Engineering Journal of Qatar University, Vol. 2, 1989.

# "FULL SCALE PERFORMANCE OF PRIMARY SETTLING TANKS"

By

**Shamim Ahmad, K.H. Javed** and **M. Murad,**
Faculty of Engineering
Qatar University

Senior Chemist
Sewage Treatment Works
Doha, Qatar

## ABSTRACT

The characteristics and the flowrate of municipal wastewater from the city of Doha, located in the Arabian Gulf have been studied to examine their effect on the performance of the primary settling tanks at the local sewage treatment plant. The wastweater is predominantly domestic and characterized by low suspended solids concentration but high total dissolved solids. The high temperature of the wastewater and long flowtime in the sewerage system turn it septic.

The performance efficiency of the circular primary settling tanks in terms of total suspended solids and BOD removal was determined. Simple empirical models relating the suspended solids removal efficiency with various loading parameters like detention time, overflow rate and solids loading rate have been developed. The solids loading rate seems to be more significant than the overflow rate or the detention time in predicting settling performance. The results of the investigation are compared with published data.

## INTRODUCTION

The wastewater treatment plant in Doha serves a population of about 250,000. The raw wastewater characteristics and the flowrate during different months are summarized in Table 1. The plant is divided into an old section and a new section. On average, three-fourth of the total quantity of wastewater flows to the new section and the remainder to the old one. In the old section the wastweater is given preliminary and primary treatment followed by trickling filters. After

**Table (1)**

**Total flow and typical average monthly raw wastewater cdharacteristics**

**(All values in mg/L except flow, pH and electrical conductivity)**

| Months | Flow ($m^3$/d) | pH | Electrical conductivity EC(uS/cm) | Total dissolved solids, TDS. | Total suspended solids, TSS. | $BOD_5$ | COD | Ammoniacal nitrogen | Total alkalinity | Chloride | Sulphide |
|---|---|---|---|---|---|---|---|---|---|---|---|
| June 1986 | 60320 | 7.30 | 4656 | 3259 | 161.1 | 199 | 401 | 26.2 | 212.0 | 1046 | 12.2 |
| August 1986 | 63250 | 7.47 | 3689 | 3583 | 124.8 | 144 | 360 | 24.1 | 212.3 | 754 | 12.5 |
| October 1986 | 62500 | 7.46 | 3513 | 2459 | 151.4 | 173 | 420 | 26.5 | 210.0 | 701 | 10.6 |
| December 1986 | 89130 | 7.29 | 4247 | 2973 | 187.3 | 131 | 375 | 23.8 | 191.3 | 931 | 7.6 |
| January 1987 | 103800 | 7.35 | 3914 | 2740 | 236.3 | 170 | 453 | 26.0 | 210.5 | 870 | 7.6 |

TSS in Dubai Wastewater – 410 mg/L (Bailey 1980).

receiving preliminary and primary treatment, the wastewater is treated by activated sludge process followed by sand filtration in the new section. As a matter of policy no effluent is discharged to the gulf waters. A high quality effluent must be produced to meet water quality standards. The treated effluent is reused for the irrigation purposes.

The primary settling tanks are circular shaped and of the upward flow central feed type. Each tank is of 22 m diameter and is 2.3 m deep with a floor slope of $10^{o}$ giving a maximum depth of 4.24 m at the center. Settled wastewater is collected on the periphery and flows over the V-notch weir to a common collection chamber before flowing forward to secondary treatment. Settled sludge is continuously removed with the help of scrapers and pushed towards a sludge pocket provided at the bottom. A travelling bridge on each tank allows scum and sludge removal to a common collection chamber. It then flows by gravity to the sludge consolidation tank.

This paper summarizes the results of the study conducted to characterize the wastewater according to the Standard Methods (American Public Health Association et al., 1975), to observe the hourly variation in the flowrate, and to determine the performance efficiency of the settling tanks. Simple empirical models have been developed to predict settling tank performance in terms of the various design parameters including the detention time, the overflow rate and the solids loading rate which is the product of the suspended solids concentration and the overflow rate.

## SAMPLING PROGRAM AND ANALYSIS

At the inlet and outlet of the primary settling tanks composite samples were collected with the help of automatic samplers collecting up to 24 samples per day. Sampling was done on a random basis twice a week during June, August, October and December of 1986. The mean monthly values of suspended solids removal during 1986 were used to determine the average performance.

During December 1986 and January 1987, grab samples were collected once, a week every 2-hours between 7 AM and 3 PM and then composited. This was done to study the effect of hourly variation in the characteristics and flow of the wastewater on the performance of the settling tanks.

## VARIATION IN FLOW

The variation in hourly flow to the treatment plant during weekdays and on the weekend Friday were investigated during two weeks in June and July 1986 and are shown in Fig. 1. The average flowrate on Friday is about 1.06 times the average weekly flowrate whereas the peakflow on Friday is about 1.27 of the average flow and occurs between 10 AM and 3 PM because of the weekend. The peakflow on weekdays is about 1.14 of the average daily flow and the minimum flow is between 0.73 and 0.82 of the average daily flow. These values are within the range of values normally experienced (Fair et al., 1966; Mahmoud et al., 1977).

There is little diversification in the activities of the community. People are mostly engaged in public and commercial undertakings which operate only during the day. Industrial activity is presently limited and, as a matter of policy, industrial wastewater is completely segregated from municipal wastewater. In spite of the absence of any night life in the city, the treatment plant continues to receive considerable flow during the night. The analysis of the flowrate shows that presently the volume of wastweater during the night ranges between 30 and 35% of the total daily flow which is fairly high indicating considerable groundwater infiltration through leaking joints and damaged sewers.

## RESULTS AND DISCUSSION

The average total dissolved solids (TDS) in the potable water is between 400 and 500 mg/L, whereas the TDS in the wastewater lies between 2800 and 3600 mg/L (Table 1). The chloride and sulphate concentrations are also high. Due to this the TDS and consequently the electrical conductivity (EC) of the wastewater are high when compared with the similar characteristics of the wastewater (Mahmoud et al., 1977; Steel and McGhee, 1984). However such concentrations are typical of the gulf region because of the groundwater infiltration (Bailey, 1980; Paul and Smith, 1984).

The wastewater in general may be classified as of weak to medium strength in accordance with the criteria of Steel and McGhee (1984). The total suspended solids concentration (TSS) in the wastewater is low when compared with the values observed in Dubai (Bailey, 1980). This could be explained by the fact that in many districts a great deal of solids tend to settle inside the sewerage system due to small flows and flat gradients. The wastewater is characterized by high

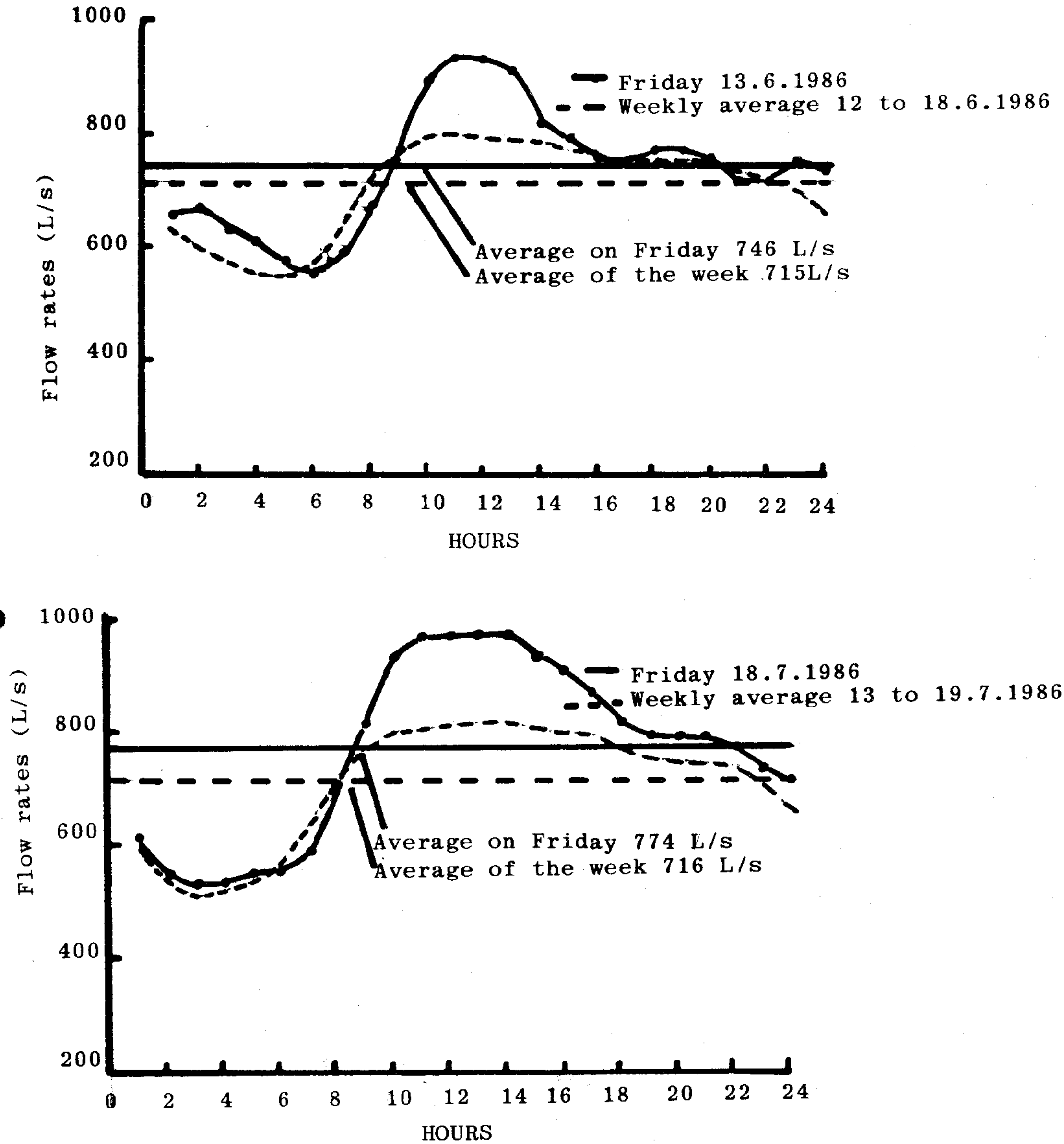


**Fig. (1) – Typical variation in wastewater flow rates to the treatment works.**

EC values, large sulfide concentration and high temperature which is generally close to 30°C. The high temperature coupled with deposition of organic matter in the sewerage system and long flowtime to the treatment plant turns the wastewater septic. It causes corrosion of materials and produces objectionable odor near pumping stations.

The mean monthly results of the influent and effluent TSS and BOD-removals are presented in Fig. 2. The TSS and BOD removals are within the range of values reported in the literature but vary from month to month (Fair et al., 1966; Steel and McGhee, 1984). The pattern of variation in the effluent TSS is similar to the influent TSS.

The mean monthly detention time, overflow rate, solids loading rate and weir loading along with TSS and BOD removals are plotted in Fig. 3. From this figure the general impression is that the settling performance varies in spite of that the overflow rate, weir loading and detention time are nearly constant. This may be because the daily variation in different parameters mentioned above gets masked in their average values. Performance data based on the average monthly values of a full scale plant do not show the effect of variation in the characteristics and loadings on the removal efficiency of settling because the settling process is a complex interaction of a large number of variables such as the character and concentration of the suspended solids, detention time, overflow rate, hydraulic turbulence, density currents, wind action and temperature. Furthermore the wastewater contains a considerable proportion of flocculent particles which do not have constant settling characteristics. At higher temperatures the settling velocity of particles increases and therefore should lead to improved settling performance (Bradley, 1975). But comparatively little is known about the performance of settling tanks in hot climâtes.

There is no correlation between suspended solids and settleable solids. Therefore, for a given suspended solids concentration, a settling tank may give different removal efficiencies on separate occasions because of the varying concentrations of the settleable solids and also due to the factors discussed earlier (Tebbutt and Christoulas, 1975). For the same overflow rate and detention time different TSS removal was also observed during the study. It was found that there is no direct dependence of the TSS removal on the overflow rate and the detention time (Fig. 4).

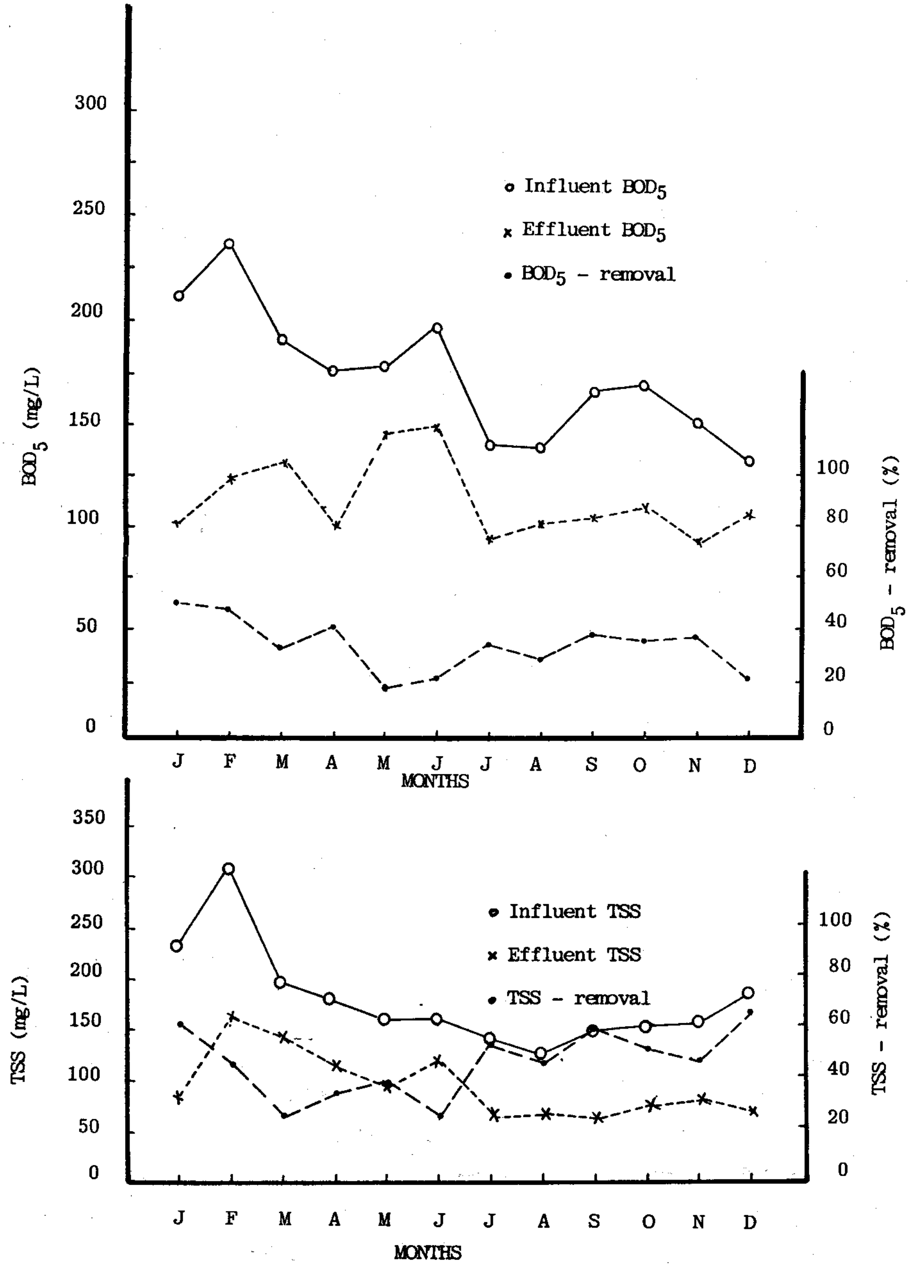


Fig. (2) – Monthly Performance of Primary Settling Tanks

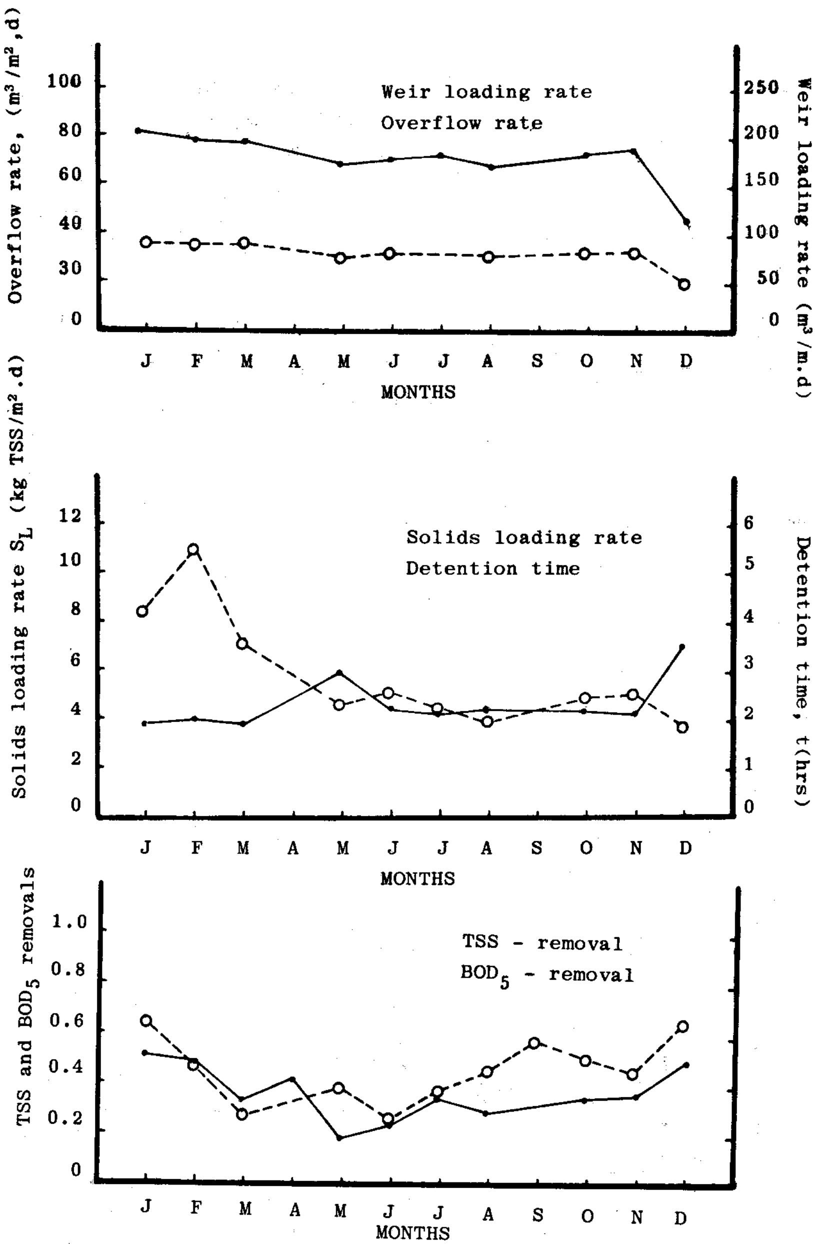


**Fig. (3) – Variation in Loading Parameters and Operating Efficiency of Primary Settling Tank.**

Similar full scale operational data have been reported for the suspended solids removal related to the overflow rate in the primary settling tank at US and Brazil plants (Bradley, 1975; Steel and McGhee, 1984). Based on the pilot plant study, Tebbutt and Christoulas have suggested a mathematical model for the overflow rate and the suspended solids removal efficiency and compared it with the results of other workers. Such models can be useful tools in comparing alternative configuration and design of settling tanks.

The effect of various loading parameters on TSS-removal is presented in the form of the following empirical models developed by least squares regression analysis of the data collected during the field study.

$$Y = 0.40818\ e^{0.025346t} \quad (1)$$

$$Y = 0.46128\ e^{-0.0019678q} \quad (2)$$

$$Y = 0.34014\ e^{0.055646S} \quad (3)$$

where;

$Y$ = TSS-removal
$t$ = Detention time (hours)
$q$ = Surface overflow rate ($m^3/m^2/day$)
$S$ = Solids loading rate ($kg/m^2/day$)

The fitted curves according to equations 1 and 2 show that for a considerable change in the detention time and the overflow rates only a marginal change in the removal of suspended solids takes place. This indicated that only these two parameters do not control the settling process. The solids loading rate influences the process to a much greater extent as depicted by the slope of the fitted curve (Fig. 4). However, there are variations in the values of the coefficients reported in the literature confirming that the settling process is influenced by various interlinked factors (Table 2).

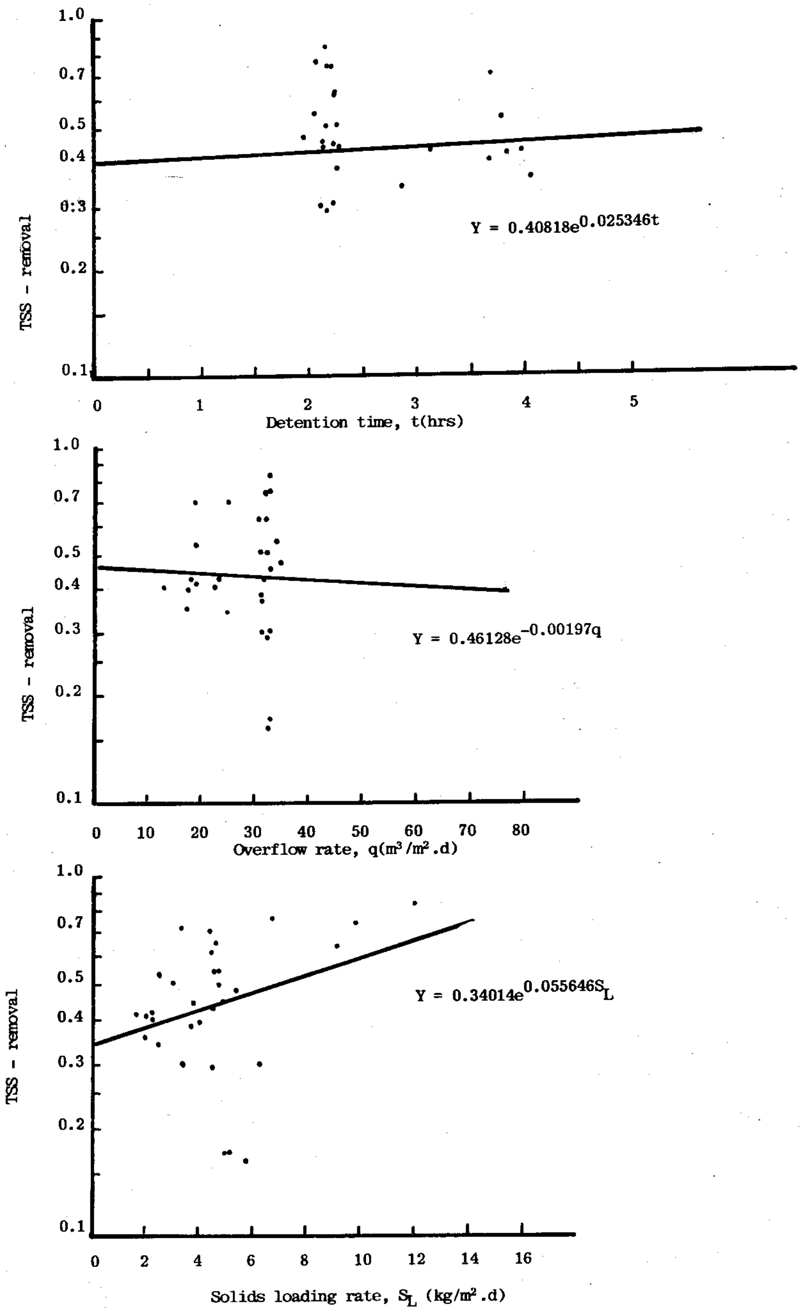


**Fig. (4) – Effect of Various Loading Parameters on TSS Removal.**

**Table (2)**

**Comparison of the values of coefficients in the equation $Y = Ke^{-cq}$**

| References | K | c |
|---|---|---|
| Present work (Eq 2) | 0.461 | 0.00197 |
| Steel and McGhee (1984) | 0.725 | 0.0047 |
| Tebbutt and Christoulas (1975) | 0.510 | 0.0029 |
| CIRIA (1973) | 0.750 | 0.0123 |
| Smith (1969) | 0.820 | 0.0088 |
| Escritt (1956) | 0.770 | 0.0023 |

The hourly data presented in Table 3 shows that even at shorter detention time, higher overflow rate, and solids loading rate the settling pefrormance is satisfactory. In spite of the low coccentration of suspended solids as compared to the wastewater in temperate climates the TSS removal in general is high, which may be attributed to the prevailing high temperature. The values of the design parameters like detention time and overflow rate are within the range used in practice which are generally conservative (Bradley, 1975; Tchobanologous and Schroeder, 1985).

Considerable BOD removal also takes place during primary settling. The TSS-removal against BOD-removal is presented in Fig. 5. A straight line was fitted to the data by least squares regression so that an estimate of BOD removal can be made corresponding to any TSS-removal.

During the study the sulfide concentration in the raw wastewater reaching the treatment plant was between 7.6 and 12.5mg/L. However, concentrations upto 30 mg/L have been reported (Paul and Smith, 1984). Coagulation-flocculation causes the particles to settle easily, as a result of which 20 to 60% of the sulfide is removed during primary settling (Table 3). Sometimes desludging of the settling tanks could not be done as per schedule due to operational problems in the subsequent units which led to low sulfide removal.

Table (3)

**Effect of loading parameters on the performance of primary settling tank**

| Date | Detention time t. (hrs) | Surface overflow rate, q ($m^3/m^2.d$) | Solids loading rate, ($Kg/m^2.d$) | TSS-removal | $BOD_5$-removal | Sulphide removal |
|---|---|---|---|---|---|---|
| 2 Dec. 1986 | 1.28 | 55.3 | 29.3 | 0.90 | 0.74 | — |
| 11 Dec. 1986 | 1.50 | 46.9 | 7.0 | 0.65 | 0.50 | 0.59 |
| 19 Dec. 1986 | 1.65 | 42.8 | 4.9 | 0.58 | 0.31 | — |
| 24 Dec. 1986 | 1.36 | 52.0 | 14.8 | 0.77 | 0.37 | 0.20 |
| 2 Jan. 1987 | 1.42 | 49.8 | 7.4 | 0.61 | 0.28 | 0.57 |
| 18 Jan. 1987 | 1.25 | 56.5 | 21.2 | 0.80 | 0.48 | — |

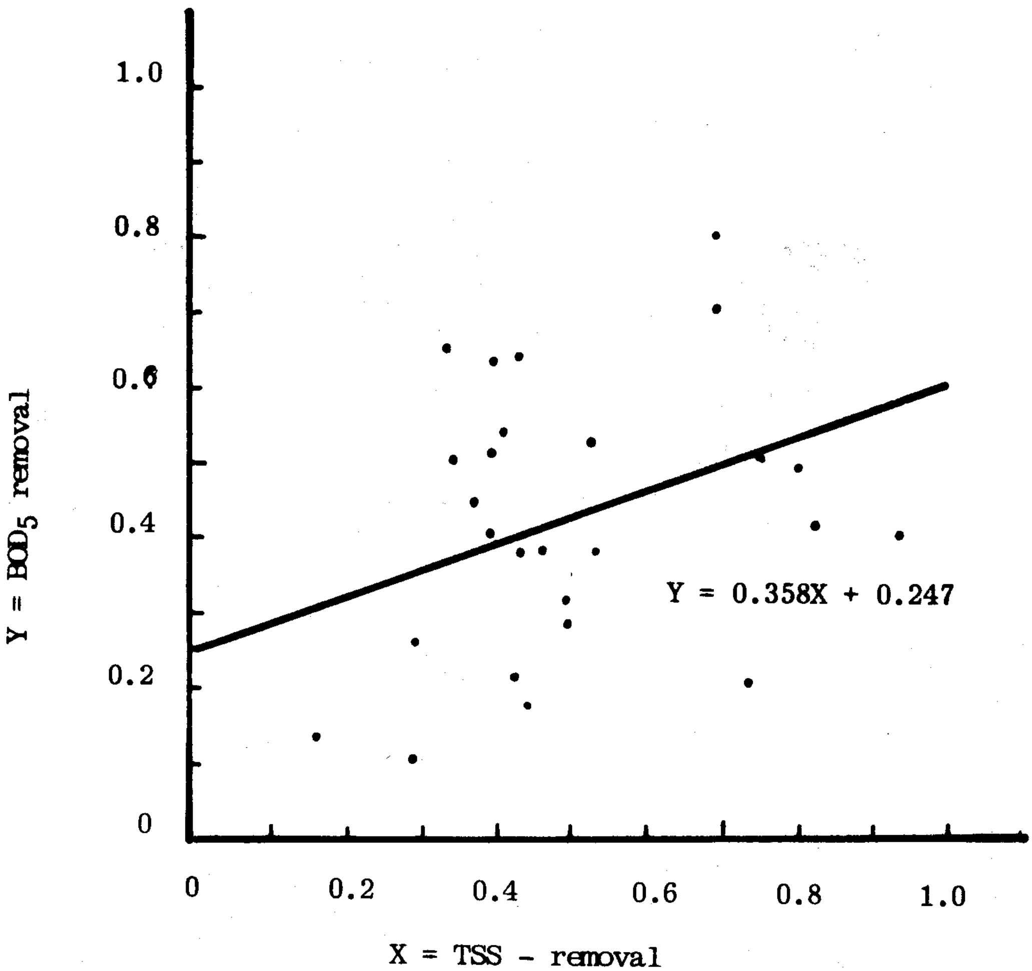


Fig. (5) – **Relationship Between TSS and BOD Removals.**

## CONCLUSION

Solids loading rate which incorporates both the suspended solids concentration and the overflow rate is of greater significance in predicting the performance of settling tanks than the overflow rate and the detention time.

The empirically developed performance relationships for the settling tanks can be used to predict their performance and they might prove to be useful in the design of new settling tanks in the event the plant has to be expanded in future.

## REFERENCES:


1. APHA, AWWA and WPCF (1975). "Standard Methods for the Examination of Water and Wastewater", 14th Edition. American Public Health Association, New York.

2. **Bailey M. C. (1980).** "Sewerage and Sewage Treatment in Dubai An Overall View", Middle East Water and Sewage, July/August, 161–170.

3. **Bradley R. M. (1975).** "The Operating Efficiency of Circular Primary Sedimentation Tanks in Brazil and United Kingdom". Public Health Engineer, No.13, Vol.5, 5–19.

4. Construction Industry Research and Information Association (1973). "Cost effective sewage treatment – The Creation of an Optimizing Model", Report 46, 2, CIRIA, London, 13.

5. **Escritt L. B. (1956).** "Sewerage and Sewage Disposal", Contractor's Record, London, 282.

6. **Fair G. M., Geyer C. G. and Okun D. A. (1966).** "Water and Wastewater Engineering", John Wiley and Sons, New York.

7. **Mahmoud T. A, Kanbar S. A. and Ahmad S. (1977).** "Wastewater Survey of A Partially Sewered City". Journal Institution of Engineers (India), Vol. 57, part EN, 3, June 103–107.

8. **Paul P.N. and Smith L. J. (1984).** "Sewage Treatment in Abu Dhabi, In IAWPRC Conference-Design and Operation of Large Wastewater Treatment Plants". (Ed) W. von D. Emde and H. B. Tench, Water Science and Technology, Vol. 16, No. 10/11, Vienna 609–620.

9. **Smith R. (1969).** "Preliminary Design of Wastewater Systems". J. Sanitary Engineering Division, ASCE, 95, SAl, 117.

10. **Steel E. W. and McGhee T. J. (1984).** "Water Supply and Sewerage", 5th. Edition, Mcgraw Hill, New York.

11. **Tchobanologous G. and Schroeder E. D. (1985).** "Water Quality". Addison Wesley Pub. Co., Reading Massachusetts.

12. **Tebbutt T. H. Y. and Christoulas, D. G. (1975).** "Performance Relationships of Primary Sedimentation". Water Research, Vol. 9, 347–356.