Treatment of Wastewater using Trickling Filter: A Review

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Abstract: *Treatment of wastewater becomes a very essential factor in to overcome the water crisis in the near future. Dairy wastewater obtained from dairy industries have been very polluting in terms of amount of effluent generated and the characteristics of the effluent. The treatment of the dairy wastewater can be done using aerobic or anaerobic secondary treatment.This Study aims at treating the dairy wastewater using an aerobic down-flow low rate using a trickling filter. According to the principle of a trickling filter, to provide a pre-eminent surface area and adsorption pall rings have been used as a major part of filter media below which occupies the coarse aggregates. The bacterial slime layer will be formed on the surface of the pall rings after a noticeable period of 25 days or so by a process named acclimatization which tend to consume the organic matter present in the waste water thereby giving out a treated effluent. The acclimatization according to the literature review made can be done using kenaf retting water, cow dung etc. This paper focuses on different filter media used for treating wastewater in trickling filters.*

Keywords—Treatment of Wastewater, Treatment of dairy wastewater, principle of trickling filter, Acclimatization.

I. INTRODUCTION

Trickling filters are used to remove organic matter and its components from the wastewater. The trickling filter is an aerobic treatment system that utilizes microorganisms attached to a medium for the removal of organic matter from wastewater. This type of system is commonly usedin a number of technologies. It is a biological system used after the primary treatment in order to remove the impurities and remaining solids by bacterial decomposition due to which the levels of oxygen changes at different stages .While trickling filters may sometimes seem like old technology, there has been a worldwide resurgence in their use. The combination of modern engineering designs and inherent energy efficiency of trickling filters enable wastewater treatment plants to comply with strict limits and achieve high levels of treatment. Trickling filters will be in usage for years from now on.
The terms trickle filter, trickling biofilter, biofilter, biological filter and biological trickling filter can be used to refer to a trickling filter as percolating or sprinkling filter. A trickling Filter is like a well having depth up to about 2m and filled with some granular media. The **s**ewage which is sprinkled over the media and which passes through the filter media and is collected through the under-drainage systems.

II. HISTORY

Trickling filters are the mostly used for wastewater treatment in the first half in the twentieth century. In 1912, The first trickling filter used for a large public treatment system was installed in Madison,Wisconsin. By the middle of the twentieth century, suspended growth activated sludge systems started were more common. The effluent quality achieved with the new activated sludge systems is often better than the ones achieved from trickling filters. The inventionof lightweight and synthetic media increased the treatment capability of trickling filters to an extent.The low energy and maintenance requirements make Trickling filters a viable alternative for treatment of varying organic loads, toxic substances and wastes.

The trickle bed is also used for recovery of citrate. The wastewater taken from mining, textile and other industries has been treated successfully.For the removal of various pollutants, it can be concluded that the trickling filter systems provides a very feasible and economical alternate solution for wastewater treatment. Various modifications are possible and are being explored for making this more efficient and economical for the future.

III. TRICKLING FILTERS FOR TREATMENT OF WASTEWATER

A modern daytrickling filter consists of a bed with highly permeable media for which micro-organism are attached and the sewage trickles down. Hence the name “Trickling Filter”. The filter media consists of rocks that vary in size from 25-100mm. The depth of rock varies from 0.9-2.5m or average of 1.8m. A rotating arm is eventually provided for evenly distribution of sewage. The air is provided through under-drainage system from the ventilation of filter.

Trickling filters can be circular with a rotary distributor, stationary with a dosing chamber and a spray field.

Trickling filters are mainly composed of three basic components:

- Distribution System
- Filter Media
- Underdrain System

i. Distribution System: The Distribution System distributes wastewater over the media surface. Uniform and optimum hydraulic loading results in an efficient treatment. Circular trickling filters mainly use the rotary arms to distribute wastewater. The spray heads in the stationary trickling filters are use to distribute wastewater.

ii. Filter Medium: The Filter Medium provides a surface for the biological slime layer or zoogloeal film to attach and grow. This layer consists of bacteria and micro-organisms, such as protozoa. The filter media needs to be durable, insoluble, and resistant to chemicals. There are mainly three types of filter media:
   - ♦ Rock (or slag)
   - ♦ Redwood
   - ♦ Synthetic Materials

iii. Under drain System: In this system ,it collects treated wastewater and solids discharged from the filter media and conveys them to a sedimentation tank. The system is located below, or underneath, the filter media and operates by gravity flow.
   ♦ It has a sloped bottom which directs flow to a centre channel
   ♦ It provides support for filter media, which sits on top of the underdrain system
   ♦ It allows the circulation of air through the media. The requirement for a free passage controls the size of openings in the underdrain of the filter.

Classification of Trickling Filters

1. Conventional trickling filter / ordinary trickling filter /standard rate or low ratetrickling filter.
2. High rate / high capacity trickling filters

1. Low Rate Filters

They are also known as standard rate /conventional rate filters. The settled sewage is applied to the filter bed and after trickling itpasses through the sedimentation tank for the removal of most of the stabilized solids present in the wastewater.

2. High Rate Filters

In the high rate trickling filters the settled sewage is applied at higher rate than that for the low rate filter. These filters with modern advancements may also function in the same pattern and can have the same build detail but with a difference that provision is made in them for recirculation of sewage water through the filter by pumping a part of the trickling filter's effluent to the primary settling tank (or the dosing tank of trickling filter) and re-passing it within the filter.

The Single trickling filters may be used in the treatment of small residential septic tanks discharges and very small rural sewage treatment plant systems. Larger centralized water/ sewage treatment plants typically use one or more trickling filters in parallel.

Systems can be configured for the single-pass use where the treated water is applied to the trickling filter once before being disposed off, or for the multi-pass use where a portion of the treated water is cycled back and re-treated through a closed loop. Multi-pass systems usually result in better treatment quality and nitrification of aerobic filter bed as well as denitrification of anaerobic filter bed. Some systems may use the filters in two banks operated in series so that the wastewater can have two passes through a filter with a sedimentation stage placed in between the two passes. Every few days the filters are switched around to balance the load. This method of treatment can help to improve nitrification and de-nitrification since much of the carbonaceous oxidative material is removed on the first pass through the filters.

The hydraulic loading rate is total flow including recirculation applied on unit area of the filter in the day, while the organic loading rate is at 5-day 20°C BOD, excluding the BOD of that of recirculant applied per unit volume in a day. Much higher organic loadings that are indicated here have been used in roughing filters. Recirculation is not generally adopted in low rate filters and media depths for low rate filters ranging from 1.8 to 3.0 m. But they require larger media volumes than high rate filters. However, they are easy to operate and give consistently good quality of effluent and are preferred when plant capacities are small, as in the case for institutions. In contrast to the low rate filters, high and super rate filters a part of the settled or filter effluent is recycled via filter. Recirculation has an advantage of bringing the organic matter in the waste in contact with the biological slime more than once, hence increasing the efficiency of the filters. It enables higher hydraulic loading, thereby reduces filter clogging and aids uniform distribution of organic load over the filter surface. It also helps to dampen the variations in the strength and the flow of sewage applied on the filter. The ratio of the sewage flow is known as the recirculation ratio. Recirculation ratios usually ranging from 0.5 to 3, and values exceeding 3 are considered to be uneconomical in the case of domestic sewage, but with ratios of 8 and above have been used with industrial waste filters and super-high rate filters, which may be single stage or multi stage. Media depths ranging from 0.9–2.5 m have been used for high rate filters for an optimum range of 1.5–2.0 m for the first stage and 1–2 m for the second-stage filters. The Single-stage units consist of a primary setting tank, the filter, secondary settling tank, and facilities for recirculation of the effluent etc.

Two-staged or multi stage filters consist mainly of two filters in series with a primary settling tank, an intermediate settling tank, which may be neglected in few cases, and final settling tank where Recirculation facilities are provided in each stage. The effluent from the first-stage filter is applied on the second-stage filter either after settlement or without any settlement. An intermediate clarifier is used for settling the first-stage effluent before it is applied to the second-stage filter, and the recirculation is only through settling tanks.In the series-parallel system, a part of the settled raw sewage is applied directly to the second-stage filter, increasing the efficiency during that stage. Two-stage filtration will provide a higher degree of treatment than the single stage for the same total volume of media. Two-stage units are used for strong sewage when the effluent BOD has to be less than 30 mg/L.

A well-operated low rate trickling filter in combination with secondary sedimentation tank may remove of 75–90% BOD and produce highly nitrified effluent. It is mainly suitable for treatment of low to medium strength domestic wastewater. The high rate trickling filter, single stage, and two stage are recommended for medium to relatively the high-strength domestic and industrial waste waters. The BOD removal efficiency is around 75–90%, but the effluent is the only partially nitrified. The super rate of the roughing filters find application for high-strength wastewaters. They have also been used as roughing filters to reduce BOD of high-strength wastewaters for further treatment. The effluent from these filters may be partially nitrified only when the low organic loadings have been employed.

Mechanism of Trickling Filter

When the sewage from primary sedimentation tank is uniformly loaded into the reactor it develops a nitrifying bacterial film on the surface of the filter media. The film so formed is known as slime layer. It mostly consists of bacteria. (Oxidation of the organic matter is carried out under aerobic conditions. A bacterial film is formed around the particles of the biological film and for retaining this film oxygen is supplied by the rational working of the filter and by the provision of necessary air ventilation systems for the reactor). The sewage is oxidized by the bacteria producing effluent in the form of water, gases and new cells.

The trickling filter treatment process occurs through the biological decomposition of organic material by bacteria and micro-organisms contained in the zoogleal film on the filter media. These micro-organisms initially reduce the harmful carbonaceous biochemical oxygen demand (CBOD) of the wastewater; however, they can also be utilized to reduce ammonia nitrogen (NH3-N) by "nitrification."

The treatment efficiency of a trickling filter is the result of the metabolizing actions of bacteria and microorganisms present in the zoogloeal film that develops on the filter media. Controlling the biological populations on a trickling filter is not crucial as controlling the biological populations in an activated sludge system. Most of the wastewater stabilization process in a trickling filter involves the zoogloeal film which consists of plant forms such as algae.

Types of Filter Media:

Several filter medias can be used in a trickling filter. The most commonly used filter medias include *coke*, *pumice*, *plastic matrix material*, *open-cell polyurethane foam, clinker, gravel, sand and geotextiles*. Ideal filter medium provides sufficient surface area for biological film, wastewater retaining time, allows air flow, resists plugging, and does not degrade. Systems which mandatorily require aeration units will increase maintenance and operational costs.

Biofilm, an effective Filter media grows on the surface of the inert bed. Different porous materials such as *rocks, coke, moss, ceramic, pumice stone, polyurethane, foam, peat , or plastic media* can be used for making the porous bed. Wastewater enters from the top of the fixed film bed making use of a rotating arm distributor or static nozzles fed with a variable loading. Microbial biofilm grown on the surface of the inert support helps to decrease the waste. Aerobic condition is achieved by active or passive aeration by using either a blower or fan (forced aeration) or natural convection of air due to the temperature difference between the water and ambient air. Low strength wastewaters (COD < 1000 mg l^{-1}) such as sewage (domestic wastewater) can easily be treated using the system and desired effluent quality can be achieved by maintaining a typical HRT of 1 day. Clogging and channeling are two very common problems associated with its operation. Periodic cleaning of the filter bed is required to get efficient performance. An ideal trickling filter used for treating sewage uses 0.22 kWh energy to remove 1 kg-COD.

Medium like stones, ceramic material, hard coal, or plastic media can be used in trickling filter. Polyvinyl chloride (PVC) also known as polypropylene are used today in high-rate trickling filters. Passage of organic matter through the trickling filter, converts the waste into microbial biomass which forms a thick biofilm on the filter medium. The biofilm that forms on the is called a *zoogloeal film*. It may be composed of bacteria, fungi, algae, and protozoa. Over time, as the thickness of biofilm increases it results in an anaerobic condition to the bacteria. As a result, the organisms detach itself from the surface and a new biofilm is formed. BOD removal of 85% can be achieved for low-rate filters (U.S. EPA, 1977). Effluent from the trickling filter further passes through tertiary treatment for removal of solids

Plastic Pall Ring This product was advanced on the basis of Plastic Raschig Ring, and compared with it. Both of them have similar cylindrical dimensions but the Plastic Pall Ring has two rows of punched out holes, with hollow in the centre, which significantly increases the surface area, performance of the packing, efficiency and pressure drop.

Advantages-

- High free volume
- Low pressure drop
- Low mass-transfer unit height
- High flooding point
- Uniform gas-liquid contact
- Small specific gravity
- High mass transfer
- Efficiency

Application- Absorption, scrubbing and stripping services. Versatile alternative to metal Pall rings. A wide range of sizes can be used to serve for different applications.

- Hanging Urethane Sponge: Sponges are non- biodegradable, inexpensive, highly stable, increases sludge retention time & provides better surface area for microorganisms. Sponges with undulations on sides can increase surface area. Sponges with hollow gap at end but compact in between can provide a better contact area for growth of nitrifying bacteria. However, Anammox reactor packed with sponge achieved a higher nitrogen conversion rate when compared to other reactors with packing materials like non-woven material and acrylic fibre.

Yet every media has its own drawbacks as in case of sponge it is that as more water is added to the reactor the media tends to become more soggy hence making the reactor less efficient and practically difficult to maintain.

Cotton Sticks: A relatively low-cost and operationally effective TF wastewater treatment system was developed using farm waste cotton sticks as biofilm support media. With constant flow rate into the filter media an efficient biofilm can be developed over the cotton sticks.

As a drawback, additional seeding is required if the BOD/COD ratio in the wastewater decreases less than 0.6.

Other Filter Media: there are various other filter medias which can be used for the purpose. Filter medias like microbead, natural coagulants like (Camellia sinensis) can be used as in-vitro and in-vivo acclimatization etc.

IV. LITERATURE STUDIES

OKUBO, T et al studied that the sponges which are non-biodegradable are Inexpensive, highly stable, increases sludge retention time and provides better surface area for microorganisms can be used as a filter media in purification of sewage water. Three types of sponge medium were considered to determine water distribution and oxygen mass transfer. Water was supplied to the device, which consisting of 40pieces of sponge media connected in series, and the experiment was carried out. Depending on the type of support medium the ratios ofactual hydraulic retention time (HRT) to theoretical HRT were in the range of 25-67%. The feasibility of the reactor was tested using NaCl. At having flow rates of more than 44 mL/min, we were unable to calculate the correct KLa precisely. For the reason being, the results were presented only for flow rates of 5, 10, and 20 mL/min. Test was done with new sponge filter layer FOR EVERY New flow rate test. It was found that the suspended solids concentration in the influent had an effect in increasing the actual HRT/theoretical HRT ratio, suggesting that managing the influent SS concentration is very crucial for preventing clogging problems in the DHS. The sponge which showed adequate retention time and surface area was preferred for the reactor.

RAKESH G K, et al studied that Greywater recycling is emerging as a new trend in water management practices. A rational design is not available for greywater recycling unlike domestic wastewater. Hence, a study was taken in National Institute of Engineering (NIE), Mysuru campus to evaluate the feasibility of treating greywater using river sand and PPPR. The methodology involved designing, fabricating and installing a greywater treatment model in NIE campus. Greywater treatment system installed in NIE campus consisted of anaerobic and aerobic treatment units. The system was monitored over a period of time to check the performance. The sampling of greywater was done weekly and the samples were analyzed for different water quality parameters like pH, TDS, TSS, BOD, COD, turbidity and nutrients. The greywater treatment system with river sand and PPPR as anaerobic and aerobic filter media was effective in removing the turbidity, TSS, COD, BOD and nutrients from the greywater samples to significant extent. It has shown moderate efficiency in removing TDS compared to other parameters. The greywater treatment system developed in the Institute is found to be efficient in removing BOD and COD by 90% and nutrients (Sulphates, nitrates and phosphates) by 100%. The system has an overall efficiency of 90% in removing pollutants from greywater. Hence the treated greywater can be used for gardening and flushing toilets. But further treatment is required for reuse in other purposes in urban households.

CAROLINE CROSBY et al studied that Napier City Council has been operating a pilot scale Biological Trickling Filter in an extended Losluj configuration for the past 15 months, in order to assess the suitability of this relatively novel configuration for the Napier community. The pilot was designed robustly so that it could be operated as a full-scale plant would be, and results could be extrapolated to the future performance of a full-scale filter. Performance of the pilot plant at an organic

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loading rate of 0.4 kg cBOD5 /m3.d has been good. Operational parameters of great importance for this process configuration are the flushing cycle and dose rate. At this organic loading rate, industry standard design models can be used to predict pilot performance. This paper details the design and construction, and assesses the performance of the pilot plant to date, in the context of the development of the Napier community's wastewater scheme.

ROHAN S GAURAV et al studied that the dairy waste water obtained from Belagavi Milk Union Limited (BMUL) was tested for various characteristics of the influent and the same was compared with that of effluent to determine BOD removal, alkalinity, chlorides and solids. For the treatment, a Hybrid Downflow Aerobic Trickling Filter Bed was developed by using coarse aggregates, steel scrubber and pall rings as filter media. The test was conducted for different HRT's of 72hrs, 48hrs, 24hrs, 18hrs, 12hrs and 6hrs at different flow rates. The results so obtained from the model showed an 80%-90% efficiency of the filter media

V. CONCLUSION

It can be concluded that poly-propylene pall rings can be used as the prime filter media in the purification of dairy wastewater. Although both pall rings and sponge media give appropriate results, the pall rings have been chosen over sponge media based on certain challenges that could occur in future by using sponge and also by studying a comparison between the filter media. By adopting acclimatisation for development of biofilm on the plastic filter media an overall efficiency of about 80% can be obtained by testing for parameters like BOD, Chlorides, PH, total solids etc.

It is evident that the purification is more efficient if the loading are optimum. The reactor can be designed in such a way that by maintaining a flow rate of 0.04 m3/m2-day a BOD removal efficiency of 80-%-85% can be obtained.

Hence it can be concluded that the dairy wastewater thus treated may not be suitable for drinking according to the parameters tested but it isdefinitely safe to discharge it into water bodies without causing any sort of water pollution.

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