Modeling of Actiflo Water supply Treatment Plant

Mohammad A.M. Al-Tufaily **Entesar K.H.**
Department of Environmental Engineering

Abstract

This study presents a computer program written in Visual Basic software (6.0) to design and operation new technology of water treatment called "Actiflo Water Treatment Plant ", we benefit from the program to discuss and evaluate different environmental factors that affect the design of treatment processes then compute very efficient equations that show the relationship between these factors.

الخلاصة

تُقدِم هذه الدراسة برنامج حاسوبي مصممٍ َبلغةِ فيجوال بيسكِ 6.0. لتصميم وتشغيل تقنية جديدة في معالجة المياه. كذلك تمت الاستفادة من البرنامج في تحليلُ وتقييم العواملَ البيئيةَ المختلفةَ المؤثرة على تصميم خطوات معالجة مياه الشرب.

تم إثبات دقة نتائج البرنامج بمقارنتها مع نتائج لمحطه فعليه مصممه بواسطة الطرق التقليديه وتفاصيل هذه المحطه تم الحصول عليها من التقارير ألمنشوره المعتمده.

البرنامج المعد في هذه الدراسة سهل الاستخدام، ومرن من حيث اختيار الأنواع المختلفة من المعالجات داخل المحطة ، وإفادة المهندسين والباحثين في مجال الهندسة البيئية (الهندسة الصحية) بالنتائج المتعددة للارتقاء والتقدم في مجال البحث العلمي في سبيل خدمة الإنسان والبيئة.

1.2 Introduction

Model becomes a central point in knowledge exchange and input for calibration and validation come from practice. Engineers/technologists can use models to evaluate pilot and full scale plant and come to improvements in design and operation water treatment plant processes so at present study we produce computer program to design whole system of Actiflo water treatment plant from intake unit passing through required treatment steps to disinfection unit the same program has sludge treatment system.

1.2 Objective of Research

Construct a computer program written in (Visual Basic V 6.0 software) to design, control, and operation of Actilo water treatment plant. Discuss and evaluate different environmental factors that affecting design and operation of different steps of treatment process.

1.3 Objectives of Water Treatment

Three basic purpose of Water Treatment Plant are as follows:

- To produce water that is safe for human consumption.
- To produce water that is appealing to the consumer.
- To produce water using facilities which can be constructed and operated at a reasonable cost, (CPCB**,** 2003).

1.4 Actiflo Water Treatment Plant

The treatment processes of raw water before it can be used for public consumption must be based on removal level of impurities to comply with various guidelines. The extent of treatment depends upon the quality of the raw water and the desired quality of treated water, (Hong, 2006).

The choice of which treatment to use from the great variety of available processes depends on the characteristics of the water, the types of water quality problems likely to be present, and the costs of different treatments.

The increment in modern society and population make the engineers breast greet challenge to create new technology to treatment with high efficiency, little cost, and little footprint, these requirement was presented by a Sand-Ballasted high rate settling technology called " **Actiflo Water Treatment Plant**".

1.5 Uses of Actiflo Water Treatment Plant

- For the treatment of surface water prior to use by industries for industrial supply water.
- Particularly as an effective pretreatment system prior to membrane systems used to produce high purity water.
- Treatment of surface water for drinking purposes.
- Treatment of high wastewater flows during wet weather at less cost

1.6 Properties of Actiflo Water Treatment Plant

Sand ballasted settling is a high rate coagulation / flocculation / sedimentation process that utilizes microsand as a seed for floc formation. The microsand provides a surface area that enhances flocculation and acts as a ballast or weight.

The resulting floc settles very fast, allowing for compact clarifier designs with high overflow rates and short detention times. These designs results in system footprints between 5 and 30 times smaller than conventional clarification systems of similar capacity.

The use of microsand also permits the unit to perform well, even when the inlet flow rate and influent water quality dramatically change either separately or in tandem, while still producing high quality treated effluent. (Blumenschein et al., 2006 ;Latker, 2002)

1.7 Actiflo Operating Principles

Fundamentally, the Actiflo process is very similar to conventional (coagulation, flocculation, and sedimentation) water treatment technology.

Both processes utilize chemical conditioning using coagulant for destabilization and flocculant aid polymer for the aggregation of suspended (insoluble) materials to enhance the settling velocity. These materials then subsequently settle and are removed from the untreated water stream.

The primary advance made in the Actiflo process is the addition of microsand, typically 100 to 150 microns with a specific gravity of 2.65, as a "seed" or "ballast" to induce and promote the formation of high density robust floc. These flocs have considerably higher settling velocities than conventional flocs and allow significantly higher clarifier overflow rates. **(**Blumenschein, et al., 2006; Latker, 2002).

1.8 Role of Sand in Actiflo Water Treatment Plant

The microsand serves several important roles in the Actiflo process:

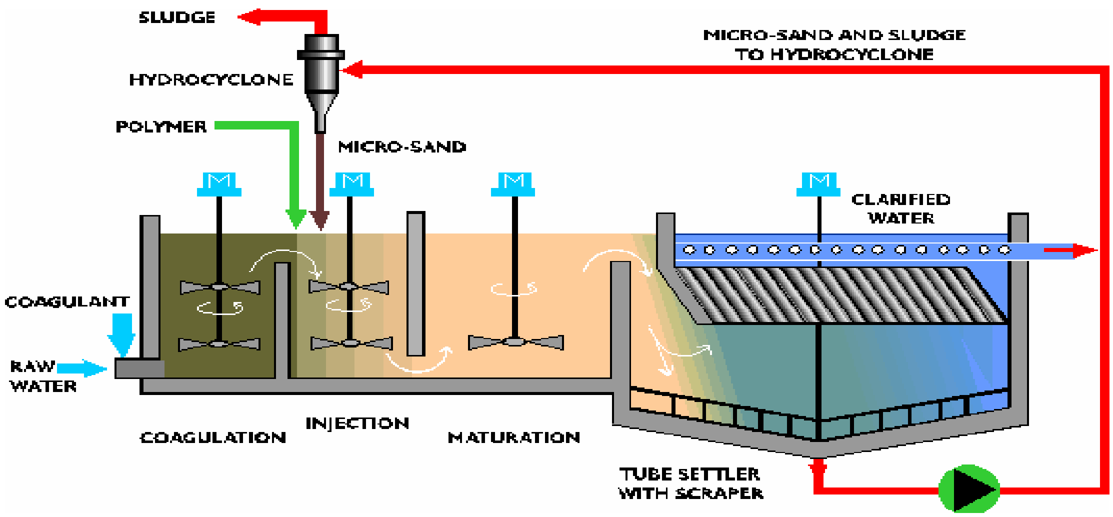
- The high specific surface area to volume ratio of the microsand particles serves as a "seed" for floc formation;
- The microsand and polymer "seed" promote the enmeshment of suspended materials and result in the formation of large stable floc;
- The relatively high specific gravity of the microsand (~2.65) serves as a ballast for the formation of high-density floc;

- The high microsand concentration within the Actiflo process effectively dampens the effects of changes in the raw water quality;
- The chemically inert microsand does not react with the process chemistry, allowing it to be effectively removed from chemical sludge and reused in the process.

1.9 Description of Actiflo Water Treatment Plant

The Actiflo Process is a high performance water clarification system that combines the advantages of microsand enhanced flocculation with lamellar plate settling .a flow diagram of the Actiflo process is provided in Figure 1.

Figure (1) Actiflo Process Flow Diagram



1.9.1 Intake structure

Raw water intake structure are used to control withdrawal of raw water from a surface source, thier primary purpuse to selectively withdrew the best quality water while excluding fish, floating debris, coarse sediment, and other objectionable suspended matter,that acheived by supplied the intake with screen technology (e.g fine screen, coarse screen and strainer).(Qasim et al.2000)

The design of water supply intakes requires a series of design considerations in order to arrive at a desirable concept that can obtain and deliver the water economically with an acceptably low impact on the environment. (Alsaffar and Zheng, 2007)

1.9.2 Pre-sedimentation

Pre-sedimentation is a step that is often required before coagulation and flocculation in order to remove large particles from the raw water stream. These larger particles can reduce the efficiency of the coagulation and flocculation process. Settling of larger-sized particles occurs naturally when surface water is stored for a sufficient period of time. (FSCI, 2003)

1.9.3 Coagulation Process

Raw untreated water is pumped into the coagulation tank of the sand ballasted system (See Figure 1) where a coagulant, such as alum, ferric chloride, ferric sulfate or poly-aluminum chloride is added to destabilize the suspended solids and colloidal matter in the influent stream. Typically, hydraulic retention time in this tank is approximately two minutes, (Parsons and Jefferson, 2006).

1.9.4 Injection Process

The water flows into the injection tank where polymeric flocculent and microsand are added to initiate floc formation. These serve as a "seed" for floc formation and development in the next process step. A hydraulic retention time of about two minutes is maintained in this tank also.

1.9.5 Maturation Process

At Actiflo Process treatment continues as water passes through the underflow passage from the injection tank into the maturation tank. Although chemical floc formation actually begins with the addition of polymer and microsand in the injection tank, the majority of ballasted floc formation occurs during the maturation process step. Gentle mixing and increased hydraulic retention time of approximately six minutes provide ideal conditions for the formation of polymer bridges between the microsand and the destabilized suspended solids. (Blumenschein, et al., 2006)

1.9.6 High Rate Sedimentation Process

The fully formed ballasted floc enters a settling tank equipped with inclined lamella plates or tube settlers depending on the application, which provides the rapid and effective removal of the "microsand/sludge" floc. The clarified water is collected and exits the unit via a series of weirs and collection troughs. The combined mircosand-sludge floc settles to the bottom of the clarifier and is moved to the center of the unit using a sludge scraper mechanism for removal from the unit. The microsand-sludge stream is pumped to a hydrocyclone. The hydrocyclone separates the floc from the microsand stream. The much higher density microsand is discharged from the bottom of the hydrocyclone and reinjected into the process for re-use.

1.9.7 Filtration Process

Filtration is the process of passing water through a porous medium with the expectation that the filtrate has a better quality than the influent, the medium is usually granular bed, such as sand, anthracite, garnet, or activated carbon. (Qasim et al. 2000)

Filters can be classified according to the medium type as:

1. Single (mono.) medium filters.
2. Dual media filters.
3. Mixed-media filters·

The mechanisms by which granular filtration media remove solids from water are complex and are not fully understood. Common suggest a number of mechanisms that act simultaneously in the solids removal process, these mechanisms are:

- Straining.
- Sedimentation.
- Impaction, and
- Interception.

The feature of the typical filter media is: (1) sufficient coarse media with large porous opening to confine the maximum quantity of the flocs while the media must be fine to prevent passing the small size of the suspended particles**,** (2) typical depth to allow long period for filter operation, and (3) will gradation to clean the filter by the backwash process with high efficiency.

1.9.8 Disinfection

Disinfection is normally the last step in purifying drinking water. Water is disinfected to destroy any pathogens which passed through the filters Chlorine is the one of the most common disinfection chemical that being used. Most of the plants surveyed used chlorine as their disinfection agent. (Hong, 2006), is widely used for the disinfection of water because it:

- Is readily available as gas, liquid, or powder and is cheap.
- Is easy to apply due to relatively high solubility.
- Leaves a residual in solution which, while not harmful to humans, provides protection in the distribution system.
- Is very toxic to most microorganisms, stopping metabolic activities, (Parsons and Jefferson 2006).

2.1 Sludge Treatment Processes

The sludge produced from the Actiflo Process is robust and has good settling characteristics, so it is amenable to removal and thickening in a sludge thickener unit. Likewise, the sludge from the thickener shows good dewatering characteristics, without additional conditioning.

2.1.1 Sludge thickening

The lighter density sludge is discharged from the top of the hydrocyclone to the sludge thickener. Thickening can be economically attractive in that it reduces the sludge volume and produces a more concentrated sludge for further treatment in the dewatering process, or for perhaps hauling to a land application site. Thickening tanks can also serve as equalization facilities to provide a uniform feed to the dewatering step. Although there are a few types of thickeners available on the market, the water industry almost exclusively uses gravitational thickening. (Latterman, 1999)

2.1.2 Sludge dewatering

An advantage of dewatering is that it makes the sludge odorless and non-putrescible, the simplest method of drying the sludge is to apply it on open drying beds, in a sludge-drying bed, part of the sludge water is removed by seepage and part is evaporated by sun's heat, (Metcalf and Eddy, 1991).

3.1 The Computer Program

A computer program is written by using Visual Basic(V.B) 6.0 language which is an event-driven programming language and associated development environment prototyped by Alan Cooper as Project Ruby, then bought and vastly improved upon by Microsoft.

3.2 Design and Operation of Treatment Plant

1. Inter the general information data which will be used to determine of future population (P_f), total average flow rate (Q_{avg}), maximum design flow rate (Q_m) .
2. Design intake unit
   - ❖ Design of intake, input data include maximum flow rate and maximum velocity through gate or pipe (according to type of intake structure).
   - ❖ Design of storages units, input data include detention time, width to length ratio, selected depth.
3. Design of coagulation treatments units, input data includes detention time, velocity gradient, length to width ratio, selected depth or width, width to depth ratio, type of flow created by impeller, impeller type.

4. Design of injection treatments units, input data includes detention time, velocity gradient, length to width ratio, selected depth or width, width to depth ratio, type of flow created by impeller, impeller type.
5. Design of maturation treatments units
   Input data includes detention time, velocity gradient, and length to width ratio , selected depth , width to depth ratio gear efficiency and bearing efficiency for agitation requirement. There are input data for flocculates equipment design include paddle wheel diameter to water depth ratio, width of blades, space between blades , and velocity of paddle to water velocity ratio.
6. Design sedimentation treatment units
   Input data includes assuming values of surface overflow rate SOR, detention time, weir loading, height of lamella plate to tank depth ratio, angle of inclination of lamella plate , space between lamella plate and thickness of lamella plate; for determining volume of the basins, dimensions, actual SOR, number of lamella plate. Another input data for effluent launder troughs equipment design needed, include width of center effluent collection trough, depth of effluent launder trough, and space between launder troughs
7. Design of filtration units.
   - ❖ For unit sizing design by assuming values of area of unit, average loading rate, length to width ratio.
   - ❖ For backwash system design by assuming backwash rate, surface wash rate, backwash time, surface wash time, filtration cycle.
   - ❖ For filter media design, input data include type of filter media then the program will choose number of layers, uniformly coefficient of media and effective size of media.

For under drain system design, by assuming size of opening in lateral then the program will automatically select the space for opening in lateral, space between laterals, number of laterals and main header, number of opening in lateral, total opening in unit, all required check with standard design criteria.

8. Design of Disinfection units:
   Input data includes detention time, length to width ratio, selected depth, width to depth ratio, and then the program will be work to determine the suitable dimensions, check detention time.
9. Design of sludge process system, Input data needs for design these system include (detention time and over flow rate for filter backwash recovery basin) and minimum and maximum hydraulic solid loading, solid loading) for thickening units.

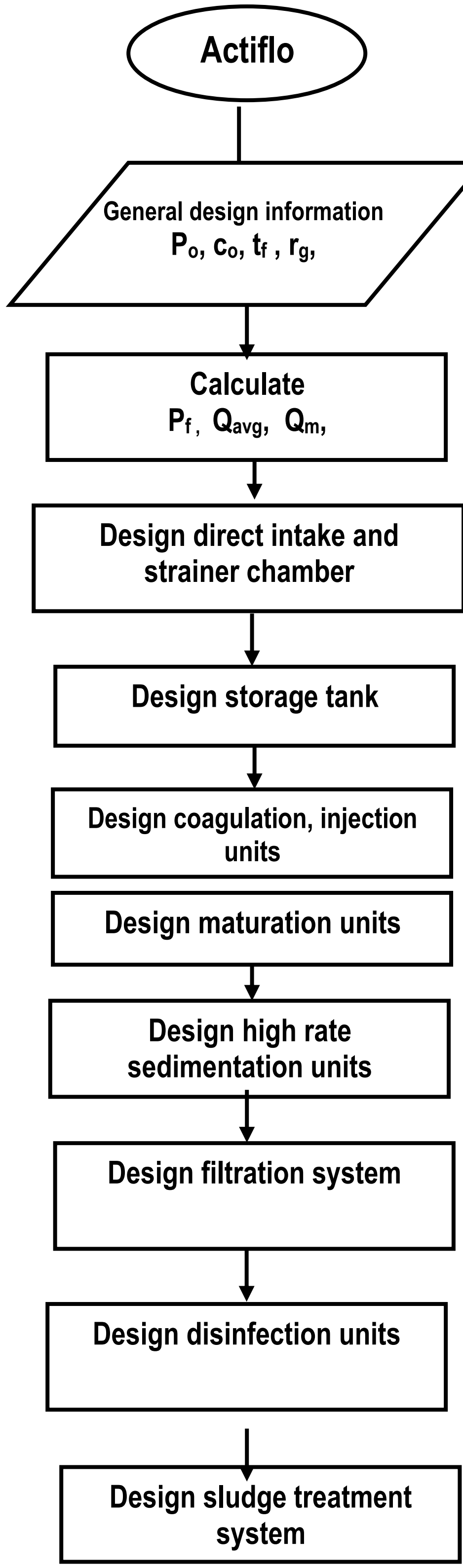


Fig.(2): Flowchart for Computer Program

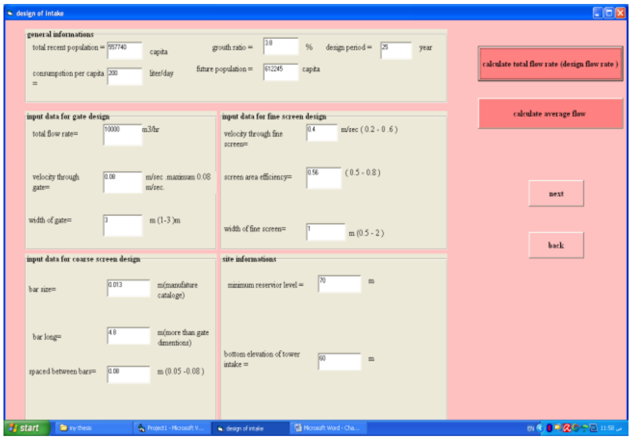
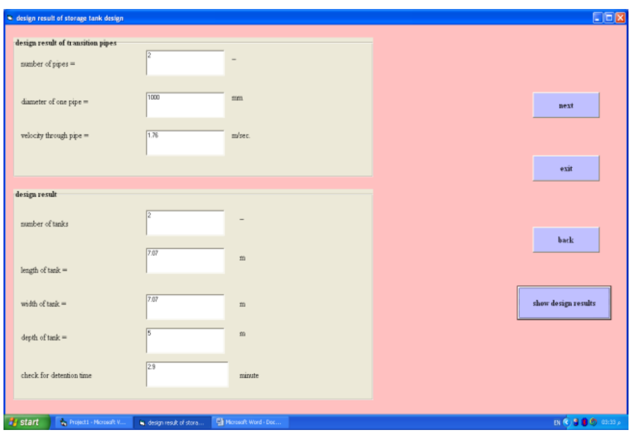


Fig.(3) General Information necessary for design the Actiflo Water Treatment Plant

Fig. (4): Module for design intake



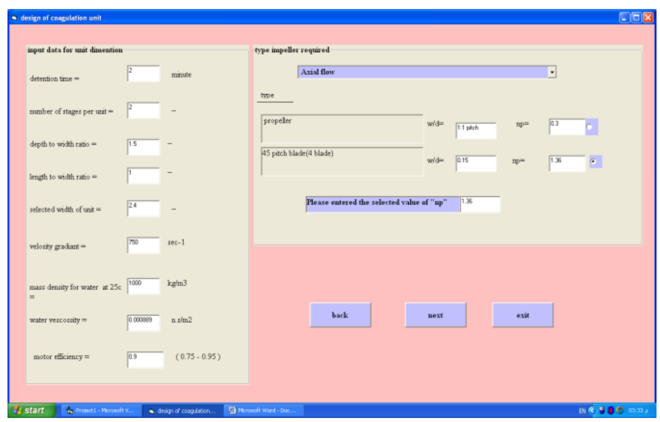


Fig. (5) Module for design transition pipes and Storage unit

Fig. (6) Input data needed to design coagulation unit

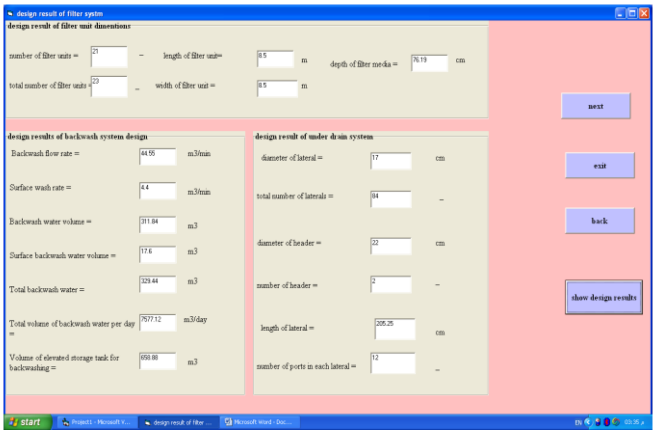


Fig. (7) Module for design filtration unit

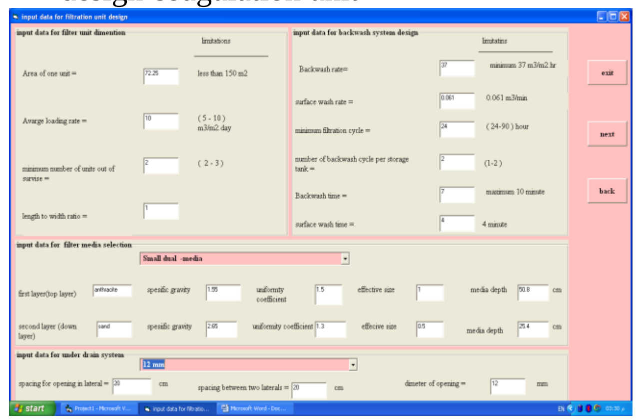


Fig. (8) Input data needed to design filtration unit

4.1 Analysis of Result

For ensure the perfect operation for the program and the relations between the factors that affecting the design of the studied water treatment plant, the statistical models which are describe was established.

4.2 The Regression Analysis Technique

The relationship between a single variable Y, called dependent variable, and one or more independent variables, x_1, … x_k are explained or modeled by a multiple regression analysis. The regression analysis was done by using "Data Fit" program version 8.0.

4.2.1 The Dependent Variables (y)

In the present work, the volume of treatment units, required area and power required assumed to be the dependent variables (y)

4.2.2 The Independent Variables

Multiple independent variables (also named as explanatory variables) following table (1.1) shows these variables.

Table (1.1) Independent variables

Variable	Description
x_1	Population factor, capita
x_2	Design period, y
x_3	Growth rate
x_4	Consumption, l/c.d

x_5	Time of storage, min.
x_6	Coagulation time, sec.
x_7	Maturation time, min.
x_8	Surface loading rate $m^3/m^2.d$
x_9	Filtration rate, m/h.

4.3 Regression Models for Designing water Treatment Plant

Multiple non-linear regression models in three forms were used for each one of design requirements to choose which form gives the best fitting of data, from these models we selected three models that give the best fitting of data.

Table (1.2): The Proposed Models

No.	Equation Description
A	$y = b_1x_1 + b_2x_2 + ... + b_kx_k + G$
B	$y = \exp(b_1 x_1 + b_2x_2 + ... + b_kx_k + G)$
C	$y = b_1x_1 + b_2x_2 + ... + b_kx_k$

Where;

y = dependent variables. **$x_1, x_2, …, x_k$ = the independent variables.**

$b_1, b_2, b_3, …b_k$ = are model coefficients, and **G = model constant term.**

4.5 Results of Study: The results are presented in table (1.3).

Table (1.3) Result of Study

Y	Models	R^2	Stand. Err
Opening area of intake	$y = 0.000083x_1 + 0.11x_2 + 0.707x3 + 0.108x4 - 34.874$	0.999	0.02
Volume of storage unit	$y = 0.001x_1 - 1.586x_2 + 11.382x3 + 1.553x4 + 139.052x5 - 928.37$	0.999	3.134
Volume of coagulation unit	$y_1 = 0.000x_1 - 0.442x_2 + 2.014_3 + 0.397x_4 + 1.973x_6 - 181.518$	0.902	13.395
Power of coagulation unit	$y_2 = 0.000x_1 + 0.235x_2 + 1.349x_3 + 0.215x_4 + 1.293x_6 - 127.29$	0.999	0.243
Volume of maturation unit	$y = 0.012x_1 - 16.18x_2 + 101.724x3 + 15.685x4 + 141.153x7 - 9257.917$	0.999	2.547
Volume of sedimentation unit	$y = \exp\left[\begin{matrix} 0.00000225*x_1 + 0.0034*x_2 + 0.027*x_3 + 0.003*x_4 \\ -0.035*x_8 + 9.602 \end{matrix}\right]$	0.983	1223.24
Area of filtration	$y = \exp\left[\begin{matrix} 0.0000023*x_1 + 0.003*x_2 + 0.023*x_3 + 0.003*x_4 \\ -0.095*x_9 + 5.866 \end{matrix}\right]$	0.987	29.495

4.6 Verification of Computer Program Results

To make sure that the program works successfully, verification must be done. That achieved either comparison hand calculation results for specific design values with program result for same design values (that processes repeated many times then verification will be estimated), or comprised program result for specific condition with actual water treatment plant exists around us worked with same conditions.

4.6.1 Verification by Compression with Actual Plant Result:

In order to get verification for the present models, comparison was adopted between the program results with Actiflo water treatment plant results for Lincolntone city that plant designed by Kruger Ins., North Carolina, with:

- Initial population 10000 capita.
- Design flow 9mgd, (1417.5m^3/hour).

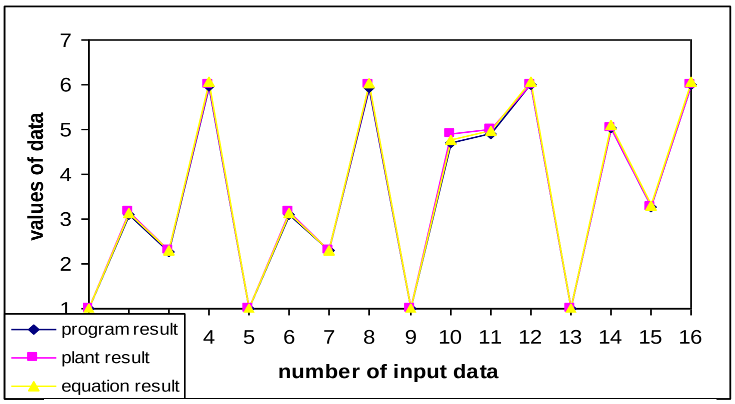


Fig.(9)Verification model of Actiflo watertreatment plant after applying calibration equation

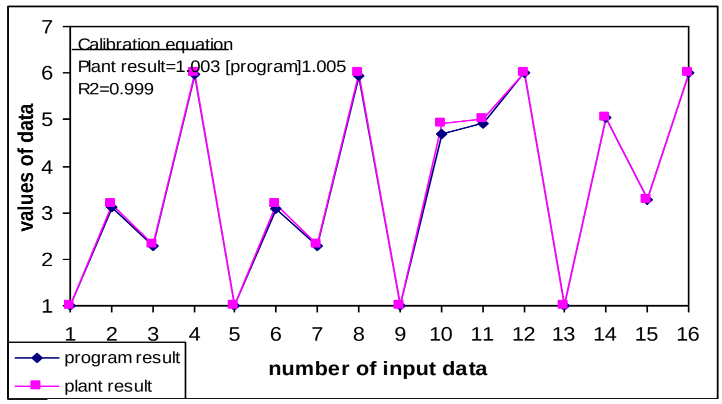


Fig.(10)Verification model of Actiflo water treatment plant before applying calibration equation

4.6.2 Verification for Program Results with Hand Calculations

In the present work, another comparison was conducted between the running of program results with these results of free hand calculations in order to get verification of the present models. More than one factor could be taken for comparison but the population had been use because it is the most important factor.

The computer program was run according to the sec.(3.2) and the results as follows in figure(11), which compare the design requirements of water treatment plants with those resulted by hand results for the population varaition which is represented the most important factor, as we see the small difference between the results shows very good agreement.

The inputs data were used to run the program as well to conduct hand calculations procedure as follow:

- Population = (350000-550000) capita
- Consumption per capita per day = 200 l/c. day
- Design period = 25 year ; •Growth rate :3.8%

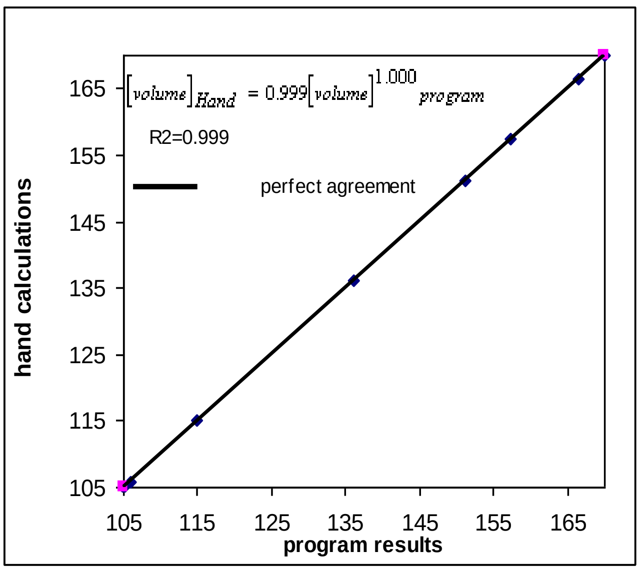


Fig.(11) : Verification for Volume of flash mix unit

5.1 Conclusions

From the present study the following conclusions can be obtained:

1. A computer program for the design of Actiflo water treatment plants was developed, user can design the different water treatment processes as well as maintain the plant operation. This application is simple through inter input data needed for each process that provided , the program provide feature that enable the user to change the input data needed for each unit from lists contained different type of these parameters .

2. The program had been designed to provide separate operation for treatment processes that we can pass one of the treatments which consider not required, dependent on the raw water quality and treated water quality required.
3. The design was developed considering the effect of the environmental factors, by use data statistics program called (data fit), we can successfully produce an equations connect between these environmental factors and plant variables. The verification for the program had been adopted, shows a very good agreement.

References

Alsaffar A. M., and Zheng Y. , (2007), "Water Intakes - Siting and Design Approaches" Bechtel Corporation 9801 Washingtonian Blvd.Gaithersburg, Md 20878, , Maryland, USA.

Blumenschein, C.D. Latker, E. and K. Banerjee K., (2006), "Sand Ballasted High Rate Clarification Process for Treatment of Process Water" IWC-06-20.

Central Pollution Control Board, (CPCB), (2003), "Status of Water Treatment Plants In India" Ministry of Environment and Forests, India, Website: www.Cpcb.Nic.In, E-Mail: Cpcb@Nic.In.

FSC Architects and Engineers, (2003) "Class I Water Treatment Plant Operator Program Manual "Government of the Northwest Territories Municipal and Community Affairs, 53 4910 rd Street P.O. Box 1777 Yellowknife, NT X1A 2P4.

Hong, C. K., 2006, "Development Of A Decision Support System For Drinking Water Treatment Process Design (Water-Dss)" MSc. thesis, College of Engineering, Department of Environmental Management, University Technology, Malaysia.

Latker, E., (2002), "Lincolnton, NC, Welcomes the ACTIFLO® Process to Western North Carolina"I. Kruger, Inc.

Parsons, S. A. and Jefferson, B., (2006), "Introduction to Potable Water Treatment Processes" School of Water Sciences Cranfield University, by Blackwell Publishing Ltd UK.

Qasim, S. R., Motley, E.M. and Zhu, G., (2000), "Water Works Engineering", Chiang, Patel and Yerby, Inc., Dallas, Texas.

Latterman, R. D., (1999), "Water Quality and Treatment" A handbook of community water supplies. American Water Works Association, McGraw-Hill. New York.

Metcalf and Eddy, Inc., 1991 "Wastewater Engineering Treatment, Disposal, and Reuse", McGraw- Hill, New York.