TAPERED CONTACT FLOCCULATION: PROCESS AND APPLICATION

خواص تكوين الندف المتدرج بالتلامس وتطبيقاته

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خلاصة ـ تكوين الندف المتدرج بالتلامس هو تطوير لعملية تكوين الندف بالتلامس حيث اقترحه المؤلف في بحث سابق . وتكوين الندف بالتلامس درس سابقا كخاصية تحدث في المرشحات الرملية حيث تتقابل الحبيبات مع الشبه داخل الفراغات الموجودة بالمرشح الرملي حيث تحدث عملية تكوين الندف كما أن تكوين الندف بالتلامس طبق في خزانات الترسيب التي تعتمد على طبقة الحمأة في عمل تكوين الندف المطلوبة . ويقترح هنا أن يتم عمل وسط من كرات البلاستيك لها قطر وفراغات معينة ومحسوبة وتصنع كما في الوسط البلاستيك للمرشحات الزلطية وأنابيب المواسير في خزانات الترسيب بحيث تعطي تكوين الندف المطلوب ويكون التدرج بزيادة قطر الكرات في اتجاه التصرف . وبدراسة العوامل المؤثرة على تكوين الندف وجد أن G - Value تزيد بزيادة درجة الحرارة والسرعة السطحية لتكوين الندف وتقل مع زيادة القطر وزيادة حجم الفراغات المسامية . ويمكن تطبيق عملية تكوين الندف المتدرج بالتلامس بالطريقة والشكل الذي تم وصفه في البحث في كل طرق معالجة المياه حيث يمكن استبدال الطرق الميكانيكية بهذه الطريقة .

Abstract- Tapered Contact Focculation (TCF) is a modification of fixed bed contact flocculation. The process employs a bed of graded spherical plastic media to obtain a tapered velocity gradient.

A general equation for calculating the velocity gradient in any fixed bed medium with spherical grains was developed using the Ergun equation for determining the head loss across the medium.

In the TCF process, theoretically, increasing the flocculation rate and tempereature increase the G-value, while increasing the media diameter and porosity reduce the G-value.

TCF can be applied to different water treatment plant systems which use flocculation. TCF media can be manufactured of plastic balls stacked in place and welded together.

Extensive research work is required to determine the best configuration of TCF for application in the water industry and to determine the required TCF time.

Key words-Tapered Contact Flocculation, velocity gradient, flocculation rate.

INTRODUCTION

Flocculation is the process whereby finely divided particles agglomerate to form larger aggregates. In the water industry the term is especially reserved for the formation of large flocs by gentle stirring by hydraulic or mechanical means.

The flocculation process involves "perikinetic flocculation" whereby the floc formation is brought about by Brownian motion, and "orthokinetic flocculation" whereby the floc formation is achieved by imparting velocity gradients to the dispersion through stirring.

Ives (1977) classified the means of stirring in flocculation into four groups: paddles, baffles, pipes and particles. With the use of these devices attempts have been made in water treatment practice to improve and optimize the flocculation process. One of the latest trials is the Tapered Contact Flocculation (TCF) proposed by Fadel (1987).

The process employs a bed of graded gravel to obtain a tapered velocity gradient. Three or more layers of large diameter particles may be stacked with the smaller diameter layer at the top followed by layers of successively lager particles. The surface loading rate, "Flocculation Rate", proposed is greater. than 15 m/h to reduce the filtration effect.

The purpose of this study is to "theoretically" examine the factors that affect the process.

BACKGROUND

Flocculation depends on the number of particles present in the water and the probability of collision due to charge reduction (Amirtharajah, 1987). The magnitude of the probability of collision depends on the degree of mixing induced in the mixing vessel. This is traditionally measured by time of mixing, t, and the velocity gradient, G, as developed by Camp (1943 a). Optimizing these parameters to obtain the best performance of the flocculation process has been the target of previous studies. The optimization of G and t values to obtain the best flocculation results in costeffective design of the flocculation basin.

The G value at any instant in the basin is greatest at the solid boundaries of the paddles or other mechanical devices used to introduce mixing motion and is least arthest from the point of introduction of motion. In the jar test Camp (1943 a) showed hat by adding stators to a 2 liter beaker the G value was increased three fold over beakers without stators at the same power input. The presence of stators also increased the power dissipation 10 times over that without stators. at the same power input. This means that stators help to dissipate power more uniformly.

Table I present the non-dimensional G.t values obtained by several researchers with the conditions of their experiments. The range between the smallest and the largest values obtained is very wide. One important reason for such a wide range may be due to the way in which the mixing power was dissipated in the flocculation container used in their experiments.

In the previous paper (Fadel, 1987) an example was presented in which a floccula- or was composed of 3 layers of 5, 10, and 28 mm diameter particles. The flocculation rate was 15 m/h and the G values for the 3 layers were 100, 70, and 40 sec^{-1} . respectively the average porosity of the randomly packed media was 0.368.

tors affecting the TCF process

Because of the high flocculation rate and the large media size proposed for the TCF, the flow regime will be either in the transitional or turbulent range. The Reynolds number will be much greater than 6 (laminar condition as reported by Camp (Cleasby and Fan, 1981). For this flow regime the Ergun equation (1) for head loss through a fixed bed is appropriate. The equation is adequate for the full range of laminar, transitional and turbulent flow:

$$H/L = 150\ p\ u(1 - E)^2 V\ g^{-1}\ E^{-3}\ D^2 + 1.75(1 - E)V^2\ E^{-3}\ D^{-1} g^{-1} \qquad (1)$$

where H = head loss across the media, cm
L = the layer depth, cm
g = acceleration due to gravity, cm. sec^{-2}
E = media porosity
p = water density, gm. cm^{-3}
u = water viscosity, N.s/cm^2
D = particle diameter, cm
V = Flocculation Rate, cm. sec^{-1}

The velocity gradient, G, is related to the power dissipation and expressed

$$G = (.P / V_u)^{1/2} \qquad (\ 2\ )$$

where V = the water volume, Cm^3
= E A L
A = media surface area, cm^2
P = power dissipation, w
= p g Q H .
Q = flow rate, cm^3 . sec^{-1}

When the values of P and V are substituted in equation (2), the equation for G becomes

$$G = ((pg / uE)(Q / A)(H / L))^{1/2}$$

$$= ((pg / uE)\ V\ (H / L))^{1/2} \qquad (\ 3\ )$$

When the value of H/L of equation (1) is then substituted into equation (3), the expression becomes

$$G = 1.32\ V\ [85.7\ (1 - E)^2 + (1 - E)\ R\ ]^{1/2}\ D^{-1}\ E^{-2} \qquad (\ 4\ )$$

where R = the Reynolds Number
= p V D / u

Equation (4) is the general equation for calculating the velocity gradient in any fixed bed medium with spherical grains. The effect of the porosity, flocculation rate, temperature, and grain diameter on the velocity gradient generated in the medium can be studied using such an equation.

a. Porosity: When large spherical more sized particles are used, the porosity will range from 0.26 to 0.476 depending on the arrangement as illustrated in Figure 1 . When the porosity E is varied from 0.26 to 0.476 and the G value is calculated from equation (4) at V of 20 m/hr temperature of 20 °C and D equal to 1 cm, the relationship between E and G is as shown in Figure 2. It illustrates that increasing the porosity will reduce the G value.

b. Flocculation rate: When the flocculation rate is increased from 15 to 60 m/h the G value is increased from 42 to 278 sec^{-1} with temperature at 20 °C, E = 0.26 and

$D = 2$ cm. Figure 3 presents this effect.

c. Temperature: Increase in temperature from 5 to 30 °C increases the G value from 95 to 110 $\sec^{-1}$. This is shown in Figure 4., $D = 2$ cm .

d. Media diameter: The effect of the media diameter on the G value is presented in Figure 5. Although increasing the media diameter will increase the Reynolds number, the G value will decrease. At $E = 0.26$ and $V = 30$ m/h, increasing the diameter of the medium from 2 to 20 cm decreases the G value from 250 to 50 $\sec^{-1}$

Flocculation Time in the TCF

An important factor in the flocculation process is the flocculation time, t. It is not possible to calculate the required time theoretically. However, it is expected to be much shorter than that found in other flocculation processes because of the uniform power dissipation created by the arrangement of the medium.

The actual flow time through the medium with a depth L, surface area A and porosity E will be

$$t = V / Q$$

$$t = E\,A\,L / (V\,A) = E\,L / V \qquad (5)$$

In the literature the minimum time stated was around 4.5 min. (Hutchson, 1976). Therefore, by knowing the required time the required depths of the TCF layers may be determined. The determination of the required time should be accomplished practically

TCF Application

For practical application, as in the application of plastic shapes for high rate trickling filter bio-towers, it is suggested that TCF media be made of plastic balls. Modules with specific porosity and ball diameter could be manufactured by stacking the balls and welding them together. The following are proposed applications in water treatment.

Calariflocculators: Two configuration may be employed. The first is the upflow CF where three modules are positioned in descending order with regard to the diameter s presented in Figure 6.. The second is the downflow TCF where the modules are used n as sending order as shown in Figure 7. For example: For a water treatment plant that s processing 19,000 m^3/ day, three 80 cm deep modules with media of 2, 5, and 10 cm diameters and porosity of 0.476 are theoretically required. The G values will be 95, 60, and 40 $\sec^{-1}$ repectively for a flocculation rate of 75 m/h. The total head loss across the flocculator media will be 3 cm. The surface area of the flocculator will be 10.5 m^2 the flocculation time will be 1 minute based in equation (5).

Package Units: Figure 8 illustrates the use of TCF in a conventional package unit water treatment plant.

Research Needs

While flocculation is a well known process in practice and design procedures are well developed, research efforts are nevertheless, required to improve the design and evaluate the operation of the new proposed TCF system. The area most needing investigation is the required flocculation time and accordingly the layer depths.Accurate determination of the media diameters and porosities could lead to the design of an efficient and lo cost flocculator. Also, practical investigation of the possibility of clogging of the me due to adsorption and accumulation of the suspended particles, shall be studied .

Summary and Conclusion

The TCF is a modification of the fixed bed contact flocculation process. employs three or more layers of graded spherical media with diameters much larger than that used in filters. The media can be manufactured in the form of modules as for trickling filters and tube settlers.

A general equation for determining the velocity gradient across the TCF med was developed using the Ergun equation for calculating the head loss across the media.

The application of the equation showed that increasing the media diameter an porosity reduces the G value, while increasing the flocculation rate and temperatur increases the G value.

Possible applications of TCF in the water industry are presented. Research required to determine the best configuration for these applications and to determine the flocculation time for the TCF, and material used.

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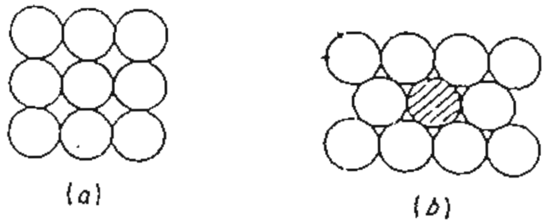


Fig. 1 Maximum and minimum porosity for spherical granular particles

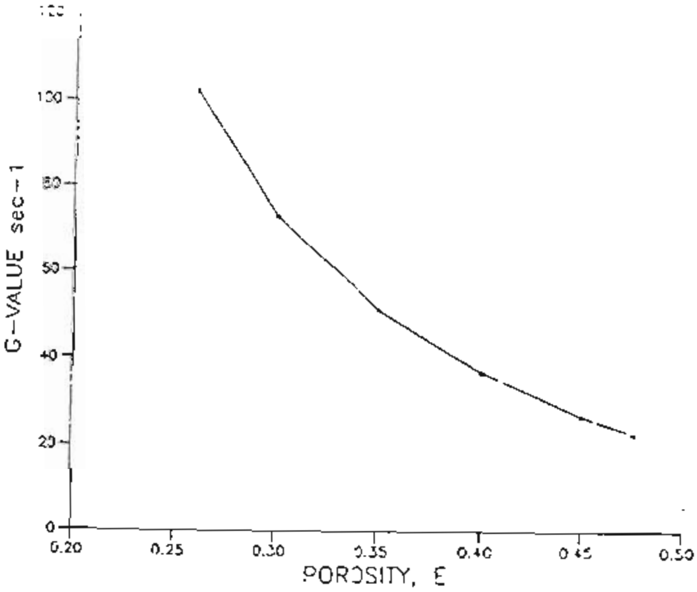


FIG. 2. G-Value Versus Porosity for V = 20 m/h at 20 C and D = 1 cm.

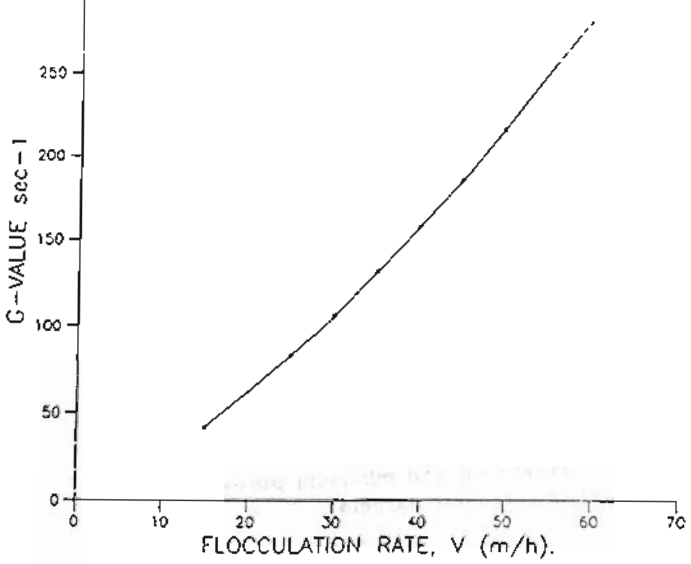
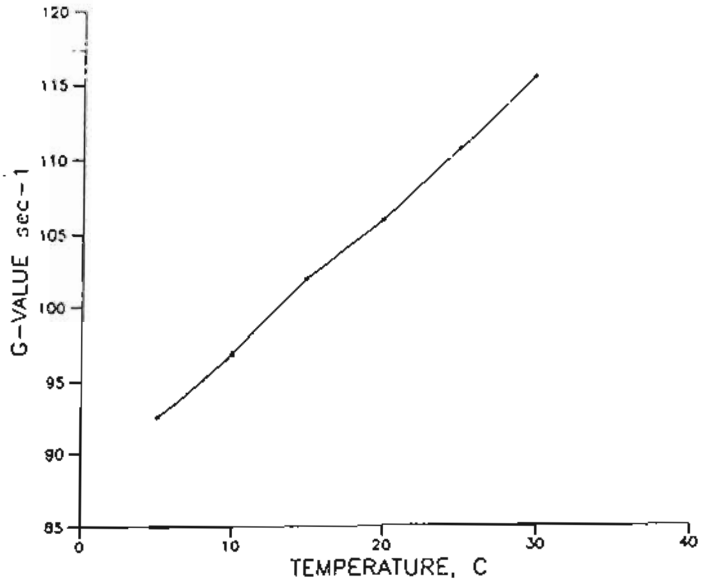


FIG. 3. G-Value Versus Flocculation Rate V (m/h) at 20 C. C = 0.26, and D = 2 cm.



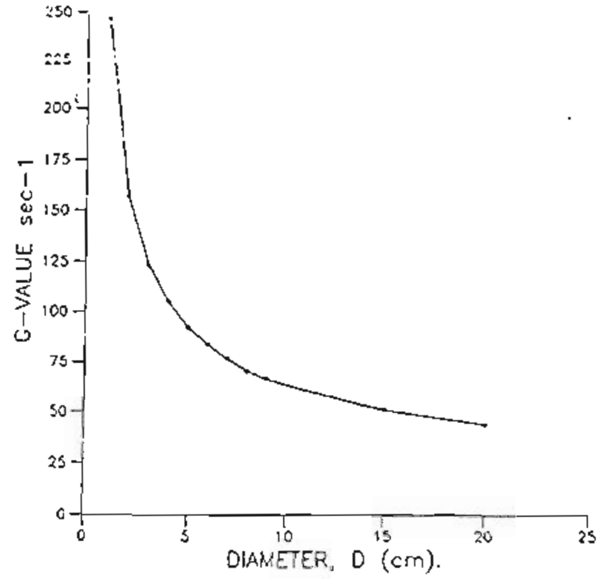


FIG. 5. G-Value Versus Grain Diameter for V = 40 m/h at 20 C and E = 0.26.

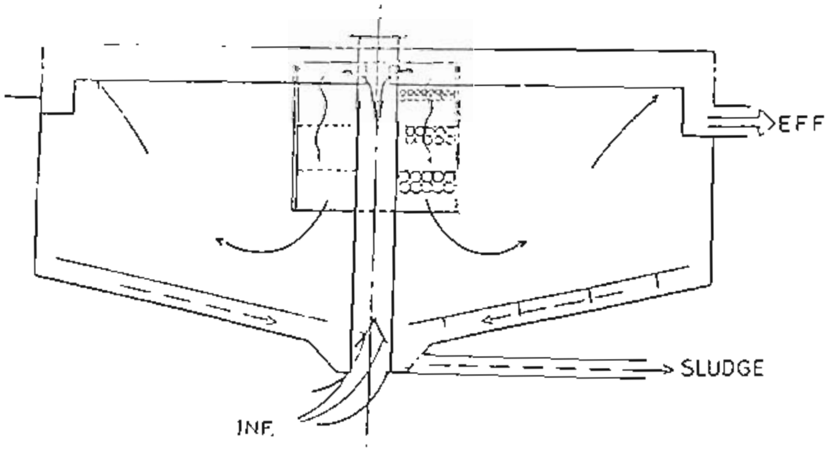


FIG. 6 Downflow - TCF - Application In Clariflocculator

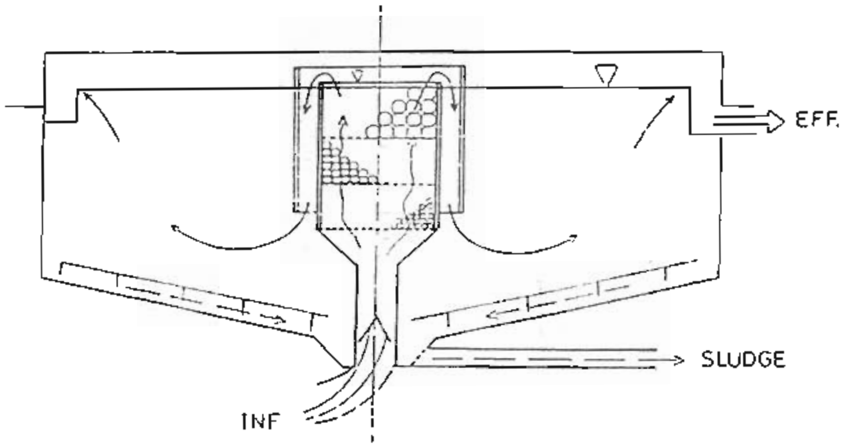
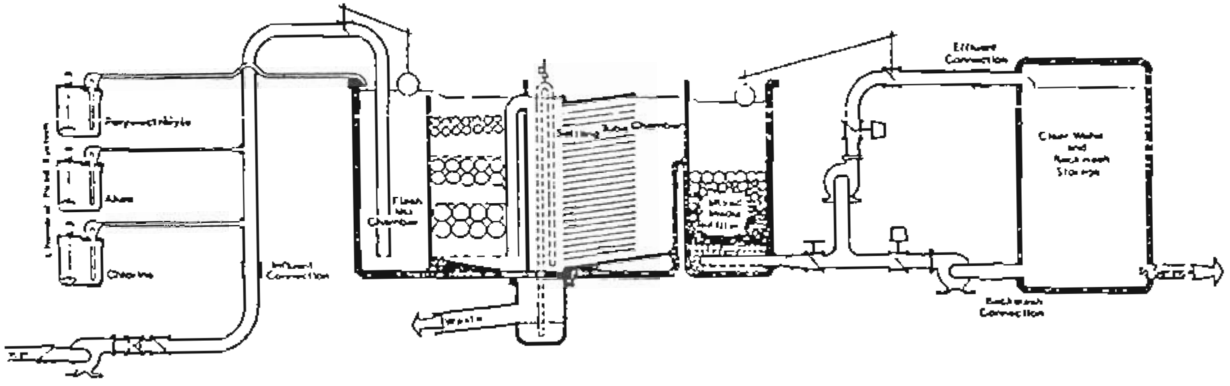


FIG 7 , Upflow - TCF- Application In Clariflocculator.



Application in A Conventional Package Unit Water Treatment Plant.