Prof. M.S. ANANTH ENDOWMENT FUND

SOCIALLY RELEVANT PROJECTS:

1. Accelerated Composting Systems for urban and rural households Indumathi M Nambi

Taskspleted

I. Literature review of composting practices and optimized conditions
II. Status of Micro Composting plants set up by corporation
III. Low cost composting bins using tyres
IV. BSF larvae composting
V. Accelerated composting Rotating In- vessel composting Design

Ongoing: Fabrication

Assessment of Micro Composting Plants

Microcomposting plants were set up by Chennai corporation and municipalities for organic waste composting. After site visits to 22 different units of Chennai corporation, the following observations were made and suggestions for improvement are presented .

- The size of the tank is not standardised. The height of the tank is above 1.2 meters
- The depth makes difficult for the labourers to turn the waste. So no turning happens
- Mostly anaerobic conditions only prevail below the lop layers
- No understanding of the c/n ratio or what to add to maintain c/n ratio of 25
- The waste is crushed and mixed with jaggery and saw dust and found to have high moisture content . This adds to the cost.
- There is no propoer arrangement to drain the leachate. The leachate is found to be leaking from the tanks

Modifications suggested

- Eucating thehe operators about right mix of ingrediants commonly available to maintain c/n ratio
- Low cost fillers like coir pith and corn cobs / sugarcane refuse can replace saw dust
- The aeration inside the tank has to be improved. By mechanical methods
- Compost quality should be monitored before packaging
- Leachate should be minimized by drying .
- Proper leachate system should be designed and installed

Status of composting yards of GCC

Low Cost Composting units using Tyres for urban and rural housholds

The composting unit was built using used tyres. The rim of the tyres are cut to make them more annular and piled one above the other as shown in the pictures. The base is prepared by placing a PVC banner on the ground to prevent any leachate penetration into the soil. The first tyre is laid on it. A rigid PVC mesh is placed on it followed by a un bleached cotton sheet which filters the leachate coming from the above layers. A layer of fibrous material like coconut coir is laid on the cloth filter followed by alternate layers of leaves and solid waste (fruits and vegetables kitchen refuse) . We need to ensure that enough fibrous materials like corn corbs/ squeezed sugarcane/ banana stem / saw dust/ coconut coir pith is mixed in with the solid waste. This is required for maintaining the adequate C/N ratio and providing moisture absorbance and aeration of waste. It has many advantages over the Micro Composting plants.

- Easy to construct a bin wherever required.
- Less time and cost for construction.
- Easy to turn the waste by just pulling the tyres out
- Enables aerate the waste by reversing the order
- Modular construction by increasing number of tyres stacked.

IITMadras Trials

Step 1: Placing the bottom tyre over an impermeable membrane and covering the tyre with an mesh.

Step 2. A permeable cotton cloth is spread over the mesh. The leachate will be collected from the bottom tyre

Step 3
The other tyres are placed one over other. The topmost tyre is covered with the lid or impermeable membrane to prevent the rainfall from entering.

Step 4:The waste is placed in layers of dry leaves and kitchen waste and filling Material like corncobs/ saw dust/ cocunt coir pith with soil / old compost

Composting using Black Soldier Fly Larvae

Using black soldier fly is a very effective way of converting all these organic wastes to valuable compost not only because of its efficiency, which is close to 95% but also because of the short time in which it is done. Additionally, the process is odourless as it does not involve the emission of methane or other greenhouse gases. A training session on the black soldier fly was undertaken at the ICAR – National Bureau of Agricultural Insect Resources, Bangalore to implement it at IIT Madras.

Black Soldier Fly (BSF):

BSF can cope with a range of temperature (25-30 °C) and humidity (30 – 90%) allowing it to survive in a range of environmental conditions. BSF larvae feed on the organic wastes and convert the waste to nutrient-rich residue, in the process it grows into protein-rich biomass, which can be fed as feed to poultry and fish farming. The nutrient-rich compost can be used as a soil conditioner for improving soil quality and thereby leading to enhanced vegetation. BSF is known scientifically as Hermetia illucens belonging to the family of Stratiomyidae. It uses only a single pair of wings to fly so it belongs to the Diptera order. The larvae have a single tube that runs through the body from the mouth to the back of the larvae, the adults do not have any mouthparts and they do not transmit any diseases making it safe to handle them. The adults are black in colour with a translucent white abdomen and black legs with white tarsi. Both the male and female have a small sharp-like structure at the bottom of their body with the female having a slightly larger protrusion that helps lay eggs.

Training:

The training at ICAR – National Bureau of Agricultural Insect Resources conducted by Senior Scientist Dr. Mahesh involved the handling, feeding, and maintenance of optimum environment for BSF. The biology of the fly is important to understand the way they behave in the environment; the following points discuss the biology of the BSF.

Lifecycle:

Adult; They are similar to wasps in appearance and they do not feed at this stage and do not transmit any disease as they do not have mouths or stingers to sting, however they need water as adults. Their life span is around 7 – 8 days. Eggs; Usually the eggs (yellow in colour) are laid in hundreds of numbers, on average 460 eggs are laid by a single fly. Eggs

are laid by adults in two days since their emergence. Larvae; After 4 -5 days the eggs hatcn and larvae start feeding waste in their surroundings, the larvae are a voracious feeder that has an appetite that makes them continuously feed for around 12 to 16 days after which it stops feeding completely. As this stage of feeding is the most important as larvae feed and changes waste to compost, the stage is split into 5 stages for classification. Black soldier fly has 5 instars as the larval phase. Each instar stage every three days totaling the larvae days to around 15 days on average. Larvae have a small black dot at their head through which the larvae feeds, it starts as 1mm larvae (white) and could reach up to 27 mm larvae (half white to light brown) in length and 6 mm in width. Pupa; At this stage, the larvae become dark coloured and it undergoes a dormant stage with no movement for 16 to 24 days depending on the environmental conditions. The adult emerges after this period and reproduces in two to three days from its emergence and thereby the cycle continues.

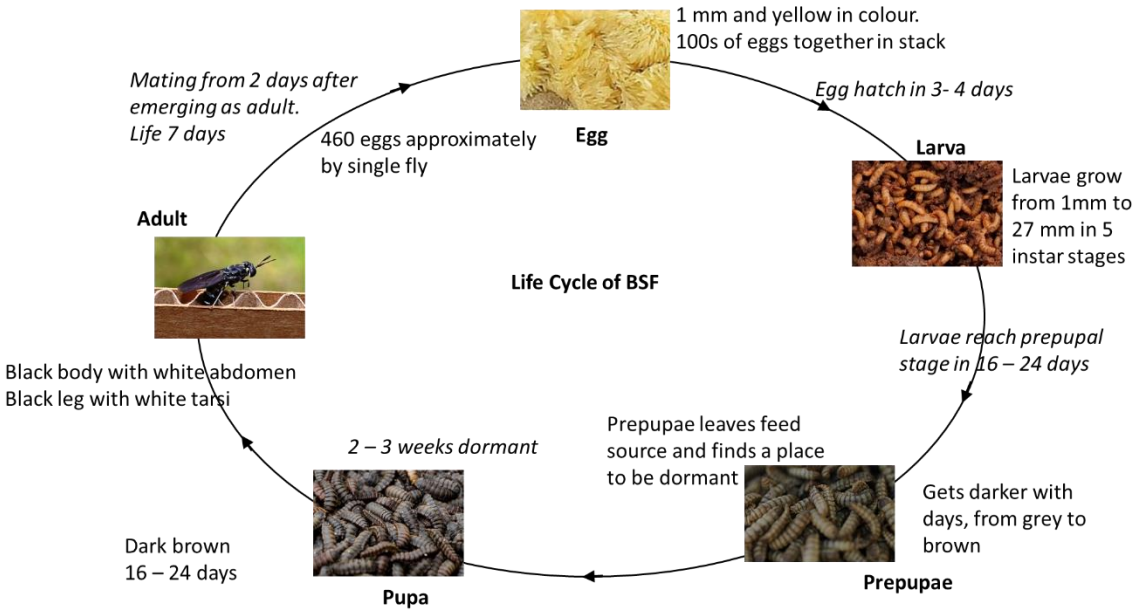

Figure 1: Black Soldier Fly lifecycle

Optimum environmental Conditions:

Black soldier flies are most efficient when the temperature is around 27°C. It is observed that at this temperature larvae, pupa and adults have better longevity. The relative humidity is also an important parameter that decides the survival of eggs as well as adults. Eggs cannot

survive in dry conditions as low humidity leads to water loss through egg membranes. In the case of adults, adults need a humid environment to produce offspring so a humidity of 30 – 90% is required.

Diet:

The adult BSF fly does not consume any food as it has enough fat stored from the larval stage and only requires water. For diet for larvae includes all types of organic waste at a 40-50% moisture level, the feed should not be a slurry, it needs to be solid with moisture for larvae to travel up and down in the feed source. It acts in a similar way benthic organisms consume food at sediment sites in water bodies; mixing the sediment up and down making them fluffy. The nature of substrate, nutrient composition, texture, and moisture content plays a role in which how food is consumed by larvae. Food rich in carbohydrates is preferred to be fed if compost is expected in few days, protein-rich food though can be consumed by larvae it takes more time and sometimes could lead to a reduction in larvae number if the acidity of the substrate increases.

Rearing of BSF:

Based on the training from the ICAR institute, a setup comprising a 60L bucket padded with mesh to hold substrate and provision for leachate collection was fabricated as shown in figure 2. The setup consists of a tube placed at a 30-degree angle from inside to the outside of the bucket. This arrangement is to help larvae that have turned to the prepupae stage and searching for a place to remain dormant during the pupa stage. The tube has multiple openings cut for larvae to enter, the tube begins from inside of the bucket and ends at the pupa collection jar where pupa remains dormant. A mesh fabricated with plastic support is placed at the bottom of the bucket on which substrate will be added. The gap between the mesh and the bottom of the bucket is around 10 cm, this gap provides space for excess water in the substrate to be drained and hold. A tap provision is added at the bottom of the bucket to remove and collect this water/leachate.

Figure 2: Bucket design system for BSF rearing fabricated at IIT Madras.

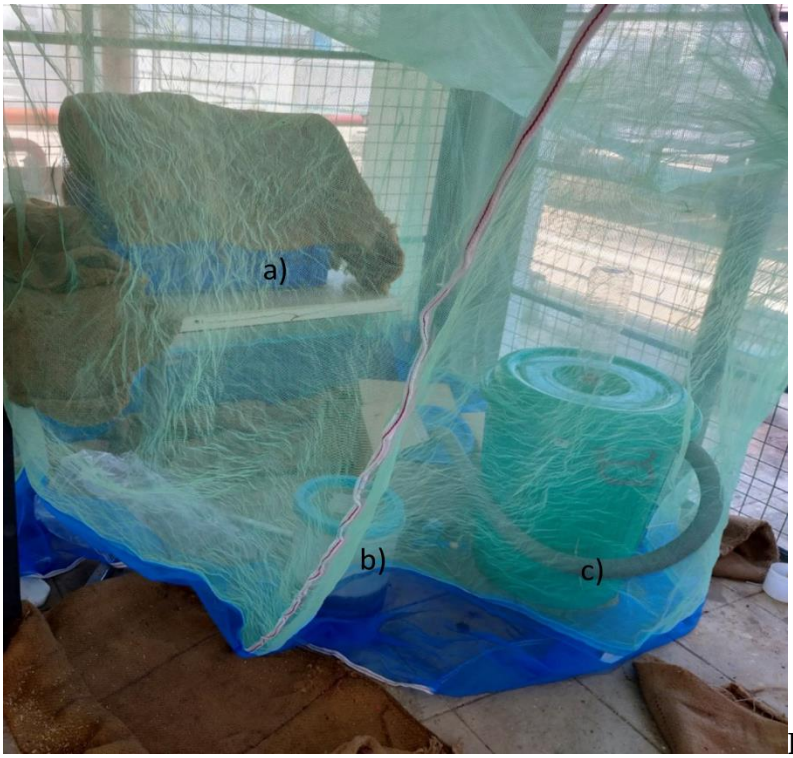

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Figure 3: Current system a) a tray system, b) plastic box, c) bucket design system enclosed in a mosquito net.

To test larvae efficiency on different types of feed, the larvae obtained from ICAR are spııt into three sections. Two sections are fed with bajra flour which the larvae convert to compost in the shortest time around 4 - 6 days, the third section is fed with vegetables which larvae takes around 10 days approximately to convert to compost. Figure 3. Show the current setup which has three sections, a tray system, a plastic box, and a bucket design system enclosed in a mosquito net. Figure 4 shows the BSF fly that emerged after 40 days from larvae stage at the ED building, IIT Madras.

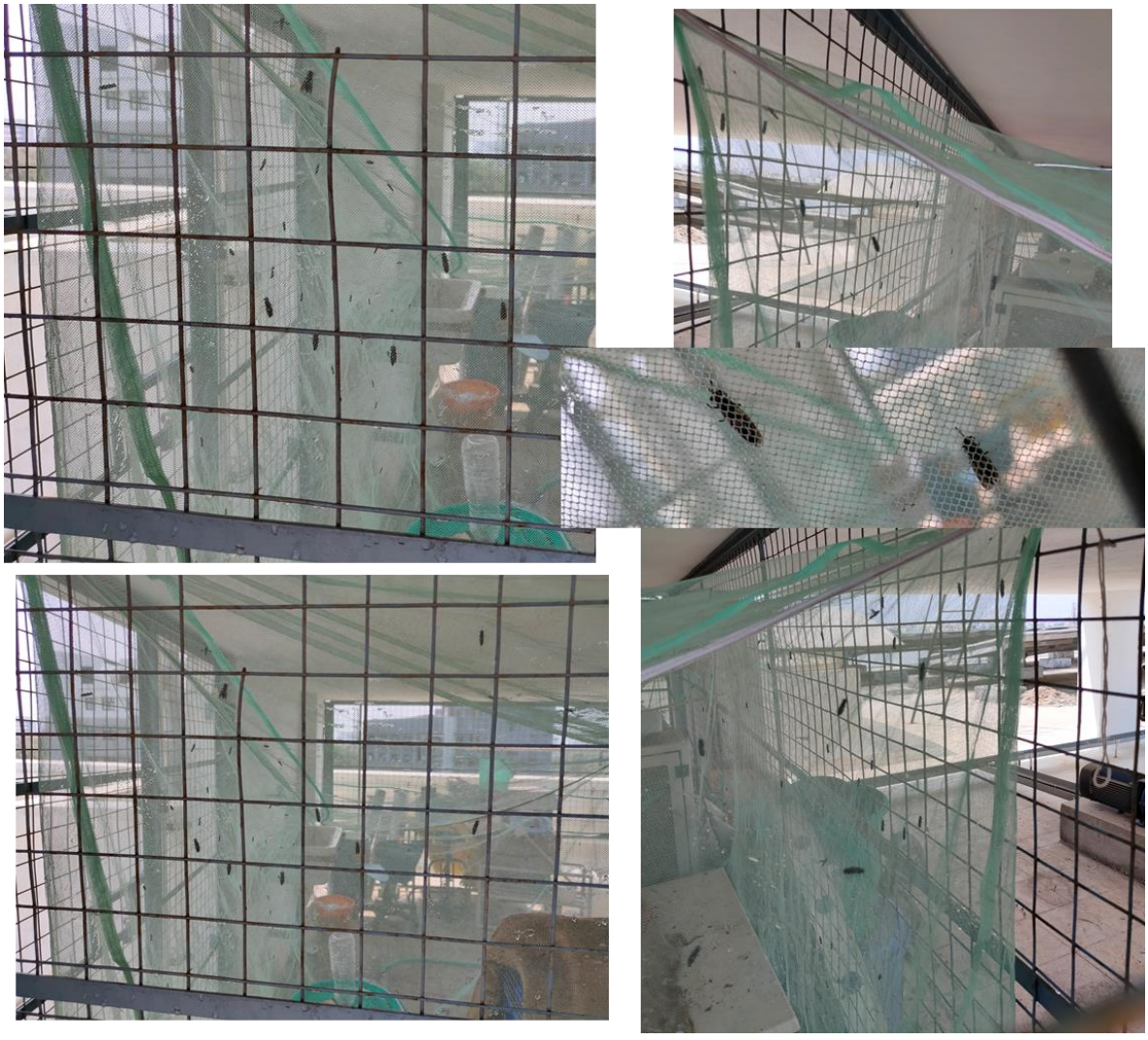

Figure 4: Black soldier fly larvae and flies at the terrace of Engineering Design building, IIT Madras.

Reproduction of BSF:

To grow BSF exponentially, it is important to provide it with suitable environmental conditions. The importance of lighting in reproduction BSF should not be undermined, several researchers have pointed out that lightings play a huge role in the reproduction of BSFs. To achieve this LED lights of wavelengths corresponding to 300nm to 650nm are used when BSFs are grown indoors. Even for the outdoors, LED lights are recommended for better productivity during the night.

To maintain moisture level at the rearing site, humidity probes that trigger water sprayer when levels are low is recommended. LED lights can also be set with a control panel to switch on automatically during the evening when enough lumens are not registered in the sensors. Artificial plants or real plants in pots should be placed around the BSF cabin for the flies to rest, additionally, it also gives BSF a sense of being in the natural environment.

Placing cartons and woods is essential as the BSF flies prefer to lay their eggs in crevices. Usually in the wild, the broken wooden logs and folding in leaves are preferred by the flies, so in the artificial cabins, wooden blocks are kept together to make crevices that the flies could use. Also, recently people have started using cut pieces of cartons (commercial cardboard boxes) instead of wooden blocks as this works better than wooden blocks. The success of mating is 30% for BSF. Once a batch of larvae is used for treating organic waste, it is recommended that at least 30% of the larvae are allowed to reach the adult stage for further reproduction while 70% can be used as feed to poultry.

Figure 5. Growing BSF Larvae in IITM

Once eggs are laid, they are transferred to small boxes by scraping them from cartons or wooden blocks with good care. The small boxes must contain carbohydrate-rich substrate such as flours. After 4 – 5 days the eggs (1 mm) hatch and start consuming the carbohydrate feed and start growing. Once the egg has reached 3-4mm in length it is then transferred to the bucket system for consuming organic food waste. If the organic waste is very hard, then it needs to be shredded before it is fed to larvae, also if it is dry, water should be added to increase the moisture content to around 50%.

Best Practice:

To have a successful BSF system, the tray method is strongly suggested. The tray system uses a separate tray for each larvae stage. A larvae stage is decided either based on the size of the larvae or based on the number of days from the day egg hatched. The tray system helps keep track of day to production and helps segregate larvae and help collect larvae for poultry feeding at the right time and prepupae to nurture to fly stage for further production at the right time.

Advantages of BSF:

Apart from the fact that it is very helpful in handling the food waste problem, there are several other advantages to BSF. BSF reproduce at a much higher rate and have less lifespan, they are packed with protein-rich fat which is full of energy, they are easy to farm and they harvest themselves with little effort from us, and the most important advantage is the production of compost that is an excellent fertilizer when compared to the product of other forms of compost.

Conclusion:

The training at the ICAR – National Bureau of Agricultural Insect Resources, Bangalore helped in setting up a BSF unit at the terrace of ED building, IIT Madras. The rigorous training helped us understand the Black soldier fly and the way it has to be farmed to treat food waste and recover valuable compost out of it. BSF has emerged out from the larvae stage to flies in the current setup by consuming vegetable waste and different types of flour, in the coming days reproduction and an exponential increase in its population is expected.

Task 5 : In- vessel composting Design and Fabrication

After extensive literature review and survey of several products in the market, a novel invessel composting has been designed. The advantage of this invessel composting unit are

1. Hands free mixing , no exposure to labourers
2. Odour reduction
3. Uniform aeration
4. Faster composting

The in-vessel composter has been designed with significant improvements to what is available in the market. The new features are compartmentalization for weekly/ daily loads, aeration slots, motorized tumbling , leachate and gas collection, and slots for monitoring probes.

The work order has been issued and fabrication will be completed in 30 days. Meanwhile, a small market available tumbling composter is also being modified and tested with the optimized conditions determined from trials.

Invessel Composter with individual compartments (In Fabrication)

Market available Tumbling composter

Quality of Compost:

The important step in composting is to assess if the compost is ready and fit to be applied on to plants. C/N ratio and stability of compost has to be decided before we package it. Often temperature and moisture are not monitored to make sure the pathogens are killed by elevating temperature for a few days. Plans to develop a simple sensors and control unit for tumbling is under way .

Conclusions and Way Forward

The optimised conditions of mixing and aeration based on the trials in the lab will be adopted in the tumbling composter and the In- vessel composter after the fabrication is complete. Modifications of the same will be suggested for developing a second prototype.
Sensors have to be developed and placed in the composter for continuous monitoring

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To

Professor Srinivasa Chakravarthy

Coordinator – Social Responsibility Projects

Department of Biotechnology

IIT Madras

Chennai 600036

17th March, 2021

Dear Sir,

Ref.: End Term Report for SRP reference No.: SP/19-20/608/**SRP**X/005021

Please find enclosed the endterm report for the above referenced project titled

"**Potent, Economical And Agro-Waste Based Adsorbent Filter; Developed in-house To Treat Textiles Dyeing Units Effluents in Villages"**

If you require any further details please inform me.

Thanks.

Sincerely

Dr. Kannan A.
Coordinator

Dr. T. Renganathan
Co-cordinator

Encl.: a) Midterm Report b) Statement of expenditure

2. "Potent, Economical And Agro-Waste Basaed Adsorbent Filter; Developed ... Treat Textiles Dyeing Units Effluents in Villages"

The objectives of the project, were to understand the ground realities in a nearby village where dyeing effluents disposal is a problem taking the help of an NGO. After analyzing the water quality, a methodology has to be developed for pretreating the water before sending it into an adsorbent filter. The adsorbent's capacity for simultaneously taking different dyes had to be estimated and the physicochemical properties of the adsorbent were to be characterized. The ultimate aim is to implement the technology in the village and disseminate the application, maintenance and reuse of the filter. Data collected may be used for scaling up the process.

At the midterm, the progress of activities are summarized as follows

a) Project coordinator (Dr. Kannan A), co-coordinator (Dr. T. Renganathan) visited Kanchipuram to get firsthand view of the situation. Accompanied by an NGO representative from NEEDS, we visited a typical fabric coloring unit and a dye plant and observed the processes and nature of effluents. Also visited Weavers Service Center to talk to officials on the problems in the locality.
b) A few common dye samples that were commonly used on textiles were procured at Kanchipuram
c) Due to intermittent showers, water sample collection had to be delayed to avoid dilution effects
d) The dyes procured were analyzed with uv-vis. We also tested dyes such as acid orange 10, acid blue, reactive orange 16 which are used for coloring textiles
e) Simultaneous removal rates with different adsorbents were investigated at different conditions – pH, temperature, initial concentration and different types of activated carbons
f) Point of zero charge was also estimated for the adsorbent
g) Adsorbent capacities for different dyes were measured and suitable isotherms were developed
h) A small continuously operating adsorbent filter was developed in-house to study the adsorbent removal capacities for different dyes. It has been made operational and results on breakthrough curve have been collected.

The future plans proposed at the time of submission of midterm report were

a) Analyze actual water samples collected from Kanchipuram locality for dissolved ions
b) Devise pretreatment operations to remove non-dye related ions from water before treating the dye containing effluents in the filter
c) Show videos of the process to sensitize suitable small scale dyeing plant owners in Kanchipuram and discuss possible measures to adopt the technology for their units.

The progress subsequent to the submission of midterm report is as follows

a) Two interns were hired to work on this project (from November 2020)
b) For trial runs, IITM water was used for preliminary pretreatment and adsorption studies
c) IITM water was found to have low suspended matter

d) Surprisingly, chloride ions dissolved in water led to better removal of dyes using activa[illegible]
e) Pretreatment of the wastewater was carried out using alum and poly aluminum chloride flocculants. Both had tremendous effect in reducing the turbidity comprehensively
f) Improved activated carbon was generated by acid treatment of existing activated carbon
g) Batch studies were conducted to test the type of activated carbon on removal of dyes (acid orange and acid blue). Low pH and acid treated carbon led to best performance
h) Continuous column studies were conducted for single dyes (acid orange and acid blue) as well mixture of these two dyes. Acid treated carbon had significantly high breakthrough times indicating superior performance
i) Real wastes from Pallavaram tannery wastewater treatment facility and Kanchipuram dyeing unit were collected, the former easily and latter with great difficulty, and analyzed for their composition in a standard testing lab.
j) These samples were tested for color removal using activated carbon, with special emphasis on untreated carbon at natural pH. Since these compounds had a mixture of wastes, uv-vis method failed and COD analyzer was used instead for measuring concentrations. Breakthrough profiles in terms of COD were obtained.
k) Parallel studies revealed that addition of hypo (NaOCl) reduced substantially the amount of sludge and the supernatant liquid containing excess chlorine could be used to reduce further the dye and COD in the subsequent adsorption treatment unit. Further addition of hypo was found to substantially reduce the BOD as well.

Work yet to be done

a) Consultations are in progress with workshop technicians to prepare the water filter cartridge
b) An you-tube video will be created at the end of the project

Expenditure of Funds

As of now, Rs. 93,978 is left in balance (Table 1). After settling of commitments and payment of bills, the money left in project will be less than Rs. 8000/-.

Conclusions

Adsorption is a very effective treatment technique to spectacularly reduce the color of dye effluents as well as COD. However, for this treatment to be effective, proper pretreatment of the wastewater is critical. Innovative methods may be adopted to reduce the volume of sludge and use the resulting supernatant solution in further rapid detoxification of the wastewater.

Highlights

Figure 2. Simultaneous adsorption of two dyes (acid orange AO and acid blue AB) using untreated activated carbon (MAC)

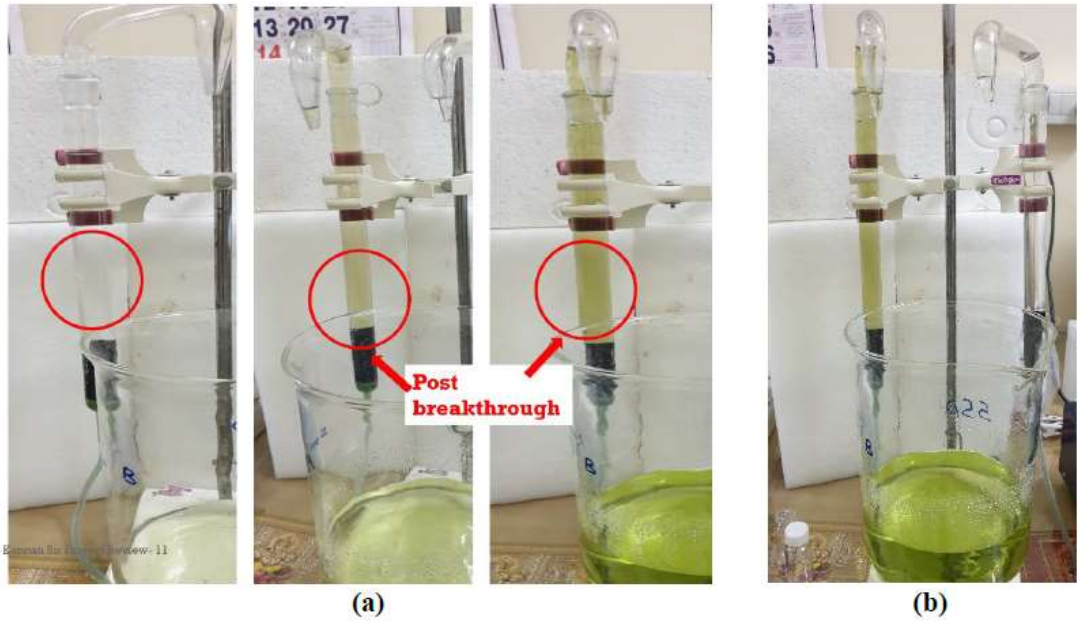


Figure 3. Color of effluent containing mixture of dyes before and after breakthrough (b) Comparative image of the untreated MAC column(left) and acid activated AAC column(right) after 8 h contact time. AAC shows clear solution even after 8 hours of operation

Figure 4. Flowsheet for treatment of Kanchipuram dye sample – (coagulation+flocculation) pretreatment, batch and continuous adsorption, post treatment (chlorination)

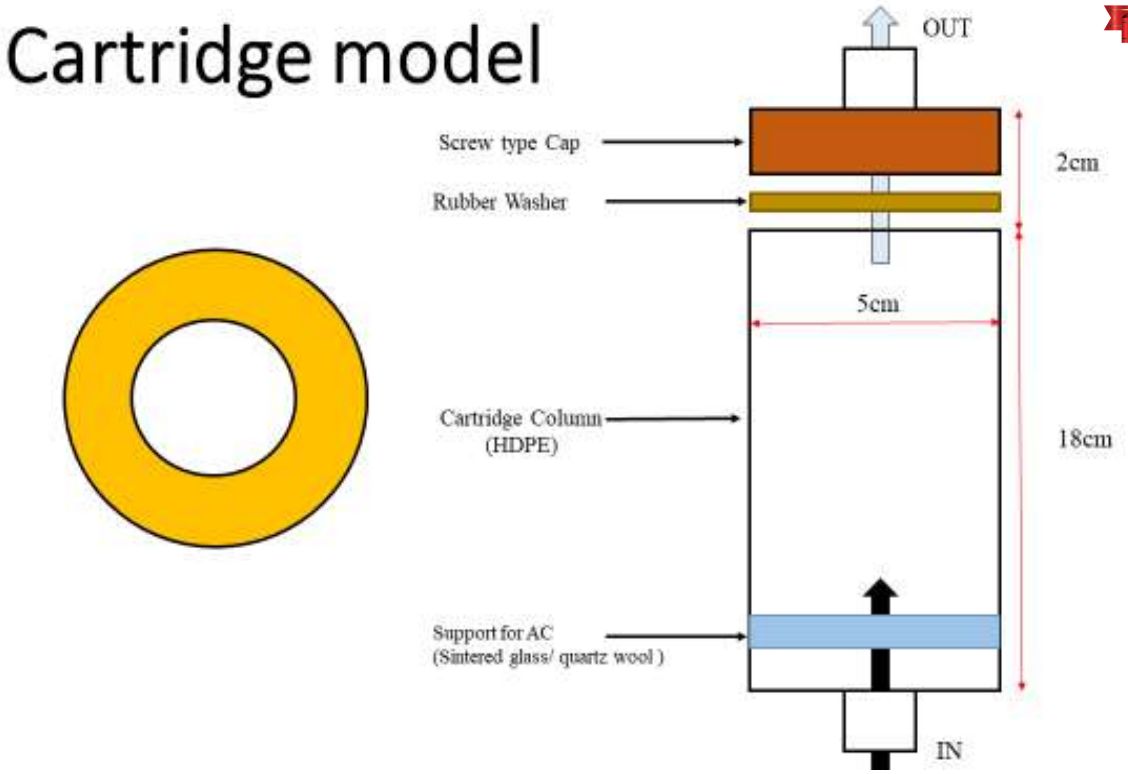


Figure 5. Proposed preliminary model for cartridge filter (design modifications are in progress)

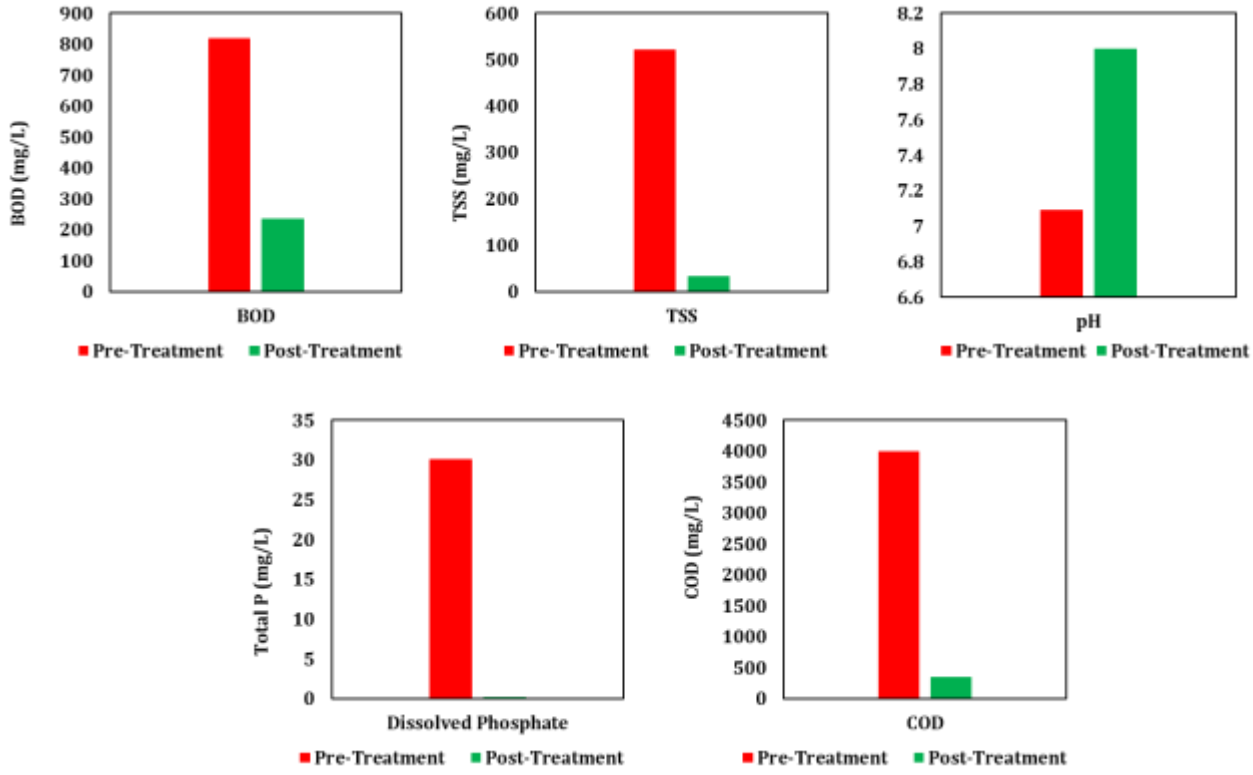
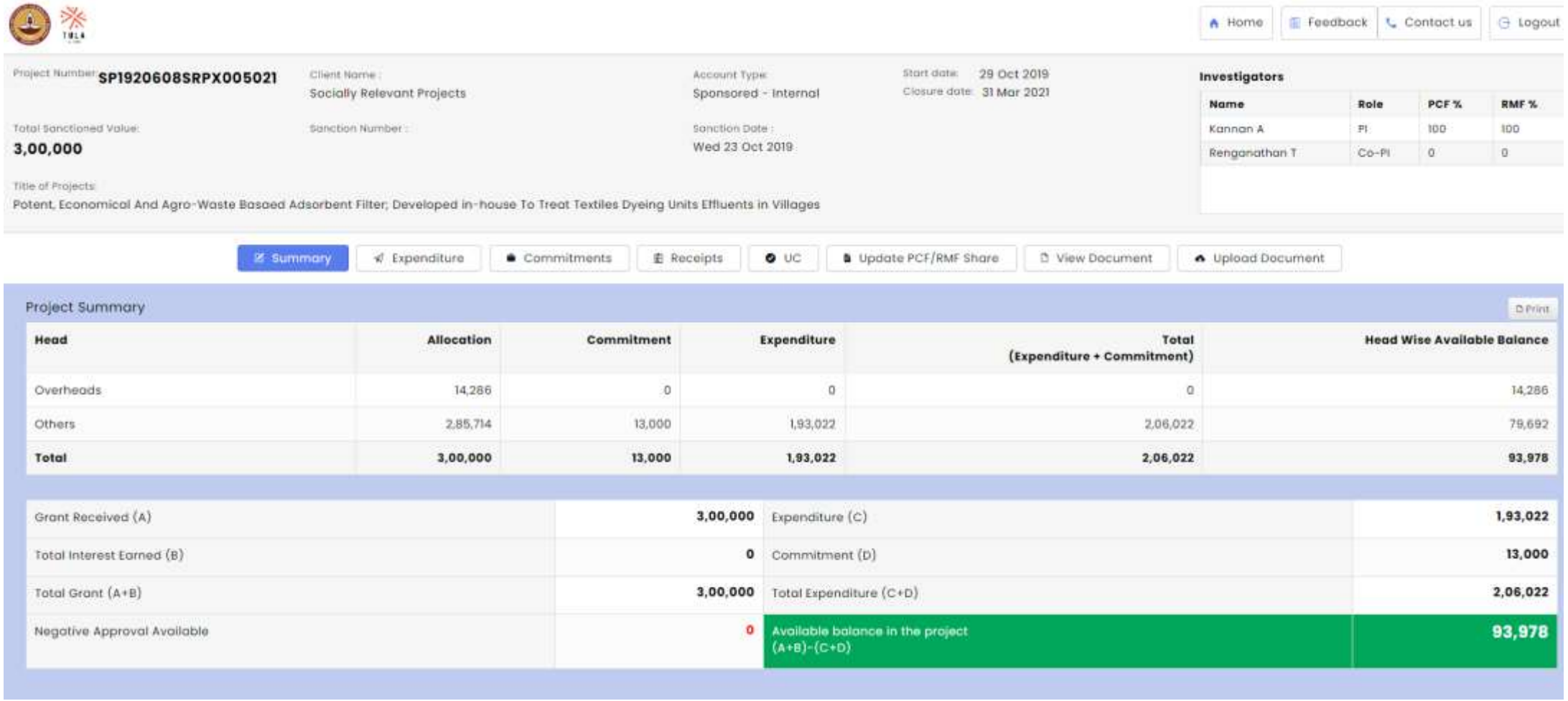


Figure 6. Bar diagrams representing the change in the values of various properties, pre and post treatment of Kanchipuram wastewater. It can be observed that a significant reduction in the COD, BOD, TSS and dissolved phosphates can be observed pre and post treatment which is extremely desirable. The increase in the pH of the solution is also a desirable outcome.

Table 1. Expenditure Summary



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Project Number: **SP1920608SRPX005021**
Client Name: Socially Relevant Projects
Account Type: Sponsored - Internal
Start date: 29 Oct 2019
Closure date: 31 Mar 2021

Total Sanctioned Value: **3,00,000**
Sanction Number:
Sanction Date: Wed 23 Oct 2019

Title of Projects:
Potent, Economical And Agro-Waste Based Adsorbent Filter; Developed in-house To Treat Textiles Dyeing Units Effluents in Villages

Investigators

Name	Role	PCF %	RMF %
Kannan A	PI	100	100
Renganathan T	Co-PI	0	0

Summary | Expenditure | Commitments | Receipts | UC | Update PCF/RMF Share | View Document | Upload Document

Project Summary — Print

Head	Allocation	Commitment	Expenditure	Total (Expenditure + Commitment)	Head Wise Available Balance
Overheads	14,286	0	0	0	14,286
Others	2,85,714	13,000	1,93,022	2,06,022	79,692
Total	**3,00,000**	**13,000**	**1,93,022**	**2,06,022**	**93,978**

Grant Received (A)	**3,00,000**	Expenditure (C)	**1,93,022**
Total Interest Earned (B)	**0**	Commitment (D)	**13,000**
Total Grant (A+B)	**3,00,000**	Total Expenditure (C+D)	**2,06,022**
Negative Approval Available	**0**	Available balance in the project (A+B)-(C+D)	**93,978**

3. Kidney Exchange – Models and Algorithms

(SP1920610SRPX008607)

Meghana Nasre, CSE, IIT Madras

March 24, 2021

Kidney Failure, also called End Stage Renal Disease (ESRD) is a condition that is not treatable. Patients with this condition have to resort to either dialysis at regular intervals or undergo a one-time kidney transplant. Much like blood donation, a patient can receive kidney from donors who are "mutually compatible" with him/her. However, when the donor (typically a close relative) is incompatible, one needs to look at another patient-donor incompatible pair and facilitate a *kidney exchange*.

The current project involves investigating the challenges in Kidney Exchange and the use of software based systems to enable certain components. The tasks are divided into three parts – meeting and discussing with Nephrologists, investigating the notions of optimality to suit the Indian context, and building a working prototype as a proof of concept.

Work done till June 2020 (MidTerm Report was submitted in June 2020)

- We have developed a back-end which allows us to represent Patient Donor pairs and their properties in a particular file format called the JSON file format. Using this format we have implemented known cycle based linear programming algorithms which give candidate matches for the input data. The implementation has 3 optimization parameters and is able to clear a pool of about 75 patient donor pairs in reasonable time – we are working on identifying and fixing the bottlenecks to speed this up. However, we do not expect the pool of patient donor pairs to be huge in practice.

Work done till March 2021

- The front-end portal along with the database implementation has been completed. The front-end portal enables patient-donor pairs to be entered with the data entries being validated. The portal also allows multiple hospitals to have registered admins / transplant co-ordinators. The front-end part of this portal has been developed closely with our consultant Nephrologist from Mehta Hospital.
- The portal provides a functionality to find a match for a given patient donor pair (called as pairwise match) and also an overall match (called as global match) based on a selection of criteria. This part uses the backend code developed in the first part of the project and there are a few integration issues that we are ironing out.
- A working prototype can be found at this link.
  Login and Password are: admin1, kep1 respectively. One can view the (dummy) patients summary using Data → Summary from the portal Menus.

Fund Utilization:

- One project staff for 5 months (Jan 15, 2020 – June 15, 2020): Rs. 21,500 per month = Rs. 1,07500.
- One student intern for 6 months (July 2020 – Dec 2020): Rs. 10,000 per month = Rs. 60,000.

Tasks to be completed in the upcoming months

- Obtain real patient donor data with which we can test the effectiveness of the scoring functions that we are using. We are working towards it.
- Based on the Indian aspects, fine-tune the scoring functions on the edges which determine the *goodness* of the match.
- Testing and improving the user interface for the portal especially for the Match menu.

4. Energy Generation Using VAWT-Focus On Incorporating Modular Design And Low rpm Generation

Objective:

- To build the Savonius turbine using modular design concept
- To obtain the relation between wind velocity (m/s) and turbine speed (rpm)
- To obtain the relation between turbine speed (rpm) and torque on the rotor (Nm)

Design of Savonius turbine:

Projections of assembled savonius turbine depicted in Figure1

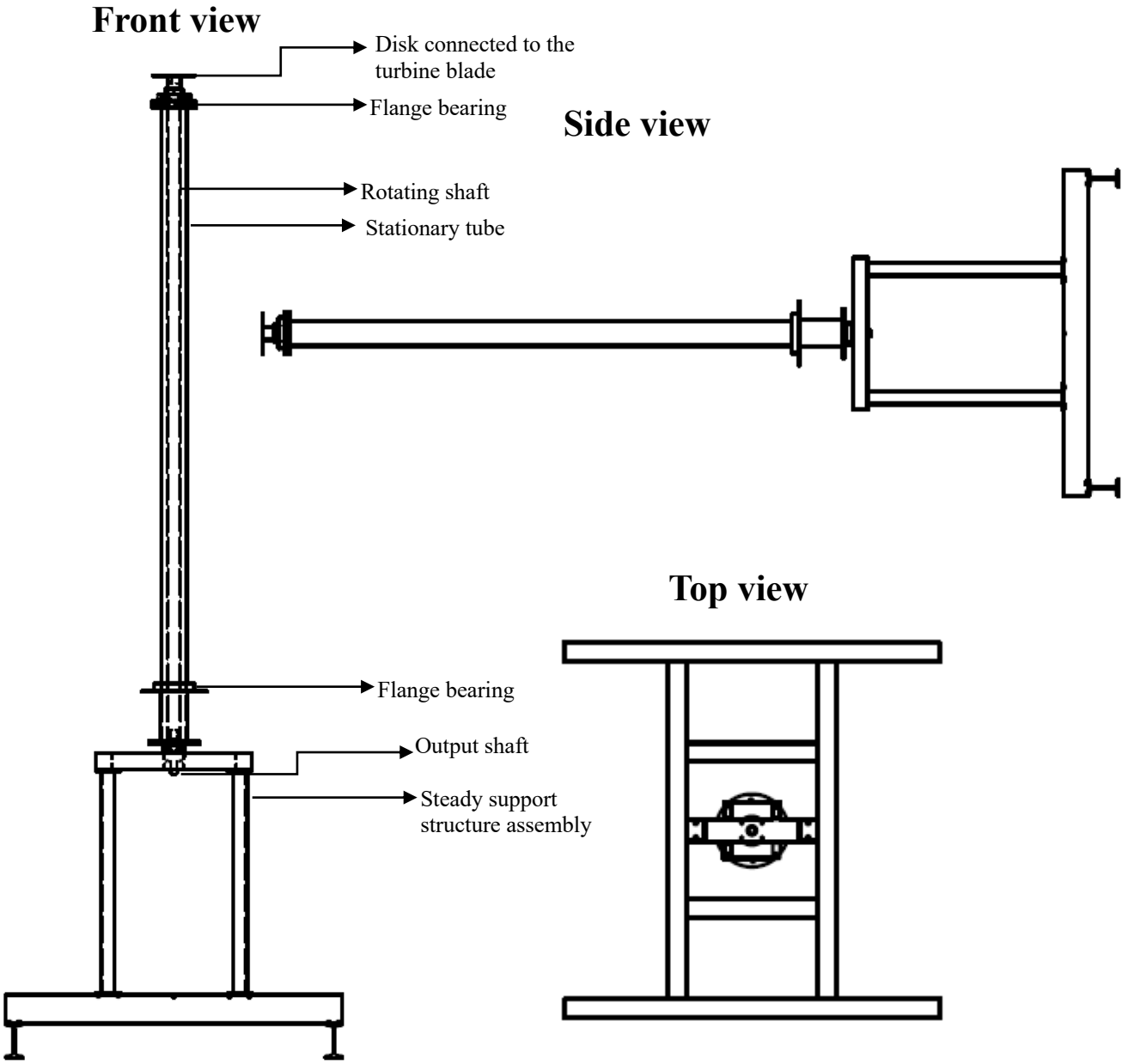


Figure 1. CAD modeling of savonius turbine assembly

Machined parts of Savonius turbine:

Some of the machined components of savonius turbine are shown in Figure 2.

Laser cutting

Bearing housing

Bush

Square tube

L angle

Figure 2. Picture of machined component

Table 1: Expenses for the manufacturing of Savonius turbine

Job/material	**Price (Rs.)**
Structural Material	9007
Fabrication	11163
Bearings	2940
Fasteners	1457
Paint and thinner	200
Plastic barrel	2124
Grant total	**26891**

Total expenditure spent on material and fabrications are tabulated in Table 1 and the individual split up of expenses is attached in the end of the report for reference.

Savonius turbine final assembly:

Assembly without turbine blade **Final assembly**

Figure 3: Final assembly of savonius turbine

Data logger:

- Proximity sensor used to get the rpm of the turbine blade by measuring pulse per rotation.
- Anemometer used to get the wind velocity

The data logger was set to measure the wind speed and rotor rpm with a time frequency of 5 sec. Once the data was obtained which is presented in Table 2, a regression equation was fit to the data as shown in Figure 4. This equation can be used to find rpm for any wind velocity.

Table 2: *Wind speed and rotor rpm (data logger reading)*

Data sorted as maximum rpm corresponds to the maximum wind velocity from the data		**Regression model**	
Wind velocity m/s	**Turbine speed rpm**	**wind velocity m/s**	**Turbine speed rpm**
2.88	36	2.1	28
4.74	60	2.4	34
3.36	60	2.7	39
3.54	60	3	44
4.14	60	3.3	49
4.68	84	3.6	55
5.1	72	3.9	60
4.32	72	4.2	65
5.76	96	4.5	71
4.38	60	4.8	76
5.88	108	5.1	81
4.68	84	5.4	86
5.88	84	5.7	92
2.64	36	6	97
3.66	60	6.3	102
3.06	48	6.6	107
3.96	48	6.9	113
4.38	72	7.2	118

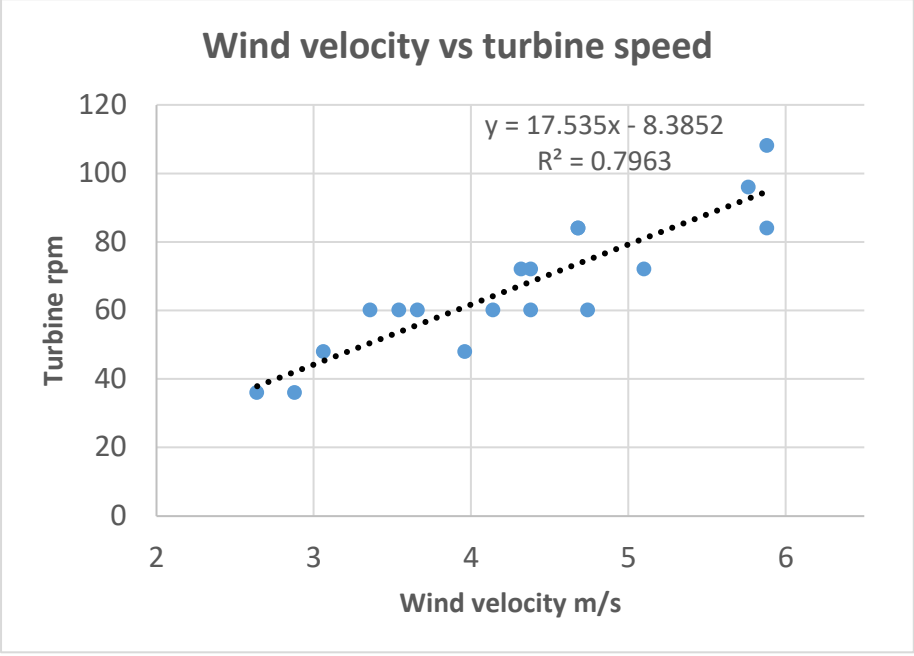


Figure 4: *Curve fitting to data in* Table 2

Theoretical power calculation of turbine rotor:

Theoretical power of turbine rotor is usually calculated using Betz law[1]. Betz power in Watts is expressed in Eq.1.

$$P_s = 1/2 C_p \rho A v^3 = 0.36 h D v^3 \quad (1)$$

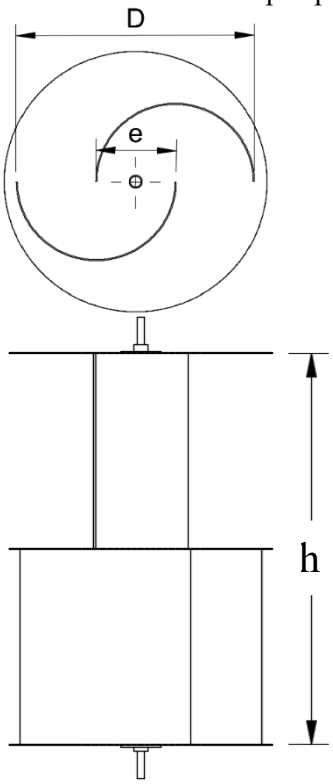
Where, C_p (=0.593) is Betz coefficient, ρ (=1.2 Kg/m^3) is density of air, A =$h \times D$ m^2, h is height of blades, D is wing spread of rotor, and v is wind speed
We consider the aerodynamic and mechanical losses to be 50%. Then, the Betz power in Watts is

$$P_s = 0.18 h D v^3 \quad (2)$$

Torque can be expressed as:

$$T_s = P_s / \omega \text{ Nm} \quad (3)$$

Where, $\omega = \frac{2\pi N}{60}$ is the angular velocity of the rotor, N is rotor speed. Usually, ω is computed theoretically from the tip speed ratio but here, we use the rpm data directly to compute ω and the results are presented in Table 3.The current turbine set up is presented in Figure 5. h = 1.76 m and D = 0.854 m



e → Overlap ratio
D → Wing spread of rotor
h → Height of blades

Figure 5: *Basic sketch of Savonius rotor*

[1] *http://kho.unis.no/doc/Savonius_windrotor_basics.pdf*

The results from the above equations are presented in Table 3

Table 3: *Turbine shaft power corresponds to wind velocity*

Velocity	**Rotor speed**	**Angular velocity of rotor**	**Theoretical power on rotor shaft**	**Torque on rotor**
m/s	**rpm**	**rad/s**	**Watts**	**Nm**
v	***N***	ω	P_s	***T***
3	44	4.63	7.30	1.58
3.3	49	5.18	9.72	1.88
3.6	55	5.73	12.62	2.20
3.9	60	6.28	16.05	2.56
4.2	65	6.83	20.04	2.93
4.5	71	7.38	24.65	3.34
4.8	76	7.93	29.92	3.77
5.1	81	8.48	35.89	4.23
5.4	86	9.03	42.60	4.72
5.7	92	9.58	50.10	5.23
6	97	10.13	58.44	5.77
6.3	102	10.68	67.65	6.33
6.6	107	11.24	77.78	6.92
6.9	113	11.79	88.88	7.54
7.2	118	12.34	100.98	8.19

Relationship between rotor speed and torque on rotor is plotted as in Figure 6.

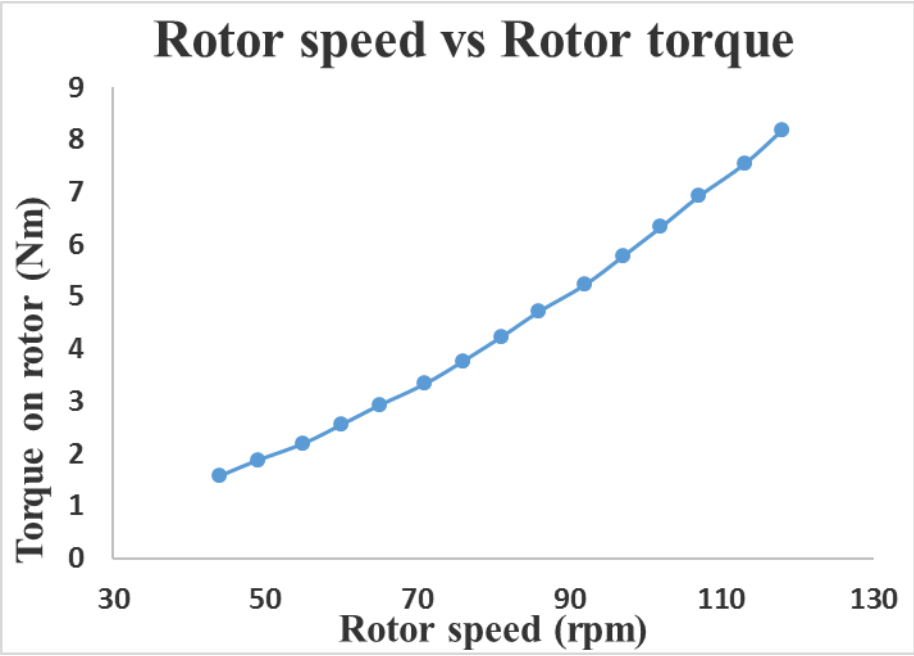


Figure 6: *Curve fitting between rotor speed and torque on rotor*

Grant Received	**3,00,000**
Salary (Jan- Nov 2020)	**2,82,915**
Materials reimbursement	**2,787**
Total	**2,85,702**
Overheads	**14,286**

Individual split up of total expenses (supported through department funds)

Material	Price (Rs.)
4mm thickness sheet	600
L channel and square tube	1000
Bar material for bearing housing	200
Circular rod for connecting shaft	250
I angle	2034
Square tube	170
C channel	140
M.S pipe	222
Square tube	104
L angle for blade assembly	520
Aluminium pipe 38mm OD 2m length	1400
M.S pipe 63mm OD 2m length	916.5
Total sum	7556.5
Total (Including GST)	8916.67
Circular plate (No GST included)	90
Total	**9006.67**

Fasteners	Price (Rs.)
Nut and bolt	240
Handsaw and cutter	55
Bolts, nuts, spanner and Allen key set	862.67
Bolts and Nuts	77
Total	1234.67
Total	**1456.9106**

Bearing	Price (Rs.)
Flange bearing 40mm id and emery cloth	436.45
63mm id flange type bearing	1400

Fabrication work	Price (Rs.)
Laser cutting of sheet	1000
Labour charge for milling	850
Labour charge for welding	750
Milling work of bearing housing	350
TIG welding of L angle	150
Turning work of shaft	430
Gas cutting	500
Facing milling and drilling	3500
Welding	600
Gas cutting of square tube	45
Welding of Circular base joint	200
Machining work of circular tube	900
Cutting	100
Total sum	9375
Total (Including GST)	11062.5
Gas cutting (No GST included)	100
Total	**11162.5**

Paint	Price (Rs.)
Primer paint and thinner	170
Total	**200**

Plastic barrel	**2124**

Roller bearing 42mm* 20mm	180
Bearing	475
Total	2491.45
Total (Including GST)	**2939.911**

5. HomoSEP: Robot for Homogenization Of Contents And Cleaning Of Septic Tanks

October 2019 – March 2021

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IIT Madras, Chennai, TN, India; email: prajagopal@iitm.ac.in

Executive Summary: This report presents the results of detailed simulations carried out for various subsystems to understand the functionality, reliability, performance and safety of the HomoSEP robot. Developments in regard to the HomoSEP robot are presented in this Report, the key aspects are: (a) development of a synthetic sludge (b) novel dual-blade mechanism for better homogenization. For the purpose of Laboratory trials, the improved HomoSEP robot was tested in a Laboratory set-up with synthetic sludge, and superior homogenization was demonstrated. For Mock-up purposes, a quantity of cow-dung was procured as a means of mimicking human fecal sludge, and the miniature tank was filled with it: again, an improved HomoSEP robot was tested in a Laboratory set-up with synthetic sludge, and superior homogenization was demonstrated.

Technical Summary: HomoSEP consists of three main components, namely the Inset, (blades, inverted umbrella mechanism), Feeder (feeder system, portable system), and Control (remote controller, camera, sensors, etc.) Modules. Multiple blades (0.3 m in diameter, 0.05 m in thickness) were custom-designed by our team for 200 W of power, 5 Nm of torque, 40-60 RPM for homogenizing hard sludge with water. Electromechanical actuator with RF system is provided in the Inverted Umbrella Module shaft for opening and closing blades with a load of 38N, with a stroke length of 0.095 m. Telescopic shaft with parallel actuators is provided for the mixing of sludge by blades at high depths of Septic Tanks capable of holding a load of 347N with a stroke length of 0.2 m. Onboard cameras together with LED lights provide for monitoring the mixing of tank contents. Rheometer (Parallel Plate) and Displacement Volume Method is used to measure the viscosity and density of the different sludge samples. This test helps us to choose the desired synthetic sludge (Psyllium-Yeast) for testing in our laboratory.

The associated theory and test procedure for our sludge homogenization with water in a tank with HomoSEP robot experimental studies are explained. The Psyllium-Yeast and Cow Dung sludge tests were performed. We find the Multi Pitch Blade is capable of mixing viscous fluids like sludge with water while rotating at 60 RPM and 5 Nm of torque. The flow pattern of the fluid mixture is the same for Psyllium-Yeast and cow dung sludge, but the discrepancy is the time needed for the homogenizing mixture. Cow dung sludge is harder than Psyllium-Yeast sludge, which is why it took more than 15-20 minutes to completely homogenize with water.

1 Simulations

1.a Computational Fluid Dynamics (CFD) simulations of blades

We have performed extensive simulation studies, in order to obtain optimal profiles for the blades of the HomoSEP robot. The properties used for the Computational Fluid Dynamics (CFD) simulations (volume of fraction method in multiphase mixing, K-omega explicit turbulence) are given in Table 4 below, with fluids as sludge (red) and water (blue). Based on our analysis and as shown in Fig. 1 below, the 'Dual Blade' configuration seems to be the optimal design.

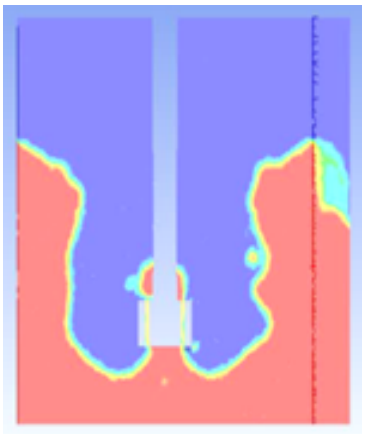
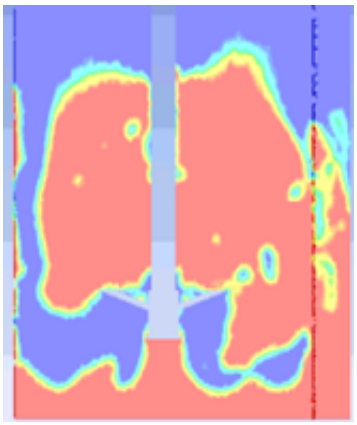
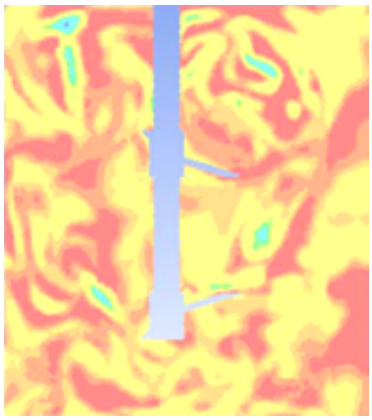
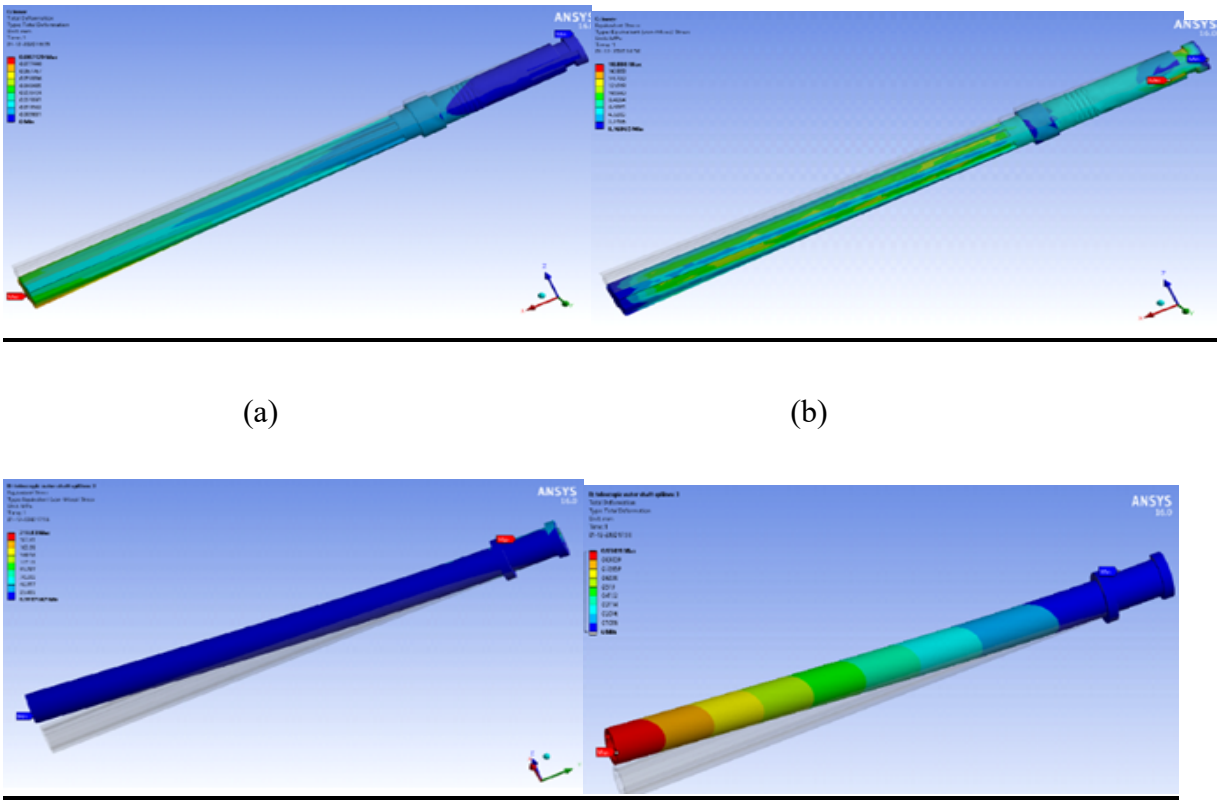
Flat blade	Pitched blade	**Dual Blade**
		
Radial flow patterns	Axial flow patterns	**Combination of two-blade offset to each other generating mixing of fluids**

Fig. 1: CFD simulation results showing flow patterns for various blade designs

1.b Finite Element Analysis (FEA) simulations of feeding system

The feeder mechanism is used to provide vertical motion along with the transmission of the torque to the inverted umbrella mechanism. We performed some simulation order to verify the capacity of the splines to withstand force and torque, convert the total torque acting on the shaft to force, and divide this force evenly on the faces of the splines, as shown below in Figure 2.



(a) (b)

(c) (d)

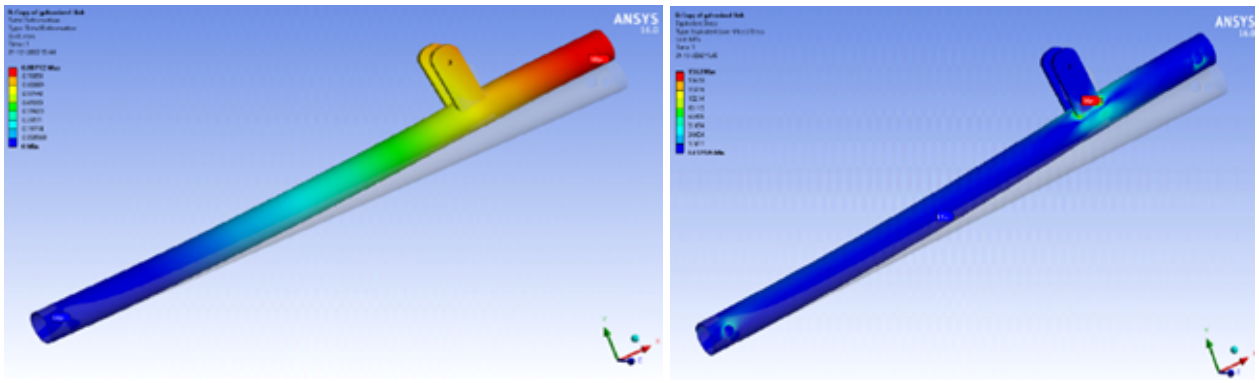
Fig. 2: Snapshot of the FEA simulation of the feeding mechanism telescopic shaft. (a) Total deformation of the inner shaft. (b) Von-Mises stress distribution in the inner shaft. (c) Total deformation of the telescopic outer shaft. (d) Equivalent distribution of the telescopic outer shaft.

The maximum and minimum values of the total deformation is tabulated below:

Maximum Equivalent stress developed	18.88 MPa
Minimum Equivalent stress developed	0.1686 MPa
Maximum permissible principle stress	235 MPa
Maximum permissible shear stress	117.5 MPa

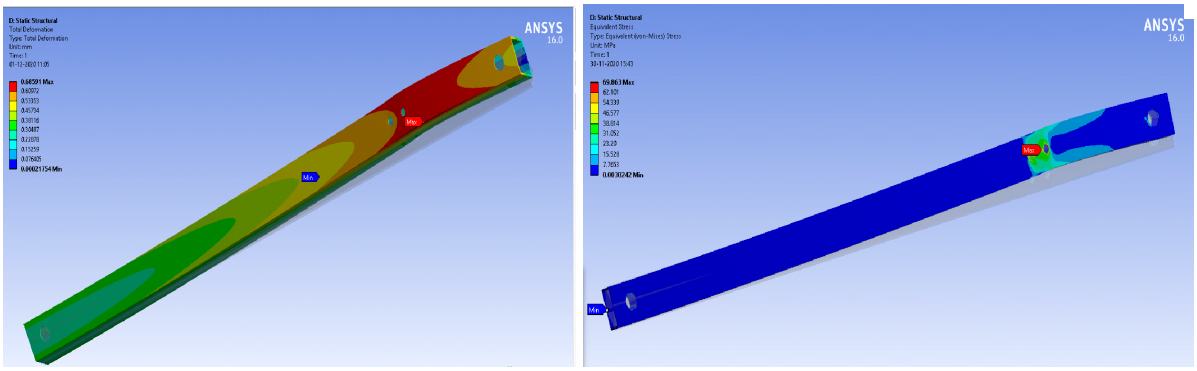
From the above table it is clear that the maximum Von-Mises stress is less than the permissible principle stress and permissible shear stress. Hence our design is inferred to be safe.

We performed a series of FEA simulations to measure deformation and stress distribution in a rigid link for the safe performance of its functionality, as shown below in Figure 3. We found that the maximum deformation is 0.89 mm and the maximum stress developed on the rigid connection is 153.2 MPa. Since the maximum value is less than the permissible value (260MPa), our design is safe.



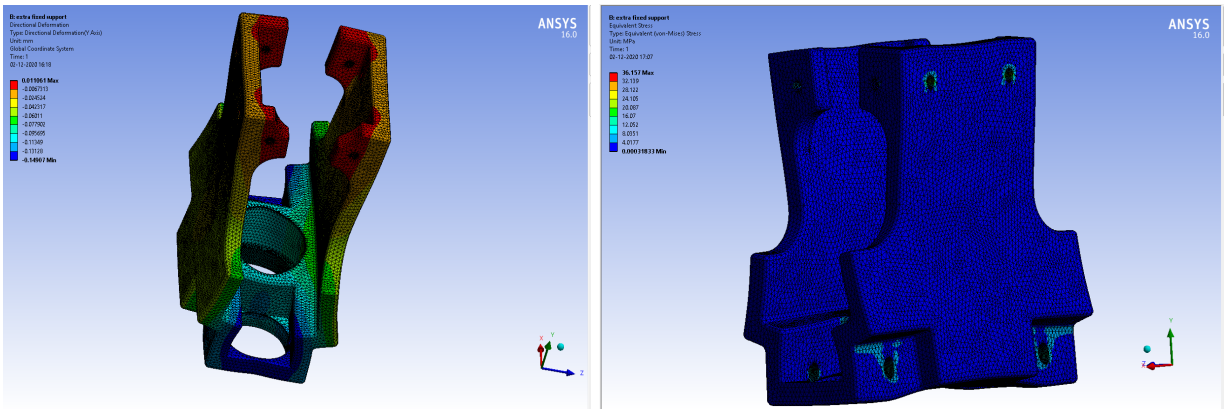
(a) (b)

Fig. 3 Snapshot of the FEA simulation of a circular rigid link. (a) Total deformation (b) Equivalent distribution of stresses.



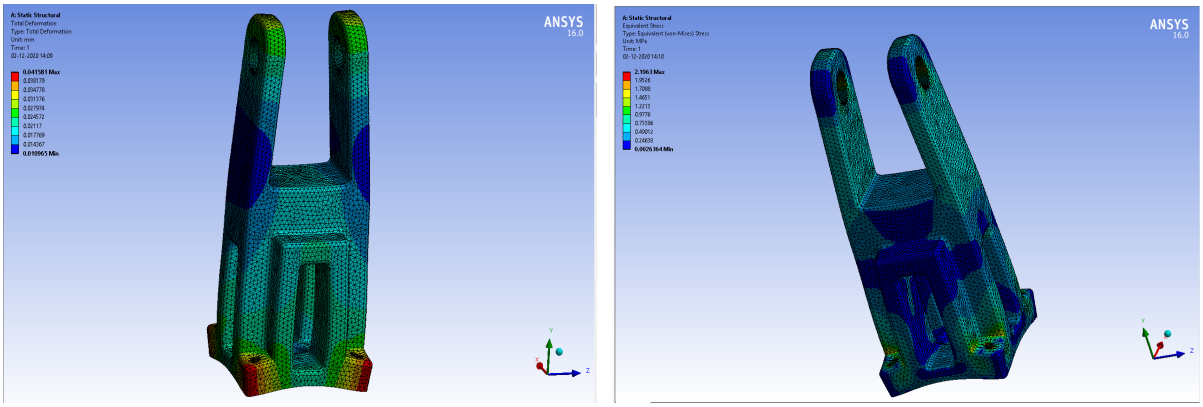
(a) (b)

Fig. 4 Snapshot of FE simulation of square rigid link. (a) Total deformation (b) distribution of stresses.



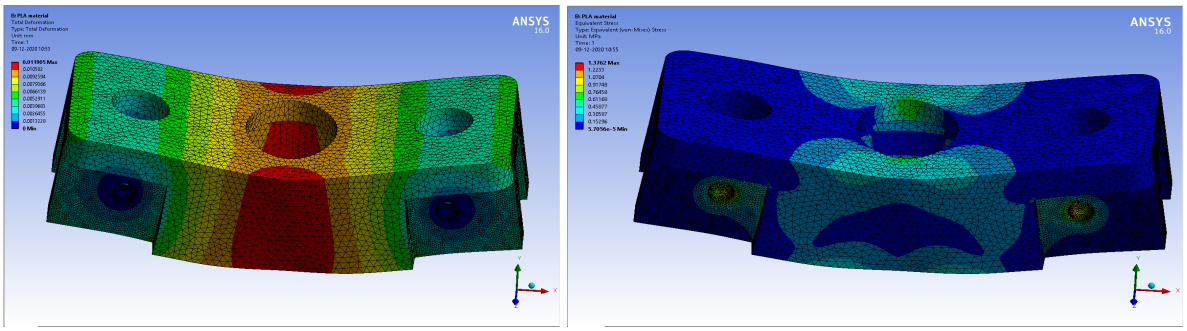
(a) (b)

Fig. 5 Snapshot of FE simulation of feeding system upper base (a) Total deformation (b) distribution of stresses.



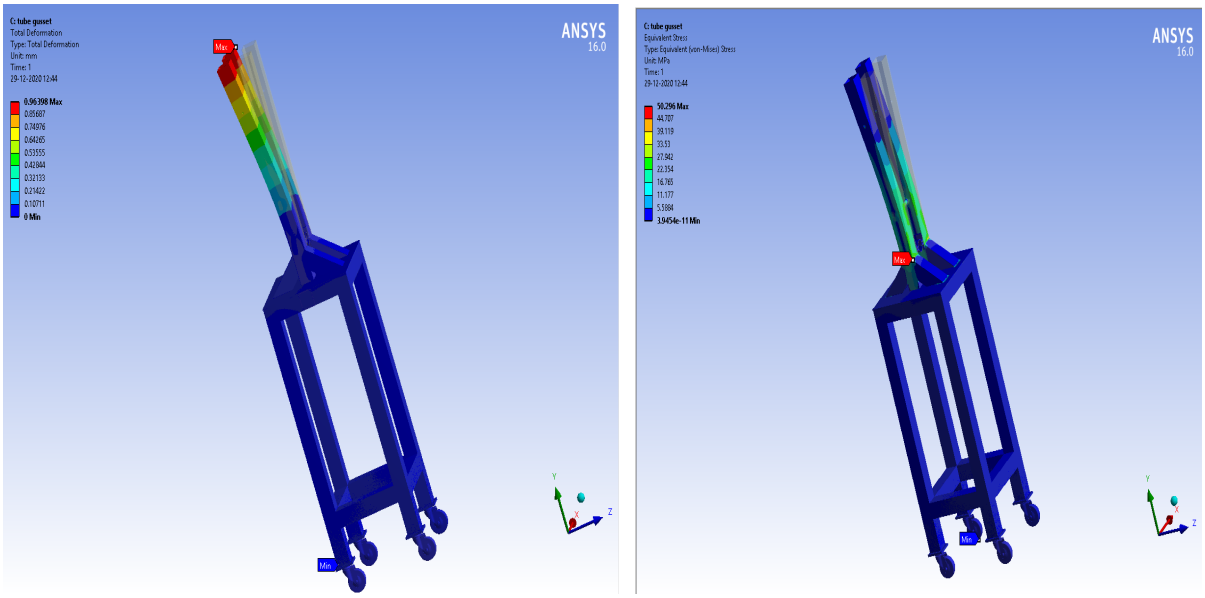
(a) (b)

Fig.6 Snapshot of FE simulation of an upper crown of the feeding system. (a) Total deformation (b) distribution of stresses.



(a) (b)

Fig. 7 Snapshot of FE simulation of a lower base of the feeding system. (a) Total deformation (b) distribution of stresses.



(a) (b)

Fig. 8 Snapshot of FEA simulation of a frame. (a) Total deformation (b) distribution of stresses.

2. Description of Laboratory and Mock-up Trial

2A. Experimental Setup

The experiment used Psyllium-Yeast synthetic sludge and cow dung with water in the tank to homogenize with the HomoSEP robot as can be seen in figure 9 below.

Fig. 9 Photograph of the HomoSEP robot assembly

The system consists of multiple blades, telescopic shaft with parallel actuators, bevel gearbox, cardan shaft, portable actuator, rigid link, motor, SMPS, remote controller, acrylic tank and frame as shown in figure 10 below.

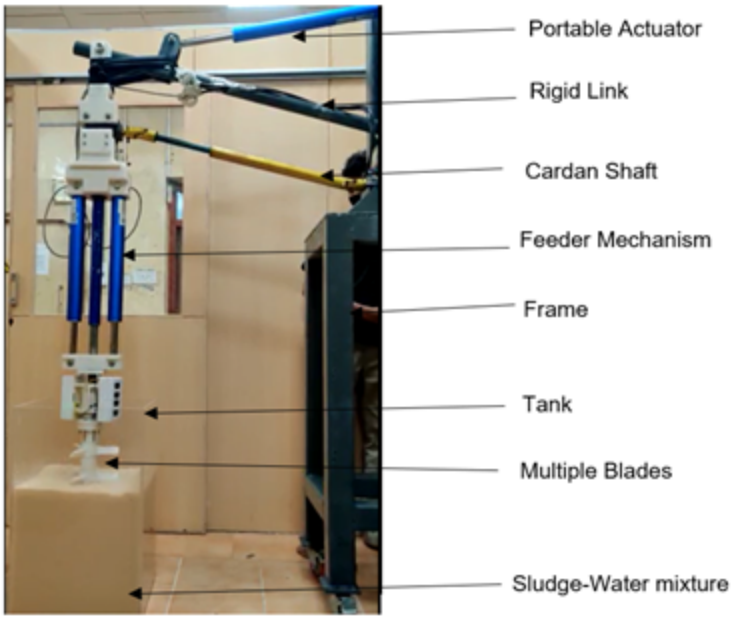


Fig. 10 Photograph of the experimental setup of the robot HomoSEP

2B. Procedure for carrying out the experiments

Laboratory experiments and mock-ups of Psyllium-Yeast and Sludge have been completed successfully. The following experiments are carried out in our laboratory with the purpose of checking the homogenization capability of the HomoSEP robot. We filled 20 kg of Psyllium-yeast sludge with water in Test 1 and 20 kg of cow dung with water in Test 2 to understand the efficacy of the HomoSEP robot as seen below in Figure 11.

Both tests were carried out in the following steps:

Step 1: Load the tank with sludge and water.

Step 2: Inspect all electrical connections, mechanic joints, nuts and bolts.

Step 3: Use the portable actuator to centralize the robot to the tank.

Step 4: Use the portable and feed actuator to take the blade at the depth of the sludge.

Step 5: Switch on the umbrella actuator to open the blades and start the motor.

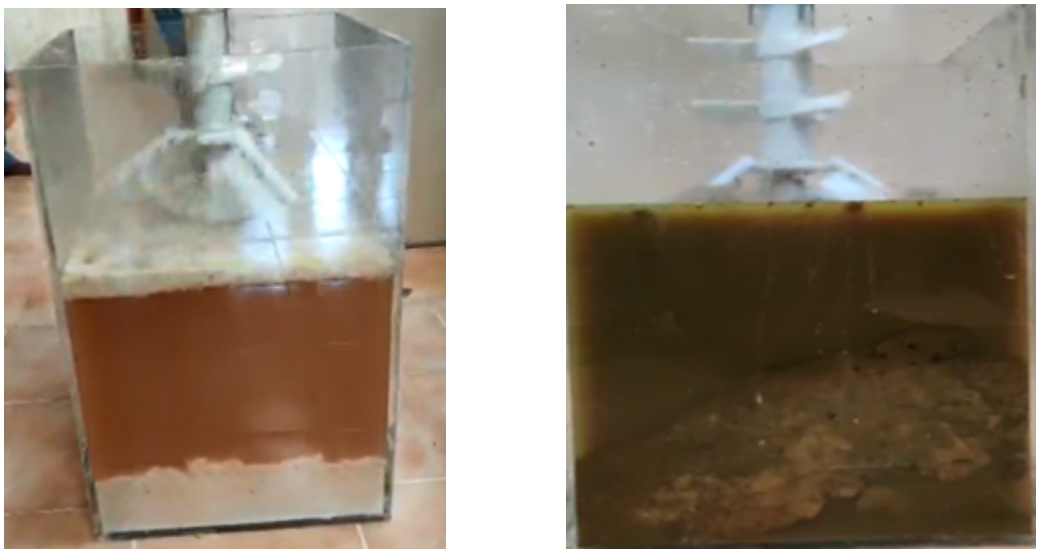
Step 6: Use the feed actuator to slowly carry the blades to the depth of the tank while rotating.

Step 7: Cause the blade to travel to the depth of the tank to homogenize the sludge with water.

Step 8: Switching off the motor after the mixing is complete.

Step 9: Use the portable and feed actuator to take the blades out of the tank.

Step 10: Switch OFF all the DPDT switches.



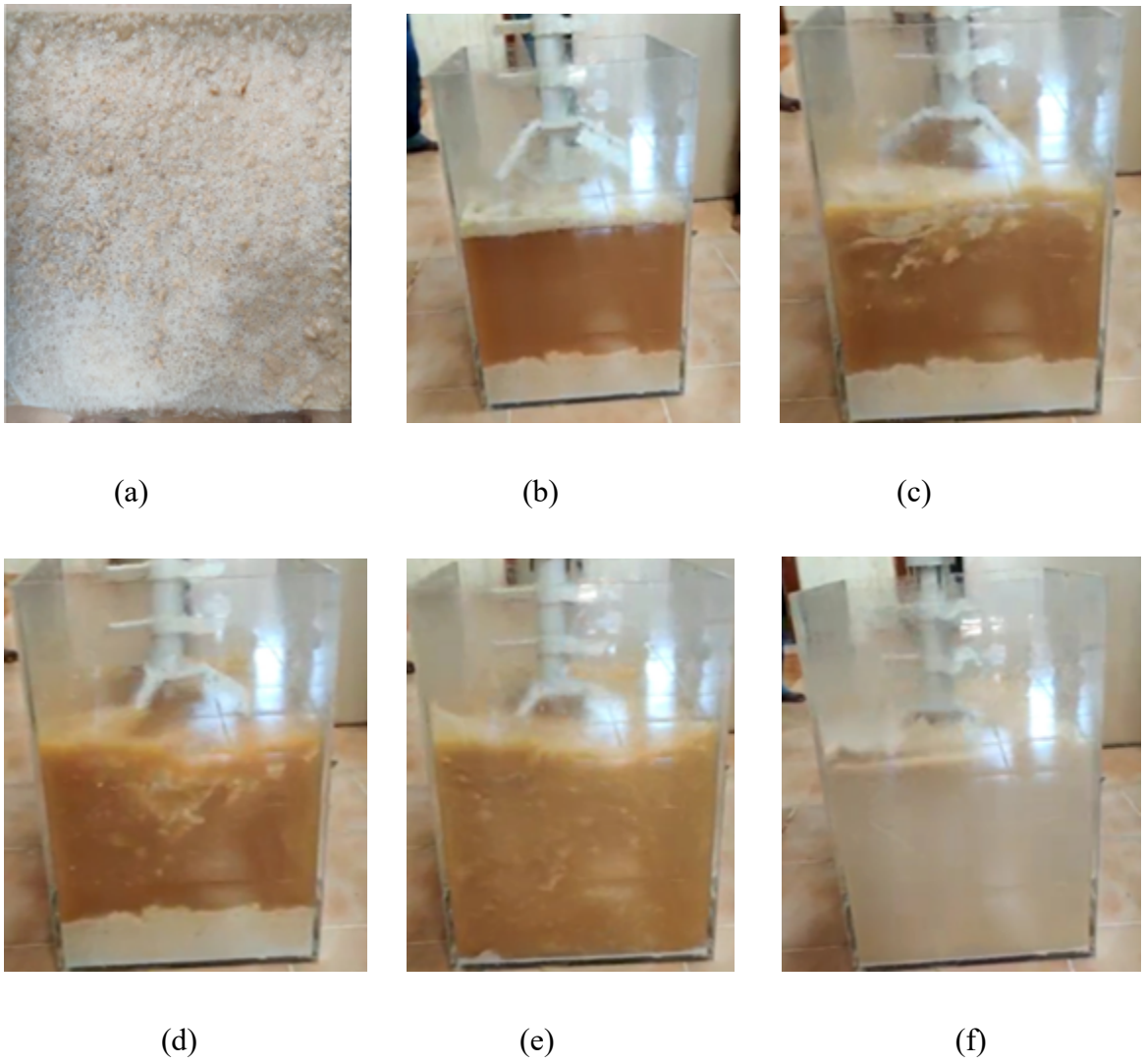
(a) (b)

Fig. 11 Photograph of a tank filled with sludge. (a) Psyllium yeast with water (***Setup 1***) (b) Cow dung with water (***Setup 2***).

2C. Results & Discussion

The mechanism is tested in a tank with 20 kg of sludge (Psyllium-Yeast) deposited on the bottom of the tank. Fig. 12(a) shows the sludge deposited on the bottom of the tank, the floating sludge particles, the dirt layer, and the hard sludge layer deposited can be better seen below in Fig. 12(b). Figure 12(c) represents the state at which the blade opens and begins to rotate and sweep the floating sludge layer with its sharp tip.

We found that after providing little vertical feed as the blade continues to rotate, the blade starts to drive both the sludge and the water both in radial and vertical directions. This caused the vertical thrust on the particle deposited on the bottom of the tank, which accelerated the penetration, pushing and collision of the particles due to the configuration of several blades that can be seen in Fig. 12 (d) and Fig. 12 (e). After running the whole system for 10-15 minutes, all three layers disappeared and at last became a uniform slurry mixture of sludge and water within the tank, as shown below in Fig. 12(f).

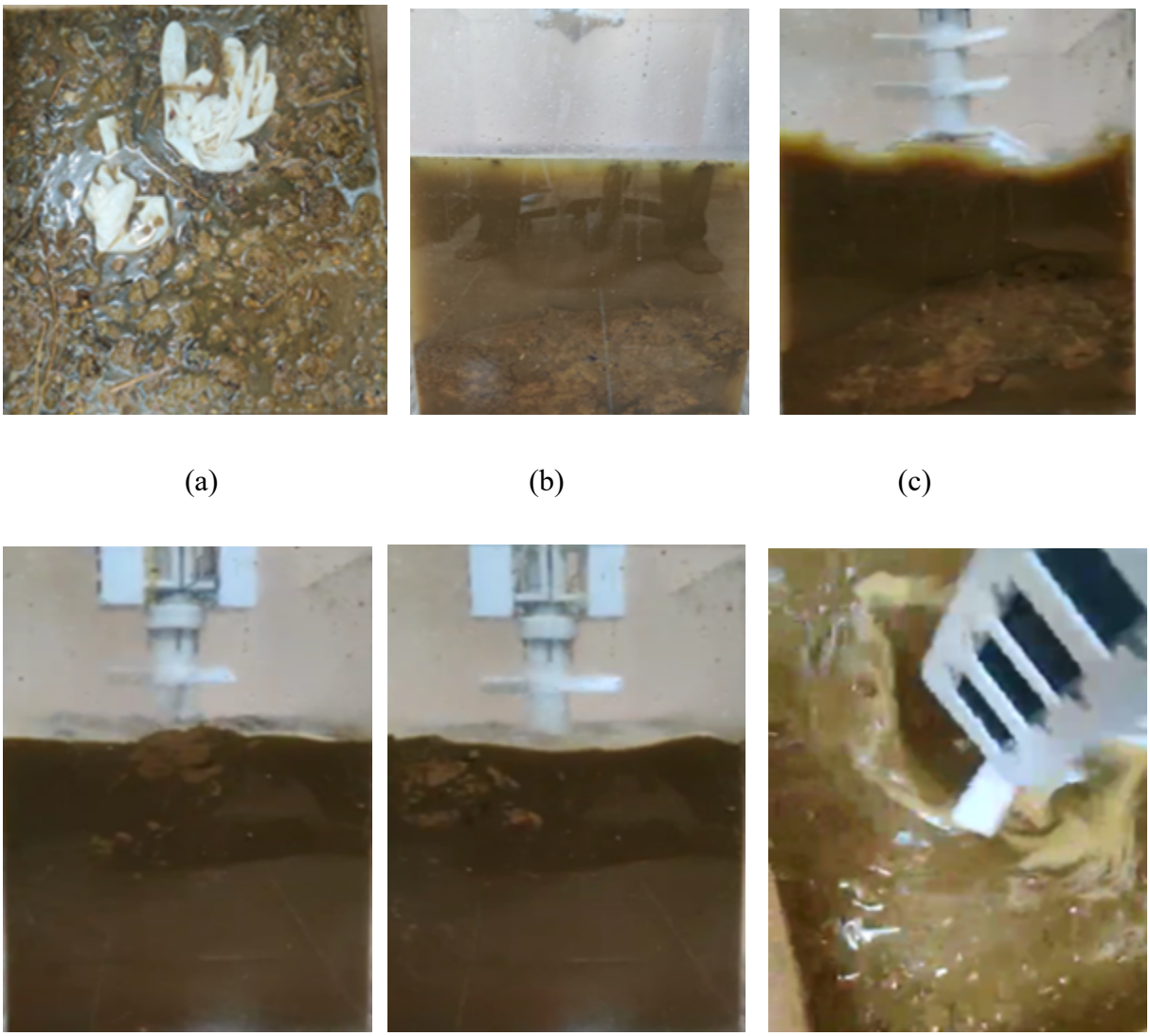


(a) (b) (c)

(d) (e) (f)

Fig. 12 Snapshot of Psyllium-Yeast sludge water mixing in a tank at different intervals ***(Setup 1)*** (a) Psyllium-Yeast hard sludge (b) Different layers of sludge in a tank (c) Blade hitting the top layer of the sludge (d) Mixing start as blades rotates and feed provided (f) Slurry of sludge and water.

Similar experiment is carried out with 20 kg of cow dung and water in a separate setup, as seen ın Fig. 13. The blade and the sludge act in the same way, but this experiment took 20-25 minutes to obtain a uniform mixing of cow dung and water, as seen below in Fig. 13 (f).

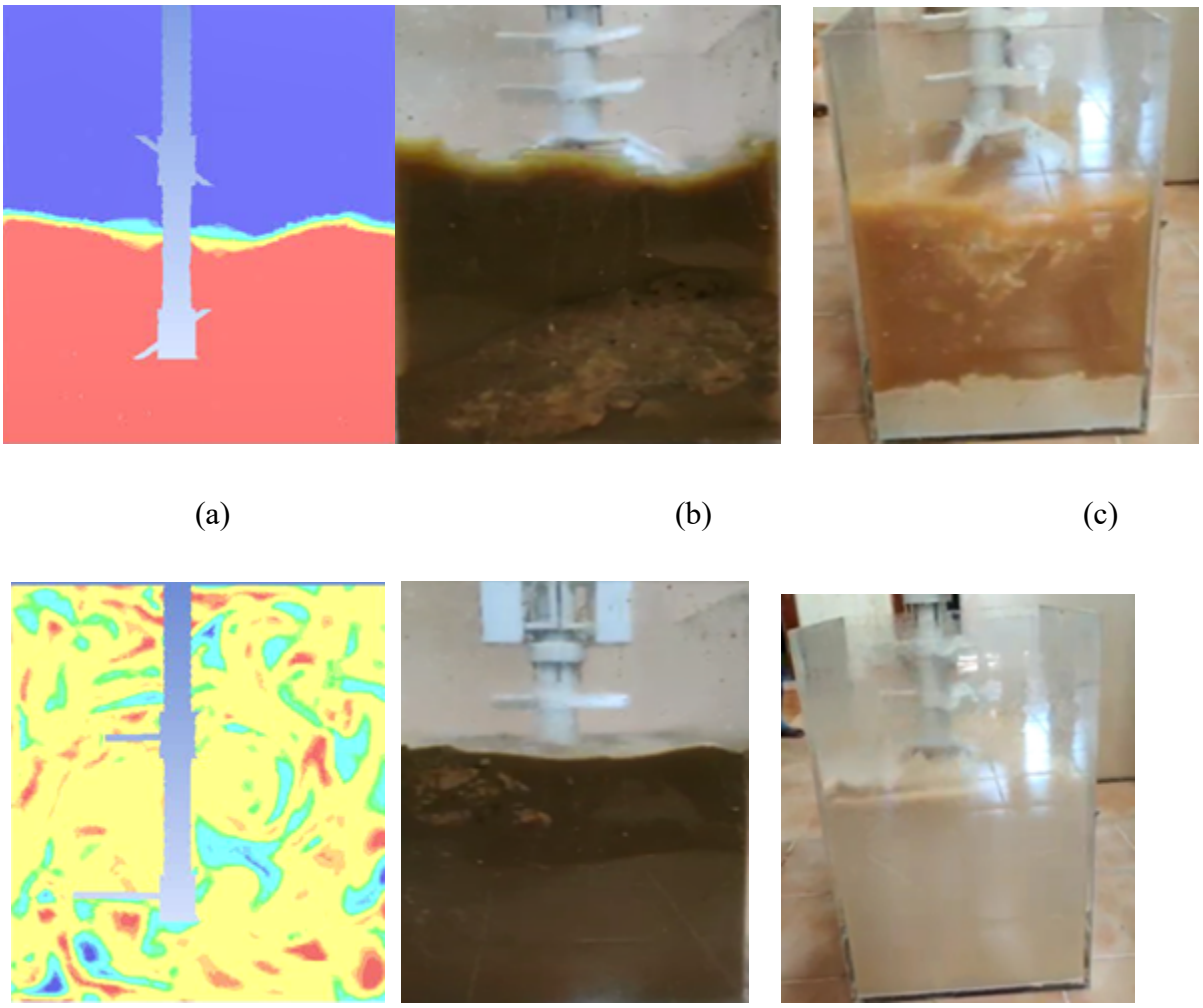


(a) (b) (c)

(d) (e) (f)

Fig. 13 Snapshot of cow dung water mixing in a tank at different intervals (***Setup 2***).(a) Cow dung hard sludge (b) Different layers of sludge in a tank (c) Blade hitting the top layer of the sludge (d) Mixing starts as blades rotate and feed provided (f) Slurry of sludge and water from top view.

Our laboratory experiments validate the CFD simulation of mixing flow patterns, as shown below in Figure 14.



(a) (b) (c)

(d) (e) (f)

Fig.14 Snapshot of mixing flow patterns for CFD, Psyllium-Yeast, Sludge test data, when the blade begins reaching various levels of sludge (a,b,c) and when it is completely mixed during such blade rotations (d,e,f).

3.Conclusions The Multi Pitch Blade is capable of mixing viscous fluids like sludge with water while rotated at 60 RPM and 5 Nm of torque. The flow pattern of the fluid mixture is the same for Psyllium-Yeast and cow dung sludge, only the difference is the time required for the homogenizing mixture. Cow dung sludge is harder than Psyllium-Yeast sludge, which is why it took longer than 15-20 minutes to fully homogenize with water.

Conclusions were also drawn from the CFD simulation of the blades. CFD simulation helped us design the RPM blades, the torque, the power, the motor selection before it was made. Our experimental tests verify the CFD simulation of mixing flow patterns as seen in Figure 9 above.Feeding system performs very well to achieve mixing at high depths by moving the whole bottom module to 0.3 m and the portable system provides extra height which helps in centering the bottom module with the tank. This is a significant achievement and sets the stage for full-scale field trials that are to be commenced shortly.

Fund Utilization and Traction: The SRP funded this project at a critical early stage. Through the funds, we were able to perform small fabrications, obtain computing resources for high-end simulations, and thus obtain results that helped attracted larger scale-up support. Most of the allocated funds have been spent in this way and a small amount (Rs. 20000) left will also be consumed in the coming month or so. Today this overall project has attracted support through CSR from GAIL and CapGemini, and won recognition through the National Bio Entrepreneurship Award (2019). IP filings and journal publications are also under preparation.

6. Status Report of SRP Project

PI: V Srinivasa Chakravarthy

The objective of the project is to write/translate, publish or procure science books in Telugu and Tamil and send copies of the same to 300-500 rural, local-language medium schools.

Title: Publish science books at high school level in regional languages (Telugu and Tamil) and donate them to village school libraries

Project number: SP1920613SRPX005028

Work on Telugu books:

The following books were written, translated by VSC. To increase the number and range of titles we also procured titles of science related books by another writer. On the whole we have 7 titles for this year. Just 2 weeks ago, we began to mail sets of these 7 books to schools.

The titles are as follows:

1. Understanding Sound through fun experiments – VS Chakravarthy
2. ఆసక్తికర ప్రయోగాల ద్వార ధ్వని ఏమిటో తెలుసుకుందాం – (Telugu translation of the above book by P. Vikram Kumar)
3. జీవశాస్త్ర చరిత్ర – 2 (History of Biology – part 2, Translation of the book 'History of Biology' by Isaac Asimov by VS Chakravarthy.
4. విరబూసిన బంతి చెట్టు –by TV Ramakrishna (introducing plant life to children through stories and colorful pictures.)
5. ప్రకృతి నేర్పిన పాఠాలు - Biomimicry (Lessons from the Nature) by TV Ramakrishna (a collection of chapters on bio-inspired engineering.) Vijnana Prachuranalu.
6. మానస డైరీ (Manasa's diary) by TV Ramakrishna. Life of an 8th grader, seen from the perspective of a girl named Manasa. It gives a peep into the struggles of a high school girl in coping with the stress of the school, classmates, family and the society at large.
7. వింతప్రాణి ప్రపంచం (Wonders of the Animal World) by TV Ramakrishna. Published by Vijnana Prachuranalu.

Copies of the above set of 7 books have already been sent to about 160 schools. Totally we plan to send them to 500 schools. We will complete the mailing by the end of May 2021.

Work on Tamil Books:

The following books originally written by Isaac Asimov and translated into Tamil by a group enthusiastic Tamil translators from remote locations.

1. How did we find out about - Beginning of Life?
2. How did we find out about - Blood?
3. How did we find out about - Computer?
4. How did we find out about - Dinosaurs?
5. How did we find out about - Earth is round?
6. How did we find out about - Earthquake?
7. How did we find out about - Humanroots?
8. How did we find out about - Microwaves?
9. How did we find out about - Pluto?
10. How did we find out about - Universe?

The books were published by Thooral Books, Chennai.

300 sets of these books were procured through this project. We have begun posting the book parcels to schools 1 week ago. So far 70 packets were mailed. We are planning to mail 100 more this week.