Parameters Affecting Wastewater Filtration in Arid Regions

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Introduction

4.0 millions cubic meter filtration units in STP in operation or under construction in Saudi Arabia with total cost of wastewater filtration of 2.0 Billion S.R , The optimization of operation or design of wastewater filters needs deep understanding of parameters affecting filters performance.

There are numerous variables which affect the performance of wastewater filters.

Earlier researchers have studied the effects of some of the important parameters such as: sand size, depth, approach velocity and variation of media type.

However the relative effects of these variables have to be analyzed using rational approach.

One of the aims of this research was to study the relative effects of the important parameters of wastewater filtration in local environmental conditions.

- The blacket-burman method was used to form matrix of important parameters and statistical analysis of experimental results were made.
- New indices which can account for the fluctuations of influent and effluent water qualities observed in field experiments was introduced.

Literature survey

According to the literature survey ,the important parameters affecting wastewater filtration can be summarized as : media type , media size , bed depths, approach velocity , influent characteristics.

The study of relative affects of each of these parameters requires numerous experiments if one parameter is varied within the range used in practice while the others are kept constant.

The application of Plackett and Burman statistical method will eliminate the need for tedious experiments.

Plackett and Burman Statistical method

The Plackett and Burman method have been devised in 1946 will be used as a rapid screening method to select the most important variables affecting filtration process. Plackett and Burman stated that each design of N experiments can study up to N-1 variables. One Variable is used as a dummy variable to measure the variance of the system.

The final matrix for eight variables at two levels is as shown in table 1.The positive sign indicates the high level and the negative sign indicates the low level. The definition of variables levels are listed in Table 2.

Table 1 : Final matrix for eight variables at two levels.

Exp #	Parameters						
	ds	v	Dummy	La	Ls	BOD-5	SS
1	+	+	+	-	+	-	-
2	-	+	+	+	-	+	-
3	-	-	+	+	+	-	+
4	+	-	-	+	+	+	-
5	-	+	-	-	+	+	+
6	+	-	+	-	-	+	+
7	+	+	-	+	-	-	+
8	-	-	-	-	-	-	-

Table 2 : The levels of Variables

Variables	Units	Low level	High Level
Sand size , ds	mm	0.55	1.2
Approach velocity, v	m/h	3	10
Coal depth ,La	cm	0	45
Sand depth, Ls	Cm	35	60
BOD	mg/l	60	87
Suspended solids ,SS	mg/l	30	60

The results of experiments will be measured by filtration indices. The affect of each variable (i) , Ei will be measured by comparing the average value of results at positive values ,R(+) ,with the results at negative values ,R (-).

$$Ei = Rat(+)/4 - R\ at\ (-)/4$$

The greater the value between the two averages (positives or negatives) ,the greater is the effect of the variable in determining the final filtration properties.

Filtration Indices

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In this research , the filterability number (F) and the solids capture index (SCI) will be applied. However in both indices C and H values are the values at time t.

There fore the whole filtration process till time t is not taken into consideration .Also , the fluctuations in C_0 which is common in practice are not taken into account .

- In this research ,the area based averages of C_0 ,C and the H values were used in calculating F and the SCI.
- Two more modified indices: mass captured per head loss(MPH) and a “K” index will be introduced.

Table 3 : Original Filtration Indices

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Index	Definition of variables	Filtration Performance
(Biskner and Young) Solid capture Index SCI= $((C_0 - C)*V*T) / H_T$	C_0 = Influent concentration	Dimensionless unit , High value means better performance
	C=Effluent concentration	
	H_T=Terminal head loss	
	V=Approach velocity	
	T=Filtration time	
Ives Index F=$(C/C_0)*(H_T/V*T)$	C_0 = Influent concentration	Low value means better performance
	C=Effluent concentration	
	V=Approach velocity	
	H_T= Terminal head loss	
	T=Filtration time	

Table 4 : Derived New Filtration Indices

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Index	Definition of variables	Filtration Performance
Mass capture per head loss MPH= M_C / H_T	M_C = Mass Captured	High value means better performance
	H_T=Terminal head loss	
$K = \Delta H / (V*T*C_0*R)$	Δ H = Head loss drop cross the filter bed	Low value means better performance
	C_0 = Influent concentration	
	V=Approach velocity	
	T= Filtration time	
	R=Removal Ratio (M_C/Min)	

Experimental Set-up

Figure 1 shows a simplified block diagram of treatment plant in which this research was carried. The location of the pilot plant filters are also indicated in Figure 1.BOD and SS of filter influent could changed by receiving effluent either from 1st stage , or from 2nd stage trickling filters ,by these changes BOD and SS values were kept close to values given in table 2

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The pilot scale filters consist of 150 mm diameter ,14 mm thick and 1200 mm long permeable PVC columns

Fig. 1 FLOW DIAGRAM OF SEWAGE TREATMENT PLANT OF HOLY CITY OF MAKKAH

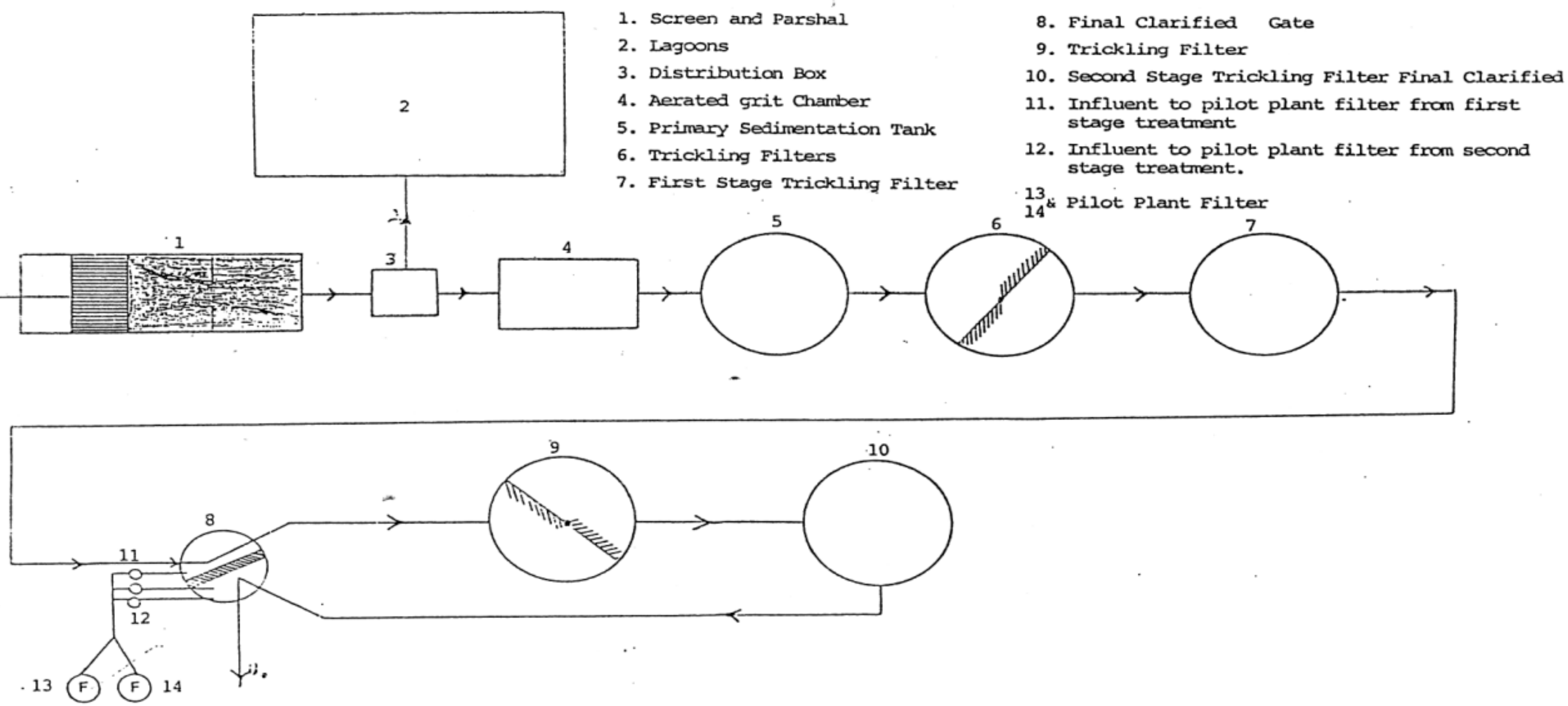
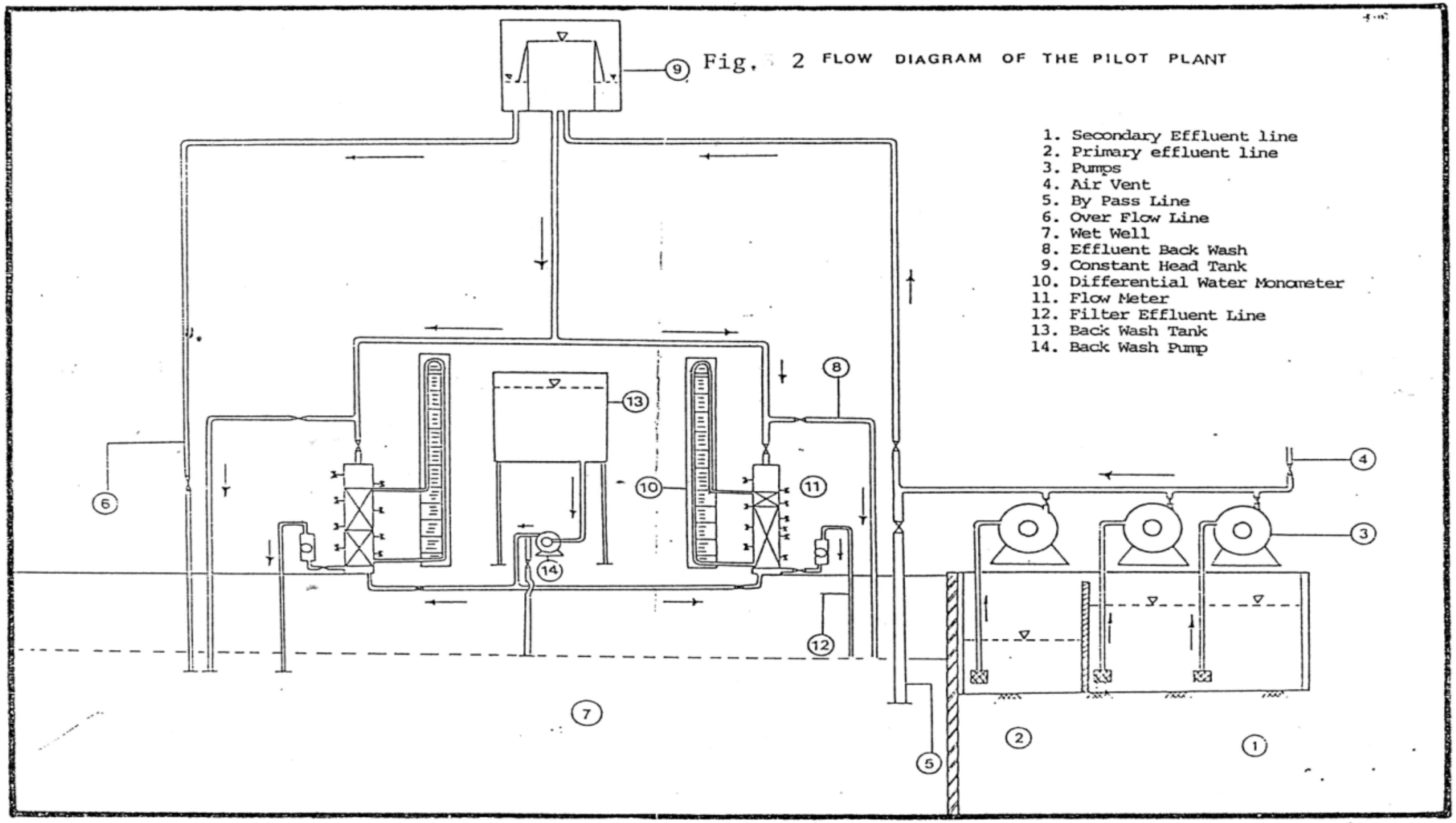


Fig. 2 FLOW DIAGRAM OF THE PILOT PLANT



Results

Indices for eight runs with different parameters were calculated. The indices were based on using area based averages values of C,C_0,and H .The averages were obtained using the area under C-t,C-t_0 and the H-t experimental curves.

Table 5.F,K,SCI and MPH indices

Index	Experiment #							
	1	2	3	4	5	6	7	8
F*10^3	1.6	2.3	1.4	0.7	11.9	6.8	2.6	4.2
K*10^3	6.4	9.9	6.2	2.9	54.0	35.3	10.6	16.5
SCI,g/l	10.6	4.4	8.2	14.9	0.6	1.0	5.9	4.0
MPH,g/cm	1.9	0.8	1.5	2.7	0.1	0.2	1.1	0.7

The variable effects calculated using different indices is presented in table 4.

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Table 6. Variable Effects calculated using different indices

Index	ds	V	Dummy	La	Ls	BOD	SS
	0.55-1.2	3-10		0-45	35-60	60-87	30-60
	mm	m/h		cm	cm	mg/l	mg/l
F*10^3	-19.6	14.7	-17.6	-42.3	-0.8	29.3	3.8
K*10^3	-5.4	5.4	-6.6	-20.7	-1.0	14.8	16.8
SCI,g/l	3.8	-1.6	0.4	4.3	4.8	-2.0	-4.6
MPH,g/cm	0.8	-0.3	-1.0	-0.8	1.1	-0.4	0.8

Percentage confidence of the t-test results for a set of experiments with parameters as given in Table 2 are presented in Table 6.

Table 6. Percentage confidence of t-test results

Index	ds	V	Dummy	La	Ls	BOD	SS
	0.55-1.2	3-10		0-45	35-60	60-87	30-60
	mm	m/h		cm	cm	mg/l	mg/l
F*10^3	53	43	50	74.8	6.4	66.2	70.4
K*10^3	43	43	50	80.8	6.4	72.8	76.6
SCI,g/l	93.7	86.1	50	94.6	95.1	88.4	95.0
MPH,g/cm	93.9	86.6	50	94.8	96.0	88.6	95.1

Table 7 and 8 shows the chronological results for variable effects

Table 7. Chronological Results according to F and K indices.

Index	Variable values					
	La	SS	BOD-5	ds	V	Ls
F	42.3	34.8	29.3	19.6	14.7	0.9
K	20.7	16.7	14.8	5.4	5.4	1.0

The F and the K indices gave similar chronological order.

Table 8. Chronological Results according to SCI and MPH indices.

Index	Variable values					
	Ls	**SS**	**La**	**ds**	**BOD-5**	**V**
SCI	**4.8**	**4.6**	**4.3**	**3.8**	**2**	**1.6**
MPH	**1.09**	**0.81**	**0.77**	**0.67**	**0.34**	**0.29**

The chronological order obtained from the SCI and MPH indices are the same but differs from the F and K indices order. The variables SS and ds keep the same chronological order in both sets of indices.

Conclusions

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1- Area based averages values for fluctuating filter influent and effluent concentrations were used to calculate he filterability number,F and the solids capture index ,SCI .Two more indices : the K index and the mass capture per head loss were introduced.

2- The t-test results showed that F and the K indices gave the highest percentage confidence (74.8 -80.0 %) for anthracite bed depth parameter. The SCI and MPH indices gave the highest percentage confidence (95.1 – 96 %) for sand depth parameter.

3-From percentage confidence results it seems that sand depth , anthracite depth , sand size, approach velocity having the highest effectiveness on wastewater filtration applying ranges of variables studied.

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