Potential and Validation of Sustainable Natural & Advance Technologies for Water &Wastewater Treatment, Monitoring and Safe Water Reuse in India.

Type of action: Research and Innovation action (RIA)

Project duration: 48 months (01.02.2019 – 31.01.2023)

Deliverable D7.4

1st update on the on-going Theses

Version: 2

Work package:	**WP7 – Capacity Building & Organizational Development: EU-INDIA Cooperation**
Responsible partner:	**4-UPC**
Due date of deliverable:	**31.07.2020**
Actual submission date:	**27.07.2020**
Nature of Document:	**Report**

Dissemination Level:		
PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under **grant agreement No 821410**

Document change history

Version	Date	Author	Description
1	09.07.2020	UPC	1st Preliminary version relying on input from NEERI, AMU, SIU, AU, UFZ, UPC and BOKU,
1.1	20.07.2020	TTZ	Revision
2	22.07.2020	UPC	Final Version
2	27.07.2020	TTZ	Final revision and Submission

Table of content

1. Executive Summary

Within Work Package 7, task 7.2 is devoted to the India-EU Exchange Student Program. This task is entirely dedicated to the development of twinned internships, master or doctoral theses in order to contribute to the improvement of the research partnership and the establishment of the foundations for a long-term EU-India collaboration in the water technologies field.

A total of 10 EU and 11 Indian MSc/PhD Students will participate in the exchange program.

The current deliverable D7.4 is the first deliverable of a series of four (D7.5, D7.6 and D7.8) to present updated information on the advances and achievements of various on-going theses within the exchange program.

This deliverable presents a first overview of the on-going theses under the PAVITR project. More details and results will be available once the pilots of the projects will be ready for the experiments. Accordingly, further details will be presented in the following deliverables.

Note that some of the activities of task 7.2 have been impacted by the COVID-19 pandemic. Unfortunately, the exchange of students is currently postponed and the development of some laboratory activities is also delayed.

2. Introduction and objectives

One of the main objectives of the PAVITR project is to strengthen and consolidate the collaboration and partnership between EU and Indian researchers. WP 7 has been conceived to promote the research activity of young researchers within the framework of the project, by means of exchange programs of master and PhD students from both EU and India. These will grant the technology and transfer of knowledge between partners, exchanging the experiences and ideas and leading to improved and innovative solutions.

The objective of deliverable D 7.4, "1st update on the on-going Theses", is to give an overview of the theses that are currently being carried out within the PAVITR framework, including those theses that will start in the near future. Following deliverables D7.5, D7.6 and D7.8 will provide updated information on the development of the different research work.

Note that some of the activities of task 7.2 have been impacted by the COVID-19 pandemic. Students exchanges are not possible at the moment. Likewise, some laboratory activities related to the theses are delayed both in EU and India.

3. Partners involved

A total of 8 Universities and Research centres from EU and India participate in the different exchange programs.

From the Indian side:

- National Environmental Engineering Research Institute (NEERI) (2 students);
- Aligarh Muslim University (AMU) (4 students);
- Indian Institute of Technology Kharagpur (IITK) (1 student);
- Indian Institute of Technology (IIT(ISM)Dhanbad) (1 student);
- Symbiosis International University (SIU) (3 students)

and from the European side:

- Aarhus University (AU), Denmark (3 students);
- Helmholtz-Zentrum für Umweltforschung GmbH (UFZ), Germany (3 students);
- Universitat Politecnica de Catalunya (UPC), Spain (2 students);
- Universität für Bodenkultur Wien (BOKU), Austria (2 students).

4. Ongoing theses

4.1. Ongoing theses at National Environmental Engineering Research Institute (NEERI)

Two PhD theses will be carried out at NEERI institute (Table 1). Both PhD candidates have already been selected and already started their theses.

In both cases, a future exchange with European partners (UPC, IRIDRA or BIOAZUL) is forecast. The destination of the exchange will be defined in the future, and it will be specified in the next Deliverable to be submitted.

Table 1: Theses carried out at NEERI institute.

Name of the student	Type of these	Subject of the these	Progress of the these and expected exchange
Divya Dixit	PhD	Electro chlorination	Under development (lectures period) Future exchange with UPC/IRIDA/Bioazul yet to be defined
Elsa Sony	PhD	Environmental Engineering	Under development (lectures periods) Future exchange with UPC/IRIDA/Bioazul yet to be defined

4.2. Ongoing theses at Aligarh Muslim University (AMU)

As shown in Table 2, 1 PhD and 3 MSc theses will be carried out at AMU University in the field of Environmental Engineering.

All the candidates have already been selected. Two MSc theses are in the final stage and nearly finished (more details about the results will be provided in Deliverable 7.5), and the third one has not started yet.

Table 2: Theses carried out at AMU University.

Name of the student	Type of these	Subject of the these	Progress of the these and expected exchange
M. Shahzeb	MSc	Environmental Engineering	Final thesis ongoing
Shuja Rasooly	MSc	Environmental Engineering	Thesis ongoing
Mohd Wamiq Khan	MSc	Environmental Engineering	Not yet started
Salman Khursheed	PhD	Environmental Engineering	Under development

4.3. Ongoing theses at Indian Institute of Technology Kharagpur (IITK) and Indian Institute of Technology (IIT(ISM))

IITK and IIT(ISM) institutes will supervise one thesis each, but for the moment no information has been provided regarding the status of any of them. More details will be provided in Deliverable 7.5.

4.4. Ongoing theses at Symbiosis International University (SIU)

Three PhD theses will be carried out with the PAVITR framework at SIU (Table 3).

All PhD candidates have already been selected and started their theses. Two candidates are completing the first year and will do an exchange probably at BOKU.

A first draft of the abstracts of the theses can be found in the annex.

Table 3: Theses carried out at SIU University.

Name of the student	Type of these	Subject of the these	Progress of the these and expected exchange
Sapana Shinde	PhD	Drinking water disinfection	Under development
Sagar Kolekar	PhD	Assessment of the techno-financial and Environmental sustainability of constructed wetlands to reduce water pollution and support small scale irrigation	Completed first year of PhD. Exchange yet to be decided, probably with BOKU (Austria)
Vandana Patyal	PhD	Study of material for enhancing the performance of Constructed Wetlands for wastewater treatment	Completed first year of PhD

4.5. Ongoing theses at Aarhus University (AU)

Two PhD theses will be carried out with the PAVITR framework at AU university (Table 4).

Both PhD candidates have already been selected and started their theses in April 2020. Exchange programs with one or more PAVITR partners will be organized during the next years.

Table 4: Theses carried out at AU University.

Name of the student	Type of these	Subject of the these	Progress of the these and expected exchange
Andrés Acosta	PhD	Use of nature-based solutions [NBS] & disinfection systems for	First year (started in April 2020)

		water reclamation and the evaluation of subcritical water treatment [SCW] to assess resource recovery potential.	
Mirko Hänel	PhD	NBS-sanitation and recovery of resources.	First year (started in April 2020)
Marco Antonio rodriguez	PhD	biomass production of plant species used in Constructed Wetlands for wastewater treatment for the recovery of resources	Third year (started in February 2018)

4.6. Ongoing theses at Helmholtz-Zentrum für Umweltforschung GmbH (UFZ)

Three MSc theses will be carried out within the PAVITR framework at UFZ (Table 5).

One candidate has already been selected and she is currently working as research associate. She will start her thesis in October 2020. The other 2 theses are not yet defined.

A first draft of the abstracts of the thesis started can be found in the annex.

Table 5: Theses carried out at UFZ institute.

Name of the student	Type of these	Subject of the these	Progress of the these and expected exchange
Sara Paola Ramos Rodriguez	MSc (Technical University of Dresden, Germany)	Development of GIS-based wastewater management scenarios to identify the lowest-cost solution for a selected region in India (Title not finalized yet)	Currently working as a Research Assistant (April – Sep.'2020) at UFZ, she will start MSc Thesis in October 2020.
To be defined	MSc	To be defined	To be defined
To be defined	MSc	To be defined	To be defined

4.7. Ongoing theses at Univeristat Politècnica de Catalunya (UPC)

Researchers from UPC will supervise 1 PhD and 1 MSc theses (Table 6).

All candidates have already been selected. The PhD thesis started in February 2019 and will participate in an exchange with AMU University as soon as possible. The MSc thesis will start in January 2021, and will also do an exchange at AMU University if possible (depending on COVID-19 pandemic evolution).

A first draft of the abstracts of the thesis started can be found in the annex.

Table 6: Theses carried out at UPC University.

Name of the student	Type of these	Subject of the these	Progress of the these and expected exchange
Antonio Ortiz	PhD	HRAP design and microalgae harvesting. Title "Optimization of microalgae biomass harvesting from wastewater treatment at demonstrative scale"	2nd year. Exchange with AMU as soon as possible (possibly during HRAP construction and start-up)
Joel Serantes	MSc Environmental Engineering	MFC implementation as monitor sensor in CW	2021

4.8. Ongoing theses at Universität Für Bodenkultur Wien (BOKU)

Two MSc theses will be carried out within the PAVITR framework at BOKU University (Table 6).

One of the theses will be finished by December 2020. In this case, the exchange planned for summer 2020 has been cancelled due to COVID-19 pandemic. The other thesis has not yet been defined.

A first draft of the abstracts of the thesis started can be found in the annex.

Table 6: Theses carried out at BOKU University.

Name of the student	Type of these	Subject of the these	Progress of the these and expected exchange
Klaus Ettenauer	MSc	Adaptation of costs functions of water and sanitation technologies for India	To be finalized end of 2020; exchange was planned for summer 2020, cancelled due to COVID-19
To be defined	MSc	To be defined	To be defined

5. Conclusion

The PAVITR project has envisaged the promotion and development of different experiments and research activities by novel researchers from both EU and Indian partners, leading to exchange opportunities between the different research institutes and universities and eventually leading to the production of MSc and PhD theses. These are pointed as one of the main milestones of the project, ensuring both the transfer of knowledge between young and more senior partners and a more interdisciplinary approach to improve and validate the different technologies developed in PAVITR.

The present Deliverable summarizes the current status of the ongoing PhD and MSc theses planned within the PAVITR project. It provides preliminary information about the topics addressed and will be updated in more detail including major results achieved in the frame of the student exchange program in the following Deliverable 7.5 (month 30).

6. Annex

Ongoing theses at Symbiosis International University (SIU)

Name of the student: Sapna R. Shinde

Type of thesis: PhD thesis

Tentative title: Drinking water disinfection using electro-chlorination system

Abstract: The research is based on the monitoring and system optimization for ECL2 pilot which is based on the novel technique of Electro-chlorination for drinking water disinfection. The ECL2 pilot will be installed at the village Lavale situated in district Pune of the state Maharashtra in India. The ECL2 will be installed by both the project partners (SIU and AUTORCON) with the mutual collaboration. The system will be under supervision of SIU and AUTORCON for four years and during this period research scholar would monitor the water quality for chlorine demand, residual chlorine and biological characteristics for raw and treated water. The research scholar would also optimize the system for electrolyte concentration and performing the laboratory studies. The weekly sampling of the raw water and treated drinking water from the village Lavale and then weekly testing of the both water sample parameters is the major task. Variation in the parameters like pH, Electric conductivity, TDS (Total Dissolved Solids), Alkalinity, Chloride content, Chlorine Demand, CFU, Turbidity would be monitored and the data will be analysed to check the efficiency and sensitivity of the system. Testing the concentration of required NaCl electrolyte for production of chlorine stock solution weekly. Optimizing the system for electrolyte concentration by performing the laboratory studies through a lab-scale model for variation in the concentration of NaCl electrolyte.

Name of the student: Sagar Kolekar

Type of thesis: PhD thesis

Tentative title: To assess the techno-financial and environmental sustainability of constructed wetlands to reduce water pollution and support small scale irrigation

Abstract: Water is essential for all life forms, and it has a significant connection with public health and environmental concern. Many regions in India face acute water stress problems. The advancements in agriculture, industry, and urban activities around streams have effected badly on aquatic ecosystems and river downstream ecological conditions. The generation of wastewater due to population increase has become a concern for India. Developing countries have a higher concentration of viruses, protozoan parasites, and helminths in wastewater than developed countries. While treatment methods exist, the reuse of wastewater is less understood in India. Treated wastewater reuse in agriculture is an efficient way of managing water resources. The use of treated wastewaters for crop irrigation may reduce stress on freshwater and also provides benefits of fertilizer due to its nutrient content. It is also an environmentally friendly option, wherein it avoids pollution, and eliminates potential health hazards, as

currently, untreated or partially treated wastewater is being released into surface water bodies, thereby polluting about 80% of the nation's surface water. The environmental and socio-economic advantages of reuse of wastewater can be achieved if treatment technology eliminates the pollutants which are harmful to the environment and public health. The wastewater treatment methods are mainly classified in to artificial and natural. The example of artificial wastewater treatment methods are Anaerobic Membrane Bioreactor (AnMBR), Membrane Distillation (MD) and ozone treatment whereas constructed wetland, french reed bed, and water stabilization pond are the examples of natural wastewater treatment methods. In the current study, artificial and natural methods were compared, cost-benefits evaluated, and reviewed. Results indicate that the maintenance cost is higher in the case of artificial wastewater treatment methods when compared to natural methods. The results of reviewed research papers show that the average total phosphorus and total nitrogen removal rate by natural wastewater treatment method is 46 and 51%, respectively. Artificial wastewater treatment methods reduce 88% of COD, 68% of BOD and eliminate up to 75% suspended solids. In addition, decentralized wastewater treatment technologies like constructed wetlands with preliminary treatments as Anaerobic Baffled Reactor (ABR) can be a cost-effective solution for the removal of micro-pollutants. The continuous treatment and reuse of wastewater will reduce pressure on freshwater resources and groundwater depletion.

Name of the student: Vandala Patyal

Type of thesis: PhD thesis

Tentative title: Study of materials for enhancing the performance of Constructed Wetlands for wastewater treatment

Abstract: Constructed wetlands are being increasingly used worldwide to treat domestic wastewater by applying various technological designs. Substrates are indispensable parts of CWs, and most of the physical, chemical and biological reactions in CW's occur on the substrates. These substrates not only support the growth of wetland but also play a significant role in contaminant removal. A variety of materials could be used as substrates for CWs, including natural materials (e.g., gravel and sand), agricultural/industrial wastes (e.g., oyster shell and fly ash) and artificial materials (e.g., activate carbon and ceramsite) and different other materials possessing different characteristics. Substrate selection is one of the major steps in CWs wastewater treatment, as suitable substrates can effectively remove various pollutants, and avoid clogging thereby improving the operation cycle. The proposed research incorporates the identification of locally available materials for remediation of domestic wastewater via. CW's. These materials chosen via. primary studies would be incorporated in CW lab models for further research on their remediation tendencies, to be further utilised as efficient materials for use in CW's. Research would aim at exploring some natural materials for wastewater remediation and a comparison of the chosen few materials for their wastewater treatment efficiencies.

Ongoing theses at Helmholtz-Zentrum für Umweltforschung GmbH (UFZ)

Name of the student: Sara Paola Ramos

Type of thesis: MSc thesis

Tentative title: Development of GIS-based wastewater management scenarios to identify the lowest-cost solution for a selected region in India (definitive title yet to be defined)

Abstract: One of the challenges of the EU-India cooperation project PAVITR is to develop and/or adapt the most suitable, innovative and affordable solution for wastewater management under local circumstances. The Assessment of Local Lowest-cost Wastewater Solution (ALLOWS) enables the decision makers to develop various scenarios for wastewater management solution and is aimed to be applied on a study area pre-selected by the EU-India project partners which comprises an area of ca. 350 km² in the Indian state of Uttar Pradesh. Numerous villages and towns in India lack wastewater treatment infrastructure to guarantee adequate sanitation conditions, resulting in a high risk of public health. Therefore, it is essential to stablish and analyze potential scenarios to determine the best wastewater treatment system options among centralized or decentralized alternatives. The lack of cartographic information of the study area hinders the analysis needed to determine the best options, thus a methodology based on globally available data is required as an input for ALLOWS. The research objectives of this thesis are: 1) to develop a methodology to obtain relevant geographic and demographic information from satellite images using GIS tools, to present the current local conditions of the study area as realistic as possible and 2) to identify the best cost-effective local solution for 180 towns/villages by analyzing scenarios for decentralized and clustered wastewater treatment systems in the study area.

Ongoing theses at Universitat Politècnica de Catalunya (UPC)

Name of the student: Antonio Ortiz

Type of thesis: PhD thesis

Title: Optimization of the biomass harvesting process from microalgae culture for wastewater treatment at demonstrative scale

Abstract: In the recent years, the interest in microalgae-based wastewater treatment systems has increased, mainly due to the improvement of microalgae culture technologies as high rate algae ponds (HRAP), along with the search for alternative fuels to mitigate climate change. One of the main bottlenecks and challenges is the harvesting process, representing 20 to 30% of biomass production costs. Microalgae harvesting based on coagulation, flocculation and sedimentation is the most satisfactory technique regarding to economic and environmental criteria. Microalgae harvesting is technically challenging due to the small size of the cells and their cell wall with negative surface electric charge, resulting in very low sedimentation rates. Knowledge of correct hydrodynamic behaviour into the settlers at full scale is essential to maintain a laminar flow and maximize the sedimentation process. Furthermore, the correct biomass harvest also depends on the correct hydrodynamic operation in the production phase, usually in HRAP, to avoid stratification and low speed areas where biomass can settle. By means of Computational Fluid Dynamics (CFD) of hydrodynamic behaviour, it is possible to obtain a detailed analysis of the flows and to estimate the behaviour of suspended solids. In this thesis, the harvesting and thickening of microalgal biomass by gravity will be assessed and optimized in a lamella settling unit and two thickeners in a pilot plant at demonstrative-scale. The aim will be to identify the optimal operational strategies and achieve a successful settling and thickening performance. Two HRAPs, 100 m3 each, have been designed using biokinetic and CFD modelling in order to assist, verify and optimize the design of the ponds. Besides, a hydrodynamic behaviour study of the lamella settler, also by means of CFD, will be carried out in order to know the hydraulic behaviour, detect turbulent flow areas and propose improvements in its design.

Ongoing theses at Aarhus University (AU)

Name of the student: Andrés Acosta

Type of thesis: PhD thesis

Title: Use of nature-based solutions [NBS] & disinfection systems for water reclamation and the evaluation of subcritical water treatment [SCW] to assess resource recovery potential.

Abstract: The EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities aims to position the EU as leader in 'Innovating with nature' for more sustainable and resilient societies.

In this context, the European Commission define nature-based solutions to societal challenges "as solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience"(European Commission, 2015). In addition, the goal of Circular Economy (CE) is to remodel the life-cycle of a product/process wherein the net reduction of environmental impacts is achieved at an organizational level while minimizing resource consumption and waste generation (Ubando, Felix and Chen, 2020).

The biomass produced NBS, which treat wastewater is a renewable resource, it has the potential to provide a complete range of renewable, sustainable materials, biofuels and platform chemicals. The biorefinery concept can be employed in NBS to efficiently produce high-value products from different feedstocks such as lignocellulosic biomass (Özdenkçi et al., 2017) and algal biomass (Ubando, Felix and Chen, 2020). Recently, enzymatic technologies have also been developed and integrated with biorefineries to generate advanced biofuels (Singh et al., 2019).

In this project, the utility of NBS combined with disinfection systems to produce reclaimed water in tropical and sub-tropical regions will be studied. In addition, the PhD project aims to evaluate the resource recovery potential of NBS biomass in a bio-refinery approach. It targets to develop a Subcritical Water Treatment process to asset the molecules which can be extracted from NBS Biomass (e.g, *Salix spp., Phragmites australis, Phragmites karka, Sagittaria sagittifolia, Iris pseudacorus, Canna Indica, algae*) and also study the reaction of cellulose present in the biomass and its subsequent transformation into 5-HMF under subcritical water conditions.

Ongoing theses at Aarhus University (AU)

Name of the student: Mirko Hänel

Type of thesis: PhD thesis

Title: NBS-sanitation and recovery of resources.

Abstract: Overall, the aim of this PhD project is to examine and evaluate the potential of wastewater irrigated SRP schemes to support specifically a more circular nutrient cycle in rural areas in India and other developing countries in South-East Asia. Main focus will be on the nutrient removal and fixing potential of individual designed and selected wastewater irrigated SRPs. More specifically, the project will investigate newly developed schemes that potentially can be used for Nitrogen (N), Phosphorus (P), Potassium (K) removal, recovery and reuse. In addition, the project will address the concept of resource recovery in a specific full-scale combined willow, tee tree and bamboo system in India.

India like many other countries in Asia is facing three basic issues in the water sector. Insufficiently treated wastewater discharged into surface water systems or tickled into groundwater puts serious threat on the quality of natural water resources. In addition, the lack of suitable and affordable treatment and disinfection technology of water for use leads to unsafe water with resulting serious health risks, especially for people in rural areas.

When aiming at making the win-win economy-environment developments a reality, the green economy decision makers should thus focus on the implementation of ecological economics approaches such as industrial ecology, circular economy and nature-based solutions of green infrastructure (Loiseau *et al*., 2016). The so-called nature-based solutions (NBS) are offering high potential technologies especially for the application in rural areas. One of the most promising NBS for rural conditions in India and other developing Asian countries are Short-Rotation-Plantations (SRP) approaches. The ongoing deforestation for gaining cheap firewood for cooking and heating purposes deteriorate the environmental situation. Wastewater-irrigated Short Rotation Plantations systems could be the key to improve the situation of water resources and forest ecosystems in Asian countries. SRPs irrigated with pre-treated wastewater offer a cheap, easy to operate, environmental friendly and sustainable way to treat wastewater, recycle nutrients, to protect natural water resources and providing a source of renewable and CO_2-neutral material and energy.

The main target groups for this sustainable water and energy/material management concept include rural communities, municipalities, farmers, industry but also authorities and political decision makers and NGOs.

Ongoing theses at Universität Für Bodenkultur Wien (BOKU)

Name of the student: Klaus Ettenauer

Type of thesis: MSc thesis

Title: Adaptation of costs functions of water and sanitation technologies for India

Abstract: Facing the increasing demand of drinking water on the one hand and the pollution of fresh water sources due to insufficient wastewater treatment on the other hand, a big challenge is drawn. Particularly in countries such as India the situation causes serious concerns and requires urgent action. The PAVITR project is tackling these challenges in validating, developing, and deploying sustainable and cost-efficient solutions for water supply and wastewater treatment. In this project, a Simplified Planning Tool (SPT) developed in a previous project should be adapted to Indian conditions to serve as a preliminary cost analysis tool, supporting decisions in comparing water and sanitation system alternatives. Adaptation to Indian conditions includes comparison with Indian standards, updating costs functions of existing technologies as well as developing costs functions for novel PAVITR technologies. The main steps to adapt the costs functions comprise of the comparison of the design assumptions for each technology to Indian regulations, the assessment of local specific unit costs, which are required to provide the bill of quantities and the incorporation of these results to revise the cost functions. If existing designs are valid under Indian conditions only the local costs items have to be adapted. In case of significantly different design assumptions of the existing technologies compared to Indian standards, new designs and bill of quantities have to be developed. Further, for the development of costs functions for novel technologies, the design assumptions have to be determined, the local unit costs have to be evaluated and the cost functions for the investment-, operation- and maintenance-, and reinvestment-costs, have to be created. The evaluation of the designs and the development of new costs functions are compiled in cooperation with the PAVITR partners. Extending and adapting the STP to Indian regulations and standards gives the opportunity for preliminary cost analysis in a very early stage of project planning. The costs functions developed will be incorporated in the ALLOWS tool developed by UFZ (not part of the MSc thesis).