International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 4 Issue 8|| August 2015 || PP.39-43

Design of a Filtration System for a Small Scale Water Treatment Plant for a Rural Community around Maiduguri Area in Borno State, Nigeria

[1]Hussaini A Abdulkareem, [1]Nuhu Abdullahi, [2]Kabiru M Shehu,
[1]Department of Mechanical Engineering and School of Industrial Engineering College of Engineering Kaduna Polytechnic, Nigeria
[2]Applied Science Department School of Science and Technical Education College of Science and Technology Kaduna Polytechnic, Nigeria

Abstract: *The provision of safe clean water is one of the paramount responsibilities of all government. This is more difficult to achieve in rural communities, hence the need for a simplified and economic design of a filtration system. The daily water consumption for the treatment plant is 0.057 mgd (million gallons daily). The filter area is evaluated as 24m^2 with the sand occupying 1m deep of the total length of bed. The gravel also cover a deep of 1.05m thereby gives the length of the bed as 3.60m to avoid overflow. The gravel is arranged asymmetrically below the sand from round washed gravel to stone gravels. Filter stones should be kept 50cm from all sides of the filter; the filter sand will rest on the bottom of the filter around the edges.*
Key words: *filtration, water treatment, design, turbidity.*

I. Introduction

A treatment plant consists of many processes, which can generally be subdivided into pre-treatment, and treatment. Some of these include screening, coagulation, flocculation, filtration etc. The impurities are removed in order of size, the bigger ones being eliminated first, since not every water source requires all the treatment process [1].

The impurities are mainly removed by the following process:
Floating objects by screening;
Algae (if possible) by straining;

Excessive iron, Manganese and hardness in solution by precipitation in basins after the addition of chemicals; remaining fine and some bacterial by filtration and excessive bacteria pollution by pre-chlorination, final bacteria surviving filtration by chlorination. Rapid filtration provides another means of removing suspended matter algae and some organic matter from water and; it form slow sand filtration. Use of this method prevents excessive growths of algae and relieves the load on the slow sand filters [2].

The first successful water treatment plant for domestic use was in New York (United States) in 1871, which was based on the slow sand filtration process, in addition to other purification techniques [3].

II. Filtration

Filtration follows settlement and to a certain extent they are interchangeable; the more effective the settlement the less the filters have to do and vice versa. It is the final process in water clarification and except in case of clear underground sources, where it is unnecessary; there is a tendency nowadays to regard it as essential. Basically the processes of filtration consist of passing water through a bed of sand, or other suitable medium, at low speeds. The sand retains suspended matter while permitting the water to pass and the filtrate should be clear and sparkling in appearance. There are practical limits to the capacity of filters to achieve this final degree of clarity, unless the incoming water from the settling basins is itself of fairly low turbidity, the degree of which may vary with the type of filter adopted.

The filters most commonly found are the rapid gravity sand type. They are normally operated with coagulants and very often follow settling basins. They ought to produce excellent results with incoming water of less than 10JTUsof turbidity, work reasonably well when the turbidity of the incoming water is10-20JTUS and under occasional emergency conditions can be operated for a short period to produce an acceptable filtrate when the settled water has a turbidity of 20 - 50 JTUs (Beyond this the whole works would go out of operation) [1].

The depth of water above a filter bed is generally about2m. The flow of water through sand is streamline flow and the loss of head is proportional to the velocity and is also affected by the absolute viscosity of the water and the porosity ratio of the sand and therefore temperature and cleanliness of the filter sand both affect performance. [1]

Filter sand has a grain size of 0.4-1.0mm which is large in comparison with many of the smaller particles carried by water and the rapid gravity sand filter can only operate as intended when coagulants have been used. Interception of the suspended matter by the sand is a fairly complex process, but most of the suspended matter is removed by adhesion to the surface of the sand grain. The velocity in the waterways increase and suspended matter is carried deeper into the filter. The filter action therefore process in depth and is only to a limited extent influenced by the formation of a film on the surface of the sand. If the filter is working properly the sticky floc particles will not find their way through the intricate pattern of channels between the sand a film on the surface of the sand.

If the filter is working properly the sticky floc particles will not find their way through the intricate pattern or channels between the sand grains and perfectly clear water should emerge. If the head loss in the sand at any point exceeds the static head of water on the filter, a vacuum will be induced which may cause dissolved air to be given off from the water and result in air binding of the filter. This occasionally happens just before the filter needs washing but disappears during the washing [1].

Another phenomenon of dirty filter with high head loss is shrinkage of the sand surface and the formation of cracks. Surface cracking can be cured by paying greater attention to washing. The use of coarser sand is less desirable as turbidity of the filtrate occurs at low loss of head than if finer sand is being used. If filters bed is too dirty the head loss developed becomes excessive and break through may occur. In this condition turbid water will pass to supply [1].

The usual rates at which water is passed through a filter, lies between 3.9m/h to 70m/h. A compromise should be made between efficiency and the number of washings to be done. The more sediment there is deposited in the sand in a given time, the more frequently the filters have to be washed.

High temperatures and slightly coarser sand grains facilitate the higher rates and filters can in theory work with rates as high as 50m/h [1]. (In practice they do not).

The working rate of filters is stated in terms of flow through a unit surface area in a given time through the filter and its efficiency depends essentially on the adherence of impurities to the surface of the sand grains themselves. Thus, the depth of bed and fineness of grain contribute as much to filter efficiency as filter area, thus the head loss through the filter should never exceed 2m [1].

III. Types of Filters

The slow sand filters.

They are relatively of simpler construction than the rapid sand filter. In the slow sand filter, a bed of sand 0.9m deep rests on graded gravel in which under drains of open jointed tiles are buried. The sand is carried to the full depth of the bed near the outer walls and to avoid carrying it into the under drains no pipes should be laid within0.6m of the wails. The sand is normally finer than that in a rapid filter and its quality and grading are less exacting.

The pressure filters.

They are similar to the rapid filters but are enclosed in pressure vessels and are normally used where hydraulic conditions in the system make their adoption desirable. They can be installed at any point in a pressure pipeline without unduly interfering with the hydraulic gradient and often eliminates the need for double pumping. They do not usually follow settling- basins and use coagulants to aid its performance. [3]

The mixed media filter.

It is a refinement of the rapid gravity sand type. Instead of a bed of sand supported on gravel with particles of somewhat similar density but greater size, various layers consisting of media of different densities are used. As a result a very coarse upper layer of light weight material (anthracites or pumice) can provide increased void space to store the impurities removed from the incoming water. Under normal operating condition, with the turbidity of the incoming water <5TUs the performance is better and the filter runs are longer than for the rapid gravity sand filter. Incoming water 30 – 50JTUs turbidity can be treated in an emergency. [3]

The Iraq type filter

It was developed for small town use in Iraq in 1954.It is basically a rapid gravity sand filter of very simple construction, in which all controls are eliminated and automatic operation is attained by the simple expedient of building the pure water tank with its top water level to coincide with that in the filter. It is extremely cheap and effective but does not easily lend itself to scaling up in larger installations [1].

Green leaf filters.

They are basically rapid gravity filters which are controlled by an automatic controller, the outlets are control by weirs and the additional head required to maintain uniform flow is supplied by a rise in water level above the sand. Those hydraulic conditions are not dissimilar to those of the Iraq type filter in reverse [1].

Diatomite filters.

They are not commonly found on water works. They are compact, high efficiency filters which are suitable for atomic in the field and swimming pools and for meeting short term emergencies. They are small and potable and depend on the deposition of filter powders of diatomaceous earth (kieselgu) on porous filter 'candles' for their filtering action. They cannot deal with highly turbid water and because of extremely high head losses in the filter their running costs are high. For most practical water works applications they would probably prove to be less satisfactory than other methods [1].

IV. Wash Tank and Pumps

In most conventional filter plants awash water system must be provided. The water used for backwashing the filters must itself have been filtered and in most cases it will have been fully treated. It is usual for filters to be washed one at a time so that the total rate of flow through the works suffers the minimum of disturbance. The wash water flow has a rate about five times the normal filter rate and lasts for about 7min, and therefore the total water required per wash is about (7/60) x5x normally hourly filter rate x area of the filter. As the required rate of flow of wash water and thus the required capacity of pipe work, pumps and wash water equipment depend directly on the area of the filter, this imposes a limit on the filter size.

The pressure of the wash water required at the filter nozzles is about 0.6bar, which can be provided by wash water tanks situated on the filter house roof or by special wash water pumps. If tanks are stalled they provide storage and the size of the pumps feeding them can be reduced as there is no longer a necessity to match pump capacity with up wash rate.

The water tanks should not have a capacity less than that require for one complete filter wash and. in practices they are normally made somewhat bigger to alleviate periods of waiting for the tank to refill when the whole battery of filters is being washed as is customary, by the day shift. The maximum amount of tank age required should never exceed the equivalent of about 30min total station out put on a small works and as the works get bigger it gets proportionally small. (In terms of total output) because there are more filter units. The top water level of the wash water tanks is normally about 9m above the filter bed level.

It is not considered desirable to use high pressure water from the pumping main for filter washing. For one thing the pressure would need to be reduced and if this were done continuously over the life of the paint it would represent a significant waste of energy [1] .

Pure water tanks when the water leaves the filters it passes into a pure water tank before being pumped, or gravitating, to supply. These pure water tanks serve three purposes. They maintain output or short periods when the filters are shut down, they provide balance between the flow rates of the filter and the high lift pumps and incidentally they provide adequate contact time for the chlorination process. [3]

Pure water tanks are commonly made with a capacity equivalent of 2h of works output there is little logical basis for this but wide spread custom suggests that the practice has proved satisfactory.

V. Filter Design

The filtration rate for slow sand filters is1 to 10 mgad (million gallons daily per acre). [3]

The daily water consumption for our purpose is 260,000

(1/day 5.7 x 10^4GAls/day)

= 0.057 mgd (million gallons daily)

Since the filter is going to serve for the present consumption and when expanded in future, the maximum filtration rate of 10mgad is selected. Equating the filtration rate to the daily water consumption,

10mgad = 0.057mgd

It follows that, area of filter in acres (a)

$$a = \frac{0.057}{10}\frac{mgd}{mgd}$$

a = 0.0057 acres.

But

1 acre = 4.048.35m^2

a = 4,048.35 x 0.0057

a = 23m^2

Hence the area of filter sand a = 23m^2

Approximating the area to 24m and selecting a length of 6m, the width of the filter will be 4m.

VI. Filter Bed

The filter bed is made up of sand and gravels (round washed coarse and stones).

The sand occupies 1.0m deep of the total length of bed.

Total length of bed (1_b) = length of sand (L_s) + length of gravel (L_g) that is,

$L_b = L_s + L_g$………………………. (1)
$L_b = 1 + L_g$……………..………....(2)
But length of gravel L_g = length of (round washed L_1) + coarses
(L2) + stones (L3)
$L_g = L_1 + L_2 + L_3$………………….. (3)
But
L_g = K (Log d + 1.4) inches..………(4)
1m = 39.37.
Where d is diameter of gravel in inches and k is a constant and varies from 10 – 14, selecting k to be 12
L_g = 12 (log d + 1.4)
Diameter of round washed gravel) d_1 = 0.25 = 0.006m
Diameter of coarse gravel d_2 = 0.5 = 0.013m
Diameter of stone d_3 = .5 = 0.038m
For d_1 =0.25
L_1= 12 (log 0.25 + 1.4) = 18.91 = 0.48m
For d_2 = 0.5
L_2 =12 (log 0.5 + 1.4) = 13. 18 = 0.33m
For d_3 = 1.5
L_3 = 12 (log 1.5 +1.4) = 9.58 = 0.24
It follows that,
$L_g = (L_1 + L_2 + L_3)$
L_g= (0.48 + 0.33 + 0.24)
L_g = 1.05m
From eqn (4.51.0),
L_b= 1.0 + 1.05 = 2.05m
The depth of water above filter bed is generally between 1.0 to 1.5 [3], taken a depth of 1.5m,
Total length of filter = 1.5 + 2.05 = 3.55m.
To avoid overflow, Total length of filter is taken as 3.06m.
The gravel is arranged asymmetrically below the sand from round washed gravel to stone gravels. Filter stones should be kept 50cm from all sides the filter, the filter sand will rest on the bottom of the filter around the edges.

VII. Under Drains

The under drains are made of perforated channeled blocks, which also acts as floor for the gravel and sand. The water is drained through the perforations and transported through channels into the collecting port. The perforations are relatively small and closely spaced and acts as orifices.
Taking a standard block size of 250mm x 500mm, the floor will have along its length 12 blocks and along its width 16 blocks, thus over the area of the filter bed there will be 12 x 16 = 192 perforated blocks.

VIII. Filter Inlet Sump

The inlet of the filter is separated from the bed by a weir 0.05m above the filter bed so as to avoid washing away of the filter sand by the splashing water and also provide an inlet sump for the incoming water. The inlet pipe is 100m diameter and 1.5m long with a union at the midpoint for futures expansion and an inlet control valve as indicated in the functional expansion and an inlet control valve as indicated in the functional layout diagram appendix I, the pipe is positioned 3.65m from the floor.

IX. Filtered Water Outlet Sump

An important feature of the filter is an outlet such *as* in the filter diagram, which uses the telescopic pipe system. This system prevents the possibility of negative pressure (back pressure).

The telescopic pipe is passed into the outlet pipe and keep to float by a floating ball attached to the telescopic pipe with *a* flexible string, this ensures continues floating of the telescopic pipe with rise or fail of water level in the sump. The outlet pipe in the sump is at the same level with the filter sand bed, and 100mm diameter.

The chlorinator is mounted on the top of the filtered water sump [3].

X. Material Selection

The whole filter unit is constructed with bricks. The outlet pipe is of galvanised steel, well coated with paint, telescopic pipe is of PVC material to give it the light weight necessary for it to float. The floating ball is also made of PVC material as the telescopic pipe.

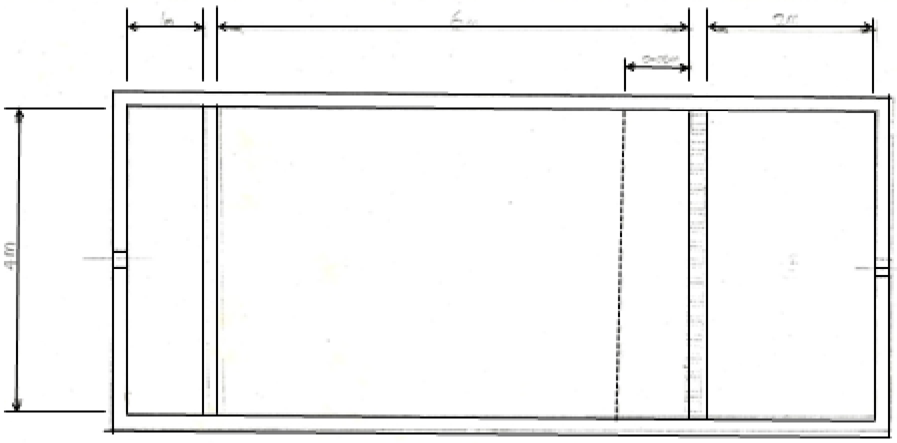
XI. Conclusion

Slow sand filter have been for long being known for its adaptability in rural areas as such use was made of this simple process of filtration. But to ease the task of building a separate filtration/sterilization chamber, the pure water chamber of the slow sand filter was combined to serve both as the pure water unit and the chlorinating chamber; this also reduces cost [5].

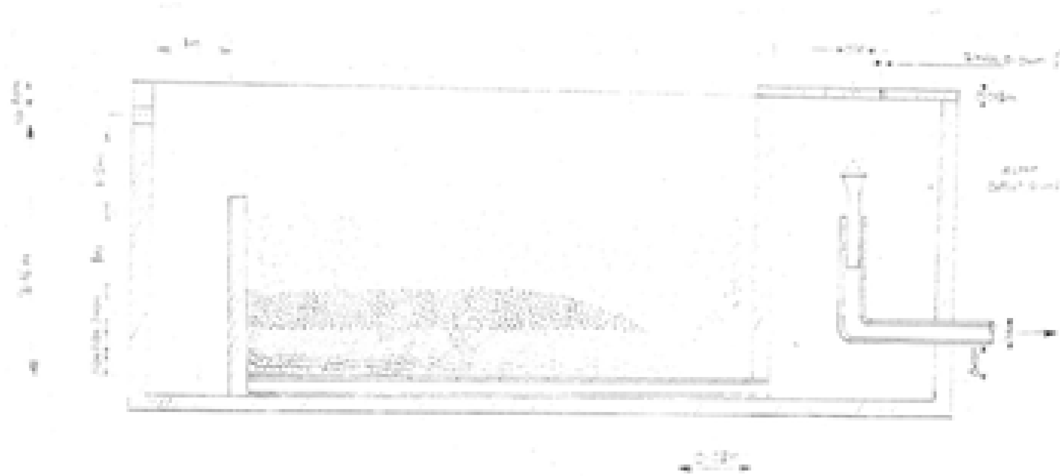
Reference

[1]. Smsrthurst G.: Basic Water Treatment 1979; Thomas Telford Ltd, London.
[2]. James G. V.: Water Treatment.
[3]. Lorch: Handbook of Water Purification
[4]. M. Fair, Gordon/C. Geyer, John/A. Okun, Daniel; Water and Waste water Engineer Vol. 2,1968, John Willey and Sons Inc.
[5]. H. A. Abdulkareem, M A Abdullahi, S O Aliu, (2015), **"**Design of a Chlorinator in a Water Treatment plant for Small Village Community in Borno State, Nigeria" American Journal of Engineering Research (AJER)e-ISSN : 2320-0847 p-ISSN : 2320-0936 Volume-4, Issue-3, March 2015, pp-133-135 www.ajer.org
[6]. H. A. Abdulkareem,S. B. Abdurrahman, Isyaku Umar, (Nov., 2014),"Design of a water treatment Mechanical Mixer for a pre-chlorination tank as an effective algae control, aeration and coagulation processing."International Journal of Engineering Science Invention ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726 www.ijesi.org Volume 3 Issue 11 November 2014, PP.25-36.

Appendix I



FILTER PLAN VIEW



FILTER SECTIONAL FRONT VIEW