Template/Pro forma for Submission

NMHS-Himalayan Institutional Project Grant
NMHS-FINAL TECHNICAL REPORT (FTR)
Demand-Driven Action Research and Demonstrations

NMHS Reference No.:	

Date of Submission:								
	d	**d**	**m**	**m**	**y**	**y**	**y**	**y**

PROJECT TITLE (IN CAPITAL)
PINE NEEDLE BASED WASTEWATER TREATMENT SYSTEM FOR RECYCLING OF DOMESTIC WASTE EFFLUENTS

Project Duration: *from* (**10.01.2019**) *to* (**31.03.2023**).

***Submitted to*:**
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National Mission on Himalayan Studies, GBP NIHE HQs
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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, GBP NIHE 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, GBP NIHE 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	Letter of Head of Institution/Department confirming Transfer of Equipment Purchased under the Project to the Institution/Department
Annexure VI	**Details, Declaration and Refund of any Unspent Balance transferred through Real-Time Gross System (RTGS) in favor of NMHS GIA General**

NMHS-Final Technical Report (FTR) *template*

Demand-Driven Action Research Project

DSL: Date of Sanction Letter
DPC: Date of Project Completion

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

				2	**0**	**2**	
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	**Pine Needle based wastewater treatment system for recycling of domestic waste effluents**					
iv.	State under which Project is Sanctioned	**UTTRAKHAND**					
v.	Project Sites (IHR States covered) (Maps to be attached)	UTTRAKHAND					
vi.	Scale of Project Operation	Local	√	Regional		Pan-Himalayan	
vii.	Total Budget/ Outlay of the Project	Appx. Rs.0.45 (in Cr)					
viii.	Lead Agency	G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand					
	Principal Investigator (PI)	Dr. Vasudha Agnihotri					
	Co-Principal Investigator (Co-PI)	Dr. Sumit Rai					
ix.	Project Implementing Partners						
	Key Persons / Point of Contacts with Contact Details, Ph. No, E-mail	Dr. Vasudha Agnihotri vasudha@gbpihed.nic.in					

2. Project Outcomes

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

Background: Water shortage and water pollution have become global issues, scarcity of water resources, mismanagement, population growth, and climate change industrial and domestic wastewaters' constituents contribute to water resource and soil pollution Wastewater treatment and recycling of useful products (i.e., water, nutrients, and organic matter) mitigate water shortages and environmental pollution. To maximize the possibility of recycling and minimize the energy required for treatment, industrial and domestic wastewaters have been separately treated and source separation of domestic wastewaters into grey and black waters has been promoted grey water contribution to domestic wastewater is 60–75% of the water. Numerous studies have been conducted on the treatment of grey water with different technologies which vary in both complexity and performance. In this background studies on the evaluation of the appropriate technologies for grey water reuse/recycling will be essential.

Objectives/ Aim: In the present study, the grey water treatment is being studied for three major aspects (1) To Synthesize the activated and bacterial activated carbon in bulk and their characterization (2) To Standardize combined water purification system having Phytoremediation, bioremediation and fixed bed activated carbon-based process (3) To demonstrate the standardized purification system with model contaminants mixture and actual contaminated water.

Methodology: Various standard methodologies were followed to accomplish the proposed objectives.

Results: In the present study different carbon are prepare using pine carbonization. Nine types of carbon are prepared by using a different impregnating agent with their different ratio, IA concentration, and duration were tested for the preparation of activated carbon. On the basis of methylene blue test, the carbons are selected for absorption experiments. For the preparation of biological activated carbon (BAC) the bacteria isolated from Indian Himalayan region already screened their degradation potential are used for the attachment into the carbon. After the batch and fixed bed experiment the bacteria show the maximum attachment on the bacteria the lowest desorption rate is selected for the batch and fixed bed experiments for the removal of caffeine and BPA. After that the lab scale set is standardized for on the flow rate and bed height to achieve the highest biodegradation and well as absorption. The bed height 7 cm and flow rate 1mL/min was suitable for to achieve best degradation of contaminants. The lab scale set is further tested for the grey water treatment and this set is also best for the treatment of grey water. This set up was further upscaled to pilot set for the treatment of grey water. The upscaled set also shows the promising results for the treatment of grey water. In phytoremediation experiments the two plants Mentha and Lai shows the promising results for the treatment of caffeine, BPA and the grey water.

Conclusion: The study concludes that there are significant differences in quantity and quality of greywater between in-house sources and outside sources and this is largely influenced by lifestyle and water use. This is an indication that there is the need for a critical look at the impact of greywater management in periurban areas in developing countries. Due to the level of contamination coupled with the practice of irrigation with water from open drains as practiced in most developing countries, public health could be at a great risk. The contaminated greywater can also serve as drinking water for

some livestock which stray out of their pens to graze in the open fields and the implications of these cannot be over emphasized.*Recommendations:* A very less comprehensive study on treatment of grey water using pine needle and phytoremediation using mentha and lai. As a result, both treatment methodologies are used for the treatment of grey water. It should also bring to bear the need to start thinking about domestic greywater treatment systems in such areas before the greywater is finally discharged into the environment.

2.2. Objective-wise Major Achievements

S. No.	Objectives	Major achievements (in bullets points)
1.	To Synthesize the activated and bacterial activated carbon in bulk and their characterization	• 27 types of activated carbon samples were prepared following design of studies method and based on their characteristics, only one was selected for adsorption studies.
2.	To Standardize combined water purification system having Phytoremediation, bioremediation and fixed bed activated carbon-based process	• Complete pilot setup is designed and separate component study was done successfully, but standardization of complete pilot setup was not done due location change of PI. The phytoremediation setup has been connected to the final outlet.
3.	To demonstrate the standardized purification system with model contaminants mixture and actual contaminated water	• The complete setup has been installed • A public awareness program on domestic wastewater (grey water) management was held in adjacent villages with different stakeholders. • Pilot unit was demonstrated to school children and other stakeholders

2.3. Outputs in terms of Quantifiable Deliverables*

S. No.	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations made, if any, & Reason thereof:
	01 Waste water treatment pilot plant will be developed for recycling of domestic waste water effluents.	• Development of waste water treatment plant • Establishment of Phytoremediation set up at pilot site	Domestic waster treatment pilot plant developed and installed	The final standardization of the pilot setup was not completed due to the sudden transfer of the project PI, who had designed and developed

	Phytoremediation set up will be also standardized for purification as soil-plant setup at pilot site. Standardization of process for Pine needle generated activated carbon for water purification.	• Demonstration model Developed (Nos.) • Policy framework/ draft (No.) for assisting in scaling up the process for commercialization • No. of Stakeholders benefitted (No. of Rural Youth, No. of Women, and Total No. of Beneficiaries) • Other Publications and Knowledge Products (Nos.)	Phytoremediation setup installed and tested with *Brassica juncea* and *Mentha spicata* Adsorption efficiency of pine needle based activated carbon was checked and tested in fixed bed setup.	the pilot plant and was the subject expert for managing it. Due to the COVID-19 pandemic, the installation of the pilot plant was significantly delayed. The final setup was installed during July-August 2023, and the PI left in November 2023. The current posting location was too far to run this type of setup regularly, especially given the non-availability of research staff as the project was in a no-cost time extension stage.

(*) 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/ Brief Details	Remarks/ Attachment
1.	New Methodology developed		
2.	New Models/ Process/ Strategy developed	1	Photo attached
3.	New Species identified		
4.	New Database established		
5.	New Patent, if any		
	I. Filed (Indian/ International)		

S. No.	Particulars	Number/ Brief Details	Remarks/ Attachment
	II. Granted (Indian/ International)		
	III. Technology Transfer (if any)		
6.	Others (if any)		

3. **Technological Intervention** NA

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		
2.	Diffusion of High-end Technology in the region		
3.	Induction of New Technology in the region		
4.	Publication of Technological / Process Manuals		
	Others (if any)		

4. **New Data Generated over the Baseline Data** NA

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						

2.	On Field Trainings						
3.	Skill Development						
4.	Academic Supports						
	Others (if any)						

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

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: NA

S. No.	Stakeholders	Support Activities	Impacts
1.	Gram Panchayats		
2.	Govt Departments (Agriculture/ Forest)		
3.	Villagers		
4.	SC Community		
5.	ST Community		
6.	Women Group		

	Others (if any)		

8. Financial Summary (Cumulative)

S. No.	Financial Position/Budget Head	Funds Received	Expenditure/ Utilized	% of Total cost
I.	Salaries/Manpower cost	1628273	1646224	>100
II.	Travel	47199	31377	66.48
III.	Expendables &Consumables	906478	720131	79.44
IV.	Contingencies	236279	234508	99.25
V.	Activities & Other Project cost	207719	226140	>100
VI.	Institutional Charges	00	00	00
VII.	Equipment	1470000	1470350	>100
	Total	4495948	4328730	96.28
	Interest earned	95376		
	Grand Total	4591324		

* 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 Equipment	Cost (INR)	Utilisation of the Equipment after project
1.	Fabricated grey water treatment pilot plant with accessories	1470000	-

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

10. Quantification of Overall Project Progress

S. No.	Parameters	Total (Numeric)	Remarks/ Attachments/ Soft copies of documents

1.	IHR States Covered	-	
2.	Project Site/ Field Stations Developed	-	
3.	New Methods/ Modeling Developed	1	
4.	No. of Trainings arranged	-	
5.	No of beneficiaries attended trainings	-	
6.	Scientific Manpower Developed (PhD/M.Sc./JRF/SRF/ RA):	2	
7.	SC stakeholders benefited	-	
8.	ST stakeholders benefited	-	
9.	Women Empowered	-	
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	-	
13.	Technical/ Training Manuals prepared	-	
14.	Processing Units established	1	
15.	No of Species Collected	-	
ll16.	New Species identified	-	
17.	New Database generated (Types):	-	
	Others (if any)	-	

11. Knowledge Products and Publications:

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
1.	Journal Research Articles/ Special Issue:	1			
2.	Book Chapter(s)/ Books:		2		
3.	Technical Reports		-		
4.	Training Manual (Skill Development/ Capacity Building)		-		
5.	Papers presented in Conferences/Seminars		3		
6.	Policy Drafts/Papers		-		
7.	Others:		2		Under review

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

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

Particulars	Recommendations
Utility of the Project Findings	Pine leaf litter can be used for synthesizing the carbon-based materials for purification of domestic wastewater, which will be helpful for getting rid of forest fire issue to some extent and also be helpful for addressing water scarcity issue specially for non-potable purposes
Replicability of Project	Lab level setup is completely standardized, while once standardized as a whole unit at pilot level, the complete set up can be tested in other locations similar to current project, where kitchen waste water of Hostel mess was tapped for purification purposes.
Exit Strategy	More upscaling or refinement will be helpful for managing domestic waste effluents for non-potable purposes

(**PROJECT PROPONENT/ COORDINATOR**)

(Signed and stamped)

(**HEAD OF THE INSTITUTION**)

(Signed and stamped)

Place: ………………..

Date: …../……/……

PART B: PROJECT DETAILED REPORT

1 EXECUTIVE SUMMARY

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

2 INTRODUCTION

2.1 Background of the Project (max. 500 words)

Domestic wastewater is a combination of effluents from residences, commercial buildings, institutions and similar facilities. The non-consumptive portion of water used in an area constitutes most of the domestic wastewater. It is generated from kitchen, bathroom, laundry, lavatories, toilets, garbage grinders, dishwashers, washing machines, and water softeners. As a by-product of life and living processes, its characteristics are strongly associated with the life- style and population of the served area, and the time of the year. The major concerned pollutants of domestic wastewater include suspended solids, organic matter measured as BOD5, COD, or TOC, microorganisms, pathogens, nutrients, coliform bacteria and refractory organics. Emerging pollutants, like bisphenol A (due to plastic items used of personal purposes), caffeine (due to the consumption of tea, coffee and many cosmetics), are easily becoming part of domestic waste effluents, specially greywater. Removal of these compounds from domestic waste effluents are also an important task due to their presence in ng/L level which cannot be removed using basic filtration processes. Their unintentional presence in various compartments of the aquatic environment (e.g. water, sediments and biota), at different concentrations has the ability to cause detrimental effects to the aquatic organisms as well as to the human health which are increasing day by day. This is a major concern due to extensive use of these compounds by humans, resulting in their continuous release to the environment. Due to which, their presence in water are of major concern. Wide range of PPCPs has been detected in a variety of environmental samples at levels ranging from ng kg^{-1} up to g kg^{-1} fresh as well as in waste water. Proper treatment of greywater is necessary before disposing off into the environment.

2.2 Overview of the Major Issues to be Addressed (max. 1000 words)

Scarcity of water is major issue throughout the world. Domestic wastewater makes a major portion of total waste water, which affect the environment in the form of causing water pollution. In most of the cases, it is also not well documented.. type of waste water is a combination of effluents from residences, commercial buildings, institutions and similar facilities. Mainly it is generated from kitchen, bathroom, laundry, lavatories, toilets, garbage grinders, dishwashers, washing machines, and water softeners. As a by-product of life and living processes, its characteristics are strongly associated with the life-style and population of the served area, and the time of the year. So, their treatment at point source level will help a lot. If any system is available, which can recycle this waste effluent at its source, can create a revolution, and if this recycled water can be used in the same place for irrigation or other cleaning purpose then this will become more useful. Pine needle are treated as problem in study area and domestic waste water effluents are the problem worldwide as it is one of major source of addition of contaminants in ground and surface water along with the soil contamination. The present proposal is an attempt to utilize pine needles for preparation of material which can treat the contaminants present in such type of water and give an economic solution for this problem along with use of phytoremediation. Proposed work, on one hand provide another use of pine needle for water purification and also provide an eco-friendly solution of domestic waste water problem through recycling it. This The present project targeted the treatment of model mixture having representative greywater contaminants and GBPNIHE hostel kitchen greywater effluent at lab sale and pilot scale level. Grey water characteristics were monitored continuously for the identification of organic contaminants as the targeted greywater is originated from kitchen. The identified organic contaminants were treated in model mixture using adsorption process.

2.3 Baseline Data and Project Scope (max. 1000 words) **Not applicable**

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

S. No.	Objectives	**Target Deliverables**
1.	To Synthesize the activated and bacterial activated carbon in bulk and their characterization	27 types of activated carbon samples were prepared following design of studies method and based on their characteristics, only one was selected for adsorption studies.
2.	To Standardize combined water purification system having Phytoremediation, bioremediation and fixed bed activated carbon-based process	Complete pilot setup is designed and separate component study was done successfully, but standardization of complete pilot setup was not done due location change of PI. The phytoremediation setup has been connected to the final outlet.
3.	To demonstrate the standardized purification system with model contaminants mixture and actual contaminated water	The complete setup has been installed A public awareness program on domestic wastewater (grey water) management was held in adjacent villages with different stakeholders. Pilot unit was demonstrated to school children and other stakeholders

3 METHODOLOGIES, STARTEGY AND APPROACH

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

Pilot plant designed under the project have different components including sand-silt filtration setup, coagulation chamber, adsorption unit for activated and bacterial activated carbon along with phytoremediation setup. Each component was tested in lab scale setup which was taken as base for the upgradation up to pilot scale. In lab scale, sand-silt filtration unit was designed with the use of different types of sand and silt particles ranging from >5 mm to >20 mm particle size with varying bed heights. Alum was used as coagulants with the dosage varying from 0.5 to 5 g/L. The agitation speed was varying from 150-180 rpm. Coagulation efficiency increased with the increase in dosage. The optimum coagulant dosage was 1 g/L at 180 rpm agitation speed in terms of turbidity removal. At pilot level best turbidity removal was obtained using 1g/L coagulant dosage at 120 rpm speed.

Activated carbon (AC) samples were prepared using pine needle litter. Different chemical impregnating agents were used for structural modification during activated carbon preparation e.g., sulphuric acid, ortho phosphoric acid, zinc chloride etc and the treatment conditions were designed using Taguchi method. The treatment conditions were temperature 300-500°C; duration 1-3 h; impregnating solution 10-20; pine needle powder/IA ration 0.3-0.5. Carbon was prepared in Nabertherm tubular furnace. The AC samples were characterized using iodine number method for surface area (ASTM-D4607-94), Boehm titration for acidic and basic sites, SEM for getting morphological details.

Based on the surface morphologies, few AC samples were selected for adsorption studies. Fixed bed mode experiments were conducted for analysing the efficiency of the selected AC samples against selected pollutants and actual greywater by varying the contaminant concentration, carbon bed depth and feed flow rate variations in lab scale setup.

Adsorption efficiency of the activated carbon and biological activated carbon was estimated using the equation:

$$q_e = \frac{(C_0 - C_t)V}{m}$$

Target contaminant removal was estimated using the equation:

$$\%\,Removal = \frac{C_0 - C_t}{C_0} \times 100$$

Adsorption isotherm study was conducted using Langmuir and Freundlich isotherm.

Freundlich isotherm

Liner form $logqe = logkf + \frac{1}{n}logce$

Nonlinear form $qe = kfCe^1/n$

Langmuir isotherm

Liner form $\frac{Ce}{Qe} = \frac{1}{Klqmax} + \frac{Ce}{q}max$

Nonlinear form $qe = (qmax * Kl * \frac{Ce)}{(1 + Kl * Ce)}$

Different kinetic models have been tested for understanding the order of reaction occurring during water treatment using AC and BAC.

Pseudo First order kinetic equation (Non-linear kinetic method)

$$q_t = q_e[1-\exp(k_f\, t)]$$

where q_t (mg/g) is the amount of adsorbate adsorbed at time t (min), q_e (mg/g) is the adsorption capacity in equilibrium, and k_f (min^{-1}) is the rate constant.

Pseudo Second order kinetic equation (Non-linear kinetic method)

$$q_t = \frac{q_e^2 K_2 t}{q_e K_2 t + 1}$$

where K_2 (g/mg min) is the rate constant of pseudo-second order adsorption

Elovich model

$$q_t = \beta\ ln(\alpha\beta) + \beta\ ln(t)$$

where α (mg/g min) is the initial adsorption rate and β (g/mg) is the desorption constant

Intra-particle diffusion model (Weber–Morris equation)

$$q_t = k_{id} t^{1/2} + C$$

Where kid (mg/g min) is the intra-particle diffusion rate constant and C (mg/g) is constant proportional to the extent of boundary layer thickness

During fixed bed experiments, Length of unused bed was analysed using the equation:

$$\frac{LUB}{L_T} = 1 - \frac{t_b}{t^*}$$

where t_b is breakthrough time, t* is stoichiometric time, L_T is the total bed length and LUB is the length of the unused bed at breakthrough.

Upscaling of the lab-scale unit was done following Gabelman, A. (2017).

Greywater collected from GBPNIHE hostel mess was treated using sand-silt filter and in coagulation chamber. Fixed bed study using activated carbon and Biological activated carbon in pilot level was not performed due to official reasons.

Phytoremediation experiments were conducted through pot experiments with model feed (containing different ratios of plasticizer Bisphenol A and pharmaceutical compounds Ibuprofen) as well as with grey water effluents using the plants *Mentha spicata* and *Brassica juncea*. The bioconcentration factor (BCF), bioaccumulation factor (BAF), and translocation factor (TF) were used to evaluate the ability of the plants to absorb, translocate, and remove compounds, according to the following equations (Zeng et al., 2019; Xiao et al., 2019).

$$BCF = \frac{Concentration\ of\ compound\ in\ root\ and\ shoot}{Concentration\ of\ compound\ in\ soil}$$

$$BAF = \frac{Concentration\ in\ root}{Concentration\ in\ soil}$$

$$TF = \frac{Concentration\ of\ compound\ in\ shoot}{Concentration\ of\ compound\ in\ root}$$

Phytotoxicity was deduced from the effect of contaminants on the growth of the plant. Which is measured using the equation given below

Phytotoxicity (%) = Radicle length of control (cm) − Radicle length of test(cm) radicle length of control (cm)

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

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

Model mixture and real greywater treatment data was collected from sand-silt filtration set up, coagulation step, adsorption step using activated and bacterial activated carbon and finally phytoremediation. Lab scale and pilot scale setup was used for the treatment of model mixture and greywater respectively. The samples were analysed following standard methods using YSI multiparameter analyser, Shimadzu TOC-N analyzer, and UV-Vis spectrophotometer, HPLC-PID etc.

3.4 **Primary Data** Collected (max 500 words)

Quality of greywater coming out from GBPNIHE Almora Hostel Mess was collected and analysed for their phyco-chemical properties mainly for knowing turbidity, pH, electrical conductivity, chemical and biological oxygen demand, total organic carbon, cations and anions etc. The data of treated water was collected and analysed for understanding the lab-scale treatment set up.

3.5 **Details of Field Survey arranged** (max 500 words) NA

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

Activity 1: Synthesis of activated carbon in bulk, their impregnation with microbes and their characterization

Activated carbon was prepared in Muffle and Tubular furnace, but not in bulk due to very late supply of final pilot setup with vertical furnace (full unit was installed only after July 2022). Different types of carbon samples were prepared and characterized for their surface area, acidic and basic nature of the carbon surface, using standard methods. Surface morphology of some of the selected carbon samples was analyzed using SEM.

Activity 2: Phytoremediation capability of selected plants, having capability to grow in sandy-loamy soils, will be analyzed

Brassica juncea and *Mentha spicata* was tested for their phytoremediation capacity with identified organic contaminants in pot experiments and with greywater effluent in pilot attached setup.

Activity 3: Remediation capacity of positively and negatively charged activated carbon will be checked in small and pilot level fixed beds

Activated carbon having different surface charges characterized and one having best iodine value and suitable charges were tested in batch and fixed mode for assessment of AC's adsorption activities.

Activity 4: Remediation capacity of bacterial/biological activated carbon will be checked in small and pilot level fixed beds

Bacteria, tested efficient for degradation of identified organic contaminants, were taken for the preparation of bacterial/biological activated carbon (BAC) using the best performing activated carbon. Hydrogel was also prepared using the prepared BAC. Both the BAC and BAC hydrogels were tested for their adsorption capacity in fixed bed experiments.

Activity 5: All the separately analyzed setup will be tested in pilot scale in combination with model mixture of contaminants as well as with real contaminated water for the development of small-scale pilot setup

All the setup was combined at lab scale and very good efficiency was observed at lab scale setup. Actual task of activity 5 was not repeated due to sudden place change of the PI, who was having the expertise to perform pilot scale experiments. The project was on without cost extension, so the manpower was also not there. So it was not possible to conduct combined experiments. Whole setup was run only once and showed around 67% reduction in Total Organic Carbon content.

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

Activities	**Months**					
	6	**12**	**18**	**24**	**30**	**36**
Recruitment of staff	■					
Preparation of activated carbon and biological activated carbon		■	■	■	■	
Phytoremediation studies for the selection of plants		■	■	■	■	
Optimization of lab scale setup		■	■	■	■	
Installation of pilot plant				■	■	
Pilot studies for the treatment of grey water					■	
Pilot set of phytoremediation studies					■	
Effect of different parameters of the absorption, biodegradation studies		■	■	■		

Creation of awareness among the local inhabitants						
Data compilation, analysis, synthesis and documentation (Publications of manuals, pamphlets, books/booklets, etc.)						
Annual reports						
Final Technical Report						

4 KEY FINDINGS AND RESULTS

4.1 Major Research Findings (max. 1000 words)

- The surface area of activated carbon (C-5), selected for adsorption studies, was comparable to the commercially used activated carbon (Figure 1). SEM of the selected carbon sample also showed good porous structure.

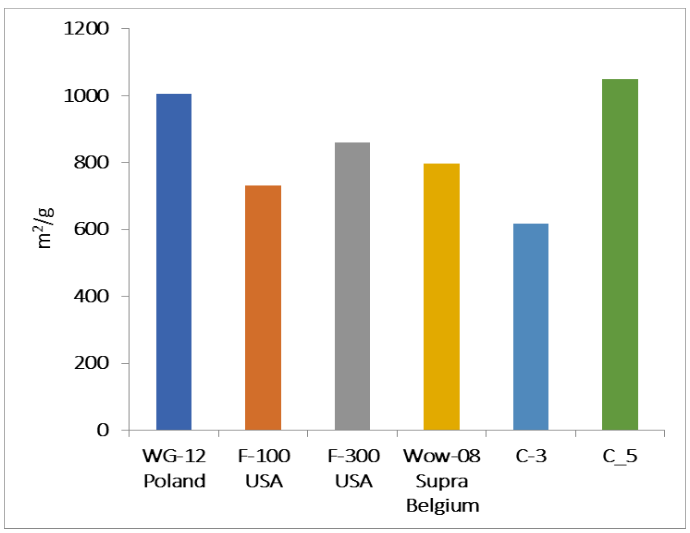

Figure 1. BET Surface Area (Commercial AC Vs. Prepared AC)

Greywater treatment setup was designed at lab scale and then upscaled at pilot level. Lab scale setup is shown in Figure 2.

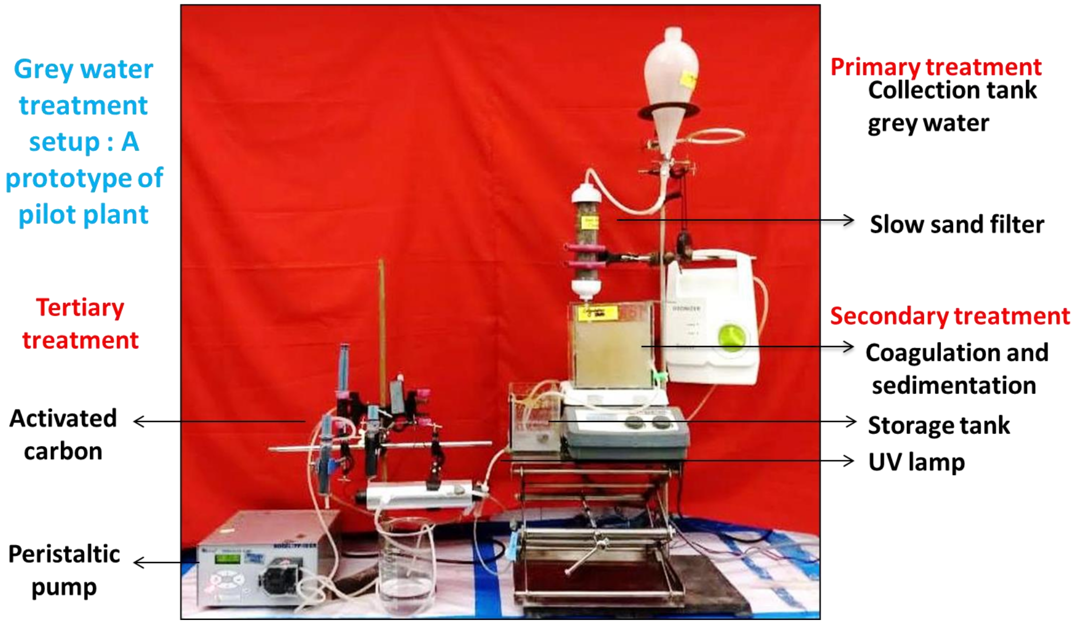

Figure 2. Prototype of pilot plant in lab scale setup

- 100% turbidity removal was observed at 180 rpm with 1 g/L coagulant dosage in lab scale experiments with greywater sample within 20 minutes time.

- The best performing carbon have shown very high breakthrough time even at a very small bed height during fixed bed experiment at lab scale studies. 7 cm bed height was found suitable (Figure 3).

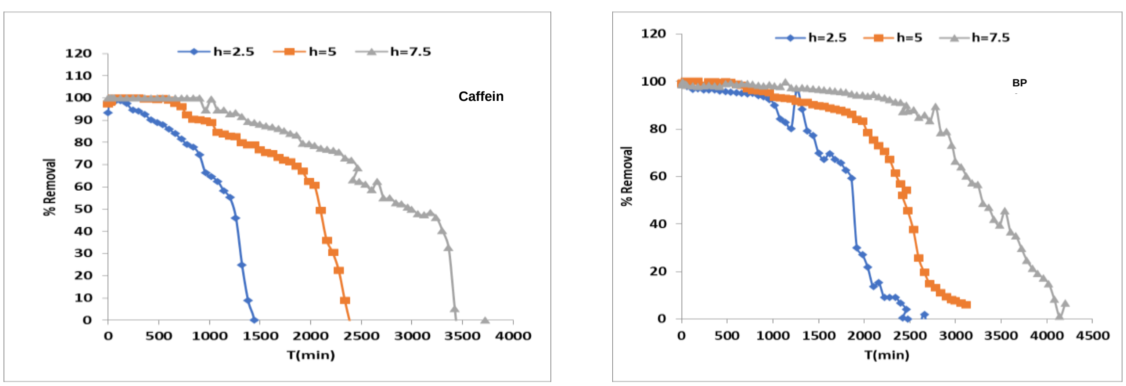

Figure 3. Effect of fixed bed height on adsorption capacity of activated carbon

1 mL/min flow rate was found suitable due to high residence time (Figure 4).

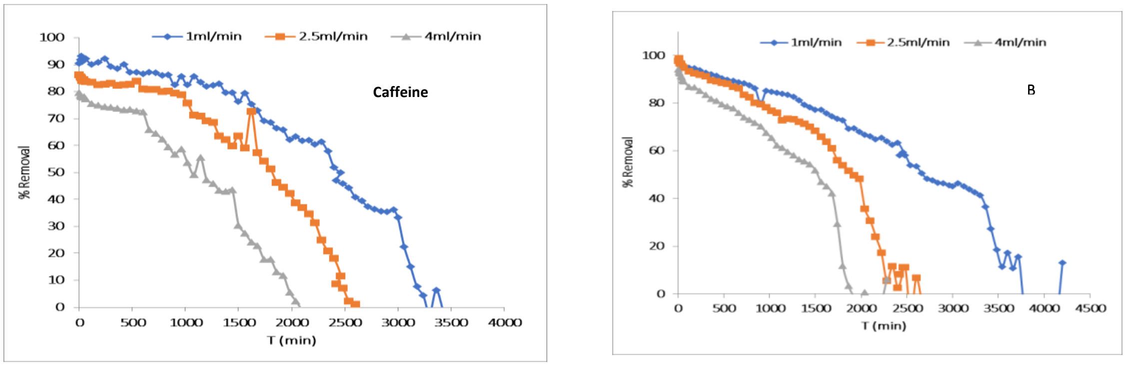

Figure 4. Effect of feed flow rate on adsorption capacity of activated carbon

Breakthrough time as higher with lower contaminant concentration.

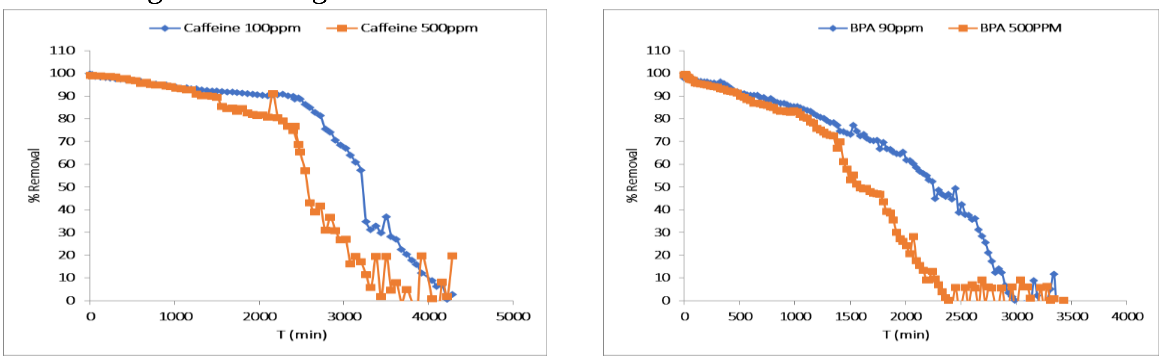

Figure 5. Effect of contaminant concentration on adsorption capacity of activated carbon

- Regeneration capacity of both the activated carbon and bacterial activated carbon is very good at lab scale set up with small bed height with higher concentration of contaminants and low flow rate of model contaminant mixture (Figure 6).

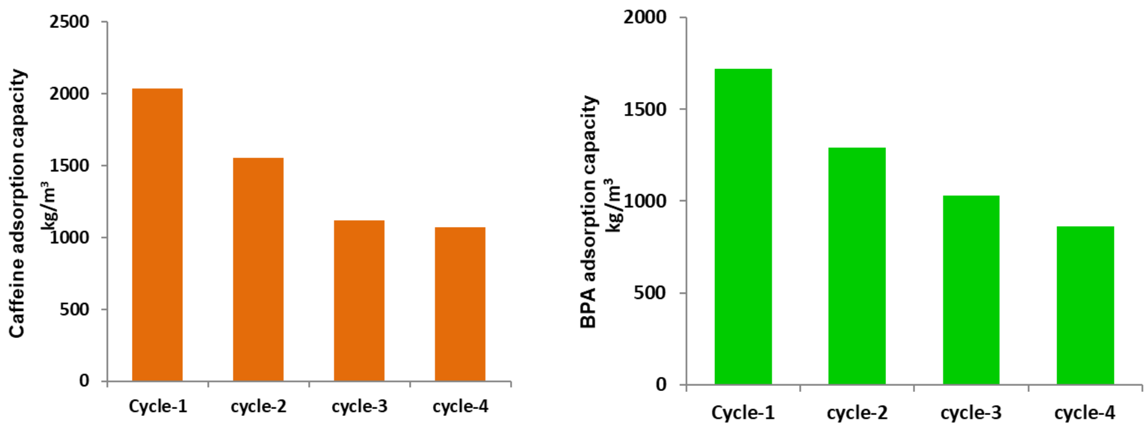

Figure 6. Effect of regeneration cycles on adsorption capacity of activated carbon

- Bacterial activated carbon, prepared by impregnation of bacteria, showing organic compound degradation capacity, on the best performing activated carbon. Fixed bed studies were also conducted using prepared BAC. Good absorption capacity was observed for prepared bacterial activated carbon samples after each regeneration cycles with Effluent concentration having 500 mg/L caffeine, 500 mg/L BPA and 14 mg/L ibuprofen concentration at the experimental conditions pH 7, bed height 5 cm, flow rate 1mL/min, (Figure 7).

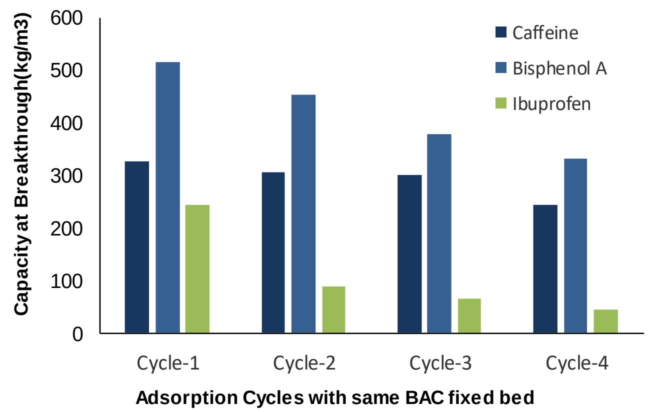

Figure 7 Changes in adsorption capacity of BAC for the mixture of caffeine, BPA and IBU at different adsorption cycles

- Bacterial immobilized carbon hydrogel was also prepared using best performing activated carbon samples and was tested at fixed bed mode under controlled experimental conditions. Good absorption capacity was observed for prepared bacterial activated carbon samples after each regeneration cycles with Effluent concentration having 500 mg/L caffeine, 500 mg/L BPA and 14 mg/L ibuprofen concentration at the experimental conditions pH 7, bed height 5 cm, flow rate 1mL/min, (Figure 8).

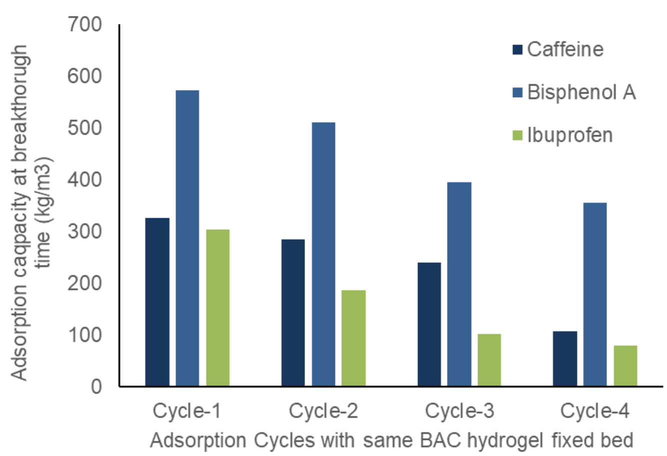

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Figure 8. Changes in adsorption capacity of BAC hydrogel for the mixture of caffeine, BPA and IBU at different adsorption cycles

- During phytoremediation experiments with *Brassica juncea* and *Mentha spicata* plants, changes in morphological features like root and shoot length, plant dry weight, soil and plant enzyme variations were observed along with the changes in the target contaminant concentration. Soil was treated with different contaminant (BPA and IBU) ratios during experiments and measured bioaccumulation factor, bio-concentration factor and translocation factors indicated that the leaves are free from the targeted contaminants, so are safe to use if grown in the area contaminated with target contaminants (Figure 9).

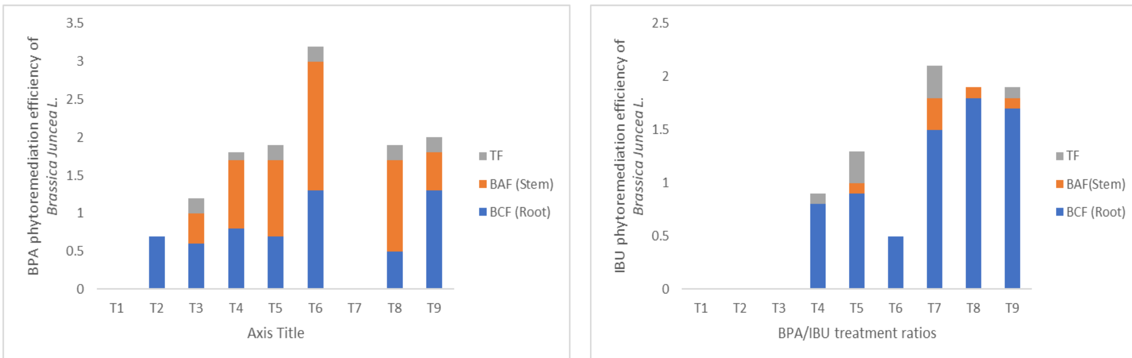

Figure 9. BPA and IBU phytoremediation efficiency using *Brassica Juncea L.*

- While treating real greywater using targeted plants, *Mentha spicata* showed better performance than *Brassica juncea* (Figure 10) while tested in terms of Chemical oxygen demand and nitrate concentration. Chemical Oxygen Demand (COD) was reduced up to 75% for *Mentha spicata* and up to 65% for *Brassica juncea*, while treated greywater in phytoremediation pilot setup.

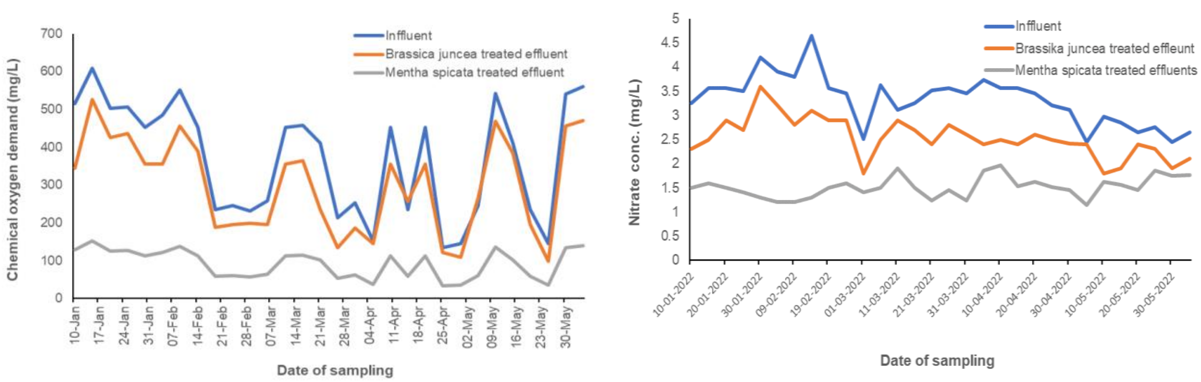

Figure 10. Greywater treatment efficiency using *Brassica juncea* and *Mentha spicata* plants

- Parameters such as nitrogen, and chloride, are within the standards of drinking water as per I.S. Specifications, while conducting lab-cale combined setup.

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

- The selected activated carbon had shown BET surface area equivalent to the commercially available activated carbon samples, used for wastewater treatment.

- The selected carbon sample has shown the presence of phenolic, lactonic and carboxylic groups on its surface which might be helpful for the removal of different contaminants present in contaminated water as well as from model mixture.
- Higher bed height with low flowrate and contaminant concentration was found suitable for efficient removal of selected contaminants while treating with selected carbon sample.
- Adsorption capacity was high for selected activated carbon, biological activated carbon (BAC) and BAC hydrogel.
- Efficient removal of contaminants was obtained after passing the grey water through different pilot plant components individually.

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

Pine needle based activated carbon, BAC and BAC hydrogel samples showed good efficiency for target contaminants along with grey water. In combination with pilot plant components like sand-silt filter, coagulation tank, activated carbon, BAC and in between minor treatments, The setup has shown the capacity to treat organic contaminants as well as greywater (Figure 11).

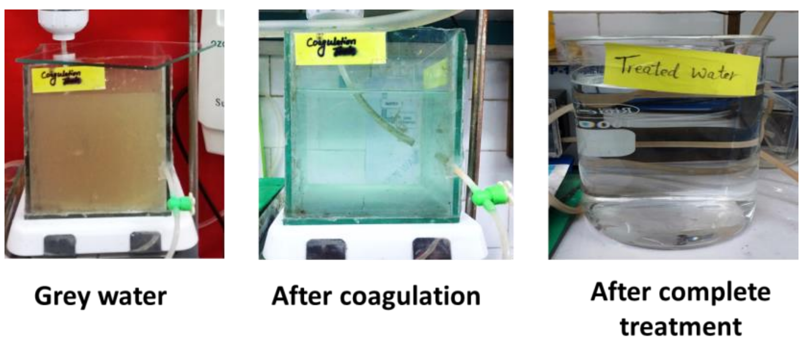

Figure 11. Different turbidity status of grey water before and after treatment

The combined pilot set up standardization and testing would give better picture.

Phytoremediation capacity of commonly used plants for eating purposes i.e., *Brassica juncea* (Lai) and *Mentha spicata* (pudina), were tested and the plants have shown higher accumulation at root, less accumulation in stem and no accumulation in leaves which are generally taken as food for both the plants.

5 OVERALL ACHIEVEMENTS

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

Pine needles are successfully used for the preparation of activated carbon, BAC and BAC hydrogel, which showed good surface area and micropore volume. The surface characteristics like functional groups, surface morphology were also found good for AC and BAC samples selected for adsorption studies. Batch mode, and fixed bed studies have shown high adsorption efficiency of selected carbon samples for targeted organic contaminants. So the AC and BAC samples could be further tested for larger volumes of greywater samples for pilot and onsite usages along with targeted organic and ion contaminants model mixture.

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

5.3 Generating Model Predictions for different variables (if any) (max 1000 words in bullets) **NA**

5.4 Technological Intervention (max 1000 words)

Pilot plant for the treatment of greywater is developed where pine needles have been used for development of activated carbon samples. Biological activated carbon was also developed by he impregnation of bacteria over the activated carbon sample. The selected bacteria showed capacity to degrade organic contaminants in our earlier studies. Both types of carbon samples (AC and BAC) have shown high adsorption capacities for all the targeted compounds (caffeine, bisphenol A and ibuprofen) along with the real grey water originated from GBPNIHE hostel mess. Two edible plants (*Brassica juncea* and *Mentha spicata*) were used for treatment of greywater and the targeted organic contaminants (BPA and IBU combinations) and the plants have shown accumulation of contaminants mainly in roots and no accumulation was observed in leaves. So these plants can be grown in kitchen garden while using partially treated or real grey water (based on the chemical constituents).

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

5.6 Promoting Entrepreneurship in IHR **NA**

5.7 Developing Green Skills in IHR **NA**

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

6 PROJECT'S IMPACTS IN IHR

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

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

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

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

The work would have positive impact on the IHR environment, but its not yet tested as the study was performed mostly at lab scale.

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

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

7 EXIT STRATEGY AND SUSTAINABILITY

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

The project work is related to Sustainable development Goal (SDG) target 6.3, which is related to improving water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally. The present project output would be helpful for treatment of greywater before release in natural water bodies. It would also be helpful for reuse of greywater in close vicinity of common housing areas for non-potable purposes, after being tested in real situations.

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

Integrated pilot setup can be tested at different locations across IHR, with location based modifications like

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

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

The replicas of the standardized pilot setup could be standardized with different combinations of contaminants, there after the same can be upscaled for wider usages in different residential setups like universities hostels and hotels mainly for treatment of greywater effluents. This will be helpful for beneficial utilization of pine needles at large scale. Though carbon based column manufacturing would be required for wider usage of pilot setups.

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9 ACKNOWLEDGEMENT

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during the household data collection and organizing capacity building cum awareness programmes is thankfully acknowledged.

APPENDICES

Appendix 1 – Details of Technical Activities (Described earlier)

Appendix 2 – Copies of Publications duly Acknowledging the Grant/ Fund Support of NMHS

1. Thathola Pooja, Agnihotri Vasudha (2022). Biochemical Parameters and Their Optimization Strategies for Microbial Bioremediation of Wastewater. In: Suyal, D.C., Soni, R. (eds) Bioremediation of Environmental Pollutants. Springer, Cham. https://doi.org/10.1007/978-3-030-86169-8_17.
2. Vasudha agnihotri and Dinesh Chandola (2022). Recent Perspectives of Immobilized Enzyme Reactors Used for Wastewater Treatment. In: Suyal, D.C., Soni, R. (eds) Bioremediation of Environmental Pollutants. Springer, Cham. https://doi.org/10.1007/978-3-030-86169-8.
3. Pooja Thathola, Dinesh Chandola, Vasudha Agnihotri, and Sumit Rai. Phytoremediation: A Potential Tool for Waste Water Recycling (2019). Research Biotica, 1(1): 5-8.
4. Growth, Physiological response and Phytoremediation efficiency of *Brassica Juncea L.* in the soil contaminated by bisphenol A and Ibuprofen (Paper submitted)
5. Phytoremediation potential of (Mentha spicata L.) for micropollutants bis-phenol A and ibuprofen (Paper submitted)

Due to possible patent processing the papers were on hold, now adsorption studies-based papers are under preparation.

Conference presentations

1. Agnihotri Vasudha (2023). Emerging contaminants in water resources of India: distribution and remediation. Presented in fifth international conference on Water: From Pollution to Purification (ICW2023) during Feb.9-12, 2023, organized by School of Environmental Sciences, Mahatma Gandhi University, Kottayam, Kerala, India.
2. Agnihotri Vasudha (2023). Phytoremediation of emerging contaminants bis-phenol A and ibuprofen using Mentha spicata L. Presented in International Conference on Designing A Sustainable Future: Advances and Opportunities In Green during 3-5 July 2023, organized by University of Leh, Ladakh, India

3. Thathola Pooja, Agnihotri vasudha, Pandey Anita (2024). Lab-based setup for the removal of micropollutants using biological activated carbon filters. Presented in International conference on Mountain Ecosystem Processes and sustainable Livelihood during 5-7 March 2024, organized by Himachal Regional Centre of GB Pant National Institute of Himalayan Environment, Mohal, Kullu, Himachal Pradesh.

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

Two villages (Simtola and Gadhwali) were chosen based on past work experiences such as water shortages and other water-related activities for the assessment of greywater generation, recycling, and management. A questionnaire was created, and 150 households were surveyed in all. As a result of the study, it was discovered that an average of 80-100 L of water is used for kitchen and laundry uses. There are also no facilities for recycling grey water generated at home. During the survey, no collecting tank was discovered, and the grey water is being immediately disposed of in the gardens or in the surrounding region.

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

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

Appendix 6 – Details of Technology Developed/ Patents filled

Pilot plant for the treatment of greywater was developed (Photo attached)

Appendix 7 – Any other (specify)

Annexure 6: Pilot scale model contaminants mixture and greywater treatment system

The pilot set for grey water treatment (a) activated carbon-based set up (b) phytoremediation set up


Parts of pilot setup for grey water treatment