Report of the work done	
Project number & Title of the Project	T2F, Development of Functional Materials and Systems for Environmental Applications with Special focus on pollution Reduction and Control
Name and Address of the PI & Co-PIs	1. Dr. V. Sivanandan Achari Professor & Dean Principal Investigator RUSA 2.0 Major Project T2F School of Environmental Studies Cochin University of Science and Technology Kochi- 682 022 2. Dr. Suja Haridas Associate Professor & Co-PI RUSA 2.0 Major Project T2F Department of Applied Chemistry Cochin University of Science and Technology Kochi- 682 022 3. Dr. C S Ratheesh Kumar Assistant Professor & Co-PI RUSA 2.0 Major Project T2F School of Environmental Studies Cochin University of Science and Technology Kochi- 682 022 4. Dr. Preethy Chandran Assistant Professor & Co-PI RUSA 2.0 Major Project T2F School of Environmental Studies Cochin University of Science and Technology Kochi- 682 022
RUSA grant allotted	Hard components: 1,50,00,000/-
	Soft components: 29,00,000/-
Expenditure as on March 31, 2024	Hard components: 1,49,99,924/-
	Soft components: 9,89,179/- (through PFMS)
	Soft components: 14,80,639/- (through SR)
Details of SR settled	
Contingency SR/320/2023-24/14 dated 08/09/2023-40,000/- SR/320/2023-24/32 dated 25/09/2023-80,000/-	Adj-CB/320/2023-24/218 dated 06/03/2024 Rs.1,20,000/-
Consumables SR/320/2023-24/13 dated 08/09/2023-2,87,979/-	Adj-CB/320/2023-24/219 dated 06/03/2024 Rs.2,87,979/-
Manpower SR/320/2023-24/12 dated 07/09/2023-6,85,160/-	Adj-CB/320/2024-25/2 dated 03/04/2024 Rs.6,85,160/-
Technical Services SR/320/2023-24/33 dated 25/09/2023-1,65,000/- SR/320/2023-24/15 dated 08/09/2023-82,500/	Adj-CB/320/2023-24/220 dated 06/03/2024 Rs.2,47,500/-
Workshop and Skill Training	Adj-CB/320/2023-24/217 dated 06/03/2024

SR/320/2023-24/23 dated 18/09/2023-1,00,000/-	Rs. 1,00,000/-
Travel SR/320/2023-24/11 dated 05/09/2023-40,000/-	Rs. 40,000/- Adj-CB/320/2024-25/9 dated 17/04/2024
Hard Component-ICPMS-IC SR/320/2023-24/31 dated 25/09/2023-14,999,924/-	Rs. 1,49,99,924/- Adj-CB/320/2024-25/11 dated 25/04/2024- will be settled soon
Total amount withdrawn through SR	**Rs. 1,64,80,563/-**
Total amount settled through Adjustment CB	**Rs. 1,64,80,563/-**
Brief report of the work done (500 words)	Separate sheet attached
Milestones achieved:	**i.** 1 PDF, I PA and 1 JRF joined as soon as Project came into implementation **ii**. Procured ICPMS-IC instrument under RUSA2.0 Major Project T2F of Rs. 1,49,99,924/-, Installation completed and training is going on. **iii)** Conducted workshop and skill training on "Functional Materials & Systems for Environmental & Energy Applications: Pollution Reduction and Control" on 23/02/2024. **iv)** 99% fund has been utilized
Publications	Published: 3
	Submitted: 2
Patents	Applied: Nil
	Approved: Nil

Fig.1: Procured ICPMS Instrument under RUSA2.0 Major Project T2F 2023-24 of Rs. 1,49,99,924/-, consignment arrived and waiting for installation

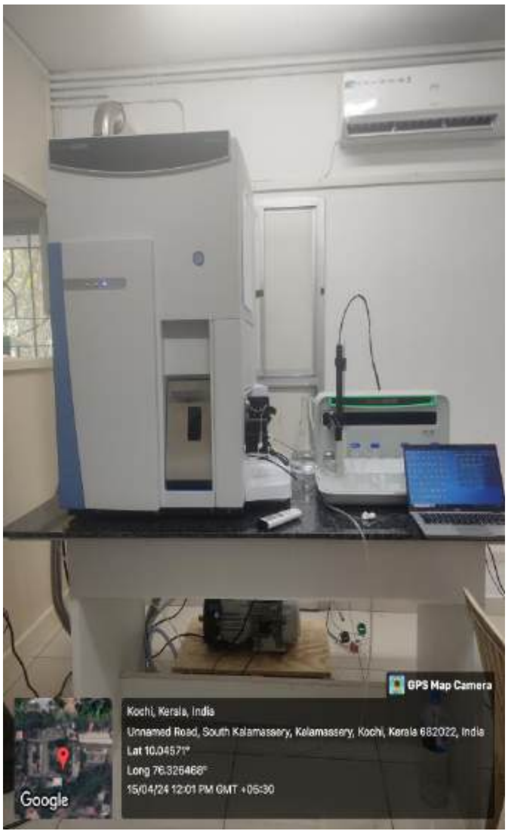


Fig.2: Procured ICPMS Instrument under RUSA2.0 Major Project T2F 2023-24 of Rs. 1,49,99,924/-, installed and Waiting for calibration to complete

International Conferences Attended by Project staff T2F

1. Dr. Raichel Mary Lopez, PDF, RUSA 2.0, T2F and Mr. Ajith C, PA, RUSA 2.0, T2F, participated in a one-day workshop and International Conference- **Energy Summit 2023 at Indian Institute of Technology, Madras, 5-7th December 2023.**
2. Ms. Salva M, JRF, RUSA 2.0, T2F presented a paper in the 2nd International Conference on Energy Storage devices 2023 & Industry Academia Conclave **at Indian Institute of Technology, Roorkee, 7-10th December 2023.**

National Conference attended by Project staff T2F

1. Dr. Raichel Mary Lopez, PDF, RUSA 2.0, T2F has done an oral paper presentation "Carbon Surface Chemistry of Oxidized- and nano La_2O_3 Dispersed Granular Carbons: Activation, Tuning, Texture and Adsorption" at **National Conference on Functional Materials and Applications** on 18-19 January 2024 at the Department of Physics, Cochin University of Science and Technology, Kochi.

Conducted one day Workshop and Skill Training on 23/02/2024 under RUSA2.0 Major Project T2F

Conducted workshop and skill training on "Functional Materials & Systems for Environmental & Energy Applications: Pollution Reduction and Control" on 23/02/2024 by Convenor: Dr. V Sivanandan Achari, PI, RUSA2.0, Major Project T2F at School of Environmental Studies, CUSAT.

Fig.3: Inauguration of One day Workshop and Skill Training by the Honourable Vice Chancellor Dr. P.G Sankaran

Fig.4: Invited talk by Dr. R Ratheesh, Director C-Met, Hyderabad

Fig.5: Invited talk by Dr. U Rambabu, Senior Scientist, C-Met, Hyderabad

Fig.6: Invited talk by Dr. S Rajesh Kumar, Senior Scientist, C-Met, Hyderabad

Fig.7: Invited talk by Dr. M. Junaid Bushiri, Professor, Department of Physics, CUSAT

Fig.9: Audience present in the workshop and skill training.

Procured Laptops- 3 Nos for PI and Co-PI's under the Head- Computer and minor components

Fig.10: HP LAPTOP 5-fd0012TU Intel 13th Gen-i5-1335U 16GB 1TB SSD.

Minor components procured under the Head- Computer and minor components

Fig.11: Glassy electrodes

Fig.11: Infra-red lamp

Instrument- Water bath Shaker procured under the Head- Contingency

Introduction

Carbon aerogels are 3D nanoporous carbon materials obtained from the carbonization of organic aerogels which are prepared by the sol-gel polycondensation, from organic monomers (eg: melamine, resorcinol, formaldehyde) or from biomass- derived precursors (eg: polysaccharides, proteins, sugars). These materials have significant role as they hold high surface area, ultra-low density, and electric conductivity make them promising materials for energy storage, electro catalysis, desalination, bio-sensing and gasification, gas cleaning etc. Cellulose is the most abundant organic polymer in nature. It is organic, cheap, abundant, and a suitable precursor for making porous material for energy application as well as to serve as an adsorbent. Coir an abundantly available form of agricultural waste having a rich cellulose content of 23-43%. It is a naturally occurring fiber from coconut husk, a renewable resource. In terms of physical characteristics and chemical content, coir fibers are similar to wood fibers. Coir fibre production globally totals 1.3 million tonnes annually, while more than 45 % of it is produced in India. Kerala, land of coconut is famous for the coir fibres, was chosen for preparing the aerogel. Arecanut fibres were also chosen to prepare the aerogels to compare its efficiency with coir fibres as well. Arecanut, also known as betel nut, is the kernel obtained from the fruit of arecanut palm (*Areca catechu* Linnaeus). India dominates the world in area (57%), production (53%) and productivity of arecanut (0.379 million tonnes in 2002). Arecanut finds place in religious, social and cultural functions of India. The presence of the betel nut is a must in the ceremonial plate, as betel nuts are believed to increase prosperity.

Transition-metal (e. g. Fe, Co, Ni, etc.) based materials have been gaining tremendous research attentions as oxygen reduction catalysts in the past decade for many reasons, including abundant reserves in Earth's Crust, low cost, and excellent stability. To further improve the performance, various strategies have been developed in recent years, including defect engineering, electronic structure modulation, and the integration of proper support. Transition metal single-atom aerogels are emerging as a research hotspot since they can provide many binding sites to the molecules. So the present study is focusing on incorporating cobalt atoms to cellulose based carbon aerogels and to evaluate its efficiency towards electrochemical applications, as a suitable adsorbent and to use the materials as anode in Li ion batteries. Carbon aerogels prepared from resorcinol and formaldehyde organic monomers were also prepared for the comparative assessment of aerogels towards the applications.

Objectives

1. Preparation cellulose based carbon aerogel from coir and arecanut fibres.
2. Preparation of cobalt incorporated cellulose based carbon aerogel from coir and arecanut fibres.
3. Preparation of Carbon aerogels were also from resorcinol and formaldehyde organic monomers with sodium carbonate as catalyst
4. Characterization of prepared aerogels by SEM, HRTEM, XRD, FTIR, thermal analysis, XPS and Raman spectroscopy analysis.
5. Porosity and surface area analysis by N_2 adsorption- desorption isotherm analysis.

6. Electrochemical application of the prepared samples to find the cyclic voltammetry, EIS, GCD and specific capacitance.
7. To apply the prepared aerogels as anode material for Li ion batteries.

Work done

Freeze drying of coir, arecanut and commercial cellulose aerogels were done and send to IIT Madras for carbonization.

Fig.12: freeze-dried raw coir based cellulose

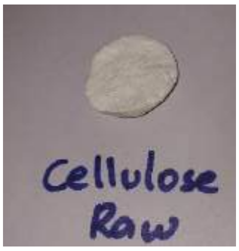


Fig.13: freeze-dried commercial based cellulose

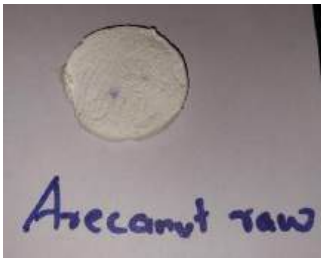


Fig.14: freeze-dried raw arecanut based cellulose

Fig.15: freeze-dried cobalt incorporated coir based cellulose

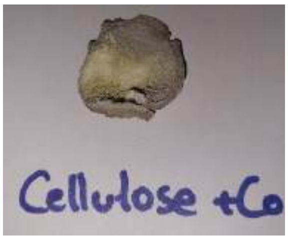


Fig.16: freeze-dried cobalt incorporated commercial based cellulose

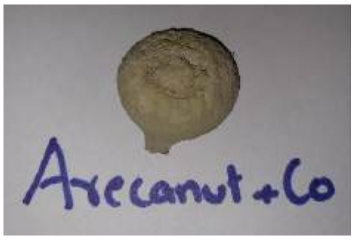


Fig.17: freeze-dried cobalt incorporated arecanut based cellulose

Carbon aerogels were also prepared from resorcinol and formaldehyde organic monomers. Resorsinol and formaldehyde were mixed together with Na_2CO_3 as catalyst. R/C 100, R/C 500, R/C 1000, R/C 2000, R/C 3000. Carbonized at 1000ºc for 1h hold time in presence of N_2 gas at a rate of 5ºC/min.

Fig.18: RF Carbon aerogel initial mixing stage.

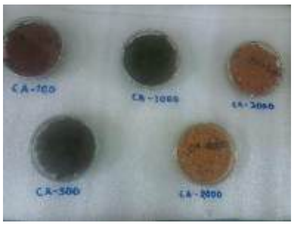


Fig.19: RF Carbon aerogel formed after drying.

Fig.20: RF Carbon aerogel before carbonization.

Fig.21: RF Carbon aerogel after carbonization.

1) Carbonization of prepared cellulose aerogels and resorcinol formaldehyde aerogels under N_2 atmosphere.
2) Characterization of prepared carbon aerogels were done using TG-DTA, FTIR, SEM and XRD
3) Porosity and surface analysis of CA500 and CA100 were done by N_2 adsorption-desorption isotherm analysis.
4) Adsorption isotherm and Kinetic studies of the prepared carbon aerogel samples were done using As solution.

Future Works…

1. Carbonization of cellulose aerogels
2. Characterization of cellulose aerogels
3. Electrochemical application of both cellulose and RF aerogels
4. Adsorption isotherm and Kinetic studies of the prepared cellulose carbon aerogel using As solution.

Work done by Co-PI- Dr. Preethy Chandran

Title: Bioremoval of Cr (VI) from wastewater using bacterial biomass

The three chromium-resistant bacteria isolated from Kuzhikandam Creek were subjected to growth studies in different conditions. The isolates were grown at different pH, different heavy metals, and different media. The OD at 600nm after 48 hours was measured using a UV-visible spectrophotometer. These isolates were tested for antibiotic susceptibility and measured the inhibition zones. FTIR analysis of three bacteria was done to find the functional groups present in them. The three isolates were grown in single and combination and prepared as charcoal alginate beads and also attached to clay balls. SEM images were taken to find out the best attachment of the isolates to each of these materials for adsorption studies. The work paper is written based on the work done from the beginning to date.

Work done by Co-PI- Dr. C S Ratheesh Kumar

Title: Metal and nutrient distribution in sediments as ecological health indicators in Ashtamudi Ramsar wetland, south west coast of India

Surface water samples and sediments were collected from twenty-two locations located in Ashtamudi wetland on board during Non-Monsoon Season of the year 2023. pH of water samples were measured in situ using portable pH meter (Eutech Instruments-Cyber scan PCD650 portable meter). DO was fixed carefully by the addition of Winkler A and Winkler B to samples collected in BOD bottles. The samples for analysis of other water quality parameters were transported to the laboratory in ice box and stored in a deep freezer till analysis. General hydrographical parameters and nutrients (DO, BOD, Alkalinity, Salinity, Nitrite, Phosphate, Sulphate, and Silicate) in water samples were analysed using standard methods (Grasshoff et al., 1999). Surface sediment samples were collected using a stainless steel Van Veen Grab (0.042 m^2) and stored in polythene bags and kept deep frozen till analyses. Fresh wet sediment was used for pH, E^h and texture analysis. Other portion of sediment was freeze dried, crushed using mortar and pestle to make homogeneous fine powder and was used for further analyses. Total carbon, nitrogen and sulphur were determined using a Vario EL III CHNS Analyser. The sequential extraction scheme by Golterman (1996) using chelating agents was employed for estimating different phosphate fractions.

pH of the study area was controlled by freshwater influx from Kallada river and its tributaries coupled with tidal influx from Arabian Sea. Electrical conductivity displayed significant spatial variation ($P<0.01$) and ranged from 12.69-47.76mS/cm. In the study area, alkalinity recorded significant seasonal variation ($p<0.01$) and ranged from 71.82 to 155.61mg$CaCO_3$/L. Input of suspended particulate matter via river run-off recorded elevated turbidity and silicate content in water column. The increased salinity, alkalinity and enriched levels of major cations at sites near to Arabian Sea was attributed to seawater ingression. Elevated phosphate and nitrite levels in water column arise from release of the nutrients from decay of phytoplankton debris, terrestrial run-off, industrial and agricultural activities.

pH of sediments exhibited variation from 7.48 to 8.12 and was controlled by the fresh water input from river Kallada and sea water ingression from Arabian Sea. The values of redox potential ranged from -67 to -28mV. The depleted negative values of E^h indicate accelerated mineralisation of organic matter. The grain size has immense influence on the distribution of various sedimentary parameters in the aquatic environments. Texture analysis showed a progressive increase in fine fractions (silt+ clay) from riverine zone to the estuarine zone. The observed sand content in the sediments ranged from 0.89 to 92.30%. Level of silt varied from 2.40 to 50.26% whereas the clay content varied from 5.30 and 89.04%. Sediments from a majority of sites exhibited significant fluctuations in textural characteristics indicating the discharge dependency. Fine sediments get entrained during the river run-off, leaving behind the coarser sediments in the river dominated locations of the study region. Intermediate values of C/N indicated mixed origin of organic matter from in situ primary production and also inputs from terrestrial sources.

Work done by Co-PI- Dr. Suja Haridas

Throughout the duration of this year-long project, notable achievements have been attained, placing considerable importance on acquiring essential chemicals and laboratory apparatus crucial for development of advanced materials for energy storage applications. We have developed graphene quantum dot–polyaniline heterohybrids for supercapacitor applications. The synthesis strategy involves a sequential sol–gel synthesis of strontium titanate, followed by hydrothermal aided interface formation with graphene quantum dots (GQD) and polyaniline (PANI) deposition by chemical oxidative polymerization. A high specific capacitance could be observed in 1 M H_2SO_4 electrolyte at a current density of 1 A g^{-1}. The 97.7% retention of specific capacitance demonstrated at higher current densities

ensures high-rate capability. Further, the device demonstrated a capacitance retention of 80 % at 10 A g^{-1} after 10000 galvanostatic charge–discharge cycles. Low interfacial charge transfer resistance as evidenced by impedance spectroscopy analysis and high performance could be attributed to the synergistic interaction at the interface. These findings underscore the potential of the synthesized materials for future advancements in supercapacitor technology, highlighting the importance of synergistic interface interactions in enhancing device performance.

Introduction

The progress in chemistry gives rise to fresh environmental issues and unforeseen harmful side effects, underscoring the imperative for greener chemical methods and products. Green chemistry, alternatively recognized as sustainable chemistry, is a developing realm of ongoing research that seeks to make chemical synthesis in the industry more environmentally sustainable. Green chemistry is founded on twelve principles that seek to reduce or eliminate hazardous materials throughout the synthesis, production, and application of chemical products. The goal of green chemistry is to reduce the negative impact of chemistry on human health and the environment throughout the entire life cycle of a product, from its design and synthesis to its use and disposal. These principles aim to guide scientists and engineers in the development of sustainable and environmentally friendly chemical processes and products.

As per these guidelines, catalysis is deemed as one of the essential tools for the applying green chemistry. Catalysis provides several benefits in the realm of green chemistry, such as reduced energy demands, employment of catalytic rather than stoichiometric amounts of materials, enhanced selectivity, diminished reliance on processing and separation agents, and the opportunity to utilize less toxic materials. Heterogeneous catalysis, in particular, aligns with the objectives of green chemistry by facilitating the easy separation of product and catalyst. This eliminates the necessity for separation techniques like distillation or extraction. Currently, one of the primary areas of research in the field of chemistry revolves around advancing efficient heterogeneous catalytic systems for various chemical transformations.

Bis(indolyl)methanes (BIMs), 3-substituted indole derivatives have attracted attention due to their myriad pharmacological activities. In general, the synthesis protocol involves acid catalysed condensation of indoles with carbonyl compounds; both Bronsted and Lewis based catalysts being effective for the process. Different kinds of heterogeneous solid acid catalysts were employed for the synthesis of Bis(indolyl)methanes (BIMs). we attempted the synthesis of BIMs catalysed by phoshotungstic acid (HPW) acid incorporated sulphonic acid functionalised SBA-15. The incorporation of phosphotungstic acid into the one-pot synthesised SBA-15-SO_3H was carried out by wet impregnation methodology. Successful functionalisation of SBA-15 with retention of the mesoporous framework was ensured by chemical and morphological characterisation. Both thermal and light assisted synthesis of BIMs were attempted. Good to excellent yields were obtained in all the cases. The synergistic interaction between HPW and sulphonic acid moieties acclaim the enhanced catalytic performance of the material.

Synthesis of Sulphonic acid functionalised SBA-15 (SSA)

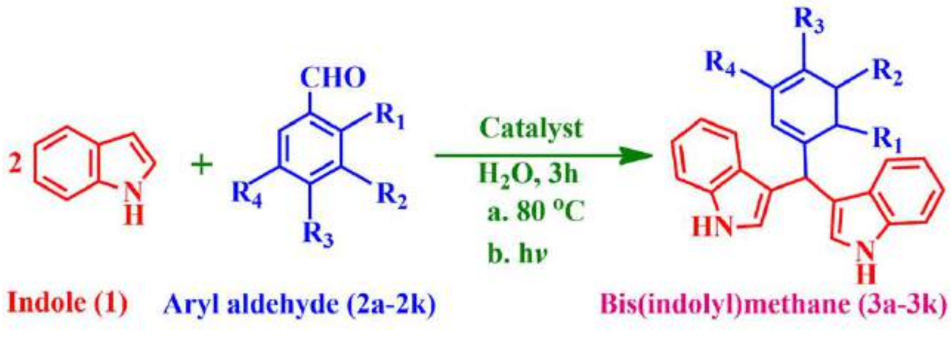
Synthesis of sulphonic acid functionalised SBA-15 was carried out by a one-pot method. 4g of P123 was dissolved in 120 ml 2M HCl and stirred at room temperature until a clear solution was obtained. The solution was heated to 40 °C for 30 minutes followed by the addition of TEOS (10 ml) with continuous stirring. Following the pre-hydrolysis of TEOS, 2 ml MPTMS and 10 ml H_2O_2 were added simultaneously and the mixture was maintained at 40 °C for 20 h under constant stirring. The resultant mixture was aged at 100 °C for 24 h and the solid product was recovered by filtration and dried in an oven overnight. The template was removed by soxhlet extraction with ethanol followed by oven drying and the sample (SBA-15-SO_3H) obtained was marked as SSA.

Synthesis of HPW immobilized SBA-15-SO_3H

Wet impregnation method was used to accomplish HPW loading. To 1g of SBA-15-SO3H, the required quantity of HPW in aqueous solution was added (to obtain 10, 20 and 30 % of HPW loading), and the resulting mixture was stirred at room temperature for 8 h. The suspension was heated to 100 °C to completely remove the solvent. The samples were dried in an oven for 10 h at 150 °C. The samples obtained were labelled as x HPW/SSA (x representing the percentage loading of HPW).

General procedure for the synthesis of bis(indolyl)methanes

For conventional thermal synthesis, a mixture of indole (2mmol), benzaldehyde (1mmol) and catalyst (0.05g) was taken in a 50 ml R.B flask mounted on a magnetic stirrer equipped with precision temperature control. The mixture was homogenized with 2 ml water and kept under continuous stirring at the required temperature. Time and temperature for maximum yield were optimized by monitoring the progress of the reaction by TLC. After the reaction was completed, the reaction mixture was cooled to room temperature. The crude product was then dissolved in ethanol, and the catalyst was separated *via* filtration. Pure crystals of bis (indolyl) methane were obtained after solvent evaporation of the filtrate. Further purification of the crystals was done by recrystallization [48]. The schematic illustration of reaction is given in Scheme 1.
Light assisted condensation was carried out in an open beaker under illumination from a white LED source (100 W). The progress of the reaction was monitored by TLC and the crude product isolated was purified by recrystallisation as mentioned before.



3a : R_1= H, R_2 = H, R_3= H, R_4 = H
3b: R_1= H, R_2 = H, R_3 = OH, R_4 = H
3c: R_1= H, R_2 = H, R_3 = OCH_3, R_4 = H
3d: R_1 = H, R_2 =H, R_3 = Cl, R_4 = H
3e: R_1= H, R_2 = H, R_3 = Br, R_4 = H
3f: R_1 = H, R_2 = H, R_3 = NO_2, R_4 = H
3g: R_1 = H, R_2= H, R_3 = $COOCH_3$, R_4 = H
3h: R_1 = H, R_2 = H, R_3 = CHO, R_4 = H
3i: R_1 = H, R_2 = OCH_3, R_3 = OH, R_4 = H
3j: R_1=H, R_2 = OCH_2CH_3, R_3 = OH, R_4 = H
3k: R_1= CH_3, R_2= H, R_3 = H, R_4 = CH_3

Results and discussion

The prepared catalytic systems were characterized by various analytical techniques such as FTIR, small angle and wide angle XRD, BET analysis, SEM-EDAX, TEM, TGA, pyridine adsorbed FTIR, XPS etc.

Catalytic activity: Conventional thermal catalysis

The catalytic activity of the prepared systems for the synthesis of BIMs was scanned through conventional thermal protocol. A preliminary scan was conducted at 100 ^oC using 0.05 g catalyst and 1 mmol of benzaldehyde and 2 mmol indole. Product analysis after 3 hours indicated maximum activity for 20 HPW/SSA system. Further, we set out to optimize the reaction conditions with 20 HPW/SSA as the catalyst. First attempt was to optimize the reaction temperature and the reaction was carried out in the range from room temperature (30-35 ^oC) to 90 ^oC. A yield of 46% was observed after 3 hours at room temperature which gradually increased to 95% at 80^oC. Further increase in temperature did not have any improvement in the yield. Thus, 80^oC was chosen as the optimum temperature for the reaction. The plausible explanation for this is the fact that indole polymerizes at higher temperatures under acidic environments.The duration for maximum conversion was found to be 3 hours. A comparative evaluation of the catalyst systems was carried out under the optimised reaction conditions where a 95% yield of BIM was obtained with 20 HPW/SSA. Blank run without catalyst generated a meagre yield. HPW gave almost comparable yield as 20 HPW/SSA. However, with pristine HPW, the catalyst recovery was tedious which limited the prospects for recyclability. Nevertheless, 20 HPW/SSA exhibited excellent recyclability for over 5 successive runs without significant loss in activity indicating the robustness of the catalytic system.

Energy efficient synthesis of BIMs was also performed in presence of visible light (white LED (100 W) source) at room temperature using 1 mmol benzaldehyde, 2 mmol of indole and 0.05 g of 20 HPW/SSA. Yields were monitored as a function of time and maximum yield was observed after three hours and the yields were comparable to that obtained at 80^oC after three hours. It is worth mentioning that the yield of BIM obtained in the presence of light at room temperature was comparable with the yield at 80 ^oC using conventional thermal protocol.

The broader scope of the synthesis protocol was validated through synthesis of a series of bis indolyl methane derivatives using substituted aldehydes with both electron releasing and withdrawing groups. Both the synthetic routes provided good yields of BIMs under optimized reaction conditions

Publications:

1. Rajalakshmi A.S, **Achari V S**, Sekkar V, Organo-inorganic hybrid IPN sourced porous carbons and their lead decontamination perspectives, Surfaces and Interfaces 48 (2024) 104196, https://doi.org/10.1016/j.surfin.2024.104196, Elsevier Publications, **Impact factor: 6.2**
2. Asha S. Raj, Gadha Anup, Rajathy Sivalingam, Preethy Chandran, "Biodegradation of chlorpyrifos by charcoal-alginate immobilized bacterial consortium isolated from pesticide-polluted Kuzhikandam Creek, Kerala,

India", Bioremediation Journal, Taylor & Francis online, https://doi.org/10.1080/10889868.2024.2312463, **Impact factor: 2.0**

3. R. Joy, M. K. Wilson, A. Antony, B. Konkena, S. C. Padmanabhan, M. A. Morris and S. Haridas, *New J. Chem.*, 2023, **47**, 22215–22225. *10.1039/d3nj04413k* , **Impact factor: 3.5**, Publisher: Royal Society of Chemistry.

Paper submitted

1. Arun R , Gopika Jagannivasan Salva M , Athira M P , Suja Haridas Phosphotungstic Acid Modified Sulphonic Acid Functionalised Sba-15: Exploring The Synergistic Effect For Thermal And Light Assisted Synthesis of is (Indolyl)Methanes.

Paper Submitted

1. Raichel Mary Lopez and V S Achari, Carbon Surface Chemistry of Oxidized- and nano La_2O_3 Dispersed Granular Carbons: Activation, Tuning, Texture and Adsorption.

Papers Published by Principal Investigator RUSA2.0 T2F from May 2023 to upto March 2024

1. Krishna, B., **Achari, V.S.**, 2023. Groundwater chemistry and entropy weighted water quality index of tsunami affected and ecologically sensitive coastal region of India. Heliyon 9 (10), e20431, Elsevier Publications. https://doi.org/10.1016/j.heliyon.2023.e20431 . **Impact factor: 4.0**
2. Krishna, B., **Achari, V.S.**, 2023. Groundwater for drinking and industrial purposes: A study of water stability and human health risk assessment from black sand mineral rich coastal region of Kerala, India. J. Environ. Manage. 351, 119783. https://doi.org/10.1016/j.jenvman.2023.119783 . Elsevier Publications, **Impact factor: 8.9**
3. Mohanadas, M., **Achari, V.S.**, Lekshmy, J., Namboothiri, Y.K., Sathyachandran, A., 2023. The hidden impact of seafood processing on coastal aquifers: Hydrogeochemistry and water quality assessment. Mar. Pollut. Bull. 196, 115611. https://doi.org/10.1016/j.marpolbul.2023.11561, Elsevier Publications, **Impact factor: 5.8**

Thesis submitted by Principal Investigator RUSA2.0 T2F on April 2024

PhD Thesis submitted to Cochin University of Science and Technology, Kochi on April 2024 by Balamuralikrishna under the supervision of **Dr. V Sivanandan Achari, PI, RUSA2.0, Major Project T2F**, "Groundwater chemistry, industrial and irrigation suitability of water: A hydro geoanalytical study from placer mineral enriched coastal regions of Kerala, India".

Acknowledgement

Principal Investigator is thankful to the Rashtriya Uchchatar Shiksha Abhiyan (RUSA 2.0), Government of India, New Delhi for financial support through RUSA2.0, Major project T2F as per the order No. CUSAT/PL(UGC).AI/2314/2023 dated 24/05/2023.