

Technical Field

[001] The invention relates to an apparatus and system for wastewater treatment and water filtration, which combines the trickling and filtration functions found in trickling filters but is now employed in a novel and innovative wastewater treatment system.

Background

[002] Conventional trickling filters are usually comprised of beds of crushed rocks, as the trickling media. The classic trickling filter would therefore consist in the main of a trickling filter tank, and a washed and graded stone or other artificial media. Slime growth is also one of the main components of a trickling filter. The slime, which appears as a layer on the trickling filter media, is also sometimes referred to as “bio-mass”, “bio-film” or a “microbial layer”. Such filters are thus used to remove organic matter, from wastewater.

[003] In a conventional system, settled wastewater is sprayed over the bed rock surface and is further purified as it trickles downward, coming in contact with the bio-film attached to the trickling filter media. The bio-film absorbs the organic matter in the sewage and stabilises it by aerobic metabolism, thereby removing oxygen-demanding substances from the wastewater.

[004] The slime will however gradually thicken through microbial growth, and oxygen will then find it increasingly difficult to penetrate the microbial layer. Anaerobic organisms will then develop. As the slime continues to grow and thicken, the micro-organisms near the surface lose their ability to cling to the medium, and a portion of the slime layer then falls off the trickling filter. This portion of the falling slime is called “slough”, and this process is known as “sloughing”. The slough are picked up by the usual under-drain system employed in such trickling filter systems, and transported to a clarifier or settling tanks for removal from the wastewater.

[005] Trickling filters are usually used to remove organic matter from wastewater. A United States Environment Protection Agency (“USEPA”) Wastewater Technology Fact Sheet dated September 2000 listed several advantages of trickling filters. It states that it is a simple and reliable biological process and is suitable in areas where large tracts of land are not available for land intensive treatment systems. It is also an efficient nitrification system and requires low power to operate generally. Moderate level of skills and technical expertise are needed to manage and operate such systems. It is therefore appropriate for use by small- to medium-sized communities. Trickling filters are thus also known to be effective in treating high concentrations of organics, but this is dependent on the type of medium used.

[006] The same USEPA Wastewater Technology Fact Sheet listed disadvantages of trickling filters as well. For example, additional treatment may be needed to meet more stringent

discharge standards, imposed by some authorities in some countries. The possible accumulation of excess bio-mass that cannot retain an aerobic condition can therefore impair the trickling filter performance. Trickling filters require regular operation attention as well, as it may have vector, odour, and snail problems, and the incidence of clogging is relatively high. Flexibility and control are limited, in comparison with activated-sludge processes. Activated-sludge processes are often used for comparison, as it is a technology that, to some extent, supersedes trickling filter and precedes membrane filtration technology.

[007] Although a clarifier tank is usually interconnected with trickling filter operations, problems such as hydraulic overloading may still occur. In trickling filters, hydraulic loading is often referred to as being “high-rate” or “low-rate”. Re-circulation in trickling filters involves the return of filter effluent back to the head of the trickling filter. The operator must therefore check the rate of re-circulation to ensure that the rate is within the design specifications. Rates above design specifications indicate hydraulic overloading, whereas rates under design specifications indicate hydraulic underloading. When the slough solids do not settle well in the clarifier tanks, the operator may need to (1) adjust the re-cycle rate, (2) adjust the airflow if forced draft blowers are available, or (3) adjust the rotary arm speed if it is motor drive.

[008] Trickling filters may also require large structures, since there are operational problems under cold temperature conditions and perhaps some odour problems. One of the most common operational problems is related to the maintenance aspects. For example, the filter under-drain which is made up of a channel which collects the wastewater and allows proper ventilation to support the growth of bio-film, must never exceed more than 50% of its level. Otherwise, there will not be enough exchange of gases that will eventually leads to a breakdown of the system.

[009] The trickling filter serves only as a substrate for the growth of bio-film, and the removal of sludge is handled downstream. Management of the trickling filter is a crucial job for the treatment plant operator, so that a proper type of microbial layer is produced and maintained, thereby sloughing to produce the most efficient waste removal rates. For maximum efficiency, the microbial growth should be kept fairly aerobic.

[0010] The maximum hydraulic and organic loading rate must also be determined so that the trickling filter does not operate beyond its designed capacity. This can be controlled by adjusting the re-circulation rate and once the best flow ratio has been determined, it must be maintained throughout in order not to cause overloading. Further, in order to ensure optimal performance, growth of bio-film that sloughs away from the filter media and collects in the underdrain channel should be periodically removed or else, it will cause excessive slime build up that will prevent proper ventilation.

[0011] If not properly monitored and maintained, bio-film may accumulate to an undesirable level under which the structured media can no longer support the increased weight of the bio-film.

The collapse of conventional trickling filters are not unheard of, as the structure of the material used for the trickling filters are not specifically catered for the weight of the bio-film layer, which are formed on the said filters.

[0012] A number of trickling filter collapses have occurred in the past decade. The most common cause of the failure as noted by Denny S. Parker in the abstract “Trickling Filter Mythology” as found in the July 1999 Journal of Environmental Engineering, was actually weak media. Of the 12 “catastrophic” collapses studied, seven involved poor quality control relating to the supplier of the particular media involved. Three of the seven instances involved vertical flow media and four had cross flow media.

[0013] Some designs of the trickling filters are such that the filter media (e.g. crushed rocks) is too thick and aeration is restricted. This results in the building-up of bio-film. Since there is no gap between the filter media, it is thus difficult to remove excess bio-film. On the other hand, excess bio-film on the ceramic membrane plates, as disclosed in this invention, can be easily washed off as part of the routine water sprinkling process that feeds the wastewater into the ceramic membrane plates.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] For the purpose of illustrating the invention, there is shown in the drawings a form that is presently preferred; it being understood, however, that this invention is not limited to the precise arrangements and instrumentalities shown.

[0015] FIG. 1 is a plan view of a trickling and filtration of wastewater apparatus according to the present invention.

[0016] Fig. 2 is a top view of a modular housing frame and the ceramic membrane plates within

[0017] FIGS. 1 and 2 are not shown to scale.

DETAILED DESCRIPTION

[0018] The aim of this present invention is to provide a simplified wastewater treatment process that enhances or maintains the advantages of the conventional trickling filter design, and yet minimises its disadvantages, but still providing a very high degree of purification outcome.

[0019] The invention uses rigid porous ceramic membrane plates **120** in a strong plastic modular housing frame **110**. The modular housing frame **110** is able to bear the additional weight of the bio-film and thus addresses the problem of collapsing trickling filters. The ceramic membranes

plates **120** are fixated within the modular housing frame **110**, and equally distanced from each other. Ventilation is at an optimal level since the airflow is not restricted and ample oxygen is supplied to the aerobic bacteria forming the bio-mass. This also eliminates the need for an aerobic tank, which would usually be found in a membrane bioreactor system.

[0020] The use of a modular housing frame **110** for the apparatus allows more ceramic membrane plates to be vertically arranged on top of one another. This method of increasing storage capacity also enhances space efficiency. This results in overall lower costs in constructing and maintaining the apparatus and system.

[0021] This invention combines the trickling and filtration functions, and eliminates the need for clarifier tanks where the slough are usually directed to. It offers a compact and effective wastewater treatment apparatus. This enhances flexibility, because it can be used by an individual household, a small community, or even on a larger scale.

[0022] In addition, this invention can be used to treat water to make it suitable for drinking as well. In this case, the aeration of the water during filtration will facilitate precipitation of pollutants such as iron and manganese in the water, thus making it suitable for drinking. When specifically exposed to oxygen, iron and manganese are oxidised and change from colourless, dissolved forms to coloured, solid forms. These particles then settle and are filtered out of the water.

[0023] FIG. 1 shows a plan view of an exemplary embodiment of a trickling filter and filtration of wastewater apparatus which combines the functions of trickling and water filtration. In this embodiment, spray nozzles **130** extend from the top layer **140** to the second layer **150** of this embodiment. It is preferred that the spray mechanism **130** ensures an even spread of water to the membrane plates to maximise the efficiency of the filtration. The remaining 5 layers of the modular housing frame structural **110** (which houses the ceramic membrane plates **120**) provide the trickling and water filtration functions.

[0024] Traditionally, ceramic membrane plates are entirely submerged in wastewater. In this invention, ceramic membrane plates **120**, which are within each modular housing frame of the apparatus **110** are not submerged, and the wastewater will trickle through instead. The apparatus though a pipe **150** into a tank, also known as a “feed tank” **160**, draws wastewater for the trickling and filtration process, and then the excess re-circulation recycles back into the feed tank **160**, via the re-circulation pipe **170**. In this embodiment, an anoxic tank **160** is used. Raw wastewater is mixed with the returned sludge and re-circulated sludge from the end of the trickling and filtration process.

[0025] In this embodiment, the wastewater is sprayed **130** into the modular housing frame and onto the ceramic membrane plates **120** at preferred rate between $3 \times (X)$ to $6 \times (X)$, where (X) is the filtration flux rate. In this embodiment, (X) can be 30L to 60L per meter of the membrane surface area per hour. The typical flux rate for a membrane bioreactor system is approximately 5L to 10L for polymeric membranes, and 25L to 35L for ceramic membranes. This preferred rate optimises the wastewater treatment duration and the amount of wastewater absorbed into the ceramic membrane plates **120**. Excess wastewater, which is not absorbed by the ceramic membrane plates **120**, will then flow to the bottom of the apparatus **180** and re-circulated to the top via the anoxic tank **160**.

[0026] The ceramic membrane plates **120**, which are inside the modular housing frame of the apparatus **110**, are vertically arranged. The modular housing frame of the apparatus **110** is designed to hold the ceramic membrane plates **120**. The ceramic membranes plates **120** are fixated within each modular housing frame of the apparatus **110**, and equally distanced from each other. The distance does not affect the functionality or performance of the apparatus. The modular housing frame of the apparatus **110** is made of durable plastic, or some other structurally similar material that is similarly lightweight but possess similar structural strength. In one embodiment, acrylonitrile butadiene styrene plastic is preferred. The use of strong plastic modular housing frame **110** allows ceramic membrane plates **120** to be vertically arranged, thereby increasing the apparatus' capacity and/or improve efficiency.

[0027] This invention uses a rigid porous ceramic membrane plate, so as to encourage the growth of bio-film. Conventional trickling filters use crushed rocks as the media, which has been eliminated by this invention. Instead, the ceramic membrane plate **120**, which is itself a filtration material, also serves as a substrate for growing bio-film. As the ceramic membrane plates **120** also functions as a filter medium, the wastewater will first percolate through the bio-film and then filtered into the ceramic membrane plate **120**. The clean water will be collected within the lumens of the ceramic membrane plate, via a pump **190** connected at the side. The pump **190** creates a suction that draws the clean water out. The ceramic membrane **120** will prevent or block the pollutants from going through into the lumens. In most embodiments, the clean water will flow to a collecting product tank. This product tank is used to store the clean water before discharge or distribution.

[0028] In this embodiment, the anoxic tank **160** is a normal water tank that is tightly sealed, so that there is minimum airflow. It is important to maintain a low oxygen level, so as to promote the growth of anaerobic bacteria.

[0029] Wastewater can be clarified by biologically treating the wastewater in a membrane bio-reactor ("MBR") system. MBR technology is considered a most promising form of wastewater treatment. A traditional MBR system consists of an anoxic tank, an aerobic tank, and membrane filtration housing, where the membranes sieve the suspended solids or biomass from the treated wastewater, to produce clean water.

[0030] In this embodiment, the anoxic tank **160** is part of the membrane bio-reactor system. On the other hand, this embodiment further eliminates the need for an aerobic tank. Aerobic tanks have a mechanism for injecting air and circulating the air inside, thus promoting the growth of biofilm or bacteria which breaks down the organic matter more quickly. However, this air injection mechanism requires electricity to operate, thus restricting large market scale applications, because energy is a scarce resource. The additional energy consumption also leads to environmental pollution and increases carbon emissions.

[0031] In a traditional MBR system, the membranes are entirely submerged in the wastewater. In this embodiment, the ceramic membrane plates **120** are not submerged and the wastewater will trickle through instead. This invention uses a rigid porous ceramic membrane plate **120**, so as to encourage the growth of bio-film.

[0032] This embodiment therefore uses the ceramic membrane plates **120** to provide the aeration functions. As such, the bio-film are exposed to air and hence, oxygen. An aerobic tank is therefore no longer needed to inject air or to circulate the air, as this function is fulfilled by the ceramic membrane plates **120**, which are comprised within each modular housing frame **110**.

[0033] In this embodiment, the rigid porous ceramic membrane plate **120** has pore sizes that typically ranges from 0.1 micron to 1 micron. The pores allow clean water to percolate through but yet retain the bacteria from the bio-film on the surface of the ceramic membrane plates **120**.

[0034] In another embodiment, a cheaper material such as porous polyurethane flat tubes, can be used as an additional substrate material, which will also be comprised within the modular housing frame **110** of the apparatus. This additional layer of trickling filter will increase the surface area available for biological processing, in a cost-effective manner.

[0035] In this invention, the modular housing plastic structural frame **110** can support thicker layers of bio-film. The strong modular housing frame **110** could comprise for example, of acrylonitrile butadiene styrene (also referred to herein as “ABS”), which is a common thermoplastic. The glass transition temperature of ABS is approximately 105°C. ABS is amorphous and therefore has no true melting point. ABS is a terpolymer made by polymerising styrene and acrylonitrile, in the presence of polybutadiene, and would be a suitable material for use in this invention.

[0036] In the creation of both an aerobic outer layer as well as an anoxic inner layer of bacteria. Anaerobic are more effective at breaking down tougher wastewater, whilst aerobic bacteria would feed on the wastewater which are already broken down by the aerobic bacteria. An anaerobic bacterium operates without oxygen and these bacteria are able to remove oxygen molecules from pollutants. When the biofilm becomes thicker, the inner regions of the substrate transits into an

anaerobic environment which allows the growth of anaerobic bacteria. In this embodiment of the invention, ABS is able to support the weight of the ceramic membrane plates, and hence supports the weight of the biofilm.

CLAIMS

We hereby claim:

1. A system for filtration and treatment of waste material, comprising:

the use of flat sheet ceramic plates as the substrate and support for the filtration media;

a tank or housing frame consisting of a modular system allowing the use of the said ceramic plates where such plates are housed with a fixed distance between them;

such modular housing frame is arranged in a vertically layered manner permitting easy extension to the housing frame as may be required by the desired filtration output; and

the use of an anoxic feed tank.

2. The system of claim 1, where the modular housing frame comprises the use of a strong plastic material such as acrylonitrile butadiene styrene.
3. The system of claim 1, further comprising the use of porous polyurethane flat tubes as an additional substrate material.
4. A method for filtration and treatment of waste material,

Such modular housing frame is arranged in a vertically layered manner permitting easy extension to the housing frame as may be required by the desired filtration output;

the use of an anoxic feed tank, whereby the wastewater is sprayed over the ceramic membrane plates and subsequently collected through the lumens and directed into a collecting product tank.