The Operation of Filters by Suction Method

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Received on: 25/4/2011 & Accepted on: 2/2/2012

ABSTRACT

In this research the filtration process in water treatment plants was studied to increase the filtration rates in the sand gravity rapid filters.

A model was designed with dimensions (60*60*225) cm with sand media of two layers . Seven experiments were done in this research for each case of filter media thickness,(which are five cases) . Using new method of operation , involves the suction of water from the drainage pipes network through the sand media .

In this method, the filtration velocity was Doubled, with filtration efficiency nearly to (92%).

تشغيل المرشحات بطريقة السحب

الخلاصه

درست في هذا البحث عملية الترشيح في محطات تصفية المياه لغرض زيادة معدلات الترشيح في المرشحات الرمليه السريعه

صمم نموذج لمرشح رملي سريع بأبعاد(225*60*60)سم وبأستخدام وسط رملي مؤلف من طبقتين .

أجريت سبع تجارب في هذا البحث لكل حاله من حالات سمك الوسط الرملي في المرشح (والتي بلغت خمس حالات). و استخدمت طريقه جديده لتشغيل المرشح من خلال أستخدام طريقة سحب المياه المرشحه من خلال شبكة المبازل السفليه تحت الوسط الرملي .

لقد تم مضاعفة سرعة الترشيح في هذه الطريقه الى مايعادل الضعف مع تحقيق كفاءة ترشيح وصلت الى (92%) .

INTRODUCTION

Filtration is an important process in water treatment plant . Many theories and equations were related for this process . Such as Solids Clarification Equation (Iwasaki,1937 and Jerry,Huang,1986), Mass Balance Equation (Deb,1969) , Deposition scouring Equation (Ives and sholy,1965) , and Super Filtration Coefficient Equation (Omelia , 1965):

$$\frac{\partial C}{\partial Y} = l\, C \qquad ....(1)$$

https://doi.org/10.30684/etj.30.9.4
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$$\frac{\partial s}{\partial t} + v \frac{\partial c}{\partial Y} = 0 \qquad .....(2)$$

$$\frac{\partial s}{\partial t} = a\, vc \qquad .....(3)$$

$$\frac{l}{l_{\circ}} = (1 - \frac{s}{s_u})^{x} (1 + \frac{b s}{e})^{Y} (1 - \frac{s}{e})^{z} \qquad ....(4)$$

Where: C = Concentration of suspended particles in filtered water .

l = Filtration coefficient.

Y= Thickness of filter media.

s = Volume of settled material due to unit volume.

v = Filtration velocity.

t = Time.

$l_{\circ}$ = Initial filtration coefficient.

s_u = Standard typical sedimentation.

e = Media porosity.

x,y,z = The powers of typical surface of particles, and filtration velocity respectively.

b = Constant.

Many researches have studied the development of filters such as using filters dealing with medias of multilayer(Ives,1970 and Yao,1971).

Campos , et al,2006 , used a deterministic slow sand filter process model to investigate and assess some of the fundamental aspect and mechanisms operating during slow sand filtration . The structure of the model provides description for the role of the Schmutzdecke layer , the spatial and temporal profile of deposits andBiomass , and variation of the three principle kinds of microorganisms typically present. The results demonstrate that the presence and nature of a schmutzdecke layer profoundly influence the spatial and temporal development of interstitial biomass within the sand and , consequent the head loss profile. The model also demonstrates the significance of residual deposits within the filter after surface cleaning on the subsequent filter behavior .

Newcombe, et al ,2006 used moving bed active filtration process to remove the arsenic from drinking water . The regent used in the process was (43.3%) $Fecl_3$ solution with a specific gravity of (1.4) diluted with deionizer water . This process was followed by separation of waste residuals from clean water discharge . The results shows that the Arsenic concentration were reduced to (3.3 $\pm$ 1.4) m g/liter.

This research suggested a new method for operating the filters by using a suction.

THEORETICAL ANALYSIS

Since individual particles of granular subsurface materials (e.g. sand grains) are seldom spherical when deposited under water , they usually come to rest on their flat side as one hand , and on the other hand the coarser size will deposit first and then followed by the finer size. Such phenomena will lead the sand filter to be a layered media system. The average hydraulic conductivity (K_z) of the media in the vertical direction is given by the following equation:

$$K_z = \frac{Z}{\frac{Z_1}{K_1} + \frac{Z_2}{K_2}} \qquad .....(5)$$

Where: Z_1, Z_2 =The thickness of layers(1,2)

Z = The height of the entire system

The vertical discharge from the system is computed from the equation:

$$Q = K_z A \frac{\Delta H}{Z} \qquad .....(6)$$

The grain size distribution becomes obvious from the screening analysis . Materials with an uniform or possible grain size (narrow grain size distribution) are preferred for filter purposes . The content of oversized and undersized grains is defined by the applicable standards for filter materials.

PORE VOLUME

The pore volume of a grainy heap of particulate material is made up at:

-The sum of the pore rooms(V_{pk}) contained in the grain particles,which can partly be opened and partly closed(grain porosity).

- The sum of all interfaces(V_{pz})between the individual grains contained in the material(porosity).

HOLLOW SPACE PART(POROSITY)

Under the condition of an negligible core porosity (e.g. quarry of sand)the hollow space part is understood as the portion between the hollow spaces in the material (V_{pz}= volume between the grains) and the total volume of the material (V_s) .

$$n = \frac{V_{pz}}{V_s}. \qquad ....(7)$$

Since: $V_{pz} = V_s - V_{pk}$

So that:

$$n = \frac{V_s - V_{pk}}{V_s} \qquad .....(8)$$

The hollow space rate(n) depends also on the non-uniformity degree and storage density of the grain material.

$$n = C + aU^{b} --- \quad forU \geq 1, \; where \; \left[U = \frac{d_{60}}{d_{10}} \right] \quad ....(9)$$

Storage type	C	a	B
Loose storage	30	14.6	-0.6636
Medium storage	26	16.0	-0.6941
Dense storage	22.4	16.5	-0.5890

The discharge could be designed according to the hydraulic conductance of the filter. The conductance is defined as the product of hydraulic conductivity and the cross- sectional area of flow divided by the length of the flow path . Start with Darcy low defining one – dimensional flow in porous media as:

$$Q= -KA(h_2-h_1)/L \quad ..... (10)$$

Where : Q= Volumetric flow

K= Hydraulic conductivity

A= Cross- sectional area perpendicular to the flow

h_1,h_2= Head difference along the flow

L= Length of flow path

Then the hydraulic conductance , C=KA/L

Considering the porous media consisting of two or more layers in a series and knowing the conductance in each layer, then the hydraulic conductance representing the entire media (equivalent hydraulic conductance) could be computed and given by the equation:

$$C= Q/ (h_A-h_B) \quad .....(11)$$

Since the total head loss is ($i = \sum_{i=1}^{n} \Delta h_i = h_A - h_B$)

Applying Darcy low across each layer leads to

$$\sum_{i=1}^{n} \frac{q_i}{C_i} = h_A - h_B \quad .....(12)$$

Since the flow is one dimentional and there is no accumulation as depletion in storage then all (q_i) are equal to the total flow (Q), then:

$$Q \sum_{i=1}^{n} \frac{1}{C_i} = h_A - h_B \quad \text{and} \quad \frac{h_A - h_B}{Q} = \sum_{i=1}^{n} \frac{1}{C_i}$$

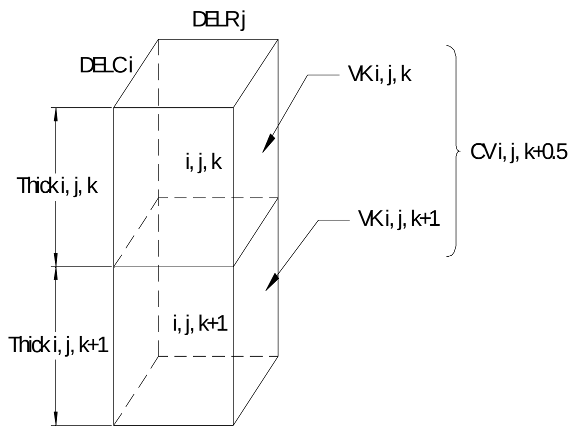
Substituting for (C) from the above equation , leads to:

$$\frac{1}{C} = \sum_{i=1}^{n} \frac{1}{C_i}. \quad ...(13)$$

Which states that for a set of hydraulic conductance arranged in series, the inverse of the equivalent conductance equal to the sum of the inverses of the individual conductance. For two layers the equivalent hydraulic conductance is:

$$C=C_1C_2/(C_1+C_2) \quad ….(14)$$

Applying mode flow 2000 for vertical hydraulic conductance,assuming that nodes are in the center of cells and discrete changer in vertical hydraulic conductivity occur at the boundaries of the layers as illustrated below(Mc Donald, 2000) :



And by using equation(14) leads to:

$$CV = \frac{DELR_j DELC_i}{\frac{0.5THICK_{i,j,k}}{VK_{i,j,k}} + \frac{THIGK_{CB}}{VKCB_{i,j,k}} + \frac{0.5THICK_{i,j,.k+1}}{VK_{i,j,k+1}}} .....(15)$$

The actual flow between the nodes in the upper and lower cells is the flow through the layering beds($q_{i,j,k+0.5}$) computed using(Todd and Mays,2005):

$$q_{i,j,k+0.5}=CV_{i,j,k+0.5}\,(h_{i,j,k+1} - h_{i,j,k}) \quad ……..(16)$$

So that the flow from any cell to the next upper or lower cell would be dependent on the head at the cell.

Rose equation is an accurate one which is used for determining the energy losses through filters(Jerry,Huang,1986):

$$\frac{\partial H}{\partial Y} = 1.067 \frac{C_d Q^2}{e^4 Dg} ....(17)$$

Where: H= Head loss.

C_d = Drag coefficient.

Q = Discharge.

e = Media porosity.

g = Gravity acceleration.

The velocity gradient through the filter media is important in calculating the efficiency of filter . The accurate equation which was used in the velocity gradient is Camp equation(Jerry,Huang,1986):

$$G = \frac{gv\,\Delta H}{e} \qquad \text{....(18)}$$

Where: G = Velocity gradient.

ΔH = Head loss.

And the shear stress through the filter media found from this equation:

$$t = G\,m \qquad \text{......(19)}$$

Where:

τ= Shear stress through the filter media .

μ=Dynamic viscosity.

LABORATORY WORKS:

A filter model was manufactured from steel frame with dimensions (60*60*225)cm as shown in fig(1).

The media which was used in this filter was similar to that used in the normal filters . But in this type the media contains two layers of specifications illustrated in in the table shown belows:

Layer No.	Thickness(cm)	Uniformity coefficient	Filter Media Grain Size
1	60	1.3	600mic.-1 mm
2	20	1.4	(425-600) mic.

Five types of media were used in this research related to the thickness of each layer.

The turbidity was measured to find the efficiency of filtration using turbidimeter M2100A.

DISCUSSION AND ANALYSIS OF DATA

Seven experiments were done on the filter model for a period of filter operation of(12)hours for each experiment.

The filter model was operated using the method of suction water instead of pressuring it. This method included the changing of the connection of pipes with pump as shown in fig(2) .

In order to ensure a uniform distribution of the vacuums pressure among the whole sectional area of sand media the gravel layer was raised (20)cm above the drainage pipes network .

The first experiment was done by operating the filter using the same filtration velocity which is used in operating high sand filters which is (5 m/hour) .

The turbidity was measured in the filtered water during the operating period of filter , and the efficiency of filtration was calculated , and the results was illustrated in fig(3). This figure could be used as a reference to compare its results with those of another cases.

Fig(3) shows that the filtration efficiency varies between(85 - 90.5%) which indicates that the filter is of high filtration efficiency , and the model gave results that are identical to those ofrapid sand filters which have the same specifications.

Another set of experiments were done by using another filtration velocities more than the velocity of (5 m/hour) , which are (9 ,12 ,15 ,18) m/hour .

In all experiments the turbidity of filtered water was calculated and the results are shown in fig(4) . The figure shows that the filtration efficiency decreased to (72%) at filtration velocity (9 m/hour) while it reach to (32%) at filtration velocity (18 m/hour).

Due to the reduction in the filtration efficiency due to increase of filtration velocity , the thickness of the second layer of sand filter media was increased by (10)cm and the same set of experiments were followed using the same filtration velocities . The results were presented in fig(5) , which shows clearly that the filtration efficiency decreased from (77%) at filtration velocity (9 m/hour) to (37.5%) at filtration velocity (18 m/hour).

Another increments to filter media thickness of (10) cm and the same procedures of experiments were followed until the thickness of second layer of filter media became (70) cm and the results were drawn in figs(6,7,8 and 9) . It was clearly shown that the filtration efficiency reached (92%) at minimum range for filtration velocity (9 m/hour) and decreased to (46%) at filtration velocity (18 m/hour).

From the above results it can be noticed that the optimal filtration velocity that can be used in this type of filters be (9 m/hour).
This velocity gave filtration efficiency about (92%) with thickness of Filter media (130) cm for the two sand layers (60 cm for the above layer and 70 cm for the second layer).

CONCLUSIONS

1- Method of filtration by suction to rapid filter causes to double the filtration velocity with filtration efficiency of (92%).

2- The filtration efficiency in this method was found to be increased with increasing the thickness of sand media to (130)cm.

3- In filters operating by suction the head of water above the filter media is not considerable .

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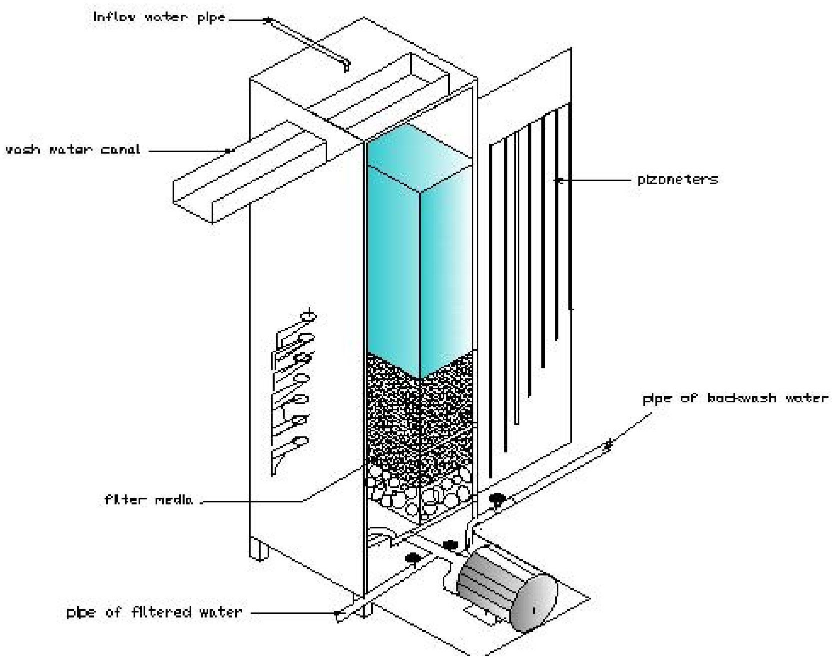

Figure (1) Laboratory Filter

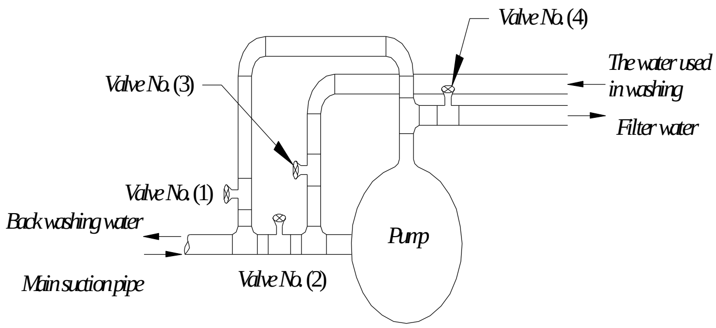

Figure (2) the Pattern of Changing in Pipe's Connection

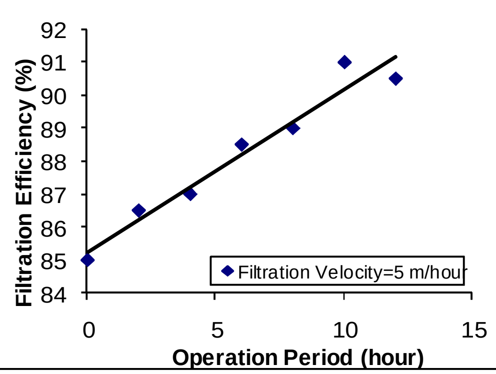

Figure.(3) The variation of filtration efficiency due to operating period for media thickness=80cm

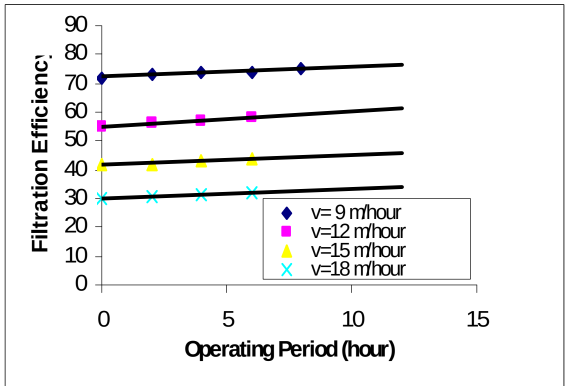

Figure (4) The variation of filtration efficiency due to operating period for media thickness=90cm

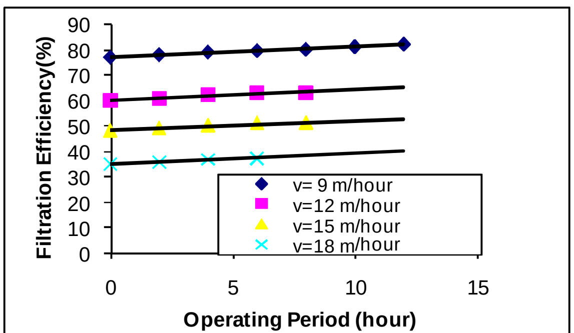

Figure.(5) The variation of filtration efficiency due to operating period for media thickness=90cm

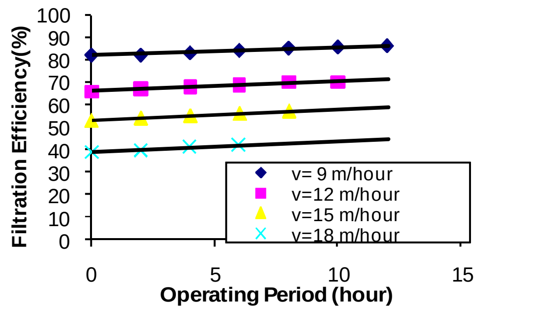

Figure.(6) The variation of filtration efficiency due to operating period for media thickness=100cm

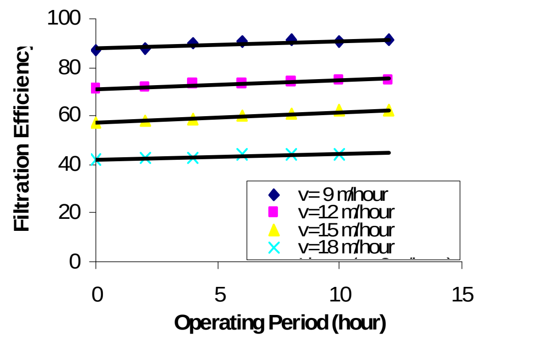

Figure.(7) The variation of filtration efficiency due to operating period for media thickness=110cm

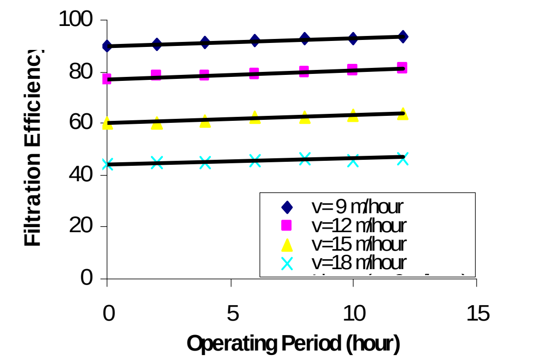

Figure.(8) The variation of filtration efficiency due to operating period for media thickness=120cm

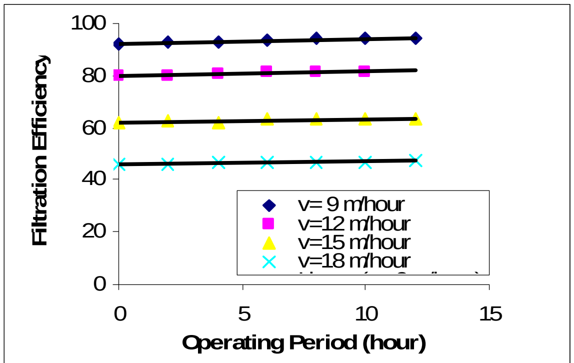

Figure (9) The Variation of Filtration Efficiency Due to Operating period for media Thickness=130 cm