Water Technology Research and Innovation Centre

Centre for Sustainable Treatment, Reuse and Management

for Efficient, Affordable and Synergistic solutions for Water

(WATER-IC of SUTRAM for EASY WATER)

Department of Science and Technology, Government of India

By

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2. Project Title :**WATER-IC of SUTRAM for EASY WATER**

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7. Reporting Period: **April 2021 to March 2022**

8. **Accomplishments in Terms of Activities for the Review Period (WP-1 to WP-5):**

Work Package	Activity	Progress	Responsible Organization
WP1	Analysis of emerging contaminants	Received emerging contaminants results for one quarry water sample. Planning to analyze more samples from successive sampling	Anna University and IITM
	Sample evaporate residues preparation	Residues prepared for two quarry samples and yet to be analyzed to identify some rare trace elements	Anna University and IITM
	Development of research methodology to accomplish a regional level planning of SUDs as well as their impact assessment	Completed	IITM
	Determination of Soil hydraulic properties for IITM Campus	Completed	IITM
	Analyze the long-term performance of sustainable practices using SWMM and HYDRUS-1D coupled model.	Ongoing	IITM
	Integration of LID modules with SWAT sub-routines	Ongoing	IITM
	Water quality Analysis & collection of Secondary data on water quality (storm-water & runoff)	Secondary data on water quality as well as collection of samples and laboratory analysis have been carried out for Orathanadu taluk of Thanjavur, which was selected for exploration micro hydrological regime. Besides the University campus was explored to track run-off pattern of stormwater, following which specific sampling points were identified for characterization	PRIST

		and periodic assessment of hydro dynamic and hydro geochemical variations (both temporal and spatial) . Besides, the variation of rainfall patterns for the current year and their time series analysis for Thanjavur, Nagapattinam and Chennai were estimated and the previously developed rainfall prediction model was calibrated.	
	Estimation of significant parameters for each zone	Water quality characterizations of the two zones taken during the present study (namely Orathanadu taluk and University campus) were statistically assessed for the significant correlation among them. Successively principal component analysis (PCA; Rotated) were used to identify the dominant parameters and their groupings, using Eigen value >1. The selected factors were used for further geospatial analysis.	PRIST
	Zone-wise Water quality contours for dominant parameters	The water quality (WQ) parameters obtained from PCA were used for geospatial analysis wherein the contours for individual parameters as well as stormwater quality index (developed based on previous studies) were obtained.	PRIST
	Segregation of Cyclicity, Seasonality & Trend of Time Series Hydrological data of study area	Completed	PRIST
	Time & frequency domain-based modeling	Completed	PRIST
	Integrated Time Series Modeling for each storm-water zone	Ongoing	PRIST
WP2	Fabrication of portable colorimetric sensor based on Basic Fuchsine for the	Completed	IIT Madras

detection of nitrite ion in aqueous system		
Assessment of competitive adsorption of pharmaceuticals and personal care product on carbonized absorbent derived from waste: Single and Multicomponent study	Completed (Manuscript published)	IIT Madras
Colorimetric Sensors for the detection of phosphate	Completed. Patent Filed	IIT Madras
Risk Dynamics of Emerging Contaminants and Heavy Metals in the River Ecosystems	Completed	IIT Madras
Adsorptive removal of plasticizers using composite biochar	Completed	IIT Madras
MOF derived structure for capture of Phosphate	Completed (Manuscript under Review)	IIT Madras
Synthesis of biochar derived from bamboo fiber (BDB)	Completed	Kumaun University
Synthesis of biochar using wastewater treatment plant sludge (SDB)	Completed	IIT Madras
Characterization of BDB and SDB	Going on	IIT Madras
Sorption and sono-sorption of three textile dyes and its kinetic and equilibrium study using BDB	Going on	IIT Madras
Textile dye degradation study in pulse power plasma	Completed	IIT Madras
Effect of catalyst in pulse power plasma	Completed	IIT Madras
Effect of the input voltage on the degradation of dyes	Completed	IIT Madras
Effect of other parameters	Going on	IIT Madras
Degradation mechanism study	Going on	IIT Madras
Synthesis of triptycene based polymer	Completed	IISER Bhopal

	Adsorption study for pharmaceuticals using triptycene based polymers	Going on	IIT Madras
	Fluoride free drinking water	Lab-scale performance evaluation	IIT Madras
	Sensors and Kits for Water Quality Monitoring	Combining sensing moieties with detection techniques	IIT Madras
	Low-cost microfluidic platform for multi-analyte assessment of water quality	Detection of single contaminants	IIT Madras
	Atmospheric Water Capture	Completion of large area nano-engineered surface fabrication	IIT Madras
	CDI Prototype	Incorporation of ion exchange membranes Integration with electronic and photovoltaic system	IIT Madras
	Synthesis and characterization of affordable composite materials for the removal of heavy metals and microbes	Completed	IIT Tirupati
	Performance evaluation of the materials	Completed	IIT Tirupati
	Reuse/Recycle of spent materials	Completed	IIT Tirupati
	Prototype: design, development, and evaluation	On-Going	IIT Tirupati
	Field trials - household unit	On-Going	IIT Tirupati
	Documentation and data analyses: report making, manuscript preparation, patent filing	On-Going	IIT Tirupati
	Development of single probe multi-analyte sensor for different metal ions with specific focus on Cr (III & VI), As (III & V), and Hg (II)	1. A simple, low-cost and sensitive multiplexed electrochemical sensor using dual functionalizatized graphene oxides. Evaluation of handheld electrochemical device. 2. Synthesis of L- Cysteine, L-Glutathione, Dithiothreitol on graphene oxide	CSIR-CLRI

		3. Development of novel, low cost colorimetric and fluorescent probes	
	• Optimization of fabrication conditions for molecular cage-derived crystalline covalent organic framework based free-standing film for nanofiltration • Testing of pristine and sulfonated HCPs for real-time removal of pharmaceuticals found in Indian surface water • Optimization of ionic porous polymers for toxic metal anion removal • Manuscript writing and publication	• Optimization of the fabrication conditions for cage derived crystalline covalent organic framework based free-standing film through interfacial polymerization • Nanofiltration study using crystalline COF films • Pristine and sulfonated HCPs for the removal of pharmaceutical compounds from water (e.g., carbamazepine) • Optimization of fabrication conditions of triaminoguanidinium based porous organic polymers for dichromate, permanganate anion removal • Publication of manuscript on Nanostructured triptycene-based hypercrosslinked porous organic polymers for rapid separation of polar organic micropollutants	IISER Bhopal
	Synthesis of nanocomposites with agricultural waste/waste plastic derived graphene oxide for lead removal application	Completed	Kumaun University
	Characterization and Lead removal study	Under progress	KU and IIT Madras
	Toxicology assessment of synthesized materials	Under progress	IITR Lucknow

	Synthesis of graphene-based sponge for oil-water separation	Completed	KU and NIT Rourkela
	Synthesis of material for water purification membrane	Completed	Kumaun University
	Testing of material for water purification membrane	Under progress	Kumaun University
	Toxicity profiling of various materials/compounds	Preliminary *in vitro* experiments were performed on various cell lines to assess their toxic profile	CSIR-IITR and Kumaun University, Nainital
	Quantum Dots for Anticancer activity	Cytotoxicity assay (MTT), Quantum dots internalization through flow cytometry, and Fluorescent microscopy study are underway.	CSIR-IITR and Kumaun University, Nainital
	Carbon nanotubes for water treatment	Cytotoxicity assay (MTT) to determine the effective concentration of IC_{50} of the carbonaceous material is in progress.	CSIR-IITR and Kumaun University, Nainital
	Chitosan-RGO-Ag nanocomposite films for disinfection of water	Cytotoxicity assay (MTT) to determine the effective concentration of IC_{50} of the leachate sample is underway.	CSIR-IITR and IIT, Tirupati
WP3	Laboratory studies on identification of appropriate adsorbent materials for the removal of pharmaceutically active compounds and nutrients	Completed	IIT Madras
	Fabrication of large scale 4 µm pilot ceramic filter for the treatment of secondary treated wastewater.	Completed	IIT Madras
	Batch study with 4 µm pilot scale ceramic filter membrane by fixing feed flow rate below 15 m^3/h with secondary treated wastewater as feed.	Completed	IIT Madras

Quality analysis for the parameters like pH, COD, Fecal coliform, and Turbidity for Ceramic filter and it was compared with existing UF system.	Completed	IIT Madras
Flux monitoring study along with Transmembrane pressure in batch process.	Completed	IIT Madras
Modification work for continuous process with 4 µm pilot scale ceramic filter membrane.	Completed	IIT Madras
Continuous experiments with 4 µm pilot scale ceramic membrane filter by fixing feed flow rate below 15 m^3/h with secondary treated wastewater as feed along with air plus water backwash.	Completed	IIT Madras
Optimization of air plus water backwash timing.	Completed	IIT Madras
Continuous filtration cycle with 4µm pilot scale ceramic membrane followed by air plus water backwash (1-90 cycles) with secondary treated wastewater along with chemical enhanced backwash (CEB).	Completed	IIT Madras
Comparison of energy and chemical consumption for Ceramic and ultrafilter	Completed	IIT Madras
Optimization of operation time and flow rate.	On going	IIT Madras
Studies on decolorization of high concentration of azo dye-Methyl Red via denitrification pathway	Completed	VIT Chennai
Batch studies on decolorization of model azo dyes (Orange G, Tartrazine, and Chrysodine Y) via	Completed	VIT Chennai

denitrification pathway		
Gene expression studies on Nitrifiers, ammonia oxidizers and sulfur reducers (Oct 2020 - March 2021)	SBR and UASB studies have been restarted and the work is in progress. Subsequent to the stabilization and continued operation of SBR and UASB studies, the gene expression of the bacteria consortia will be carried out.	(CSIR-CLRI)
Effect of COD loading and total nitrogen rates in tannery waste water (April 2021 – Sep 2021)	Removal of COD and TKN were evaluated with different loading rates in SBR.	(CSIR-CLRI)
Effect of nitrogen loading rates in tannery wastewater with SBR	Removal of TKN and Ammoniacal nitrogen were evaluated with different loading rates	Central Leather Research Institute (CSIR-CLRI)
Initial study of AD-MEC, system in continuous mode for COD removal, biogas generation and ammonia recovery	Based on the study of graphene coated electrode based microbial fuel cell (MFC) and subsequent optimization of the process parameters namely PEM (Salt bridge, varying length), Salinity (anode Chamber), pH (anode Chamber), Aeration (anode Chamber), Temperature (cathode chamber), Stirring speed (both cathode and anode Chambers), Electrode (both cathode and anode Chambers) Light (both cathode and anode Chambers), anaerobic decomposition (AD) – microbial enzymatic cell (MEC) was initiated and a surveillance on the scale of COD reductions in the effluent, biogas generation at cathode and ammonia conversion efficiency were carried out in addition to electricity generations.	PRIST

	Fine tuning of AD-MEC, system in continuous mode	Ongoing	PRIST
WP4	scheduling for water distribution networks	Pure data driven methods demonstrated on laboratory network Heuristics for reducing computational effort for model based formulation developed Python based web application is being developed and will be released Retrofit model for sewer networks using on-site Grey water recycling on real life situation has been published. Its testing for real situation in Kurichi (Coimbatore) is in progress. Retrofit model for existing sewer networks using decentralized wastewater system has been completed and tested for IIT Madras network A model has been developed for optimal design of a new sewerage system with grey water recycling and reuse to bridge the gap in water supply has been developed and tested for realistic situations An integrated model for optimal design of water supply and sewerage systems has been developed and validated. Testing for realistic systems is in progress.	IIT Madras

WP5	Incubation Hub	Continuation and completion of process set up	IIT Madras

9. Accomplishment in Terms of Milestone for the Review Period:

Work Package	Milestones	Target month	Progress
WP1	Collection of data supporting the study (Lithologs, Toposheets, Soil, Rainfall, Water level, Satellite imageries)	March 2019	The basic data related to the study were collected and the maps were prepared by the target month mentioned. The Time series data like Rainfall, water levels have been collected till date.
	Preparation of thematic maps	July 2019	Completed
	Identification of pits/ quarries/ tanks	August 2019	Completed
	Assessment of quarry water, surface water and groundwater quality	Periodical collection up to June 2023	Sample collection and analysis have been completed until September 2021; next sampling will be carried out in February 2022
	Identification and assessment of various interventions	May 2022	Controlled reservoir operation has been planned and assessed using HEC-HMS software package and procured feasible results. Some hydrological interventions that facilitate flood mitigation and groundwater augmentation like additional check dams, interlinking waterbodies are under assessment using MIKE11 NAM and MIKESHE packages

	Modelling to assess the impact of identified measures	June, 2023	Conceptual Rainfall-runoff (R-R) modelling had been set up for the upstream part of Chembarambakkam reservoir, calibrated and validated with good correlation. The simulation has to be continued with the projected rainfall. Integrated flow modelling of Adyar watershed have to be calibrated and validated.
	Data collection for the monsoon event 2020-2021 and data analysis	Nov 2021 – January 2022	Completed
	Preliminary coupled model SWMM-HYDRUS1D has been setup to access the long-term hydrological behaviour of catchment.	Dec 2021	Completed
	Development of LID modules for designing sustainable drainage plans	Dec 2021	Completed
	Data collection for the monsoon event (Cyclone Nirvar)of Dec 2020 and analysis of data	January 2020	Completed
	Mapping/Modelling loss of water bodies and urban sprawl using satellite imagery(M.Tech thesis)	July 2021	Completed
	Water availibity modelling for Chennai basin using WEAP model.(M.Tech thesis)	July 2021	Completed
	Storm water management by using traditional water storage systems as flood control structures(M.Tech thesis)	July 2021	Completed

	Time Series Models for each zone (coupled deterministic & stochastic)	31-36 Months	1. Calibration of time series model developed for rainfall prediction at the study area for current year 2. Evaluation of variation of cyclicity, seasonality and trend of time series hydrological data of study area 3. Time and frequency domain-based modeling for estimating suitable ARIMA model for the study area 4. Development of water quality contours and flow-patterns (using SWAT) for selected study area
	Zone-wise Water quality contours for dominant parameters	25-30 months	1. Calibration of time series model developed for rainfall prediction at the study areas. 2. Collection of secondary data as well as primary data (through collection at site and analysis at lab) from a selected taluk (namely Orathanadu). 3. Ground surveillance of the University campus to explore hydrological and hydro geochemical characteristics and establishment of sampling locations catering to spatio temporal and hydrological resolutions for development of optimal water utilization masterplan. 4. Selection of dominant WQ parameters using PCA and successive development of WQ contours.
WP2	Fabrication of Capacitive deionization cell and development of material for deionization	June 2022	On going

	Synthesis of biochar derived from bamboo fiber (BDB)	April, 2021	Completed
	Synthesis of biochar using wastewater treatment plant sludge (SDB)	June, 2021	Completed
	Characterization of BDB and SDB	September, 2021	Completed
	Sorption and sono-sorption of three textile dyes and its kinetic and equilibrium study	August, 2021	Completed
	Lab-scale performance evaluation	Sept 2021	Complete
	Combining sensing moieties with detection techniques	Feb 2022	In progress
	Detection of single contaminants	Feb 2022	In progress
	Completion of large area nano-engineered surface fabrication	Feb 2022	Complete
	Incorporation of ion exchange membranes	Feb 2022	In progress
	Continuation and completion of process set up	Sept 2021	Complete
	Textile dye degradation study in pulse power plasma	October, 2021	Completed
	Effect of catalyst in pulse power plasma	November, 2021	Completed
	Effect of the input voltage on the degradation of dyes	December, 2021	Completed
	Synthesis of triptycene based polymer	December, 2021	Completed
	Effect of other parameters	February, 2022	In Progress
	Degradation mechanism study	March, 2022	In Progress
	Characterization of triptycene polymers	March, 2022	In progress

	Adsorption study for pharmaceuticals using triptycene based polymers	March, 2022	In progress
	Pilot-scale performance evaluation	Feb 2022	Completed
	Combining sensing moieties with detection techniques	Feb 2022	Nearly complete
	Detection of single contaminants	Feb 2022	Nearly complete
	Completion of large area nano-engineered surface fabrication	Sept 2022	Nearly complete
	Incorporation of ion exchange membranes Integration with electronic and photovoltaic system	Sept 2022	Nearly complete
	Continuation and completion of process set up	Sept 2021	Complete
	Long term performance of the antibacterial silver nanocomposite (AgNC) film	33-39 Months	Sustained release of silver ions from AgNC in distilled water, surface water, and groundwater was established
	Coating of the developed AgNC onto citrate-functionalized glass plates for making a reactor for disinfection applications	33-39 Months	We have optimized the protocol for the functionalization of glass plates. A coating methodology was developed, and the hydraulic stability of the coating was evaluated
	A protocol has been developed to recycle/reuse exhausted AgNC films	33-39 Months	We have recycled the spent AgNC and demonstrated its potential to repair micro-cracks in damaged concrete cubes. The repaired cubes were evaluated for their potential leaching of Ag via modified TCLP analysis, and the results show that the leaching of Ag from the cubes is around 150

			times lesser than the permissible limits.
	Study on performance evaluation of self-combustion graphene-oxide (SCGO) for the removal of uranium (U) in water	33-39 Months	Batch adsorption studies like kinetics, pH, isotherms, Co-ions, ionic strength, and groundwater samples are performed
	Study on performance evaluation of Fe-chitosan-Phosphate (Fe-Cs-P) granular composite to remove U(VI).	33-39 Months	The composition of Fe-CS-P granular composite was optimized for achieving better hydraulic stability and U(VI) removal efficiency.
	Evaluation of the antibacterial activity of the prepared nanocomposite (AgNC) in the presence of various co-ions in water	26-32 months	The antimicrobial activity of AgNC in the presence of various co-ions, including hardness, alkalinity, chlorides, and humic acid, was studied.
	Long term performance of the antibacterial silver nanocomposite (AgNC) film	26-32 months	Sustained release of silver ions from AgNC in distilled water, surface water, and groundwater was established
	Synthesis of AgNC coated beads and development of a reactor for PoU disinfection of water.	26-36 months	We have optimised the composition and procedure for the synthesis of AgNC coated Fe-beads. We have optimised and evaluated the release of silver and disinfection performance of the prepared beads in a batch reactor
	Project initiation, identifying the structural motif's	6th Month	Structural motifs are identified and are synthesized.
	Synthesis of intermediate compounds	12th Month	Signaling units and receptor units were identified. Three derivatives were synthesized and characterized and their preliminary studies are in progress.
	Preliminary investigation of sensing the metal ions	24th Month	Few receptors were developed to sense the Hg^{2+} at the picomolar level using optical methods

	Fabrication of electrochemical device and multiplex sensors for different ions	36th Month	Multiplex sensor for chromium and Hg has been developed. The work on the addition of functional groups for arsenic is also in progress. In addition, the molecular probes to improve the sensitivity and selectivity is also in progress
		36 -49 Months	**Activity 1**: In vitro studies were performed and preliminary data regarding the toxicity of materials/ compounds were generated on various cell lines. A complete set of cytotoxicity data was generated using A549 and Kera 308 was performed and communicated to PI. The second set of data on HaCaT and MCF 7 is in process.
		36 -49 Months	**Activity 2**: One set of data on Human keratinocyte cell line (HaCaT) for Cytotoxicity assay (MTT) to assess the effective IC_{50} concentration of the carbon nanotubes was generated which is further being confirmed for reproducibility.
		36 -49 Months	**Activity 3**: One set of data on Human keratinocyte cell line (HaCaT) for Cytotoxicity assay (MTT) to assess the effective IC_{50} concentration of the Chitosan-RGO-Ag nanocomposite films leachate was generated which is further being validated for reproducibility.

	Study on performance evaluation of self-combustion graphene-oxide (SCGO) for the removal of uranium (U) in water	26-32 months	We have optimised the individual ingredients for the preparation of SCGO and the screening of the prepared SCGO material for the removal of Uranium (U). Isotherm batch adsorption studies and the effect of pH in the removal of U(VI) were evaluated.
	Study on performance evaluation of Fe-chitosan-Phosphate (Fe-Cs-P) granular composite for the removal of U(VI).	26-32 months	The composition of Fe-CS-P granular composite was optimized for achieving better hydraulic stability and U(VI) removal efficiency.
	Project initiation, identifying the structural motif's	6th month	Structural motifs are identified and are synthesized.
	Synthesis of intermediate compounds	12th month	Signaling units and receptor units were identified. Three derivatives were synthesized and characterized and their preliminary studies are in progress.
	Preliminary investigation of sensing the metal ions	24th month	Few receptors were developed to sense the Hg^{2+} at picomolar level using optical methods
	Fabrication of functionalized graphene modified electrodes	36th month	Functionalization of graphene suitable for the specific metal ions detection and optimization of detection methods, improving the limit of detection
	Standardizing gram scale protocol for HCP and testing with a wide range of micropollutants, Optimization of fabrication conditions for macrocycle and cage-based network polymers	30th – 35th month	1.Toluene-based HCP was synthesized in gram scale 2.Optimization of the fabrication condition for macrocycle/cage-based porous networks for nanofiltration applications 3.Optimization of the solution processable triptycene-based HCPs using flexible halogenated linkers
	Writing of the manuscript	30th – 35th month	Revision and further fine tuning of the

			manuscript for triptycene-based HCPs for broad spectrum micropollutant removal and elucidation of morphological impact on micropollutant removal
	Water samples collection from the lakes of Nainital region	0-6 months	Completed
	Examination and Identification of the collected samples	06-12 months	Completed
	• Synthesis of porous carbon nanomaterials/activated carbon black by using traditional precursors and waste plastic. • Research Paper	12-24 months	Completed
	• Carbon nanomaterials /activated carbon black/nano-zeolite based polymer nano composites as filter membranes for water filtration unit. • Research Papers and patent	24-36 months	In progress
	In vitro studies were performed and preliminary data regarding the toxicity of materials/ compounds were generated on various cell lines	36 -49 Months	In progress
WP-3	Identification and characterization of low-cost adsorbent materials	Jan 2020	Completed
	Batch adsorption study for three pharmaceutical compounds and nutrients with the selected eight materials	Feb 2021	Completed
	Screening of materials through multi-criteria decision-making tool	June 2021	Completed

(MCDM)		
SBR studies on model azo dyes (Tartrazine, Orange G, Chrysodine Y) under denitrifying conditions	32nd month	Completed
Writing manuscripts for Journals using existing data and book chapters	34th month	Completed
Setting up of laboratory-scale constructed wetland units at IIT-Madras	Jan 2021	Completed
Performance monitoring of the laboratory-scale constructed wetland units with different substrate materials	Sep 2021	Completed
Quantification of accumulation of PhACs in the plants and substrate materials	Oct 2021	Completed
Batch biodegradation studies	Dec 2021	Completed
Fabrication of large scale 4 µm pilot ceramic filter for the treatment of secondary treated wastewater at STP, IITM.	Mar-Apr	Completed
Batch study with 4 µm pilot scale ceramic filter membrane by fixing feed flow rate below 15 m^3/h with secondary treated wastewater as feed and quality analysis study for CF and existing UF.	Sep-Oct	Completed
Flux monitoring study along with Transmembrane pressure evolve in batch process and Modification work for continuous	Oct- Nov	Completed

	process.		
	Continuous filtration cycle with 4µm pilot scale ceramic membrane followed by air plus water backwash (1-90 cycles) with secondary treated wastewater along with chemical enhanced backwash (CEB). Energy and chemical consumption per unit volume for Ceramic filter and existing Ultra filter system.	Nov- Dec	Completed
	Continuous experiments with 4 µm pilot scale ceramic filter membrane filter at fixed feed flow rate below 10 m^3/h and optimization of operation time and flow rate.	Dec- Jan	On going
	Decolorization of high concentration of azo dye Methyl Red in sequencing batch membrane bioreactor	39th Month	Completed
	Working models of AD-MEC in continuous mode	31-36 Months	1. Study of Anaerobic degradation (AD) of MFC/MEC with varying degree of anaerobic conditions 2. Estimation of optimized recirculation ratio and flow rate for continuous mode operation 3. Assessment of energy generation potential (voltage, current and power-density), water quality variation and sludge characteristics 4. Tracking bacteriological dynamics during MFC operation

	Quantitative real time (RT-PCR) data analysis of nitrifiers, denitrifiers and sulphur reducers	5th Half-yearly period (End of March 2021)	SBR and UASB studies have been restarted and the work is in progress. After stabilization of reactors, the consortia from SBR and UASB will be evaluated.
	CNS removal in SBR under different COD loading rates	6th Half-yearly period (End of September 2021)	CNS removal of Synthetic Tannery Wastewater has been carried at COD loading of 1.85 kg $COD/m^3/d$ with SBR and UASB. Kinetic studies on removal of pollutants in SBR were performed.
	CNS removal in SBR under different nitrogen loading rates	7th Half yearly period (End of March 2022)	CNS removal of tannery wastewater has been carried at nitrogen loading of 0.145 $kg/m^3/d$ with SBR and UASB.
WP-4	Methodology for network mapping	Month 30	Network mapping methodology developed
	Software for network mapping and scheduling	Month 36	Scheduling software has been converted to python. Web app will be released shortly.
	Coding for retro-fitting of sewer networks for recycling of greywater and wastewater.	Months 36	Completed
	Testing of retro-fit models for sewer networks	42 months	Completed Demonstration of application to a real life case is in progress
WP5	Continuation and completion of process set up	Sept 2021	Complete

10.   Completed/ongoing activities during the review period: April 2021- March 2022 (WP 1 - WP 5)

S. No	Review Period	Completed Activities	Ongoing / Pending Activities
WP1	April 2021 – March 2022	• Identification of pits, quarries and lakes for water storage and recharge • Spatial and temporal rainfall analysis for past 39 years • Box model for controlled reservoir operation of Chembarambakkam reservoir • Rainfall-runoff modelling using MIKE11 NAM for the upstream side of Chembarambakkam reservoir. • Downscaling and bias correction of projected rainfall till 2100 under RCP 4.5 and RCP 8.5 • Water quality analysis of surface, ground and quarry water samples (periodic analysis – till September 2021)	•Next set of water sampling has been planned for February 2022 and this will be the periodic process • Calibrated R-R model has to be used to simulate discharge using different scenarios • Integrated flow model of the entire Adyar basin is under refinement using calibration and validation • Prediction of changes in future runoff due to climate change
	September 2021	• Analysis of hydrological behaviour of existing drainage system to storm event. • Collection of Rainfall data, Ground water levels, soil samples and measurement of soil hydraulic parameters.	
	June, 2020	• Assessment of the impact of SUDS on hydrological behaviour. • Calibration and validation of the SWMM model carried out for SUDS. • Design of SUDS for the study area	• Parameterization of SWMM LID module hydraulic properties for design storm event, antecedent moisture content and soil types.

	Feb, 2021	• Preliminary model to evaluate optimal placement and sizing of SUDs has been setup.	• Calibration and validation of the existing drainage network model is ongoing. • Effect of optimal scenarios of SUDs on hydrological response of study area is being analyzed.
	August, 2021	• Development of methodology for achieving river basin scale planning of SUDs	• Developing LID modules for improving the SWAT model formulation. • Development of methodology for site suitability analysis of LIDs.
	December, 2021	• The preliminary coupled SWMM-HYDRUS1D model has been setup to evaluate effect of design storm events, antecedent moisture content and soil types on performance of proposed LIDs components	• To develop the SWMM-HYDRUS-1D coupled model using pySWMM and phydrus.
	August, 2021	• Development of methodology for achieving river basin scale planning of SUDs	• Verification of the developed LID modules with HYDRUS 1D. • Development of methodology for site suitability analysis of LIDs.
	25-30 Months	Water quality Analysis & collection of Secondary data on water quality (storm-water & runoff)	Stormwater zonation study for two micro hydrological regions (Orathanadu taluk and campus)
	25-30 Months	Estimation of significant parameters for each zone	Development of zone-specific micro clustering of WQ parameters for optimal modeling and forecasting

		25-30 Months	Zone-wise Water quality contours for dominant parameters	Model calibrations (temporal, spatial and hydrological)
		31-36 Months	Time Series Model calibration & Assessment of Trend, cyclicity and Seasonality	Compilation of ongoing precipitation data and exploring potential variability
		31-36 Months	Time and Frequency domain modeling to develop ARIMA predictive models	Comparative assessment of optimized predictive models
		31-36 Months	Surface hydrological Modeling of Selected Zone (i.e., University campus)	Tracking the specific water-harvesting potential
WP2		Jan April 2021	Fabrication of Capacitive deionization cell and MOF derived structure for capture of Phosphate	Ongoing
		May-Dec 2021	Selective removal of Phosphate via electro sorption	Ongoing
		Feb, 2021 – Aug, 2021	Synthesis of biochar derived from bamboo fiber (BDB)	Completed
		July- Dec 2019	Fabrication of portable colorimetric sensor based on Basic Fuchsine for the detection of nitrite ion in an aqueous system	Completed
		July – Jan 2020	Assessment of competitive adsorption of pharmaceuticals and personal care product on carbonized absorbent derived from waste: Single and Multicomponent study	Completed
		July -March 2020	Colorimetric Sensors for the detection of phosphate and nitrate	Completed
		July-September 2020	Risk Dynamics of Emerging Contaminants and Heavy Metals in the River Ecosystems	Completed
		Jan Dec 2021	Selective removal of Phosphate via MOF	Completed
		Jan-June 2022	Fabrication of Capacitive deionization cell and LDH derived structure for the capture of	Ongoing

		phosphate	
	Feb, 2021 – Aug, 2021	Textile dye degradation study in pulse power plasma	Completed
		Effect of catalyst in pulse power plasma	Completed
		Effect of the input voltage on the degradation of dyes	Completed
		Synthesis of triptycene based polymer	Completed
			Characterization of triptycene polymers
			Adsorption study for pharmaceuticals using triptycene based polymers
			Effect of other parameters
			Degradation mechanism study
	Feb, 2021 – Aug, 2021	Synthesis of biochar using wastewater treatment plant sludge (SDB)	
	Feb, 2021 – Aug, 2021	Characterization of BDB	
	Feb, 2021 – Aug, 2021	Sorption and sono-sorption of three textile dyes and its kinetic and equilibrium study	
	Feb, 2021 – Aug, 2021		Modification of BDB
	Feb, 2021 – Aug, 2021		Characterization of SDB
	Feb, 2021 – Aug, 2021		Manuscript writing initiated

	1-24 Months	Identification of structural motifs, their synthesis and characterization and evaluation of sensing activities.	Further studies on sensing are in progress.
	24-36 Months	Few target compounds were synthesized and demonstrated for sensing purposes	Further studies to improve the sensitivity and selectivity
	1st -29th month	Submission of Indian patent and writing of manuscript on triaminoguanidinium-based ionic porous organic frameworks (POFs) for heterogeneous catalysis and broad-spectrum antimicrobial application	Patent (ongoing) Application No. 201921010663 A
	1st -29th month	Multifunctional ionic porous frameworks for CO_2 conversion and combating microbes	Chem. Sci. 2020, 11, 7910-7920
	30th -35th month	Manuscript revision on unfolding the morphological importance of triptycene-based hypercrosslinked polymers toward micropollutant removal	Submitted
	Sep 2020-July 2021	Preliminary toxicity screening	Toxicity assessment to understand the environmental impact of the tested materials/compounds
	Sep 2021-Jan 2022	Preliminary toxicity screenings on cell lines of different origins for the three different materials are performed to generate baseline data.	The initial data which were generated for the three activities are now being validated for reproducibility.
	1-36 Months	Identification of structural motifs, their synthesis and characterization and evaluation of sensing activities. Fabrication of functionalized electrodes, development of the handheld device developed by CSIR-CLRI for Cr(VI) sensing	Evaluation of the low-cost sensing device developed by SUTRAM for EAST Water and optimization process. Development of new sensor molecules
	36-42 Months	Synthesis of nanocomposites with agricultural waste/waste plastic	Characterization and Lead removal study

		derived graphene oxide for lead removal application	
	36-42 Months	Synthesis of graphene-based sponge for oil-water separation	-
	36-42 Months	Synthesis of material for water purification membrane	Testing of material for water purification membrane
	36-42 Months	Synthesis of nanocomposites material	Toxicology assessment of synthesized materials
WP3	August 2021 – January 2022	Laboratory-scale constructed wetland studies for the removal of organics, nutrients and pharmaceutically active compounds (PhACs)	NA
	Jan 2021 – Jan 2022	Fabrication of large scale 4 µm pilot ceramic filter for the treatment of secondary treated wastewater at STP, IITM.	
		Batch study with 4 µm pilot scale ceramic filter membrane by fixing feed flow rate below 15 m^3/h with secondary treated wastewater as feed and quality analysis study for CF and existing UF.	
		Flux monitoring study along with Transmembrane pressure evolve in batch process and Modification work for continuous process.	
		Continuous filtration cycle with 4µm pilot scale ceramic membrane followed by air plus water backwash (1-90 cycles) with secondary treated wastewater along with chemical enhanced backwash (CEB).	
			Continuous experiments with 4 µm pilot scale ceramic filter membrane filter at fixed feed flow rate below 10 m^3/h and

			optimization of operation time and flow rate.
	Month 34-39	Decolorization of high concentration of azo dye Methyl Red in sequencing batch membrane bioreactor and manuscript draft preparation	Completed
	October 2021 – January 2022	• COD & TKN removal in SBR with different nitrogen loading rates (0.101, 0.145, 0.178, 0.237 g/L/d) have been carried out. • Presence of Ammonia oxidizing genes were analyzed in the bacterial consortia.	• Removal and conversion of sulphates and sulphides in tannery wastewater • Meta genomic studies of microbial consortia from SBR and UASB
	Month 29-32	Operation of lab scale anoxic SBR under denitrifying conditions for simultaneous removal of color, COD, and TN	Completed
	Month 33-34	Prepared 3 new manuscripts and 2 invited book chapters; Addressed the revisions of 2 manuscripts that were under review which got published now	Completed
	April 2021 – September 2021	COD and TKN removal in SBR with different loading rates have been carried out. Performance of SBR followed by UASB was evaluated. Kinetic studies on removal of pollutants in SBR were performed.	Microbial community from SBR and UASB has to be studied. Residual Sulphide from the UASB has to be removed.
	31-36 Months	Fine-tuning of AD-MFC/MEC system with optimization of process parameters (recirculation, anaerobic potential)	Exploration of graphene-electrode based AD-MEC system.
WP-4		Systematic methodology for leak identification using minimum valve operations & flow balance is demonstrated experimentally in a complex test network.	Web based application for leak detection is in progress
		Developed method for reconstructing networks from road layout and explainable AI	Web based application is in progress
		Robust optimization formulations	Web based application

	April-2021 – March 2022	developed to address uncertainty in data	will be released shortly
		Problem for network calibration has been formulated and demonstrated on small sized networks	Demonstration and extension to large scale networks is in progress
		Testing of model for retrofitting of sewer networks with on-site greywater treatment and recycling for realistic systems has been completed. Testing of model for retrofitting of sewer network with decentralized wastewater treatment and recycling through dual piping system is for realistic systems has been completed Coding of model for design of new sewerage systems with on-site grey water treatment and recycling to bridge the gap between demand and supply in existing water supply systems is completed and tested for realistic systems. Coding for integrated design of new water supply and sewerage systems which incorporate recycling and reuse of on-site grey water treatment has been completed and tested.	Demonstration of all developed models on real life situations is in progress. Conversion of computer codes to "software products" is in progress.
WP-5	Sept 2021	Continuation and completion of process set up	Complete

11.   A Brief Description of Technical/Scientific Achievement for the period (April 2021 – March 2022):

WP-1

- The Topographic map (from SRTM), digital elevation model (from SRTM), geology & geomorphology map (from GSI), drainage map (from toposheet, DEM), Stream order

- map, land use land cover map (from LISS-III, 2017), Thiessen polygon map (from rain gauge stations) were prepared and used as layers in integrated flow modelling.
- Demarcation of various quarries, old channels in Chennai region were carried out with Satellite imagery and toposheets and possible interventions were noted based on the base maps prepared in ArcGIS 10.4 software package.
- Volume of the quarries, water availability in quarries and water bodies, surface and groundwater level in different locations and elevations were assessed, thus possible links and diversions were conceptualized.
- Rainfall occurrence and variation studies for the Adyar sub-basin for the past 39 years were analyzed using the homogeneous and autocorrelated rainfall records procured from IMD and PWD.
- a box-model approach for reservoir operation (Chembarambakkam reservoir) under extreme conditions has been developed and the performance was ascertained using the correlation coefficient and Nash–Sutcliffe efficiency with an average error estimation of 15% and 25% in water level, 21% and 18% in outflow simulation, respectively.
- The R-R model for the Chembarambakkam sub-catchment was set up using MIKE11 NAM package and the performance of this model was ascertained using the Coefficient of determination and water balance error with 0.72 and -10% respectively.
- The Chembarambakkam reservoir (3.65 TMC) and the three abandoned quarries (1 TMC approx.) at the downstream part of the modelled Chembarambakkam sub-catchment were used for distributing and storing the simulated discharge to achieve improved water storage, reduced inundation and better water supply.
- The flow model of Adyar watershed using MIKESHE package has been set up. Calibration and validation are in progress.
- The daily rainfall data, projected under RCP 4.5 and 8.5 from RegCM 4.4 prepared by IITM, Pune was acquired for the Chennai region and was downscaled and bias-corrected by linear scaling method using IMD daily rainfall data. The projected rainfall data until 2100 will be used for further simulations of the model.
- The water samples from abandoned quarries, lakes, ponds and groundwater were collected and analyzed periodically once in three months
- Collection of real time data of river discharges at critical locations across Adyar River and Kosasthalaiyar River.
- Evaluation of the hydrological response of the catchment due to the application of different combinations of SUDS using SWMM.
- Vadose zone modelling using HYDRUS -1D to simulate the infiltration based SUDS to combat the limitations of SWMM in SUDS representation through SWMM-HYDRUS coupling.

- Development of the SWMM-HYDRUS-1D coupled model using pySWMM and phydrus to simulate hydrological response of rainwater harvesting, permeable pavement, infiltration trench, infiltration basin and recharge shaft for IIT Madras campus, India.
- Formulation of methodology for strategizing a regional level planning of SUDS that would facilitate holistic water resource management for the basin.
- Development of modules for SWAT model formulation of LIDs using MATLAB to facilitate river basin scale decision making.
- LID modules for bio-retention cells, rain gardens, green roofs, permeable pavements, infiltration trenches and swales were formulated and the verification of the same is going on using HYDRUS 1D model.
- Conceptual model for recharge shaft was formulated and the development of the module is completed.
- Hydrological and hydraulic modelling to estimate the impact of traditional water storage tanks to control flood inundations in the Pallikaranai Marshland.
- Data sets that represent critical watershed parameters for site suitability analysis of LID components were collected from various sources.
- Methodology for site suitability analysis of LID components using Multi-Criteria approach was formulated.
- Thematic data layers viz., depth to bedrock, drainage density, geology, geomorphology, land use & land cover, lineament density, profile curvature, rainfall, slope, soil, Topographic Position Index (TPI), and Topographic Wetness Index (TWI) was created in GIS.
- Preliminary site suitability map of detention basin using Analytical Hierarchy Process (AHP) was prepared for Chennai basin using 11 of 14 thematic layers.
- Collection of rainfall data and calibration of time series predictive model developed at the study areas, and tracking the change in trend, cyclicity and seasonality
- Spatio-temporal hydrological modeling at University campus and estimation of water quality contours
- Assessment of water flow pattern variation through SWAT modeling and exploration of improved water utilization approach.

WP-2

- Development of portable and low-cost techniques for detecting and removing trace pollutants. For this, a traditional method such as paper strip sensor and carbon-based adsorbents from waste have been tested. At the same time, two low-cost green adsorbents were made from agriculture and sewage sludge to remove emerging contaminants. A risk assessment model was developed to characterize the hazard efficiency of micropollutants

in the Cauvery river basin. Additionally, the application of MOF for sorptive and electrosorption removal of phosphate was tested

- Degradation studies of three dyes (methylene blue, methyl orange and basic fuchsin) using pulse power plasma technology was completed
- Utilization of the pulse power plasma for activation of catalyst was studied to improve the efficiency of technology and to reduce the cost of the treatment process
- Effects of various parameters such as input voltage, initial dye concentration, treatment time etc were studied to find the optimized treatment condition
- The degradation mechanism and cost of treatment are being carried out to understand the feasibility of such process in dye degradation
- The synthesis of triptycene based polymers was completed to use for sorptive removal of pharmaceuticals (diclofenac and carbamazepine) from wastewater
- Adsorption studies and the effect of ultrasonication are being studied
- The model-based analysis will be carried out to optimize the various parameters involved
- Characterization of the polymers is carried out to find out the mechanism behind the sorption
- Nanocellulose reinforced organo-inorganic nanocomposite for synergistic and affordable defluoridation of water and an evaluation of its sustainability metrics
- Sensors and Kits for Water Quality Monitoring
- Scalable drop-to-film condensation on a nanostructured hierarchical surface for enhanced humidity harvesting
- The properties of the electrochemical cell (adopted with three-electrode configuration) was measured by Electrochemical impedance spectroscopy (EIS) and cyclic voltammogram (CV). This work is in progress now
- A Covalently Integrated Reduced Graphene Oxide–Ion-Exchange Resin Electrode for Efficient Capacitive Deionization
- Industrial Utilization of Capacitive Deionization Technology for the Removal of Fluoride and Toxic Metal Ions ($As^{3+/5+}$ and Pb^{2+})
- Low-cost microfluidic platform for multi-analyte assessment of water quality
- The standalone AgNC film showed good stability in water, and the system could release silver ions of the required quantity till 500 cycles in distilled water and 250 cycles in surface and groundwater
- The AgNC films subjected to various water conditions were investigated with microscopic and spectroscopic tools
- The spent AgNC films were recycled to form composite termed as "G Plug," and it is disposed of as a sealant to heal micro-cracks in the concrete

- The G Plug has demonstrated excellent potential to seal the micro-cracks in the concrete and enhanced the compressive strength of the concrete cubes that are subjected to damage
- The interaction between G Plug and the cement were studied using spectroscopic and microscopic characterization tools
- The concrete cubes sealed with G plug was evaluated for the potential leaching of Ag ions via modified TCLP analysis, and the results showed that the release of Ag ions is around 150 times lesser than the permissible limits given by RCRA
- Based on the results, a manuscript titled "Chitosan-based nanopolymer composite as a sustainable point-of-use reservoir of silver ions: Water disinfection and safe disposal" is being prepared
- Methods of coating nanocomposite film on various surfaces for developing a PoU system were studied. Among various methods, (i) coating on a glass substrate after pretreatment at high temperature and pressure in the presence of Tri-sodium citrate and (ii) packed bed reactor employing nanocomposite beads were found to be feasible
- The coating of nanocomposite coated citrate-functionalized glass plates is found to be hydraulically stable
- The studies showed approximately 100% removal of U(VI) [5 mg/L]. Isotherm studies showed a maximum adsorption capacity of 183 mg/g at 30 oC
- An article titled "A critical review of uranium contamination in groundwater bodies: Treatment and safe disposal" is accepted with minor revisions in the Journal Science of Total Environment
- Article titled "Chitosan immobilized granular FeOOH-MnXOY bimetal-oxides nanocomposites for the adsorptive removal of lead from water" is accepted with minor revisions in the Journal of Environmental and Chemical Engineering
- The electronic components are procured locally and assembled. The instrument comprises of linear voltage regulator powered by a 12V battery, which has been fed into the switching voltage converted to 5V. This is to provide the differential voltage at the potentiostatic unit. An integrated circuit LM2902N has been used to connect the three electrode system comprises of working, counter, and reference electrode. An LED display is also integrated into the device, which indicates the changes in the potential and has been proportional to the concentration of metal ions present in the system. The electrode was constructed using the carbohydrazide and thymine functionalized graphene oxide drop cast on the screen-printed carbon electrode surface. Further, fabricated electrodes were used for the electrochemical sensor using the handheld device developed by us. Initially, the electrode was validated for sensing using the electrochemical workstation. The fabricated handheld device was evaluated for sensing chromium(VI) and control samples. The electrode senses the metal ions by indicating the potential

changes corresponding to the specific metal ion. This handheld electrochemical device can use for on-site detection of chromium (VI) in an environmental water sample (Fig. 1). Further, evaluation of the device is in progress and the total materials cost of the device is around Rs.1000/-.
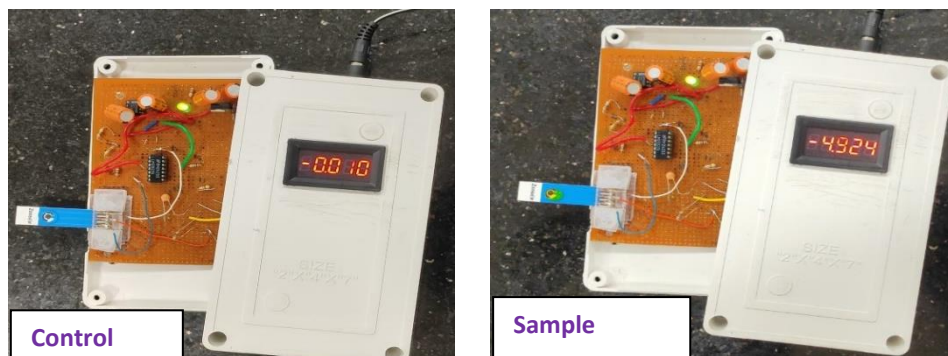

Fig.1: handheld electrochemical device can use for on-site detection of chromium (VI)

- Graphene oxide (GO) was synthesized as a building block for the reporter and grafted are L-Cysteine functionalization. The grafted and graphene oxide are connected covalently via C-S conjugation. The solid-state nuclear resonance spectroscopy (ss-NMR) data shows the functionalization of graphene oxides (Figure 2). It confirms the attachment of L-cysteine on the graphene oxide layer. Further evaluation of the materials for sensing is in progress.
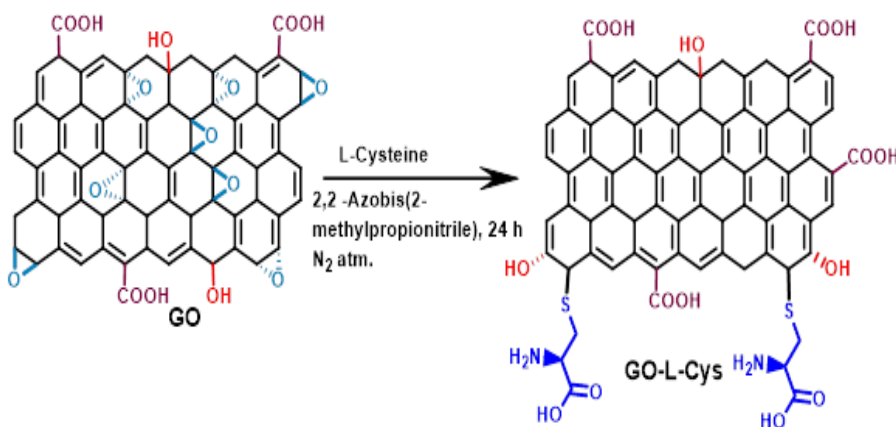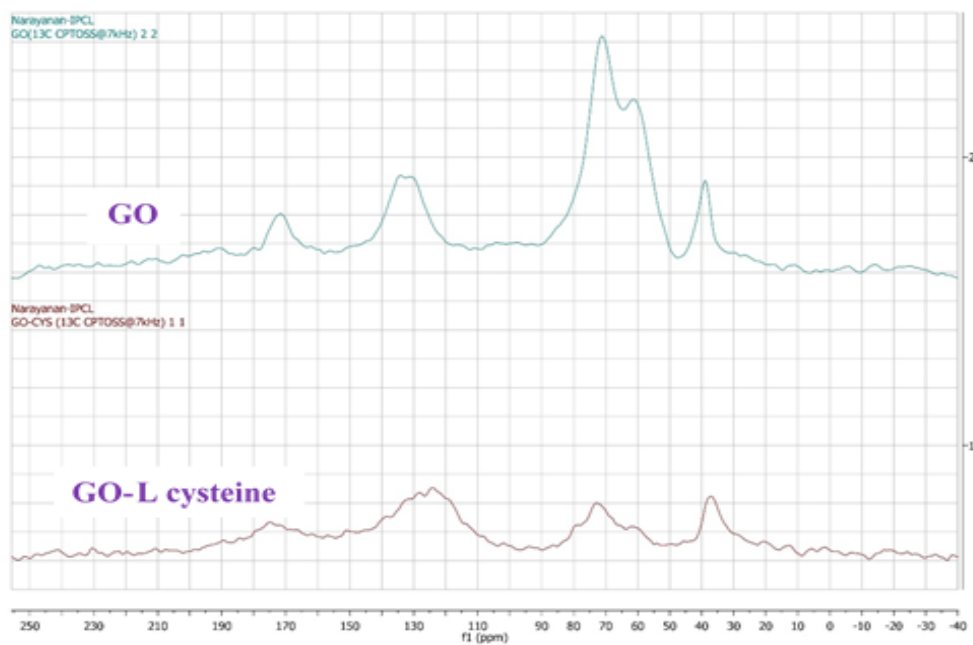
Fig. 2: Functionalization of grapheme oxides

- For colorimetric sensing, the following molecules (Fig. 3) were synthesized, characterized and the sensing studies are being evaluated.
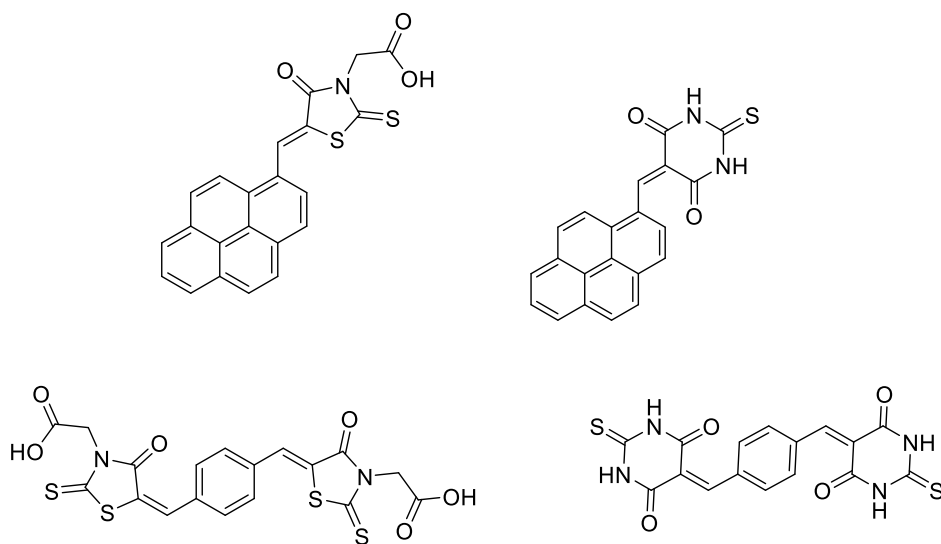

Fig. 3: Molecules for colorimetric sensing

- The toxicity studies of the synthesized compounds were evaluated using MTT assay.

- Human skin origin, HaCaT and Kera cell lines as well as A549 and MCF 7 cancer cell lines were used for the study.
- Fabrication conditions for molecular cage derived crystalline covalent organic framework based free-standing film for nanofiltration.
- The recent research findings on broad-spectrum micropollutant removal from water published in ACS Appl. Mater. Interfaces has been shared with the media team. The news is going to be covered with frontline print media.
- Testing of pristine and sulfonated HCPs for real-time removal of pharmaceuticals found in Indian surface water in collaboration with Prof. Ligy Philip Group, IITM
- We have successfully developed a simple, greener, and cost-effective way to synthesize 2D and 3D GBM from the extract and fibre of Drepanostachyum falcatum. At low temperatures (150 °C), the 2D-MDGOs are extremely hydrophilic and readily bluish fluorescent under UV light of 365 nm. This material is biocompatible and nontoxic, whereas the synthesized 3D-GNR at high temperature (300 °C) is hydrophobic and has a 3D network-like structure. This 3D-GNR shows its excellent behavior for the removal of cationic dyes, i.e., MB. Therefore, the 3D-GNR can act as a promising candidate in the field of water purification.
- We have submitted the manuscript titled "Green and cost-effective synthesis of 2D and 3D Graphene-based nanomaterials from Drepanostachyum falcatum for Bio-imaging and Water purification applications" to a reputed journal, "Chemical Engineering Journal Advances." The manuscript is under revision.
- In addition, in this time frame, we successfully synthesized graphene-based sponge for oil water separation, and manuscript has been submitted.
- We have successfully developed nanocomposites using agricultural waste and waste plastic derived graphene. The synthesized materials have been characterized by Raman, XRD, FTIR, UV, and TGA. Some characterization and lead removal studies are in progress.
- Also in this frame of time, we developed the material for graphene-based water filters. The synthesis of the material has been completed and the testing of the water filter made from our sample is in progress.

WP-3

- The fate of three PhACs – atenolol (ATL), carbamazepine (CBZ), and diclofenac (DCF) were investigated in each component of the CW.
- The hydroponics study with *Canna indica* removed 19.3 to 31.2% without substrate materials (initial PhACs:100 µg/L each).

- The breakthrough and sorption capacity of unplanted CW followed the order: natural zeolite (1.6-2.15µg/g) < Light-weight expanded clay aggregate (LECA) (5.37-8.27µg/g) < waste autoclaved aerated concrete (AAC) block (9.27-10.79µg/g) < wood charcoal (24.1-26.4µg/g), according to their surface and textural properties.

- Four laboratory-scale CW units with enriched microbes, *C. indica*, and different supporting materials were monitored for the removal of organics, nutrients, and PhACs.

- The synergistic interaction among AAC blocks, macrophytes, and microbial population in the system exhibited higher removal of COD, TN, TP, and PhACs as 88.6%, 81.6%, 77.6%, and 95.3%, respectively.

- Owing to the highly porous nature of waste AAC blocks, higher microbial activity was observed in the CW unit with AAC as substrate material.

- Performance of pilot scale ceramic membrane filter with pore size of 4 µm was tested for treating secondary treated wastewater under different operating conditions.

- Study showed that the filter was able to achieve desired treated wastewater quality with respect to pH, Turbidity, COD and Fecal coliforms.

- Removal efficiency of different pollutants such as turbidity, TSS, COD, and Fecal coliform ranged between 94-98.5%, 86-100%, 45-60%, and 80-85% respectively for 4µm pilot scale ceramic filter.

- Batch process was carried out to check the efficiency of filter by fixing the flow rate below 15m^3/h till the pressure reaches 1.5 bar.

- For every cycle, the flux value has been calculated by using volume of water filled in the permeate tank w.r.t time and the Transmembrane pressure evolve during each cycle.

- Air + water Backwash was initiated at the end of each cycle. The provision of air + water backwash was able to recover the original flux during each cycle of operation.

- After modification work for continuous process, Flux Monitoring study has been carried out by fixing flowrate below 15m^3/h for continuous process.

- Air + water Backwash was initiated for 30sec at the end of each cycle and the volume along with percentage of water used for backwash also estimated for every cycle.

- Optimization of running time by 20 minutes and 25 minutes was carried out for every cycle and flux also calculated.

- Chemical backwash was found to be effective in flux recovery Chemical washing was initiated to clear the blockage due to fouling when the transmembrane pressure not reduced as much after the air + water backwash.

- Chemical backwash was initiated in an efficient way by combining Caustic and hypochlorite and found to be effective.

- Overall cumulative net treated water and backwash water volume for 90 cycles was 2,53,718 L and 11,240 L, respectively. Percentage of water used for backwash was found to be below 5.

- Overall studies showed that the treated wastewater quality from ceramic filter (CF) was as same as the existing ultrafiltration (UF) outlet in IITM STP.
- The feasibility of decolorization of high concentration of azo dye Methyl Red (MR) in the presence of sucrose and NO_3^--N was evaluated in a laboratory scale membrane bioreactor operated in sequencing batch mode. Mixed microbial culture, which was previously enriched in a simple sequencing batch reactor under anoxic and static conditions, was used as seed biomass to decolorize high concentrations of MR (500 mg/L) using NO_3^--N as electron acceptor during start-up. After successful start-up, the reactor performance was assessed in increasing loading rates by decreasing the Hydraulic Retention Time (HRT) in different phases of reactor operation. Results indicate an effective decolorization of MR. Maximum removals of color (93%), COD (85%), and TN (81%) were achieved in phase I at a HRT of 16 d. On increasing the loading rate, the average removals obtained in phase III at a HRT of 4 d were color (77%), COD (78%), TOC (76%), and TN (95%). This process may help in treating dye effluents cost-effectively using hybrid technologies (biological treatment followed other advanced techniques) because around 75% of dye could be treated in anoxic conditions without external aeration.
- A review paper published based on nutrients recovery from wastewater to promote circular economy and sustainable agricultural practice in India
- A book chapter (Springer) published titled 'Hybrid Bioreactors for Dye Biodegradation'
- A mini review paper published based on preliminary results of bio solids management using nano-scale oxides of Iron
- Fine tuning AD-MEC unit and optimization of nitrogen flow rate as well as recirculation ratio (and flow rate)
- Estimation of energy harvesting and water quality purification potential of the MFC/MEC system along with accompanying efficient sludge utilization approach
- Inoculum development (SBR) – Development of bacterial consortia for the removal of carbon and nitrogen removal in Sequential batch reactor.
- Batch studies were performed to evaluate the efficiency of bacterial consortia.
- After acclimatization process, Sequential batch process was performed to study the efficiency of inoculum for the aerobic process (C & N removal) with the cycle time of 36 and 24 hrs was evaluated over a period of 240 days.
- Inoculum development (UASB) – Cultivation and enrichment of sulfur reducing bacteria (SRB) using three different medium
- The acclimatization of bacterial consortium for the removal of Sulphur and Nitrate and residual COD from the synthetic tannery wastewater.
- The initial concentration of COD in UASB was 830 ($\pm$165) mg/L which got reduced to 270 ($\pm$80) mg/L. The maximum removal efficiency of Sulphate was found to be 58.8 %

with the initial concentration of 1028 ($\pm$86) mg/L and the sulphide concentration in the final effluent was 315 ($\pm$ 58) mg/L.

- The performance of the SBR for three different COD of loading rates (1.36, 1.85, and 2.45) has been evaluated.

- SBR Kinetic studies has been performed to find the complete cycle and its treatment efficiency

- Degradation kinetics were performed based on the experimental data obtained from SBR and found that Monod and first order model fits well.

- The performance of the SBR for four different nitrogen of loading rates (0.101, 0.145, 0.178, 0.237 g/L/d) has been evaluated over a period of 30 days at each loading rate and TKN removal efficiencies were found to be 83.3, 87.7, 83.3 and 80.9 respectively.

- Gene amplification was performed in the Bacterial sludge from SBR and confirmed the presence of ammonia oxidizing and nitrifying bacteria using PCR.

- Preliminary studies with Combined De-Sulfurization, De-nitrification and conversion of sulphide into elemental sulfur showed enhanced performance in the UASB with microaerophilic process.

WP-4

- Model based operation of water networks require a well calibrated model. Using available data (flow, pressure, heights of water in tanks), a nonlinear least squares problem is formulated to estimate the network parameters. Network parameters are guessed in an outer loop while the hydraulic simulation is carried out in the inner loop.

- Model based scheduling of water distribution networks results in a nonlinear mixed integer optimization problem. In the past, we have reformulated the same as an integer linear program improving the tractability of the problem. We have developed heuristics to improve the solution times considerably. A web based application will be released for public use shortly.

- We have also developed pure data driven techniques for scheduling which use only flow data and require no network or hydraulic model. This has been validated on a 9 tank system in the IIT Madras laboratory network using discrete valves and 4 tank system using continuous control valves.

- We have formulated and demonstrated a methodology for reconstrucitng a putative water network from street network. Openstreetmap data of Chennai city from openstreetmaps was used to extract the network and connectivity structure of the road/street along with additional useful and relevant information (eg., type of structure- residential/commercial etc.) Appropriate graph algorithms (eg., shortest path tree/minimum spanning tree) were used to generate candidate network structures for the WDN.

- An optimization model for the retrofitting of existing sewerage networks with on-site greywater treatment and reuse for non-potable supplies has been developed and tested. This

model essentially maximized the net benefit accruing out of retrofitting (benefit due to decrease in the use of freshwater resources i.e. cost of procuring fresh water from a distant source – capital cost of grey water treatment plants – operation cost of on-site treatment plants – increase in the maintenance cost of existing sewerage system) of sewerage systems. The model finds the optimum fraction of greywater recycling at each site i.e., how much of grey water generated at each site should be treated. Testing on few realistic systems showed the savings of as much as 40% of present fresh water demand.

- An optimization model for the retrofitting of existing sewerage networks with decentralized wastewater treatment and reuse for non-potable purposes through dual piping system supplies has been developed and tested. This model essentially maximized the net benefit accruing out of retrofitting (benefit due to decrease in the use of freshwater resources i.e. cost of procuring fresh water from a distant source – capital cost of water treatment plants – operation cost of treatment plants – capital cost of dual piping system - increase in the maintenance cost of existing sewerage system) of sewerage systems. The model finds the optimum amount of wastewater treatment at each specified site for DWWT i.e., how much of wastewater should be treated at each site and pumped back into dual piping system. Testing on few realistic systems showed the savings of as much as 45% of present fresh water demand.

- Results have been published in the journal *WATER*

- An optimization model has been developed for the design of a new sewerage system with embedded on-site grey water treatment and recycling to reduce the stress on existing water supply system has been developed and tested for realistic situations. Besides finding how much greywater should be treated at each on-site location, the model finds optimal diameters of the new sewerage system. Objective of design is to minimize the net cost of the new sewerage system.

- An optimization model has been developed for the integrated design of new water supply and sewerage systems with embedded recycling of treated greywater. The optimization model finds out how much grey water should be treated at each site, diameters of new water supply pipes in the distribution system and diameters of new sewer lines in wastewater collection system. Objective is to minimize the net cost of combined water supply and sewerage systems.

12. Provide details of any Technologies/ Prototype/ Process/ Materials developed:

<u>IIT Madras</u>

<u>1. Fabrication of Portable Colorimetric Sernsor for the Detection of Eutrophying Ions in an Aqueous System</u>

The low-cost and straightforward colorimetric paper strip-based method was developed for detecting nitrite (NO_2^-), nitrate (NO_3^-) , and phosphate(PO_4^{3-}) in aqueous systems. The colorimetric probe were developed using stable dyes like Basic Fuchsine (BF) (for NO_2^- and NO_3^-) and Brilliant Green (BG) (for phosphate). To make the sensors portable, the selected dye were loaded on Whatmann paper using surfactant like Tween-80. The naked eye detection limit obtianed for nitrite and phosphate were 0.05 mg/L and 0.17 mg/L respectively. Moreover, the developed strips were stable for more 90 days when stored in amber bottle. In the presence of interfering ions, high selectivity was maintaied, this was due to the target ion specific innteractions. For example, for nitrite diazotization reaction was primary meachanism, while for phosphate, formation of phophomolybednum complex goverened the detection. The cost analysis confirmed that the synthesizeda low-cost (Rs. 1-1.5/ 10 strip). Overall, cost-effective and portable toll for on-site measurement of eutophying ion was developed..
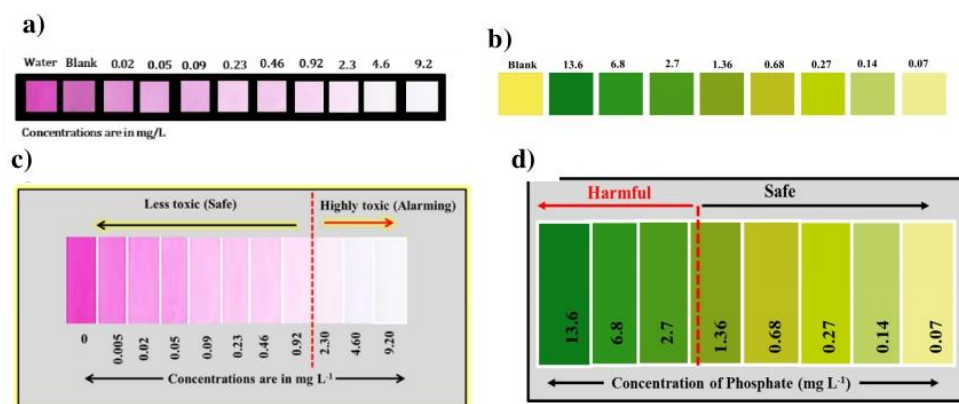

Fig. 4. (a)Sensing of nitrite using portable colorimetric strips at various concentration ranges (b) color pallet for selective nitrite sensing, (c) detection of phosphate using developed strip, (d) standard colorimertic chart for phosphate measurement.

2. Vertical Flow constructed wetland Treating Greywater and Septic Tank Effluent from the Rural Community in India

Rural sanitation is gaining greater attention for achieving the environmental and economic development of the country. Due to lower maintenance and less labor-intensive, constructed wetlands (CWs) may be suitable for wastewater treatment in rural areas. A widespread occurrence of pharmaceuticals and personal care products (PPCPs) is reported in all the environmental matrices. Thus, the present study investigated the prevalence of these emerging contaminants in the wastewater from the rural community of Vichoor village, Tamil Nadu, India and its fate in the decentralized treatment system.

Greywater and the septic tank effluent from each household were transported to a treatment site through a small-bore system. The pre-treatment of wastewater was done with a three-chambered septic tank and a three-staged settling tank. The effluent from the settling tank was fed into the vertical flow constructed wetland (VFCW). Among the 14 investigated PPCPs, caffeine, triclosan, bisphenol A (BPA), and diethyl phthalate (DEP) were the most frequently detected compounds in the concentration range of 5 ng/L to 250.14 µg/L. The overall removal efficiencies of organics, ammonia, phosphate, and pathogens were found to be more than $90.25 \pm 1.71\%$, 85.25 ± 1.51, $79.81 \pm 1.15\%$, and $99.9 \pm 0.81\%$, respectively. Also, VFCW exhibited substantial removal of the selected pollutants in the range of 81 to 97.7%. Microbial degradation (74.9 to 93.8%) and sorption over the substrate materials (0.54 to 12.56%)seem to be the predominant mechanism for pollutants degradation. The ecological and human health risk assessment witnessed that PPCPs concentration in the treated effluent contributed lower risk to human and aquatic organisms. The quality of reclaimed water from the system (with little disinfection) could comply with the discharge standard suggested by the central pollution control board (CPCB) of India.

3. Pilot Scale Pulse Power Plasma Reactor for Pharmaceutical Degradation

The study was carried out at operational conditions of input voltage of 23 kV, frequency of 1.5 kHz, a flow rate of 20 lit/hour,HRT of 3.75 hours, and pollutant load of 1 mg/l. The synthetic wastewater was prepared with IIT Madras wastewater treatment plant treated effluent.The results showed, 67.33% and 89.52% degradation of DCF and CBZ respectively. The TOC reduction was 49.18% and 65.87% in the case of DCF and CBZ spiked wastewater. Moreover, other water quality parameters such as pH were increased slightly from 8.76 to ~ 8.83, electrical conductivity increased from 2.59 mS/cm to 2.64 mS/cm, and NO_3 concentration was also found to increase due to the atmospheric nitrogen reaction with plasma in the reactor.

4. Prototyping of smartphone-based fluoride sensor is in progress.
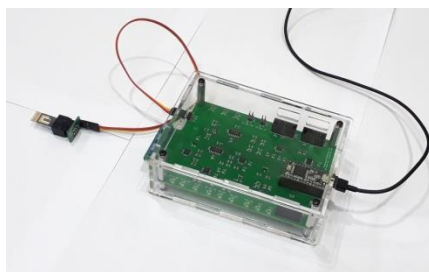

Fig. 5: A hand-held electrochemical sensor system developed in the lab, output goes to a mobile phone
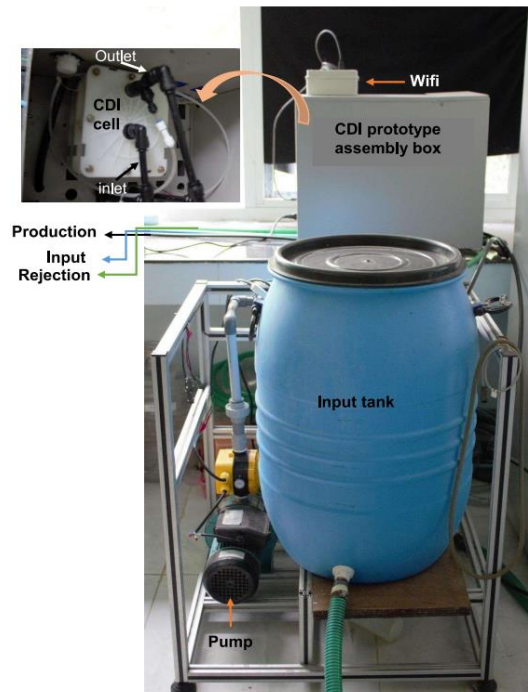
5. Prototype of CDI

Fig. 6: Prototype of CDI experimental setup, developed in the lab

6. Sensor for Fluoride

Fig. 6: An integrated sensor assembly for fluoride sensing.

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- A safe disposal protocol for the AgNC composite was developed
- AgNC coated chitosan beads were developed, and it produced a complete 3 log reduction within 30 min

- The reactor packed with AgNC coated beads are being developed
- A protocol for coating of AgNC on citrate-functionalized glass plates for fabricating the PoU reactor is developed, and its hydraulic stability is evaluated
- A synthesis protocol for large scale SCGO was optimized, developed, and used for U(VI) removal
- A stable Fe-CS-P granular composite that showed an enhanced U(VI) removal capacity was developed for making a small household point-of-use (POU) filter for the removal of U(VI)

Kumaun University

- Graphene based nanomaterials derived from Drepanostachyum falcatum for water Purification

13. Shortfalls in Achievements of Activities for the Period:

Activity	Shortfall (*if any*) in Specific Terms	Responsible Organization
Sample collection	As funds for travel was not sanctioned, field work could not be completed as planned	Anna university
Running the reactor for extensive studies Dynamic column studies related the performance evaluation of heavy metal removal media	• The previous JRF was resigned from the project during February 2021, and the new JRF was recruited during August 2021 • The studies were affected due to the suspension of lab activities from April 2021 to June 2021 due to the second wave of COVID-19 lockdown. • Due to lockdown, the consumables required for some of the essential instruments (ICP-MS) were not accessible; Also, we could not address some of the equipment service issues on time due	IIT Tirupati

	to restrictions.	
Mixed dye continuous decolorization studies	Unable to start due to lockdown	VIT Chennai
Feasibility studies for recovery of nutrient	Unable to start due to lockdown	VIT Chennai
Quantitative real time (RT-PCR) data analysis of nitrifiers, denitrifiers and sulphur reducers	Gene expression studies on Nitrifiers, ammonia oxidizers and sulfur reducers after stabilization of SBR and UASB could not be completed and will be initiated shortly.	Central Leather Research Institute (CSIR-CLRI)
	CoVID induced disruptions, closure of laboratory facilities has affected the progress of the work. However, we have made full attempts to make up for shortfall by optimizing resources and time.	IIT Madras
Manpower recruitment	Funds allocated are too small for the purpose. Need to release more funds in this head	IIT Madras
Environmental Impact Assessment	Delay in manpower recruitment due to COVID-19.	CSIR-IITR

14. Journal publication during the period:

Title of the paper	Journal, Issue, etc.	Authors
Spatio-temporal analysis of rainfall, meteorological drought and response from a water supply reservoir in the megacity of Chennai, India	Journal of Earth System Science / 2021	Anandharuban P, Elango L
Sustainable Agro Landuse Evaluation through Life Cycle Assessment for Sugarcane Cultivation in Cauvery Deltaic Regions of India	Research Journal of Chemistry and Environment Volume 25, Issue 4, Pages 214 – 219 April 2021	Parthiban, P., Alagar raj, K., Das, A
Removal and risk assessment of pharmaceuticals and personal care products in a decentralized greywater	Journal of Envionmental Chemical	Ravichandran M.K, Yoganathan.S and Ligy Philip

treatment system serving an Indian rural community	Engineering, 2021	
Stable paper-based colorimetric sensor for selective detection of phosphate ion in aqueous phase	Microchemical Journal, 2021	Choudhary, V and Ligy Philip
Enhanced degradation of complex organic compounds in wastewater using different novel continuous flow non – Thermal pulsed corona plasma discharge reactors	Environmental Research, 2021	Nippala N, Kamaraj Ramakrishnan and Ligy Philip
Spatio-temporal distribution of pharmaceutically active compounds in the River Cauvery and its tributaries, South India	Science of The Total Environment, 2021	Jayakumar Renganathan, Insamam Ul Huq S, Kamaraj Ramakrishnan, Ravichandran M.K, and Ligy Philip
Insight into the uptake, fate and toxic effects of pharmaceutical compounds in two wetland plant species through hydroponics studies	Chemical Engineering Journal, 2021	Ravichandran M.K, and Ligy Philip
Potential nanomaterials-based detection and treatment methods for aqueous chloroform	Environmental Nanotechnology, Monitoring and Management, 2021	Choudhary, V., Vellingiri, K., Ligy Philip
Performance evaluation of solar thermal systems as an alternative for human waste treatment	Sustainable Energy Technologies and Assessments, 2021	Krithika, D, Sharon, H, Reddy, K.S and Ligy Philip
Continuous flow pulsed power plasma reactor for the treatment of aqueous solution containing volatile organic compounds and real pharmaceutical wastewater	Journal of Environmental Management, 2021	Jerin Jose, and Ligy Philip
Sorption of pharmaceutical compounds and nutrients by various porous low-cost adsorbents	Journal of Environmental Chemical Engineering, 2021	Manthiram Karthik.R, and Ligy Philip
Comparative study of degradation of toluene and methyl isobutyl ketone (MIBK) in aqueous solution by pulsed corona discharge plasma	Journal of Environmental Sciences (China), 2021	Jerin Jose, and Ligy Philip
Removal of antibiotics from aqueous solutions by electrocatalytic degradation	Environmental Science: Nano, 2021	Choudhary, V., Vellingiri, K., Thayyil, M.I., Ligy Philip
A Cantilever-based Flow Sensor for Domestic and Agricultural Water Supply System	IEEE Sensors, 2021	Harija H., George B. and Tangirala A
Assay of Inductive-Capacitive Probe	IEEE Transactions on	Tejaswini K. K., George B.

for the Measurement of the Conductivity of Liquids	Industrial Electronics, 2021	and Kumar V. J.,
Analysis of a Direct Microcontroller Interface for Capacitively-Coupled Resistive Sensors	IEEE Transactions on Instrumentation and Measurement, 2021	Areekath L., George B. and Reverter F
Aminoclay-graphene oxide composite for thin-film composite reverse osmosis membranes with unprecedented water flux and fouling resistance	Adv. Mater. Interfaces, 2021, 2100533. (DOI:10.1002/admi.2 02100533)	Md Rabiul Islam, Pratishtha Khurana, Pillalamarri Srikrishnarka, Ankit Nagar, Madhuri Jash, Shantha Kumar Jenifer, Mohd Azhardin Ganayee, Mathava Kumar and Thalappil Pradeep
Industrial utilization of CDI technology for removal of fluoride and toxic species ($As^{3+/5+}$ and Pb^{2+})	Global Challenges, 2022, 2100129. (DOI: 10.1002/gch2.202100 129)	Md Rabiul Islam, Soujit Sen Gupta, Sourav Kanti Jana and Thalappil Pradeep
Nanocellulose reinforced organo-inorganic nanocomposite for synergistic and affordable defluoridation of water and an evaluation of its sustainability metrics	ACS Sustainable Chem. Eng. 2020, 8, 1, 139-147	Sritama Mukherjee, Haritha Ramireddy, Avijit Baidya, A. K. Amala, Chennu Sudhakar, Biswajit Mondal, Ligy Philip, and Thalappil Pradeep
Scalable drop-to-film condensation on a nanostructured hierarchical surface for enhanced humidity harvesting	ACS Appl. Nano Mater., 2021	Ankit Nagar, Ramesh Kumar, Pillalamarri Srikrishnarka, Tiju Thomas and Thalappil Pradeep
A covalently integrated reduced graphene oxide-ion exchange resin electrode for efficient capacitive deionization	Adv. Mater. Interfaces, 2020	Md Rabiul Islam, Soujit Sen Gupta, Sourav Kanti Jana, Pillalamarri Srikrishnarka, Biswajit Mondal, Sudhakar Chennu, Tripti Ahuja, Amrita Chakraborty and Thalappil Pradeep
A smartphone-based fluoride-specific sensor for rapid and affordable colorimetric detection and precise quantification at sub-ppm levels for field applications	ACS Omega, 5 (2020) 25253–25263	Sritama Mukherjee, Manav Shah, Kamalesh Chaudhari, Arijit Jana, Chennu Sudhakar, Pillalamarri Srikrishnarka, Md Rabiul Islam, Ligy Philip and Thalappil Pradeep

Dissolved arsenic in groundwater bodies: A short review of remediation technologies in "Pollution Control Technologies: Current Status and Future Prospects"	Pollution Control Technologies, June 2021, Pages 75-111,	M. S. V. Naga Jyothi, Gayathri S., T. Pushparaj Gandhi, S. M. Maliyekkal
Advanced Oxidation Processes: A Promising Route for Abatement of Emerging Contaminants in Water in "Pollution Control Technologies: Current Status and Future Prospects"	Nanomaterials and Nanocomposites for Environmental Remediation, August 2021,	Divya Kusuma T., M. S. V. Naga Jyothi, Chebrollu Pulla Rao, S. M. Maliyekkal
A critical review of uranium contamination in groundwater: Treatment and sludge disposal	Science of Total Environment, (Accepted with minor revisions)	T. Pushparaj Gandhi, S. Venkata Sampath. S. M. Maliyekkal
Chitosan immobilized granular FeOOH-MnXOY bimetal-oxides nanocomposites for the adsorptive removal of lead from water	Journal of Environmental and Chemical Engineering (Accepted with minor revisions)	M. S. V. Naga Jyothi, Afrah Harafan, Gaurav Singhal, Neethu Nalini, Soujit Sen Sengupta, B. Janaki Ramaiah, and S. M. Maliyekkal
Nanoscale silver-based point of use drinking water disinfection system	Book chapter submitted for publication in the book titled "Nanoremediation," Elsevier (in Press)	Uthradevi Kannan, Gayathri Pullangott, Swatantra Pratap Singh, and S. M. Maliyekkal
Application of plasma-assisted advanced oxidation processes for removal of emerging contaminants in water	New Trends in Emerging Environmental Contaminants, 333-370, Springer, 2022. DOI: 10.1007/978-981-16-8367-1_15.	S. M. Allabakshi, P.S.N.S.R. Srikar, R. Gangwar, S.M. Maliyekkal
Hydrogen Bond Assisted Julolidine-Barbiturate for Colorimetric Picomolar Level Detection of Hg^{2+} and Ag^+ ions in 100% Aqueous Solution.	ACS Sustainable Chem. Eng. 2021, 9, 30, 10309–10317	Palani Yuvaraj, Joseph Ajantha, Shanmugam Easwaramoorthi, Masiyappan Karuppusamy, Venkatesan Subramanian, and Jonnalagadda Raghava Rao
Nanostructured hypercrosslinked porous organic polymers: morphological evolution and rapid separation of polar organic micropollutants	ACS Appl. Mater. Interfaces 2022, DOI:10.1021/acsami.1c24393	Arkaprabha Giri, Subha Biswas, MD. Waseem Hussain, Tapas Kumar Dutta, and Abhijit Patra*
Nanospheres to Nanosheets:	Manuscript submitted	Arkaprabha Giri, Subha

Unfolding the Morphological Influence of Microporous Organic Polymers on Micropollutants Removal	(DOI: 10.26434/chemrxiv. 14333936.v1)	Biswas, Tapas Kumar Dutta, MD. Waseem Hussain, and Abhijit Patra*
Agricultural Waste Derived Metal Doped Graphene Oxide for Selective and Visual Detection of Iron(III) in Water: Experiment and Theory	Sustainable Chemistry and Pharmacy	Chetna Tewari, Boddepalli SanthiBhushan, Anurag Srivastava, Nanda Gopal Sahoo
Waste Plastic Derived Graphene Sheets as Nano fillers to Enhance Mechanical Strength of Concrete Mixture: An Inventive Approach to Deal with Universal Plastic Waste Inventive Approach to Deal with Universal Plastic Waste	Cleaner Engineering and Technology, https://doi.org/10.1016/j.clet.2021.100275	Gaurav Tatrari[1], Chetna Tewari[1], Bhashkar Singh Bohra, Sandeep Pandey, Manoj Karakoti, Sumit Kumar, Himani Tewari, Nanda Gopal Sahoo*
Classification and management of waste via upcycling into value added nanomaterials for water remediation	Waste management strategies, challenges and future directions (Published by Nova Science Publishers, Inc. New York, ISBN: 9781685073947)	Chetna Tewari, Sandeep Pandey, Sumit Bhardwaj, Nanda Gopal Sahoo*
A review on metal oxide (FeOx/MnOx) mediated nitrogen removal processes and its application in wastewater treatment	Reviews in Environmental Science and Bio/Technolgy (2020)	Swathi Desireddy Sabumon P. C
Development of aerobic granulation system for simultaneous removal of C, N, and P in sequencing batch airlift reactor	Journal of Environmental Chemical Engineering 9 (2021) 106100	Swathi Desireddy Sabumon P. C
Recovery of struvite from wastewaters as an eco-friendly fertilizer: Review of the art and perspective for a sustainable agriculture practice in India	Sustainable Energy Technologies and Assessments, *Vol. 48,* 101573, 2021 https://doi.org/10.1016/j.seta.2021.101573	Tejas N Vasa, Sabumon Pothanamkandathil Chacko
A mini review on effect of nano particles of Fe in the anaerobic digestion of waste activated sludge	Materials Today: PROCEEDINGS, 2022, https://doi.org/	Ragasri S, Tejas N Vasa, P.C. Sabumon

	10.1016/ j.matpr. 2021.10.265	
Hybrid Bioreactors for Dye Biodegradation	https://link.springer.com/chapter/10.1007/978-981-16-5932-4_10	Swathi Desireddy, Sabumon Pothanamkandathil Chacko
Control Release of Adenosine Potentiate Osteogenic Differentiation within a Bone IntegrativeEGCG-g-NOCC/Collagen Composite Scaffold toward Guided Bone Regeneration in a Critical-Sized Calvarial Defect	ACS Biomacromolecules, 2021 22, 3069-3083	Verma NK, Kar AK, Singh A, Jagdale P, Satija NK, Ghosh D, Patnaik S∗
pH-responsive eco-friendly chitosan modified cenosphere/ alginate composite hydrogel beads as carrier for controlled release of Imidacloprid towards sustainable pest control	Chemical Engineering Journal, 2021, 131215	Singh A, Kar AK, Singh, D, Verma R, Shraogi N, Zehra A, Gautam K, Anbumani S, Ghosh D, Patnaik S∗
Optimal Implementation of Wastewater Reuse in Existing Sewerage Systems to Improve Resilience and Sustainability in Water Supply Systems	Water, July 2021	Aakash Dev, Timo C. Dilly Amin E. Bakhshipour, Ulrich Dittmer, and S. Murty Bhallamudi

Communicated and under review

Title of the paper	Journal, Issue, etc.	Authors
Evaluation of infiltration based LIDs for urbanizing coastal catchments of Chennai City, India - A case study	Under review	Bagya Lakshmi, Rutwik Borkar, and Narasimhan,B.
Process optimization of conventional MFC through factorial design approach	Environmental Science and Pollution Research (Submitted)	Sathiskumar P., N. Baskar., Bharathirajan S., Nilavu B., Parthiban P., and Das, A
Evaluation of dephenolation capacity by column adsorption studies	Desalination and Water Treatment (Submitted)	Srihari V., Subramanyam B., and Das, A
Parametric Optimization and performance assessment of	Suwam 2022 (Conference)	Ponmani P., Nilavu B., Parthiban P., Mahesh R., Sivanantham M., Tewari C.,

graphene impregnated polyaniline coated electrode based Microbial Fuel Cell using mixed culture obtained from Canteen wastewater	(Abstract submitted)	Sahoo N.G and Das, A
Steady-state Assessment of Hydraulic Potential at Agniyar River Basin, India using GMS-MODFLOW	Suwam 2022 (Conference) (Abstract submitted)	Sugam Verma, Ravikumar K, IC Das and Das A
Hydrogen Bond Assisted Julolidine-Barbiturate for Colorimetric Picomolar Level Detection of Hg^{2+} and Ag^+ ions in 100% Aqueous Solution.	Analytical Chemistry (to be submitted)	Palani Yuvaraj, Joseph Ajantha, Shanmugam Easwaramoorthi, Masiyappan Karuppusamy, Venkatesan Subramanian, and Jonnalagadda Raghava Rao
Multiplex Electrochemical Sensor for Metal Ions using Covalently Dual Functionalized Graphene Oxides	Manuscript under review	J. Narayanan, Shanmugam Easwaramoorthi, and Jonnalagadda Raghava Rao
Performance Evaluation of Novel Non-Thermal Pulsed Corona Plasma Reactors for the Degradation of Pharmaceutical Compounds	Journal of Separation and Purification	Nippatla n and Ligy Philip
Sustainability assessment of acid-modified biochar for sorptive removal of pharmaceuticals and personal care products from secondary treated wastewater	Journal of Environmental Chemical Engineering Journal	Choudhary, V., & Philip, L.
A comprehensive review on catalytic removal of paraben from water: Insight into experimental and theoretical evaluation	ACS ES&T Water	Vellingiri, K., Choudhary, V., Boukhvalov D., & Philip, L.
Sorptive removal versus catalytic degradation of aqueous BTEX: A comprehensive review in the perspective of life-cycle assessment	Environmental Science: Water Research & Technology	Vellingiri, K., Choudhary, V., Kumar, S., &Philip, L.
Mechanistic insights into carbo-catalyzed per-sulfate	Journal of Hazardous	Sumit Kumar, Chetna Tewari, Nanda Gopal Sahoo, Ligy Philip

treatment for simultaneous degradation of cationic and anionic dye in multicomponent mixture using plastic waste derived carbon	materials	
Simultaneous detection of Cr(VI), Hg(II) at ppb level using functionalized graphene	Manuscript under preparation	J. Narayanan, Shanmugam Easwaramoorthi, and Jonnalagadda Raghava Rao
Green and cost-effective synthesis of 2D and 3D Graphene-based nanomaterials from *Drepanostachyum falcatum* for Bio-imaging and Water purification applications	Submitted	Chetna Tewari, Gaurav Tatrari, Sumit Kumar, Sandeep Pandey, Anita Rana, MintuPal, Nanda Gopal Sahoo
Waste Plastic Derived Graphene Sheets as Nano fillers to Enhance Mechanical Strength of Concrete Mixture: An Inventive Approach to Deal with Universal Plastic Waste	Cleaner Engineering and Technology (Under revision)	Gaurav Tatrari1, Chetna Tewari1, Bhashkar Singh Bohra, Sandeep Pandey, Manoj Karakoti, Sumit Kumar, Himani Tewari, Nanda Gopal Sahoo* 1 Authors contributed equally to this work
Plastic derived graphene impregnated polyaniline coated electrode based Microbial Fuel Cell using mixed culture obtained from Canteen wastewater	Communicated	Ponmani P., ParthibanP.,MaheshR.,SivananthamM.,Nilavu B., Tewari C., Sahoo N.G and Das, A*
Development and long term operation of aerobic granular system for simultaneous removal of COD, nitrogen, and phosphorous in a simple conical SBR	Under review in Environmental Engineering Research	Swathi Desireddy, Sneha Madhavan, Sabumon P. C.
Development and long term operation of aerobic granular system for simultaneous removal of COD, nitrogen, and phosphorous in a simple conical SBR	Under review in Journal of Environmental Chemical Engineering	Swathi Desireddy, Sneha Madhavan, Sabumon P. C
Feasibility studies on decolorization of high concentration of azo dye	communication to Environmental Technology and	Desireddy Swathi Sabumon P. C

Methyl Red in sequencing batch membrane	Innovation	
Effect of pH, salinity, dye and biomass concentration on decolorization of azo dye methyl orange in denitrifying conditions	communication to Environmental Technology and Innovation	Aditi Trivedi Swathi Desireddy, Sabumon P. C
Book Chapter: Emerging contaminants removal from wastewater by nanotechnological methods	Under review in New Trends in Emerging Environmental Contaminants	Desireddy Swathi Sabumon P. C
Book Chapter: Advances in Nano Filtration (NF)	Under Bio-membrane Filtration in Industrial Wastewater Treatment - Innovative Approaches	Desireddy Swathi Sabumon P. C
Biological treatment of tannery wastewater using sequential batch reactor and its kinetics.	Manuscript will be communicate shortly	V. Nagabalaji, S. Karthick Shankar,. Nishanthi, R. Suthanthararajan, S. V. Srinivasan*
Effect of initial inoculum in symbiotic bacterial – microalgal system and its optimization for the treatment of tannery wastewater	Communicated	V. Nagabalaji, P. Maharaja, R. Nishanthi, G. Sathish R. Suthanthararajan, S. V. Srinivasan*

15. Presentations in Symposia/ Conferences during the period

Title of the paper presented	Symposium/ Conference	Dates of the Symp/Conf.	Authors
Quarries encompasses a fast-growing metropolitan city in India – retrospect and prospect, an approach for water sustainability	International Conference on Innovative technologies for clean and sustainable development by Chitkara University & NITTR, Chandigarh	14-15 October, 2021	Rinisha Kartheeshwari M and Elango L
Significance of reservoir operation during extreme	EGU general Assembly 2020	4 – 8 May, 2020	Anahdharuban P, Michele La Rocca and

rainfall event in flood mitigation and water demand management in a metropolitan city of India: a case study			Elango L
Groundwater quality assessment in the urbanized city, Chennai, Tamilnadu, India	Indian National Groundwater Conference (INGWC-2020) at CWRDM, Kozhikode	18 -20 February, 2020	Merin Sackaria and Elango L
Challenges and opportunities for storage and infiltration based LIDs in coastal catchments of Chennai, India.	12th Urban Drainage Modelling Conference, California	January 2022 (Abstract submitted)	B.Palanisamy, R.Borkar, K. Modi, S.Sreethu, S. Shaurabh and B.Narasimhan.
Analysis of the long-term performance of sustainable practices using SWMM and HYDRUS-1D coupled model	First International Conference on Circular Economy for Sustainable Water Management	March 2022 (Abstract submitted)	K. Modi and B.Narasimhan
Site Suitability Analysis with GIS and Multi-Criteria approach for Sustainable urban Drainage System (SuDS) components.	First International Conference on Circular Economy for Sustainable Water Management	March 2022 (Abstract submitted)	Arun RS and Narasimhan.B
Development of LID process modules for SWAT to enable planning and assessment of basin scale sustainable practices	First International Conference on Circular Economy for Sustainable Water Management	March 2022 (Abstract submitted)	Sreethu, S., Narasimhan, B., and S. Murty Bhallamudi
Challenges and opportunities for storage and infiltration based LIDs in coastal catchments of Chennai, India.	12th Urban Drainage Modelling Conference, California	January 2022 (Abstract submitted)	B.Palanisamy, R. Borkar, K. Modi, S.Sreethu, S. Shaurabh and B.Narasimhan.
Colorimetric affordable test strips	Atal innovation mission and Innovation Centre Denmark water challenge	2021 Next Generation Water Action initiative	Choudhary, V. Vellingiri, K, & Philip, L
Interpretation of the risk associated with emerging contaminants in the aquatic systems of BRICS nations	EWRI, American Society of Civil Engineers	7-11 June, 2021	Choudhary, V. & Philip, L (2021)
Gas phase electrical discharge induced degradation of single and mixed VOCs in aqueous	14th International Conference on Eco materials, CSIR-NIIST Trivandrum	Feb 5-7, 2020	Jerin Jose, Ligy Philip

solution			
Occurrence and fate of antimicrobial agents in a hybrid flow constructed wetland treating greywater	Aqua 360 water for all – Emerging Issues and Innovations	31st August – 2nd September 2021	Manthiram Karthik Ravichandran and Ligy Philip
Exploration of socio-economic factors affecting the implementation of zero liquid discharge system in peri-urban and rural households of metropolitan city	Aqua 360 water for all – Emerging Issues and Innovations	31st August – 2nd September 2021	Krithika Delhiraja, Prema Rajagopalan and Ligy Philip
Spatial and temporal variations in the concentrations of pharmaceutically active compounds in a south Indian river	Aqua 360 water for all – Emerging Issues and Innovations	31st August – 2nd September 2021	Jayakumar Renganathan, Insamam UlHuqS,KamarajRamakrishnan, Manthiram Karthik Ravichandran and Ligy Philip
Fe-Mn binary oxides granules for mercury removal from water	First InternationalConference on Circular Economy for Sustainable Water Management (SuWaM-2022)	23-25th March 2022, IIT Madras (Abstract accepted)	M. S. V. Naga Jyothi, and S. M. Maliyekkal
A scalable and affordable method for production of graphene oxide: Application in the removal of aqueous uranium.	Roorkee Water Conclave	March 02-04, 2022, IIT Roorkee (Abstract accepted)	T. Pushparaj Gandhi, S Gomosta, S Sengupta, S. M. Maliyekkal.
When Macrocycle Meets Porous Organic Polymer (POP): Resorcin[4]arene-based POPs for Selective Molecular Separation (#MatChem_MC10)	ChemSci2021 Twitter poster organized by JNCASR	Virtual poster presentation: 10th Dec., 2021	Arkaprabha Giri, Abhijit Patra
Self-assembly of π-Conjugated Molecules and Nanoporous Organic Polymers	7th International Conference on Advanced Nanomaterials and Nanotechnology (ICANN 2021), IIT Guwahati	Online seminar 15th Dec., 2021	Abhijit Patra
Porous Organic Polymers for Sequestration of Organic Micropollutants from Water	Workshop entitled "Functional Polymeric Materials; Exploring	Online seminar 7th Oct., 2021	Abhijit Patra

	towards Green and Sustainability (FPMGS-2021)" University of Melbourne and Rubber Technology Centre, IIT Kharagpur		
Porous Organic Polymers for Size and Charge Selective Sequestration of Organic Micropollutants from Water	160th Birth Anniversary Celebration of Acharya P. C. Ray and Recent Advances in Chemistry and Material Science 2021 (RACMS2021)	Virtual oral presentation: Indian Chemical Society, Aug. 2021	Arkaprabha Giri, Subha Biswas, Abhijit Patra [Best oral presentation Award (2021)]
One-pot green synthesis of 3D nanomaterial using plant of the Himalayan region for water purification application	International Conference on Environment and Energy Materials (INCEEM): Innovation of Tomorrow.	29-31st July, 2021	Chetna Tewari, Nanda Gopal Sahoo
A mini review on effect of nano particles of Fe in the anaerobic digestion of waste activated sludge	second International Conference on (SESBT 2021),VIT Chennai in collaboration with ESRIG, University of Groningen, Netherlands	23-24 July, 2021	Ragashree Srinivas, Tejas N Vasa, Sabumon P. C.
"Algal-bacterial symbiotic system for the tannery wastewater treatment".	International conference on (ASREEM-2021) conducted by Sardar Vallabhbhai National Institute of Technology, Surat,India	August 06-08th, 2021	V. Nagabalaji, P. Maharaja, R. Nishanthi, G. Sathish R. Suthanthararajan, S. V. Srinivasan*
Network reconstruction	AIAA –Graphs and complex structures	Feb 28, 22 (to appear)	Anish Diwan and Sridharakumar Narasimhan

16. Patents Filed during the period: (Copyright filed)

Sl.no	Title	Inventors	Filed on	Granted
1	Turbidometer	Ashutosh Das, Kannan TTM, Parthiban P		340684-001 (Granted)
2	Solar and wind augmented composter	Ashutosh Das, Kannan TTM, Parthiban P		341584-001

3	Permeameter	Ashutosh Das, S. Amuthavel, Sugam Verma, K. Alagar Raj, P. Parthiban		342746-001
4	Recording Seepage Meter	Ashutosh Das, P. Parthiban, S Amuthavel, Sugam Verma, K. Alagar Raj		350262-001
5	Colorimetric sensors of Detection of Eutrophying pollutants (**Under Review**)	Vaishali Choudhary, Kowsalya Vellengiri, Ligy Philip	Application No:202141012240	IDF2070
6	Sustainable greywater recycling unit for households	Ligy Philip		No: 11234/2019-COL
7	Pulsed Power Technology based water treatment unit for the removal of pesticide, Pharmaceutically active compounds and pathogens	Ligy Philip		No: 201741039931
8	Simple direct microcontroller interface for capacitively-coupled resistive sensors	Lakshmi A., Boby George, and Ferran R	22/05/2020	202041021691
9	A Planar Coil-Based Water Level and Quality Monitoring System	Gaurav L., Subham K. S., and Boby George, Subhas C. Mukhopadhyay and Ligy Philip	24-July-2019	201941021491
10	A smartphone integrated fluoride-specific sensor for rapid and affordable colorimetric detection,	Thalappil Pradeep; Sritama Mukherjee; Kamalesh Chaudhari; Manav Shah	June 20, 2020.	202041026054
11	An Integrated CDI Electrode US Patent no.: US20200331778A1	T. Pradeep, Md R. Islam, S. S. Gupta, P. Srikrishnarka, S. K. Jana	October 22, 2020.	

12	An Integrated CDI Electrode PCT patent no.: WO2019130355A1	T. Pradeep, Md R. Islam, S. S. Gupta, P. Srikrishnarka, S. K. Jana	July 4, 2019	
13	A point-of-care (POC) ampherometric device for selective arsenic sensing 202041023576	T. Pradeep, S. K. Jana, K. Chaudhari, and Md R. Islam	June 5, 2020	
14	A compact, modular and scalable continuous-flow greywater sink for potable and non-potable uses. 202141054715	T. Pradeep, A. Nagar, Md R. Islam	November 26, 2021	
15	HYDRO-SOLVO THERMAL GRAPHENE OXIDE SYNTHESIS METHOD	Nanda Gopal Sahoo,Chetna Tewari,Sandeep Pandey ,Manoj Karakoti ,Sunil Dhali ,Himani Tiwari , Gaurav Tatrari Anand B. Melkani	17/03/2020	Revised Indian patent application No. 202011011434, PCT application No. PCT/IB2021/052158
16	Process of preparation of naturally doped Silicon, Magnesium and Calcium Graphene nanosheets from Paper Waste for Energy Applications (Australia Innovation Patent)	Sandeep Pandey ,Manoj Karakoti , Sunil Dhali, Chetna Tewari ,Nanda Gopal Sahoo	28/01/2021	2021100550 Granted
17	Triaminoguanidinium-based ionic porous organic frameworks (POFs) for heterogeneous catalysis and broad-spectrum antimicrobial application'	A. Patra, A. Chande, MD. W. Hussain and V. Bhardwaj	19/03/2019	Application No.201921010663 A

17. **Other Achievements during the Period:**

(i) Collaboration with CMWSSB

As part of the research and development activities, Water-IC for SUTRAM of EASY WATER has resolved to study the pressing problems related to water supply in Chennai city, in collaboration with Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB). A brainstorming session was conducted on how the academic consortium members can get involved with governmental agencies (CMWSSB, Tamil Nadu Water Supply and Drainage Board (TWAD), Public Works Department (PWD), Pollution control board, etc.) to come up with a Sustainable water management plan for Chennai city (on 19th July 2019). The session brought out the holistic planning and management of water taking into account short-term and long-term issues (emerging contaminants, increase in total dissolved solids in closed systems, climate change impact on surface and subsurface water sources, the impact of land use on inflows into the storage, impact on urban flooding, etc.).

In this regard, the center has provided specific recommendations on the appropriate location and technologies for sewage treatment, monitoring the quality of the recovered water, the impact of using existing lakes/quarries as storage facilities, and policy on source augmentation. In addition, the center is jointly working with CMWSSB for the quality analysis of water from various quarries around Chennai city regarding the source augmentation. The consortium also provides recommendations and strategies on how to access the amount of Non-Revenue Water and quantify losses in the distribution system. As part of this, the center is helping in identifying the appropriate choice of meters for measuring the quality of water supplied to consumers (including transmission and storage of the data). The center wishes to make the best efforts to provide knowledge and information to the decision-makers and public utilities, which would help them in their untiring efforts to provide safe drinking water to all.

The suggestions provided by Water-IC for SUTRAM of EASY WATER (Ligy Philip, IIT Madras) have been accepted and a new 30 MLD plant is going to be commissioned soon for tertiary treatment of wastewater. The treated wastewater will be stored and integrated with other sources of water in the water supply system.

(ii) Urban Drainage and Flood Risk in Chennai Metro

The ongoing works in flood mitigation aspects are being discussed by Anna University (Prof. L. Elango) with the "Advisory Committee on mitigation and management of flood risk in Chennai metro" for implementation.

Prof. Balaji Narasimhan is part of the apex body, advising the honorable Chief Minister of the State of Tamil Nadu on matters of drainage systems and flood protection. Many of the ideas regarding sustainable drainage systems being evolved as part of SUTRAM project are being discussed.

(iii) Book Publication

Book "Waste strategies, challenges and future directions"; edited by Prof. Nanda Gopal Sahoo has been published by Nova Science Publishers, Inc. New York, ISBN: 9781685073947.

(iv) Inter-Institutional Collaborative Work

- *Solvent knitted triptycene-based polymer-based adsorption study for pharmaceutical removal (IIT Madras & IISER Bhopal):* Solvent knitted triptycenes polymers (SKTP) were synthesized by the IISER Bhopal research group and the IIT Madras research group conducted the adsorption experiments for the removal of CBZ, a persistent pollutant. The experiments were conducted using 0.1 g/l of adsorbent dose and 50 mg/l of CBZ. The kinetic and equilibrium plots are shown in figure-3 and the model fitting parameters are tabulated in table-1.The PSO kinetics fitted with the highest regression coefficient inferring chemisorption and the rate constant was 7.48. The Freundlich isotherm fitted well for CBZ and the maximum adsorption capacity was 1046 mg/g. It indicates a heterogeneous surface with multilayer adsorption.

- *Synthesis of various agricultural waste-derived biochar for textile dye removal (IIT Madras & CSIR-CLRI Chennai):* Four different agricultural wastes were chosen such as coconut shell, tender coconut, banana flower, and sugarcane bagasse. All these materials were pyrolyzed and biochar synthesized and named CS, TC, BF, and SB respectively. The adsorption capacity was evaluated by adsorption studies carried out for three textile dyes i.e., methylene blue (MB), and methyl orange (MO). The experimental data were fitted with different kinetic models and isotherm models.

- *Kumaun University (Prof. N. G. Sahoo) and IIT-Madras (Prof. Ligy Philip):* Collaborative research is being carried out for better outcome of the project (SUTRAM). In this collaboration work, the organization "Kumaun University" worked on the development of carbon nanomaterials from various solid waste materials as well as its modification and optimization for water purification. The collaborated institute (IIT-Madras) is studying their performance for metals

removal and other studies. IIT Madras facilitates characterizations facilities for the developed materials which will help to achieve target of the project timely.

- *Kumaun University (Prof. N. G. Sahoo) and PRIST University (Prof. Ashutosh Das):* Kumaun University is engaged in developing carbon nanomaterials and Prof Das group's is using our materials for their water research work. They used our material for development of polyaniline graphene impregnated cotton fabric electrode based low-cost Microbial Fuel Cell using mixed culture obtained from Canteen wastewater.

- Kumaun University (Prof. N. G. Sahoo) and IITR-Lucknow (Dr. Satyakam Patnaik)

  Collaborative work is being carried out for toxicology study of carbon nanomaterials from different sources. IITR is doing a toxicology study of waste plastic and agricultural waste derived graphene based materials (provided by Kumaun University) to ensure that the materials are safe in nature and can be utilised for water treatment.

- Kumaun University (Prof. N. G. Sahoo) and CLRI-Chennai (Dr. S. Easwaramoorthi)

  They are exploring the possibility of developed waste derived graphene as a base for sensors as well as other applications.

- Kumaun University (Prof. N. G. Sahoo) and CSIR (Dr. S. V. Srinivasan)

  Prof. Sahoo is working with Dr. S. V. Srinivasan (CSIR) for the development of graphene based materials from biochar provided by him. CSIR has sent different types of materials (as a carbon source) to KumaunUniversity and KU is trying to optimize all the parameters for their up conversion into carbon nanomaterials.

- IITR Lucknow and IIT Tirupati

  They are working together on Chitosan-RGO-Ag nanocomposite films for disinfection of water. Cytotoxicity assay (MTT) is being carried out to determine the effective concentration of IC50 of the leachate sample.

18. Financial Status on the Day of Reporting:

       18.1 Amount Sanctioned: Rs: **4,46,56,222/-**

       18.2 Amount Received: Rs:**2,58,96,930/-**

       18.3 Manpower Sanctioned: **SRF – 10, JRF – 2, Project Coordinator – 1**

       18.4 Manpower in position: **SRF – 10, JRF – 2, Project Coordinator - 1**

19. Status of Shortfalls of all the preceding Reviews:

Activity	Shortfall (*if any*) in Specific Terms	Responsible Organization
Environmental Impact Assessment	Delay in manpower recruitment due to COVID-19.	CSIR-IITR