The Pan-American Treatment Wetland Network, HUPANAM: A Brief Sketch of the Treatment Wetland Research Groups in the Latin-American and Caribbean Region

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INTRODUCTION

Treatment wetlands (TW) technology is a nature-based solution where natural processes occurring in natural wetlands are emulated and optimized through engineered designs to improve water quality (Rodriguez-Dominguez et al. 2020). The technology is also known as constructed wetlands, phytoremediation systems, reed beds, soil infiltration beds, engineered wetlands root systems, biofilters, among others (Carvalho et al. 2017). The technology has been used around the world successfully for more than 60 years, treating polluted waters from different origins and across the world (Langergraber et al. 2019).

TW have proved to be effective for treating rain-water run-off (Malaviya and Singh 2012; Istenič et al. 2011, 2012), and wastewater from domestic (Konnerup et al. 2009; Vymazal 2011; Wallace 2006; Brix and Arias 2005), slaughterhouses (Gutiérrez-Sarabia et al. 2004; Soroko 2007), industrial (Vymazal 2014; Hadad et al. 2010; Maine et al. 2019) and urban sources (Pozo-Morales et al. 2017; Stefanakis 2019). TW have mostly been used for domestic wastewater treatment (DWWT) due its relative low operative and maintenance cost (Starkl et al. 2010; Uggetti et al. 2012; Mannino et al. 2008). Additionally, TW have shown ancillary benefits such as sustaining biodiversity, climate change mitigation, CO2 sequestration, flooding attenuation, enhancing public spaces, and contributing to the habitat conservation (Sanchez Celis et al. 2018).

According to (Kadlec and Wallace 2008), natural wetlands have been used as wastewater discharge sites for at least 100 years, however, the history of TW is shorter, as it started in 1952 when the Max Planck Institute in West Germany published the results of the experiments regarding the use of TW for wastewater treatment. Thenceforth the technology has spread around the globe, being used on all the continents, including experiments in Egypt, Morocco, Tanzania, Kenya, India, Vietnam, Taiwan, Nepal, Brazil, Colombia, Chile, Argentina, Nicaragua, Guatemala, Ecuador and Mexico (Naja and Volesky 2019).

TW technology has also evolved. In 1952 the systems were characterized for not having filling media - today named Free Surface Systems (Kadlec and Wallace 2008). They evolved to the Subsurface Flow Systems, which use filling media like sand, gravel or coke to enhance treatment by increasing biofilm growth and therefore reducing the facility's footprint. During the last decades, to enhance TW systems, intensification, such as the use of external energy sources, the input of air, or the use of advanced filling media, has allowed TWs to reach higher pollutant removal rates or to eliminate specific compounds from polluted waters (Fonder and Headley 2013).

In the Latin-America and Caribbean (LAC) region, while TWs have been studied during the last two decades, only since 2010 have TW researchers, decision makers and practitioners of the region started to meet. The aim was to meet every two years in different participant countries to share and promote TW technology, to disseminate local results and to update the state of the art. These meetings led to the creation of the Pan-American Conference of Wetland Systems for Wastewater Treatment (CONFPANAM), now in its 5th edition. As the conferences thrived and the number of participants increased, a formal Pan-American Treatment Wetland Network (HUPANAM) was created and now includes members of most of the Pan-American countries. This article aims to briefly describe the evolution of the TW research in the region and provide updated information on the most active TW research groups in the region and the results of their work.

HISTORY OF THE PAN-AMERICAN CONFERENCE OF WETLAND SYSTEMS FOR WASTEWATER TREATMENT

The CONFPANAM (Table 1) is an initiative that was led in the beginning by Carlos A. Arias, Diego Paredes, Armando Rivas and other researchers in Latin America, aiming to become the first conference to bring to Spanish-speaking researchers, a platform and forum to exchange the results of the local experiments about TW (Arias 2021).

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Table 1. Resume of all the editions of the Pan-American Conference of Wetland Systems for Wastewater Treatment

Edition	Place	Date	Main host	Reference	Main topics
I	Pereira, Risaralda, Colombia	From: 26/02/12 To: 01/03/12	UTP	(CNPML 2011)	TW-design TW-removals TW-plants Natural Wetlands Cost Wetlands TW in small communities
II	Morelia, Michoacan, Mexico	From: 8/06/14 To: 12/06/14	IMTA	(Rivas-Hernández and Paredes-Cuervo 2014)	TW-design TW-removals TW-plants Natural Wetlands Cost Wetlands TW in small communities TW for education TW-benefits
III	Santa Fe, Santa Fe, Argentina	From: 16/05/16 To: 19/05/16	UNL	(Hernán and Maine 2016)	TW-design TW-removals TW-plants Natural Wetlands Cost Wetlands TW in small communities TW for education TW-benefits Emergent pollutants
IV	Lima, Lima, Peru	From: 15/05/18 To: 18/05/18	UNALM	(Sanchez-Celis et al. 2018)	TW-design TW-removals TW-plants Natural Wetlands Cost Wetlands TW in small communities TW for education TW-benefits Emergent pollutants TW and municipal swages TW for industrial ww TW for agriculture ww TW for landfills ww TW-innovation
V	Florianopolis, Santa Catarina, Brazil	From: 15/05/18 To: 18/05/18	UFSC	(Sezerino and Pelissari 2021)	TW-design TW-removals TW-plants Natural Wetlands Cost Wetlands TW in small communities TW for education TW-benefits Emergent pollutants TW and municipal swages TW for industrial ww TW for agriculture ww TW for landfills ww TW-innovation Enhanced TW

UTP – Universidad tecnológica de Pereira (Technological University of Pereira)
IMTA – Instituto Mexicano de Tecnología del Agua (Mexican Institute of Water Technology)
UNL – Universidad Nacional del Litoral (National University of the Littoral)
UNALM – Universidad Nacional Agraria La Molina (National Agrarian University La Molina)
UFSC – Universidad Federal Santa de Catarina (Federal University of Santa Catarina)

Table 2. Local TW researching groups recognized by the HUPANAM.

Country	Name	Head of the group	Reference
Argentina	Argentina Wetland Research	Maria Alejandra Maine	(Argentina Wetland Research 2019)
Brazil	Wetlands Brasil.	Pablo Heleno Sezerino	(Wetlands Brasil 2011)
Chile	Red Humedales Construidos Chile	Gladys Vidal	(GIBA 2018)
Paraguay	Wetlands Paraguay	Tomás Rodrigo López Arias	(Wetlands Paraguay 2019)
Peru	Grupo de Investigación en Agua y Saneamiento Sostenible	Rosa Miglio Toledo	(UNALM 2021)

All the conferences have had participation of experts from different countries out of the LAC region, like United States, Germany, Australia, Austria, Denmark, Spain, France, and Canada resulting in a forum to share the latest developments around the world and the advances in the region allowing knowledge and tech transfer to reach the LAC region.

HISTORY OF PAN-AMERICAN TREATMENT WETLAND NETWORK (HUPANAM)

The HUPANAM network started in 2010 as a small informal network mainly formed by scientists from the LAC region that previously attended international wetland conferences like WETPOL and International Water Association (IWA), and similar expert groups interested in transferring TW know-how to the LAC region, especially the most recent information and technological advances.

At the third CONFPANAM in Santa Fe, Argentina, attending scientists created a first steering committee of the network, with Dr. Armando Rivas from the Mexican Institute of Water Technology (IMTA) chosen as the President. Later, during the conference in Lima, Peru, the network selected the name HUPANAM, expanded the steering committee, and established for the first time the figure of "executive member", selecting Dr. Alejandra Maine as the President and having executive members from Argentina, Brazil, Catalonia, Chile, Colombia, Costa Rica, Paraguay, Mexico, and Peru. Most recently, during the recent fifth edition of the conference, the committee was renovated again, selecting Dr. Pablo Sezerino as President.

TW RESEARCH GROUPS IN THE LAC REGION

Since the creation of HUPANAM, local researching groups have been created in different countries across the region to help spread and share the advances in the TW research. The groups recognized by the HUPANAM are shown in the Table 2.

TW RESEARCH OUTPUTS IN THE LAC REGION

According to Rodriguez-Dominguez et al. (2020), the number of published articles in the LAC region regarding TW have not changed much during the last decade (Figure 1). This situation points to the need for increasing the interest and the involved actors in the region in order to increase implementation and impact of the TW technology.

During this last decade, more than 520 experiences were reported in 190 publications, reporting nutrient removal rates of chemical oxygen demand (COD), total nitrogen (TN), and total phosphorus (TP) of 65-83%, 55-72%, and 30-84%, respectively. The countries with the

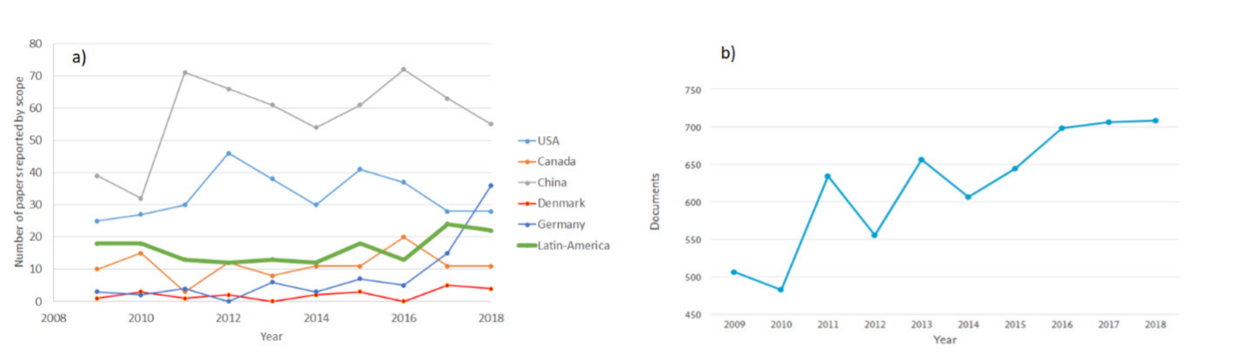

Figure 1. Publications on constructed wetlands (CW): a) CW publications comparison among LAC and selected countries between 2009 and 2018, and b) global tendency of scientific production related to CW from 2009 to 2018. Modified from (Rodriguez-Dominguez et al. 2020)

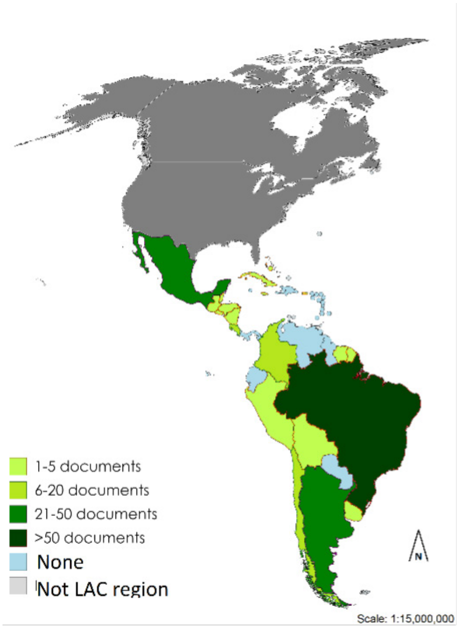

Figure 2. Number of documents related with TW found per country during the last decade. (Modified from Rodriguez-Dominguez et al. 2020)

highest number of publications in the region were Brazil, Mexico, Argentina, and Colombia (Rodriguez-Dominguez et al. 2020; Figure 2).

The most used technology in the region is the horizontal subsurface flow wetlands (HSSFW), followed by free water surface (FWS) one, and vertical flow (VF) and the intensified wetlands technology. The largest reported system in the region was a HSSFW of 6,000 m2 located in Rionegro, Colombia (Silva-Bedoya et al. 2016). The largest FWS system was reported in Argentina with a surface of 2000 m2, located in Santa Fe, Argentina (Maine et al. 2006). The largest VF system was established in the city of Palhoça, Santa Catarina, Brazil with a surface of 3144 m2 receiving domestic wastewater (Ávila et al. 2017). A total of 114 different plant species have been used in TW in the LAC region in the different experiments, with the most commonly used plants being Typha domingensis, Eichhornia crassipes, and Typha latifolia, while some systems use non-wetland species like Cocos nucifera (coconut), *Carica papaya* (papaya), or *Aloe vera*.

CONCLUSION

TW technology is gaining relevance in the region, increasing its impact and interest around all the countries, and improving water quality. Due the potential of the TW technology to bring sustainable and cheaper wastewater treatment, the inclusion of TWs in public policies in LAC countries can improve sanitary conditions, increase the life quality, and protect the environment (Denny 1997) as well as meeting the United Nations goals (United Nations 2015). Additionally, the activities taken by the network should reach universities and technical schools to ensure the proper training of technicians and help promote the utilization of this technology across Latin America.

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Figure 3. Examples of horizontal subsurface flow wetlands (HSSFW) for water treatment. On left, a 7,500 m2 full-scale HSSFW located in Jalisco, Mexico, planted with Reed (*Phragmites australis*), designed for treating up to 900 m3 of industrial wastewater, constructed by Soluciones Ecológicas del Desierto S.A. de C.V. (Photo reproduced with permission of Soluciones Ecológicas del Desierto S.A. de C.V.) To the right, a full-scale HSSFW installed in Ponte de Lima, Portugal, and planted with *Canna flaccida, Canna indica, Zantedeschia aethiopica, Agapanthus africanus*, and *Watsonia borbonica*. (Photo by Cristina Calheiros)

Figure 4. Examples of vertical subsurface flow (VF) wetlands. To the left, a VF wetland installed at the Center for Biologic and Aquaculture Research of Cuemanco, Autonomous Metropolitan University, Xochimilco, Mexico City, Mexico. (Photo courtesy of the designer Victor Manuel Luna Pabello.) To the right, a lab-scale vertical flow wetland (VF) installed at the Military University of Nueva Granada, Bogota, Colombia. (Photo by Tatiana Rodríguez Chaparro)

Figure 5. Two full-scale free water surface (FWS) wetlands, both located in Santa Fe, Santa Fe, Argentina. (Photos by Hernan Hadad)

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