SECONDARY TREATMENT OF SULLAGE WASTEWATER USING ROUGH AND SLOW SAND FILTRATION

المعالجة الثانوية لمياه الصرف الصحي الناتجة من خزانات الاستقبال باستخدام الترشيح الخشن والترشيح الرملي البطئ

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ملخص البحث:

مع التحديات في مجال معالجة مياه الصرف الصحي لا سيما فيما يتعلق بالتكلفة العالية لإنشاء محطات المعالجة وكذلك تكاليف التشغيل والصيانة والحاجة للأيدي العاملة المدربة بشكل جيد وبشكل خاص بالنسبة لمحطات المعالجة التي تستخدم الأنظمة والمعدات الميكانيكية والكهربية ، لذلك فقد أصبح من الأهمية بمكان أن يتم البحث بهدف إيجاد أنظمة معالجة تتسم بسهولة التشغيل وانخفاض تكلفة الإنشاء والتشغيل والصيانة . ولقد أثبتت المرشحات الرملية البطيئة والمرشحات الخشنة الزلطية كفاءة كبيرة في مجال تنقية مياه الشرب نظراً لسهولة الإنشاء والتشغيل ولخصائص المياه الناتجة ذات الكفاءة العالية [1 , 2].

وقد تم خلال هذا البحث دراسة إمكانية استخدام المرشحات الخشنة والمرشحات الرملية البطيئة لإتمام عملية المعالجة الثانوية لمياه الصرف الصحي الناتجة من خزانات الاستقبال والتي تم معالجتها إبتدائياً داخل تلك الخزانات .

والمرشح الخشن الذي استخدم عبارة عن وسط ترشيح من الزلط بسمك ١٠٠سم وبمقاس حبيبات زلط ٦-٨ مم . وتم تشغيلة بمعدل ترشيح ٢٠، ٣٠م.يوم $^{-1}$. في حين كان المرشح الرملي عبارة عن وسط ترشيح سمك ٦٠ سم وبمقاس فعال لحبيبات الرمل ٠,٢ مم وتم تشغيله بمعدلات ٤,٥، ٨ م.يوم $^{-1}$. وقد امتدت الدراسات علي مرحلتين الأولي أربعة شهور والثانية لمدة شهرين .

وقد حققت عمليه المعالجة نسبة إزالة للأكسجين الحيوي المستهلك في حدود ٣٥% ، ٦١% خلال كلاً من المرشح الخشن والمرشح الرملي البطئ علي التوالي وكذلك إزالة للمواد الصلبة العالقة في حدود ٤٥% ، ٨٢% خلال المرشح الخشن والمرشح الرملي البطئ علي التوالي . كذلك فقد تراوحت دورات التشغيل للمرشح الخشن من ٣٨ الي ١٧ يوم وللمرشح الرملي البطئ في حدود ١٢ الي ٦ أيام وذلك تبعاً لمعدلات الترشيح المستخدمة .

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Abstract:

Challenges of wastewater treatment concerning high construction cost of the wastewater treatment plants and operation and maintenance, also the requirements of highly qualified operators , specially with the mechanical biological treatment systems , made invesitgation to suit simple systems of low costs and easy operation and maintance of great importance. Slow sand and rough filtration were effective systems when applied in water treatment, due to these filters being easy to construct and operate , with their high filtrate quality[1 , 2] .

Investigation herein was conducted to study the ability of both the rough and slow sand filters to secondarily treat the sullage wastewater, which primarily treated through interceptor tanks.

The rough filter used in this study mainly was 100 cm gravel of 6-8 mm size operated at filtration rates of 20 and 30 $m.d^{-1}$. While the slow sand filter used was 60 cm sand of 0.2 mm effective size operated at rates of 4.5 and 8.0 $m.d^{-1}$. Studies continued for two stages of four and two months for the first stage and second stage, respectively.

BOD_5 removal of 35% and 61% was achieved through the rough filter and the slow sand filter, respectively. Also, removal of suspended solids was of 45% and 82% through the rough filter and slow sand filter , respectively. Runs of the rough filter usually extended between 38 and 17 days, while that of the slow sand filter was between 12 – 6 days, according to the filtration rates.

Keywords – sullage wastewater treatment, upflow rough filter, slow sand filter, interceptor (septic) tank, BOD removal, COD removal, filtration rate .

1. INTRODUCTION:

In Egypt, despite of the great efforts of the government with its different organizations in the field of wastewater treatment, a little number of the villages in Egypt have constructed or are constructing wastewater treatment plants.

Surveying the wastewater treatment plants in Egypt shows that several treatment techniques have been applied with several disadvantages, yet the major disadvantages, specially in the Delta, are the very high construction, and operation and maintenance cost, and the need of well trained and highly experienced operators. Therefore, there is no doubt about the necessity to promote less expensive and easily to operate and maintain wastewater treatment systems.

Slow sand filters and generally filtration was the early treatment technique for the purification of water. Slow sand filter is known with its ability to produce a high class filtered water, specially with bacterial count, through minimum operation and maintenance requirements.

Operation of slow filters in the wastewater tertiary treatment [4,5,7]referred to a suspended solids removal of 60 – 65 %, with BOD_5 removal of 35 – 55% , with filter run being relatively short when operated with high strength wastewater.

Due to its operation being simple, and because of its viability with wastewater treatment, it was decided to run a series of investigation in an attempt to enhance the capabilities of slow sand filter specially when treating sullage wastewater (effluent of interceptor tanks) and , moreover , applying rough gravel filter to per-filtrate, or pre-treat, the sullage wastewater before entering the slow sand filter. The results obtained were generally promising.

2. MATERIALS AND METHOD:

This studies on sullage wastewater treatment was carried out at Nawag village, about eight kilometers apart from Tanta city, El-Gharbiya Governorate, through the activities of the project " Development of Cost Effective

Technologies for a Sullage Conveyance System & Sullage & Septage Treatment" organized by the Department of Public Works Engineering , Faulty of Engineering , University of Mansoura, with the Academy of Scientific Research and the USAID. A subsequent investigation in the filtration of slow sand filter with pre-rough-fltration of sullage wastewater was conducted.

2.1. Primary treatment

The raw wastewater was primarily treated before entering the filters by firstly entering through a septic tanks. The septic tank is a buried water-tight tank with baffled inlet and outlet. It is designed to detain the raw wastewater flow for 24-18 hours and to remove both floating and settleable solids from the liquid [6].

Ample volume is also provided for storage of the solids, which are periodically removed through an access port. Typically a single chambre septic tanks were used as an interceptor tanks.

Primary treatment is therefore provided at each interceptor tank and only the settled wastewater, (sullag) was collected.

2.2. Wastewater filtration

This was accomplished by passing wastewater (sullage) through a granular medium. As pollutants are removed and filter medium becomes progressively more plugged, the bed loses its effectiveness by restricting the passage of water or by loss of efficiency of removing pollutants. Cleaning of the dirty bed is accomplished by skimming for the slow filter ,or by downwash for the rough filter a process whereby water is allowed downward through the bed to flush away the entrapped solids and prepare the bed for subequent filtration cycles.

The rough filter was 100cm gravel media of 6-8 mm size. The filter backwash was accomplished , at certain limit of head loss, max. of 2.0m,by sudden downflow of the filter water, existing in media pores, and then to re-fill back the media and allow it again to sudden downflow. Usually this process of sudden downflow and re-filling was repeated two or three times or more to ensure filter being carefully backwashed.

The roughing gravel filter was operated at different rates of filtration from 20 and 30 $m.d^{-1}$. Piezometric tubes were set into the filter media to measure the head loss through the filter media.

The slow sand filtration was accomplishad through single media of 60 cm sand depth with 2.0mm effective size, and a supernatant water depth of 1.5m. The filter inlet and outlet were equipped with regulating and float valves in order to control both the rate of filtration and operating head. Figure 1, illustrates a schematic diagram of the sullage filtration system of treatment.

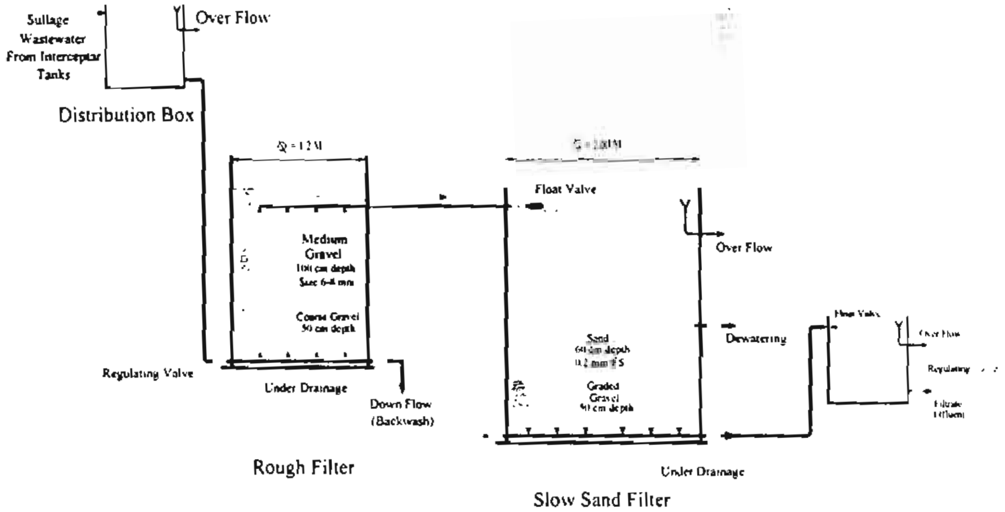

Figure 1.Schematic Diagram For The Sullage Filtration System of Secondary Treatment

Piezometric tubes were also installed through the sand to determine the head loss through the filter media and terminating filter run according to max. head loss of about 1.5m. The supernatant water is therefore being dewatered, with the dirty skin on sand surface being skimmed (about 5.0 cm of the sand depth).

2.3- Analysis:

Several parameters were measured including BOD_5, COD, pH,total Nitrogen, total Phosphorus and suspended solids. Analysis were carried out by methods given in the standard methods 1992. The experiments were conducted in the Sanitary Engineering Laboratory at the Faculty of Engineering, University of Mansoura. Part of the experiments were conducted in the microbiology laboratories in the Faculty of Science , University of Mansoura. All samples were preserved as per the methods given in the standard methods.

3. RESULTS AND DISCUSSION:

First stage investigation

The principal objective of the first stage investigation was to observe both the rough and the slow filter at relatively low rates of filtration.

The filters were located at Nawag pilot plant. Sullage wastewater effluent from several septic tanks located around the pilot plant was withdrawn through a small bore sewer system to a pump station in the pilot area. A small lifting pump was used to deliver the sullage wastewater to a distribution tank allowing the head required to operate the filters. The distribution tank and the filters were all equipped with overflow system and regulating valves to allow constant head to be maintained during all times of each filter run.

During the first stage, the rough filter was operated at rate of 20 $m.d^{-1}$,and backwashed when the head loss reached the maximum hydrostatic head over the filter (2.0m), while it was no longer possible to maintain the desired filtration rate. The slow sand filter was operated at filtration rate of 4.5 $m.d^{-1}$ and cleaned when, the maximum hydrostatic head over the filter, (1.5m), being reached , while it was no longer possible to maintain the desired filtration rate.

This stage of investigation continued over four months, yet the runs of each filter ranged from 29-38 days and 9-12 days , for both the rough and the slow sand filter , respectively. Average results obtained through different runs of the first stage operation with their removal efficiencies and run lengths are shown in table (1).

Table 1: Average results of first stage investigation

Filter	U.R.F Filtration rate = 20 m.d^{-1}				SSF Filtration rate = 4.5 m.d^{-1}			
Parameter (mg/L)	Average Inf.	Average Eff.	Average % removal	Run Length (days)	Average Inf.	Average Eff.	Average % removal	Run Length (days)
BOD_5	152	98	35	Min. 29 & Max. 38	99.5	37	61	Min. 9 & Max. 12
COD	230	163	30		167	65	60	
S.S	135	75	45		74	14	82	
Total N	38.5	30	21		30	18	41	
Total P	10.5	8.5	17		8.5	5.7	32	

Second stage investigation

Results established in the first stage proved that a relatively acceptable percent removal and filtrate quality were obtained through both the rough and the slow sand filter. It was necessary to determine whether or not , these filters could be operated at a relatively higher rates of filtration.

For the second stage of the investigation , the same filters were again employed but with filtration rates of 30 and 8 m.d^{-1} for both the rough and the slow sand filter, respectively. This second stage of investigation extended for about two months, with the run duration for each filter being relatively decreased. Runs ranged between 17 – 22 days for the rough filter, and about 6-8 days for the slow sand filter. Average results obtained through different runs of the second stage operation with the removal efficiencies and run lengths are shown in table (2).

Table 2: Average results of second stage investigation

Filter	U.R.F Filtration rate = 30 m.d^{-1}				SSF Filtration rate = 8 m.d^{-1}			
Parameter (mg/L)	Average Inf.	Average Eff.	Average % removal	Run Length (days)	Average Inf.	Average Eff.	Average % removal	Run Length (days)
BOD_5	163	129	22	Min. 17 & Max. 22	129	56	57	Min. 6 & Max. 8
COD	252	202	19		204	92	55	
SS	140	99	28		101	20	81.5	
Total N	39.5	33	14		33	22	32	
Total P	11.0	9.6	12		9.6	7.5	23	

Rough filter performance

In water treatment, the use of slow sand filters is of high efficiency from the technical view point[1, 2 , 3], yet its use is limited because of the turbidity of the raw water. Studies conducted specially in Egypt recommended the use of rough filtration to reduce turbidity and extend the filter run length, however , the results of the rough filter was of great benefits and proved the inability of using the slow sand filter without pre-rough filtration.

The rough filter received sullage wastewater from the septic tanks. The filter was operated through the two stages of investigation and conducted three runs in each stage, the operating conditions were almost the same expect for the filtration rate which being increased from $20 m.d^{-1}$ to $30 m.d^{-1}$ between the first and second stage investigation with slight differences in influent pollutants.

Comparing rough filter removal efficiencies of pollutants, specially BOD_5 and suspended solids, for different filtration rates, it seems to be clear that about 50% increase of filtration rate results in decrease of 41% and 31% in BOD_5 and suspended solids removal , respectively.

However, this decrease of efficiency compared to the increase of filtrate flow may be accepted specially when looking at the remarkable removal of pollutant of the rough filter as an equipment simple to operate and maintain.

BOD_5 removal of 35% achieved in the first stage operation at rate of $20 m.d^{-1}$ is remarkable to occur through gravel media of about 100 cm depth. Also this performance may encourage employing additional rough filter, therefore, to operate two stage rough filtration which is expected to be promising.

The minimum run duration obtained for the rough filter, 17 days, is not a disadvantage of filter operation, specially with the simple backwash of the filter media (several sudden downflow of the filter internal wastewater, usually three times was sufficient and effective for the filter to be washed and restore its initial operating conditions specially with regard to head loss and filtrate flow) after which the filter is being back in operation. filter backwash usually takes about 30 minutes using sullage wastewater for downwash.

Although filtration rate highly affect the rough filter performance concerning both of pollutants removal and run duration, yet when dealing with wastewater filtration another term may be proposed which is the volumetric loading which may indicates to either the total daily volume of filtered wastewater per cubic meter of filter media, ($m^3/ m^3/ d^{-1}$, shortly, d^{-1}), or the total volume of wastewater per cubic meter of media per run ($m^3/m^3/$ run, shortly, run^{-1}). The volumetric loading will be of importance if we considered the ability to increase filter depth from 1.0 m in this investigation to any other depth such as 1.5m or more. It is therefore expected to increase both rate of filtration and filter depth in order to maintain certain volumetric loading, this may in turn keeps the filtrate quality the same.

Rough filtration is , somewhat , similar to the packed bed reactors as one of the different types of attached growth processes which have been successfully used for separate stage nitrification. The filter is packed with medium to which microorganisms can become attached. Results obtained indicated that 14% removal efficiency of nitrogen was obtained through the rough filter and increased to 21% with the decrease of filtration rate, which may be referred to the enhancment of nitrifying bacteria through decreasing the filtration rate.

Removal of total phosphorus was little less than that of nitrogen but almost of the same manner with respect to filtration rate. phosphorus removal is referred to the microorganisms attached to the filter media.

Slow sand filter performance.

Slow sand filtration was more efficient for pollutants removal, regarding its influent being less polluted due to the effect of the pre-rough filtration, specially when considering suspended solids removal in the rough filter. Experience in water treatment proved the effect of high turbidity on slow sand filter run duration, turbidity of about 10 NTU usually results in filter run of 2 or 3 days at maximum.

The slow sand filter was operated two stages, with five runs through each stage of investigation. Filtration rate was the only operating condition being changed from 4.5 to 8.0m.d^{-1}.

The major drawback was its run length, being max. of 12 days at filtration rate of 4.5 m.d^{-1} and decreased to be minimum of 6 days at rate of 8.0m.d^{-1}. Except for the run length, the slow sand filter performance was relatively higher and more effective than that of the rough filter. Removal efficiencies of 61% and 82% were recorded for BOD_5 and suspended solids at filtration rate of 4.5 m.d^{-1}, this efficiencies decreased to 57% and 81.5% with rate of 8.0 m.d^{-1} for BOD_5 and suspended solids, respectively.

However, this decrease in efficiency is not significant when compared to about 77% increase of filtration rate. The sole problem is the run duration reduction, which was about 35 percent.

The short run duration of slow sand filter may be referred to the relatively high suspended solids and its high removal efficiency through the filter, which usually resulted in rapid formation of the dirty skin over sand surface.This dirty skin "Schmutzdecke" is the only factor consuming the available hydrostatic head.

Most of the purification is expected at the surface sand layer in the mixture of humus, sand, algae, protozoa and metazoa which in water treatment usually called the dirty skin or "Schmutzdecke". Denitrification process as being anoxic suspended or attached growth was assumed to be mainly achieved in the surface layer, with the remainder through the total depth of the sand. High removal efficiency of nitrogen was recorded through the slow sand filter, 41% and 32% , for the filtration rates of 4.5 m.d^{-1} and 8.0 m.d^{-1}, respectively. Also, high removal efficiency of phosphorus was recorded which ranged between 32% and 23% for filtration rates of 4.5 m.d^{-1} and 8.0 m.d^{-1} , respectively. High percent removal of phosphatus ability may be accounted on the biological activities. It is also believed that microorganisms in the dirty skin were able to removal high percent of phosphorus existing in wastewater.

The slow sand filter proven ability to remove coliform organisms during water treatment suggested that considerable results might also be achieved with the filtration of sullage wastewater.

4. Conclusions:

Both the rough filter and the slow sand filter were active when dealing with "sullage" or primarily treated wastewater. Although the slow sand filter gave higher removal efficiency than that of the rough filter, but the role of the rough filter was more important when conducted before the slow sand filter and receiving the raw sullage.

Short runs of the slow sand filter is only its major drawback, however, it's a great obstacle specially with the high filtration rate, usually over5-6 $m.d^{-1}$.

The rough filter is found promising in the field of wastewater treatment. Results obtained through investigations may propose that using two or three rough filters working in series alone without slow sand filter, would be of high efficiency. This will overcome the problem of slow sand filter run duration, and also the relatively large area required for it.

Increasing the filtration rate generally did not result in severe decrease in filtrate quality for both the rough and slow sand filter, but the rough filter was little more affected than the slow filter. However, this was expected due to the physical nature of their media.

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