FIELD OF THE DISCLOSURE:

The present disclosure relates to the treatment of industrial wastewater. The present disclosure particularly relates to a process for the simultaneous removal of organic content (COD) and turbidity from wastewater via biofiltration.

Definitions:

Chemical oxygen demand (COD) is a measure of the total quantity of oxygen required to oxidize all the organic material into carbon dioxide and water.

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at a certain temperature over a specific time period.

The BOD value is most commonly expressed in milligrams of oxygen consumed per liter of sample during 5 days of incubation at 20 °C and is often used as a robust surrogate of the degree of organic pollution of water.

BACKGROUND:

The treatment of wastewater is a complex field as the concentration and identity of the contaminant materials to be treated are constantly changing. Additionally, the flow rate, pH, oxidation potential, concentration of solids and temperature of the wastewater, among other factors, are also variable. Further, wastewater contains organic matter such as colloids, dissolved ionic matter, dissolved non-ionic matter, surfactants, and suspended solids. Such contaminant materials are present in combination with similar types of inorganic materials. Industrial wastewater produced during industrial processing has proven to be difficult to treat due to the many different types of contaminants present therein. Filtration systems using different types of filters have found wide use for the treatment of wastewater. A common problem with such systems is the frequent need to clean or replace the filters due to fouling and clogging.

Bio-filtration is a process which uses bacterial mass attached onto the filter media as a biofilm to oxidize much of the organics to carbon dioxide and water and utilize as a carbon source for their own proliferation and growth. Thus, the process is self-sustaining and self-regenerating. Bio-filters have been successfully used with vapor systems, e.g. odor control and treatment of volatile organic compounds, but its commercial use in liquid system is emerging.

US 5403487 discloses a process for aerobically degrading an industrial wastewater feed containing toxins for microorganisms. The process involves (a) inoculating a fixed packed bed of pieces of macroporos synthetic resin biosupport having micropores with an inoculum of a culture acclimated to aerobically degrade said toxin; (b) flowing, in the presence of a molecular oxygen-containing gas, said feed essentially free of solids, over and around said pieces of biosupport, through said fixed bed for said microorganisms in said inoculum to replicate, and incrementally increasing flow of said feed until essentially all pores of said resin have lodged therein; (c) maintaining a pH within a range from 6.0 to 8.5; and (e) recovering a purified feed containing less than 10 ppm of said toxin.

US 6100081 discloses an apparatus for the purification of wastewater and/or waste gas using a biofilter containing a filtering material, wherein the wastewater moves downwardly thereinto, while the waste gas moves upwardly or downwardly thereinto. It also discloses a filtering composition comprising filtering carrier material which is composed of wood shavings & peat.

DE 69329547 discloses a biofilter for treating contaminated air. It uses immobilized biofilm on filter support media to biodegrade the sorbed volatile organic compounds (VOCs) and biotransform inorganic oxides to sulfur (SO_x) and nitrogen (NO_x) to residuals such as carbon dioxide, water and various acids.

JP 200310329 discloses a biological treatment means comprising a plurality of means for treating wastewater containing various organic substances by using microorganisms. It consists of a turbidity meter for measuring the turbidity of a solid-liquid separation means, concentration meters for measuring the concentration of nitrous acid and nitric acid in an aeration tank, an aeration means capable of controlling aeration volume in the aeration tank and a nitrification inhibitor adding means for adding a nitrification inhibitor to the aeration tank.

US 6811702 discloses a process and installation for treating a polluted aqueous liquid having a COD value caused by organic compounds present therein and a BOD/COD ratio smaller than 0.2. To reduce the COD value, the polluted aqueous liquid is percolated through a packed filter bed of activated carbon, which is colonized with aerobic bacteria and which forms an adsorbent for at least a part of said organic compounds. To provide a thin, fully aerated biofilm of bacteria on the carrier material so that no oxygen has to be dissolved under pressure in the liquid, the filter bed is kept at the most partially submerged position in the liquid percolating there through. The percolate which has passed through the filter bed is collected and a portion of the collected percolate is recirculated to the filter bed whilst a further portion of the collected percolate is removed as treated effluent by means of a membrane filter.

US 7258793 discloses a method and an apparatus for treating an organic liquid waste with a biofilm in which the organic liquid waste is dissolved with oxygen under a first pressure higher than atmospheric pressure to prepare a pressurized oxygen-dissolved organic liquid waste. The pressurized oxygen-dissolved organic liquid waste is depressurized to prepare a depressurized oxygen-dissolved organic liquid waste. The depressurized oxygen-dissolved organic liquid waste is contacted with the biofilm to prepare a treated organic liquid waste.

US 7374683 discloses a biofilter for the purification of waste liquid using layers of filtering material, wherein the waste liquid moves downwardly by gravity while an O_2-containing gas moves upwardly therein. The biofilter comprises a gas collector to capture at least a portion of the gas moving upwardly therein to mitigate the problem of biofilter clogging due to a microbial seal at the surface of the uppermost filtering layer.

US 7887706 discloses a method for biofiltration of a liquid effluent by simultaneous nitrification and denitrification which uses the addition of an oxygen source at a predetermined rate and optionally the addition of a carbon source (such as whey) thus enabling the complete transformation of the nitrates (NO_3) present in the effluent at the time of treatment through a biofilter. The specific operating conditions favoring the simultaneous nitrification and denitrification include the controlled injection of a slight quantity of air, adjustment of the level of nitrogen load (TKN+NO_3) and the level of carbon load thereby making possible elimination, for most part of the release of the unwanted nitrogen in the form of NO_3 or NO_2.

US 20090078639 discloses a filter medium which comprises a mass of elongate, differently orientated, shape-sustaining elements comprising a sponge material. The different orientation of the elements forms a self-supporting open network which provides substantial interstitial space between the elements.

Durgananda Singh Chaudhary et al in the paper, '*Granular Activated Carbon (GAC) Biofilter for Low Strength Wastewater Treatment*' disclose use of a GAC (Granular activated carbon) biofilter for treating wastewater. However, the process of the paper is best applicable for low strength waste water. Further, the efficiency of the waste removal process has been found to be about 55%. Even further, the time period taken by the process described in the paper has been around 30 days. Still further, optimum efficiency has been achieved at steady state conditions.

Cheerawit Rattanapan et al in the paper, '*Removal of H_2S in down-flow GAC biofiltration using sulfide oxidizing bacteria from concentrated latex wastewater*' describe a biofiltration system for the removal of H_2S by means of sulfur oxidizing bacteria, immobilized on GAC. The time period for achieving H_2S scavenging is found to be about 3 days.

Though several methods and biofilters for treating wastewater have been disclosed in the prior art published documents, none discuss the reduction of the organic content and turbidity in a simultaneous manner. Also, most of the prior art methods are time consuming. A need is, therefore, felt for developing a cost effective and efficient process for treating wastewater via biofiltration.

Furthermore, considering the generation of a large amount of wastewater from the petroleum and petrochemical plants, there is a significant amount of interest in the reuse of water from the petroleum and petrochemical facilities. It is envisaged that the waste water after the treatment i.e. after the removal of dissolved and suspended solid matters can be re-utilized in the petroleum and petrochemical plants as a solution to their water needs such as a source of cooling water. Accordingly, there is a need in the art to provide an efficient process for continuous reduction of chemical oxygen demand and turbidity of the wastewater particularly generated in petrochemical and polymer plants.

OBJECTS

Some of the objects of the present disclosure, which at least one embodiment herein satisfies are as follows:

It is an object of the present disclosure to provide a simple process for simultaneous reduction of the chemical oxygen demand (COD) and turbidity of wastewater.

It is another object of the present disclosure to provide a simple process for the reduction of chemical oxygen demand (COD) and turbidity from high pH wastewater.

It is still another object of the present disclosure to provide a simple process for the reduction of chemical oxygen demand (COD) and turbidity from wastewater having poor biodegradability.

It is yet another object of the present disclosure to provide a less time consuming process for the reduction of chemical oxygen demand (COD) and turbidity from wastewater.

Other objects and advantages of the present disclosure will be more apparent from the following description and drawings which are not intended to limit the scope of the present disclosure.

SUMMARY

The present disclosure provides a process for the removal of dissolved and non-dissolved contaminants from a wastewater stream; said process comprises steps that include but are not limited to:

a. aerating a wastewater stream having pH ranging between 6.5 and 9.5, chemical oxygen demand (COD) ranging between 100 and 1000 ppm, turbidity ranging between 50 and 500 NTU and biological oxygen demand (BOD)/COD ratio <0.3 to obtain an aerated stream;

b. adding nutrients to said aerated stream to obtain a nutrient enriched stream; and

c. passing said nutrient enriched stream through a biofilm supported on granulated activated carbon (GAC) to obtain a filtered water stream having COD ranging between 5 and 200 ppm and turbidity ranging between 2 and 75 NTU.

Typically, the wastewater stream is a waste water stream settled for half an hour.

Typically, the wastewater stream is a petrochemical wastewater stream.

Typically, the wastewater stream is a polyvinyl chloride (PVC) wastewater stream.

Typically, the nutrient is at least one selected from the group that includes but is not limited to nitrogen, phosphorous, yeast extract, minerals and vitamins.

Typically, the proportion of nutrients ranges between 2.5 and 0.5 mg with respect to 100 ppm of COD.

Typically, the biofilm is a consortium of microorganisms, said microorganisms being aerobic bacteria.

Typically, the consortium of microorganisms includes at least one microorganism selected from the group that includes but is not limited to *Pimelobacter simplex, Bacillus cereus, Micrococcu--sp, Bacillus sp, Serratia sp, Sphingomonas sp, Psuedomonas sp, Microbacteriaceae bacterium, Kocuria sp* and *Aeromicrobium sp.*

Typically, the biofilm is an acclimatized bacterial culture from the sludge generated during the effluent treatment of PVC wastewater.

Typically, the contact time of said nutrient enriched stream and said biofilm ranges between 1 and 4 hours.

Typically, the step (c) is carried out at a temperature ranging between 20 and 50 ^{0}C.

Typically, the particle size of the contaminants present in said filtered water stream is less than 25 microns.

Typically, the process further comprises a step of recycling said filtered water stream.

Typically, the COD in the filtered water stream is reduced by 75-85% as compared to the wastewater stream.

Typically, the turbidity in the filtered water stream is reduced by 85-95% as compared to the wastewater stream.

Typically, the process is carried out in a biofiltration system (100) that includes but is not limited to:

i. at least one feed tank (T) adapted to hold the waste water and provide a waste water stream;

ii. at least one peristaltic pump (P) adapted to receive and pressurize the waste water stream emerging from the feed tank to obtain a pressurized waste water stream;

iii. at least one biofiltration column (C) adapted to receive said pressurized waste water stream and effect the removal of the dissolved and non-dissolved contaminants; and

iv. at least one effluent collection pot (ECP) adapted to receive the de-contaminated water stream.

Typically, the system further comprises at least one valve (V) adapted to regulate the flow of the streams passing through the biofiltration system.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

The disclosure will now be described with reference to the accompanying non-limiting drawings:

Fig. 1 illustrates a schematic diagram of a biofiltration system (100) for the removal of dissolved and non-dissolved contaminants from a waste water stream.

Fig. 2 illustrates the flow rate optimization process, wherein:

Fig. 2a represents the effect of flow rate variation on COD removal; and

Fig. 2b represents the effect of flow rate variation on turbidity removal.

Fig. 3 illustrates the extent of COD and turbidity removal before and after the optimization of process parameters, wherein:

Fig. 3a represents the extent of COD removal before the optimization of process parameters;

Fig. 3b represents the extent of turbidity removal before the optimization of process parameters;

Fig. 3c represents the extent of COD removal after the optimization of process parameters; and

Fig. 3d represents the extent of turbidity removal after the optimization of process parameters.

DETAILED DESCRIPTION

It is known that the wastewater from petrochemical and/ or polymer industries is generated in a large amount and its COD (chemical oxygen demand) typically ranges between 100 and 1000 ppm whereas, the turbidity ranges between 50 and 500 NTU. Moreover, the BOD/COD ratio of these waters is <0.3, indicating poor biodegradability. Accordingly, it is desirable to treat such a wastewater to reduce COD and turbidity simultaneously in order to re-use the same for various purposes such as cooling operations.

The inventors of the present disclosure have focused on the aforesaid problem and have found a simple and efficient process which can reduce COD and turbidity of the wastewater such as waste water from polyvinyl chloride (PVC) manufacturing plant in a continuous manner without requiring two systems for removing COD and turbidity separately. The process mainly utilizes a GAC (granulated activated carbon) supported biofilm developed from an acclimatized microbial consortium originating from activated sludge of ETP (effluent treatment plant).

In the process of the present disclosure, adsorption and biodegradation of organics present in the wastewater stream occurs continuously with simultaneous regeneration of carbon. It is found that the process can be effectively used for treating petrochemical wastewater having COD, high turbidity and low biological oxygen demand (BOD)/COD ratio, <0.3. The process of the present disclosure reduces COD and turbidity by 75 to 85 % and 85 to 95 % respectively, whereas the particle size is reduced from 100 microns to 10 microns after the treatment. It is also found that the water obtained after the treatment meets the specifications of the cooling water make-up, for re-use within the plants, resulting in zero effluent discharge and savings in the discharge cost. It can also conserve an important natural resource, namely water. It is further found that the process can efficiently treat the wastewater having pH 6.5 to 9.5 without the requirement of further arrangement or adjustment. Further, the process of the present disclosure can be carried out at an ambient temperature that may be extended to 50 ^{0}C.

In accordance with the present disclosure there is provided a process for removing dissolved and non-dissolved contaminants from a wastewater stream. The process of the present disclosure involves steps that include but are not limited to initially providing a wastewater stream having pH ranging between 6.5 and 9.5, COD ranging between 100 and 1000 ppm, turbidity ranging between 50 and 500 NTU and BOD/COD ratio <0.3; which is allowed to stand for 10 to 60 minutes. In one embodiment, the wastewater stream is a petrochemical wastewater stream. In another embodiment, the wastewater stream is a polyvinyl chloride (PVC) wastewater stream.

In the next step, the waste water stream is aerated to obtain an aerated stream. To this aerated stream, nutrients are added to obtain a nutrient enriched stream. The nutrients include but are not limited to nitrogen, phosphorous, yeast extract, minerals and vitamins. Typically, the proportion of nutrients ranges between 2.5 and 0.5 mg with respect to 100 ppm of COD.

The resultant nutrient enriched stream is made to pass through a biofilm supported on granulated activated carbon (GAC). The biofilm of the present disclosure is a consortium of microorganisms. Typically, the microorganism is aerobic bacteria. The consortium of microorganisms includes but is not limited to *Pimelobacter simplex, Bacillus cereus, Micrococcu–sp, Bacillus sp, Serratia sp, Sphingomonas sp, Pseudomonas sp, Microbacteriaceae bacterium, Kocuria sp* and *Aeromicrobium sp.*

In one embodiment the biofilm is an acclimatized bacterial culture from the sludge generated during the effluent treatment of PVC wastewater. In another embodiment the acclimatized bacterial culture is homogeneously mixed with granulated activated carbon which is then loaded into the column employed for the treatment of wastewater. Typically, the present step is carried out at a temperature ranging between 20 and 50 °C. It is found that approximately 1 to 4 hours contact time between the wastewater stream and biofilm is sufficient to reduce COD by 75-85 % and turbidity by 85 to 95 %. In one embodiment, the particle size of the contaminants present in the filtered water stream is less than 25 microns. It is also found that even after shock loadings of COD the biofilm cultures revive and perform successfully. GAC support, which is a major component of the operating cost, is found to be self-regenerating and retains its mechanical as well as physical integrity.

Upon contact with the waste water stream, the microorganisms of the biofilm, degrade the organic matter and the activated carbon causes adsorption of the non-dissolved particulate contaminants. Therefore, upon passing through the biofilm of the present disclosure, the waste water is subjected to degradation, adsorption and filtration simultaneously, resulting in a filtered water stream ready for downstream use. The step of aeration and nutrient enrichment is carried out to support the growth and proliferation of the microorganisms and to make the overall process self-sustaining and self-regenerating.

The resultant filtered water stream having reduced content of dissolved and non-dissolved contaminants is collected. The COD of the filtered water is found to be ranging between 5 and 200 ppm, whereas the turbidity of the filtered water is found to be ranging between 2 and 75 NTU. The filtered water obtained by the process of the present disclosure has specifications similar to that of the make-up cold water commonly used in various industrial plants. Therefore, the filtered water of the present disclosure may be used, as such, as a cooling media in various plants or may be re-used in the same plant. In one embodiment, the process of the present disclosure further involves a step of recycling the wastewater stream before use.

In one exemplary embodiment of the present disclosure, there is provided a process for simultaneously removing COD and turbidity of PVC wastewater. The process involves passing the PVC waste water having COD from 100 to 400 ppm, turbidity from 50 to 300 NTU, contributed chiefly by off-grade PVC particles coated with polyvinyl acetate (PVA), of size ranging between 10 to 600 microns and BOD/COD ratio of <0.3 through the biofilm supported on granulated activated carbon.

In one embodiment, the process of the present disclosure is carried out in a biofiltration system (100) that has been demonstrated in Figure 1. The system includes but is not limited to:

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i. at least one feed tank (T);
ii. at least one peristaltic pump (P);
iii. at least one biofiltration column (C); and
iv. at least one effluent collection pot (ECP).

The system further contains at least one valve (V) adapted to regulate the flow of the streams passing through the biofiltration system.

The feed tank of the system holds the waste water and supplies the same to the biofiltration column (C) via the peristaltic pump (P). The peristaltic pump (P) pressurizes the incoming waste water stream directs the pressurized stream to the biofiltration column (C). The biofiltration column (C) receives the pressurized waste water stream and causes the dissolved and non-dissolved contaminants in the stream to be removed by means of the biofilm present in the column. The filtered water stream is then directed to an effluent collection pot (ECP) which stores the filtered water for further use of re-use.

The present disclosure is further illustrated herein below with the help of the following examples. The examples used herein are intended merely to facilitate an understanding of the ways in which the embodiments herein may be practiced and to further enable those of skilled in the art to practice the embodiments herein. Accordingly, the examples should not be construed as limiting the scope of the embodiments herein.

Example 1: Process for the removal of COD and turbidity from waste water (Lab scale)

<u>1A] Process for the selection of microorganisms from the activated sludge source:</u>

Activated sludge was collected from an ETP in 5L carboy. The acclimatization of the sludge containing a consortium of microorganisms to PVC waste water (ww) for selective growth and enrichment of cultures capable of degrading the PVC ww was carried out. It was a 3 step process comprising 9 days. The consortium of microorganisms contained *Pimelobacter simplex, Bacillus cereus, Micrococcu–sp,* *Bacillus sp, Serratia sp, Sphingomonas sp, Pseudomonas sp, Microbacteriaceae bacterium, Kocuria sp* and *Aeromicrobium sp.*

The thickened sludge starting with mixed liquor suspended solids (MLSS) 3000 - 3500 ppm was used. PVC ww settled for half an hour was used for the acclimatization having COD of 164 ppm and turbidity of 234 NTU. After 72 h of 1st acclimatization the COD and turbidity reduction was 92% and 73% respectively. At the end of the 2nd acclimatization (using fresh feed) the COD and turbidity reduction was 93% and 81% respectively. After the 3rd acclimatization (again using fresh feed) COD reduction had stabilized at 94% and turbidity was as high as 97%. With MLSS, the general trend was seen as slow reduction due to selectivity until by the end of the 3rd acclimatization it comes to a level almost 1/3rd its original value, however, its ability to reduce COD and turbidity is still strong.

Thus at the end of the 3rd acclimatization when the COD and turbidity removal capacity was more or less stabilized, the cultures were ready for biofilter column preparation.

Samples of this culture were isolated on TYG media, purified and preliminarily identified as Gram +ve or –ve bacteria. The detailed identification was later carried out by DNA sequencing.

1B] Procedure for COD and Turbidity removal:

Reference is made to Figure 1, wherein a system for achieving biofiltration of waste water is demonstrated. At the end of the 3rd acclimatization, the cultures were allowed to settle and the supernatant discarded. The sludge was collected together and approximately 80 ml was added to the pretreated/cleaned GAC (Granular Activated Carbon) in a beaker with just enough PVC waste water to cover the surface of the GAC. The surface area (BET) of the GAC was around 1000 m^2g^{-1}. The beaker, covered with aluminum foil on which pin holes were made, was made to stand overnight. After about 16 hours the filter medium was filled into a biofiltration column (C) having 56 cm length and 3.4 cm intrinsic diameter. The column (C) contained 160 g of granular activated carbon (GAC bed height of 38 cm). The glass column was initially packed with glass wool at the bottom, then with about an inch of clean pebbles and some waste water was added (1/4 column height). The GAC + culture was added into the column with gentle tapping to allow for proper settling. Next, a further layer of pebbles (1/2 inch) was added on the top. The column was allowed to settle for a couple of hours and then the flow of the waste water was started with the aid of a peristaltic pump (P) in a top to bottom mode. The outlet tube from bottom of biofilter column (C) was taken up to a bend near the top of the bed and then allowed to fall into the receiver vessel to maintain the liquid level in the biofilter.

The peristaltic pump (P) was set to a flow rate of 2.4 ml/min at the outlet of the biofilter. A feed tank (T) contained the PVC waste water having COD of 350 ppm and turbidity of 200 NTU that was made to stand for 15-30 minutes and then aerated (DO = 6 - 7 ppm, about 10-12 bubbles/min), followed by addition of nutrients (Nitrogen = 8.75 mg and Phosphorus = 1.75 mg). A silicone rubber tube passed from this tank (T) through the rollers of the peristaltic pump (P) and the other end of the tube forms the inlet to the biofilter column C (at the top).

The flow rate was set slightly at the inlet end (2.4 ml/min). The water flowed through the biofilter and the outlet which was at the bottom of the column was kept open in such a position that the flow rate at this point was also at 2.4 ml/min. This was periodically checked manually and also at the end of 24 hours (by checking the total amount of treated effluent collected). The pump was given a rest of half an hour every 24 hours. Sampling of the effluent was done between 5 and 6 hours of operation and again after 23 - 24 hours for COD, turbidity, pH and dissolved oxygen (DO). This operation was carried out continuously for the whole period of study (~3 - 6 months for each set of experiments studied).

The treated effluent from the biofiltration column outlet was collected in an effluent collection pot (ECP) and was found to have 50 ppm COD (83% removal) and turbidity of 15 NTU (92% removal).

1C] Effect of elevated pH (9.5):

When PVC waste water (COD ranging from 115 to 220 ppm; turbidity 100-220 NTU) having a pH as high as 9.5 was exposed to the biofilter according to the procedure provided in Example 1B, except that the waste water stream was enriched with 5 mg of nitrogen and 1 mg of phosphorus; the treated effluent was found to have an average COD of 30 ppm leading to a removal of about 82% and turbidity of 25 NTU (80-85% removal).

1D] Effect of elevated temperature (40 °C):

When PVC waste water (average COD = 170 ppm and turbidity= 175 NTU) was exposed to the biofilter at a temperature of 40 °C for almost 2 months, according to the procedure provided in Example 1B, except that the waste water stream was enriched with 5 mg of nitrogen and 1 mg of phosphorus; the treated effluent was found to have an average COD of 37 ppm leading to a removal of about 78% and turbidity of 5-10 NTU (more than 90% removal). The temperature of 40 °C was maintained for 8 hours per day using a jacketed column and was kept at ambient for the remaining 16 hours.

When the experiments were conducted under ambient temperature conditions throughout (28 – 32 °C), the results were practically the same: treated COD being on an average 35 ppm (ranging from 5 – 55 ppm) and turbidity of 30 NTU (ranging from 20 – 30 NTU).

1E] Effect of different flow rates:

Various samples of the waste water collected from the PVC manufacturing plant having COD ranging from 100 to 200 ppm and turbidity ranging from 100 to 250 NTU were treated with the biofilter of Example 1B, at ambient temperature with the addition of 5 mg of nitrogen and 1 mg of phosphorus as the nutrients, at different flow rates (1.6, 2.0, 2.4 and 2.8 ml/min).

The results have been demonstrated in Figure 2a and 2b. It was found that COD removal was almost similar in all cases.

Table 1. Effect of flow rate on COD

Sr. No.	Flow rate (ml/ min)	COD (ppm)	Percent removal (%)
1	1.6	5 – 35	85-90
2	2.0	25 – 35	80
3	2.4	20 – 50	70 - 90
4	2.8	5 – 50	60 - 85

The turbidity results after treatment were as follows:

Table 2. Effect of flow rate on turbidity

Sr. No.	Flow rate (ml/ min)	Turbidity (NTU)	Percent removal (%)
1	1.6	10 -25	90
2	2.0	5 – 25	>90
3	2.4	5 – 30	85-95
4	2.8	20 – 40	80-85

From the experimental data, flow rate of 2.4 ml/min was found to be optimum.

1F] Effect of process parameters on COD and turbidity removal

Extent of COD and turbidity removal was studied, before and after the optimization of process parameters such as pH, flow rate, contact time and temperature. The results obtained are represented in Figures 3a and 3b (before optimization) and Figures 3c an 3d.

Process parameters prior to optimization:

Flow Rate = 1.6 ml/min and contact time = 3 hours

Figures 3a and 3b demonstrated that there was no difference in the performance of COD and turbidity removal with pH adjustment (7.3-7.5) or without pH adjustment (6.5-9.5).

Process parameters after optimization:

Flow Rate = 2.4 ml/min, contact time = 2 hours and pH = 9.5

Figures 3c and 3d indicate a significant difference in COD and turbidity levels after optimization of process parameters.

Example 2: Process for the removal of COD and turbidity from waste water (Pilot plant scale)

Up-scaling was done at the PVC plant to 12 m^3/day (scale-up factor of 5200). The Biofilter pilot column had a total volume of 3.5 m^3, the packed volume was 1.5 m^3, residence time was 3 hours, amount of GAC packing was 1 MT operating at atmospheric pressure and operating temperature of 30 – 35 °C with a flow rate of 0.5 m^3/h. The iodine adsorption of GAC was 900 mg/g. A settling time of 15 min was allowed and nutrients (Nitrogen = 5 mg and P = 1 mg) were added. Aeration was maintained. However, the dissolved oxygen (DO) in the feed never exceeded 2 ppm.

2A] COD measurement:

At the designed flow rate of 0.5 m^3/hour, the inlet COD was between 150 and 200 ppm and the COD reduction of 70-80% was achieved with 30-40 ppm of COD in the outlet.

2B] Turbidity measurement:

Turbidity in treated water was < 5 NTU throughout the treatment.

2C] Effect of shock loading:

During shock loading of high COD (320 ppm), the treated outlet COD showed 100 ppm. The biofilter, however, could recover within 3 days when the COD level dropped back to 150-200 ppm in the feed.

2D] Effect of shutdown period:

The biofilter was able to sustain a prolonged shutdown period of 10 days with just 1 intermittent replenishment of feed to the column. It reverted back to successful performance (70 – 80% removal) once the plant restarted.

2E] GAC support:

The major component of the operating cost of the biofilter, was found to be self-regenerating and retaining its mechanical as well as physical integrity during the period of the trial. Fresh GAC had surface area (BET analysis) of 750 m^2/g, the GAC collected from different regions of the column after 8 months of operation showed 720 to 700 m^2/g.

2F] Flow rates:

Designed flow rate could not be maintained, flow rates varied from 0.2 to 1 $m^3/hour$ during the period of study. At 0.5 $m^3/hour$ the COD removal was 70 – 85%. At >0.6 m^3/h, sometimes reaching even 1m^3/h, the COD removal was 65 -85%.

Example 3: Use of biofilter treated water of the present disclosure as make up cooling water

The specifications of the biofilter treated water obtained as a result of the biofiltration process of the present disclosure were compared with those of the standard make up cooling water commonly used in industries. It was found that specifications of both the samples were found to be similar. Therefore, the filtered water of the present disclosure is capable of being used as make up cooling water in different plants or re-used in the same plant.

Along with the specifications of the standard make up cooling water, those of raw water, demineralized water and PVC centrate water feed were also compared to yield the results provided in Table 3.

Table 3. Comparison of specifications of the biofilter treated water with the other type of water specifications

Sr. No.	Parameter	Specifications				
		Raw water	Demineralized water	Make up Cooling water	PVC centrate water	Biofilter treated water
1	pH	7.5-7.9	6.2-7.4	7.2-7.8	9.0-9.8	7-7.5
2	Conductivity (µS)	350	2.0	<5,000	150-200	170-210

3	Turbidity (NTU)	2	Nil	No spec.	250-300	0-5
4	COD (mg/L)	-	-	-	95-150	0-20
5	TOCA (ppm)	-	-	-	ND	2-3
6	Total hardness (ppm)	160	-	<1400	20-25	20-30
7	Calcium hardness (ppm)	75	-	<600	6	4-6
8	Magnesium hardness (ppm)	85	-	<800	14-18	14-20
9	Metal alkalinity (ppm)	300	-	<100	40-60	35-55
10	Chloride (ppm)	70	1 max	<400	20-30	30-40
11	Silica (ppm)	20	0.05 max	<180	0.3-0.5	1-2
12	Sulfate (ppm)	10	-	-	Not performed	10-15
13	Orthophosphate (ppm)	-	-	7-11	0.5-1	2-3
14	TSS (ppm)	Nil	-	<20	65-105	1-2
15	TDS	450 max	-	<500	80-100	100-125
16	TVC	-	-	<10,000	-	50,000-60,000
17	SRB	-	-	<10	-	Nil

Example 4: Comparative examples

4A] Removal of dissolved and non-dissolved contaminants using the shake flask method (conventional method) and the biofiltration method (process of the present disclosure): Effect of pH and temperature

Removal of dissolved and non-dissolved contaminants was carried out using the shake flask method (conventional method) and the biofiltration method (process of the present disclosure) and the influence of pH and temperature on COD and turbidity removal from PVC wastewater was compared.

Shake flask studies carried out in the lab represented the activated sludge process-the conventional method.

(a) Effect of pH:

- With shake flask studies, wastewaters having pH control between 6.5 and 8.5 was necessary to achieve 70-80% COD removal.
  >8.5 pH resulted in <60% removal.
- With biofiltration at a flow rate of 1.6 ml/min and nutrient addition as mentioned in Example 2, wastewaters having pH between 6.5 and 9.5 were found to be treatable without any adjustment, leading to COD removal of 70-85% and turbidity removal of 85-90%.

(b) Effect of temperature:

- With shake flask method, at a temperature of 29-30 °C, COD removal was 84-91%.
  At 35 °C COD removal was 74-83%; and
  at 40 °C COD removal was only 37%.
- With the biofiltration method, the process of removal was found to work equally well at ambient temperature (29 – 30 °C) as well as at 40 °C, leading to COD removal of 75-80% and turbidity removal of 80-90% in both cases under conditions mentioned in (a).

It was, therefore, inferred that in the process of the present disclosure, adjustment of pH and temperature in a pre-determined range was not necessary to effect removal of dissolved and non-dissolved contaminants. Better tolerance and performance demonstrated by the biofiltration method was due to the protection afforded by the biofilm to the microorganisms.

4B] Removal of dissolved and non-dissolved contaminants using plain GAC column and the GAC supported biofilm column (biofiltration method- process of the present disclosure): Effect on COD and turbidity removal

2 identical glass columns – one with just GAC and the other having GAC supported biofilm were used for treatment of PVC wastewater with respect to COD and turbidity removal under identical conditions (flow rates, nutrient addition and pH).

(a) Effect on COD removal:

- COD removal was 80% in the case of GAC while it was 85-90% in the GAC + biofilm treatment.

  Over a period of three months the COD removal steadily reduced in the GAC column until it was 47% at the end of three months until the flow was reduced significantly due to clogging.
- In the biofilter (GAC + biofilm) column, the COD removal steadied at 82% and continued to remain so (80-85% removal) during 1 year of continuous operation. During this period there was only a requirement of periodic replenishment of acclimatized cultures to the column due to washout.

  This showed the self-sustaining & regenerative capacity of the biofilter in comparison to the conventional plain adsorption process.

(b) Effect on turbidity removal:

- In the GAC column, the initial turbidity removal was found to be 94%.

  After 2 weeks of exposure to the wastewater, it reduced to 63%.

  After another month it reduced to 50% and finally before the column stopped it had reduced to 43%.
- In the case of the GAC supported biofilm column, the initial turbidity removal was found to be 90%, after which it gradually reduced to 67-85%.

  A couple of backwashes later, the removal was restored to 85% and this continued for a whole year of continuous operation.

Therefore, the COD and turbidity removal was found to decrease over a period of time in the plain GAC column; whereas that in the biofilter did not depend on lapse of time as the biofiltration method was self-sustaining and self-regenerating.

TECHNICAL ADVANCEMENT AND ECONOMIC SIGNIFICANCE

The process of the present disclosure causes simultaneous removal of COD and turbidity from the waste water stream.

The process of the present disclosure is effective for carrying out the biofiltration of waste water streams with high pH.

The process of the present disclosure is effective for carrying out the biofiltration of waste water streams at a high temperature such as 40-50 °C.

The process of the present disclosure is faster as compared to the prior art processes.

The filtered water that results by the process of the present disclosure, does not require additional membrane filter before further use.

Throughout this specification the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

The use of the expression "a", "at least" or "at least one" suggests the use of one or more elements or ingredients or quantities, as the use may be in the embodiment of the disclosure to achieve one or more of the desired objects or results.

The numerical values given for various physical parameters, dimensions and quantities are only approximate values and it is envisaged that the values higher or lower than the numerical value assigned to the physical parameters, dimensions and quantities fall within the scope of the disclosure and the claims unless there is a statement in the specification to the contrary.

While certain embodiments of the disclosure have been described, these embodiments have been presented by way of examples only, and are not intended to limit the scope of the disclosure. Variations or modifications in the composition of this disclosure, within the scope of the disclosure, may occur to those skilled in the art upon reviewing the disclosure herein. Such variations or modifications are well within the spirit of this disclosure.

Dated this 21st day of January, 2014

MOHAN DEWAN
Of R. K. DEWAN & CO.
APPLICANT'S PATENT ATTORNEY

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