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STUDY ON REDUCTION OF PHOSPHATE FROM INDUSTRIAL CUM MUNICIPAL WASTEWATER USING MOVING BED BIOFILM REACTOR

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Abstract - *The removal of phosphorus (P) from domestic wastewater is primarily to reduce the potential for eutrophication in receiving waters, and is mandated and common in many countries. However, most P-removal technologies have been developed for use at larger wastewater treatment plants that have economies-of-scale, rigorous monitoring, and in-house operating expertise. Removal of phosphorous is necessary for preventing the problem of eutrophication. There are three methods for phosphorous removal namely physical, chemical and biological. Moving bed biofilm reactor is one of the efficient methods of phosphate removal. MBBR operated for biological phosphorus removal under different redox conditions Aerobic PAO efficiently removed micro pollutants. Removal occurred simultaneously to phosphorus uptake for several micro pollutants. PHV and PHB contributed differently to removal of phosphorus and micro pollutants. We have used Polyurethane foam (PU) as bio carriers and an aquarium aerator has been equipped with MBBR to provide a constant rate of aeration to aerobic zone during the process. The aerator is equipped with pumice stone based diffuser. The Aeration rate was - 1.6 LPM. (0.096m3/hr.) Result showed that the efficiency of phosphorous removal through MBBR is 55.06%.*

***Key Words*: Municipal Wastewater, MBBR, Phosphorous, Physico-Chemical Processes, Wastewater Treatment Plants.**

1. Introduction

The main reason for removal of phosphorus (P) and nitrogen (N) from Municipal wastewater is to prevent or reduce eutrophication in the receiving surface water. Untreated municipal wastewater contains nitrogen and phosphorus both as particulate species and soluble in the form of ammonia and phosphate. Especially the soluble compounds are readily used as nutrients by micro-organisms. Excessive discharge of nitrogen and phosphorus leads to increased growth of micro-organisms with consequently increased oxygen consumption. In extreme cases the concentration of dissolved oxygen (DO) can be reduced to zero in parts of the water column. In fresh water phosphorus is normally the limiting nutrient for growth of micro-organisms, while nitrogen is normally limiting for growth in marine waters. Although removal of phosphorus has been the only requirement for nutrient removal in some cases with discharge to fresh water recipients, removal of both phosphorus and nitrogen is normally necessary to meet treatment standards that require nutrient removal in some cases with discharge to fresh water recipients, removal of both phosphorus and nitrogen is normally necessary to meet treatment standards that require nutrient removal.

Phosphorus can be removed both chemically and biologically. Chemical phosphorus removal is done by precipitation of phosphate and coagulation– flocculation of particulate phosphorus using a metal salt of calcium, aluminium or iron. The main disadvantages of chemical phosphorus removal are the cost of chemicals and the relatively large sludge production that increases the cost of sludge treatment and the problems and cost of sludge disposal. Biological phosphorus removal offers an alternative to chemical treatment methods that has a potential for reduced sludge production.

Biological phosphorus removal is performed by phosphate accumulating micro-organisms (PAO) that have the ability to accumulate phosphate over and above what is required for growth. This biological process is referred to as bio-P or enhanced biological phosphate removal (EBPR). Although the biochemical mechanism was not understood at the time, EBPR in activated sludge processes was reported as early as 1965 (Levin and Shapiro, 1965). Since then research in the field has progressed to identify some of the bacteria which are involved and also to clarify the biochemical mechanisms behind EBPR. However, there are still unresolved questions regarding both the bacteria responsible for EBPR and the biochemical mechanisms of EBPR.

In order to facilitate selection of the bacteria responsible for EBPR in a treatment plant, the biomass must be exposed to alternating anaerobic and aerobic or anoxic conditions. This can be done by alternating the conditions in a reactor, as in a sequencing batch reactor (SBR), or by moving the biomass from one reactor to another in a continuous process.

Since EBPR is achieved by incorporation of phosphorus in the biomass, a high concentration of phosphorus accumulating biomass in the process is an advantage. However, phosphorus is removed from the process by withdrawal of excess sludge. Efficient phosphorus removal will therefore depend on efficient separation of the biomass even if efficient selection of PAO and a high biomass concentration are achieved. The main disadvantage with a pure biofilm process for EBPR is that submitting the biomass to alternating anaerobic and aerobic/anoxic conditions, essential for selection of the PAO, requires a sequencing operation. In a biofilm process, this can be done by operating the reactor(s) as a SBR with alternating anaerobic and aerobic/anoxic conditions in a time sequence or by having several biofilm reactors, i.e. fixed bed filters, in a series with a sequence that changes at set intervals. This type of operation may be more complex and require more piping and valves than a continuous activated sludge process. A SBR process may also require additional volume, compared to a continuous process, to compensate for the time for filling and drawing the reactors. However, in a biofilm SBR one can empty the reactor completely after each cycle and therefore achieve an efficient utilization of the volume.

2. Materials and Methods

2.1 Moving Bed Biological Reactor (MBBR) Setup

A single cylindrical tank / vessel have been used by us. The prototype is made up of polyvinyl chloride (PVC) besides this a model have been also set up by us for precise observations

Some important data related to MBBR setup-

2.1.1 Material of construction (MOC)

- Prototype - PVC.
- Model - Pyrex glass cylindrical vessel

2.1.2 Effluent / Raw material

Industrial waste water (dye industry) along with municipal waste water

2.1.3 Bio-carrier

Material of construction- Polyurethane foam (PU)

Polyurethane foam sheets have been cut-out in the form of polymeric foam pads and dimensions of a polymeric foam pad is shown in figure 1.

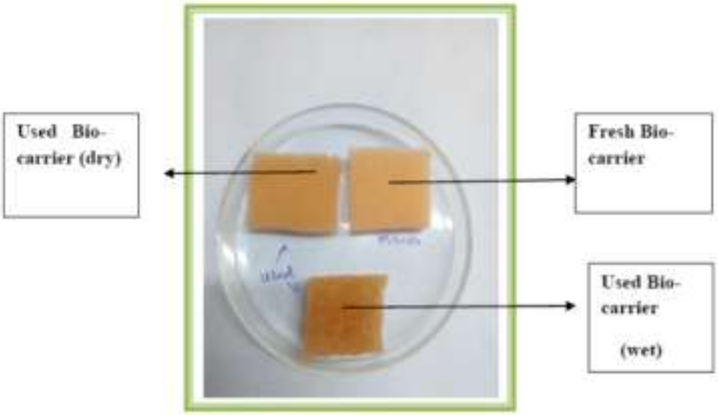

Fig: 1 Bio-carriers

2.1.4 Aeration operation –

An aquarium aerator has been equipped with MBBR to provide a constant rate of aeration to aerobic zone during the process. The aerator / air pump is equipped with pumice stone based diffuser.

Aeration rate - 1.6 LPM. (0.096m^3/hr.)

2.2 Experimental Procedure

2.2.1 Procedure of Phosphate determination in waste water using a calibration curve method

Phosphorus is the Eleventh most abundant minerals in the Earth crust. No National Criteria have been established for concentration of Phosphorus compounds in water. However to control Eutrophication the EPA makes the following recommendation total phosphate should not exceed 0.05 mg/l (as phosphorus) in a stream at a point where it enters a lake or reservoir and should not exceed 0.1 mg/l in streams that do not discharge directly into lakes or reservoirs.
Under acidic conditions, orthophosphate reacts with ammonium molybdate to form molybdate phosphoric acid . It is further reduced to molybdnenum blue by adding a reducing agent Such as stannous chloride . The intensity of the blue colored complex is measured at 700nm which is directly proportional to the concentration of phosphate present in the sample.

- **Regents**

Stock phosphate solution (100 ppm) dissolve 0.0439gm of KH2PO4 in deionized water and make up to 100ml. Standard phosphate (10 ppm) Dilute 10 ml of stock phosphate solution to 100ml of stock phosphate solution to 100 ml with deionised water.

Ammonium Molybdate Reagent - Dissolve 2.5g of (NH4)6 MO7O24 4H2O in 17.5ml of deionised water. Cool, add Molybdate solution and dilute to 100 ml.
Stannous chloride Reagent - Add 6 ml of Conc. HCI to 44 ml of deionised water with slowly stirring then boil. The add 1.4g of stannous chloride ($SnCl_2$ and H_2O) heat it until the solution becomes clear cool and dilute up to 100 ml using deionised water.

EDTA (0.001M): Dissolve 3.724 gm in deionized water and make up to 100 ml .

- **Procedure**

Transfer 0.1, 0.5, 1.0, 2.0 ml of 10 ppm standard phosphate solution into five different 10 ml volumetric flasks and add 1 ml of 0.1m EDTA followed by 0.2 ml of ammonium molybdate reagent and 20 ul of stannous chloride reagent to each . Dilute to 10 ml with deionised water. After 5-10 minutes , measures the absorbance at 700 nm against the blank prepare a calibration curve of the absorbance versus concentration of the phosphate and determine the concentration of the sample by referring the absorbance of the sample to the calibration curve

Recommended Sample volume: 5ml

Cookbook value: 0.5 µg of phosphate solution gives an absorbance of 0.39 ± 0.02.

Spectrum of Phosphomolybdate blue

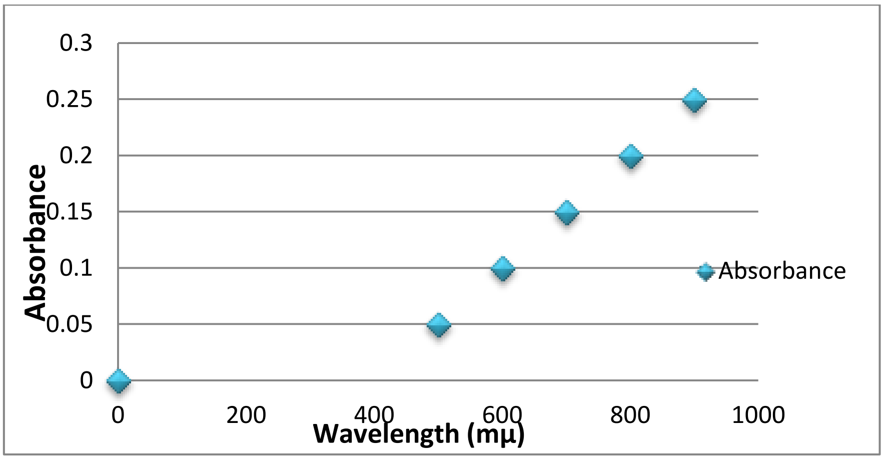

Chart- 1: Spectrum of Phosphomolybdate blue

Calibration Curve:
Phosphate Determination by stannous chloride method

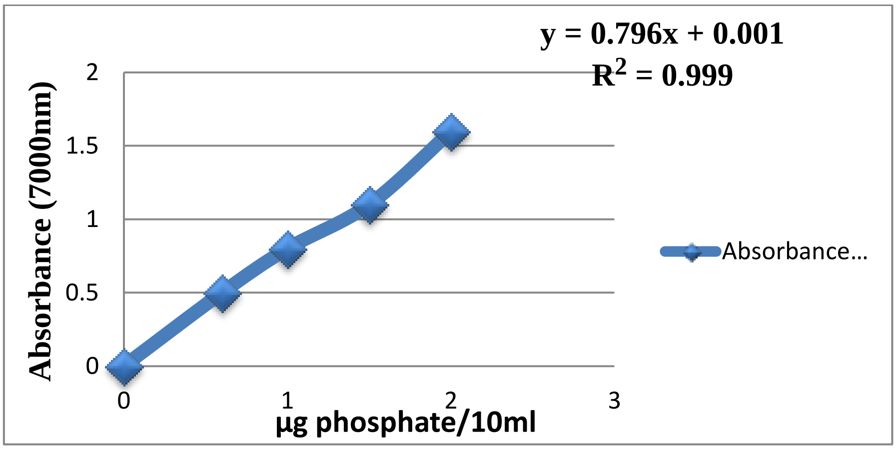

Chart- 2: Calibration Curve for Phosphate Determination

Calibration curve (700.0 nm)

Table 1 Calibration curve data of prepared sample

Sample No.	Absorbance	K * Absorbance
1	0.000	0.0001
2	0.641	0.0409
3	0.045	0.0449
4	0.050	0.0532
5	0.055	0.0420
6	0.006	0.060

3. Result and Discussions

3.1 Removal of Phosphate from wastewater (Industrial cum municipal)

On November 8, 2018, our MBBR setup has started, we assume this day as zero day – a reference point. We have divide the experiment into three phases, each phase has different HRT (hydraulic residence time).

In each phase, the aeration time zone and no aeration time zone is same . The flow rate of air has been maintained at 1.6 L/Min (0.096 m^3/hr).For the experiment, we have used cubic- shaped polyurethane (PU) foam based polymeric foam pads.

The filling fraction has been maintained at 20%, as per Xinbo zhang, Xun chen, Chunquing zhang, Haitao wen, Wenshan guo et al, (2016) , in SND process it has been observed that PU based bio carriers in the 20% filing fraction reactor is highly effective for phosphate removal per gram of carrier in comparison to other filing fractions.

3.2 Effect of Time and Temperature on pH

Table 2 Result analysis of prepared sample

Phase	Time duration (days)	pH	HRT (Hours)
I	0-30	7.4	24 hrs- for 15 days 12 hrs – for next 15 days
II	31-55	7.1	12 hrs
III	56-66	7.2	12 hrs

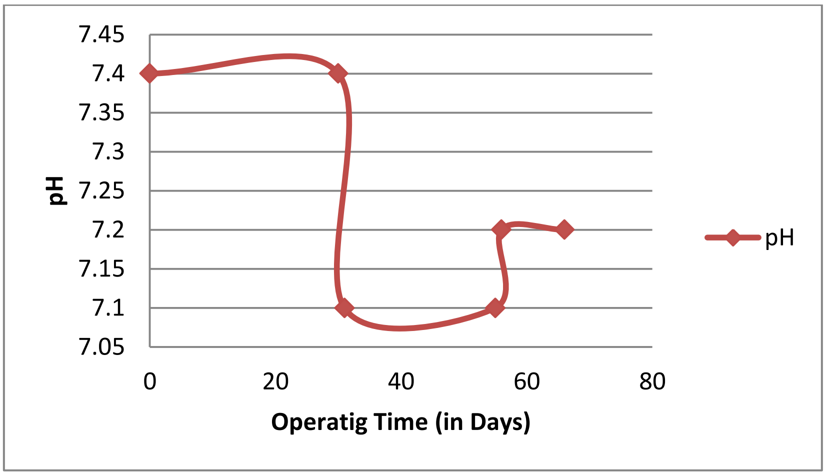

Chart- 3: Effect of time on pH

By seeing experimental data, it has been observed by us that the pH of the treating water sample is almost remain constant and it should be maintained about 7.1 ± 0.2. We can also adjust the pH value using Na_2CO_3 and H_2SO_4.

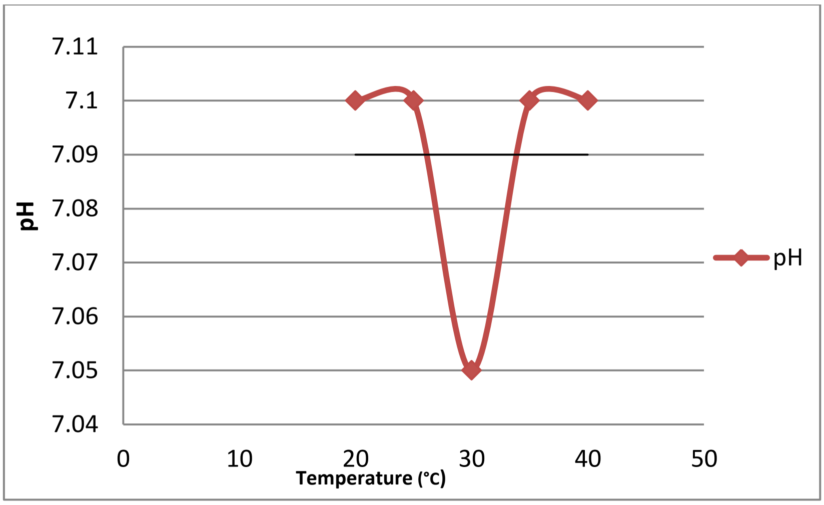

Chart- 4: Effect of temperature on pH

Our reactor has been operated at the temperature range of 20˚C to 40˚C, from the experimental data we have observed that the temperature has affected the pH value of the sample. As we increased the temperature from 20°C to 30°C the pH value has also decreased from 7.1 to 7.05 and after that the value of pH has increased at 40°C it was 7.1.
We can conclude that if the operating temperature goes below 20˚C, then the conversion of phosphate gets lower down these results to increase in hydraulic retention time (HRT).

3.3 Calibration curve of standard phosphate solution-

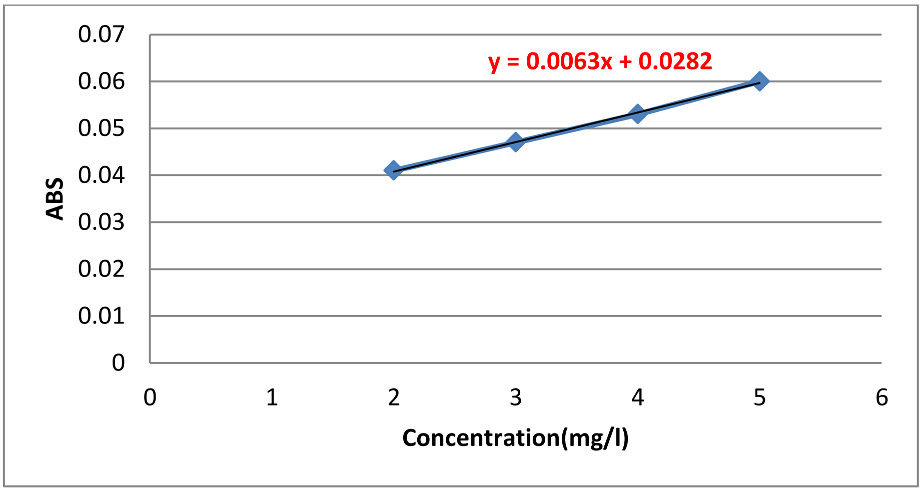

Chart- 5: Reduction of phosphate with respect to time

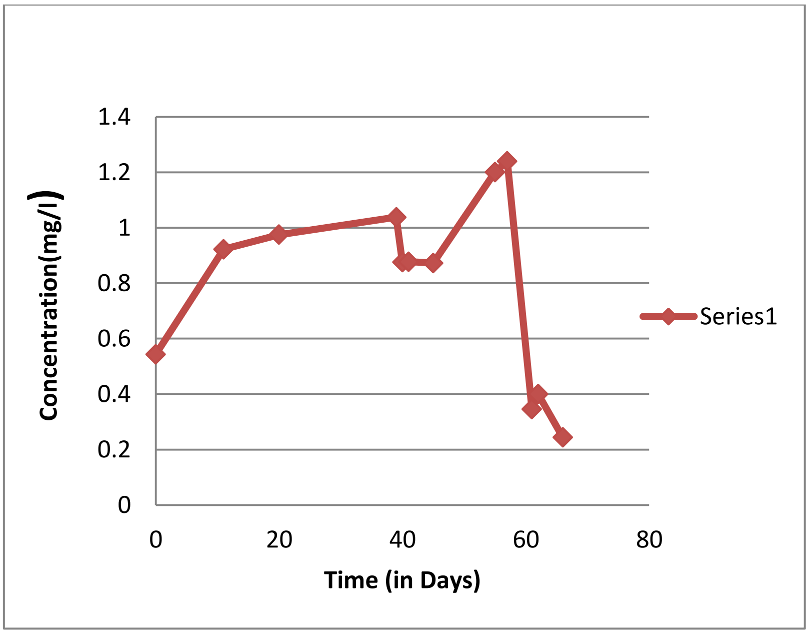

Chart- 6: Reduction of phosphate concentration

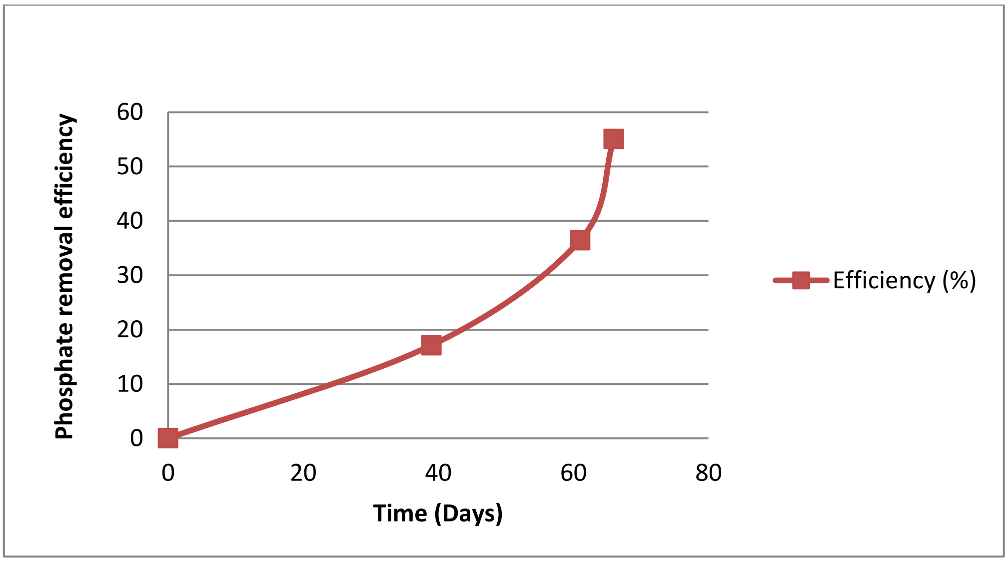

Chart- 7: Efficiency Curve

As we observed from fig: 7 that the initial concentration of phosphorous in waste water sample was 0.543 mg/l on Day 0 and the final concentration is 0.244 mg/l on 66th day. So the total reduction in phosphorous concentration is 0.299 mg/l.

Total reduction in phosphorous concentration = Initial concentration – Final concentration

= 0.543 mg/l – 0.244 mg/l

= 0.299 mg/l

Phosphorous is reduced by 55.06% within 66 days.

3.4 FTIR of phosphate sample-

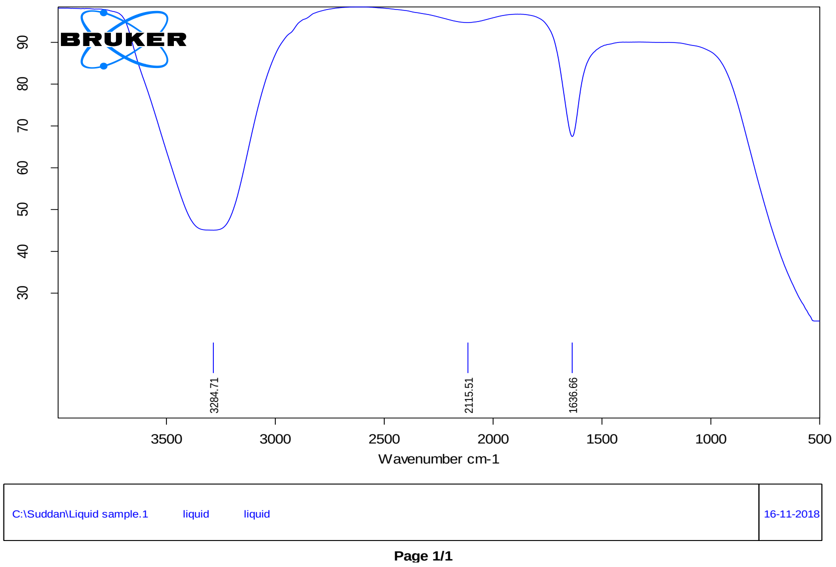

Chart- 8: FTIR Spectrograph of prepared sample

We have performed FTIR, to check the presence of bacterial growth in our respected bio carriers.
As per the results we obtained from FTIR analysis it has been concluded that the there is bacterial growth inside the bio-carriers which reduces the concentration of phosphate in our respected solution.

4 Conclusions

Moving bed biofilm reactor (MBBR) is a very cost effective and eco-friendly option for the removal of organic matters (OM) like phosphorous and nitrogen from wastewater. This particular research work analysed the removal of OM from the synthetic domestic wastewater using MBBR. In general, this research ascertained that MBBR with polyethylene media (PE) as biofilm support carrier could be efficient for phosphorous removal from wastewater. Some specific findings of this study can be drawn as follows:

1. Total Phosphorous is reduced by 55.06% within 66 days.
2. The results from the Phosphate removal experiment has indicated that the PU sponge based bio- carriers is suitable for phosphate removal due to it has high porosity as well as high specific surface area.
3. The quantity required of sponge Bio-carriers is less with respect to conventional plastic based Bio-carriers i.e. it is economically feasible.
4. As an effluent we have used mixture of industrial and municipal wastewater, that's why we don't require chemical & bacterial doping.
5. The effect of pH on removal efficiency is not very influential, throughout the process it has been observed that the pH has been maintained itself in the reactor setup.
6. High accumulations of biomass in the biofilm process when coupled with good oxygen transfer capability of the system ensure the high treatment capacity and operational stability. This can make the MBBR process attractive and promising to apply for organicmatter removal from wastewater.

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