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Design of a Settling Basin for Small Scale Water Treatment Plant in Borno State, Nigeria

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Abstract: *A settling basin being one of the major components in any water treatment plant be it small or large scale was design for a small village community with an access river or stream water source. The capacity of the settling basin is taken as 10m^3 which is same dimension of the flocculate so as to ease construction and better flexibility of unit to future expansion. The overflow rate of the settlement tank is evaluated to be 51.84m/day with a settlement velocity V_s of 0.06m/s.*

Key words: *Design, settling basin, settlement velocity, overflow rate*

I. INTRODUCTION

Preliminary settling is the most widely applied method to heavily silted and turbid waters. This makes use of gravity for particles to settle from a suspended state in the water usually from the top to the bottom of the settling tank, the time of settling depends on many factors: which includes the densities of the particles and water, the design of the tank etc. Although a further settling is needed for treatment process, this is employed to reduce the proper settling which occurs later in the stages at a sort of uniform velocity.

Some of the tank designs used is the Horizontal flow or the vertical basins. The Horizontal-flow basins tend to be a better type of pre-settlement basin especially in cases of waters with high amount of silt and turbidities. The vertical flow basins tend to be difficult to operate once the dry silt by weight is 1000mg/1. Where this occurs It is helpful to put in a small, non-chemically assisted horizontal flow basin immediately upstream of the vertical flow, to keep the peaks of suspended solids well below 1000mg/1 [1].

Once the provision of pre-settlement tanks where conditions require them can be assumed, it follows that all water reaching a main settling basin will have suspended solids of less than1000mg/1 by dry weight and under these conditions any properly designed and operated basin should be able to produce water fit to admit to rapid gravity sand filters. [1]

Settling basin:

Settling tank, sedimentation basin are synonymous terms and signify the chamber in which settlement occurs. Such chambers mostly belong to two great families, namely horizontal flow tanks in which the direction of water flow is predominant horizontal and vertical flow tanks in which the water enters the bottom and overflows from the top.

II. SEDIMENTATION

When silt-laden water is admitted to the still conditions of a sedimentation basin its velocity tends to fail to zero, its capacity to transport solids disappears, and the solids begin to settle.

It has long been established that a discrete particles setting freely through water quickly attains a constant velocity [3].

$$V_s=\left[\left(\frac{2g}{c}\right)(s-1)\frac{V}{Ac}\right]^{1/2} \quad \text{………………… (1)}$$

Where,

V_s = velocity of settlement cm/s

g = acceleration due to gravity (981cm/s^2)

c = drag coefficient
s = specific gravity of the particle
v = volume of the particle, cm^3
A_C = projected area of particle, cm^2
From the above equation, it can be seen that increases in the size of the particle (V) and the drag coefficient (c) speeds up and slow down respectively [3]. Most of the spherical particles of concern in water treatment settle in accordance with a modified form of equation (1) known as Stokes Law, in which Vs can be written as,

$$Vs = \frac{g}{18\mu}(\rho_1 - \rho)d^2 \qquad (2)$$

Where,
ρ_1= density of the particle, g/cm^3
ρ = density of the fluid, g/cm^3
μ= dynamic viscosity of the fluid, g/cms
d = diameter of the particle, cm
Or in term of the kinematic viscosity i.e $v = \frac{\mu}{\rho}$ ……………………………...…… (3)

$$Vs = \frac{g}{18v\rho}(\rho_1 - \rho)d^2 \qquad (4)$$

For settling in Strokes Law region, the drag coefficient (c) is 24/Re, where (Re) is the Reynolds number and thus it decreasing as the Reynolds number increases. Reynolds number is also inversely proportional to Kinematic viscosity, which decreases with rising temperature thus; higher water temperature decreases the drag coefficient and increases the rate of settlement [1].

III. DESIGN CONSIDERATIONS

Pure theory is of very little use in designing a settling basin. For one thing it is difficult to predict the worst condition under which the basin will have to operate. Although laboratory tests on a series of sample will give an indication of the most suitable types of basin and the required doses and of optimum floc formation and settling velocity, general factors of safety have to be allowed before the results can safely be applied in practice.
Each of the four functional zones of sedimentation basins and flotation tanks presents special problems of hydraulic and process design that depend on the behavior of the suspended matter within the tank, during removal and after deposition as sludge or scum [3].
Size, density and flocculating properties of the suspended solids, together with their tendency to entrain water, determine the geometry of the settling or rising zone. Their concentration by volume and the contemplated length of storage establish the dimensions of the bottom zone and the scum zone [3].
Putrescence and excessive accumulations are divided by removing sludge more or less continuously. Mechanical removal, it is said, becomes economical when the volume of settle able matter (including entrain water) is more than 0.1% the volume of the transporting liquid. [3] Removal devices affect tank design as well as tank operation. Thermal convection currents and wind-induced currents are held in check by housing or covering the tanks. The proper number of units is a matter of wanted flexibility of operation and economy of design [3].
Horizontal-flow tanks and vertical flow tanks have been constructed in great variety, some of which are Circular, Square or rectangular in plan. They vary in depth from 7 to 15ft, 10ft being a preferred value. Circular tanks are as much as 200ft in diameter, but they are generally held to a 100ft maximum so as to reduce wind effects. Square tanks are generally smaller. A side length of 70ft is common. Rectangular tanks have reached length of almost 300ft but a 100ft limit is generally imposed [2]. Except for steep sided sludge hoppers, the bottom of most settling tanks slopes gently. Common values lie close to 8% for circular or square tank and 1% for rectangular tanks. Foothold on a slippery surface becomes precautions at a slope of $1\frac{1}{2}$ in. per ft. The slopes of sludge hoppers range from 1.2:1 to 2:1 (vertical: horizontal). They should be steep enough for the solids to slide to the bottom [3].
The laboratory approach for the design of horizontal – flow basins are as follows.
Tests should be made to determine the period required for the water to settle naturally in a cylinder equal in depth to the basin without the addition of coagulants or stirring. In many quite heavily turbid waters the samples quickly show a clear dividing line between the upper clarified zone and the lower zone of settled silt. If this period is short and the line of demarcation is well defined, flocculation is probably not necessary. If the period is lengthy and the zone of junction is blurred, colloids are probably present and flocculation is essential. A commonly accepted settling velocity for well-formed floc is about 3m/h [1].
The time it takes for the average suspended solids of the water at all draw-off points above the silt lime to fall to 2mg/1 should be multiplied by a factor of safety of 3 to arrive at the nominal retention capacity of the settling zone of the basin. The factor of safety allows for inefficiency of the basin due to streaming.

On the more salty rivers commonly found in the tropics, characterized by high temperatures and heavy silt particles, 4h basins are common, but where conditions are particularly difficult (low temperature, colloids and heavy silt) 6-9h retention is not uncommon and in some of the more difficult cases pre-sedimentation tanks and flocculation are also necessary[1] . If coagulant aids are found to be effective it is probable that the above retention times could be reduced, but these aids need skilled administration and may not be suitable for use in developing countries [1].
The depth of the settling zone is normally about 3m; hence for turbid water one should add 0.6m in which precipitated silt can accumulate while awaiting removal.
Other recent developments in the design of settling basins include the spiral flow basins in which the water follows through an upward spiral path. This originated in Egypt to deal with exceptionally difficult waters. Others include the multi-storey tanks, where it is used when space is limited or structural cheapness, by building structures of two or more storeys. Other types of settling basins include the plated tanks. The plated tanks operate, by allowing the water to pass through plates supported by hangers and dog-legged, such that the silts deposit on the plates and slides down form plate to plate though the gaps, on to a belt scraper and can thus be ejected. Other types of recently developed designs of settling basin includes the lamella separator, the Hopper-bottomed sludge blanket basins and the modified hopper-bottom designs, the accelerator type solid contact clarifiers, the pulsator and the separator are recent developments in settling basins design.

IV. SETTLING BASINS DESIGN

A continuous-flow basin can be divided into four zones,

1. Inlet zone, in which influent flow and suspended mater disperse over the cross section at right angle to flow.
2. A settling zone in which the suspended particles settle within the flowing water.
3. A bottom zone in which the removed solids accumulate and from which they are withdrawn as underflow.
4. Outlet zones in which the flow and remaining suspend particles assemble and are carried to the effluent conduit [2].

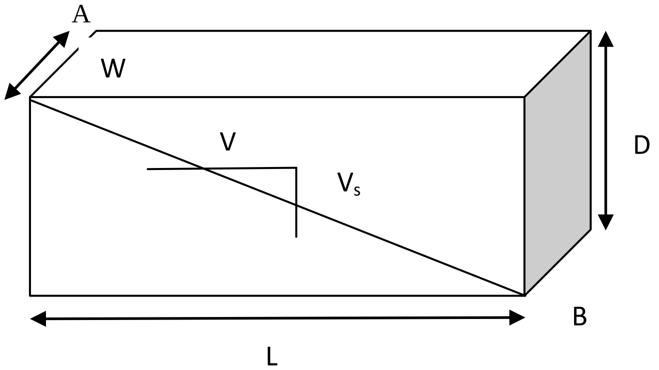
The paths taken by discrete particles settling in a horizontal flow rectangular or circular basin are almost the same. They are determining by the vectors sums of the settling velocities (V_s) displacement velocities (V) of the basin [2].
Consider a particle settling with velocity (V_s cm/s), and being carried horizontally by water flowing at a velocity (V cm/s).it would follow the inclined path AB. and by comparing similar triangle, the particle would just reach the bottom when $V_s/V = D/L$. if,
Q is rate of flow m^3/s,
W is width of basin m,
A is area (=WL) m^2
Then,

$$Q = \frac{V}{100} WD \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

And,

$$V_s = \frac{100}{A} Q \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The quality $\frac{Q}{A}$ is known as the overflow rate or velocity. It is generally stated in meters per day [1].
The importance of surface area in the simple theory of settlement is clear and it would logically appear that the depth of the basin and therefore the retention time of the liquid is of little significant [1].
Fig 1.0 below shows the theoretical settlement in a horizontal flow basin.



In upward flow basins settlement in the upper regions is controlled by making the area (A) of the tank sufficiently big, so that $V < V_s$, where v is the upward velocity of the water ($\frac{Q}{A}$) and V_s is the settling velocity of the particle. When this condition is achieved the particle must be settling through the rising water and clarification must result [1].

In practice, the upward velocity of water is kept down to about half the settling velocity of the floc particles. The normal velocity of settlement of well-formed floc is about 3m/h. if coagulant aids are used this may become 6-10m/h, and where the floc is consolidated pulsing or other devices, it may be somewhat more. In a softening plant the settling velocity of the particle of calcium carbonate is about 8m/h, applying the commonly used factor of 0.5, many upward flow basins are provided with designed to limit the upward velocity of the water [1].

To ease construction and better flexibility of unit to future expansion, the settlement basin is designed to the same dimension as the flocculation tank. In this project a flocculation tank has being design with the follow dimensions 2m X 2m X 2.5m as well.

Natural settlement time of the water as tested is 20min, hence the retention time in basin 3 X natural settlement time. Where, 3 is a factor of safety.

It follows that retention time = 3 X 20 = 60min or 1 hr.

For a well formed floc, in a horizontal flow basin equation (6) gives the settlement velocity V_s as

Vs= 100Q/A = 100 X 0.003/L X B

Where L and B are the length and breadth respectively, Thus, Vs = 100 X 0.003/2 X 2.5 = 0.06m/s]

The settlement velocity of the particles is therefore 0.06m/s. The value Q/A is the overflow rate = 0.003/2 x 2.5

Overflow rate = 0.0006m/s

= 0.0006 X 3600 X 24 metres per day

= 51.84m/day

V. MATERIAL SELECTION AND SPECIFICATION

The settlement basin is to be constructed with bricks; the floor should be slanted upwards by 10% of its height, 0.9mfrom its entry. This is done to facilitate the easy collection of silt at the lowest point of the tank, with *a* drain plug for sludge removal during maintenance. The drain is a tapered steel material with larger and smaller diameters of 100mm and60mmrespectively, which is fitted to the floor of the tank during construction. A steel rod 2.2m long and 10mm diameter is welded to a similar tapered solid steel (the plug) which *is* machined to fit into the drain this serves as a valve for the control of sludge removal, The steel rod is bent into a handle and is controlled from the top of the settlement tank.

The top of the settlement tank is covered with a light wood material 15mm thick cover the whole area of the tank.

The entry pipe is 1m long and 100mm diameter, which is provided with a union 0.5m from entry for future expansion. See diagram for necessary details.

VI. CONCLUTION

Great simplicity and economy was taken into account in the course of the design, this is necessary for a water treatment plant to be located in the villages where skilled maintenance personnel may not be readily available. However, the simplicity does not in any way compromises the required standard and safety consideration needed.

The sedimentation tank were both designed to the required purpose and made of materials appropriate for their efficient performance.

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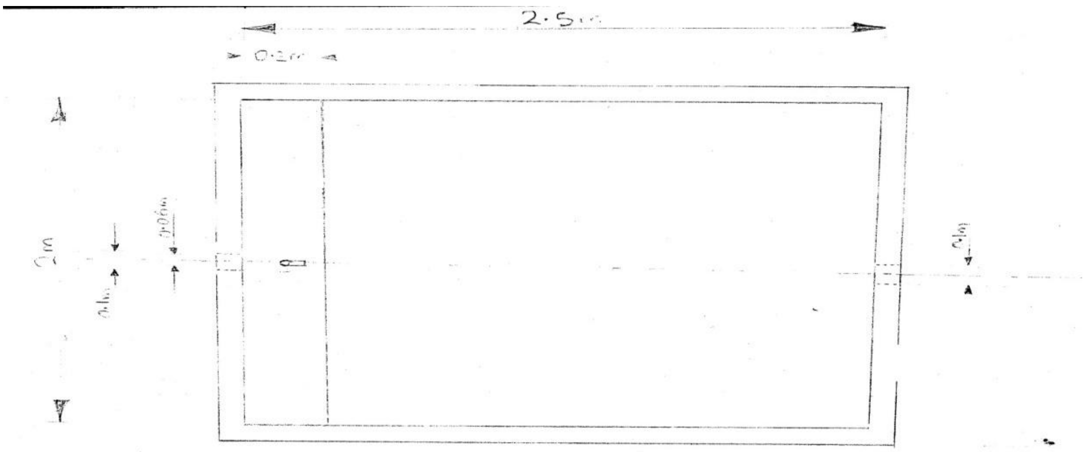
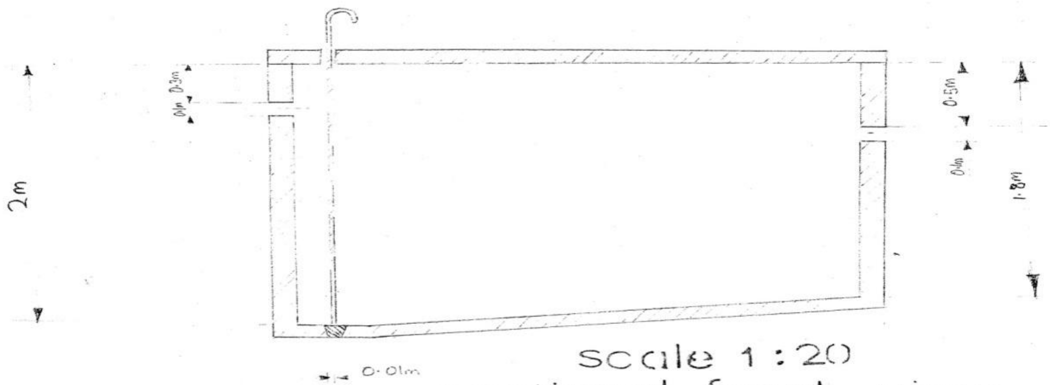
APPENDEX I



scale 1 : 20

Plan view of settlement tank



scale 1 : 20

sectional front view