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Treatment of Municipal Wastewater by using Rotating Biological Contractors (Rbc's)

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Abstract: The rotating biological contactor process offers the specific advantages of a biofilm system in treatment of wastewater for removal of soluble organic substances. It is a unique adaptation of the moving-medium biofilm system which facilitates easy and effective oxygen transfer. Media in the form of several large flat or corrugated discs with biofilm attached to the surface is mounted on a common shaft partially submerged in the wastewater and rotated through contoured tanks in which wastewater flows on a continuous basis. The compactness of the system and its economical operation makes it a viable option specially suited for decentralized wastewater treatment technologies. The process optimisation and adaptability under different environmental conditions and influent characteristics remain challenging tasks for the efficient use of this technology. Oxygen is accepted to be one of the most important and often limiting substrates in an aerobic treatment process. Oxygen transfer through the water film developed on a rotating disc revealed that the oxygen transfer coefficient varies with the rotational speed and the location on the exposed disc surface. Increase of ambient temperature resulted in decrease of the oxygen mass transfer rate. The biofilm model was implemented for a three stage rotating biological contactor based on a laboratory-scale experimental set-up. The process kinetics was adopted from the Activated Sludge which represents a mixed culture biomass environment.

Keywords: *Empirical Correlation, Factors affecting performance, Bioflim system, Influent, Behavior of overall oxygen transfer*

I. INTRODUCTION

The consumption of resources and energy based on human activities followed by huge amount of wastes has being one of the most serious problems all over the world. It leads to terrible destruction of the global or regional environment, and its negative effects on human being's health as well as global ecosystem are appearing evidently. It is therefore necessary to establish the effective technology, i.e., prevention of emissions and saving resources and energy. Water is our most precious resource. The cleanliness of our lakes, rivers and oceans is one of the pressing goals for environmental protection. The balance of nature depends therefore on the comprehensiveness of our approach to solve the problem of wastewater disposal. If water of high organic matter content or biochemical oxygen demand (BOD) value flows into a river, the bacteria in the river will oxidize the organic matter consuming oxygen from the water faster than it dissolves back in from the air. If this happens, fish will die from lack of oxygen, a consequence known as fish kill. A stream must have a minimum of about 2 mg/l of dissolved oxygen to maintain higher life forms. In addition to this life-sustaining aspect, oxygen is important because the end products of chemical and biochemical reactions in anaerobic systems often produce aesthetically displeasing colours, tastes and odours in water [1]. The implementation of suitable methods for the disposal of wastewater dates back to the times of Roman civilization. However, it was only in the later part of the 19th century that a spurt of activity in the realm of wastewater treatment took place. The growth of the human population, urbanization and industrialization necessitated the treatment of wastewater. It became evident that the untreated wastewater which was discharged directly into water bodies caused pollution and posed health hazards. The objective of sewage treatment is to produce a disposable effluent without causing harm to the surrounding environment and prevent pollution. For it analysis of the effluents COD and BOD need to be carried out and the values obtained used to establish an empirical relation for easy conversion of COD to BOD5. Comparison of BOD with COD assesses whether the compound is readily biodegradable. For BOD5, an indication is that a COD:BOD ratio of greater than 100 means that the compound is relatively non-biodegradable and a ratio of less than 10 that it is relatively degradable. However, low BOD5 may merely mean that the test microbes need longer than the test period to begin breaking the compound down and therefore ultimate BOD or other biodegradation testing is generally much more reliable [9]. The results obtained would provide the tool for effective monitoring and evaluation of the effluent by the selected industries and the monitoring agencies. In addition, this work will facilitate rapid effluent assessment or process control by the industries once the chemical oxygen demand is measured or vice versa.

II. RBC UNIT

Rotating biological contactors (RBCs) are mechanical secondary treatment systems, which are robust and capable of withstanding surges in organic load. The rotating disks support the growth of bacteria and micro-organisms present in the sewage, which break down and stabilize organic pollutants. To be successful, micro-organisms need both oxygen to live and food to grow. RBC consist of parallel, deformed discs mounted perpendicularly on a shaft that is slowly rotated in a tank through which the wastewater to be treated is passed. The shaft is mounted above the water level in the tank. Oxygen is obtained from the atmosphere as the disks rotate. As the micro-organisms grow, they build up on the media until they are sloughed off due to shear forces provided by the rotating discs in the sewage. Effluent from the RBC is then passed through final clarifiers where the micro-organisms in suspension settle as sludge. The sludge is withdrawn from the clarifier for further treatment [2]. The rotor has to turn continuously without any longer interruption that could harm the function of the bacteria and thus lower the efficiency. The bacteria need a continuous food source provided by a constant inflow of effluent from the reactor or wastewater. Therefore, the RBC inflow tank (Fig 1) is filled up with the needed amount of daily inflow. The tank is filled manually with the free submersible pump. To fill the inflow tank by pump power must be on. The upper layer on the tank indicates the fill level. The treated effluent is disposed off through the free pump directly to the environment. Make sure that the pipe outlet is placed outside the shed, at a place, where the disposal does not cause any inconvenience [3].

2.1 Factors affecting performance

Overall performance of RBC systems for nutrient removal from wastewater depends upon several factors:

- Influent wastewater characteristics
  - Hydraulic loading rate
  - Organic loading rate
  - Ammonium loading rate
  - pH
- System configuration
  - Rotational speed
  - Specific surface area of discs
  - Disc submergence
  - Number of stages
  - Recirculation rate
  - Drive mechanisms
  - Shaft arrangement (common shaft with single rpm or separate shaft for each stage)
- Oxygen transfer rate
- Ambient and wastewater temperature
- Media density

The most important physical factors affecting the overall removal efficiency of the system are oxygen mass transfer rate and temperature. Oxygen transfer rate is again dependent on operating temperature and physical set-up of the system. The thickness of the biofilm is controlled by the availability of nutrients and surface turbulence due to rotational speed. However, during scale-up, it is the peripheral speed on the discs which is the governing factor in the growth of the biofilm and the resultant thickness. Usually the peripheral velocity at the rim of the disc needs to be below 20cms-1[4]

2.2 Operating problems

- Shaft failures,
- Media breakage,

- Bearing failure and
- Odor problems

2.3 Bioflim system

Over the years, the treatment of wastewater using biofilm technologies has been established to be an efficient and proven technology with relatively stable end-products. They offer an ideal alternative, mainly as a secondary or tertiary biological treatment unit for the simultaneous removal of organic substances, nitrogen and other nutrients in municipal wastewater. Biofilm systems may be broadly divided into two categories: fixed-medium systems and moving-medium systems [5]. During the treatment process, microbes that remove the organic material in the wastewater (by using the organic material as a food source) attach themselves to the disc surfaces. They grow in a thin biofilm, whose thickness is controlled by the shearing force of the discs being rotated through the water. By rotating out of the water into the atmosphere, the microorganisms, growing on the disc, are provided oxygen. The surplus microorganisms that are sheared off the discs are carried with the wastewater to clarifiers where they are separated from the treated wastewater by settling out. The settled solids are then pumped from the bottom of the clarifier for further processing, most commonly, for use as fertilizer or soil amendment [6].

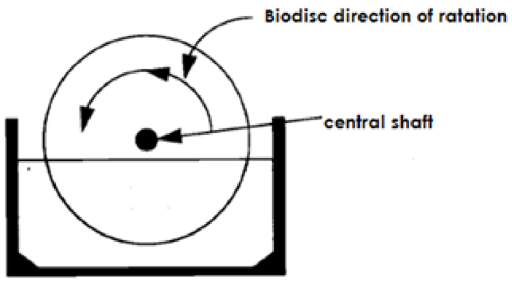

Fig 1: rotating biological contactor

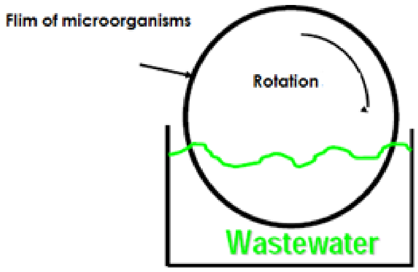

Fig 2: bioflim formation

2.3.1Biofilm system offers the following advantages [7]

- High biomass packing density and reactor compactness due to a large specific surface area
- Short contact periods and co-habitation of aerobic and anoxic micro-organisms within the ameecosystem
- Reduced sludge bulking and better sludge thickening qualities
- Lower sensitivity and better recovery from shock loadings
- Low energy requirements and more economy in operation and maintenance
- Low sludge production and superior process control
- Simple in operation and maintenance

III. MATERIALS AND METHODS

In operation, a media, consisting of a series of circular disks of different diameter sets are mounted side by side on a common shaft is rotated through the wastewater flow. The shaft continually rotates at 3 to 16 rpm, and a layer of biological growth 2 to 4 mm thick is soon established on the wetted surface of each disk. The organisms in the slime remove organic matter from the wastewater for aerobic decomposition. Typically, a single contactor is not sufficient to achieve the desired level of treatment, so a group of contactors are used in series. Each individual contactor is called a stage and the group is known as a train.

3.1 Materials

The acrylic sheet surface was made rough with the help of sand paper. PVC pipe (shaft) of diameter 20 mm having length 60 cm for each stage was mounted at the top of semi circular pipe with the help of bearings. The disks were fixed equidistant from each other on the shaft. These disks were fixed with the help of screws. The two pulleys were created with the help of card boards. The pulleys were fixed at either side of the shaft. The AC motors were fixed on the semi-circular rectangular shaped card – board sheet on the either side. Plastic pulleys were attached to the motor. Due to the pulleys on two motor and two pulleys on two shafts, two rubber belts were mounted on each motor and one shaft. Electric supply from source to the electric motor was passed through the transformer and the current regulator.

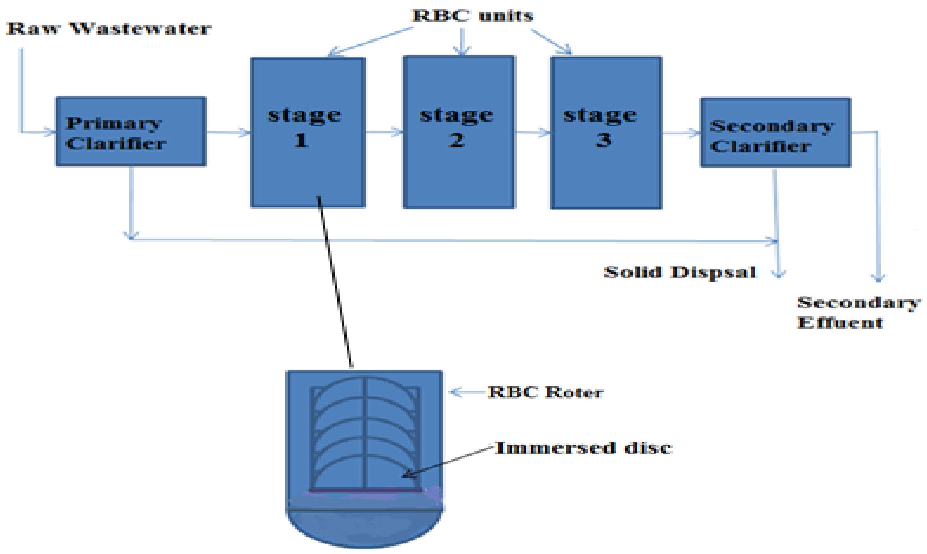

Fig 3: layout of the three-stage rotating biological contactor.

1.2 Methods

The samples collected before and after treatment were analyzed for pH, TSS, BOD_5 and COD by using standards methods.

3.2.1 Five-Day Biochemical Oxygen Demand (The Dilution Method)

The dissolved oxygen content of liquid was determined by the Azide modification of the Winkler's method before and after incubation for five days at 20°C. The difference gave the BOD_5 of the sample after allowance had been made for the dilution, if any, of the sample. For optimum biochemical oxidation, the pHs of the samples for analysis was 6.5 to 8 [8]. pH value was determined by pH meter.

3.2.2 Chemical Oxygen Demand (COD) Using the Open Reflux Method

The sample, to be measured, was oxidized under reflux with a known amount of potassium dichromate in strong sulphuric acid with silver sulphate as a catalyst. Organic matter reduced part of the dichromate and the remainder was determined by titration with iron (II) ammonium sulphate or iron (II) sulphate using ferroin as indicator. Interferences from chloride were suppressed by the addition of mercuric sulphate to the reaction mixture. The chemical oxygen demand (COD) was expressed as milligrams of oxygen absorbed from standard dichromate per liter of sample [8].

3.2.3 Total suspended Solids (TSS) Using the Gravimetric after filtration

Dry a glass fiber filter in an aluminum foil dish to constant weight at 103 °C, cool it in desiccators and weight it and the dish. Filter a known volume of sample water through the filter. Place the wet filter and trapped solids in the dish again it in the oven to constant weight at 103 °C again and weigh it again. Subtract the first weight from the second weight and divide by volume of sample in liters to get suspended solids in mg/lit [8].

IV. RESULTS AND DISCUSSION

The objective of study is to find out the variation in overall oxygen transfer coefficient and aeration efficiency by varying the parameters- no. of disks, diameter of disks, rpm of disks, supplemental aeration etc. The purpose of different scales was to observe the variation in performance efficiency with scale-up operation. Each RBC reactor configuration ha three stages separated by baffles to prevent mixing and initiate desired removal processes. The experimental work described here was consists of series of controlled experiment on wastewater (from nalla around the Amravati City premises) taken in oxidation ditch using mechanical submerged aerators only.

4.1 Source of influent and Duration of Work

Influents were taken from the sewer (nalla) containing municipal sewage (wastewater) located in the Amravati campus. For the analysis three points were decided for the wastewater collection. Sampling of wastewater was done from Aug. 1 –30, 2012 for Sample-A (no heavy organic loading), Sept 1 -30, 2012 for

Sample-B (higher COD as well as TSS) and Oct 1 – 30, 2012 for Sample-C (higher BOD). The entire period of the study was four months, spanning from July to Oct. 2012. Data were collected from a RBC reactor over a period of four months. The result of the study is given below. The tables are represented graphically for better appreciation of the results.

It was observed that the results various with dissolved oxygen level, rotational speed, numbers of disks, diameter of disks. For every set of observation, BOD5, COD, and TSS are computed and its behavior is studied with respect to other variables. The tables are represented graphically for better appreciation of the results. The results obtained during the effluent analysis from the selected source are depicted in Fig: 3.

Table 1: Characteristics of municipal wastewater

Sample			A	
Diameter of disk (cm)			24	
No. of disk			12	
r.p.m.			8	
HRT (hrs)	**Stages**	**BOD (mg/l)**	**COD (mg/l)**	**TSS (mg/l)**
0	Influent	131.72	268.82	159.25
2	PST	120.4	246.4	145.7
4	I stage	58.39	132.81	83.78
6	II stage	34.19	85.75	54.2
8	III stage	19.75	61.35	35.99
10	Effluent	12.28	49.28	28.41

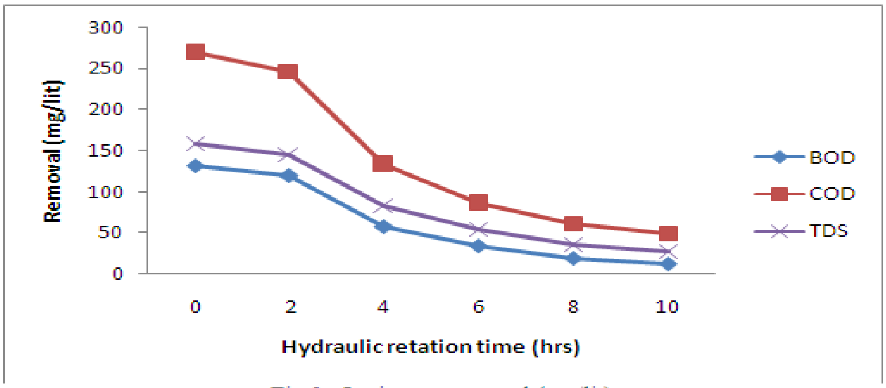

Fig 3: Optimum removal (mg/lit)

4.2 Behavior of overall oxygen transfer

4.2.1. Behavior of overall oxygen transfer with speed (rpm):

From the graphs, it is clear that result for O_2 transfer increases with the speed of 8 r.p.m. The maximum removal of BOD_5 in sample A was observed of 12.28 mg/l (89.8%). For waste water treatment, by rotating biological contractor, normally the rotational speed cannot be made very high. This checks the high peripheral velocities, which may cause shearing off the liquid film and consequently substrate limitations in the biofilm. Keeping this in mind, the rotational speed was restricted to 10 r.p.m. But the % removal rate was again get decreases with increasing or decreasing rotational speeds i.e with 10 r.p.m. and 6 r.p.m.

4.2.2 Behavior of overall oxygen transfer with surface area of the disks:

For the experimental work, the disks of 20cm, 22 cm, and 24cm diameter were used. It has been observed that the surface area of the disks increases; the value of oxygen transfer also increases. The maximum removal rate for BOD_5, COD and TDS for 24cm diameter a disk was observes as 89.8%, 80%, 55.5% and 80.5% respectively when 12 numbers of disks were rotated at 8 r.p.m.

Similarly, the maximum value of removal for 22cm diameter disks was observed as 84.2%, 77.3%, 46.5% and 75.3% respectively and for 20cm diameter disks was observed as 80.2%, 75%, 45.1% and 70.9% respectively when 12 numbers of disks were rotated at 8 rpm.

V. CONCLUSION

The RBC is an efficient method of treating wastewater because of its simplicity to maintain and operate, low energy consumption, ability to withstand shock or toxic load, freedom from odors and good sludge settling properties.RBC energy consumption is equivalent to or less than extended aeration activated sludge plants, and it requires less maintenance and operational skill. For small wastewater treatment plant, the capital cost of RBC is lower than activiated sludge plant; therefore, RBC can result in more savings for small communities. Owing to the low loading rate of sewage, biofilm was fully developed only in the first stage.

The influent with an initial BOD_5 of 131.72 mg/l was reduced to a BOD_5 of 58.39 mg/l in the first stage, a reduction of 51.5%. The average BOD_5 of the effluent over a period of 10 hours was 12.28mg/1, a reduction of 89.8%. Initial COD of the influent 268.82 mg/l was reduced to 46.1% i.e. 132.81 mg/l in the first stage and effluent COD was observed as 49.28 mg/l i.e. nearly 80% removal. TSS removal rate was nearly 80% overall. But the sludge handling from primary and secondary clarifiers requires stabilization and disposal. Also the system requires daily attendance to biological process and maintenance of the equipment.

Typical Applications of RBC:

- Municipal wastewater treatment
- Food and Beverage wastewater treatment
- Landfill leachate
- Refinery and petrochemical wastewater treatment
- Pulp and paper wastewater treatment
- Septage treatment

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