EVALUATION OF THE DIRECT FILTRATION UNDER THE EGYPTIAN CONDITIONS

Dr. Ahmed Fadel
Civil Eng. Dept.
Faculty of Eng.
El-Mansoura Univ.

Eng. Hesham K. El-Etriby
Civil Eng. Dept.
Faculty of Eng.
El-Mansoura Univ.

استعمال نظم الترشيح المباشر في معالجة مياه الشرب تحت الظروف المصرية

تستعمل طريقة الترشيح المباشر لمعالجة مياه الشرب عندما تكون درجة عكارة المياه ولونها المراد معالجتها ذات قيم منخفضة نسبيا . ولقد أجريت هذه الدراسة للحصول على تقييم ميداني لاستخدام طريقة الترشيح المباشر في معالجة مياه النيل لأغراض الشرب والاستعمال المنزلي . وكان هدف المعالجة خفض درجة عكارة المياه الى أقل من ١,٠٠ وحدة عكارة عوينية . ولانجاز هذه الدراسة أنشأ نموذج معملي لهذه الطريقة . صنع النموذج وتم استخدامه في محطة المياه الخاصة بشركة النصر للأسمدة والصناعات الكيماوية بطلخا . ويتكون هذا النموذج من مرشح يحتوي على طبقة من الزلط صغير الحجم يتبعه مرشح آخر يحتوي على طبقتين أحدهما فحم انثراسيت والأخرى رمل . ولقد تمت التوصيلات والمقارنات بالطريقة التي تمكن من استخدام النموذج كنموذج للترشيح المباشر ذو المرحلتين أو كنموذج للترشيح المباشر ذو المرحلة الواحدة باستبعاد المرشح الأول .

وقد تناولت الدراسة العديد من المتغيرات ، بعضها كان يتغير بالظروف الطبيعية كالعكارة والأس الهيدروجيني وعدد الطحالب وبعضها كان يتم التحكم فيه مثل جرعة الكيماويات ومعدل الترشيح وأسلوب التشغيل . والبعض الآخر ثبت خلال مدة الدراسة مثل نوعية طبقات الترشيح وعمقها وشكل وقطر المواد المستخدمة . وقد تم مناقشة هذه المتغيرات وثبت من خلال التجارب امكانية معالجة مياه النيل تحت مختلف الظروف بأكثر من شكل من أشكال الترشيح المباشر بكفاءة تامة

ABSTRACT

Direct filtration system has been employed as alternative to the conventional coagulation-flocculation-sedimentation-filtration system for treating surface water. The major advantage of a direct filtration plant over a conventional treatment plant is a capital cost savings of approximately 20-30 percent.

This study was conducted to obtain comparative field performance evaluation of direct filtration system for treating the Nile River water for domestic use. A pilot plant for this study was constructed. The pilot plant was located in the water treatment plant of EL-Nasr Co. for Fertilizer and Chemical Industries at Talkha, Dakahlia. The pilot plant consisted of a coarse media filter followed by a dual media filter.

In this study, several variables were monitored. Some varied naturally, other variables were modified by the researcher and others were held constant through the study. Natural variables were raw water turbidity, pH, and total plankton population, Experimental variables were chemicals dosages, filtration rates and operation methods. Media types, shapes and size, and depth were held

constant. The effect of these variables were discussed. The result of this study showed that the Nile River water can be successfully treated under different modes of Direct Filtration.

INTRODUCTION

Direct filtration system has been employed as alternative to the conventional coagulation-flocculation-sedimentation-filtration system for treating surface water. Direct filtration process used when raw water turbidity and color are relatively low. The main difference between the two processes is that complete conventional treatment includes flocculation and sedimentation facilites to reduce the solid's load going to filters, while direct filtration process eliminates sedimentation facilities in which the solids in water have to be removed by filters.

Culp (3) stated that a potential saving up to 30% of the capital costs may be realized. He also points out that direct filtration accomplishes the same water treatment goals as a conventional system, but may do so at lower costs under certain circumstance. It is, therefore, available alternative for water treatment in developing countries where funding for municipal facilities may be low.

Several flow schemes of direct filtration for low turbidity surface water have been practiced. If the flow scheme includes coagulant and/or polymer addition, rapid mixing, flocculation and filtration, the scheme is termed "Direct Filtration". If the flocculation step is absent, the flow scheme is termed "Direct In-Line Filtration". Direct filtration dose not include use of separate sedimentation facilities. When the filtration process consists of chemical addition prior to a coarse media filter followed by a dual or multi-media filter, the process is called two-stage direct filtration (4).

The Nile River water course and water quality were subjected to changes due to natural and artificial factors (the construction of Aswan Reservoir, Edfine Barrage, the large embankment near Faraskour, and the recent completion of Aswan High Dam). The construction of the High Dam has caused the annual autumn flood to disappear. Millions tons of suspended solid carried by water are being settled upstream the High Dam, and the suspended solids are being settled upstream the High Dam, hence, the raw water turbidity and color are become much lower than before constructing the High Dam . The principal objective of this study was to evaluate the direct filtration under the Egyptian conditions. Specifically, the study was designed to determine:

1. Whether the direct filtration process can be used for treating the Nile River water.
2. Which mode is more economic, Two-Stage Direct filtration or the Direct In-line Filtration mode?
3. The possibility of lowering the turbidity level to 1.0 NTU with minimal chemical pretreatment.

MATERIAL AND METHOD

A pilot plant for this study was constructed. The pilot plant was located in the water treatment plant of EL-NASR Co. for Fertilizer and chemical Industries at Talkha, Dakahlia. The pilot plant, (Figures 1 & 2) consisted of

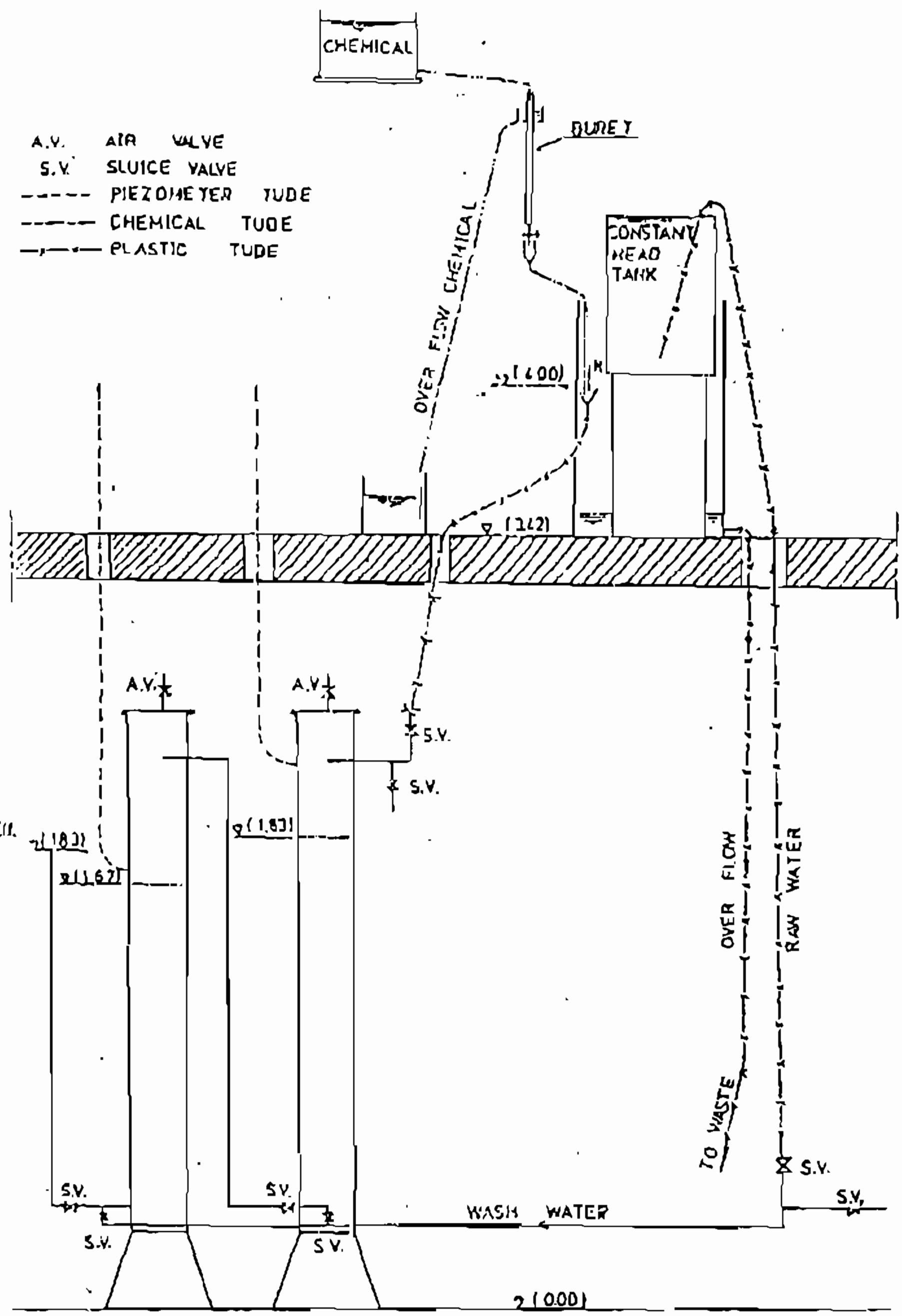

Fig. 1.Schematic flow diagram for the pilot plant during two-stage direct filtration mode

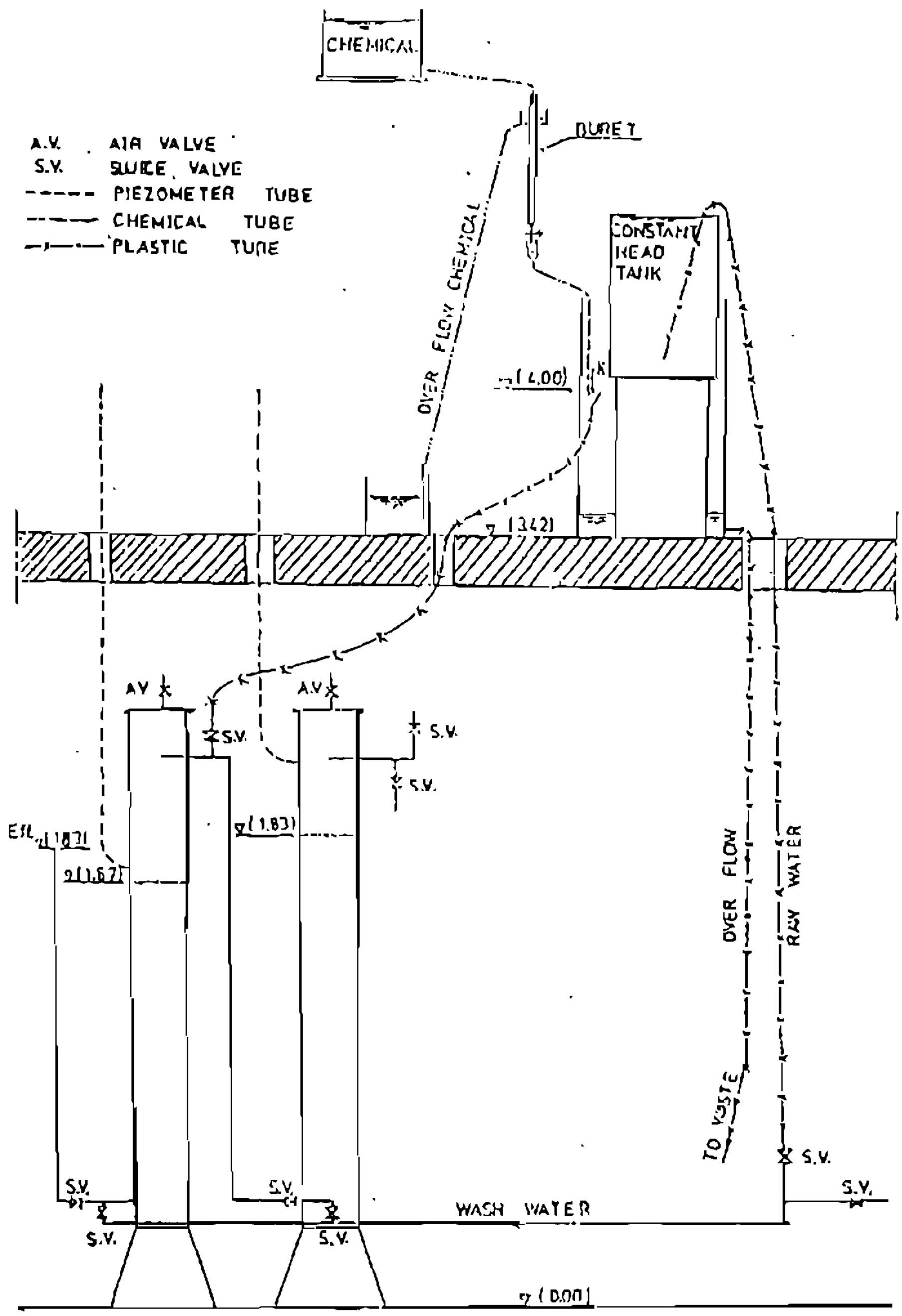

Fig. 2. Schematic flow diagram for the pilot plant during direct in-line filtration mode.

a coarse media filter followed by a dual media filter.

Two steel columns having a diameter of 20 cm were used to house the filter media. One column served as a clarifier (coarse media filter) and the second served as a dual media filter. The clarifier contained 130 cm of fine gravel having an effective size of 3.6 mm, uniformity coefficient of 1.9 and porosity of 0.35. The dual media filter contained 50 cm of anthracite coal having an effective size of 0.82 mm, uniformity coefficient of 2.0, and porosity of 0.42 mm, and 30 cm of silica sand having an effective size of 0.44 mm, uniformity coefficient of 1.55 and porosity of 0.38.

The chemical used in this study was alum because the raw water pH was in the range of 7.5 to 7.8. The percent of $Al_2(SO_4)_3$ concentration in the commercial alum was 53.35% .

The PH meter was a Model 140 A, manufactured by Fisher Accumet Instruments, U.S.A. The turbidimeter was a Model DRT-15B, manufactured by H.F. instruments, U.S.A. . The turbidimeter have four ranges of NTU readings, 0-1, 0-10, 0-100, and 0-200 .

The raw water which was used in the experimental runs was disinfected using chlorine by Talkha factories authorities. The prechlorination dose was varied according to the working condition of the water treatment plant. The pilot plant was designed to be washed by raw water.

The operations of the pilot plant were controlled by ten valves. These valves faciliated service system, backwash, and ripening modes.

Filter run breakthrough was considered to occur when the final effluent turbidity exceeded 1.0 NTU, or when the water level in the inlet tube reasched the top level of the inlet funnel certain conditions necessitated. Both the clarifier and the filter were backwashed at the same time before and after each run .

RESULTS

Shaaban et al. (5) studied the changes in the phytoplankton community (algae) in relation to water temperature, transparency, chlorosity, dissolved oxygen, total alkalinity, hardness, pH, and nutrient salts in the Damietta Branch of the Nile River from Mansoura city to the earthy dam near Faraskour. They found that the seasonal changes of temperature is one of the most important factors which control the survival and distribution of the phytoplankton population. High temperature in summer (specially June and July) is favorable for the blooming of Cyanophyta and some chlorophyta. They also found that during winter the total phytoplankton is represented by Diatoms, of which the most prevailing species is Cyclotella Meneghiniana, being an organism developing in the cooler months.

Monthly variation of phytoplankton standing crop with its main components at Talkha station according to their studies shown in Figure 3.

According to the records of the factories laboratories at Talkha, the maximum turbidity of Nile River water in years 1987 and 1988 was 4.0 NTU, and the pH ranged from 7.5 to 7.8.

After several testing runs, twelve successful runs were conducted to examine several operation modes such as direct in-line filtration mode, and two-stage direct filtration mode with or without chemical pretreatment. Several filtration rates and chemical dosages were also examined.

Tables 1, 2, and 3 summarize the conditions of each run. Table 1 presents run date, raw and treated water characteristics of turbidity and pH, and run length. Table 2 presents filtration rate, head loss due to clogging only across the clarifier, the filter, and across the system, the NTU-cubic meter of turbidity removed per meter of clogging head loss for the clarifier, filter, and for the system, and the alum dosage used in each run. Table 3 presents the head loss due to friction and clogging, and NTU-cubic meter of turbidity removed per meter of total friction and clogging head loss for system.

The twelve runs may be classified as follows:

1- Runs *5, *6, *11, and *12 were to examine direct in-line filtration system.

2- Runs *1-*4, and Runs *7-*10 were to examine two-stage direct filtration system.

3- Runs *3-*6 were conducted without using chemical.

4- Runs *1, *2, and Runs *7-*12 were conducted by using chemical

DISCUSSION

In this study, several variables were monitored. Some varied naturally, other variables were modified by the researchers, and others were held constant through the study. Natural variables were raw water turbidity, pH, and total plankton population. Experimental variables were chemical dosages, filtration rates and operation methods. Media types, shapes and size, and depth were held constant. The effect of these variables will be discussed.

Alum was used as the sol coagulant in this study; however, experimental results showed that alum as a sol coagulant was sufficient to produce filtered water with turbidity below 1.0 NTU. Alum dosages used were in the 0.0-8.3 mg/l range, but most runs were conducted in the 3.5-5 mg/l range as $Al_2(SO_4)_3$.

The values of NTU-cubic meter of turbidity removed per meter of head loss for clarifiers and for filters were used by Wityk, M. (6) to quantify the efficiencies of the clarifiers and filters for each run. The head loss due to solid accumulation was used to calculate the values of NTU-cubic meter of turbidity removed per meter of head loss, (Table 2), to make comparison among the chemical pretreatments and filtration rates of the runs.

Runs *1 and *2, and *9 and *10 (Figures 10 & 11), were conducted with the same filtration rate. NTU-cubic meter of turbidity removed per meter of solid accumulation head loss of the total system for Run *2 was greater than that for Run *1, and for Run *10 was greater than that for Run *9. The reason may be because the alum dose in Runs *2 and *10 were lower than that in Runs *1 and *9. It is clear, from Table 2, that Runs *1 have the least value of NTU-cubic meter of turbidity removed per meter of solid accumulation head loss of the total system, this may be due to the action of sweep coagulation mechanism.

In all the following pairs of runs, Run *3, (Figures 4 & 5) and Run *4, Run

Fig. 3. *Monthly variation of phytoplankton standing crop with its main components, at Talkha - (5).*

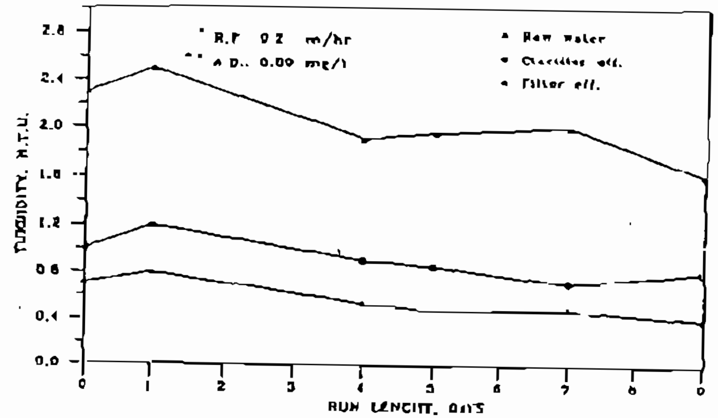

Fig. 4. Turbidity variation in Run # 3

*R.F.= Rate of Filtration **A.D = Alum Dose

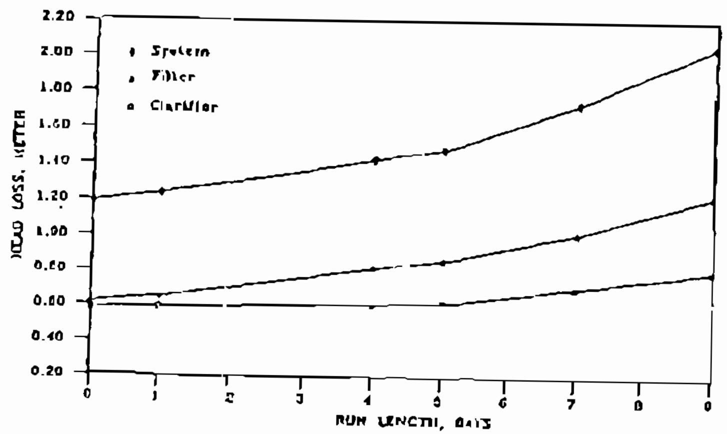

Fig. 5. Head loss variation in Run # 3

Table 1. Run dates, raw and treated water characteristics, and run lengths

Run No.	Date	pH Inf.	pH Eff.	Average raw water turbidity NTU	Average clarif. eff. turbidity NTU	Average filter eff. turbidity NTU	Run length	
1	7/10/1987	7.8	7.3	1.82	0.42	0.17	11.0	Hours
2	13/10/1987	7.8	7.5	1.61	0.43	0.165	12.0	-
3	20/10/1987 – 29/10/1987	—	—	2.05	0.91	0.56	9.0	Days
4	12/11/1987 – 23/11/1987	—	—	1.75	0.87	0.60	11.0	-
5	16/1/1988 – 28/1/1988	—	—	1.53	----	0.65	12.0	-
6	21/2/1988 – 5/3/1988	—	—	1.21	----	0.59	14.0	-
7	9/4/1988	7.7	7.4	2.76	1.81	0.89	5.5	Hours
8	5/6/1988	7.6	7.4	3.40	1.85	0.76	32.0	-
9	21/6/1988	7.6	7.5	2.90	1.2	0.41	12.0	-
10	23/6/1988	7.5	7.5	3.00	1.45	0.45	24	-
11	30/7/1988	7.6	7.5	2.75	---	0.65	30.0	-
12	2/8/1988	7.7	7.6	2.86	---	0.65	14.0	-

Table 2. Filtration rates, head loss due to solid accumulation only, NTU-cubic meter of turbidity removed per meter of solid accumulation head loss for the clarifier, filter and for the system, and the alum doses used in this study

Run No.	Filtration rate for both clarifier and filter	Head loss meters of water Clar.	Filt.	sys.	NTU-cubic meter of turbidity removed per meter of head loss Clar.	Filt.	sys.	Alum dose mg/l as $Al_2(SO_4)_3$
1	9.00	0.34	0.43	0.77	12.8[a]	1.00	6.66	8.30
2	9.00	0.31	0.29	0.60	12.94	3.10	8.18	3.00
3	9.20	0.23	0.43	0.66	309.4	34.68	108.16	0.00
4	9.60	0.15	0.59	0.74	467.0	36.42	123.70	0.00
5	9.80	——	0.71	0.71	-----	109.80	109.88	0.00
6	8.00	——	0.56	0.56	-----	93.48	93.48	0.00
7	10.35	0.07	0.07	0.14	24.3	25.50	13.30	4.60
8	10.00	0.35	0.83	1.18	44.50	15.19	22.47	4.70
9	11.00	0.67	0.35	0.96	11.56	9.36	10.78	5.35
10	10.90	0.40	0.45	0.85	31.65	14.61	22.72	3.60
11	12.20	----	1.49	1.49	-----	15.20	16.20	3.47
12	15.00	----	0.73	0.73	-----	20.78	20.28	3.50

a Sample calculation (using Run #1 data):
NTU-cubic meter of turbidity removed/meter of solid accumulation head loss = [(average raw water turbidity, NTU-average clarifier effluent turbidity, NTU) x (R.F. m/hr) x (surface area of clarifier media, m^2) x (run length, hr)) / m of solid accumulation head loss across the clarifier) =

$$[(1.82-0.42) \times 9.0 \times (\pi \times (0.2)^2/4) \times 11.0] / (0.34) = 12.8$$

Table 3. Head loss due to friction and solid accumulation, and NTU-cubic meter of turbidity removed per meter of total, friction and solid accumulation head loss for the system.

Run No.	Head loss meters of water Clar.	Filt.	sys.	NTU-cubic meter of turbidity removed per meter of total head loss of the system
1	0.94	0.90	1.93	2.66
2	0.02	0.99	1.01	2.71
3	0.01	1.24	2.05	43.98
4	0.70	1.29	1.99	46.00
5	---	1.40	1.40	55.75
6	---	1.10	1.10	47.39
7	0.04	0.07	1.71	1.93
8	1.07	1.55	2.62	10.13
9	1.30	1.23	2.61	3.96
10	1.19	1.30	2.49	7.76
11	---	2.54	2.54	6.51
12	---	2.2	2.20	4.73

*5 and Run *6, (Figures 6 & 7) and Run *11, (Figures 12 & 13) and Run *12, it is found that each pair had the same condition of chemical pretreatment and operation but the run of high filtration rate had the higher value of NTU-cubic meter of turbidity removed per meter of solid accumulation head loss of the total system. That may be because low filtration rate does not push the strained particles through the media, hence it causes rapid clogging and rapid head loss development. Another reason may be due to the fact that larger volume of water crossed the system at high filtration rate.

Although Run *8, (Figures 8 & 9) was conducted with filtration rate less than that of Run *7, and its alum dose was higher, it had higher value of NTU-cubic meter of turbidity removed per meter of solid accumulation head loss for the total system than that for Run *7. This may be because the majority of raw water turbidity through Run *8 might be due to algae, specially Run *8 was conducted in June, in which algae (Cyanophyta and Chlorophyta blooms (6).

The average raw water turbidity in Runs *3-*6 was about 2.0 NTU or less and the filtered water turbidity was in the 0.40-0.88 NTU range. In these runs, there no coagulants were used. These runs had the highests values of NTU-cubic meter of turbidity removed per meter of solid accumulation head loss of the total system.

When methods of treatment such as Two-stage direct filtration method and Direct in-line filtration are compared not only the head loss due to solid accumulation should be considered in the calculation of the NTU-cubic meter of turbidity removed per meter of head loss but also all the other kinds of losses should be considered, (Table 3). In Runs *3 - *6, Run *5, which was conducted by using the direct in-line filtration system, had the highest value of NTU-cubic meter of turbidity removed per meter of total head loss, this was due to the fact that frication losses of the clarifier (pipes, media, and underdrainage system) were saved in comparison to Runs *3 and *4. Run *6 had value of NTU-cubic meter of turbidity removed per meter of total head loss less than that of Run *5; that may be due to the lower filtration rate used in Run *6.

Run *11, which was conducted by using Direct in-line filtration system, had the highest value of NTU-cubic meter of turbidity removed per meter of total head loss in all runs with chemical, with the exception of Run *8, which conducted during the month of algae blooming.

The NTU-cubic meter of turbidity removed per meter of solid accumulation of head loss value for the total system of Run *12 was greater than that value of Run *11, (Table 2); but the value of NTU-cubic meter of turbidity removed per meter of friction and solid accumulation head loss for Run *12 was smaller than value of Run *11, (Table 3). That was because the friction head loss, across pipes and underdrainage system, is proportional to square of flow rate (2); and increasing filtration rate in Run *12 increased the friction head loss more than in Run *11. However , if hydraulic design of the underdrainage system , and connecting pipes was properly designed to reduce the effect of high flow rate; high values of NTU cubic meter of turbidity removed per meter of total head loss could be achieved.

If the alum dosages vs. pH levels are located in the design and operation diagram proposed by Amirtharajah and Mills (1), (Figure 14), one can find that all runs, at which alum were used with the exception of Run *1, agreed with

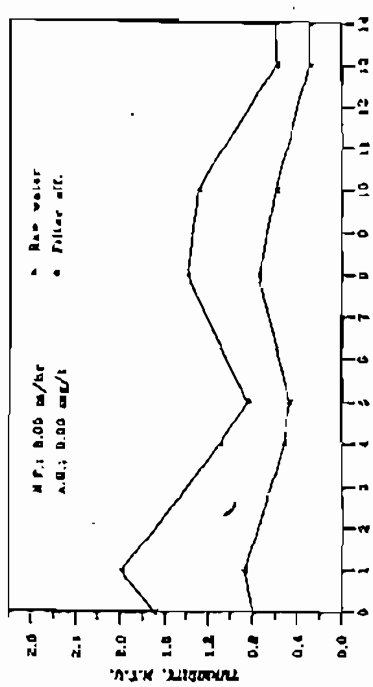

Fig. 6. Turbidity variation in Run # G

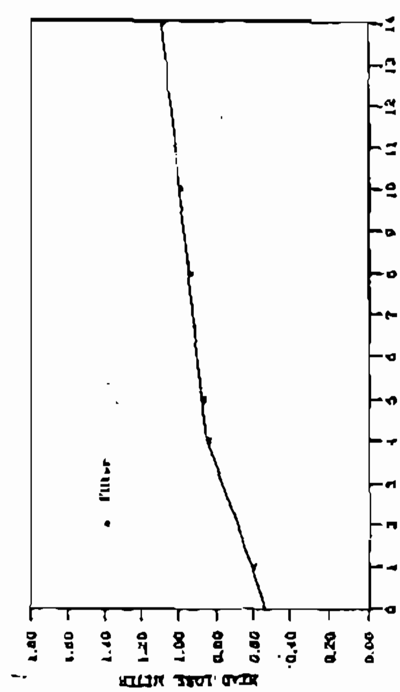

Fig. 7. Head loss variation in Run # G

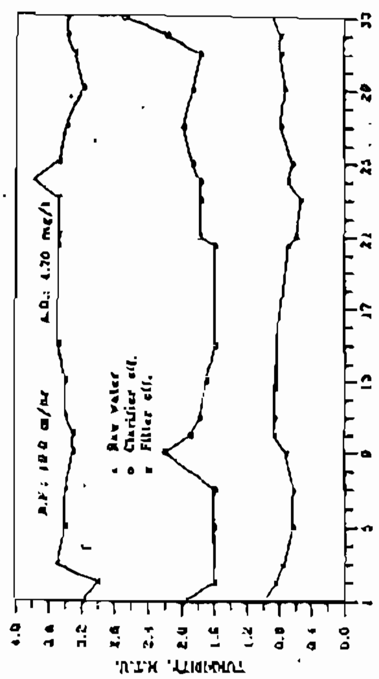

Fig. 8. Turbidity variation in Run # 0

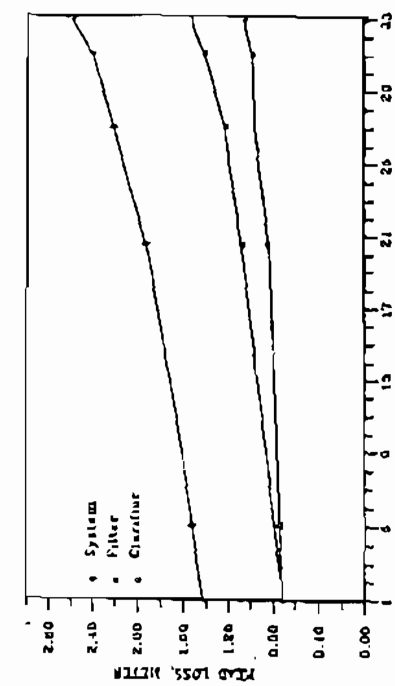

Fig. 9. Head loss variation in Run # 0

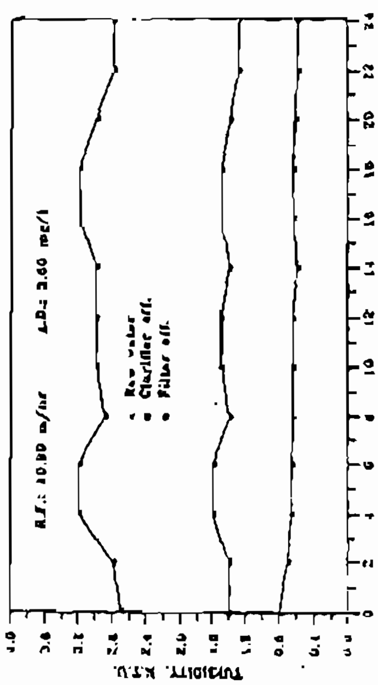

Fig. 10. Turbidity variation in Run # 10

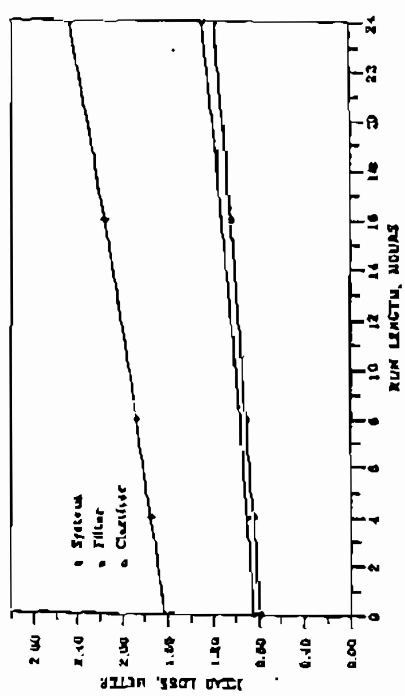

Fig. 11. Head loss variation in Run # 10

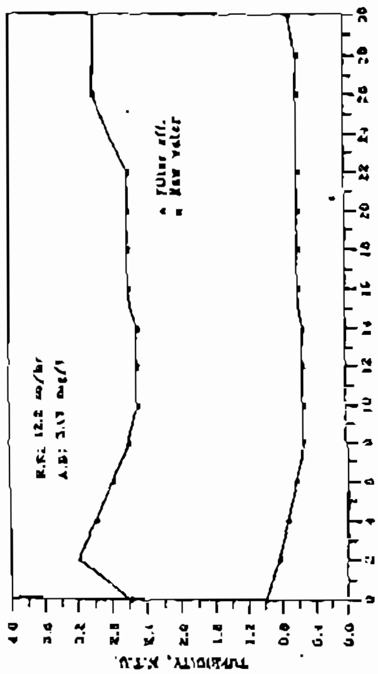

Fig. 12. Turbidity variation in Run # 11

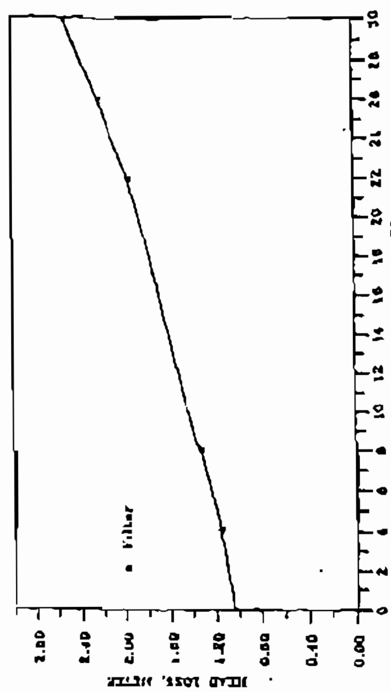

Fig. 13. Head loss variation in Run #11

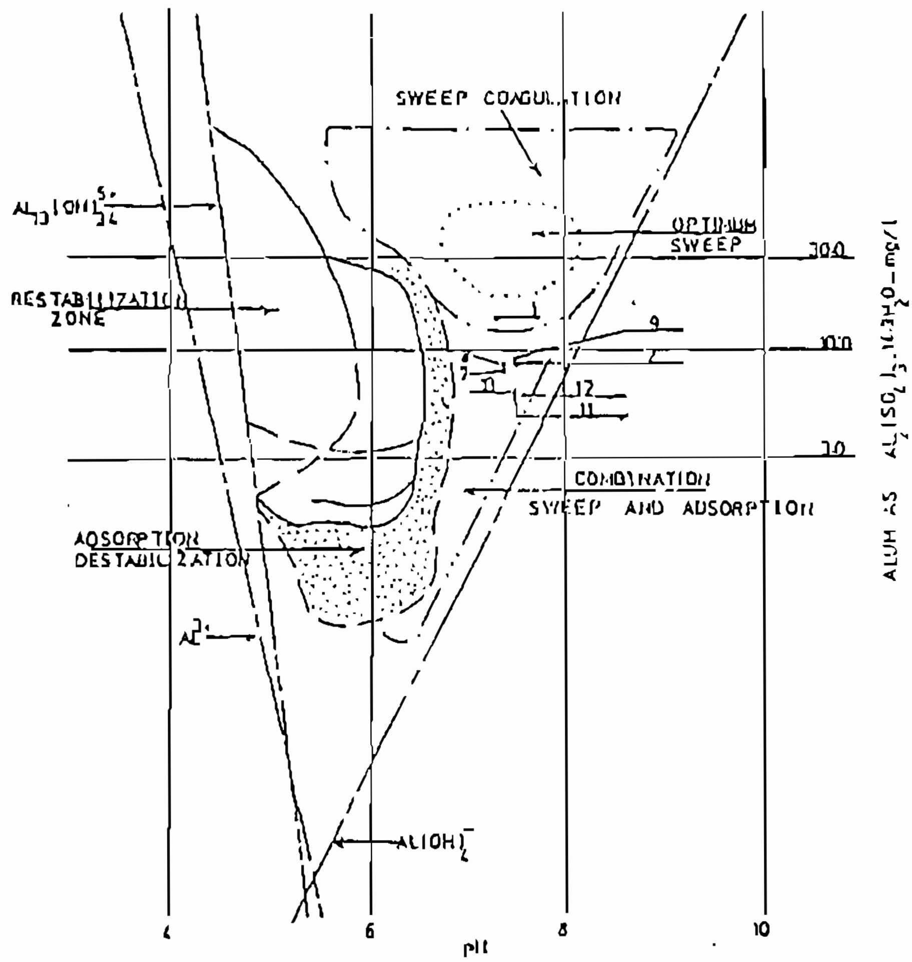

Fig. 14. *The location of alum dosages used in experimental runs, on the design and operation diagram for alum coagulation (1)*

a combination of adsorption-destabilization mechanism, which discussed by Amirtharajah and Mills (1). It can be found that the location of alum dose vs. pH level for Run *1 is in the sweep coagulation zone.

CONCLUSIONS

Results from this field study lead to the following conclusions :

1- Both, Direct In-line Filtration and Two-Stage Direct Filtration system, can treat the Nile River water without using chemicals when the river water turbidity was less than or equal 2.0 NTU.

2- When the turbidity was less than or equal to 2.0 NTU, a run length of 9.0 days was achieved at a filtration rate of 9.2 m/hr without the use of chemicals.

3- Alum was sufficient for treating Nile River water. No other chemical was required or tested.

4- During the period of algae blooming, alum feed rate as low as 4.7 mg/l (as $Al_2(SO_4)_3$) was cosistently able to produce filtered water turbidity below 1.0 NTU. On the other hand, treatment without chemical was not successful during such period .

5- Direct In-line Filtration system successfully treated the Nile River water monitored in this study at filtration rate as high as 15 m/hr.

6- The coarse and dual mediae in the Two-Stage Direct Filtration system treated the Nile River water more effectively than the dual media alone at the Direct In-line Filtration system.

REFERENCES

1. Amirtharajah, A., and K.M. Mills. "Rapid-Mix Design for mechanisms of Alum Coagulation." Journal of the American Water Works Association, 74 (1982), 210-216.

2. Baumann, E.R. "Granular-Media Deep-bed Filtration. " In water Treatment Plant Design. Ed. R. L. Sanks. Ann Arbbor: Ann Arbor Sciene, 1979.

3. Culp, R.L. "Direct Filtration. " Journal of the American Water Works Association, 69 (1977), 375-378.

4. Peterson, M.A., and E.R. Baumann. "Direct Filtration of Water." Environmental Progress, 2, No. 1 (1988), 74-80.

5. Shaaban, S., and Baka, Z. "Seasonal Changes in the Phytolankton Standing Crop Relating to Some Physical and Chemical Factors in Damietta Branch of the River Nile" Mansoura Sci. Bull. Vol. 12 No. (1), 1985.

6. Wityk, M.S. "Direct Series Filtration of Skunk River Water." M.S. thesis. Library, Iowa State University, Ames, Iowa, 1985.

7. Hesham El-Etriby "Using Direct Filtration for Water Treatment Under the Egyptian Condition". M.S. thesis, El-Mansoura Univ., Feb., 1989.