

**Sudan University of Science & Technology  
College of Graduate Studies**

**Direct And  
Horizontal Roughing Filtration Technique  
In Bank Filtration**

**A Thesis Submitted for the Fulfillment of the Degree of Doctorate of  
Philosophy in Civil Engineering**

By

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## **Dedication**

Very special thanks go to the dear wife Mayada for her never-ending support and inspiration, and for sharing the trials and tribulations of the research studies with me. This thesis is dedicated to her.

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## Abbreviations

HRF	horizontal roughing filtration
DHRF	direct horizontal roughing filtration
SSF	slow sand filter
RSF	rapid sand filter
SS	suspended solids
T	turbidity
NTU	neuphelic turbidity units
C	concentration
$\lambda$	filter coefficient
$v_F$	filtration rate
$d_g$	grain size
$\rho_g$	filter porosity
$\rho_p$	density of suspended solids
$d_p$	particle size of suspended solids
$\gamma_w$	viscosity of water
$\sigma$	filter load
E	Efficient value
$E_c$	filter efficient for suspended solids removal.
$E_T$	filter efficient for suspended solids removal.
Rem	suspended solids removal ratio
$T_{run}$ (hours)	Running time
U	The uniformity coefficient
Re	Reynolds no
$d_g$	grain size
$\nu$	viscosity of water
Con	electrical conductivity
TDS	total dissolved solids
$\zeta$	Filter Time run/volume unit

## Abstract

Efficient application of the slow sand filter (SSF) treatment process requires raw water of low turbidity; the major draw back of SSF however, is its sensitivity to turbidity. The suspended solids of turbid water will rapidly clog SSF resulting in unacceptably short filter operation runs. Therefore pretreatment of surface water containing solid matter load is necessary. Prefiltration through horizontal roughing filtration (HRF) is not only a simple, efficient and chemical-free alternative treatment process for solid matter separation, it also makes ample use of local resources and hardly require mechanical equipment. Pre-filtration by HRF is thus a potentially alternative option for suspended solids removal although Its application is predominantly limited to rural areas.

Experimental findings showed that HRF could achieve a particulate matter reduction of 90% or more.

HRF requires a low filtration rate (0.5-2.7 m/h) and thus needs a large construction volume.

In order to improve HRF performance at higher filtration rate the process is combined with direct filtration i.e. coagulant is added in a rapid mixing unit prior to HRF. The combined process is called direct HRF (DHRF). Comparing the performance of HRF and DHRF, it was found that DHRF systematically performed better, with higher removal efficiencies as well as high filtration rates.

DHRF has a potential to substitute the conventional flocculation-sedimentation process widely used before rapid sand filters.

The main process parameters of DHRF were optimized as 1.0 mg/l alum as coagulant dose effective over a wide range of pH, and a 4 m length for first compartment (grain size 12-9 mm) and filtration rate till 10 m/h.

The short filter length prevents it from absorbing shock load, which could be expected in practice, and hence an adequate length is necessary (6-7 meters).

HRF for rapid sand filters differs from that for slow sand filters. The results show mainly in the filtration rate, which should be very high to supply the rapid sand filter with sufficient flow rate (10-20 m/h).

Little has been reported in the literature about HRF for rapid sand filter, this study addressed the problems relating to rapid sand filter by dealing with high filtration rate (24 m/h) and super-high suspended solids (20,000mg/l).

The upper limits of raw water turbidity and flow rate are the two variables that limit the application of HRF to plants using rapid sand filtration.

The present investigation suggests that only one type of grain could be used (12-9 mm) in the filter the polishing compartment could be cancelled. This will result in a reduction in the efficiency of the filter to only 57% in average, but sufficient flow is then attained (10 m/h). This is because the second and third compartments are generally used for polishing and hence increasing the efficiency, which is not first priority in this case.

The distributor box, which distributes water to the numerous HRFs in the scheme, will act as a basin for plain sedimentation, and hence very high load of SS up to 20,000 mg/l could be dealt with, since 90% is got rid of.

Bank filtration which is a natural process faces the problem of clogging, which results from the nature of the bank soil gives opportunity for interference to raise the efficiency of this natural process.

One of the major parameters affecting the success of HRF is time run where the time between two hydraulic cleaning intervals of the filter could be as short as twice a day. Therefore constructing the HRF at the riverbank will allow repetitive cleaning to be readily and naturally done, and the raw water of the river will be used as the cleaning agent.

For further studies it is recommended to construct a large-scale pilot plant in the field to be investigated to determine optimum design parameters compared with lab-scale studies. Alternative for large-scale pilot plant is to design a computer program to simulate the conditions that couldn't be attained easily in the lab.

بسم الله الرحمن الرحيم

### مستخلص

ان الاستخدام الامثل لمرشحات الرمل البطيئة تستلزم ان تكون المياه الخام الداخلة لهذه المرشحات ذات عكورة ومواد عالقة قليلتين .

ان من اكبر عيوب مرشح الرمل البطيء هو حساسيته الشديدة نحو المياه العكرة . ان المواد العالقة المتسببة فى هذه العكورة سرعان ما تسد مسامات المرشح الرملى البطيء متسببة فى تقصير فترة عمل المرشح وجعلها غير عملية. عليه فان الترشيح الابتدائى للمياه السطحية او النهرية يصبح ضروريا و ذلك لتقليل حمولة المياه من المواد العالقة قبل دخول المياه لمرشحات الرمل البطيء .

ان الترشيح الابتدائى ليس فقط بسيطا و فعالا و لا يحتاج لمواد كيميائية و لكنه يمكن ايضا من الاستفادة من المواد المحلية المتوفرة فى كل بلد ولا يحتاج الا الى القليل من التقنيات الميكانيكية المستخدمة للطاقة . اذن فان الترشيح الابتدائى هو خيار آخر للتخلص من المواد العالقة فى المياه.

لقد اثبتت التجارب ان مرشح الدفق الافقى الخشن و الذى يعتبر احد المرشحات الابتدائية يمكنه ان يخفض المواد العالقة الموجودة فى المياه حتى 90% من كميتها قبل الترشيح .

ان مرشح الدفق الافقى الخشن يتطلب معدل دفق منخفض ( 0.5-1.0 متر/ساعة) وعليه فانه يحتاج الى منشآت ضخمة وامكانية تطبيقه تكون امثل فى المناطق الريفية حيث تتوفر الاراضى الرخيصة .

لتحسين طريقة الترشيح الافقى الخشن وتمكينها من العمل بمعدلات دفق عالية فان هذه الطريقة يمكن ربطها بطريقة الترشيح المباشر اى ان كمية قليلة من المروبات توضع فى اناء خلط سريع قبل اضافتها للمياه الداخلة لمرشح الدفق الخشن . ان هذا الاقتران بين الطريقتين يسمى مرشح الدفق الافقى الخشن المباشر .

بمقارنة طريقة مرشح الدفق الافقى الخشن مع مرشح الدفق الافقى الخشن المباشر نجد ان الاخيرة ذات كفاءة تشغيل اجود من الاولى . ان طريقة الدفق الافقى الخشن المباشر لديها امكانية ان تحل محل الطرق التقليدية فى تنقية المياه و يمكنها ان تعمل منفردة و ليست مرحلة ابتدائية لطريقة تقليدية اخرى .

ان الطريقة الرئيسية فى هذه الطريقة الجديدة هى اضافة مروب مياه مثل الشب بكميات 1-5 ملغ/لتر والتي يمكنها ان تعمل فى اوساط حمضية مختلفة للمياه ، و ذلك فى مرشح خشن يبلغ طوله 3-4 متر وحجم حبيبات 9-12 ملم و معدل دفق يبلغ 10 متر/ساعة . ان قصر طول الفلتر قد يتسبب فى عدم قدرته على امتصاص الاحمال العالقة العالية للمياه و هو المتوقع فى الطبيعة للانهار لذلك فان زيادة اطوال المرشحات تضمن قدرتها على احتمال الزيادات المفاجئة فى عكورة المياه و المواد العالقة فيها .

ان مرشح الدفق الافقى الخشن المخصص لمرشحات الرمل السريعة يختلف عن تلك التى تخصص لمرشحات الرمل البطيئة بصورة اساسية فى معدلات الدفق حيث انها يجب ان تكون كبيرة فى حالة مرشح الرمل السريع ( تصل الى 10 متر/ساعة ) مقارنة بتلك التى لمرشح الرمل البطيء ( فى حدود 0.5-1.0 متر/ساعة)

## VIII

كما ان القيمة الاعلى لحمولة المياه من المواد العالقة والعكورة نزيد بصورة ملحوظة فى هذه الحالة ويمكن لهذه المرشحات الخشنة ان تتعامل مع عكورة تصل حتى 20,000 ملغ/لتر .

فى مرشحات الدفع الافقى الخشن المصممة لمرشحات الرمل السريعة يمكن استخدام نوع واحد من الظلط (9-12 ملم) والغاء الاقسام الاخرى من المرشح الخشن والتي تضم مقاسات اقل من الظلط والتي كانت مخصصة لمزيدا من الكفاءة فى التنقية و ذلك لان مرشح الدفع الافقى الخشن فى هذه الحالة لا يحتاج لكفاءة عالية و يكفى فقط 57% كفاءة للمرشح . ولكن فى المقابل فان كميات كافية من المياه قد امكن الحصول عليها .

ان قناة او صندوق التقسيم و الذى يوزع المياه على المرشحات العديدة فى المشروع يمكنه القيام بترسيب كميات مقدرة من الرواسب الثقيلة التى تحملها المياه والتي تزيد عن 90% من الرواسب مخصصة بذلك المرشحات الخشنة من احمال كبيرة غير ضرورية .

ان الترشيح على ضفاف النهر هو الطريقة التى تمر فيها المياه عبر مسامات ضفة النهر لترعة التجميع بعد عدة امتار من النهر ولكن مسامات هذه التربة سريعة الانغلاق مما سمح بالتدخل لتحسين نوعية هذه التربة و احلالها بمواد ظلطية اخرى و فى هذه الحالة تصبح الضفة مرشح دفع افقى خشن .

ان احد اهم عوامل نجاح مرشح الدفع الخشن هو نظافته المستمرة من الرواسب التى علق وسط حبيباته الخشنة و التى يمكنها ان تصل حتى مرتين يوميا . عليه فان انشاء هذا المرشح على ضفة النهر يكون ضروريا و ذلك للاستفادة من مياه النهر فى الغسل المستمر و كذلك لجرف الرواسب الى النهر مرة اخرى .

لأجل الأبحاث المستقبلية ينصح بتشبيد مرشح خشن بمقاس كبير لمقارنته بذلك الذى تم تشييده فى المعمل وفى حال تعذر ذلك يمكن تصميم برنامج حاسوبى للمساعدة فى معرفة المتغيرات المختلفة .



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