Evaluating the effect of inlet arrangement in settling tanks using the hydraulic efficiency diagram

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Abstract

Flow-through curves (FTC) were obtained experimentally in 2 rectangular settling tank models consisting of an inlet slot and an outlet weir. The most important of the FTC characteristics were calculated and plotted on a diagram, which is called the hydraulic efficiency diagram (HED). Using the HED it was shown that the hydraulic efficiency of the tank improves by placing the inlet slot away from the mid-depth, either close to the surface or preferably close to the bottom. Hydraulic efficiency improves further by the use of inlet deflectors, whose position (distance and submersion) is not very critical provided that the deflectors are effective and divert the incoming jet towards the bottom. Some flow characteristics (length of recirculation areas) were measured and correlated to FTC characteristics.

Nomenclature

a = constant defined in Eq. (8)
b = constant defined in Eq. (8)
C = concentration of tracer$[M/l^3]$
C_o = M/V average tank concentration[M/P]
CM = Completely mixed
c = C/C_o normalised concentration of tracer[-]
c_{max} = maximum value of E(t) [-]
d = fraction of the stagnant region defined in Eq. (8)[-]
Dt_a = width of the FTC at E(t)=a[-]
E(t) = coordinate of the FTC defined by Eq. (3)[-]
F(t) = coordinate of the cumulative FTC defined by Eq.(4)[-]
FTC = flow-through curve
H = depth of the tank[l]
HBP = hold back parameter
L = length of the tank[l]
M = injected mass of tracer[M]
Mo = t_{90}/t_{10} Morril index[-]
HED = hydraulic efficiency diagram
p = fraction of plug flow defined in Eq. (8)[-]
PF = plug flow
PFP = plug flow parameter defined by Eq. (7)[-]
q = Q/(WL) overflow rate[l/T]
Q = inlet flow rate$[l^3/T]$
R = UH/v Reynolds number[-]
R = recovery ratio defined by Eq. (2)[-]
s = height of the inlet slot[l]
SEG = segregation parameter[-]
T = time[T]
T_{exp} = duration of the experiment[T]
T_{TH} = V/Q theoretical detention time[T]
t = T/T_{TH} normalised time defined by Eq. (3)[-]
t_a = time at which a% of the tracer has passed[-]
t_{exp} = T_{exp}/T_{TH}[-]
t_g = average time[-]
t_{max} = time for c_{max}[-]
U = Q/(WH) mean flow velocity in the tank[l/T]
v = kinematic viscosity$[l/T^2]$
V = WHL = volume of the tank$[l^3]$
V_{ar} = variance of the E(t) [-]
w = width of the tank [l]

Introduction

The removal efficiency of settling tanks is largely a function of the hydraulic characteristics of the tank. The term " hydraulic characteristics" refers to the kinematics of flow through the tank and thus to the velocity field. The calculation of local velocities is difficult, expensive and time- consuming to perform (Adams and Stamou, 1988), so that the analytical development of a realistic flow field for a settling tank is not a simple operation. It is possible, however, to employ a simple tracer technique, which yields kinematic results that are functions of the general flow field involved. The tracer technique permits the development of the FTC, whose characteristics provide important information on the hydraulic behaviour of the tank under examination.

For the derivation of the FTC a known mass (M) of tracer is injected instantaneously at the inlet of the tank. The resulting plot of the tracer concentration (C) vs. time (T) at the outlet of the tank is the FTC. The FTC is essentially the probability density function (pdf) of the detention times of the liquid (and solid) particles within the settling tank. The FTC is usually expressed in non-dimensional and normalised form by dividing concentrations by the average concentration of tracer in the tank (C_o) and times by the theoretical detention time (T_{TH}), while the area under the FTC is set equal to unity.

FTCs can be used for various purposes. From an FTC the actual (most probable) detention time and other characteristic parameters, such as the dispersion coefficient can be determined. These parameters can be used as inputs to solids removal efficiency models ranging from simple empirical equations (CIRIA, 1973) to advanced mathematical models for solids transport (Stamou et al., 1989) to determine the removal efficiency of the tank. FTCs can also be superimposed with quiescent column settling curves to determine the removal efficiency (Villemonte et al., 1966) or used for the verification of mathematical models describing the tracer transport and mixing (Stamou, 1991). By comparing the shapes and characteristics of FTCs, the effect of a parameter of a settling tank such as tank dimensions, inlet and outlet configurations, flow characteristics (e.g.overflow rate) on its hydraulic efficiency can

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