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A Novel Approach in Rotary Biological Contactor Advancements using Banana Leaves for Urban Waste Water Treatment

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ABSTRACT: Municipal wastewater mainly contains biodegradable organic matter which disrupts the marine life. Due to the high pollution load of municipal wastewater and lack of processing of discharges, the sewage causes serious environmental problems. Hence, it is important to experiment a treatment method as an initiator in order to optimize and develop an economic method to treat the whole sewage. Appropriate treatment processes are required so as to meet the effluent discharge standards specified by the government. In this study, to minimize the cost of sewage treatment, the use of an experimental RBC (rotating biological contactor) is being suggested, which is an attached growth system and is able to sustain the shock loading. The study includes design and fabrication of a prototype and performance-based observations recorded over a period.

KEYWORDS: Bio media, Characterization, Chemical Oxygen Demand, Dissolved Oxygen, pH, Rotary Biological Contactor, Sampling.

I. INTRODUCTION

For the growing population with limited and compact housing options such as residential clusters, townships and societies implying greater usage of water within a smaller vicinity, it is possible to meet the water need with proper water management and town planning. For treatment of sewage in STPs, the cost of establishment, maintenance and conduits adds up to the cost of living. Hence, a low-cost sewage treatment method needs to be discovered and implemented in individual residential clusters, societies or townships in order to reduce the strain on the municipal sewage treatment plants. The waste water run-off into water streams depletes groundwater and soil and is then very difficult to trace. Currently the purchase cost of packaged STPs ranges from 5,00,000 to 15,00,000 INR with a treatment capacity of up to 50 m³/day, 100 m³/day, 500 m³/day and a maximum of 3MLD. with power requirement ranging from 2HP to 30HP. The size approximately varies from 1.0m. x 1.6m. x 2.0m. to 5.0m. x 1.5m. x 2.5m. in width, length and height respectively. Decentralized wastewater treatment systems are usually implemented to treat wastewater generated from small housing units in close vicinity of it which distinguishes it from centralized wastewater treatment systems. It has a small conveyance network with low and fluctuating quantity of effluent. Disposal of effluent is done into natural water body or is infiltrated which shall be done under given regulations and design constraints. Residential clusters are responsible for the whole wastewater system, its design, establishment, maintenance and operation and outsourcing increase the cost even further. Operational problems such as clogging due to irregular isolation of sludge or hydraulic overloading may occur. For a modular STP initially costing around 7.5 lakh INR, the approximate annual costs of repair and maintenance is 0.3 lakh, operator cost is 0.5 lakh, electricity cost is around 0.4 lakh INR. The lifetime cost of it reaches around 38 lakh INR which not a cost friendly option for residential clusters. Direct discharge of waste water, metals, toxic chemicals from industries and households into river, stream, canal causes growth of bacteria and other pathogens, algae that depletes DO which impairs drinking water supplies and recreation uses. Untreated nutrients and biological waste lead to severe damage to the aquatic life, soil changing the whole dynamics of the water bodies. Rejuvenation of such water bodies is costly.

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Conventionally in the ASP, sewage is processed through different units where the primary clarifier separates the sludge by sedimentation which is later activated, the aeration tank holds the supernatant providing oxygen and the activated sludge to carry out the process after which the secondary clarifier detains the sludge and supernatant is further chlorinated and discharged. The cost, manpower, area required for ASP is more with an efficiency only up to 60 to 70 %. The activated sludge method is implemented at dairy farms to treat the effluent for which RBC is suggested and designed as a suitable replacement (Kamath et al., 2018). The aerobic nature of the treatment of sewage holds importance and a demonstration of which with all the related phenomena and explanation along with detailed structural demonstration of working of a filter has been studied for study of the aerobic process of treatment of waste water. The studies also explain attached growth treatment method and RBC mechanism of treatment. In the conventional sewage treatment by RBC a series of circular lightweight rotating ridged and corrugated discs of high-density plastic such as polyethylene, polystyrene or polyvinylchloride, filled with bio media for attachment of microorganisms forming biofilm. (Chang, Clech, Jefferson, & Judd, 2002) gives a short idea of membrane fouling in conventional membrane reactors and filters using study mainly observing the cleaning efficiency and frequency at which saturation of bio membranes occurs in bio filters. The drum of biofilms is submerged up to 40% across the flowing sewage and rotates at a designed RPM trapping oxygen for growth of microorganisms that use the organic material in sewage as food. The alternate exposure of the biofilm to the sewage and the air provides nutrients and oxygen to microorganism and separates the organic material from the water. Nitrogen is removed by nitrification and subsequent denitrification transforming it to gaseous N_2 , which is released to the air. The process is optimised by adjusting the speed of rotation and the depth of submergence (METCALF & EDDY Inc. 2003). (Hiras, Manariotis, & Grigoropoulos, 2004) has given a detailed analysis of performance of a conventional RBC in removal of organic and nitrogen matter treating municipal sewage. In some designs, air is added to the bottom of the tank to provide additional oxygen in case of high-strength influents. (PaDEP, 2016) has provided a practical example of implementation of RBC for a town and the operation instructions for it. It demonstrates the operation procedure that works efficiently for an RBC. This method needs lesser space, cost and energy for operation compared to ASP with an efficiency of about 80 to 90% due to high contact time and high treated effluent quality and the stability of the process remains even in fluctuating hydraulic and organic loading producing low sludge collectible in clarifier. The process is relatively silent compared to dosing pumps for aeration with no risk of channelling. RBC mechanism of sewage treatment holds flexibility to be combined with novel approaches in treatment. (Zha, Ma, & Lu, 2018) has experimented combination of RBC and anoxic filter to study the energy efficiency of the combination. The energy and parametric removal efficiency are the factors that influence the cost benefit ratio of various treatment methods and their preference over each other. Fly nuisance and odour restrict wider preference of conventional RBC for treatment. Banana leaves act as a bio media for attached growth system with provided oxygen. The characteristics of banana leaves and the role it plays in treatment of waste water is studied. Cheaply available banana leaves being a biological material, provide a bed for attached growth system with abilities to reduce fly nuisance and odour observed in conventional RBC.

II. MATERIAL AND METHODOLOGY

A reconnaissance survey was conducted to select a 24-hour operating facility for collection of raw sewage water for the study. The collected sample was contained in sterilized containers, non-reactive to the sample, thoroughly cleaned and rinsed with dilute nitric acid and distilled water before usage to avoid alteration of characteristics of raw water sample; transported and maintained according to APHA guidelines. The required volume of sample for one cycle of treatment and characterization for the designed prototype of RBC was 8 to 10 litres. The pre and post treatment characterization provided timely data of the treatment procedure and the performance of the experimental RBC. Determination of BOD by iodometric method provided the statistical data of consumption of DO by microorganisms in the water sample and helped to determine the rate of consumption of oxygen as and when the present organic matter got consumed as food by the microorganisms. COD test, performed by open reflux method on COD digester manufactured by Elico Ltd. provided the data of extent and the required course of action to be taken for removal of chemically reactive material that consume DO during the course of the treatment. The pH of the given sample was determined by electrometric method using digital pH meter manufactured by Hanna Instruments. It helped understand the suitability of the experimental bio media for growth of microorganisms and the deviation of pH of sewage under

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treatment from desired value. Electrometrically measured TDS using Hanna TDS meter indicated presence of organic, inorganic, ionic and chemical constituents dissolved in water which helped understand the strength of the assembly for treatment and suitability of end effluent for releasing further after the treatment. All the chemicals used were AR grade and from Merck laboratory.

The lab scale prototype was intended to treat 8 litres of waste water. The design constituted of three cylindrical drums varying in size, cast out of mesh placed in a concentric fashion. The diameters of three concentrically placed drums were 14 cm, 10 cm and 6 cm and their longer side as 19.5 cm each. The total surface area of each cylindrical mesh available for contact was 857.65 cm², 612.61 cm², 367.56 cm² respectively on both the sides of the mesh. This provided a largely available surface area in a compact space. These concentric cylinders were radially separated from each other at a clearance of 2 cm in between where banana leaves had to be placed as bio-media. The three drums spaced equally from each other were connected to the steel shaft of 38 cm in length passing through. One end of steel shaft was connected to the 220/240V AC 4W synchronous motor operating at 6 RPM and 50/60Hz through a coupler of 6.5 cm length. This assembly was held over by the edges of a wooden cage of size 45 x 33 x 32 cm. The detention basin was cut out of a plastic drum to be sized as 33 x 30 x 12.5 cm placed inside the cage below the drum assembly. PVC tap was provided at base of detention basin to obtain effluent.

Table 1 Details of the experimental setup

Sr. no.	Parameters		Unit	Dimension
1	Diameter of disc 1		cm	14
	Diameter of disc 2		cm	10
	Diameter of disc 3		cm	06
2	Length of shaft		cm	38
3	Dimensions of basin	Length	cm	33
		Breadth	cm	30
		Height	cm	12.5
4	Submergence of drum		percent	40
5	HRT		days	8
6	AC Motor RPM		-	6



Figure 1 Laboratory scale experimental Setup

The trials in the lab were carried out under the constant temperature and exposure conditions to maintain the characteristics of sewage under treatment which was tested for characterization. The trials were carried out in monsoon season, post monsoon season and pre-monsoon season to get a continuous data collection. The lab trials proceeded with preparing the RBC designed primarily for using banana leaves as bio media. The banana leaves were turned into thin long stripes and then cut into pieces simply by hand in the crudest way possible for avoiding any extra expenditure of energy that might make the treatment process inefficient in any aspect. The banana leaves stripes were then filled compactly in the gaps between the concentrically placed cylinders of the RBC drum, for which it was detached from

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the assembly. The filling of the leaves was very compact and uniform to avoid any large voids in the bio media. The random filling made it easier to work on than any special pattern. The drum was then assembled and about 8 litres of sewage to be treated was poured in the detention basin. The drum with bio media, 40 percent submerged in the waste water, rotated at a constant speed of 6 RPM. The lab test carried were COD, BOD, TDS, and pH out of which TDS and pH were monitored electrometrically. The COD and BOD tests were carried out averaging the readings of 3 tests for each sample. The lab tests carried out for the sample of sewage were also observed for variations under different bio media in each of the seasons. The first bio media used was the chopped banana stem exposing its circular cross section in order to provide more cellular space through its voids as attachment and for contact of oxygen. The second bio media used was the banana leaves striped and then cut into pieces and very compactly filled. The third bio media used was combination of banana leaves with a commercially available aerobic bio culture for sewage treatment. Based on manufacturer's instruction, the bio culture solution was prepared and then added in a specific quantity per 1000 ml of waste water.

III. RESULTS AND DISCUSSION

The observations during monsoon season for the experimental set up for three different bio media namely banana stem, banana leaves and banana leaves in combination with a bio culture were recorded and tabularized are as seen in the table.

Table 2 Summarized characterization of pre and post treatment for monsoon season

PARTICULARS	DURATION	pH	TDS	BOD ₅	COD	SLUDGE OBSERVED
Units		-	mg/lit	mg/lit	mg/lit	-
RBC with banana stem	(Untreated Influent)	6.8	270	130	80	EXTREMELY LOW
	Day 3	5.8	230	80	62	
	Day 5	6.3	212	142	92	
RBC with banana leaves	(Untreated Influent)	6.8	310	134	87	EXTREMELY LOW
	Day 3	6	230	120	230	
	Day 5	6.1	140	118	210	
	Day 7	5.7	110	90	208	LOW
	Day 10	6.5	90	42	148	
	Day 15	6.7	78	30	121	LOW
	Day 20	5.4	81	28	110	
	Day 25	5.6	95	20	104	
Day 30	5.8	102	22	90		
RBC with banana leaves and bio culture	(Untreated Influent)	5.8	325	142	97	LOW
	Day 3	5.2	231	121	88	
	Day 5	5.3	228	110	64	
	Day 7	5.4	195	91	52	

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Day 10	5.5	162	42	44	SIGNIFICANTLY INCREASING
Day 15	5.6	131	28	40	
Day 20	5.7	112	12	38	
Day 25	5.8	98	21	30	

Following are the graphical representations of parametric variation for the different bio media used in the experimental RBC in the monsoon season.

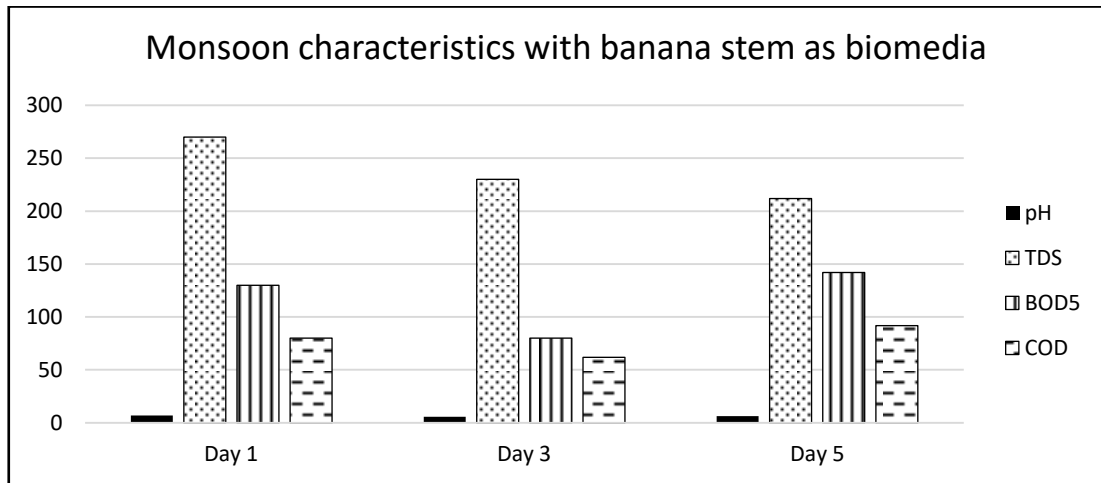


Figure 2 Parametric variation using banana stem as RBC bio media in Monsoon Season

Fig. 2 indicates the collective comparison of the parameters pH, TDS, BOD₅, COD for the use of banana stem as bio media for the RBC experimental set up during the monsoon season. The values of the parameters for the 3rd and 5th day were noted and it was observed that the TDS value decreased while the BOD₅ and COD values emerged on the 5th day suggesting the used up DO in the water and the response of the treatment process.

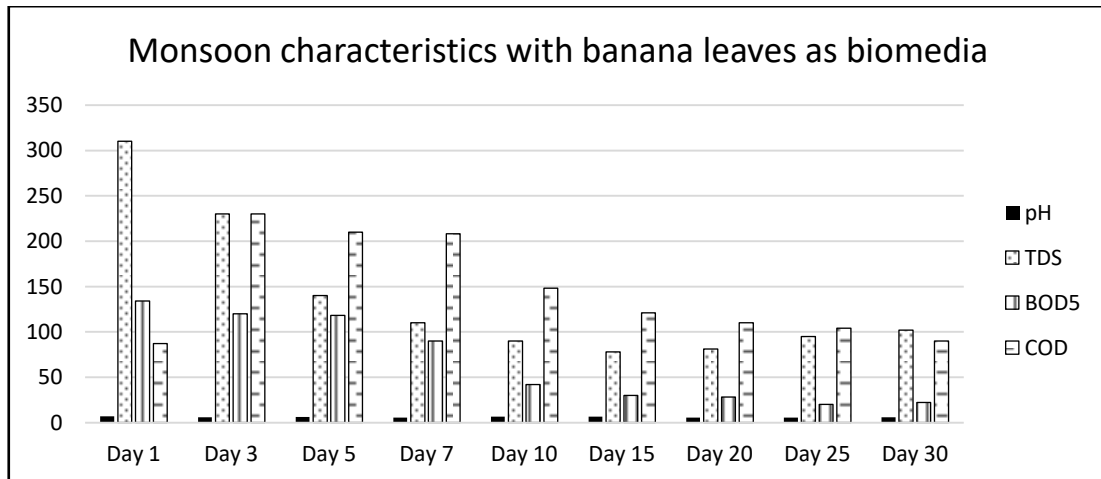


Figure 3 Parametric variation using banana leaves as RBC bio media in monsoon Season

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Fig. 3 indicates the thirty days observation and comparative parametric values for the use of banana leaves as bio media for the experimental RBC set up during monsoon season. The reduction in BOD₅ and COD values can be prominently observed during the course of treatment.

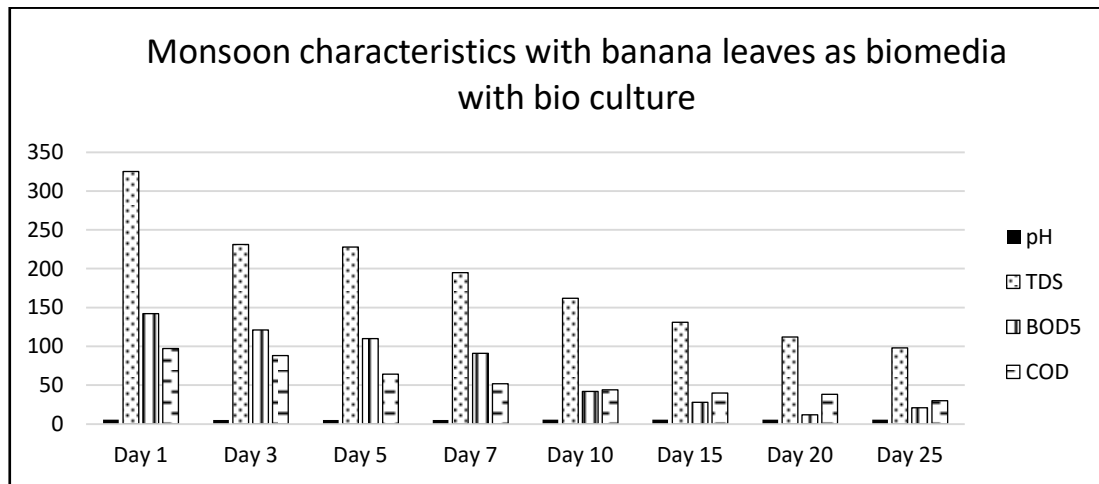


Figure 4 Parametric variation using banana leaves with bio culture as RBC bio media in monsoon Season

Fig. 4 indicates the parametric values for the use of banana leaves with bio culture as a bio media in the treatment process for the monsoon season. Gradual decrease in BOD₅ value can be observed over the period. However, COD is removed drastically implying the use of this method for treatment of waste water primarily requiring removal of COD.

The observations post the monsoon season for the experimental set up for three different bio media namely banana stem, banana leaves and banana leaves in combination with a bio culture were recorded and tabularized as seen in the table.

Table 3 Summarized characterization of pre and post treatment for post monsoon season

PARTICULARS	DURATION	pH	TDS	BOD ₅	COD	SLUDGE OBSERVED
Units		-	mg/lit	mg/lit	mg/lit	-
RBC with banana stem	Untreated Influent	6.8	232	122	87	MODERATE
	Day 3	5.8	187	80	62	
	Day 5	6.3	275	62	18	
RBC with banana leaves	Untreated Influent	6.8	274	167	110	MODERATE
	Day 3	6	187	87	61	
	Day 5	6.1	164	64	42	
	Day 7	6.2	125	48	38	MODERATE
	Day 10	6.5	110	34	32	
	Day 15	6.7	102	28	27	

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	Day 20	6	97	26	22	MODERATE
	Day 25	6.4	65	26	18	
	Day 30	6.4	31	27	28	
RBC with banana leaves and bio culture	Untreated Influent	6.8	284	174	121	SIGNIFICANTLY INCREASING
	Day 3	6.2	260	162	101	
	Day 5	6.4	248	132	111	
	Day 7	6	222	102	97	
	Day 10	6.4	187	64	75	
	Day 15	6.1	97	34	42	
	Day 20	6	72	20	31	
	Day 25	6.7	42	24	27	

Following are the graphical representations of parametric variation for the different bio media used in the experimental RBC post monsoon season.

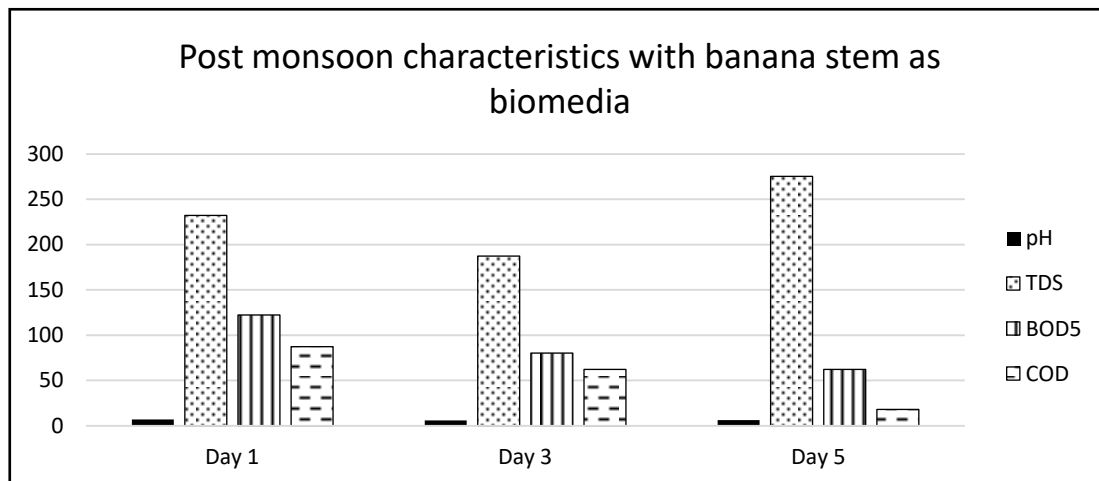


Figure 5 Parametric variation using banana stem as RBC bio media post monsoon season

Fig. 5 indicates gradual variation in BOD₅ and COD values for the use of banana stem as bio media for post monsoon season.

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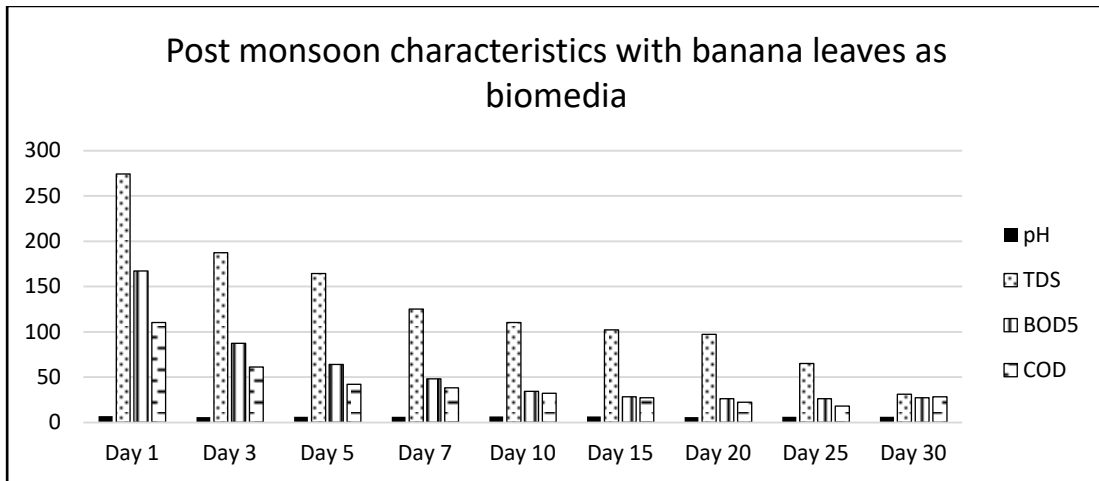


Figure 6 Parametric variation using banana leaves as RBC bio media post monsoon season

Fig. 6 demonstrates detailed parametric variation for banana leaves used as bio media post monsoon season in the experimental RBC set up. The uniformity in the trend of removal of the said parameters indicates higher suitability of this bio media for the treatment.

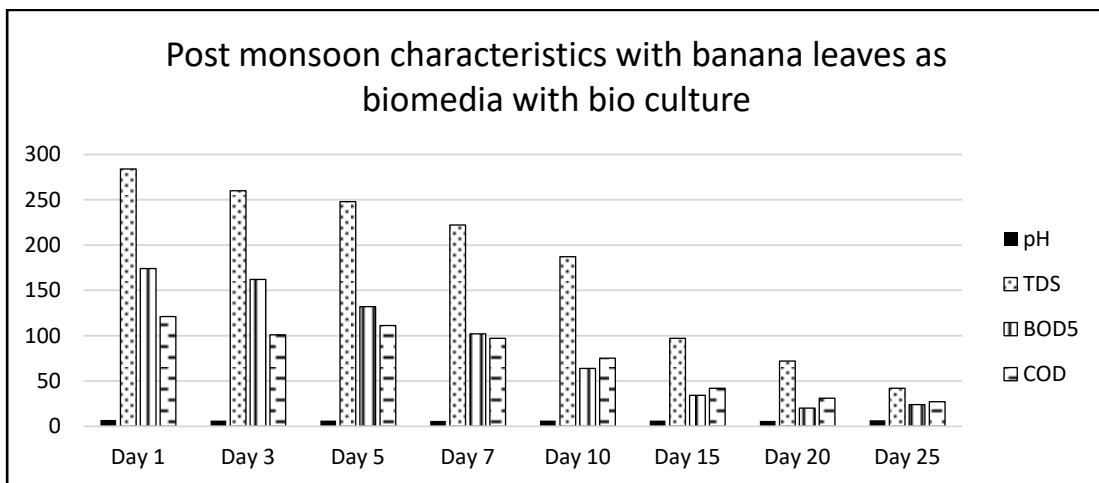


Figure 7 Parametric variation using banana leaves with bio culture as RBC bio media post monsoon season

Fig. 7 demonstrates parametric variation for the use of banana leaves with a bio culture as a bio media post monsoon season for the experimental RBC.

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The observations for pre monsoon season for the experimental set up for three different bio media namely banana stem, banana leaves and banana leaves in combination with a bio culture were recorded and tabularized as seen in the table.

Table 4 Summarized characterization of pre and post treatment for pre monsoon season

PARTICULARS	DURATION	pH	TDS	BOD ₅	COD	SLUDGE OBSERVED
Units		-	mg/lit	mg/lit	mg/lit	-
RBC with banana stem	Untreated Influent	6.8	313	323	121	HIGH
	Day 3	6.5	280	210	100	
	Day 5	6.6	212	174	97	
RBC with banana leaves	Untreated Influent	6.8	310	134	87	SIGNIFICANTLY HIGH
	Day 3	6	270	121	75	
	Day 5	6.4	180	97	72	
	Day 7	6.2	130	84	67	HIGH
	Day 10	6.5	110	74	64	
	Day 15	6.7	94	64	52	EXTREME HIGH
	Day 20	6.2	84	58	42	
	Day 25	6.7	54	52	40	
Day 30	6.2	42	50	45		
RBC with banana leaves and bio culture	Untreated Influent	6.7	325	142	97	HIGH
	Day 3	6.2	187	97	84	
	Day 5	6.4	164	51	62	
	Day 7	6.4	141	34	48	
	Day 10	6.2	132	32	40	
	Day 15	6.1	120	28	32	
	Day 20	6	90	37	47	
Day 25	6.7	81	42	54		

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Following are the graphical representations of parametric variation for the different bio media used in the experimental RBC pre monsoon season.

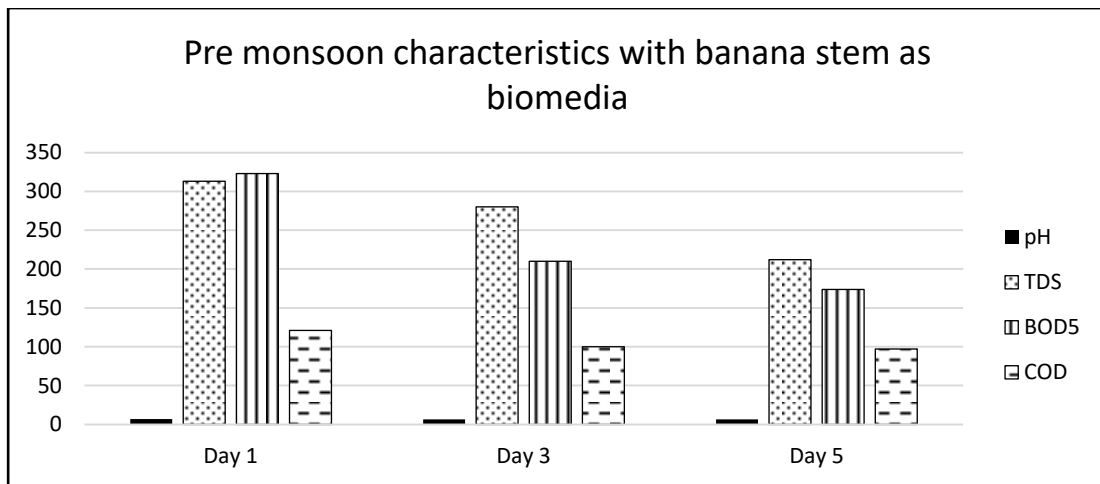


Figure 8 Parametric variation using banana stem as RBC bio media in pre monsoon season

Fig. 8 provides parametric variation for the use of banana stem as bio media for pre monsoon season in the experimental RBC set up.

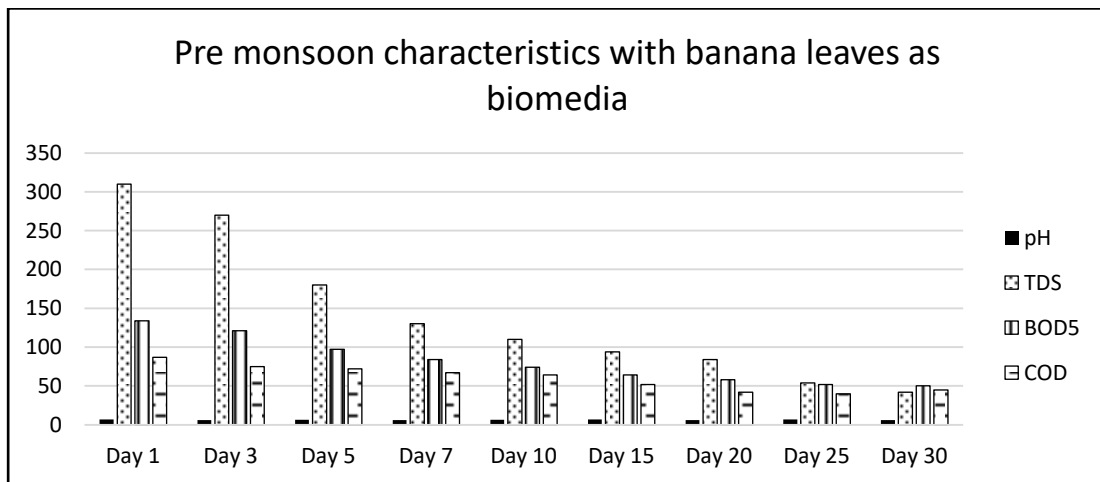


Figure 9 Parametric variation using banana leaves as RBC bio media in pre monsoon season

Fig. indicates significant removal of BOD₅, COD post treatment showing trend of removal and performance of the experimental RBC setup for the use of banana leaves as bio media in pre monsoon season.

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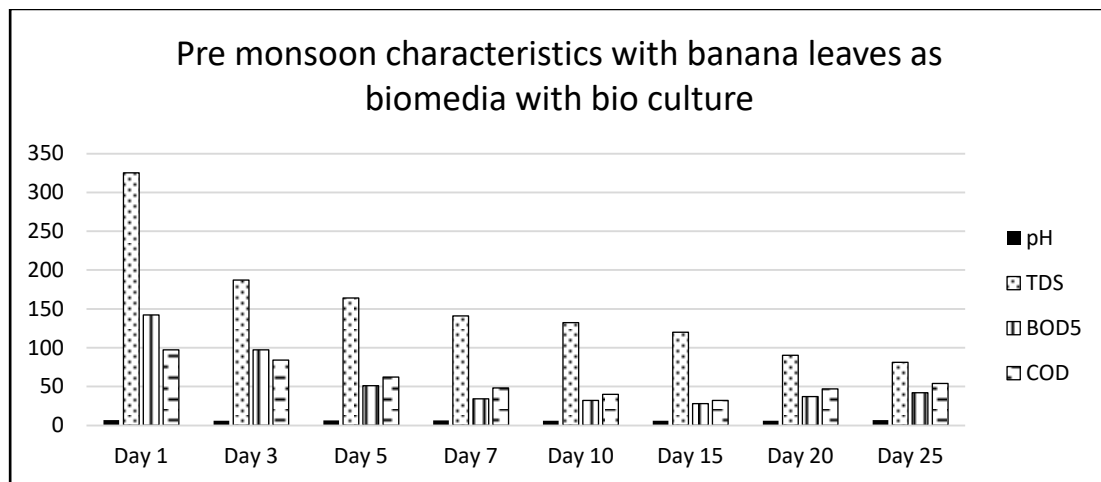


Figure 10 Parametric variation using banana leaves with bio culture as RBC bio media in pre monsoon season

Fig. 10 indicates parametric variation for the combination of banana leaves and bio culture used as bio media for pre-monsoon season.

IV. CONCLUSION

Based on the data available and the trends, it's observed that three combinations of the bio media have different results and different values of parameters upon characterization during the treatment. The RBC equipped with these bio media, thus giving positive results is the first breakthrough in finding an alternate to the ASP and the conventional RBC. The cost and energy efficient alternative among the three should be the banana leaves used as a bio media as it is abundantly available, ease of operation, swiftness along with good results in removal of BOD₅, COD and reduction of TDS. Fly nuisance and odour was not observed during the treatment for the use of banana leaves as bio media in the experimental RBC. If scaled to an actual size, this RBC with the suggested Bio media should still stand by its cost-efficient nature and prove to be an effective mechanism for treating waste water. The observed average percentage removal of TDS and BOD₅ was approximately 78% throughout the course of experimentation in all the seasons. Thus, this experimental RBC proves to have a good percentage removal rate for the said parameters at a very low cost in comparison with ongoing conventional treatment methods. This implies the performance-based cost efficiency of the set up and its capability to replace costly conventional sewage treatment methods to obtain the same results.

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