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SIMULATION OF FLOCCULATION PROCESS THROUGH COARSE MEDIA BED

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ABSTRACT: A simple and effective alternative to conventional flocculation process is the use of coarse media bed in which flocculation and removal of colloidal suspended particles take place simultaneously. Repeated contacts among small suspended particles during the sinuous flow of water through the interstices of course media cause agglomeration of suspended particles. New expressions for the average velocity gradient, and the CAMP number in a coarse media flocculator have been developed. This paper also describes the factors affecting the mean velocity gradient and CAMP number in coarse media bed.

KEY WORDS: Flocculation, mean velocity gradient, CAMP number, face velocity, floc.

INTRODUCTION

General

The most important task of a water treatment process in the separation of colloidal suspended particles from water which are roughly concentrated in the submicron size range. These particles are very difficult to remove in typical sedimentation basin without prior flocculation. Direct sand filtration is not always advisable due to high load of suspended particles and frequent clogging of the filters. To enhance the settling character it is proposed to promote coagulation/flocculation before settling.

Design Parameters for Flocculator

Flocculation depends on the number of particles and the probability of collisions among the particles. Collision may result from variable velocity of suspended particles and from micropulsation generated by mixing. The intensity of mixing can be defined by the variation in the velocity vector of fluid motion, which is described in terms of average velocity gradient. Its magnitude is a function of the useful power input, P, relative to the volume, C, of the fluid and a proportionality factor, μ, the absolute viscosity. The average velocity gradient, G, is thus expressed as (Weber 1972),

$$G = \sqrt{\frac{P}{C\mu}} \qquad (1)$$

Micropulsation generated during mixing not only contributes to floc formation but causes floc damage as well. Extended mixing also multiplies the recurrence of floc formation and damage, leads to the screening of active centres, decreases the flocculation rate and reduces of

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floc. CAMP has developed the flocculation criteria for optimum floc formation by combining the average velocity gradient with the mean or desplacement time, which is expressed as dimensionless CAMP number (Fair, Geyer and Okun 1971).

$$G.td=\sqrt{\frac{P}{C\mu}}\chi\frac{C}{Q}=\sqrt{\frac{PC}{\mu}}\chi\frac{1}{Q}..........(2)$$

A specific range of values is maintained for a particular condition. Thus, the design and performance of a flocculator can be related to the term G. td.

Theory of flocculation in flow through coarse media bed

Usually the sources of power for flocculation devices are gravitational, pneumatic, or mechanical, But neither mechanical mixing nor baffle mixing are feasible and practicable in many small community water supply systems. A simple solution to the flocculation process is the one involving coarse media bed in which water is allowed to flow through a packed bed of coarse media. The sinuous flow of water through the interstices of coarse media will provide repeated contacts among the small suspended particles to form compact settleable flocs. A portion of the agglomerated flocs will settle on the surface and within the interstices of course media, which will further help in adsorbing finer particles as they come into contact with the settled flocs. Moreover, in an upflow system as the flow of water emerges from the coarse media, due to sudden drop of velocity, agglomerated flocs will settle on the top of coarse media bed forming a layer of sludge which is also effective in the removal of finer particles. This type of flocculator occupy small area and no external source of power is required. Moreover the whole bed of coarse media is effective for flocculation purposes. Although this type of flocculators are now in use in many small community water supply systems in Thailand, India, Bangladesh and Latine American countries, the expressions for mean velocity gradient and CAMP number for such type of flocculators have not yet been developed. Moreover the factors affecting the design of coarse media flocculators need to be determined.

DEVELOPMENT OF AN EXPRESSION FOR 'G' IN COARSE MEDIA BED FLOCCULATOR

The requirements for the flocculation process in coarse media beds can be defined in terms of the expression for the average velocity gradient of fluid motion. The expression in question has been derived on the basis of hydraulic parameters. Energy dissipation has been determined from the increment of head loss. For a coarse media volume, V, and porosity, f, in which a loss of head h_L is incurred when the rate of flow is Q, the useful power input (Anon 1983)

$$P=Q\rho gh_L ....(3)$$

Where, ρg is the weight density of water. Assuming laminar flow across the gravel bed, head losses can be estimated by the Blake-Kozeny equation (Fair, Geyer and Okun 1971). They proposed an expression for flow through a uniform porous media,

$$\frac{h_L}{L}=\frac{k\mu v}{g\rho}\frac{(1-f)^2}{f^3}\left(\frac{A}{V}\right)^2 \quad \text{...............(4)}$$

or

$$\frac{h_L}{L}=\frac{k\mu v}{g\rho}\frac{(1-f)^2}{f^3}.\left(\frac{6}{\psi d}\right)^2 \quad \text{............(5)}$$

Where
h_L = head loss through bed of depth, L
k = dimensionless coefficient,
g = gravity constant,
μ = viscosity of water,
A = average surface area = πd^2 (considering spherical grain) of coarse media of volume $V = 1/6\pi d^3$,
v = face velocity of water.
ψ = sphericity of coarse media, (Varies between 1.0 for spherical and 0.78 for angular materials),
d = diameter of coarse media,
f = porosity

Putting the value of h_L in equation (3), the useful power input,

$$P=QLk\mu v\frac{(1-f)^2}{f^3}\left(\frac{6}{\psi d}\right)^2 \quad \text{.....(6)}$$

Putting the value of P in the expression of average velocity gradient, G. in equation (1),

$$G=\sqrt{\frac{QLk\mu v}{\mu fV}\frac{(1-f)^2}{f^3}\left(\frac{6}{\psi d}\right)^2} \quad \text{. .... (7)}$$

Here $fV=C$ and $Q = av$
Where, a = cross - sectional area of bed and $L = V/a$, then $QL = vV$
Putting the value of QL in equation (7)
The mean velocity gradient,

$$G=\sqrt{k}\frac{Q}{a}\frac{(1-f)}{f^2}\left(\frac{6}{\psi d}\right) \quad \text{. . . . . (8)}$$

EXPRESSION FOR CAMP NUMBER

The efficiency of the flocculation process is also affected by the duration, td, of the process itself, i.e. the mean displacement time,

$$td=\frac{C}{Q}=\frac{fV}{Q} \quad \text{. . . . . . .(9)}$$

The dimensionless CAMP number is a product of mean velocity gradient, G, and mean displacement time, td.

$$G.td=\sqrt{k}\frac{Q}{a}\frac{(1-f)}{f^2}\frac{6}{\psi d}\frac{fV}{Q} \quad \text{..... . . . .(10)}$$

$$= \sqrt{k}\frac{(1-f)}{f}\frac{6}{\psi d}\frac{V}{a} \ldots\ldots\ldots\ldots (11)$$

$$= \sqrt{k}\frac{(1-f)}{f}\frac{6}{\psi d}L \ldots\ldots\ldots\ldots (12)$$

CAMP number ,G.td = $\sqrt{k}\frac{(1-f)}{f}\frac{S}{d}L. \ldots 13)$

Where S= shape factor = 6 Ψ
Varying G can be obtained along the direction of the flow by varying or gradually reducing the cross sectional area.
k (Kozeny) is a residual dimensionless coefficient which assumes a magnitude close to 5.0 under most conditions of water filtration (Fair, Geyer and Okun 1968). Typical porosities of granular spherical materials to angular materials vary between O.38 and 0.43 (Fair, Geyer and Okun 1968). Considering an average bed porosity f = 0.4.

From equation (8), mean velocity gradient can be written as

$$G = 8.38\frac{QS}{ad} \ldots\ldots\ldots\ldots (14)$$

and from equation (13), CAMP number can be written as

$$G.td = 3.354\frac{S}{d}L \ldots\ldots\ldots (15)$$

FACTORS AFFECTING "G" AND CAMP NUMBER IN COARSE MEDIA BED

Now from equation (14), mean velocity gradient, G, is

- directly proportional to the rate of flow of water, Q, and shape factor, S,
- inversely proportional to the cross-sectional area, a, of media bed and to the size, d, of coarse media.

From equation (15) CAMP number G.td, is

- directly proportional to the length of bed, L, and shape (x) factor, S.
- inversely proportional to the size, d, of coarse media,

Since, G is directly proportional to Q and td, is inversely proportional to Q, CAMP number is independent of Q. For a constant rate of flow, Q, the displacement time, td, is a function of volume of gravel bed, V. Therefore, for a constant rate of flow, Q, and a specific size and shape of gravel, the cross-sectional area of gravel bed, a, and the length of bed, L, are the variable parameters, for the controlling of mean velocity gradient, G, and CAMP number, G. td.

For a given volume of gravel, V, the cross- Sectional area, a, can be varied by varying the length of the flow path, L, making it up and down flow. Varying G can be obtained along the direction of the flow by varying or gradually reducing the cross sectional area, a.

CONCLUSIONS AND DESIGN GUIDE LINES

In a coarse media flocculator, the mean velocity gradient, G and CAMP number, G. td are mainly a function of face velocity, Q/a and length of flocculator, L respectively. Both the terms (G and G. td) are inversely proportional to the size of coarse media, d Although G is directly proportional to Q. CAMP number is independent of Q.

For a constant rate of flow, Q, and given volume of gravel, V, varying mean velocity gradient, G, can be obtained either by increasing / decreasing the length of the flow path, L, or gradually enlarging/ reducing the cross- sectional area, a, Similarly varying CAMP number, G. td, can be obtained by increasing and reducing the length of flow path, L.

Based on equation (14) , the size of coarse media can be calculated from corresponding face velocity to obtain a desired mean velocity gradient, G as presented graphically in Fiqure-1. The cross-sectional area, a, then can be calculated from the rate of flow, Q.

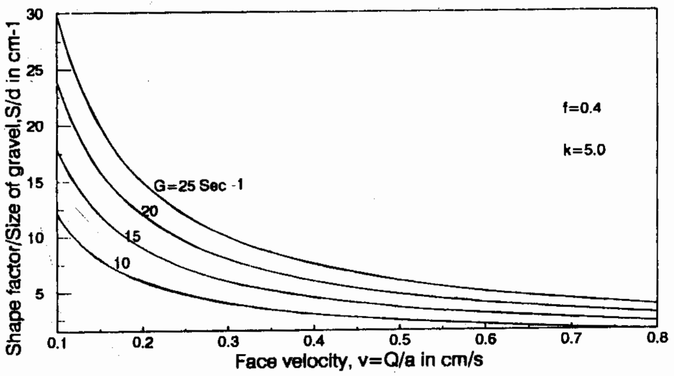

Fig 1. Variation of S/d with face velocity, V/a, as a function of mean velocity gradient, G

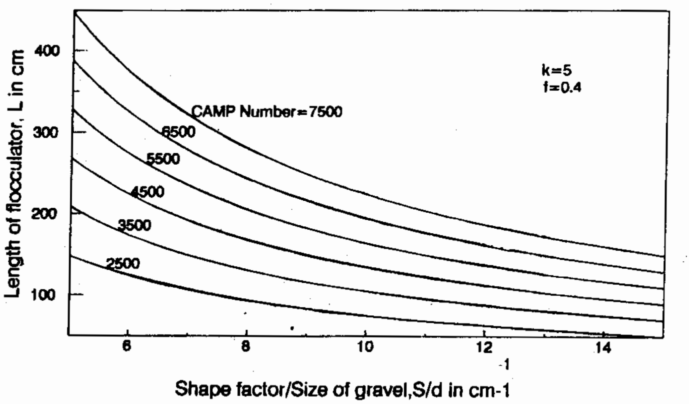

Fig 2. Variation of S/d with Length of flocculator, L, as a function of CAMP Number.

Based on equation (15), the required length, L, of bed can be calculated from coresponding size and shape of coarse media to attain a desired CAMP number, as presented graphically in Figure - 2. Multiplying cross - sectional area, a, of the bed with the length, L, the volume, V, of coarse media can be obtained.

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