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

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Deliverable D7.5

2nd update on the on-going Theses

Version: 1.1

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1.0	09.07.2020	UPC	1st Preliminary version relying on input from NEERI, AMU, SIU, AU, UFZ, UPC and BOKU,
1.1	09.07.2020	TTZ	Review before 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 along the 4 years of the project.

The current deliverable D7.5 is the second deliverable of a series of four (D7.4, 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 is an update of the previous deliverable (D7.4) and presents an overview of the on-going theses under the PAVITR project after 2,5 years (30 months). 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 7.5, "2nd update on the on-going Theses", is to update the information 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 (D7.6 and D7.8) will provide updated information on the development of the different research work.

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) (1 student);
- 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) (4 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)

One PhD these is currently carried out at NEERI institute (Table 1). The PhD candidate has been selected and already started her theses. 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: These 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 (female)	PhD	Electro chlorination	Firs year completed (started in January 2020) 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, 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 (male)	MSc	Environmental Engineering	Thesis ongoing
Mohd Wamiq Khan (male)	MSc	Environmental Engineering	Not yet started
Salman Khursheed (male)	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 7.6.

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 (female)	PhD	Development of Lab-Scale Electro-Chlorination System for Sustainable and Decentralized Drinking Water Disinfection	Completed first year of PhD
Sagar Kolekar (male)	PhD	Assessment of the techno- financial and Environmental sustainability of constructed wetlands to reduce water pollution and support small scale irrigation	Completed Second year of PhD. Exchange yet to be decided, probably with BOKU (Austria)
Vandana Patyal (female)	PhD	Study of material for enhancing Phosphorus removal in Constructed Wetlands from domestic wastewater	Second year (started in Sep 2019)
Pranav Sankapal (male)	Junior Research Fellowship PAVITR	Environmental Engineering	Started in Dec 2020

4.5. Ongoing theses at Aarhus University (AU)

Three PhD theses are being carried out within the PAVITR framework at AU University (Table 4).

The three PhD candidates are already started their theses in April 2020 and are have been conducting research. 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 (male)	PhD	Engineered wetland systems & Hydrothermal processing for biomass conversion.	First year (started in April 2020)
Mirko Hänel (male)	PhD	NBS-sanitation and recovery of resources.	First year (started in April 2020)
Marco Antonio Rodriguez (male)	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 carried out her thesis tasks and activities and already defended her thesis on 25th June, 2021. The other candidate is carrying out the tasks (ongoing) and will submit her thesis within August 2021. The 3rd potential candidate and respective thesis tasks are not yet defined.

The abstracts of the first two theses can be found in the annex.

Table 5: Theses carried out at the UFZ institute.

Name of the student	Type of these	Subject of the these	Progress of the these and expected exchange
Sara Paola Ramos Rodriguez (female)	MSc (Technical University of Dresden, Germany)	Identification of an optimal wastewater management system in a rural area in the Atrauli block – India	The thesis was developed between November 2020 and April 2021. Submitted on 7th June and successfully defended on 25th June, 2021.
Sherona Cherian (female)	MSc (Technical University of Dresden, Germany)	Identifying the risks and potential solutions for the improvement of current wastewater management practices in a pre-selected region in India	Ongoing—Started from February 9th, 2021 and will be completed on Aug 4th, 2021 (Submission)
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 be defended by the end of December 2021. An exchange with AMU University was foreseen, but it has been cancelled due to the Pandemic. A MSc student carried out an internship from March to June 2021.

A first draft of the abstracts of the PhD thesis 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 (male)	PhD	HRAP design and microalgae harvesting. Title "Optimization of microalgae biomass harvesting from wastewater treatment at demonstrative scale"	2nd year. Exchange with AMU if possible before end of 2021 (possibly during HRAP construction and start-up)
Ana Alvarez (female)	MSc Environmental Engineering	MFC implementation as monitor sensor in CW	Internship carried out between March and June 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 focussed on the development of cost functions for India. The thesis provided input for Deliverable D6.2 and is planned to be finalised in fall 2021. The topic of the second thesis has not yet been defined yet.

A draft of the abstracts of the thesis 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 (male)	MSc	Adaptation of costs functions of water and sanitation technologies for India	Thesis provided input for finalisation of Deliverable D6.2, finalisation of thesis planned for fall 2021.
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 after 30 months. 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 7.6 (month 40).

6. Annex

6.1. Draft abstract of PhD thesis at Symbiosis International University (SIU)

Name of the student: Sapna R. Shinde

Type of thesis: PhD thesis

Tentative title: Development of Lab-Scale Electro-Chlorination System for Sustainable and Decentralized Drinking Water Disinfection

Abstract: The rural and remote areas in the developing countries predominantly face the scarcity of pathogen free drinking water leading to water borne diseases and deaths due to consumption of contaminated water. Out of the total global population around 2 billion world population uses contaminated water for drinking purposes and the lack of safe and pathogen-free water leads to water-borne diseases like diarrhea, cholera, dysentery, typhoid, and polio, as stated by World Health Organization in 2017. The SDG (Sustainable Development Goal) also indicates the importance of affordable and safe drinking water supply to every region in the world. The drinking water treatment and disinfection facilities are gradually increasing with the increase in awareness about safe and pathogen-free water. But this increased rate of safe water is limited to urban areas to a great extent. Rural areas are still facing diminished facilities of safe and potable drinking water. The problem of drinking contaminated water is more apparent in rural sectors, as these areas are not connected to the centralized water supply scheme. The inaccessibility of treated water is mainly due to the high cost of treatment and its heavy maintenance which is not affordable to low-income families. Additionally, the current drinking water treatment chlorination has several disadvantages of storage, transportation and handling which need to be addressed. Due to all these reasons, installation of decentralized drinking water treatment at rural zones is a need. The present research is based on the development of lab scale Electro-chlorination which would be decentralized and comparison of developed lab-scale system with ECL2 pilot plant that would be installed at the village Lavale, Pune from the perspective of bacterial removal and DBP (Disinfection by Product) formation.

The research progress up till now is as follows, the selection of site for installation of the ECl_2 pilot is done and for the selected site (village Lavale situated in district Pune of the state Maharashtra in India) weekly sampling are done from the water source which is a well receiving water from nearby river. The various parameters that are tested for the raw water from village Lavale are pH, Electric conductivity, TDS (Total Dissolved Solids), Alkalinity, Chloride content, Chlorine Demand, CFU and Turbidity. The data generated from the weekly sampling are provided to AUTARCON, Germany for the design for ECl_2 pilot for final installation. For the electro-chlorination lab model, a thorough literature review is conducted and based on that the electro-chlorination lab -scale model being designed, and experimentations are planned.

In duration of last one year, two research paper have been published and one paper are under review:

Title	Authors	Journal Name	Date	Status
A Systematic Review on Advancements in Drinking Water Disinfection Technologies: A Sustainable Development Perspective	Sapna R Shinde, Sayali Apte	Journal of Environmental Treatment Techniques	21.6.2021	Published
Chlorination as Drinking Water Disinfection Technique and Disinfection by Products: A Scientometric Analysis	Sapna R shinde, Sayali Apte, Kanchan Khare, Philipp Otter	Library Philosophy and Practice	30.6.2021	Published
Identification, Effects and Minimization of Disinfection By Products (DBPs): A review	Sapna R shinde, Sayali Apte, Kanchan Khare, Philipp Otter	Water and Environment Journal	4.6.2021	Under review

6.2. Draft abstract of PhD thesis at Symbiosis International University (SIU)

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 important for life after air but there is a water scarcity problem worldwide. 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. The untreated wastewater pollutes freshwater resources. The reuse of treated wastewater for crop irrigation will reduce stress on freshwater and also provide nutrients. Moreover, it is also an environmentally friendly option, avoids pollution, and eliminates potential health hazards. The appropriate site for the reuse of treated wastewater for agriculture is an important step. The Anaerobic System (AnSys) and Constructed Wetland (CW) is selected as a wastewater treatment method which is a combination of both natural and artificial wastewater treatment methods. The chemical properties of soil for agricultural land have been tested and also probable water requirement was estimated. For the current study, the site was finalized at Lavale village after having investigated at Pratapnagar, Hinjewadi, and Lavale village. The wastewater treatment methods are mainly classified into artificial and natural. To design the wastewater treatment plant, wastewater testing has been done. These tests include parameters such as pH, total suspended solids, total dissolved solids, total solids, total nitrogen, total phosphate, biological oxygen demand, chemical oxygen demand, and conductivity. The results indicate that BOD/COD ratio is more than 0.3 and wastewater is alkaline as pH is more than 7. The average values of orthophosphate, total solids, and conductivity for 3 months (30th June to 6th October 2020) are 6.09 mg/lit, 379 mg/lit, and 1.02 µs/cm respectively. Based on the reviewed literature, the pros and cons of the reuse of treated wastewater for agriculture have been studied. The guava, mango, and banana will be irrigated with treated wastewater. The orchards will take three years for full growth and it may delay the research objectives. To overcome this problem, short rotation crops like Tomato having a crop period of less than 3 months will be grown. It will be irrigated with treated wastewater to assess the techno-financial and environmental sustainability of AnSys + CW. The physical, chemical and biological parameters to be tested for soil, water and tomato fruit have been finalized. The construction of AnSys + CW is delayed due to pandemic. During April to June 2021, tomatoes with regular freshwater are grown as a benchmark experiment and also identified 41 parameters to be tested.

Title	Authors	Journal name	Date	Status
Bibliometric Survey for Reuse of treated wastewater for Agriculture	Sagar Kolekar, Rahul Joshi, Kalyani Kadam, Kanchan Khare & Pennan Chinnasamy	Library Philosophy and Practice	March 2021	Published

6.3. Draft abstract of PhD thesis at Symbiosis International University (SIU)

Name of the student: Vandana Patyal

Type of thesis: PhD thesis

Title: Removal of Phosphorus from Domestic Wastewater in Constructed Wetlands using Low-cost Materials

Abstract: Constructed wetlands (CWs) are being increasingly used worldwide to treat domestic wastewater by applying various technological designs. CWs have low nutrient removal efficiency which leads to a discharge of the effluent with phosphorus (P) limits higher than the permissible limits into water bodies. The presence of excessive nutrients especially P in water bodies is increasing, mainly due to anthropogenic activities, which causes eutrophication, leading to uncontrolled algal growth, inadequate environment for aquatic life and creating anoxic conditions. Substrates are indispensable parts of CWs, and most of the physical, chemical and biological reactions in CWs occur on the substrates.

In the proposed research it is intended to identify novel materials for removal of P from domestic wastewater by adsorption study. This will be done by screening of the waste materials for phosphorus adsorption. The materials will be screened on the basis of physical, chemical characteristics and potential for P removal from synthetic solutions. The selected material/s will be used for batch adsorption studies on synthetic and domestic wastewater. The effect of different parameters such as pH, contact time, and adsorbent dosage on P adsorption will be investigated in batch studies and P adsorption isotherm equations will be studied for the obtained data. The selected material/s will be used in lab scale CW model study to assess their performance for the treatment of domestic wastewater for organics, solids and Total Phosphorus. This study will thus help in identifying cost effective and efficient materials for enhancing the overall performance of CW especially in removal of P.

Literature review of materials for phosphorus adsorption for identification of materials for preliminary studies. Based on the review the following papers have been written for publication:

Title	Authors	Journal Name	Date	Status
Wastewater Treatment Technologies: A Bibliometric Analysis	Vandana Patyal, Dipika Jaspal, Kanchan Khare	Science & Technology Libraries	16-06- 2020	Published
Materials in Constructed Wetlands for wastewater remediation: A review	Vandana Patyal, Dipika Jaspal, Kanchan Khare	Sustainable Materials and Technologies	08-06-2021	Under review
Performance enhancement of Constructed Wetlands for wastewater remediation: A review	Vandana Patyal, Dipika Jaspal, Kanchan Khare	-	-	Modifying for communication

Title	Authors	Journal Name	Date	Status
Chapter: Evaluation of bioremediation by Endosulfan-Degrading bacteria, In: Bioremediation and Phytoremediation Technologies in Sustainable Soil Management, Volume 4: Degradation of Pesticides and Polychlorinated Biphenyls	Vandana Patyal, Dipika Jaspal, Kanchan Khare	AAP CRC Press (Taylor & Francis Group)	09-06-2021	Production phase
Chapter: Constructed Wetlands in Dye Removal: focusing on operational parameters, In: Current Biological approaches in Dye Wastewater Treatment	Vandana Patyal, Dipika Jaspal, Kanchan Khare	Springer edition	20-06-2021	Submitted

6.4. Draft abstract of Junior Research Fellowship thesis at Symbiosis International University (SIU)

Name of the student: Pranav Sankapal

Title of Research Work: Reuse of wastewater for tomato crop: A review

Abstract: The availability of water is decreasing particularly where the limited natural water resources are heavily exploited. The agriculture sector itself needs 70% of the water from freshwater resources. A large amount of freshwater is getting polluted as wastewater is being disposed of to freshwater resources without any treatment. The use of treated wastewater for agriculture provides nutrients to the crop and reduces stress on freshwater. It reduces fertilizer application rate so it gives economic benefit to growers. It also has disadvantages, which include reduction of plant vegetative growth, damage to soil structure, an increase of heavy metals, and soil salinity. Any crop can be grown with treated wastewater but this paper focuses on the study of the reuse of wastewater for tomato crop. Tomato is a sensitive crop and requires more water throughout its crop period. The paper also discusses the impact of (domestic) municipal wastewater, agro-industrial wastewater, and industrial wastewater on soil characteristics, crop yield, and fruit quality for the tomato crop. The main objective of this paper is to provide a review of the impacts of treated wastewater on soil properties and tomato based on various parameters and also compare irrigation with treated wastewater and regular water.

This review also helps to decide physical, chemical, and biological parameters to be tested for soil and fruit while researching the reuse of treated wastewater for agriculture. The soil parameters are soil fertility, porosity, and permeability, while crop yield, fruit quality, firmness, size of fruits & leaves, and presence of microbial contamination in fruit are crop parameters. From the review, it can be concluded that by using treated wastewater as an irrigation source for tomatoes, soil fertility was increased but porosity and permeability of soil were decreased. The fertilizer requirement is also less when compared to normal methods, which reduces the cost of tomatoes and increases net profit among farmers. In the case of treated wastewater, the crop yield improved by 1.21 to1.59 times, and the firmness of fruit decreased by 8.1% but there was no significant impact on fruit quality. There was no change observed in the size of fruits but microbial contamination increased in many cases. Overall, the wastewater should be treated and then can be reused for the tomato crop. This review also concludes that a tertiary disinfection unit can be added to avoid microbial contamination in fruit.

Title	Authors	Journal name	Status
Reuse of wastewater for tomato crop: A review	Pranav Sankapal, Sagar Kolekar, Kanchan Khare, Pennan Chinnasamy	AGWT	Modification Phase

6.5. Draft abstract of PhD thesis at Aarhus University (AU)

Name of the student: Andrés Acosta

Type of thesis: PhD thesis

Title: Hydrothermal Processing for Biomass Conversion from Wetland Engineered Wastewater Treatment Systems [Willow-*Salix viminalis*]..

Abstract:

Introduction and study objectives

Evaporative willows-based systems are increasingly being used in wetland-engineered systems to treat nutrient-rich wastewater due to their natural capacity to translocate minerals and metals contained in the wastewater. Studies have confirmed that the nutrients supplied by the influent wastewater are effectively translocated and are accreted in the willows as biomass (i.e., the composition of the wastewater corresponds to the willows' nutrient requirements). Willow systems are mostly designed to treat all the influent water through evapotranspiration, so there is no outflow from the system. Additionally, there are also willow systems that combine percolation with evapotranspiration or that are designed as flow-through systems that produce some outflow, which is used for the recovery of resources, such as nutrients and reclaimed water for irrigation.

This application allows addressing environmental concerns related to wastewater management and, at the same time, achieving higher biomass yields. However, the end-use of this lignocellulosic biomass is often simple incineration for the production of heat and power. In contrast, producing platform chemicals from lignocellulosic biomass using hydrothermal processes has grown into a central point of interest due to the limited availability fossil resources coupled to reduce the carbon footprint of such products. Platform chemicals have a key role in a bioeconomy, which aims to replace fossil carbon sources with biomass. For instance, Furfurals are special bio-based platform chemicals because they have a wide range of application and can be produced exclusively by thermochemical conversion routes. The most important members of furfurals are 5-Hydroxymethylfurfural (HMF) and furfural. Furfural is derived from pentoses (which can be obtained from hemicelluloses). Recent studies confirmed that the HMF formation comes mainly from the dehydration of C6-sugars (hexoses and their polymers, which also includes cellulose) in the furanose form.

Therefore, as an alternative to the simple incineration of the willow-system biomass, the present on-going project aims to study the biomass, grown on wastewater irrigated willow fields (Salix viminalis), as the feedstock of a hydrothermal process to study the yields of platform chemicals and the production of HTC-Hydrochar (i.e., low-temperature hydrothermal carbonization).

Methodology

This project has two objectives, the first aims to gain a better understanding of the yields and factors affecting the generation of platform chemicals (i.e., 5-hydroxymethylfurfural, furfural, acetic acid, formic acid and levulinic acid) under subcritical water conditions (SCW; below the water critical point 374 °C and 25 MPa). Secondly, the project aims to study the effects of low-

temperature hydrothermal carbonization (HTC). Our experimental design focuses on the willow-biomass-derived HTC-carbon material. Hydrochar is our desired product in the HTC process with an estimated mass yield of about 40–70%. Hydrochar, resulting from the carbonization of willows might have the potential to be used as an adsorbent in environmental remediation applications, a novel carbon material, a storable solid fuel for energy generation (via co-combustion or use in carbon fuel cells), and possibly as a soil amendment. The concept of biochar (terminology commonly used to denote char application in soils) as an approach to carbon sequestration, as well as increasing soil fertility, raising agricultural productivity, and reducing pressure on forests, has received increasing attention over the past few years.

The experimental design will firstly determine the composition of cellulose, hemicellulose, and lignin content in the willow-biomass (extractives of hexoses, pentoses, and lignin - NREL/TP-510-42618). The project will use Swagelok-batch reactors to react water with the biomass (Salix viminalis). The reaction without catalyst (170 °C to 275 °C and 0 to 30 min reaction time) will take place in an OMEGA FSB-3 fluidised sand bath via a steel chain linked to the reactor with a carabiner. A thermocouple inside the reactor will monitor the temperature inside the reactor. LC-MS/MS will be used for the analytics. In the solid fraction Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) will be used to measure nutrients and heavy metals like Pb, Cd, Cr, Cu, Zn, As, Ni, Ag. Analysis of the high calorific values of the Hydrochar will also be performed.

Results and conclusions

The end-use of the lignocellulosic biomass produced in willow systems is often simple incineration for the production of heat and power. To diversify the uses and to identify potential and limitations with innovative developments in hydrothermal processing, fundamental research to study the reactions of willow (Salix viminalis), under subcritical conditions is necessary for determining comparative data among different lignocellulosic biomasses and treatment conditions.

6.6. Draft abstract of PhD thesis at Aarhus University (AU)

Name of the student: Mirko Hänel

Type of thesis: PhD thesis

Title: Short rotation plantations SRP) -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.

6.7. Draft abstract of PhD thesis at Aarhus University (AU)

Name of the student: Marco Antonio Rodriguez

Type of thesis: PhD thesis

Title Biomass production from plant species used in Constructed Wetlands for wastewater treatment

Abstract: Treatment wetlands (TW) technology is a nature-based solution (NBS), where natural processes are emulated and optimized through engineered designs to improve water quality, and if possible, recover resources.

Regarding sustainability, TWs are considered one of the most sustainable technologies for wastewater treatment. stated that TWs are often considered a more sustainable solution to treat many types of wastewaters, if compared to other conventional treatment technologies. TW 'sustainability' is substantiated by the fact that TW can successfully improve water quality, but can also provide a multitude of other functions, such as sustaining biodiversity, mitigation of climate change, carbon sequestration, hydrological flow regime regulation, public use, education, habitat conservation and creation among others.

Up to now, TW sustainability have been evaluated, focused in terms of their capacity to improve water quality of different concentrations and origins. TW have shown to be effective for pollution control in the domestic wastewater, urban runoff, slaughterhouses industrial and urban sewage

Circular economy is a concept where economy is envisaged as having no net effect on the environment; rather it restores any damage done by the exploitation of the resource, while ensuring that little waste is generated throughout the production processes and during the life extent of the product. TWs, transformation processes involve input of wastewater, local climate and energy, into an engineered ecosystem formed by plants, and bacteria, and depending on the type of TW, filling media to produce water to meet the local discharge standards, gases and biomass.

According to Wu, TWs emit less greenhouse gases (lower CO_2, CH_4 and N_2O) than other wastewater treatment technologies. However, the produced gases are diffuse and mainly escape to the atmosphere without any use. The treated wastewater instead, has been extensively used for productive applications, and depending on the quality obtained; different authors have reported the reclamation for irrigation), cooling and industrial proposes, groundwater recharge. Lastly, the role of the plants have extensively discussed in the treatment process in TW, but very seldom the potential reuse of the produced biomass have been evaluated except for the use for ornamental flower production, compost or the use for handcraft production.

However, the produced biomass by the plants in TW seems to be suitable for further applications. TWs use grasses as a primary element of their system. The most common plant species used in free water surface constructed wetlands around the world were *Typha spp. Scirpus (Schoenoplectus) spp, P. australis, Juncus spp, and Eleocharis spp*. The primary productivity of the most commonly used plants in TWs, is high; Scholz and Lee (2005), reported fairly high yields of estimated dry mass production. For Phragmites australis (common

reed) of 1,000–6,000 g/m2, in the Czech Republic; 2,040–2,210 g/m2 for *Typha latifolia L*. (cattail), in Oregon, USA; and 943 g/m2 for *Scirpus fluviatilis* (river bulrush), in Iowa, USA. In addition, it has been reported by different authors that the pollutant removal rate increases when the TW biomass is harvested.

On the other hand, green bio-refining, is a complex and full-integrated system of environment and resource-protecting technologies for comprehensive material and energetic use of green biomasses, represents an opportunity to recover from TW biomass, neglected resources, inherent to the systems, and that with existing technology can be readily introduced to the economy and can redound in lower stress in the environment.

Protein demand and production represent one of the current environmental challenges directly related with global warming and greenhouse gases production. The use of grasses for protein production, , have shown to be a sustainable solution for the substitution of traditional protein sources. It has been estimated, that Denmark could substitute 20% of the soy imports from Brazil, with protein extracted from locally produced clover, using green bio-refining processes, reducing the dependence on non-renewable resources, and significantly decrease GHG emissions from fossil fuel. In average, 33 of each 100 grams of protein that humans consume, comes from livestock. To produce 1 gram of livestock-protein, demands an animal average ingest of 8.4 grams of vegetal protein. This has a significant impact on the environment, mainly because the land demand for crop, ecosystem depredation, water consumption, and GHG emissions. Globally, livestock represents about 66% of total agricultural GHG emissions in the world.

Non-wood fibres, such as TW biomass, grasses, agricultural residues and annual plants, can be considered, as valid alternative sources of cellulose production for pulp and paper manufacturing , due to yielding ability, high pulping quality, good adaptation to prevailing climatic conditions and low-cost). The cellulose pulp and paper demand in the world has continued to grow globally, but the pulping industry has lagged behind and less environmental aggressive new pulping techniques have been developed. Even during the COVID-19 crisis, the global annual paper demand and cardboard production capacity increased, due the high demand of packing needs for food, personal hygiene elements, and medicinal supplies in the depletion of wood resources, to comply with the use of low-cost raw materials as an alternative resource for pulp and paper production.

Lignocellulosic materials can also be used for biofuel production. Substrates such as agricultural crops, forest residues, grasses, TW biomass and energy crops seem to be promising sources for second-generation biofuels. This second-generation renewable biofuels, include ethanol from non-eatable crop, and more sustainable since they can be used in existing engines, generate up to 85% less greenhouse gasses emissions.

The present study assess the potential and the limitations of selected TW biomass and compare them to plants growing naturally as a source for green bio-refining processes. The study evaluates the content of protein, lining, cellulose, and structural carbohydrates in the selected plants, and compare contents and yields among the plants. Finally, since the plants are exposed to pollution, and accumulation and/or translocation to the plants could become a limiting factor for the use of the recovered resources. Therefore, heavy metal concentrations in the plants are evaluated. or the recovery of high value resources

6.8. Draft abstract of MSc thesis at Helmholtz-Zentrum für Umweltforschung GmbH (UFZ)

Name of the student: Sara Paola Ramos Rodríguez

Type of thesis: MSc thesis

Thesis title: Identification of an optimal wastewater management system in a rural area in the Atrauli block – India

Abstract: For decades there has been an ongoing discussion about which wastewater management system is better: centralised or decentralised. Decision-makers have the responsibility to define the best option but do not always have the necessary tools to do so. In addition, multinational funding organisations allocate financial resources mostly to centralised wastewater management systems, and there are no effective tools to evaluate investments in different alternatives such as decentralised or clustered systems. To address this issue, previous studies have been done in small areas such as sections of urban or rapidly urbanising areas. However, in this study, an existing decision-making tool (ALLOWS - Assessment of Local Lowest-cost Wastewater Solution) is adapted and complemented for its application in rural areas and on a regional scale. An area in the district of Aligarh (India) is used as an example, but the tool can be used globally. The novelty of this study's methodology lies in finding systematically the optimal degree of centralisation in a given settlement, reached when the costs associated with the sewerage network do not exceed the savings achieved by increasing the capacity of a wastewater treatment plant. Finding this level is essential to obtain the most cost-effective alternative and to find solutions when diverse social and/or environmental factors reveal that a fully centralised or decentralised option is not the best. Hence, this study provides insight into the extent to which level of centralisation is feasible and what this scenario would look like in terms of sizing, layout, and costs.

6.9. Draft abstract of MSc thesis at Helmholtz-Zentrum für Umweltforschung GmbH (UFZ)

Name of the student: Sherona Cherian

Type of thesis: MSc thesis

Thesis title: Identifying the risks and potential solutions for the improvement of current waste water management practices in a pre-selected region in India

Abstract: Untreated sewage is the primary source of water pollution in India, which is causing multiple issues like, water-borne diseases, agricultural contamination, and environmental pollution. The inhabitants in the urban, semi-urban and rural areas often live alongside open drains and sewage canals, which are overflowing during the rainy season or monsoon time and leading to severe public health and environmental issues. This is mainly due to lack of proper wastewater management systems and poor socio-economic conditions. Therefore, the strategy and policy guidelines to increase water supply and the development of wastewater treatment systems must be urgently planned and promoted. First of all, to be aware of the policy making, it is essential to identify the risk criteria that people suffer based on improper sanitation, which affect the environment, public health and the economy directly or indirectly. After risk identification, it is important to prioritize the towns to find out which town is at greatest risk due to such pollution. Multi-criteria Decision analysis has been used in this thesis to identify the risk and priority towns in risk and priority maps that are presented by ArcGIS. Proper management of wastewater and adequate sewer lines has a direct impact on reducing the risks of the environment, economy and public health that can be resulted to the improvement of the overall socio-economic welfare of any region or area. For sustainable wastewater management, local and intermediate solutions are therefore essential. Practices like treated wastewater reuse would be of great importance to water and public health safety. Hence this study also deals with some alternative solutions and thereby associated costs for the improvement of existing wastewater management practices within the selected region in India.

6.10. Draft abstract of PhD thesis 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.

Title	Authors	Journal name	Status
Advanced biokinetic and hydrodynamic modelling to support and optimize the design of full scale high rate algal ponds	Ortiz, A., García, J., Uggetti, E., Khalil, N., Díez-Montero, R.	Computational and Structural Biotechnology Journal	Submitted

6.11. Draft abstract of MSc thesis 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).