Std. Doc.: NMHS/PG-FTR

National Mission on Himalayan Studies – 2019

<u>Template/Pro forma for Submission</u>

NMHS-FINAL TECHNICAL REPORT (FTR)

Demand-Driven Action Research Project Grant

NMHS Reference No.:	NMHS/2017-18/SG30/11	Date of Submission:	3	1	0	3	2	0	2	2
			d	d	m	m	y	y	y	Y

PROJECT TITLE

DEVELOPMENT OF LOW COST ACCELERATED WATER PURIFICATION SYSTEMS WITH ADDED MINERALIZATION FOR HIMALAYAN REGION

Project Duration: *from* (**dd.mm.yyyy**) *to* (**31.12.2021**).

***Submitted to*:**

Er. Kireet Kumar
Scientist 'G' and Nodal Officer, NMHS-PMU
National Mission on Himalayan Studies, GBPNIHESD HQs
Ministry of Environment, Forest & Climate Change (MoEF&CC), New Delhi
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***Submitted by*:**

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GENERAL INSTRUCTIONS:

1. The Final Technical Report (FTR) has to commence from the date of start of the Project (as per the Sanction Order issued at the start of the project) till its completion. Each detail has to comply with the NMHS Sanction Order.
2. The FTR should be neatly typed (in Arial with font size 11 with 1.5 spacing between the lines) with all details as per the enclosed format for direct reproduction by photo-offset process. Colored Photographs (4-5 good action photographs), tables and graphs should be accommodated within the report or should be annexed with captions. Sketches and diagrammatic illustrations may also be given giving step-by-step details about the methodology followed in technology development/modulation, transfer and training. Any correction or rewriting should be avoided. Please give information under each head in serial order.
3. Training/ Capacity Building Manuals (with details contents of training programme technical details and techniques involved) or any such display material related to project activities along with slides, charts, photographs should be brought at the venue of the Annual Monitoring & Evaluation (M&E) Workshop and sent at the NMHS-PMU, GBPNIHESD HQs, Kosi-Katarmal, Almora 263643, Uttarakhand. In all Knowledge Products, the Grant/ Fund support of the NMHS should be duly acknowledged.
4. The FTR Format is in sync with many other essential requirements and norms desired by the Govt. of India time to time, so each section of the NMHS-FTR needs to duly filled by the proponent and verified by the Head of the Lead Implementing Organization/ Institution/ University.
5. Five (5) bound hard copies of the Project Final Technical Report (FTR) and a soft copy should be submitted to the **Nodal Officer, NMHS-PMU, GBPNIHESD HQs, Kosi-Katarmal, Almora, Uttarakhand**.

   The FTR is to be submitted into following two parts:

   Part A – Project Summary Report

   Part B – Project Detailed Report

   Following Financial and other necessary documents/certificates need to be submitted along with Final Technical Report (FTR):

Annexure I	**Consolidated and Audited Utilization Certificate (UC) & Statement of Expenditure (SE)**, including interest earned for the last Fiscal year including the duly filled GFR-19A (with year-wise break-up)
Annexure II	**Consolidated Interest Earned Certificate**
Annexure III	**Consolidated Assets Certificate** showing the cost of the equipment in Foreign and Indian currency, Date of Purchase, etc. (with break-up as per the NMHS Sanction Order and year wise).
Annexure IV	**List of all the equipment, assets and peripherals** purchased through the NMHS grant with current status of use including location of deployment.
Annexure V	**Consolidated Manpower Certificate** and **Direct Benefit Transfer (DBT) Details** showing the education background, i.e. NET/GATE etc. qualified or not, Date of joining and leaving, Salary paid per month and per annum (with break up as per the Sanction Order and year-wise).
Annexure VII	**Refund of any unspent balance as Demand Draft in favor of DDO, GBPNIHESD** payable at GBPNIHESD, Kosi-Katarmal, Almora, Uttarakhand.
Annexure VIII	**Details of Technology Transfer and Intellectual Property Rights developed.**

NMHS-Final Technical Report (FTR) *template*

Demand-Driven Action Research Project

DSL: Date of Sanction Letter *DPC: Date of Project Completion* **NMHS/2017-18/SG30/11**

				2	**0**	**1**	
d	d	m	m	y	y	y	y

3	1	1	2	**2**	**0**	**2**	**1**
d	d	m	m	y	y	y	y

Part A: Project Summary Report

1. Project Description

i.	Project Reference No.						
ii.	Type of Project	Small Grant		Medium Grant		Large Grant	
iii.	Project Title	**Development of Low Cost Accelerated Water Purification Systems with Added Mineralization for Himalayan Region**					
iv.	State under which Project is Sanctioned	**Himachal Pradesh**					
v.	Project Sites (IHR States covered) (Maps to be attached)						
vi.	Scale of Project Operation	Local		Regional		Pan-Himalayan	**√**
vii.	Total Budget/ Outlay of the Project	………… (in Cr)					
viii.	Lead Agency	IIT Mandi					
	Principal Investigator (PI)	Dr. Jaspreet Kaur Randhawa					
	Co-Principal Investigator (Co-PI)	Prof. Bharat Singh Rajpurohit Dr. Samar Agnihotri					
ix.	Project Implementing Partners						
	Key Persons / Point of Contacts with Contact Details, Ph. No, E-mail						

2. Project Outcome

2.1. Abstract (not more than 500 words) [it should include background of the study, aim, objectives, methodology, approach, results, conclusion and recommendations).

Background**:** *Cutting-edge technologies for water purification are the gateway for wastewater management. Heavy metals, organic dyes, and medicinal drug pollutions present in water bodies severely affect human health upon consumption. Therefore, a great need to develop an efficient platform that helps eliminate heavy metals, organic dyes, and medicinal drugs towards wastewater treatment management. Desalination technologies are highly efficient at eliminating pollutants from contaminated water. These breakthroughs could produce freshwater from underutilized, contaminated sources. Membranes and other Nanoporous materials have long been critical solutions for addressing worldwide water scarcity. Water and wastewater filtration systems include pressure-driven seawater and brackish water reverse osmosis (RO), Nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF), as well as osmotically driven forward osmosis (FO) and pressure retarded osmosis (PRO). These technologies have grabbed the interest of both academics and industry because of their capacity to produce high-quality water while using less energy in most cases. Microfiltration (MF), ultrafiltration (UF), and nanofiltration (NF) are examples of membrane technologies that can be categorized based on separation principles and membrane properties. Membrane provides the following advantages over other water treatment technologies in terms of low energy consumption: membrane separation can be performed continuously under mild conditions. It can be used in conjunction with other technologies, and the membrane properties can be modified to meet a range of requirements while requiring minimal energy. Various treatment techniques for industrial waste treatment strategies have been addressed in order to restore the environment and prevent risks to humanity. Recent research has been performed to address many obstacles linked to material-based limits faced by polymeric membranes, with the goal of resolving the concerns using best practice techniques.*

Objectives/ Aim: *Testing and linking solar thermal energy via photovoltaic module and other renewable energy sources for a better and accelerated system for purifying the water and to apply incorporating nutrients field of photovoltaic system and incorporating nutrients to water.*

Experimental section: *The work highlights synthesis characterization and different applications of α-Fe_2O_3/PAN nanofibers mat by the electrospinning process. The matrix of α-Fe_2O_3/PAN nanofibers mat is used for methylene blue (MB) dye filtration as a pollutant in wastewater treatment. The results show that the mat can filter MB dye even present at lower concentrations and showed more than 95% removal efficiency at higher concentrations. the separation of heavy metals such as Pb^{+2} and Cu^{+2} from water using α-Fe_2O_3/PAN nanofiber mat also experimented in the present work. The maximum adsorption capacity was calculated c.a 333.33 mg/gm for the lead after 3 minutes and c.a.200 mg/gm for copper after 90 minutes respectively. Additionally, the α-Fe_2O_3/PAN nanofibers mat was calcined at 300^oC for 2 hours using a Thermo scientific tubular furnace in air atmosphere for photocatalysis, pyrocatalysis and sonocatalsis. The photocatalytic experiment shows that the calcined α-Fe_2O_3/PAN nanofibers mat can efficiently degrade MB dye c.a. 98% within 240 minutes under visible light illumination. Similarly, pyrocatalytic and sonocatalytic*

experiments show that the calcined α-Fe_2O_3/PAN nanofibers mat can degrade MB dye c.a. 94% within 70 cold and hot cycles and c.a 94% within 150 minutes respectively. Further, α-Fe_2O_3/PAN nanofiber mat was modified with the $CaCO_3$ for remineralization of the water.. Using an α-Fe_2O_3/PAN/$CaCO_3$/CTA nanofiber membrane, a method for sustaining calcium remineralization of water with a concentration of 95 mg/L in 7 days was also produced in a dilute acidic medium. In conclusion, the present work's unique approach to wastewater treatment and remineralization using a multifunctional α-Fe_2O_3/PAN/$CaCO_3$/CTA nanofiber membrane, backed up by experimental results, opens up a new window for addressing the issue of drinking water in the light of environmental remediation.

2.2. Objective-wise Major Achievements

S. No.	Objectives	Major achievements (in bullets points)
	Testing and linking solar thermal energy via photovoltaic module and other renewable energy sources for better and accelerated system for purifying the water	Literature Survey of different water purification systems. Analysis of water standards Working analysis of Solar Stills Fabrication and characterization of the nanofibers membrane Applications of the nanofibers membrane for water purification.
	To apply nanotechnologies in the field of photovoltaic system and incorporating nutrients to water;	Hybrid membrane fabrication and characterization Hybrid membrane used for organic pollutants Removal, heavy metals removal, and remineralization of water
	To ensure better health for under-served communities and especially to women and children.	A National level workshop is being organized for awareness regarding pure water.

2.3. Outputs in terms of Quantifiable Deliverables*

Quantifiable Deliverables	**Monitoring indicators**	**Quantified output/ output achived**	**Supportive documents (PDF, Word, Excel, JPG, TIFT)**

1	2	3	4
• Improved Low-Cost solar powered accelerated Water Purification System with added Minerals • Development of innovative clean accelerated Solar Thermal Energy-based systems/tools, products, new technologies • Increased hybrid energy capacity for low-cost filters • Increased access to off-grid products, i.e. without electricity for energy services for under-served populations in one village • Development of a manual for standards and best practices	• Periodic updates on new Database/ Datasets/ Maps/ Templates generated on the identified dynamics **(No.)** viz., Nanotechnologies; Photo voltaic system; Solar thermal energy; etc.	**I) We have fabricated a hybrid membrane system characterized and tested for dye degradation and heavy metal filtration.** **II) And Remineralisation of calcium with time.** **This membrane is also used to detect the drugs paracetamol and ascorbic acid in water using an electrochemical system.** Under laboratory conditions, the prototype can purify water using a variety of ways, including solar radiation, piezoelectricity, and pyrocatalysis. Heavy metals(Pb,Cu) and organic dyes can be removed from water with 95% effectiveness, and their reusability has been proven. The prototype can also use pyro catalysis to breakdown organic pollutants in waste water. In terms of specific contaminants, the prototype type may also be used as a stand-alone model for various industrial waste water treatment. To deliver nutrients in purified water, the water quality for drinking can be improved in the system. **In lab scale it can serve the purification and**	

		remineralisation for 5 lit water.	
	• No. of region-specific Pilot scale models/ techniques developed/ implemented (**No.)**		
	• Policy/ strategic framework/ drafts and Legislative Mechanisms (No.) for assisting the regional decision-making in Low-cost solar-powered accelerated water purification system;	**A solar still integrated with copper strips were investigated and found it has enhanced productivity as compared to conventional solar still.**	
	• **No**. of Beneficiaries with Alternate Options for Low-cost filters, Water purification methods, etc.	**NO**	
	• Other Publications and Knowledge Products **(Nos.)** viz., Manual for standards and best practices;	**Publications 6**	

(*) As stated in the Sanction Letter issued by the NMHS-PMU.

2.4. Strategic Steps with respect to Outcomes (in bullets)

S. No.	Particulars	Number and Brief Details	Details of Attachment/ Supporting Document
1.	New Methodology developed:		Under laboratory conditions, the prototype can purify water using a variety of ways, including solar radiation, piezoelectricity, and pyrocatalysis. Heavy metals and organic dyes can be removed from water with 95% effectiveness, and their reusability has been proven. The prototype can also use pyro catalysis to breakdown organic pollutants in waste water. In terms of specific contaminants, the prototype type may also be used as a stand-alone model for various industrial waste water treatment. To deliver nutrients in purified water, the water quality for drinking can be improved in the system. In lab scale it can serve the purification and remineralisation for 5 lit water.
2.	New Models/ Process/ Strategy developed:		
3.	New Species identified:	NA	
4.	New Database established:	NA	
5.	New Patent, if any:		
	Filed (Indian/ International)	yes	Indian Patent. 02111060593 FUNCTIONALIZED NANOFIBER MEMBRANE AND METHOD OF PREPARATION THEREOF
	Granted (Indian/ International)		
	Technology Transfer(if any)		
6.	Others (if any):		

3. Technological Intervention

S. No.	Type of Intervention	Brief Narration on the interventions	Unit Details (No. of villagers benefited / Area Developed)
1.	Development and deployment of indigenous technology	POSSIBLE IN RURAL AREA	
2.	Diffusion of High-end Technology in the region	NA	
3.	Induction of New Technology in the region	NA	

4.	Publication of Technological / Process Manuals	6	Published work 1. Water purification and biomineralization using nanofibers-based membrane technology, Manish Kumar, Siddhant Kumar, Samar Agnihotri, Bharat Singh Rajpurohit and Jaspreet Kaur Randhawa, *CURRENT SCIENCE JOURNAL*, VOL. 120, NO. 5, 10 MARCH 2021, 2. Siddhant Kumar, Manish Kumar, Sumanta Chowdhury, Bharat Singh Rajpurohit, Jaspreet Kaur Randhawa, Environmental concerns and long-term solutions for solar-powered water desalination, Journal of Cleaner Production, Volume 345,2022,131180, **Under submission** (delayed due to patent application) 1. Electrospun α-Fe2O3/PAN nanofibers mat: A multifunctional wastewater treatment platform, Manish Kumar, and Jaspreet Kaur Randhawa (to be submit). 2. Electrospun α-hematite/polyacrylonitrile/calcium carbonate/cellulose triacetate nanofiber membrane for water remineralization and wastewater remediation, Manish Kumar, and Jaspreet Kaur Randhawa (to be submit). 3. A comprehensive review on nanofibers based polymeric membranes for water remediation, Manish Kumar, Sumanta Chowdhury, and Jaspreet Kaur Randhawa (to be submit). 4. Nanofibers based multifunctional: Ultrahigh solar driven evaporator, Manish Kumar, and Jaspreet Kaur Randhawa (to be submit).
	Others (if any)	Patent submitted	1 Indian Patent. 02111060593 FUNCTIONALIZED NANOFIBER MEMBRANE AND METHOD OF PREPARATION THEREOF

4. New Data Generated over the Baseline Data

S. No.	New Data Details	Status of Existing Baseline	Additionality and Utilisation New data

5. Demonstrative Skill Development and Capacity Building/ Manpower Trained

S. No.	Type of Activities	Details with number	Activity Intended for	Participants/Trained			
				SC	**ST**	**Woman**	**Total**
1.	Workshops	**1**	**A National workshop on water filtration techniques based on solar energy 11-13 FEB 2019**				**65**
2.	On Field Trainings						
3.	Skill Development						
4.	Academic Supports						
	Others (if any)						

6. Linkages with Regional & National Priorities (SDGs, INDC, etc)/ Collaborations

S. No.	Linkages /collaborations	Details	No. of Publications/ Events Held	Beneficiaries
1.	Sustainable Development Goal (SDG)			
2.	Climate Change/INDC targets			
3.	International Commitments			
4.	Bilateral engagements			
5.	National Policies			
6.	Others collaborations			

7. Project Stakeholders/ Beneficiaries and Impacts

S. No.	Stakeholders	Support Activities	Impacts
1.	Gram Panchayats	It is prototype for low income society.	
2.	Govt Departments (Agriculture/ Forest)		
3.	Villagers	Can be applied for rural community	
4.	SC Community		
5.	ST Community		
6.	Women Group	Due to COVID 19 constrain, community empowering workshop cannot be conducted	
	Others (if any)		

8. Financial Summary (Cumulative)

S. No.	Financial Position/Budget Head	Funds Received	Expenditure/ Utilized	% of Total cost
I.	Salaries/Manpower cost	1369953. 00	1392660.00	100%(-22707) fellowship arrear
II.	Travel	276508.00	108069.00	40%
III.	Expendables &Consumables	0	0	100%
IV.	Contingencies	205514	205514	100%
V.	Activities & Other Project cost	1421954	720306	50%
VI.	Institutional Charges	468746	468746	100%
VII.	Equipments	200000	200000	100%
	Total	3942675.00		
	Interest earned	17799.00		
	Grand Total	3960474.00		

* Please attach the consolidated and audited Utilization Certificate (UC) and Year wise Statement of Expenditure (SE) separately, *ref*. **Annexure I.**

9. Major Equipment/ Peripherals Procured under the Project (if any)**

S. No.	Name of Equipments	Cost (INR)	Utilisation of the Equipment after project
1.	Multi-Parameter Water Quality Meter (1pcs)	31500/-	
2.	Dissolved Oxygen Meter-LMDO-50 (1pcs)	47250/-	
3.	Digital Ultrasonic Cleaner With LID, Timer Heater & Basket (1pcs)	12075/-	
4.	SPINWIN MC-01 Micro Centrifuge (1 pcs)	25958/-	
5.	Solar Desalination System (2 unit)	45,200/-	
6.	Various Chemicals	47,852/-	
7.	Laptop (Dell Latitude 3480, Windows 10 Home OEM Pack) (1 unit)	47880/-	
8.	Solar Hydro panel (1unit)	2,03,160/-	

Details should be provided in details **(*ref*** **Annexure III &IV).**

10. Quantification of Overall Project Progress

S. No.	Parameters	Total (Numeric)	Details of Attachments/ Supporting Documents
1.	IHR States Covered	*NA*	
2.	Project Site/ Field Stations Developed	*NA*	
3.	New Methods/ Modeling Developed	*NA*	
4.	No. of Trainings arranged	*NA*	
5.	No of beneficiaries attended trainings	*NA*	
6.	Scientific Manpower Developed (Phd/M.Sc./JRF/SRF/ RA):	***1 PhD***	*Water purification and biomerlisation using nanofibers based membrane technology.*
7.	SC stakeholders benefited	*NA*	
8.	ST stakeholders benefited	*NA*	
9.	Women Empowered	*NA*	
10.	No of Workshops Arranged along with level of participation	*1*	
11.	On-field Demonstration Models initiated	.... (attach maps about location & photos)	
12.	Livelihood Options promoted	*NA*	
13.	Technical/ Training Manuals prepared	*NA*	
14.	Processing Units established	.... (attach photos)	
15.	No of Species Collected	*NA*	
16.	New Species identified	*NA*	
17.	New Database generated (Types):	*NA*	
	Others (if any)		

11. Knowledge Products (KPs) and Publications

S. No.	Knowledge Products (KPs)/ Publication	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
1.	Journal Research Articles/ Special Issue:		6		PUBLISHES ATTACHED IMPACT 9.32
2.	Book Chapter(s)/ Books:		NA		
3.	Technical Reports		NA		

S. No.	Knowledge Products (KPs)/ Publication	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
4.	Training Manual (Skill Development/ Capacity Building)		NA		
5.	Papers presented in Conferences/Seminars		1		INTERNATIONAL ONLINE CONFERENCE ON ADVANCED NANO MATERIALS (ICAN-2021)
6.	Policy Drafts/Papers				
7.	Others:		1 Indian Patent. 02111060593		FUNCTIONALIZED NANOFIBER MEMBRANE AND METHOD OF PREPARATION THEREOF

*Please append the list of KPs/ publications (with impact factor and further details) with due Acknowledgement to NMHS.

12.1. Success Model(s)/ Best Practice(s) under the Project:

Parameters	***Description***	***Details of Attached supporting documents***
Adaptability of the Technology:	In terms of specific contaminants, the prototype type may also be used as a stand-alone model for various industrial waste water treatment.	
Acceptability (interest of the local people):		
Improvement in Ecological Variables:		
Baseline Data and Comparison with the Controlled Data:		
Outcomes of the Scientific Publications, Knowledge Products:		

12.2. Recommendation on Utility of Project Findings, Replicability and Exit Strategy

Particulars	***Recommendations***

Utility of the Project Findings:	Solar based water purification system could be used as a part of implementation of Himalayan region for rural area
Replicability of Project:	In remote areas, a solar-powered water filtration equipment can provide safe drinking wate**r. The solar still can filter water and remineralisation it at the same time, resulting in pure water. In lab scale it can serve the purification and remineralisation for 5 lit water.**
Exit Strategy:	Please describe the Exit Strategy of the project, self-sustaining and benefitting the stakeholders and local community: Under laboratory conditions, the prototype can purify water using a variety of ways, including solar radiation, piezoelectricity, and pyrocatalysis. Heavy metals and organic dyes can be removed from water with 95% effectiveness, and their reusability has been proven. The prototype can also use pyro catalysis to breakdown organic pollutants in waste water. In terms of specific contaminants, the prototype type may also be used as a stand-alone model for various industrial waste water treatment. To deliver nutrients in purified water, the water quality for drinking can be improved in the system. **In lab scale it can serve the purification and remineralisation for 5 lit water.**

(**PROJECTPROPONENT/ COORDINATOR**) **(Signed and Stamped)**

(**HEAD OF THE INSTITUTION**) **(Signed and Stamped)**

Place: …………Mandi ……..
Date: …31../…03…/2022……

PART B: PROJECT DETAILED REPORT

The Detailed report should include an Executive Summary and it should have separate chapters on (i) Introduction (ii) Methodologies, Strategy and Approach (iii) Key Findings and Results (iv) Overall Achievements (v) Project's Impacts in IHR (vi) Exit Strategy and Sustainability (vii) References and (viii) Acknowledgement (It should have a mention of **a** financial grant from the NMHS, MoEF&CC)

Further, description of Technical Activities, List of Training/ Workshops/ Seminars with details of trained resources, list of New Products developed under the project, Manual of Standard Operating Procedures (SOPs) developed, Technology developed/Transferred, etc should be enclosed as Appendix.

1 EXECUTIVE SUMMARY

The Executive Summary of the project should not be more than 3–5 pages, covering all essential features in a precise and concise manner as stated in Part A (Project Summary Report) and Part B (Comprehensive Report).

The work highlights synthesis characterization and different applications of α-Fe_2O_3/PAN nanofibers mat by the electrospinning process. The matrix of α-Fe_2O_3/PAN nanofibers mat is used for methylene blue (MB) dye filtration as a pollutant in wastewater treatment. The results show that the mat can filter MB dye with more than 95% removal efficiency at higher concentrations. the separation of heavy metals such as Pb^{+2} and Cu^{+2} from water using α-Fe_2O_3/PAN nanofiber mat also experimented within the present work. The maximum adsorption capacity was calculated c.a 333.33 mg/gm for the lead after 3 minutes and c.a.200 mg/gm for copper after 90 minutes respectively. Additionally, the α-Fe_2O_3/PAN nanofibers mat was calcined at 300^{o}C for 2 hours using a Thermo scientific tubular furnace in air atmosphere for photocatalysis, pyrocatalysis, and sonocatalsis. The photocatalytic experiment shows that the calcined α-Fe_2O_3/PAN nanofibers mat can efficiently degrade MB dye c.a. 98% within 240 minutes under visible light illumination. Similarly, pyrocatalytic and sonocatalytic experiments show that the calcined α-Fe_2O_3/PAN nanofibers mat can degrade MB dye c.a. 94% within 70 cold and hot cycles and c.a 94% within 150 minutes respectively. Further, the α-Fe_2O_3/PAN nanofiber mat was modified with the $CaCO_3$ for remineralization of the water. Using an α-Fe_2O_3/PAN/$CaCO_3$/CTA nanofiber membrane, a method for sustaining calcium remineralization of water with a concentration of 95 mg/L in 7 days was also produced in a dilute acidic medium. In conclusion, the present work's unique approach to wastewater treatment and remineralization using a multifunctional α-Fe_2O_3/PAN/$CaCO_3$/CTA nanofiber membrane, backed up by experimental results, opens a new window for addressing the issue of drinking water in the light of environmental remediation.

2 INTRODUCTION

2.1 Background of the Project (max. 500 words)

Clean drinking water is one of the main research and innovation priorities since water is a significant source of human life and the surrounding equilibrium. The main source of water contamination is impurities such as heavy metals, pharmaceuticals, dyes, and microbial deterioration. Due to the variety and structure of the matrix, as well as the low amounts of contaminants that must be identified, monitoring water quality on a large and small scale is difficult. In the past decades, nanomaterials have been under active research and development and have been successfully applied in many practical applications. Thus, nanoscale dimension with high aspect ratio, chemical reactivity, large surface area, and scope to modify the surface properties make it suitable choice for water treatment[1,2]. For the treatment of the organic pollutants and heavy metals separation many techniques have been applied such as photocatalytic- oxidation[3], adsorption[4], membrane separation[5], chemical oxidation[6], biological[7], sonocatalytic degradation[8,9] and pyro degradation methods. Metal oxide such as TiO_2, Fe_2O_3, ZnO, NiO, and Mn_3O_4 are well established photocatalys[10–14]. Amongst the many photo catalyst the α-Fe_2O_3 is promising cost-effective semiconductor material due to its, narrow bandgap ~2.2 eV, chemical stability in aqueous solution, non-toxicity and capable to absorb large portion of the visible solar spectrum and hold possibilities over the conventional material [15,16]. The major inconsistencies are that many metal oxide nanoparticles usually tend to aggregate. The particle aggregation decreases the effective surface area for adsorption, resulting in low adsorption performance for heavy metals. In addition, the separation of nanoparticle adsorbents from the treated solution is also challenging. In similar aspect, in addressing aggregation and separation problems, there is great potential for magnetic materials.

Membrane based technology is the best alternative way to overcome the issues of agglomeration and separation. The membranes are manufactured using distinct techniques such as phase inversion method[17], interfacial polymerization[18], track etching[19,] and electrospinning[10]. Electrospinning is a direct and efficient method for the production of nanofiber membranes. Electrospinning is an electrostatic process for manufacturing nanoscale solid and hollow nanofibers.

The invention of a material that performs as an efficient catalyst and can be regenerated or reused numerous times without compromising dye removal efficiency is a critical necessity. The choice of PAN is to boost the mechanical properties and the selection of iron oxide is due to its low cost, environment friendly nature, and chemical stability over a wide pH range. The electrospun nanofiber mat thus can be isolated and recycled, which could dramatically lower the cost of water purification and can extract different forms of contaminants, including phosphate, heavy metal ions, and organic dyes, with a very high-water flow. The optimal for a very high-water flux and excellent reusability. These fibers can be used to remove several pollutants from water and are not toxic to human health. In addition, these membranes offer perspective applications due to unique surface affinity such as hydrophilicity and hydrophobicity that are advantageous in adsorption, separation, photocatalysis, pyrocatalysis and Piezo catalysis. Significant work has been reported to use nanofiber in organic dye degradation in water,[20–22] separation of heavy metals[23], separation of oil-water[24], and reminerlisation[25]. Similarly, various techniques for improving catalytic performance such as doping of transition metal and non-metal in polymer matrix to develop composite photocatalysts[24, 26] ,pyro catalyst[27] and sono catalyst[28] are also studied widely.

The PAN nanofiber membranes were modified with α-Fe_2O_3 and shown excellent adsorption and purification performance[29–33]. Several studies have shown that nanofiber membranes modified with $CaCO_3$ have a high capacity for adsorption of toxins from wastewater and subsequent remineralization of the water[34]. $CaCO_3$ is a popular choice due to its natural abundance as a biomineral in nature, low-cost adsorbent, eco-friendly, highly effective, and inexpensive properties in real-time wastewater remediation[35, 36, 37] and remineralization, and tailoring thereof for heavy metal ion removal[38] from wastewater and subsequent remineralization of water in real time.

Solar-driven steam generation (SDSG), which concentrates solar heating at the air water interface, has recently been introduced as a new approach for getting clean water for daily use, mainly in regions where freshwater resources are limited. Localized heating at the air−water interface instead of bulk heating enables higher solar-to-vapor conversion efficiency and lesser utilization of photothermal materials. Compared with traditional seawater purification technologies such as reverse osmosis and ion exchange, the SDSG evaporator can improve the solar-to-vapor conversion efficiency to as high as 90%, which potentially enables the design of home-scale SDSG devices for generating fresh water at a rate of 2.5 $L/m^2 \cdot d$, which is sufficient for meeting individual daily drinking needs.

2.2 Project Objectives and Target Deliverables (as per the NMHS Sanction Order)

3 METHODOLOGIES, STARTEGY AND APPROACH

3.1 Methodologies used for the study (max. 1000 words)

Experimental section (methodologies)

Fabrication of α-Fe_2O_3/PAN nanofiber mat

Electrospun α-Fe_2O_3/PAN nanofibers mats were fabricated in two steps. The first step constitutes the solution preparation and the second is mat formation using the electrospinning process. Mechanical properties of nanofibers depend on the parameters such as viscosity and surface tension of prepared solution. To fabricate the nanofibers of high strength, an optimum viscosity and surface tension of solution was opted in synthesis process[39]. In a typical electrospinning procedure, PAN polymer (w/v 7%) dissolved in DMF and stirred at 70^oC for 12 hours at 450 rpm till the solution turns transparent. On the other hand, concentrations of Iron (III) Nitrate 3% were dissolved in DMF until uniform solution observed. Further, both the solution was mixed under stirring for 2 hours. This solution was transferred into a 3 ml syringe for the electrospinning process[22]. The electrospinning was performed on ambient temperature and humidity under a voltage of 16 kV applied on the tip of the needle. The flow rate of solution was 0.5 ml per hour constantly and distance between needle and collector was 13 cm.

Additionally, sample was calcined at 300 ^oC for 2 hours using a Thermo scientific tubular furnace in air atmosphere. The calcined sample 2 was used for the dye degradation using photo, pyro andPeizo catalysis .

3.2 Preparatory Actions and Agencies Involved (max. 1000 words)

3.3 Details of Scientific data collected and Equipments Used (max 500 words)

Surface morphologies and structural properties of α-Fe_2O_3/PAN nanofiber mat was characterized using field emission scanning electron microscopy (FESEM) and Energy dispersive X-ray spectroscopic analysis (EDAX) studies. Surface morphology of α-Fe_2O_3/PAN nanofibers mat was observed using a FESEM (NOVA Nano SEM 450) at an accelerating voltage of 10 kV. FESEM-EDAX was also performed with proper scan area in the specific region of interest in the sample. The sample was gold coated prior to FESEM imaging.

Transmission electron microscope was used to evaluate the nanofiber size and morphology using FEI Technai TEM equipped with a LaB6 source operating at 200 kV. For TEM imaging, nanofibers were dispersed in deionized water and drop casted on carbon-coated copper grid before the imaging. Crystalline structure properties of the α-Fe_2O_3/PAN nanofiber mat was carried out using X-ray diffraction (XRD) spectroscopy. The pattern of the α-Fe_2O_3/PAN nanofiber mat was recorded on a Rigaku smart Lab diffractometer, using Cu Kα radiation from 20 to 70 degree with a scan rate of 2 degree/minute. To study the functional groups on the nanofiber mat surface the Fourier transform infrared spectroscopy (FTIR) was used. An Agilent Technology, Cary 660 FTIR spectrophotometer (Model No. K8002AA Cary 660, USA) operates at 4 cm-1 resolution. A diamond ATR plate is used for efficient data collection with minimum noise and superior signal quality. FTIR analysis was performed using powder specimen samples and scanning was done from the frequency range of 400 to 4000 cm-1. FTIR spectra were recorded using a Resolutions Pro FTIR Software by subtracting the background signal with the reference spectra. The concentration of dye was measured using UV-Vis spectroscopy from the wavelength of 200-800 nm. The adsorption amount of the heavy metals was analysed using the Atomic Adsorption Spectrometer Analyst 400 (PerkinElmer).

Surface chemical composition and oxidation states in α-Fe_2O_3/PAN nanofiber mat was analysed by using X-ray photoelectron spectroscopy (XPS). The spectra were recorded on a VG (ESCALAB 250) electron photo spectrometer equipped with a monochromatic Al Kα (1486.6 ev) X-ray source at 15 kV and 10 mA. All the binding energies were referenced to the C1s peak (284.8 ev). XPS was also used to detect and confirm the presence of heavy metals adsorbed on the surface of mat. Thermogravimetric analysis (TGA) was performed on a Perkin Elmer Thermal Analyzer instrument under a nitrogen atmosphere from room temperature to 900 °C at heating rate of 10 K/min. The Brunauer-Emmett-Teller (BET) surface area and pore volume analysis was performed on Quanta chrome Autosorb IQ-3 nitrogen analyzer to measure the adsorption desorption isotherm, surface area, pore volume, and pore size distribution of the sample. BET analysis was done after degassing the sample overnight at 80 °C. The intermediate products of the MB during the photocatalytic degradation were analysed by the Bruker HD compact mass spectrometer instrument.

3.4 Primary Data Collected (max 500 words)

3.5 Details of Field Survey arranged (max 500 words)

3.6 Strategic Planning for each Activities (max. 1000 words)

3.7 Activity wise Time frame followed [using Gantt/ PERT Chart (max. 1000 words)]

S. No.	Objectives	6 Mont hs	12 Month s	18 Months	24 Months	30 Months	36 months	42 months
1.	Literature review							
2.	Membrane Fabrication and characterization and development of the solar stills							
3.	Testing of the membrane for dye and heavy metal filtration							
4.	Membrane modification and remineralization of water							
5.	Modification of the solar stills with copper and tested for water evaporation							
5.	Degradation of the organic dyes using a calcined membrane (photocatalyst, sono							

	catalyst, and pyro catalyst)							
6.	Nanofibers based multifunctional: Ultrahigh solar-driven evaporator							

4 KEY FINDINGS AND RESULTS

4.1 Major Research Findings (max. 1000 words)

Methylene blue (MB) adsorption studies

After characterizing the α-Fe_2O_3/PAN nanofiber mat, we selected MB as model water pollutant to intuitively evaluate the adsorption performance. The five different concentrations of methyl blue dye solutions were prepared i.e. 10 ppm, 50 ppm, 100 ppm, 200 ppm, 250 ppm. Figure1 (a) showed complete decolourization of MB solution when it was filtered using α-Fe_2O_3/PAN nanofiber mat. We confirmed this by UV-Vis analysis where no absorption peak for MB was observed in the filtrate. In the meantime, MB molecules would be trapped by the α-Fe_2O_3 nanofibers mat to release the clean water. The resistance time or contact time plays a very important role in adsorption capacity and superior filtration performance. As shown in the inset of Figure 1(b), the removal efficiency was c.a. 95% at higher concentrations. However, at lower concentrations, the removal efficiency was calculated to be c.a. 99%. Further layer by layer stacking of several α-Fe_2O_3/PAN nanofiber mats to form a water filter membrane with improved performance which may be useful to achieve efficient filtration of organic pollutants even at high concentration presents in water.

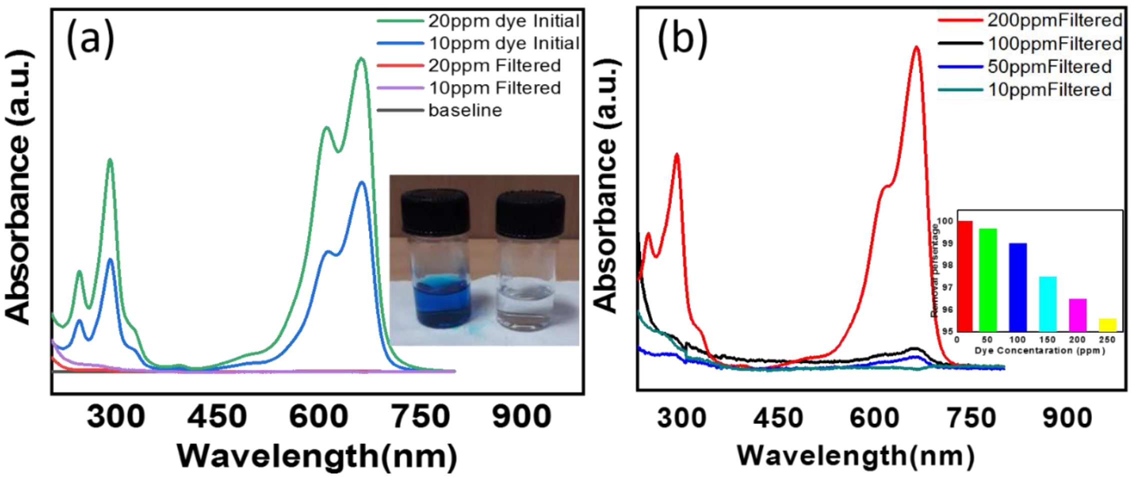

Figure 1. (a) MB removal using α-Fe_2O_3/PAN nanofiber mat at 10 ppm and 20 ppm concentrations. (b) MB filtration using α-Fe_2O_3/PAN nanofiber mat for higher concentrations (10-200 ppm). (Inset Figure 3b- MB percentage removal efficiency at various concentration (10-200 ppm).

Photocatalytic degradation of MB

Photocatalytic activity of calcined α-Fe2O3/PAN nanofiber mat was evaluated using MB as a standard organic dye commonly used in catalytic experiments. Photocatalytic degradation of MB was carried out in a closed chamber equipped with white light source.

The peak intensity of MB at 664 nm decrease with the increment of the light exposure time as shown in Figure 7(a). and Figure 2(b) shows the reaction rate constant k calculated using the above formula after complete degradation of MB. The rate constant and correlation coefficient were calculated to be 0.018 and 0.994 which was higher than other reported photocatalysts in the literature[20]. The MB degradation efficiency was calculated c.a. 98% within 240 minutes using α-Fe_2O_3/PAN nanofiber mat and c.a. 38% with only PAN nanofiber mat. Moreover, the α-Fe_2O_3/PAN nanofiber mat photocatalyst can be easily separated from the solution using a magnet due to the magnetic properties of the α-Fe_2O_3[40,33]. The MB degradation results concluded that the synthesized α-Fe_2O_3/PAN nanofiber mat has shown great potential in the MB adsorption and degradation studies. The multifunctional behavior of α-Fe_2O_3/PAN nanofiber mat advances its usage in wastewater treatment and management. Photocurrent measurements were performed for the calcined α-Fe_2O_3/PAN nanofiber mat and the result is plotted in the figure 7(c). it can be observed in the figure 7(c) that the magnitude of the photocurrent increases with the light switching ON. When we switch on of the lamp the photocurrent increases and when the switch OFF the current reduces to zero. These experiments support the enhanced photocatalytic activities of the α-Fe_2O_3/PAN nanofibers mat.

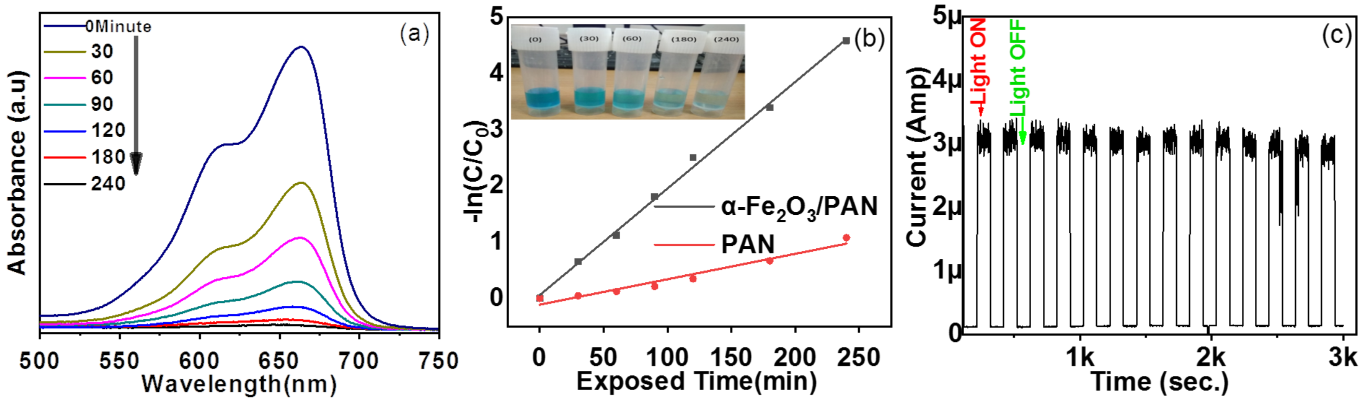

Figure 2. (a) Change in absorption spectra of MB with different exposure time intervals (b) change in -ln(C/Co) with respect to time (c) Photocurrent of α-Fe_2O_3/PAN nanofibers.

Sonocatalytic degradation of MB

Sonocatalytic degradation of MB was carried out in a bath sonicator in dark medium to eliminate the photodegradation of MB dye. Figure 3(a) shows MB dye degradation under ultrasonic irradiation without presence of any catalyst. Figure 3(b) shows the MB dye degradation under ultrasonic irradiation in the presence PAN nanofibers. Figure 3(c) shows the MB degradation under ultrasonic irradiation in the presence α-Fe_2O_3/PAN nanofiber mat. These all three experiments were performed at same conditions at room temperature. After every 30 minutes 1ml of the MB solution taken out from each vial to probe the time dependent Peizo catalysis performance. For the comparison purpose, the degradation percentage of the MB dye without any catalyst, with PAN nanofibers and with α-Fe_2O_3/PAN nanofiber mat plotted as shown in the figure 3(d).

The MB degradation efficiency was calculated c.a. 94% within 150 minutes using α-Fe_2O_3/PAN nanofiber mat and c.a. 16% with only PAN nanofiber mat. Moreover, the α-Fe_2O_3/PAN nanofiber mat photocatalyst can be easily separated from the solution using a magnet due to the magnetic properties of the α-Fe_2O_3.

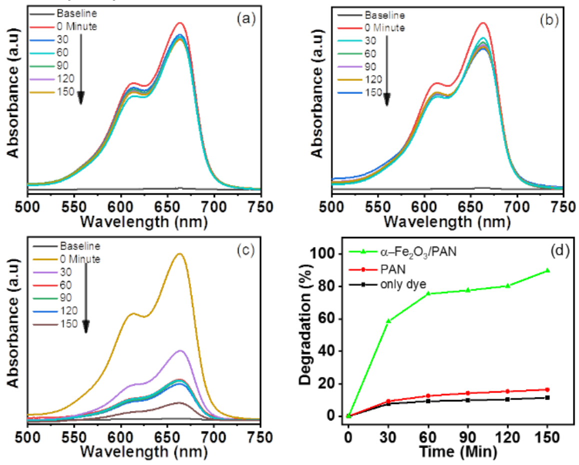

Figure 3. Peizo catalysis performance of (a) without any catalyst (b) with PAN nanofiber (c) with α-Fe_2O_3 /PAN nanofibers (d) degradation percentage

Pyro catalytic degradation of MB dye

Pyro catalytic degradation of MB was carried out in dark medium to eliminate the photodegradation of MB dye. Pyro catalysis needs temporal variations to create surface potential which ultimately separates surface charges. The MB dye solution was kept in the glass vial. The vial holds a constant temperature for 2 minutes to generate thermal gradient. The temperature of the solution was maintained at 10°C and 40 °C throughout the process. when the vial subjected to cold – hot temperature variation large numbers of charge carriers (electros and holes) are generated on the surface of the catalyst. The figure 4(a-c) show a decrement in the absorbance spectra of the MB dye with the presence of catalyst. The degradation percentage of MB dye is shown in the figure 4 (d) in which the significant pyro catalytic effect of the α-Fe_2O_3/PAN nanofiber can be seen. These results show that the PAN nanofiber shows significant degradation of the MB dye as shown in the figure 4(c) which is too high compared to pure PAN nanofibers. The MB degradation efficiency was calculated c.a. 94% after 70 hot and cold cycles using α-Fe_2O_3/PAN nanofiber mat and c.a. 22% with only PAN nanofiber mat.

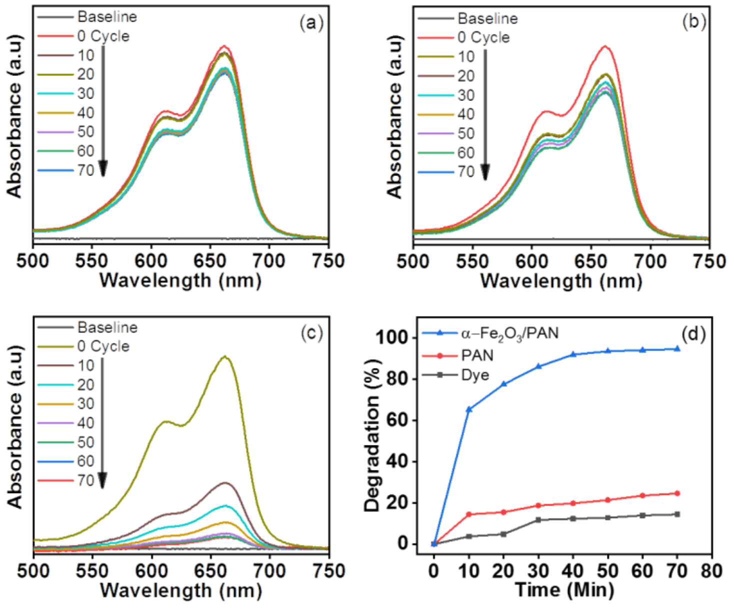

Figure 4. pyrocatalytic performance of (a) without any catalyst (b) with PAN nanofiber (c) with α-Fe_2O_3 /PAN nanofibers (d) degradation percentage

Moreover, the α-Fe_2O_3/PAN nanofiber mat can be easily separated from the solution using a magnet due to the magnetic properties of the α-Fe_2O_3. Furthermore, as shown in figure the reusability test for reactions is done to evaluate the stability of the catalyst. As shown in figure 5, The MB degradation using the α-Fe_2O_3/PAN nanofiber shows excellent degradation without reducing the efficiency even after 5 times use.

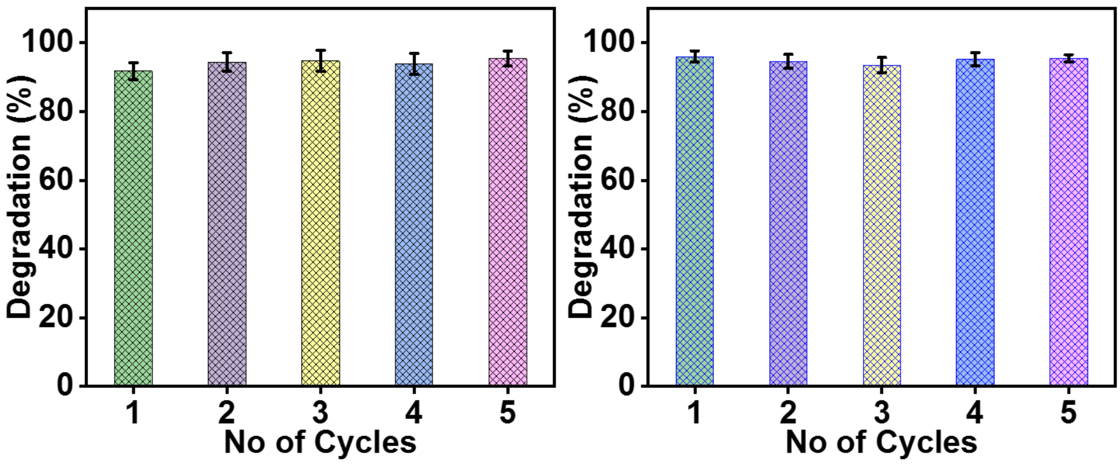

Figure 5. Reusability performance of α-Fe_2O_3/PAN nanofiber mat

Remineralization and calcium release analysis studies

Figure 6 shows the release of calcium with error bar from membrane in three physiological conditions for several days and subsequent amount of calcium was determined using ion chromatography. Further, Figure 6 shows that the calcium release under acidic pH was highest than other two conditions. We have compared the calcium release from pristine $CaCO_3$ crystal under the similar experimental conditions

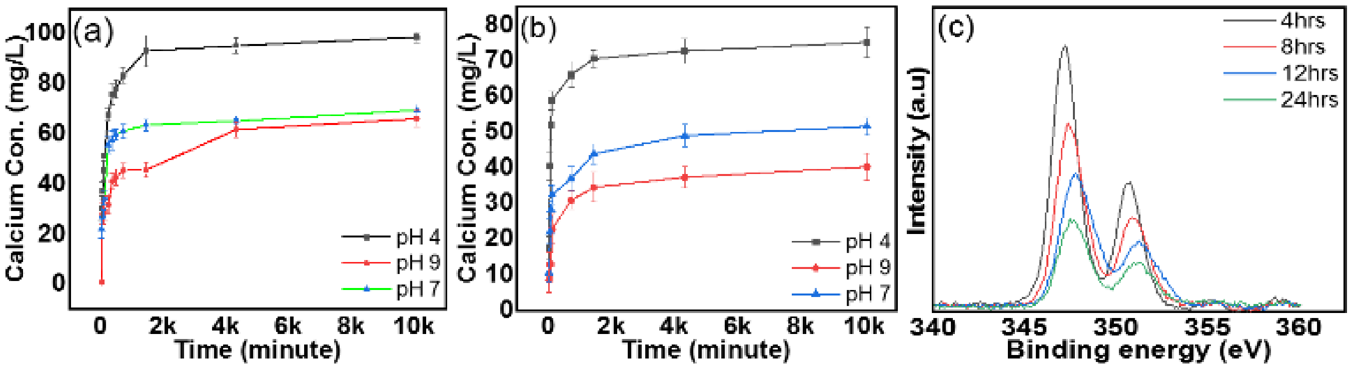

Figure 6. Calcium release experiment from (a) α-Fe_2O_3/PAN/$CaCO_3$/CTA nanofiber membrane and (b) pure $CaCO_3$ crystals at three physiological mediums respectively (c) confirmation of calcium release with XPS

Heavy metals adsorption studies

The maximum adsorption capacity was calculated c.a 333.33 mg/gm for lead after 3 minutes and c.a.200 mg/gm for copper after 90 minutes respectively. The heavy metal ion adsorption studies showed significant removal of Pb^{+2} and Cu^{+2} ions from wastewater utilizing its potential in water remediation as shown in figure 7.

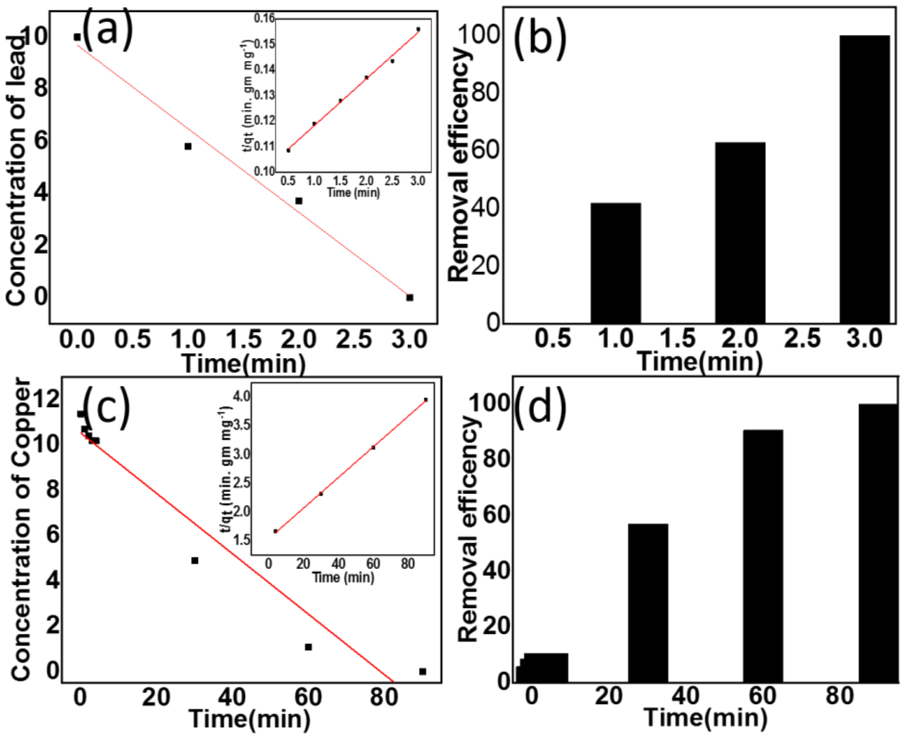

Figure 7. (a) Lead adsorption and pseudo second order kinetic model (inset a), (b) removal efficiency of lead, (c) copper adsorption and pseudo second order kinetic model (inset c) and (d) removal efficiency of copper respectively.

Solar steam generation experiment

The properties of solar steam generation of the three membranes were tested and the results were demonstrated in figure 8. Specifically, the α-Fe2O3/PAN nanofibers membrane nanofiber membrane exhibited an excellent water evaporation rate up to 3.11 kg/m2/h-1, while the evaporation rates were 1.36 kg/m2/h-1, 0.63 kg/m2/h-1, α-Fe2O3/PAN nanofibers membrane PAN nanofiber membrane and pure water.

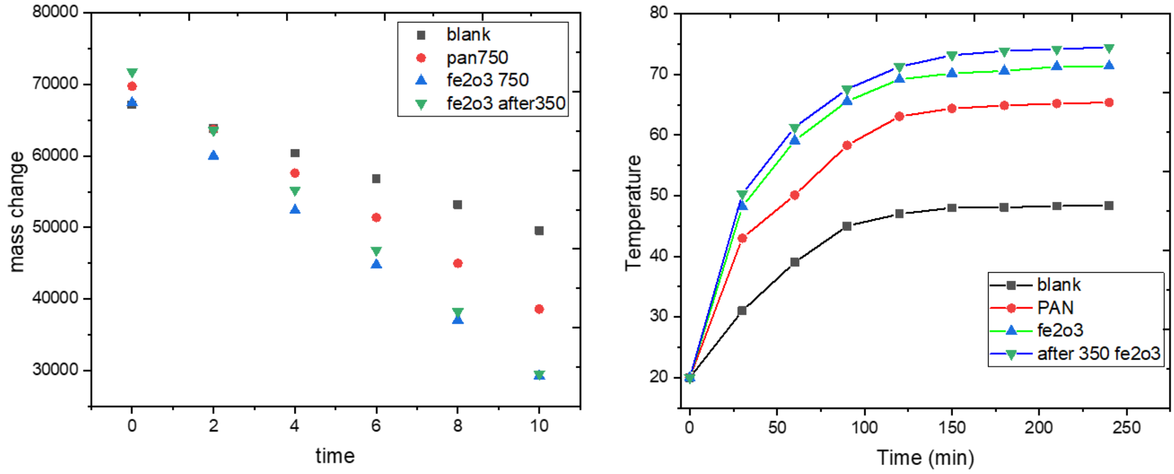

Figure 8. Mass change of water versus solar light irradiation time and temperature change of water versus solar light irradiation time

Key Results (max 1000 words in bullets covering all activities)

- Organic dyes filtration with the efficiency of 95% for higher concentrations of dye.
- Heavy metals adsorption with the maximum adsorption capacity c.a 333.33 mg/gm for lead after 3 minutes and c.a.200 mg/gm for copper after 90 minutes respectively.
- Organic dye degradation using photo, sono and pyro catalysis with the efficiency of 98%, 94%, and 94% respectively.
- Using an α-Fe_2O_3/PAN/$CaCO_3$/CTA nanofiber membrane, a method for sustaining calcium remineralization of water with a concentration of 95 mg/L in 7 days was also produced in a dilute acidic medium.

4.2 Conclusion of the study (maximum 500 words in bullets)

In summary, we have successfully fabricated α-Fe2O3/PAN nanofiber mat with nanostructure morphology and superior surface properties to achieve potential applications in the wastewater remediation. Structural and morphological characterization of α-Fe_2O_3/PAN nanofiber mat was systematically investigated using several cauterization techniques such as FTIR, XRD, XPS, FESEM, TEM, UV-Vis, BET, and TGA. The high surface area of α-Fe_2O_3/PAN nanofiber mat was advantageous in adsorption, separation and photocatalytic applications. The maximum adsorption capacity was calculated c.a 333.33 mg/gm for lead after 3 minutes and c.a.200 mg/gm for copper after 90 minutes respectively. The heavy metal ion adsorption studies showed significant removal of Pb^{+2} and Cu^{+2} ions from wastewater utilizing its potential in water remediation. The synthesized α-Fe_2O_3/PAN nanofiber mat showed high efficiency in adsorption and photocatalytic degradation of methylene blue. The results show that α-Fe_2O_3/PAN nanofibers mat can filter MB with c.a. 95% efficiency at higher concentrations. Additionally, the photocatalytic experiment showed that the calcined α-Fe_2O_3/PAN nanofibers mat can efficiently degrade MB dye c.a. 98% within 240 minutes under visible light illumination. The mass spectroscopy analysis shows two possible degradation pathways the auxochrome group and generation of single ring structures of MB, degradation. In the light of present work, we wish to develop a portable water purification system as a prototype to address the real time challenges of wastewater management.

5 OVERALL ACHIEVEMENTS

5.1 Achievement on Project Objectives [Defining contribution of deliverables in overall Mission (max. 1000 words)]

- The contact angle was measured for all the prepared nanofiber membranes to determine the surface hydrophilicity compared to pristine PAN nanofiber membrane.
- The α-Fe_2O_3/PAN nanofibers membrane exhibited better mechanical strength then the pristine PAN nano fiber membrane[41]
- The MB degradation using the α-Fe_2O_3/PAN nanofiber shows excellent degradation without reducing the efficiency even after 5 times use.
- Organic dyes filtration with the efficiency of 95% for higher concentrations of dye.
- Heavy metals adsorption with the maximum adsorption capacity c.a 333.33 mg/gm for lead after 3 minutes and c.a.200 mg/gm for copper after 90 minutes respectively.
- Organic dye degradation using photo, sono and pyro catalysis with the efficiency of 98%, 94%, and 94% respectively.
- Using an α-Fe2O3/PAN/CaCO3/CTA nanofiber membrane, a method for sustaining calcium remineralization of water with a concentration of 95 mg/L in 7 days was also produced in a dilute acidic medium.

5.2 Establishing New Database/Appending new data over the Baseline Data (max. 1500 words, in bullet points)

5.3 Generating Model Predictions for different variables (if any) (max 1000 words in bullets0

5.4 Technological Intervention (max 1000 words)

5.5 On field Demonstration and Value-addition of Products (max. 1000 words, in bullet points)

5.6 Promoting Entrepreneurship in IHR

5.7 Developing Green Skills in IHR

5.8 Addressing Cross-cutting Issues (max. 500 words, in bullet points)

6 PROJECT'S IMPACTS IN IHR

6.1 Socio-Economic Development (max. 500 words, in bullet points)

6.2 Scientific Management of Natural Resources In IHR (max. 500 words, in bullet points)

6.3 Conservation of Biodiversity in IHR (max. 500 words, in bullet points)

6.4 Protection of Environment (max. 500 words, in bullet points)

6.5 Developing Mountain Infrastructures (max. 500 words, in bullet points)

6.6 Strengthening Networking in IHR (max. 700 words, in bullet points)

7 EXIT STRATEGY AND SUSTAINABILITY

7.1 How effectively the project findings could be utilized for the sustainable development of IHR (max. 1000 words)

1. Under laboratory conditions, the prototype can purify water using a variety of ways, including solar radiation, piezoelectricity, and pyrocatalysis.
2. Heavy metals and organic dyes can be removed from water with 95% effectiveness, and their reusability has been proven.

3. The prototype can also use pyro catalysis to breakdown organic pollutants in waste water.
4. In terms of specific contaminants, the prototype type may also be used as a stand-alone model for various industrial waste water treatment.
5. To deliver nutrients in purified water, the water quality for drinking can be improved in the system.
6. **In lab scale it can serve the purification and remineralisation for 5 lit water.**

7.2 Efficient ways to replicate the outcomes of the project in other parts of IHR (Max 1000 words)

7.3 Identify other important areas not covered under this study needs further attention (max 1000 words)

7.4 Major recommendations for sustaining the outcome of the projects in future (500 words in bullets)

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List of publication

- Published work

1. Water purification and biomineralization using nanofibers-based membrane technology, Manish Kumar, Siddhant Kumar, Samar Agnihotri, Bharat Singh Rajpurohit and Jaspreet Kaur Randhawa, CURRENT SCIENCE JOURNAL, VOL. 120, NO. 5, 10 MARCH 2021,

2. Siddhant Kumar, Manish Kumar, Sumanta Chowdhury, Bharat Singh Rajpurohit, Jaspreet Kaur Randhawa, Environmental concerns and long-term solutions for solar-powered water desalination, Journal of Cleaner Production, Volume 345,2022,131180,

Under submission (delayed due to patent application)

1. Electrospun α-Fe_2O_3/PAN nanofibers mat: A multifunctional wastewater treatment platform, Manish Kumar, and Jaspreet Kaur Randhawa (to be submit).

2. Electrospun α-hematite/polyacrylonitrile/calcium carbonate/cellulose triacetate nanofiber membrane for water remineralization and wastewater remediation, Manish Kumar, and Jaspreet Kaur Randhawa (to be submit).

3. A comprehensive review on nanofibers based polymeric membranes for water remediation, Manish Kumar, Sumanta Chowdhury, and Jaspreet Kaur Randhawa (to be submit).

4. Nanofibers based multifunctional: Ultrahigh solar driven evaporator, Manish Kumar, and Jaspreet Kaur Randhawa (to be submit).

1 Indian Patent. 02111060593 FUNCTIONALIZED NANOFIBER MEMBRANE AND METHOD

OF PREPARATION THEREOF

9 ACKNOWLEDGEMENT

APPENDICES

Appendix 1 – Details of Technical Activities
Appendix 2 – Copies of Publications duly Acknowledging the Grant/ Fund Support of NMHS

Appendix 3 – List of Trainings/ Workshops/ Seminars with details of trained resources and dissemination material and Proceedings

Appendix 4 – List of New Products (utilizing the local produce like NTFPs, wild edibles, bamboo, etc.)

Appendix 5 – Copies of the Manual of Standard Operating Procedures (SOPs) developed

Appendix 6 – Details of Technology Developed/ Patents filled

Appendix 7 – Any other (specify)

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