal 0.982, and, the model adequacy which can be seen from Fig. (9).

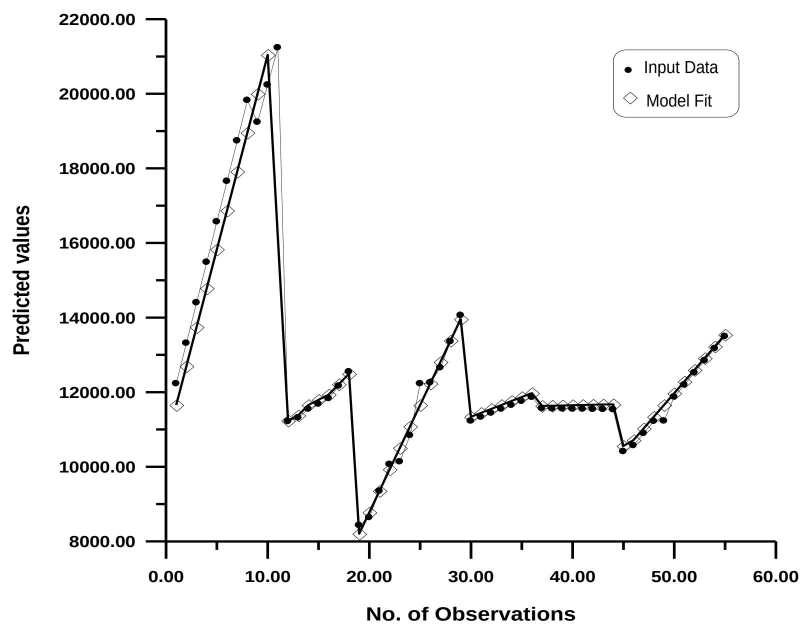


Fig. (9): The Estimated Versus Observed Values of Volume of Settling Tanks

5) Volume of Gravity Thickeners Model

The final suitable model (Model No. A) was found to best model. The predicted model as:

$$Y = 0.0056X_1 + 3.025X_2 - 0.45X_3 + 2.15X_4 + 5.86X_5 + 0.01X_6 - 615.67$$

Where;

Y= volume of gravity thickeners, m^3

The explanatory power of the model R^2, which indicates that the model has a high accuracy because of the value of $R^{2,}$ is equal to 0.999.

The Fig. (10) shows the adequacy of this model when the variation of the estimated and observed values of the volume of gravity thickeners.

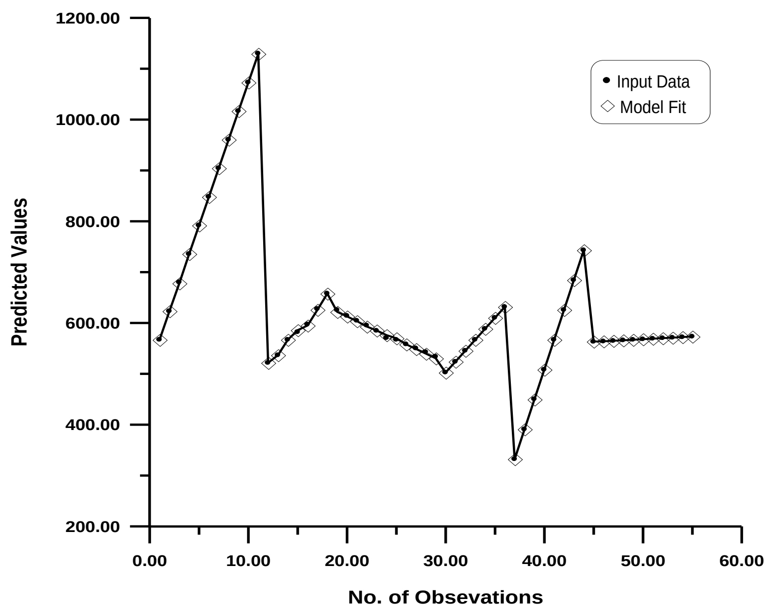


Fig. (10): The Estimated Versus Observed Values of Volume of Sludge Thickeners

6) Volume of Anaerobic Digesters Model

Model No. A was found to be the best model for express digesters volume. This model can be written as:

$$Y = 0.011X_1 + +2.83X_2 - 0.5X_3 + 2.0X_4 + 5.76X_5 + 0.031X_6 - 585$$

Where;

Y= volume of anaerobic digesters, m^3

The explanatory power of the model R^2 is equal to 0.999 which indicates that the model has a high accuracy. The Fig. (11) shows the adequacy of this model when the variation of the estimated and observed values of the volume of anaerobic digesters.

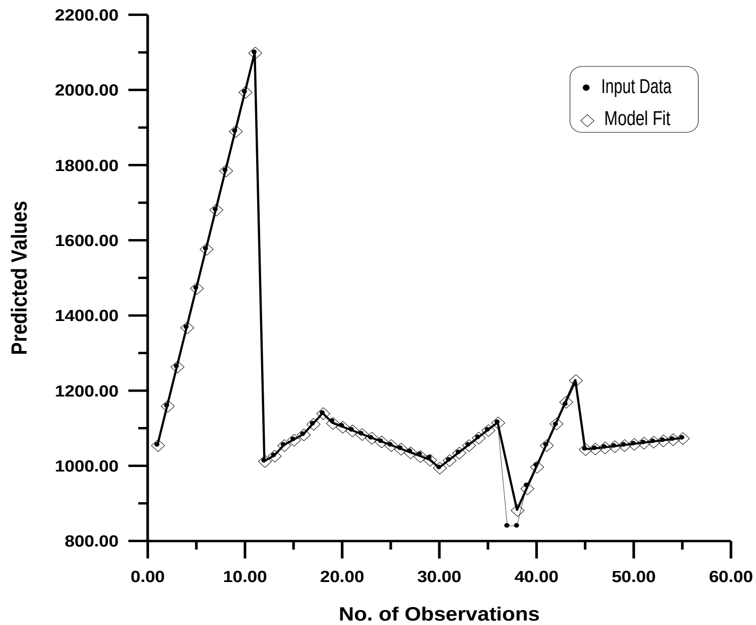


Fig. (11): The Estimated Versus Observed Values of Volume of Sludge Digesters for Total Model

7) Quantity of Sludge Produced Model

The predicted model to evaluate the quantity of sludge produced can be written for deferent factors as:

$$Y = 0.031X_1 + 16.66X_2 - 2.53X_3 + 12.0X_4 + 32.42X_5 + 0.06X_6 - 3396.7$$

Y= quantity of sludge produced, kg/day.

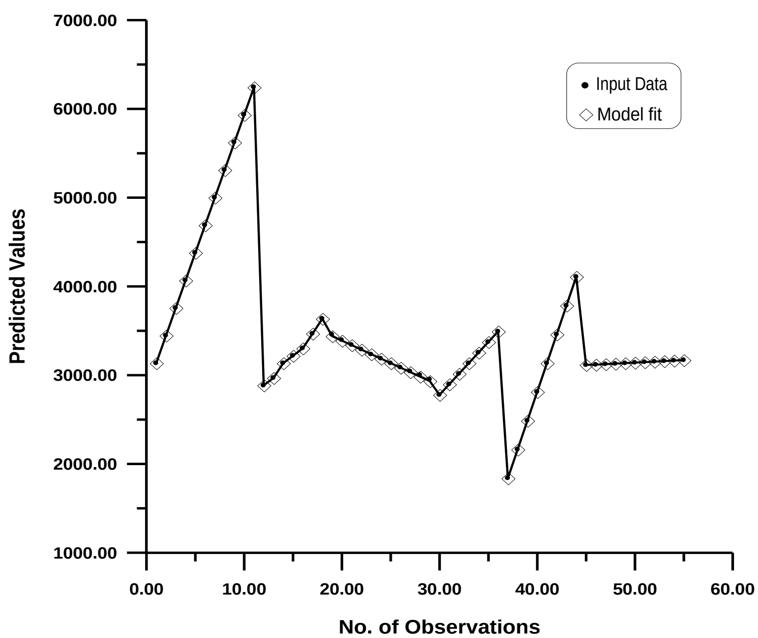


Fig. (12): The Estimated Versus Observed Values of Quantity of Sludge Produced

The value of R^2 indicated for the predicted model has a high accuracy because of the value of R^2 is equal to 0.999 in which the adequacy of this model can be seen from Fig. (12). This figure indicates that the fitted model is a good predictor of quantity of sludge produced .

8) Quantity of Gas Produced Model

The suitable model was found to be the most appropriate mode to express the quantity of gas produced from sludge digestion under affect of different factors can be formulated as:

$$Y = 0.024\ X_1 + 7.3X_2 + 0.53X_3 + 5.0X_4 + 13.4X_5 + 0.037\ X_6 - 1880.5$$

Where;

Y= quantity of gas produced, kg/day.

The model has high accuracy because of R^2 value is equal 0.958, and the adequacy of the model can be seen from Fig. (13).

This figure indicates that the fitted model has good predictor for quantity of gas produced.

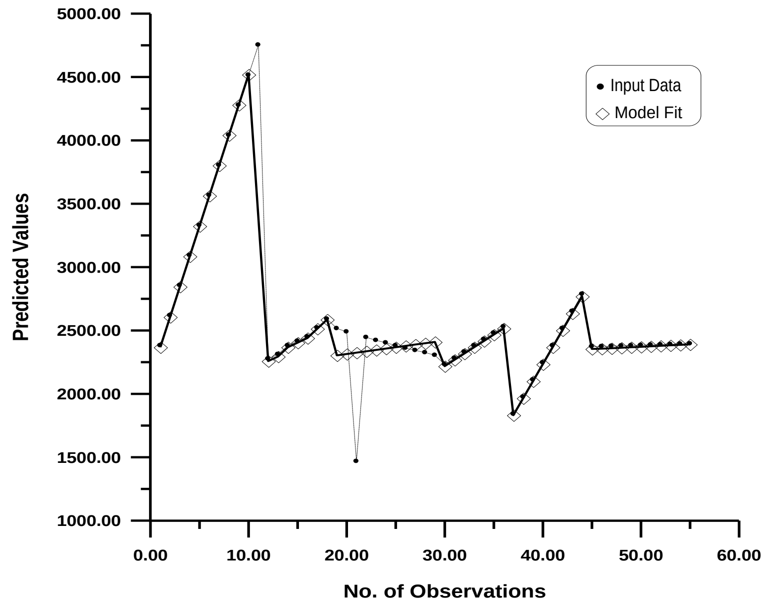


Fig. (13): The Estimated Versus Observed Values of Quantity of Gas Produced

Conclusions

1- Build an interactive computer program that used for designing a conventional activated sludge wastewater treatment plant with considering the affect of the environmental factors on the design. The verification of results showed a good agreement between program results and those obtained by hand calculations.

2- According to the regression analysis of results, it was concluded that the most suitable predicting model was Model No.A. The most appropriate models with the most significant independent variables are:

a) For volume of primary sedimentation tank model:

$$Y = 0.017\ X_1 + 0.005X_2 + 6.31\ \ X_3 + 2.56X_4 - 0.003X_5 + 0.54\ X_6 - 1703$$

By correlation matrix analyses, the results showed that population factor has a significant impact on basin volume, when this factor increase the increment in volume about (11.5 %), at the same time an increasing in sewage contribution leads to increase in volume as (20.2 %), while temperature, BOD and TSS concentrations, and area served by network have a very small influence on the volume.

b) For volume of aerobic reactors basins model:

$$Y = 0.052\,X_1 + 247.7X_2 - 3.14X_3 + 87.0X_4 + 0.28X_5 + 1.7X_6 - 10047.8$$

The results of analyses showed that when population factor increases the reactor volume increased by (11.5 %). Also, the temperature variation leads to increase in reactor volume as (21.2 %) while an increasing in sewage contribution reduces volume as (2.8 %). At same time an increasing in BOD concentration leads to increase volume as (16 %).The other factors have a very small affect on reactor model.

c) For volume of total air required model:

$$Y = 0.0041\,X_1 - 5.14X_2 - 0.27X_3 + 6.7X_4 - 0.025X_5 + 0.13X_6 - 288.16$$

It can be noticed that by analyses of results that when population factor increases the total air required increased by (9.5 %). Also, the temperature variation leads to decrease in volume of air by (4 %) while an increasing BOD concentration leads to increase volume of air as (22.8 %).The other factors have a very small effect on it.

d) For volume of final clarifiers' model:

$$Y = 0.104\,X_1 + 27.88X_2 + 28.77X_3 + 10.61X_4 + 0.63X_5 + 3.14X_6 - 9157$$

For the above model there are a positive correlation between dependent variable and all explanatory variables. It can be noticed that when population factor increases the volume of basins increased by (11.2 %). Also, the temperature variation leads to increase in volume by (1.5 %). In the other hand an increasing in sewage contribution leads to increase volume as (18 %). While the increasing in BOD concentration leads to increase basins volume as (8.5%).

e) For volume of gravity thickeners model:

$$Y = 0.0056\,X_1 + 3.025X_2 - 0.45X_3 + 2.15X_4 + 5.86X_5 + 0.01X_6 - 615.67$$

By correlation matrix analyses, the results showed when population factor increases the thickeners volume increased by (13 %). The increasing in temperature leads to increase in volume by (2 %). While the increasing in TSS concentration leads to increase basins volume as (2.8%). The other factors have no significant effect on thickeners volume.

f) For volume of anaerobic digestions model:

$$Y = 0.011X_1 + 2.83X_2 - 0.5X_3 + 2.0X_4 + 5.76X_5 + 0.031X_6 - 585$$

In the above model, the results showed that population factor has a significant impact on digesters volume, when this factor increases the volume increased by (10.5 %). At same time the increasing in temperature leads to increase in volume by (2 %). While the increasing in TSS concentration leads to increase basins volume as (2 %). In the other hand the other factors have very small influence on digesters volume.

g) For quantity of sludge produced model:

$$Y = 0.031\,X_1 + 16.66X_2 - 2.53X_3 + 12.0X_4 + 32.42X_5 + 0.06X_6 - 3396.7$$

Only four explanatory variables were found to have a significant effect on quantity of sludge produced which are population when increasing leads to increase of quantity of sludge produced as (13%). The other factor is temperature leads to increase in quantity of sludge by (2.76 %). While the increasing in TSS concentration leads to increase basins volume as (11.4 %).

h) For quantity of gas produced model:

$$Y = 0.024\,X_1 + 7.3X_2 + 0.53X_3 + 5.0X_4 + 13.4X_5 + 0.037\,X_6 - 1880.5$$

In the above model, the results showed that population factor has a significant impact on quantity of gas, when this factor increases the gas volume increased by (13 %). While the increasing in TSS concentration leads to increase quantity of gas produced as (5.3 %). The other factors have no significant impact on quantity of gas produced.

3-The infiltration caused by the high water table and defects in the network pipes increases the plant influent flow and decrease the concentration of BOD in the sewage. Consequently the effect of the area served by network has a low significance effects on design parameters of wastewater treatment plant.

Recommendations

The following recommendations are suggested for the future studies:

1. Studying other factors affecting the design such as (industrial wastewater, pH, type of network (separate and combined systems), aesthetics conditions, population habits, and land use).
2. Environmental factors that affecting design of different types of biological treatments.
3. The effect of flexibility (stability against shock loads and toxicants) and the effect of workability (number of units to be checked and necessity of high operating and maintenance cost technique on the design of WWTP).
4. Cost analysis (construction cost) for all units of treatment plant including liquid system and sludge system with more details of estimating materials and equipments.

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