Statistical Modeling of the Treatment Processes of A Shallow Depth Settling Water Treatment Plant

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1.Abstract

The main purpose of this work is build a Statistical modeling of the treatment processes of a shallow depth settling water treatment plant designed and constructed at Al-Nekhela Al-Gharbia village (population 4800 in 500 dwellings) in the city of Hilla (Babylon Governorate) to produce potable water. The raw water is taken from Al-Hilla River, a branch of the Euphrates. The best was done to construct a water treatment plant that is simple to operate and made of reinforced concrete and locally available materials.

The theory of shallow depth settling is adopted here due to the nature of the solid suspension of the raw water. The treatment system produced filtered water at a rate of 5 m^3/m^2.hr under a head of 1.85 m above the surface of the sand layer in the filter.

المستخلص:

ان الغرض الرئيسي من هذا العمل هو بناء النماذج الإحصائية لعمليات المعالجة في محطة معالجة مياه تعتمد مبدأ الترسيب الضحل حيث تم تصميمها وبناؤها في قرية النخيلة الغربية (عدد السكان ٤٨٠٠ في ٥٠٠ مسكنا) في مدينة الحلة (محافظة بابل) لإنتاج مياه الشرب. .يؤخذ الماء الخام من نهر الحلة، وهو فرع من نهر الفرات. وقد بذلت الجهود لبناء محطة لمعالجة المياه بسيطة التشغيل ومصنوعة من مواد بسيطة ومتاحة محليا.

اعتمدت نظرية الترسيب الضحل في هذا العمل نظرا لطبيعة المواد الصلبة العالقة في المياه الخام . أنتج نظام المعالجة مياه مرشحة بمعدل ٥م٣/م٢/ساعة وتحت ضغط مقداره ١.٨٥ متر فوق سطح طبقة الرمل في المرشح.

2. Present Situation

Hundreds of thousands of people living in Iraq lack reasonable access to an adequate supply of safe drinking water. The problems are particularly acute for countless small communities in the rural areas, as well as for urban fringe areas. Their water supply situation often is grossly inadequate.

In providing water supply systems for small communities, factors such as organization, administration, community involvement and finance are frequently the major constraints, rather than technical considerations. However, the selection of suitable technology remains important since other problems are compounded when techniques, methods and equipment are used that are not compatible with the conditions and situations of small communities.

It is a misconception to regard small community water supply systems as ‘scaled down’ versions of urban installations requiring less engineering skill or ingenuity. The exact opposite may be the case. Simplicity and smallness should not be regarded as backward or second rate, but rather as appropriate for the purpose. Technologies must be selected but can be integrated with the approach of community involvement, which is essential in small-scale schemes. Misapplication of technologies is likely when the designer does not clearly understand the basic consumptions implicit in them. This usually will result in costly over designs and unrealistic manpower, operation and maintenance requirements.

3. Study Area

The study was performed at the village of Al-Nekhela Al-Gherbia located on the Al-Hilla River just upstream from the city of Al-Hilla. The population was approximately 4800 in 500 dwelling unit.

Table 1shows the statistics of the daily observations of physical, chemical and biological characteristics of the river water during the period of study.

Table 1: Statistical description of the daily observations of physical, chemical and biological characteristics of the river water.

Parameter	Max.	Min.	Mean	St.dev.
Turbidity, NTU	42	18	28.2	7
pH	8.15	7.75	7.9	0.107
Temperature, ^{0}C	24	32	28.4	2.7
Total plate count, cells/ml	700	2100	1090	324.8
Coliform bacteria, MPN/100 ml	1100	5800	3135	1159.7
Fecal coliform, MPN/100 ml	90	1800	702	513.76

4. Literatures Review

Common problems faced by small communities are isolation, limited financial resources, lack of economies of scale, lack of qualified personnel for design, operation & maintenance and reluctance to commit funds to untried technology.

Some of the desirable requirements of a small community water treatment plant are low capital, low operating and maintenance costs, simple operation and maintenance, ability to be left unattended for long periods, manageable residuals, reliability, no chemical dosing (if possible), and spare parts and repair capabilities readily available *(Inter-net, web site, NDWC, 2004)*.

The types of water treatment plants serving small communities in the word are varied. The range covers conventional treatment, direct filtration, traditional package plants with tube settlers, continuous contact sand filters to microfiltration and desalination.

5. Compact Water Treatment Plants

Water treatment plants based on compact designs may be built more quickly than conventional plants, while still allowing contributions from the local community by way of materials, and involvement in construction. Standardized compact designs can reduce the type and number of plant devices that need to be ordered and stored, thereby facilitating a more efficient system of procurement of spare parts, training of operators, and ease of repairs. To save more time for project implementation, plants may be made of compact elements that are prefabricated and transported to the construction sites for final assembly.

Although compact designs are amenable to either concrete or steel construction, concrete is generally preferred because of its wide availability in developing countries, comparatively low cost, and resistance to corrosion. Moreover, most of the skilled and unskilled workers employed in developing countries are more familiar and proficient with concrete construction than with steel. Two types of compact water treatment plants developed in Latin America and Indonesia are described below.

The water treatment plant serving the city of Prudentopolis, Brazil (population 7500), consists of a compact unit 4 m square in plan, having a capacity of 1000 m^3/day (*Arboleda*, *1976*; *Sperandio* and *Prez*, *1976*).

Standard designs were developed for both concrete and steel plants having capacities of 1730, 3460, 5190, and 6920 m^3/day

An international seminar held in Indonesia on compact approaches for water supply programs (*IRC*, *1981*) recommended that the Indonesian designs be used as models in other developing countries with (if possible) intercountry field testing of the compact treatment plant. An unpublished report on the standard water treatment plants in Indonesia, which includes general and detailed design criteria, description of the concrete and steel plant designs, and application of the standard designs for various types of surface waters, is available from the *(IRC, 1981)*.

A small developed compacted unit Model HH-4 treats water from pressurized water sources and re-pressurizes it for distribution. Water enters the system under pressure and flows through 5- micron and activated carbon filters and the disinfections unit. Clean water is discharged to a 212 liter storage tank. After that, water is pumped into a pressure tank, from which it is fed into the house under pressure, providing 15-19 l/min at 310 kN/m^2.

Model HH-4 includes the UV water works disinfections unit, one 5-micron and one activated carbon filter, one pressure tank and pump, and controls to automate pump functions and system operation. The system can be installed outdoors or indoors.

Each model includes an extra UV lamp and fuse and one set of replacement filter cartridges, which should last for one year under normal usage*, (Inter-net, web site, household HH-4.htm, 2001)*.

The *ACTIFLO* process is a breakthrough in water treatment technologies. The maximum water volume for this facility is 200 m^3. It combines two well proven principles of rapid settling:

1. microsand assisted coagulation and flocculation, which allows the formation of ballast floc or rapidly settling floc of high specific gravity.
2. lamella clarification, allowing a considerable reduction of the settling basin surface, (*ACTIFLO, 2004*).

5.1 Compact Water Treatment Plants in Iraq

Al-doory (2001), suggested a water treatment plant system to produce water which is pure, pristine, and sparkling used as feed water. The proposed water treatment system, which was made of 100% locally, produced materials, consisted of a slow sand filter preceded by a gravel filter. The filtering media for the slow sand filter was the unsieved “glass sand” taken from (Irthima) in the western desert. This filtering media was used for the first time in such a field. Results of experiments indicated that high removal efficiency of turbidity (less than 2 NTU), bacteria, phytoplankton (algae), and zooplankton was possible. The system produced filtered water at a rate of 1.2 m^3/m^2 .h, under a head of 1.56 m above the surface of the sand in the filter at the start of the run.

Hadi (2002) constructed a water treatment compact unit fabricated from ferrocement. The compact unit consisted of two basins, the first basin was a gravel-bed, up flow settling basin, while the other was a rapid sand filter. The compact unit was assembled at the Wathba Water Treatment plant in Baghdad. It was found that the compact unit can remove over 90% of the turbidity of the Tigris water. No presence of any E-coli was recorded on samples of finished water during the experimental runs.

6. Results of Treatment Processes

6.1 Coagulation

Aluminum sulfate is used as the main coagulant agent in most water treatment plants. In relation to raw water quality, the amount of alum dose is added depending on turbidity as the main parameter. This is used as an indicator to determine the required alum dose. The relation between levels of turbidity and optimum alum dose is shown in Fig. 1.

The efficiency of coagulation increases as turbidity of raw water increases because of increasing probability of contact between particles of raw water. On the other hand, and for the range of turbidity equal to 18 - 42 NTU with average of 28.2 NTU, the required alum dose for optimum coagulation equals to 22 mg/l. The ranges of temperature and pH value are equal to 24-32 ^{0}C and 7.75 – 8.15 respectively.

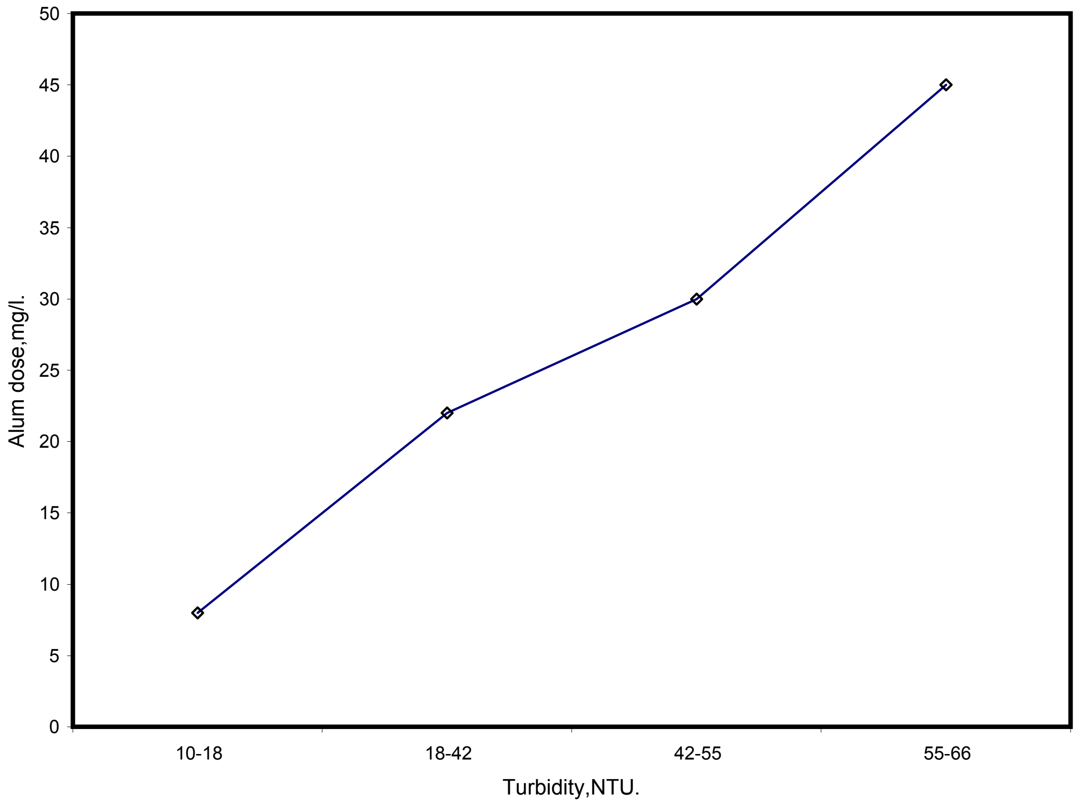


Fig.1: Relationship between raw water turbidity and alum dose of treatment plant

6.2 Clarification

The performance of clarifier at water treatment plant for turbidity removal is shown in Fig. 5.2. The figure shows the relation between raw and clarified water turbidities.

For turbidity range of 18-42 NTU with an average of 28.2 NTU, the average of removals percentages is 64 %.

The statistical relation that describes this clarifier performance is: -

$$Y = 0.3589X - 0.0005 \qquad ,R^2 = 0.9891$$

Where

X = raw water turbidity, NTU, for turbidity range of 18-42 NTU and

Y = clarified water turbidity, NTU.

R^2 = coefficient of determination.

The clarifier performance in bacterial removal is shown in Figs. 3-5. The percentage of bacterial removal increases as bacteria original concentration increases in a linear relation. The equations that describe the clarifier performance in removal of total coliform, fecal coliform and total plate count are respectively:

$$Y = 0.7696X + 12.504, \quad R^2 = 0.9981, \text{ for } X = 1100 - 5800$$

$$Y = 0.2087X + 0.7391, \quad R^2 = 0.9994, \text{ for } X = 90 - 1800$$

$$Y = 0.7817X + 9.2226, \quad R^2 = 0.9805, \text{ for } X = 700 - 2100$$

Where

X = concentration of total coliform, fecal coliform, and total plate count entering clarifier respectively.

Y = concentration of total coliform, fecal coliform, and total plate count leaving clarifier respectively.

R^2 = coefficient of determination.

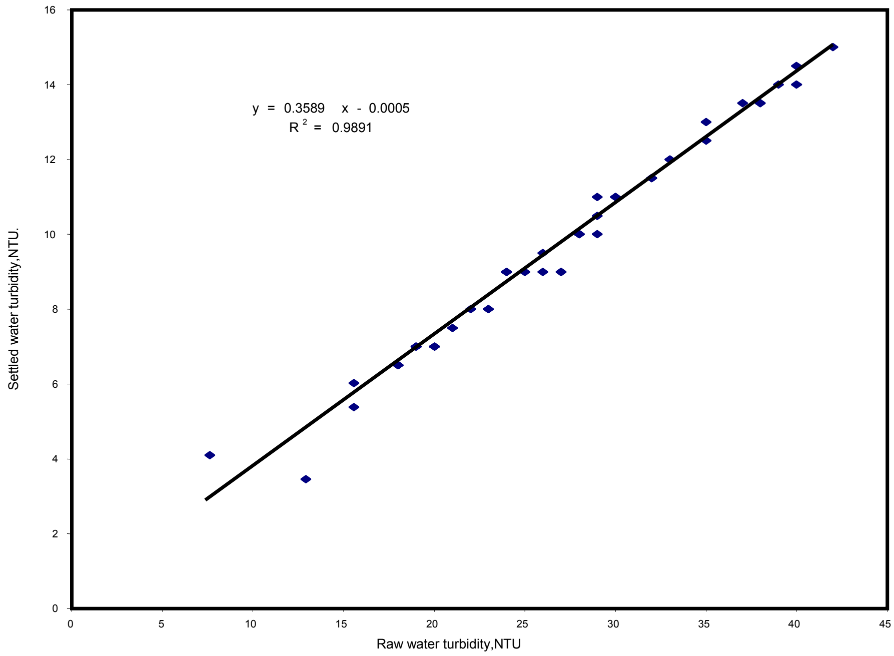


Fig. 2: Relationship between raw and settled water turbidity of treatment plant .

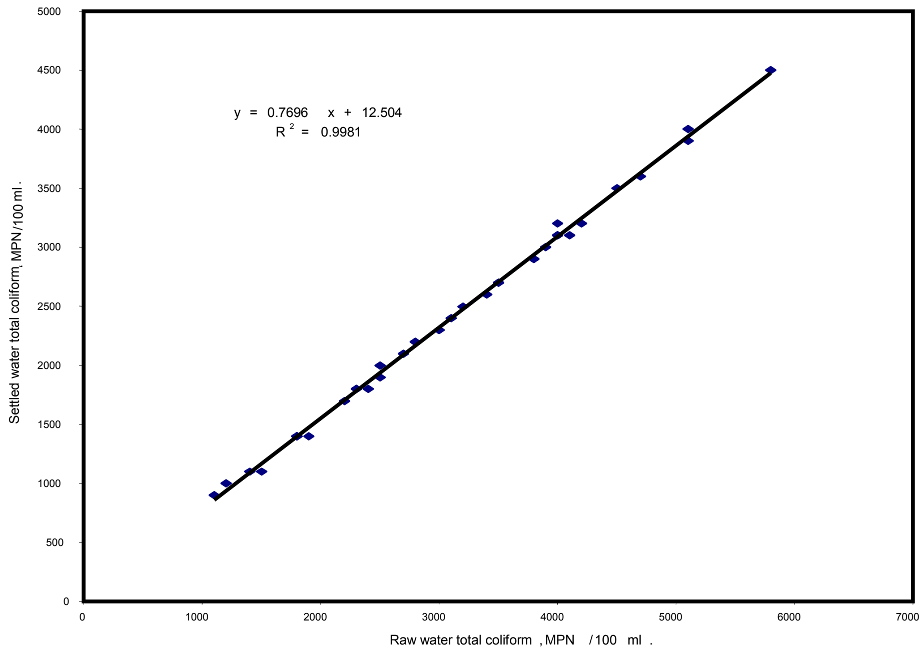


Fig. 3: Relationship between raw and settled water total coliform at treatment plant .

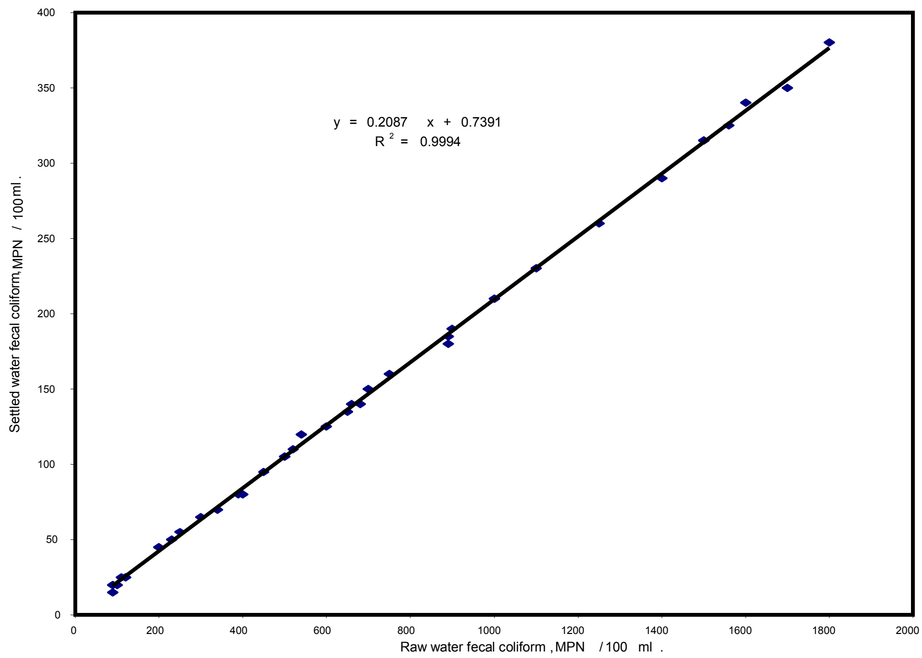


Fig. 4: Relationship between raw water and settled water fecal coliform of treatment plant.

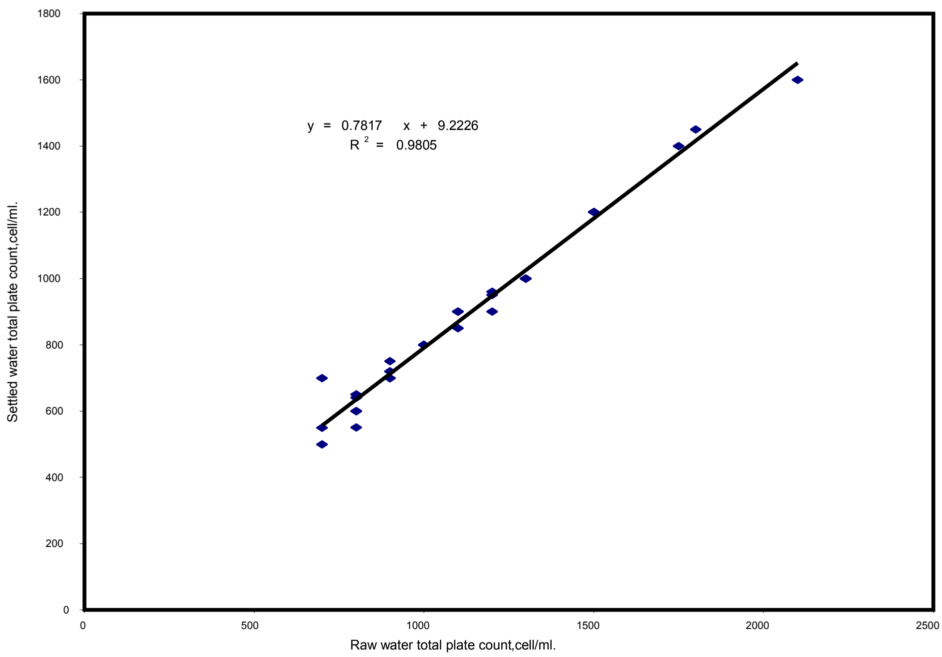


Fig.5: Relationship between raw and settled water total plate count of treatment plant .

6.3 Filtration

The effect of clarified water turbidity on filtered water turbidity is shown in Fig. 6. As shown in figure, filtered water turbidity increases with the increasing raw water turbidity. The average of removal percentages is 78.8 %, for a range of turbidity of 6.5 - 15 NTU with average of 10.1 NTU.

The equation that describes filter performance in turbidity removal is:

$$Y = 0.3186X - 0.2816 \qquad ,R^2 = 0.83146$$

Where

X = clarified water turbidity, NTU for a range of turbidity of 6.5-15 NTU

Y = filtered water turbidity, NTU.

R^2 = coefficient of determination.

The filter performance in bacterial removal is shown in Figs. 7-9. The equations that describe the filter performance in removal of total coliform, fecal coliform and total plate count are respectively:

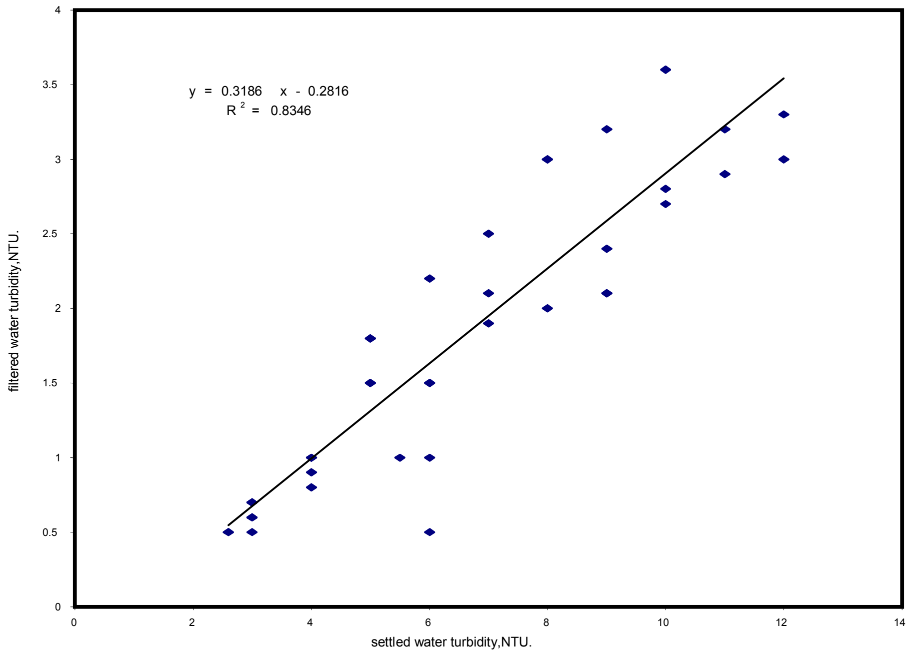
$$Y = 0.0004X + 0.3699, \qquad R^2 = 0.7964$$
$$Y = 0.0002X + 0.3059, \qquad R^2 = 0.7892$$
$$Y = 11.814LnX - 70.066, \qquad R^2 = 0.8395$$

Where

X = concentration of total coliform, fecal coliform, and total plate count entering filter respectively,

Y = concentration of total coliform, fecal coliform, and total plate count leaving filter respectively.

R^2 = coefficient of determination.



. Fig. 6 : Relationship between settled water and filtered water turbidity of treatment plant.

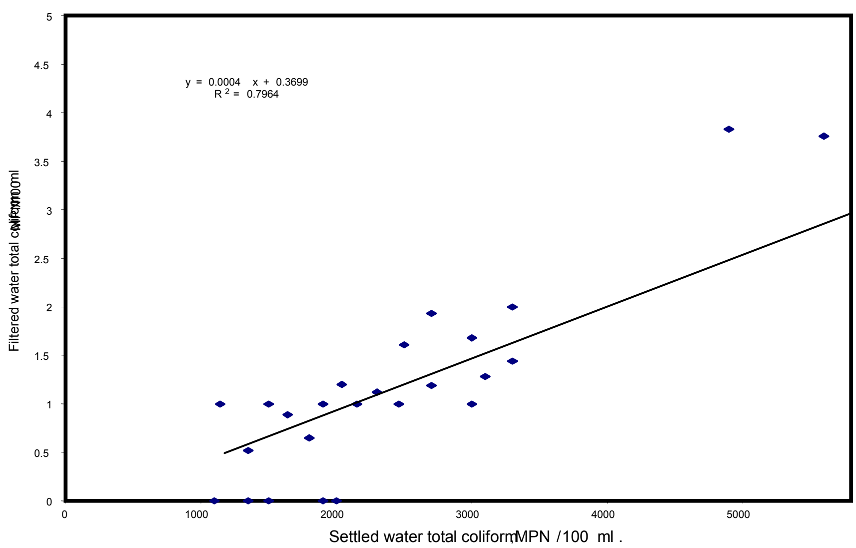


Fig.7: Relationship between settled and filtered water total coliform of treatment plant

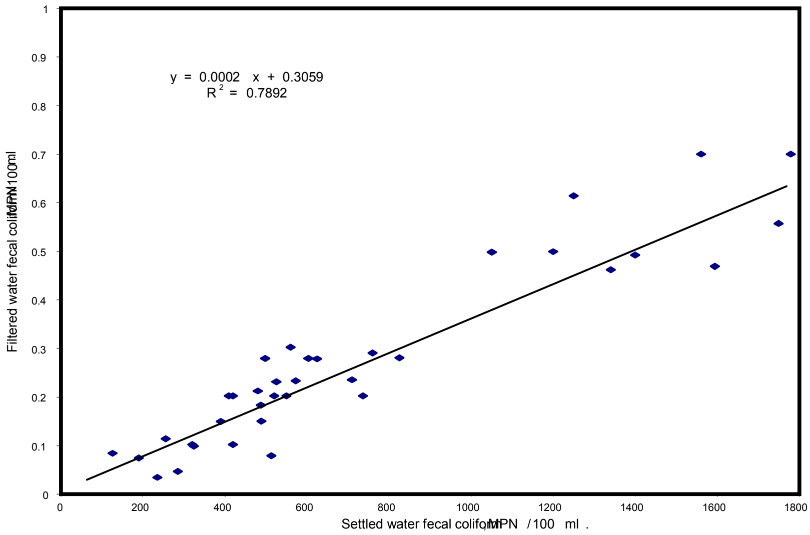


Fig.8 Relationship between settled and filtered water fecal coliform of water treatment plant

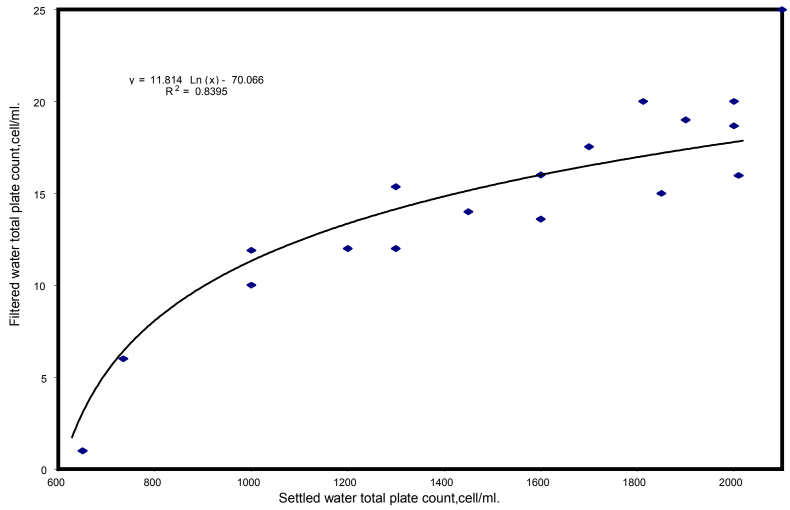


Fig.9: Relationship between settled and filtered water total plate count of treatment plant

7. References

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