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Design and Construction of a Model Sedimentaion Tank Using Existing Slow Sand Filter For NDA Treatment Plant

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Abstract

The treatment of water for human consumption involves various processes in which raw water passes through. This processes includes; screening, flocculation/coagulation, sedimentation, filtration and chlorination. Sedimentation is a process between flocculation/coagulation tank and filtration tank. The design of sedimentation tank is necessary to receive effluent of the flocculation/coagulation tank and achieve efficient settling of particles under gravity and then discharge to the slow sand filter as effluent for further treatment. To achieve this grate settling efficiency, a rectangular sedimentation tank withthe following dimensions; depth 3.58m, width 5.76m and 23.0m long, is designed and constructed with a baffle across the inlet perforated with holes, this provides calm area at the settling zone for efficient settling of particles. The base of the tank is sloped towards the inlet zone for collection and disposal of sludge gate valve. While at the outlet zone, a baffle is provided to prevent any particle which did not settle from going out.

Introduction

Water to be supplied for public use must be portable i.e. satisfactory for drinking purposes from the stand point of its chemical, physical and biological characteristics. Drinking water should preferably be obtained from source free from pollution. The raw water normally available from surface water source is how ever not directly suitable for drinking purpose. The objective of water treatment plant is to continuously provide a portable supply of water. It should also improve the athletic acceptability of the water and remove any toxic or health-hazardous material. Other function is to remove or deactivate a diseases-producing organism.

All surface water and ground water require treatment prior to consumption to ensure they do not represent a health risk to the user. Health risk to consumers from poor quality can be due to microbiological, chemical, physical or radioactive contamination.

Some of the common treatment process used in the past includes plain sedimentation, slow and filtration, rapid sand filtration with coagulation-flocculation units as essential pretreatment units. Pressure filters and diatomaceous filters have been used, under certain circumstances, as pretreatment units for the conventional filters.

Definition of Sedimentation

Sedimentation or classification is the processes of letting suspended material settle by gravity. Suspended material may be particles such as clay or silts originally present in the source water. More commonly, suspended materials or floc is created from material in the water and the chemical used in coagulation or in the treatment processes, such as lime softening.

Sedimentation is the removal of suspended solids through the setting of particles moving through a tank at a slow rate. There are a number of forms of sedimentation. In water treatment plants, treating source water a high proportion of suspended solids of coarse grade level e.g. clay and coarse silt) a grit chamber may be used to remove the largest particles through simple sedimentation. In this process, water is passed through a tank at a slow rate and suspended solids fall out of suspension. In small supplies simple sedimentation may also be used, while functioning in a simple fashion to grit chambers, although with a smaller rate of water through flow. Simple sedimentation will not remove fine-grained particles because the flow remains too high and the retention time is insufficient. A further common fault with simple sedimenters is that design flow rates are rarely achieved in practice and a certain element 'short-circuiting' can occur unless construction, operation and maintenance is done in a careful manner.

As a result of the drawbacks in simple sedimentation, it is common to find that the sedimentation process is enhanced through the addition of chemicals.

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Sedimentation Process Description

Sedimentation which is also called clarification is the removal of settleable solids by gravity. The process takes place in a rectangular, square or round tank called sedimentation or setting basin or tank.

In the conventional water treatment process sedimentation is typically used as a step between flocculation and filtration. Sedimentation is also use to remove the large amount of chemical precipitate form during lime-soda ash softening process.

Basins designed for efficient sedimentation allow the water to flow very slowly, with a minimum to turbulence at the entry and exit point and with as little short-circuiting of flow as possible. Sludge, the residue of solids and water, accumulates at the bottom of the basin and must then be pumped out of the basin for disposal or reuse.

Types of Sedimentation Basin

Sedimentation basins may be of different shapes which includes; rectangular, circular and square.

Rectangular Basins

Rectangular basins are commonly found in large scale water treatment plants. Rectangular tanks are popular as they tend to have.

- High tolerance to shock over load
- Predictable performance
- Cost effective due to lower construction cost
- Minimal short circuitry.

Circular and Square Basins

- Circular basins are frequently referred to as clarifiers'. These basins share some of the performance advantages of rectangular basins, but are generally more prone to short circuit and particle removal problems. For square tanks the design engineer must be certain that some type of sludge removal equipment for the corners is installed.

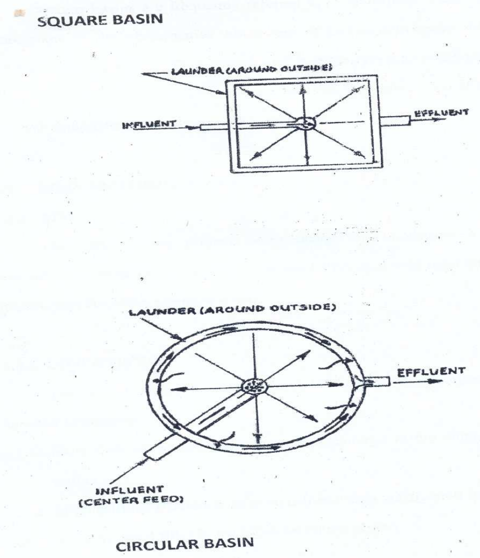

Figure 1: Circular and square Basin

Literature

Although drinking water should be palatable it must be potable, i.e. free from disease or toxic substances "Disease producing organism (pathogens) will be transmitted by water contaminated by feaces". (Bichi, 1997).The first large municipal water filtration system was built in Poujhkeepsie in New York, United States in 1871, more sophisticated surface water treatment plants were constructed immediately before world war 1, using chlorination to control out breaks of typhoid fever.

Today municipal water treatment plants use a variety of processes which includes screening, pre-chlorination and sedimentation. Coagulation can remove sediments, turbidity, colour and organic matter, softening reduces hardness" (Lehr et al 1980) clarification, filtration. Filtration, oxidation, as well as sedimentation are all used to remove very fine particles and manganese. Lehr (1980) reported that post-chlorination is probably the final treatment process in most plants. He also observed that fluoride may be added to some supplies to protect children from tooth decay.

By 1939, the techniques of clarification and filtration grew, mechanically sludge sedimentation tanks were in general use. The micro-strainer, for the removal of plankton from the impounded water was developed by Boucher, and was introduced by Glenfreld and Kennedy in 1945. Coagulation of water with sulphate of chemical began experimentally in 1827 but was adapted practically only in 1881 to treat Bolton's water supply. The first permanent use of chlorination originated under the direction of Sir Alexander Houston at Lineoln in 1905.

The aim of this project is to design and construct a model sedimentation tank using existing slow sand filter that will meet the water requirement for NDA permanent site.

Methodology

Materials and Methods

The material used in the construction of the model Rectangular sedimentation tank is a polymer product called Perspex; they are produced from synthetic materials obtained from petroleum products. The Perspex comes in sizes denoted by their thickness. For the purpose of this work, 3mm thick sheets were used.

To constructthe rectangular sedimentation tank the following steps were observed:

- Water resistance adhesives had to be used and the UHU 'All Plast' glue became a handy material for sticking the various sections together.
- Cutting of the dimensional sections were carried out using a special cutting blade known as plastic blade, the principle of which is by chipping off sections of the area under cut.
- Perforations were made using an electric drilling machine so as to provide holes of equal sizes in an array to achieve a sieve like pattern.
- The pipe pits were made by first making a sequence of drilling holes around the diameter size of the pipe size already marked on the required surface and knocking it off later. The component of the sedimentation tank are also described below:

Components of Sedimentation Tank

Inlet Zone

The inlet or influent should provide a smooth transition from the flocculation zone and should distribute flow uniformly across the inlet to the tank. The normal design includes baffles that gently spread the flow across the total inlet to the tank and prevent short-circuiting in the tank. The baffle could include a wall across the inlet, perfected with holes across the width of the tank.

Settling Zone

The settling zone is the largest portion of the sedimentation basin. This zone provides the calm area necessary for the suspended particles to settle.

Sludge Zone

The settling zone, located at the bottom of the tank, provides a storage area of the sludge before it removed for additional treatment or disposal.

Basin inlets should be designed to minimize high flow velocities near the bottom of the tank. If high flow velocities are allowed to enter the sludge zone, the sludge could be swept up and out of the tank.

Sludge is removed for further treatment from the sludge zone by scrapes or vacuum devices which move along the bottom.

Outlet Zone

The basin outlet zone or launder should provide a smooth transition from the sedimentation zone to the outlet from the tank. This area of the tank also controls the depth of water in the basin weirs set at the end of the tank control the overflow rate and prevent the solids from rising to the weirs and leaving the tank before they settle out. The tank needs enough weir length to control the overflow sale, which should not exceed 20,000 gallons per day per foot of weir.

Analysis and Design

Design Criteria for Sedimentation Tank

A well designed tank should have an efficiency of 30 to 50%, some design criteria for sedimentation tanks are:

Period of detention 2 to 8 hours, length to width ratio of flow through channel 3:1 to 5:1 depth of basin 10 to 25ft (15ft average), width of flow through channel not over 40ft (30ft most common 10ft). Flow through velocity not to exceed 1.5ft/min (most common velocity, 10ft/min) surface loading or overflow velocity, gal per day, per ft of surface area-between 500 and 200 for most settling basins.

Sources: (Susumu Kawamura 1985).

Sedimentation Tank Specification

Sedimentation tank can be made of non-reactive surfaces such as concrete or plastic of various sizes depending on the water demand of the treatment plant.

In the design of our Rectangular Sedimentation tank,the following specifications were used;

Depth 3-5m

Width: 3-24m

Length: 4 x width

Detention time 4-8hrs

Flow through velocity: <$0.00254m^3$/sec.

Overflow rate: <$3,800L/day\text{-}ft^2$

- Influent battle perforated with holes to reduce inflow momentum
- Slope of bottom at sludge zone towards the gate value > 1%

SOURCE: Camp T.R (1946).

Cost Information

In terms of cost, the size of the tank determines how expensive it is. Tanks should be kept short, so that depths and costs can be kept down. In some cases, a double row of tanks (back to back), may be convenient to reduce the tank length.

For tanks with mechanical and electrical equipment's, a large number of tanks also implies an increase in capital costs and also increased running cost. The shape of rectangular tanks should be determined on the ground of cost unless contrary to overall plant efficiency.

Design of Sedimentation Tank

Overview of Calculations

The following will be determined, flow rate, dimension and volume of the sedimentation tank. The calculations are as follows:

1. Determine the flow rate
2. Calculate the required surface area
3. Calculate the required volume
4. Calculate the tank depth
5. Calculate the tank width and length
6. Flow through velocity.

Flow Rate

The flow rate is being obtain as the effluent rate of the coagulation/flocculation tank which is **0.033m^3/s**

Surface Area

In order to design the most efficient sedimentation tank, we will base this surface area on overflow rate of 2000L/day-ft^2, therefore the surface area is calculated using he following formula;

A = QC/O.R

Where:

A = surface area (m^2)
QC = flow rate, L/day
O.R = overflow rate, L/day-ft^2
A = (2,851,200/2,000)
= 1425.6ft^2
= 132.43 m^2

Volume

The volume is calculated by multiplying flow by detention time.

Take t = 4hrs
V = Qt
Where: V = Volume
Q = Flow rate
T = Detention time
V = 0.033x4x60x60
= 475.2 m^3

Depth

The tank depth is calculated as follows,

D = V/A

Where

d = depth, m
V = volume, m^3
A = surface weir, m^2
d = (475.2/132.43)
d = 3.58m

Width and Length

Volume of a rectangular solid is calculated as follows:

V = Lwd

Where:

V = volume
L = length
w = width
d = depth

For our tank, the length has been defined as follows

L = 4w

Combining these two formulas, we set the following formula used to calculate the width of our tank.

$W = \sqrt{^{v}/_{4d}}$

$W = \sqrt{\frac{475.2}{4(3.58)}}$

W = 5.76m

Therefore the length is calculated as:

L = 4(5.76)

= 23.0m

Flow through Velocity

First, the cross sectional area of the tank is calculated

A_x = w.d
A_x = (5.76x3.58)
A_x = 20.62m^2

Then the flow through velocity of the tank is calculated.

V = QC/ A_x
V = (0.033/20.62)
V = 0.0016m/s

The velocity is less than 0.00254m/s, so it is accountable

The schematic drawing of the designed and constructed rectangular sedimentation tank is shown below:

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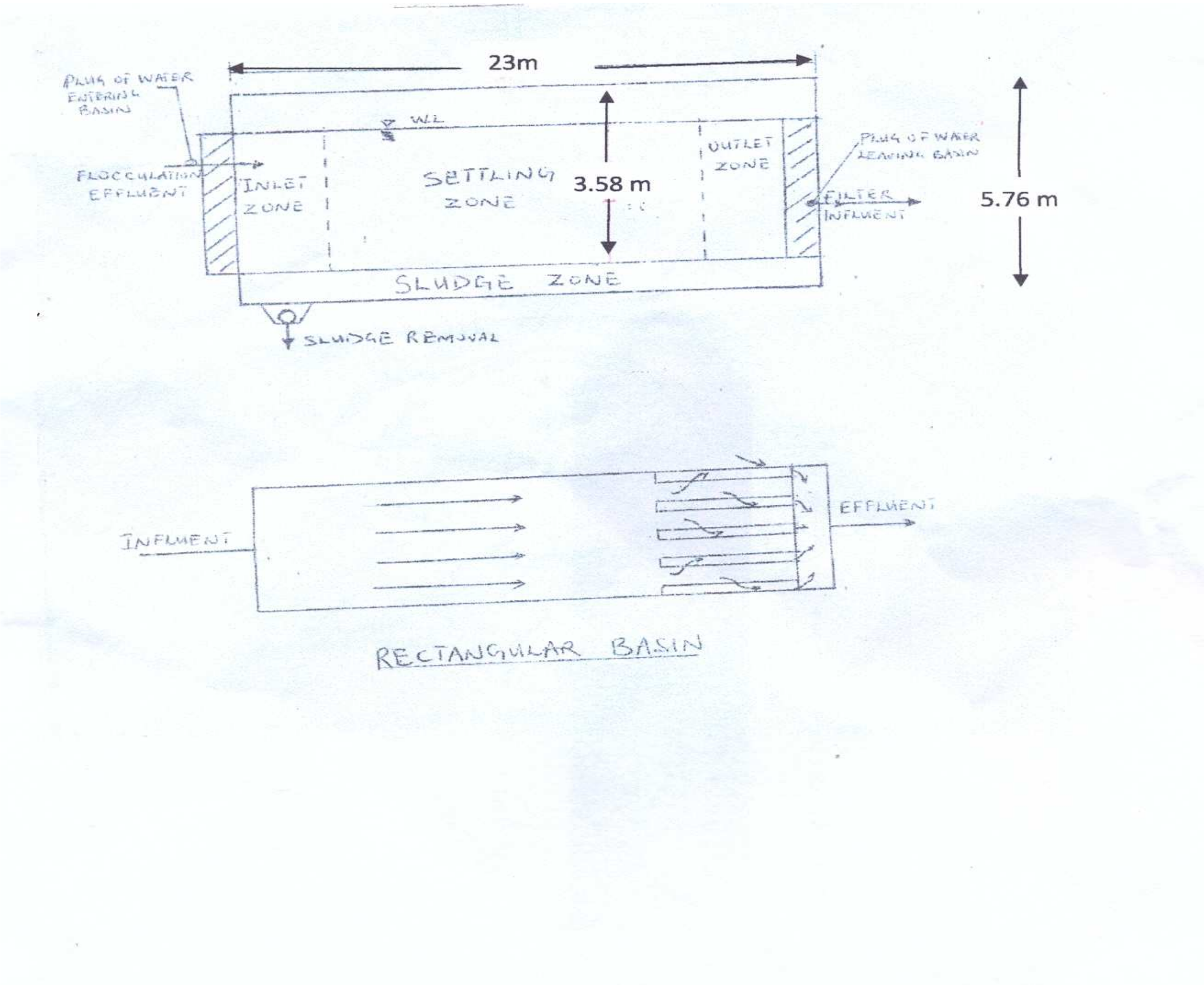

Figure 2: Designed and constructed rectangular sedimentation

Conclusion

For effective settlement of suspended particles, the sedimentation tank for NDA permanent site treatment plant should have the following dimensions; depth 3.58m, width 5.76m and 23.0m long.

The tank will have a surface area of 132m^2 and a volume of 475m^3. The flow through velocity will be 0.0016m/s.

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