SUSTAINABILITY OF WASTEWATER SYSTEMS: CURRENT AND FUTURE PERSPECTIVES – AN ASSESSMENT WORKSHOP

PROCEEDINGS

Panajachel, Guatemala, 20–23 March 2018

UNITED NATIONS UNIVERSITY

UNU-FLORES

Institute for Integrated Management of Material Fluxes and of Resources

SPONSORED BY THE

Federal Ministry of Education and Research

Proceedings

Sustainability of Wastewater Systems: Current and Future Perspectives – An Assessment Workshop

UNU-FLORES (ed.)

20–23 March 2018
Panajachel, Guatemala

Co-organised by:
United Nations University - Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES), Germany;
University of San Carlos of Guatemala (USAC), Guatemala;
Fideicomiso de Infraestructura Ambiental de los Valles de Hidalgo (FIAVAHI), Mexico

Acknowledgements:
Technische Universität Dresden (TU Dresden), Germany;
Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V. (DWA), Germany;
as well as of the presenters.

Sponsored by:
Consejo Nacional de Ciencia y Tecnología (CONCYT) of Guatemala and the Federal Ministry of Education and Research (BMBF) of Germany

Contributors to the proceedings: Tamara Avellán, Lucía Benavides, Serena Caucci, Néstor De la Paz Ruíz, Laura Ferráns, Angela Hahn, Sabrina Kirschke

The views expressed in this publication are those of the authors. The authors are responsible for ensuring that all figures, tables, text, and supporting materials are properly cited and necessary permissions have been obtained.

United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES)

Ammonstrasse 74, 01067 Dresden, Germany
Tel.: + 49-351 8921 9370
Fax: + 49-351 8921 9389
Email: flores@unu.edu

Editor: Atiqah Fairuz Salleh
Design & Layout: Claudia Matthias
Cover Image: Regional School of Sanitary Engineering (ERIS), USAC, WWTP Aurora II, Guatemala City, Zone 13. (Photo: Laura Ferrans/UNU-FLORES)
Images: University of San Carlos of Guatemala (USAC), Tamara Avellán, Serena Caucci, Néstor De la Paz Ruíz
Figures: UNU-FLORES, if not otherwise specified
Print: Reprogress GmbH
Print run: 300

ISBN: 978-3-944863-74-0
e-ISBN: 978-3-944863-75-7

This publication should be cited as:
UNU-FLORES. 2018. *Sustainability of Wastewater Systems: Current and Future Perspectives – An Assessment Workshop. Proceedings, Panajachel, Guatemala, 20–23 March 2018*. Dresden: United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES).

Executive Summary

Poor management of wastewater treatment systems is a common reality in small to medium-sized cities of developing countries. This has negative impacts on ecological systems as well as the health and wealth of human beings. Against this background, the international community calls for a sustainable management of wastewater treatment systems. The identification of such sustainable systems is, however, not straightforward, given lacking methodologies for sustainability assessment in this field.

The lack of methodological approaches addressing sustainability is well reflected in the case of wastewater management at Lake Atitlan in Guatemala. While there exist wastewater treatment plants, the wastewater flowing into the lake is of poor quality. This has negative impacts on the quality of the lake's water, the provision of drinking water, and tourism, an important source of income for the basin population. Whereas solutions to this problem are urgently needed, lacking methodologies for sustainability assessment impede the identification and implementation of relevant solutions.

In this context UNU-FLORES and partners have developed an integrated approach to identify sustainable solutions in the field of wastewater management in Latin America. This implies (i) approaching the problem in a participatory manner by involving all interested and affected parties, (ii) thoroughly understanding the complexity of the nexus problem at hand, and (iii) assessing current and future wastewater treatment systems based on ecological, social, and economic criteria and thresholds.

The workshop in Guatemala aimed at validating this approach and served for the identification of sustainable solutions in the Guatemalan case. The workshop was structured in three main blocks. After a short introduction, participants collaboratively worked on (i) a shared understanding of the problem, (ii) the identification of locally relevant criteria and thresholds against which the problem and solution options can be assessed, and (iii) criteria for probable solution options on site.

Overall, the integrated approach proved to be very helpful for addressing the problem of wastewater management in Latin America. Specific outcomes are: (i) sustainable wastewater management is found to be a wicked problem, characterised by goal conflicts, system complexities, and uncertainties; (ii) locally relevant indicators and thresholds for good solutions to address this problem were identified; (iii) and possible criteria for solution options from Germany, Mexico, and beyond were identified.

The results set the scene for a follow-up workshop at which stakeholders shall co-design solutions for the wastewater problem at hand.

Figure 1: Group photo of workshop attendees.

Table of Contents

1. Setting the Scene

1.1 Introduction

Unsustainable management of wastewater is a major problem in the region of Lake Atitlan in Guatemala. Treated wastewater is of poor quality, which has negative impacts on its existing and potential beneficial uses like tourism (poor bathing-water quality), consumption (poor drinking-water supply), and food production (unsafe use of wastewater for irrigation). Sustainable solutions to this problem are needed but are difficult to achieve given a lacking methodology for sustainability assessment.

The workshop in Panajachel, Guatemala, aimed at applying the integrated approach of UNU-FLORES and partners to identifying sustainable solutions to wastewater management. This integrated approach considers: (i) a co-design of solutions between experts and local stakeholders, based on (ii) an in-depth understanding of the complex nexus problem at hand, and (iii) a comprehensive assessment of wastewater treatment systems based on various sustainability criteria and thresholds.

To achieve this goal, different stakeholder groups were invited to the workshop, amongst them public authorities, non-governmental organisations, technicians, scientific experts, and others. These different stakeholder groups aimed at jointly developing: (i) a shared understanding of the problem, (ii) locally relevant sustainability criteria and thresholds against which the problem and its solution options can be assessed, and (iii) probable solution options on site.

1.2 Workshop Overview

The workshop started with providing background information, discussing experiences of project partners (see 1.3), and a general workshop overview. The workshop was then structured into three main parts. In part one, the main goal was to collectively *understand the status quo of wastewater management* in Guatemala. This includes collectively outlining the problem in a drawing session, a discussion of previous research on the Panajachel case, as well as the analysis of the wickedness of the problem at hand. Part two related to the *assessment of sustainability*. This included a presentation of a comprehensive framework for sustainability assessment by UNU-FLORES, a determination and prioritisation of locally relevant indicators for sustainability assessments, and an identification of local data holders. Part three then looked at criteria for probable *solutions to the problem*. This comprised an overview of past solutions implemented in Panajachel, a look at technical solutions from an international perspective, as well as discussions on the application of solutions in Guatemala, including targets, thresholds, and prerequisites for solutions. The workshop was accompanied by field visits to local wastewater treatment plants and the launch of the 2018 UN World Water Development Report in an evening reception.

Figure 2: Workshop overview. A three-step approach from understanding the problem to identifying criteria for sustainable solutions.

1.3 Experiences from Mexico

As a starting point, the Fideicomiso de Infraestructura Ambiental del Valle de Hidalgo (FIAVHI) shared its experiences in addressing wastewater management-related problems in the states of Hidalgo and Oaxaca in Mexico. The talk focused on the efforts and results of the institute in facilitating the implementation of a Safe Use of Wastewater in Agriculture (SUWA).

Carlos A. Paillés (FIAVHI) (Figure 3) highlighted topics such as an Integrated Management of Natural Resources, water requirements in terms of quantity and quality, alternatives to treated wastewater reuse, and the integrated and timely management of the different qualities of water.

Carlos A. Paillés mentioned the 100-year long journey of its engineers, technicians, and users related to wastewater management (WWM), resulting in outcomes such as the launch of the Manual of Drinking Water, Sewerage and Sanitation (MAPAS) by CONAGUA and the representation of a significant institutional input to update and improve WWM in Mexico, also considering recommendations of international agencies.

Moreover, key aspects of decentralised wastewater treatment plants (WWTP) for agricultural, environmental, and municipal reuse were shared, focusing on developments in Tepeji, Hidalgo, and la Sierra Juarez de Oaxaca. Here, water qualities and risk management are vital to ensure a proper performance of decentralised WWTP. Also, plants specifications influencing the efficiency of decentralised WWTP were discussed, such as mini-collectors, size, and positioning of WWTP.

To close, self-sufficiency and sustainability were highlighted, as well as the concept of zero discharge as the 'engines' of sustainable development. Efforts in Panajachel may focus on discussing design, construction, operation, maintenance, certification, and the evaluation of WWM.

Figure 3: Carlos A. Paillés shares his experience as a facilitator of solutions related to resource recovery from wastewater in Tepeji, Hidalgo.

2. Understanding the Status Quo: Wastewater Management in Guatemala

2.1 Collectively Outlining the Problem

The first day of the workshop focused on understanding the status quo of wastewater management in Guatemala. During the first session, participants were asked to describe the problem through artwork. The participants were asked to draw an image of the current situation and the problem in general. They were then asked to highlight the main problem and to identify the most important stakeholders related to the problem.

The images had in common the very broad perspective on the problem, including economic, environmental, technical, and social aspects of the wastewater management situation at Lake Atitlan. Many of the drawings show how the untreated sewage flows into the lake or how people throw garbage into it. In terms of the social aspects, corruption and a lack of financial resources were often highlighted.

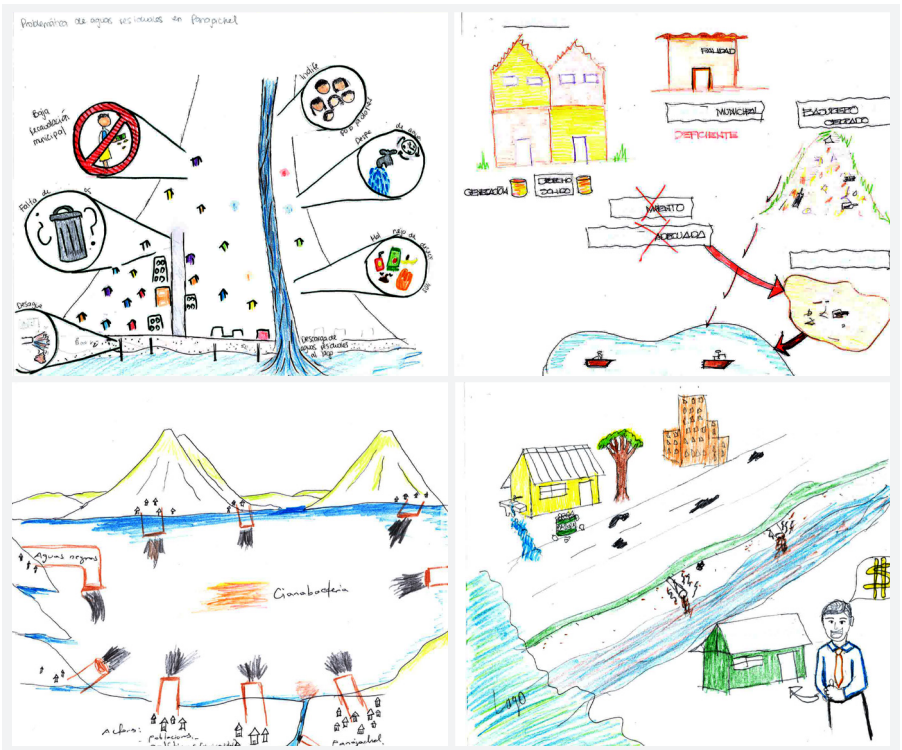

Figure 4-7: Selected drawings from the participants who graphically expressed their views of the problem.

Overall, the methodology of drawing was positively received by the stakeholders. The participating stakeholders actively took part in the drawing exercise regardless of their position or status.

The same exercise was applied on the last day of the workshop with a focus on solution options. The participants were requested to draw a second image of their vision of the ideal situation.

Figure 8-11: Participating stakeholders draw and discuss their problem understanding.

2.2 Previous Research on the Panajachel Case

In this session, **Laura Ferráns (UNU-FLORES)** presented the results of her work on the wastewater situation in Lake Atitlan from 2017, which are summarised in UNU-FLORES Working Paper #6 "Wastewater Management in the Basin of Lake Atitlan: A Background Study" (Ferráns et al. 2018). The main purpose of this presentation was to show the results gathered through literature analysis and stakeholder consultation, and to provide stakeholders with the opportunity to correct any of the presented data and information and to provide feedback on it.

In general, the work reveals that 55% of the community around the lake is connected to a sewage system and that the remaining 45% use latrines, septic tanks, or soak latrines, which are mostly not being collected and disposed of safely. In total, 45,500 m^3 of wastewater is generated every day in the basin, and only approximately 20% receives treatment, which is much less than the roughly 65% of wastewater that is being treated in Guatemala in general (Ferro 2017). Most of the 12 existing WWTPs exhibit very poor performance with regard to removal of pathogens and nutrients; and none comply with all parameters stipulated in the norm #12-2011. WWTPs face, among others, operation and maintenance problems. The most common bottlenecks are the lack of laboratory facilities, continuous technical training, handling plans for by-products, personnel, and supplies, operation and maintenance manuals, and willingness to pay by users. To address these issues, participatory processes are suggested.

Figure 12: Laura Ferráns presents her work.

2.3 Wastewater Management as a Wicked Problem

As a third step in understanding the status quo of wastewater management in Guatemala, workshop participants analysed the "wickedness" of the problem.

Many infrastructural projects in the field of wastewater treatment have failed because of difficulties in the areas of implementation and maintenance. "Wickedness" is a social science concept that describes these difficulties in addressing problems. First suggested in the 1970s, the concept has recently gained momentum in the field of natural resource management and beyond. Three aspects of wickedness are of importance: (i) goal conflicts related to the problem area; (ii) system complexity, referring to the number of dynamic and interconnected factors; and (iii) informational uncertainty regarding these factors; and these aspects can vary between low, middle, and high values (adapted from Head 2008). Based on the outputs of the workshop, the problem of wastewater management in Guatemala seems highly wicked.

After an introductory presentation on wicked problems by **Tamara Avellán (UNU-FLORES)**, three groups with assigned moderators and participants were formed, representing the three dimensions of wicked problems (see Figure 13). The groups were given altogether 90 minutes to discuss the wickedness of the problems. In the first 15 minutes, the groups prepared the discussions by assigning a rapporteur to report back to everyone and discussing open questions related to the procedure. In the following 60 minutes, the groups each discussed three predefined questions. Here they first wrote down individually the answers to the questions (15 minutes) and then they discussed the three questions as a group (each 15 minutes). In the final 15 minutes, the groups agreed on the message to be delivered to the audience. In the following 30 minutes, all groups presented their results to all workshop participants and results were openly discussed. A summary of the main outcomes from this session is presented below and details of the questions are given in Appendix 1.

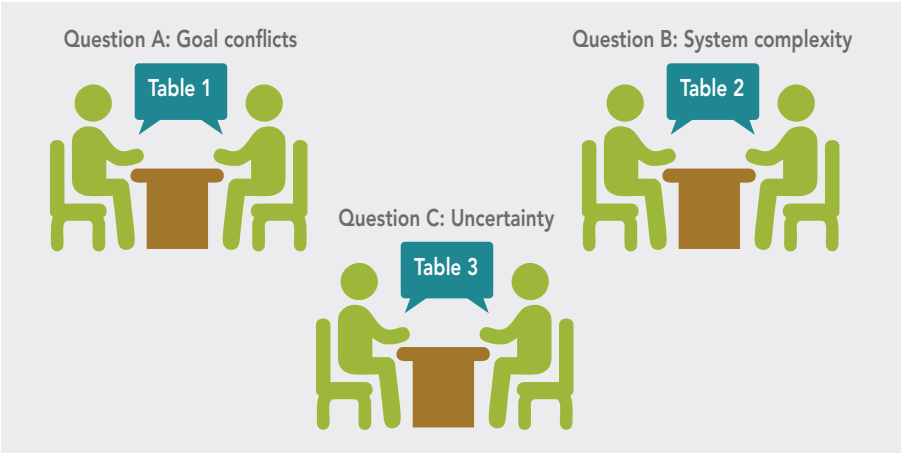

Figure 13: Roundtables on wicked problems.

Goal conflicts (wickedness level: high): Participants at the workshop highlighted that there is joint interest in achieving good freshwater quality. However, there are conflicts on a social, economic, technical, and institutional level that impede the achievement of good water quality. On the social level, the population does not necessarily agree on solution options such as the use of treated wastewater. In terms of economic aspects, the capacity to pay for treatment technologies is limited in the local population, part of which is living in absolute poverty. In terms of the technical conflicts, there is a lack, for instance, of skilled personnel. With regard to institutions, a lack of coordination leads to a duplication of functions of individual institutions, which again results in potential conflicts between those institutions.

System complexity (wickedness level: high): The problem is influenced by many factors, amongst them natural factors (e.g., the specific topography, climate) and social factors (e.g., responsibilities of governments, the level of education, interests of indigenous communities, associations, tourist organisations, and three governmental levels). Factors influencing the solution to the problem are also subject to dynamic processes. There are, for instance, exponential dynamics associated with climate change (e.g., changing temperatures). Moreover, participants highlighted linear dynamics with regard to social dimensions (e.g., demographic development and related social and political conditions, an increasing number of tourists in the region). These factors are also highly interconnected, especially at the social level in terms of the actors.

Informational uncertainty (wickedness level: high): While there are data and information at hand, they are sometimes dispersed across different institutions. Moreover, there is also a lack of important information with regard to natural and social factors. In terms of natural factors, the data and information gap regard, for instance, the quantity and quality of water, precipitation, temperature, soil types and topography, existing forests, and others. In terms of social data and information, there is a gap with regard to the actual directory of inhabitants and future demographic developments, evaluations of economic, social, and environmental benefits, a characterisation of typical uses of water, as well as operational instructions, among others. Obtaining data and information is hindered by a lack in planning capacities, methodologies, and the willingness to gather and share information, among others.

Figure 14: Participants discuss the wickedness of the problem.

3. Assessing Sustainability

3.1 Determining and Prioritising Locally Relevant Indicators for Sustainability Assessments

The second day of the workshop focused on the selection of indicators for sustainable solutions as well as the identification of data holders.

Four thematic groups were formed, one for each dimension of sustainability: environmental, technical, social, and economic. Participants joined the groups according to their field of specialty or interest. In each group, the moderator asked participants to discuss and reflect together to identify the indicators (or parameters) that seem important to them for the understanding of that particular dimension of sustainability with regard to the wastewater management system they were working on. Through conceptual mapping and discussion, the different groups identified indicators and organised them in categorised lists (datasets). In total, the stakeholders identified 170 indicators.

Moderators then introduced the importance of prioritising datasets, given various contexts, related data availabilities, and perceptions of different stakeholder groups. When carrying out a sustainability assessment, different working sites and different project conditions may result in different data requirements, or data-finding possibilities. In some cases, for example, a certain indicator may be important for the assessment, but its values may turn out to be impossible to obtain due to data unavailability, time issues, and so on. Further, different priorities of stakeholder groups shape stakeholders' perceptions of what the most important data is. Some stakeholders might find a certain piece of information crucial, while others may find it secondary. Therefore, when trying to assess sustainability in a holistic and inclusive manner, the construction of datasets should include the scoping of information priorities among various stakeholder groups.

The second activity for the groups was to prioritise the indicators they have produced according to what, in their knowledge and experience, the most pressing issues around the local wastewater management situation are. The final priority indicators contain 70 indicators, as can be seen below in Table 1. This prioritising exercise entailed considerable debate and discussion, and participants at the end of the day shared a reflection on how the activity had made it clear that different people have different ideas about what knowledge is important.

The indicators contributed by the stakeholders gave the research team insight into how different stakeholder groups identify and prioritise knowledge, and what value they give to different types of indicators, which at the same time also widens our understanding of the relative importance of different elements of the wastewater problem for different population groups.

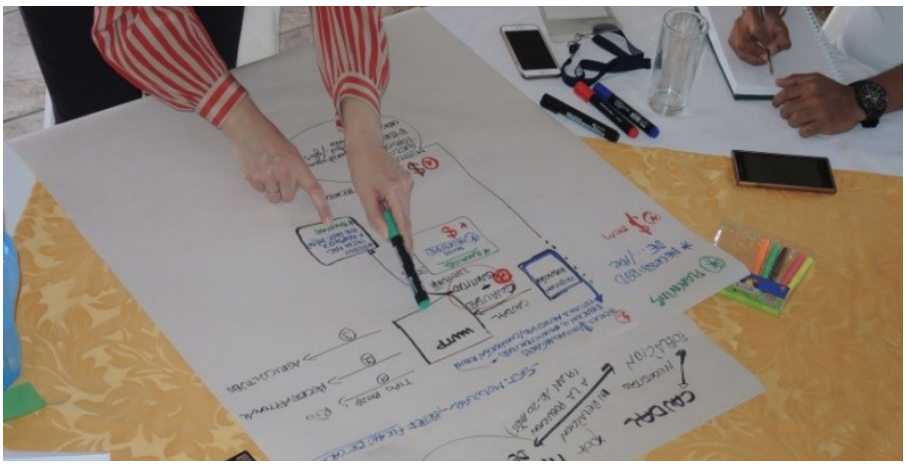

Figure 15: Participants identify and prioritise indicators at the SludgeTec workshop.

Table 1: Priority Indicators for Assessing Sustainability of Wastewater Management Systems Identified by Stakeholders at the Panajachel Assessment Workshop

	TECHNICAL
1	WWTP effluent quality
2	Sludge quality
3	Plant technical design
4	Efficiency of the plant process
5	Personnel knowledge level
6	Quality certification of the process
7	Security parameters in the operation of the plant
8	Data communication (logbook, social communication, information digitisation)
9	Effluent Quality monitoring

SOCIAL	
1	Corruption level of the individual
2	Corruption level society level
3	Corruption level at the political level
4	Clarity of laws and regulations (clarity of content)
5	Clarity of laws and regulations (clarity in jurisdiction)
6	Level of citizen involvement
7	People's attitude towards environmental issues
8	Amount Number of environmental projects (is there any regulation that specifies how many environmental projects there must be, for example, in schools)
9	Quality of environmental projects
10	Amount Number of health projects
11	Social initiative
Economic	
1	Percentage of WWTP budget destined toallocated for maintenance
2	Budget destined toallocated for sanitation issues
3	Proportion of workers per inhabitant (in water and sanitation sector)
4	Economic feasibility study to build and operate plants
5	Costs of connection to water system
6	Costs of connection to sewerage
7	Financing sources for construction and operation of WWTP
ENVIRONMENTAL	
1	Environmental Impact study
2	Wastewater disposal
3	Final disposal of solid waste from WWTP
4	Final disposition of grease coming from WWTP
5	Final destination of sludge coming from WWTP
6	Risk assessment before WWTPs are built
7	Emissions travel
8	Use of treated water
9	Use of sludge from WWTP
10	River water quality monitoring

3.2 Identifying Local Data Holders

After identifying important indicators, the next step was to identify where relevant information for measuring indicators can be obtained. For this purpose, the participants also participated in an activity linking indicators to the institutions, documents, or individuals who potentially hold or should hold the relevant information.

Because there are known issues of insufficient data generation and availability in Latin America, compiling these potential data holder lists is quite useful to ease a potentially difficult and time-consuming data gathering process. The data holder lists identify all possibly relevant data sources for each priority indicator. In further steps, this list is to be complemented with contact information, so that data requests can be made. Having this comprehensive data holder lists helps carry out a better organised and systematic data gathering process, thus improving the chances of finding the data that is needed.

The tracking of the data gathering process (registering which information requested to which data holder and what the results of the request are, that is information on the data availability and quality, etc.) will serve to shape a data availability report. Such a report is crucial to close data gaps, in a context where existing data is often poorly communicated and seldom compiled across sectors, institutions, or researchers.

Figure 16: Discussions on data holders for assessing the current state in Panajachel.

4. Solution Options

4.1 Treatment Technologies Implemented at the Lake Atitlan Basin

One major goal of the workshop in Panajachel was to review existing solution options for addressing wastewater-related problems. Research has shown that solutions have been mostly technical (Ferráns et al. 2018).

In the basin of Lake Atitlan, there are 12 Wastewater Treatment Plants (WWTPs) (see Table 2). Four WWTPs use activated sludge technology, one employs facultative lagoons and septic tanks, and the other eight facilities use anaerobic reactors and biological percolating filters (AMSCLAE 2015). The table lists all WWTPs along with their capacities, technologies, discharges, and sludge treatment units and the discharge routes of treated wastewater.

Overall, 33% of the treated wastewater is reused for crop irrigation while only 4% reaches the lake directly and 16% is infiltrated into soil. The remaining 47% of the treated wastewater is discharged into the lake's tributary rivers. The large portion of untreated wastewater is discharged into rivers reaching the lake, or onto open grounds (Romero 2013).

Table 2: Wastewater Treatment Plants Present at Lake Atitlan and Daily Volume of Wastewater Generated

WWTP	Municipality	Q_{design} (lps)	Technology	Discharge route	Sludge treatment
Cebollales	Panajachel	37	Activated sludge + Chemical flocculation	River – Lake Atitlan	Anaerobic digestion + Drying beds
Chuk Muk	Santiago Atitlan	19	Inhoff + Biological filtration + Facultative pond	Infiltration into the ground	Drying beds
Maria Tecun	Sololá	5	UASB + Biological filtration	River – Lake Atitlan	Drying beds
San Antonio	Sololá	10.5	UASB + Biological filtration	Crop irrigation	Drying beds
San Bartolo	Sololá	24	UASB + Biological filtration + Sand filtration	Crop irrigation	Drying beds
San Jorge la Laguna	San Jorge la Laguna	3.9	UASB + Biological filtration	River – Lake Atitlan	Drying beds
El Novillero	Santa Lucia Utatlán	1.9	Septic tank + Facultative lagoon	River – Lake Atitlan	Drying beds
San Andres Sametabaj	San Andres Sametabaj	7.5	Inhoff + Biological filtration	River – Lake Atitlan	Drying beds

Santa Catarina Palopo	Santa Catarina Palopo	3	Activated sludge + Aquatic plants for nutrient removal	Lake Atitlan	Aerobic digestion + Drying beds
Santa Cruz la Laguna	Santa Cruz la Laguna	6	Inhoff + Biological filtration	River – Lake Atitlan	Drying beds
San Lucas Toliman	San Lucas Toliman	1	Activated sludge	Lake Atitlan	N.A.
San Marcos	San Marcos	N.A.	SBR + Chlorine disinfection	Irrigation plant nurseries	Aerobic digestion + Gravitational thickening

Source: AMSCLAE 2015
UASB: Upflow Anaerobic Sludge Blanket, N.A.: Data not available

Further, in each municipality, the percentage of treated wastewater varies according to the availability and capacity of existing WWTPs. Figure 17 shows the portion of treated wastewater per municipality around the basin of Lake Atitlan.

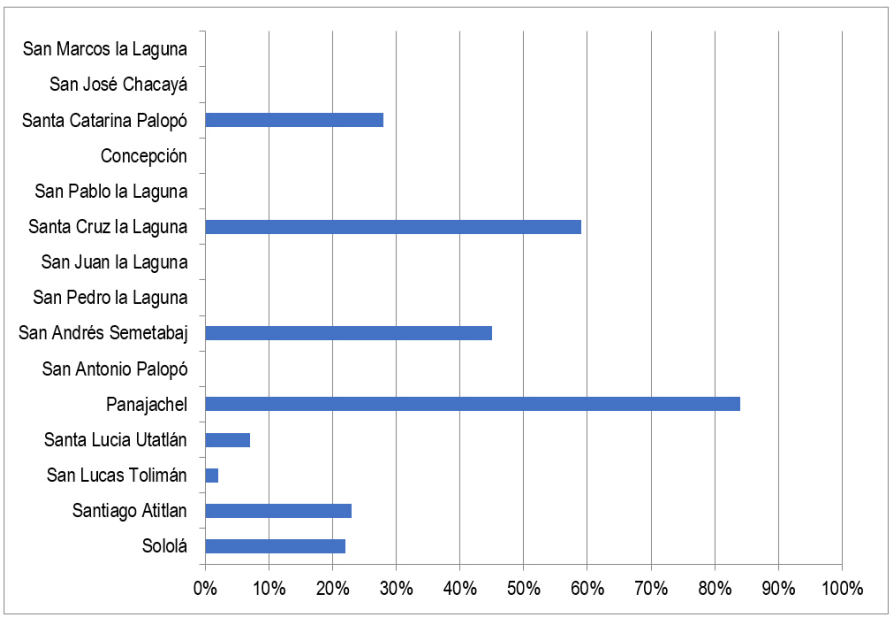

Figure 17: Percentage of treated wastewater at each municipality around Lake Atitlan (Ferráns et al. 2018).

4.2 Looking Beyond Borders: Technical Solutions from an International Perspective

This session focused on sharing experiences from abroad. Presentations referred to different aspects of wastewater treatment that can enhance its sustainability, such as the use of sludge for different purposes (presentation by Laura Ferráns), the use of biogas for energy production (presentation by Jorge Cifuentes), the use of treated wastewater for agricultural irrigation (presentation by Ana Lilia Velasco), and the role industry can play to set good examples (presentation by Oscar Gramajo). In addition, Roland Knitschky of the German Water and Wastewater Association (DWA) gave a short overview of wastewater treatment in Germany.

Laura Ferráns (UNU-FLORES) presented on the outcome of the research she had conducted within the preparatory work for the SludgeTec project. Laura Ferráns used the case of the treatment plant of Panajachel to set up a decision support system for the sustainable use of sludge that is produced in wastewater treatment plants around the world. Through a framework of data collection and stakeholder consultation, she assessed the usefulness and applicability of using sludge for five different purposes namely (1) agriculture, (2) soil conditioning, (3) construction, (4) co-incineration, and (5) landfills. The first two scenarios were considered to be feasible with the first one being the most favoured. In her concluding slide, she also gave recommendations about the procedures to be followed to implement this solution in the specific case of Panajachel.

Figure 18: Laura Ferráns presents her work on sustainable sludge management.

Jorge Cifuentes (USAC) laid out the process of biogas production from wastewater and sludge (see Figure 19) and outlined the possibilities of the use of this for domestic purposes. The treatment plant in Panajachel has facilities to produce biogas and an upgrade of its system could facilitate the production of biogas for domestic use.

Figure 19: Jorge Cifuentes lays out the process of biogas production.

Ana Lilia Velasco Cruz (FIAVHI) presented on the usefulness of treated wastewater for the irrigation of quinoa and corn at two sites in Mexico. For both crops, irrigation with treated wastewater showed higher growth rates than when irrigated with freshwater. In both localities, consultations were held with local stakeholders about which site to use for the treatment and for the irrigated land. Preparation of land and planting was also carried out with the support of the local population ensuring their understanding of the process and the overall purpose of the project.

Figure 20: Ana Lilia Velasco Cruz addresses crop irrigation using treated wastewater.

Oscar Gramajo (Cementos Progreso) showcased the work that Cementos Progreso is carrying out with the use of their waste products, that is wastewater and sludge, solid waste, and chalk. Wastewater and leachates are treated in wastewater treatment plants; solid waste is classified and recycled; sludge and organic waste are composted and used for soil conditioning; and chalk is used as a base for outside paint that is provided to the local population.

Figure 21: Oscar Gramajo showcases the work of Cementos Progresos.

Roland Knitschky (DWA) presented on the overall situation of wastewater treatment in Germany, displaying the amount of treatment systems per size of population served. He walked the audience through the different technical infrastructure employed for different size systems, as well as the relative number of personnel with different levels of expertise that are employed in German utilities. He also explained the history of the DWA and how it had evolved over time, starting with a handful of engineers that saw the need to tackle the water infrastructure after World War II.

Figure 22: Roland Knitschky presents on the wastewater situation in Germany.

4.3 Looking Ahead: Finding Solutions in Guatemala – Targets, Thresholds, and Prerequisites for Solutions

After having learnt about different solutions on site and abroad, participants of the workshop worked further along the SludgeTec assessment method, looking into the identification of sustainability criteria, milestones, and benchmarking thresholds for the priority parameters identified during the previous day's activities.

Participants worked on two tasks. The objective of the first one (*"Targets and thresholds"*) was to identify, in national and international documentation, target states for the 37 priority parameters identified as priority the previous day (see section 3.1). The participants were asked to reflect on the policies, regulations, and norms they are aware of that could contain such information, and/or write down the target parameter if they knew it. For example, "water quality at treatment plant exit" had been identified as a priority data item. Participants who directly work in this field were able to identify the specific articles of certain laws where the normative values are contained in national legislation, for example. Other participants were able to name precise thresholds or recommended values for certain parameters such as biochemical oxygen demand (BOD) and total suspended solids (TSS).

The second task consisted of adding a final layer to the initial problem drawing that participants had drafted the first day. Using graphical language and an (optional) bit of text, participants expressed ideas, aspirations, needs, and feelings as to what it is that can make a solution "sustainable" or "desirable". This activity provided the participants with the freedom of using non-precise or non-technical language if desired, thus opening a door to qualitative data, which is crucial for understanding a baseline and its desired direction of change.

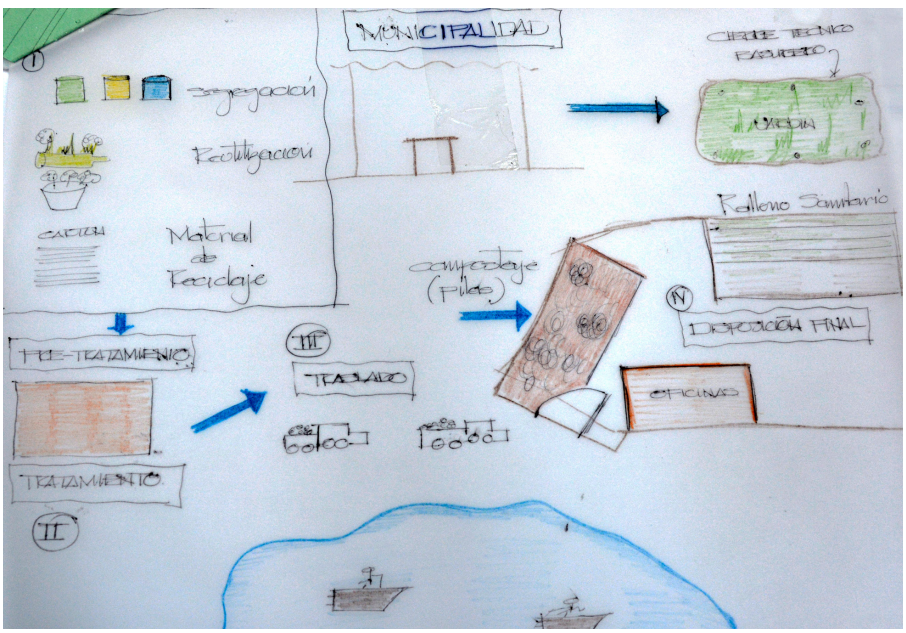

Figure 23: A drawing by one of the workshop participants, expressing what a sustainable system for wastewater management would look like in Panajachel.

5. Special Events

5.1 Field Visits

The workshop was accompanied by field trips to three different wastewater treatment plants. The first WWTP, located in Hotel Kaqchiquel, was one example of a WWTP in a touristic area. The second location, the centralised WWTP of Cebollales, represented a municipal treatment plant that does not implement resource recovery from wastewater. The third plant, the peripheral WWTP of Panajachel, had already implemented resource recovery from wastewater.

Figure 24: Field trip to wastewater treatment plants (UNU-FLORES).

WWTP in Hotel Kaqchiquel: This WWTP is located in the basement of Hotel Kaqchiquel, around 250 metres from Lake Atitlan where its treated wastewater is discharged. The main function of the plant is to treat the wastewater generated by the customers of the hotel. Treatment is done based on an anaerobic reactor, and in accordance with environmental regulations.

The manager of Hotel Kaqchiquel is motivated to protect Lake Atitlan since the protection of the lake is particularly important for the tourism sector and thus the customers of the hotel. The satisfactory performance of this treatment plant was noted.

WWTP Los Cebollales: This WWTP is adjacent to the Panajachel River, approximately 300 metres from Lake Atitlan where its treated wastewater is discharged. Its main function is to treat municipal wastewater generated by an urban area, preventing pollution of Lake Atitlan and following environmental regulations.

This WWTP has primary, secondary, and tertiary treatment. However, part of the experience shared by the operator of this WWTP was the lack of an operation manual and proper equipment, resulting in improvisations when resolving emerging issues, and a significant gap between the expected and actual performance.

Figure 25: Wastewater treatment plant in Hotel Kaqchiquel.

Figure 26: Tank of activated sludge; secondary treatment unit.

Figure 27: Tertiary settler; tertiary treatment.

Figure 28: Peripheral WWTP in Panajachel.

Figure 29: Field visit to the WWTP in Panajachel.

Peripheral WWTP of Panajachel: Located in the peripheries of the City of Panajachel, its main function is to treat domestic wastewater generated by nearby neighbourhoods. Its treated wastewater is mainly used to irrigate agricultural land. The wastewater that cannot be used for irrigation is discharged into Lake Atitlan. Gas that is generated by the plant is sent to the closest neighbourhoods.

This WWTP has primary, secondary, and tertiary treatment. The performance of the WWTP has been evaluated positively. The community's awareness of the benefits of the WWTP is high and they are very interested in the WWTP.

The field trips helped different actors – communities, academia, institutions, technical agencies, and local governments – to familiarise themselves with the topic of the workshop. They showed in particular that all actors influence wastewater management processes and their impacts on sustainable development in their social, economic, and environmental dimensions.

5.2 World Water Development Report 2018 Launch

Nature-based solutions can play an important role in improving the supply and quality of water and in reducing the impact of natural disasters, according to the 2018 edition of the United Nations World Water Development Report. The study, which was launched on World Water Day (22 March 2018) around the world argues that reservoirs, irrigation canals, and water treatment plants are not the only water management instruments at our disposal.

As part of the workshop, the report was launched in Panajachel in the attendance of workshop participants, who received copies of the report and further supporting material.

Figure 30: Launch of the World Water Development Report 2018 in Panajachel.

"We need new solutions in managing water resources so as to meet emerging challenges to water security caused by population growth and climate change. If we do nothing, some five billion people will be living in areas with poor access to water by 2050. This Report proposes solutions that are based on nature to manage water better."

– Director-General of UNESCO

References

AMSCLAE. 2015. Informe de Muestreo de las plantas de tratamiento de aguas residuales de la cuenca del Lago de Atitlan 2012–2015. Guatemala.

Ferráns, Laura, Serena Caucci, Jorge Cifuentes, Tamara Avellán, Christina Dornack, and Hiroshan Hettiarachchi. 2018. *Wastewater Management in the Basin of Lake Atitlan: A Background Study*. Working Paper. Dresden: United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES).

Ferro, Gustavo. 2017. "América Latina y el Caribe hacia los Objetivos de Desarrollo Sostenible en agua y saneamiento." CEPAL. http://repositorio.cepal.org/bitstream/handle/11362/41136/1/S1700195_es.pdf.

Head, B.W. 2008. Wicked Problems in Public Policy. Public Policy 2008, 3(2):101–118.

Romero Santizo, Marvin Alfonso. 2013. "Caracterización de Las Aguas Residuales Generadas En La Cuenca Del Lago de Atitlán Y Su Impacto." Master's Thesis, Universidad Europea Miguel de Cervantes.

Appendix 1: Questionnaire on Wicked Problems

Table 1 – Goal Conflicts

- Are there any **conflicting interests** related to the problem (e.g., conflicts related to values, methods, costs)?
- If there are conflicting interests, is there a certain **prioritisation of specific interests** on the side of one or all actors concerned?
- Is there a need for **tough negotiations** to address problems or do actors rather have to coordinate their actions?

Table 2 – System Complexity

- **What types of factors influence the solution** to problems (e.g., different solution options, natural factors, actors and their interests)?
- Are these factors **dynamically evolving** (linearly/exponentially)? Is there a need for models to understand dynamics?
- Are the **factors interconnected** with each other? And is there a need for decision-support tools to understand these connections?

Table 3 – Informational Uncertainty

- Is there **enough information for decision-making** or is there a need to gather additional information?
- If additional information has to be gathered, **what types of information are lacking**?
- If additional information has to be gathered, is it **possible to gather this information** or are there any hindrances (e.g., lacking methods and skills, or financial restrictions)?

Appendix 2: Workshop Evaluation

Participants evaluated the workshop based on an evaluation sheet. Respondents were both female (11) and male (14), and represent various stakeholder groups, namely academia (10), civil society (3), private sector (3), government officials (5), and others (4).

Firstly, participants provided numerical evaluations on a five-point scale (1 = minimum/poor and 5 = maximum/excellent). The following data represent averages rounded to two decimals, referring to this scale. In general, the majority of participants evaluated the workshop very positively. This relates to the overall assessment of the workshop (mean = 4.28), as well as to the organisation of the event (mean = 4.24), the balance of presentations and breakout sessions (mean = 4.16), as well as the quality of presentations (mean = 3.96), discussion sessions (mean = 4.28), and interactive sessions (mean = 4.32). Moreover, the majority of the respondents found the workshop very useful. The workshop helped participants to understand the Nexus Approach (mean = 4.08), the complexity of the problem (mean = 4.6), and the assessment framework (4.36). The workshop also helped in identifying sustainable management options for wastewater and sludge (mean = 3.76). In addition, the majority of respondents mentioned that they would be able to use what they had learned in their work (mean = 4.04).

Secondly, respondents also provided personal opinions in an open category. When asked about the most interesting topics of the workshop, participants highlighted various points, amongst them information about technical aspects and the analysis of the problem along economic, technical, environmental, and social aspects. In terms of future events, participants suggested to add practical cases as well as more actors, especially local people (community representatives) and representatives from the government and ministries in order to increase knowledge transfer.

Appendix 3: Programme Highlights

PROGRAMME HIGHLIGHTS

DAY 1 Tuesday, 20.03.18

8:00–18.30	**Field trip**

DAY 2 Wednesday, 21.03.18 - Understanding the Status Quo

8:00–8:30	**Registration**
8:30–10:00	**Opening and Welcome** Workshop overview & Experiences from Mexico Group Photo
10:00–10.30	***Coffee break***
10:30–12:30	**Session 1- Status quo: Wastewater Management in Guatemala (I)** Activity: Collectively outlining the problem Presentation: Previous research on the Panajachel case
12:30–14:00	***Lunch break***
14:00–16:00	**Session 2- Status quo: Wastewater Management in Guatemala (II)** Presentation: How to identify 'wicked' problems? Activity: Discussion roundtables on conflicts, complexities and uncertainties
16:00-16:30	***Coffee break***
16:30-17:30	**Closing of day 2** Report back from discussion groups Wrap-up and look-out

DAY 3 Thursday, 22.03.2018 – Assessing Sustainability

8:30–10:00	**Session 3** Synthesis Day 2 Presentation: Assessing sustainability of wastewater treatment systems
10:00–10:30	***Coffee break***
10:30–12:30	**Session 4: Assessing sustainability (I)** Introduction: Determining and prioritizing indicators for sustainability assessments Activity: Determining and prioritizing locally relevant indicators at Panajachel
12:30–14:00	***Lunch break***
14:00-16:00	**Session 5: Assessing sustainability (II)** Introduction: Identifying data holders Activity: Identifying local data holders
16:00-16:30	***Coffee break***
16:30-17:30	**Closing of day 3** Report back from discussion groups Wrap-up and Look-out
18:30	**World Water Development Report 2018 launch**

DAY 4 Friday, 23.03.2018 – Solution Options

8:30–10:00	**Session 6** Synthesis Day 3 Plenary discussion: A revision into past solutions implemented at Panajachel
10:00–10:30	***Coffee break***
10:30–12:30	**Session 7 – Solution options (I): Looking beyond borders** Technical solutions from an international perspective Plenary discussion Q & A
12:30–14:00	***Lunch break***
14:00-16:00	**Session 8 - Solution options (II): Looking ahead** Introduction: Applying technical solutions in Guatemala Plenary discussion: Identifying targets, thresholds and prerequisites for solutions
16:00-16:30	***Coffee break***
16:30-17:15	**Closing** Key listener impressions Workshop evaluation
17:15-17:30	**Closing remarks and acknowledgments**

Appendix 4: International Team of Experts

INTERNATIONAL TEAM OF EXPERTS

in alphabetical order

Dr. Tamara Avellán
United Nations University (UNU-FLORES)
Dresden, Germany

As a Research Fellow in the Water Resource Management Unit at UNU-FLORES, Dr. Avellán focuses on the linkages of water, soil, and waste for reducing resource losses. A biologist by profession, she has conducted research on the ecological impacts of water quality in aquatic life and on the effects of excess nutrient loads on plant morphology. She worked with farmers in Uruguay to find sustainable solutions to the increasing sewage loads in the watershed, which led to the installation of the first local constructed wetland that uses endogenous plants species in 2008.

MSc. Lucía Benavides
Consultant at the United Nations University (UNU-FLORES) Dresden, Germany.

Ms. Benavides has a background in community-led environmental work, as well as in sustainable architecture and urban planning. She holds a Master degree on Natural Resources Management from the TH-Köln. She researches on the relations between human and natural systems, human-driven natural resource flows towards other human settlements, and the ways to improve sustainability of these flows. Her work has focused on Latin American cities, where she has studied, for example, the possibilities for recovery of water-related urban ecosystem services in Mexico city, and the natural resource metabolism of mid-sized cities in the region.

Dr. Serena Caucci
United Nations University (UNU-FLORES)
Dresden, Germany

As a researcher at UNU-FLORES, Ms. Caucci contributes to the realisation of capacity development work related to multistakeholder projects such as the Safe Use of Wastewater in Agriculture (SUWA) Initiative and sludge management options. Ms. Caucci has worked closely with transdisciplinary partners and developed wide international collaborations in the field of microbial risks assessment related to sanitation processes and environmental pollution management. Before joining UNU-FLORES, she worked at the Institute of Hydrobiology at the Technische Universität Dresden (TU Dresden) and at the Helmholtz Centre for Environmental Research (UFZ) on water sanitation and antibiotic resistance in anthropogenic-driven environments.

Prof. Jorge Cifuentes
University of San Carlos of Guatemala (USAC)
Guatemala City, Guatemala

Prof. Cifuentes is a Research Professor at USAC. He conducts research in the areas of nanotechnology, biomaterials, and wastewater treatment in the School of Mechanical Engineering and the Engineering Research Centre at USAC. He is keen on teaching post-graduate courses such as Instrumentation and Control, Renewable and Non-Renewable Energy. He obtained his graduate degree in mechanical engineering and nanocomposites at Kyung Hee University in South Korea. Currently he is also conducting research on climate change and sustainability to earn his doctoral degree.

MSc. Néstor De la Paz
Consultant at the United Nations University (UNU-FLORES) Dresden, Germany

As a consultant at UNU-FLORES, Mr. De la Paz applies transdisciplinary approaches with a Geomatics perspective to projects related with sustainability and integrated urban water management. During his recent postgraduate studies at CentroGeo (Mexico City), Mr. De la Paz was involved in applied research to address social needs related to wastewater management through the design, development, and implementation of solutions in Geomatics, GIS and spatial analysis.

Prof. Dr.-Ing. habil. Christina Dornack
Technische Universität Dresden (TU Dresden) Dresden, Germany

Professor Dornack is the Director of the Institute of Waste Management and Circular Economy at TU Dresden. Her key research focus is on sludge and industrial/bio-waste management. Prof. Dornack also teaches courses in circular economy, bioenergy management, and alternative energy supply. Before joining TU Dresden she held various positions within the industrial sector such as Energy Saxony e.V. and obtained years of extensive experience in energy, pulp and paper, and recycling and material resources management.

MSc. Laura Ferráns
Consultant at the United Nations University (UNU-FLORES) Dresden, Germany.

Laura Ferrans is a researcher at the Water Resources and Waste Management Units at the United Nation University (UNU-FLORES). Her research focuses on sustainable wastewater systems. Particularly, she has conducted studies on how to achieve circular economies by implementing the recovery of nutrients through the use of sewage sludge. Her study area focuses on Latin America, where she worked in the wastewater management sector for five years. In 2017, Ms. Ferrans completed her Master studies on Hydro-science and Engineering at Technical University Dresden, Germany. Her Master thesis included a case study of the current sewage sludge management situation in Panajachel, Lake Atitlan, Guatemala.

MA. Angela Hahn
United Nations University (UNU-FLORES)
Dresden, Germany

Angela Hahn is Project Manager of the SludgeTec project. She holds a Bachelor of Arts in Social Work and Master of Arts in Intercultural Conflict Management from Alice Salomon University Berlin, Germany. She worked at the Alice Salomon University as Research Assistant and in the coordination of international projects. Her study focus is on community development and resilience, social vulnerability, conflict resolution, peacekeeping as well as cultural aspects of development. During her studies, she had several opportunities to carry-out various participatory research projects in the field, deepening her special interest in community-based work in Latin America.

MSc. Sabrina Kirschke
United Nations University (UNU-FLORES)
Dresden, Germany

Sabrina Kirschke is a research assistant with the Water Resource Management unit at UNU-FLORES. As a political scientist and PhD student, she is particularly interested in the governance of complex water quality problems. Before joining UNU-FLORES, she worked in several water governance-related projects at the Helmholtz-Centre for Environmental Research (UFZ) and at the Deutsche Gesellschaft für Technische Zusammenarbeit und Entwicklung GmbH in Germany and Uganda

Dipl.-Geol. Roland Knitschky
German Association for Water, Wastewater and Waste (DWA) Hennef, Germany

Mr. Knitschky is a Hydrogeologist and Capacity Developer in the water sector. He is currently the DWA Project Manager and the Subject Specialist for International Cooperation. He has over 20 years of German and international experience within the water and wastewater sectors and specifically in the areas of technical standards and associations as tools for self-organisation in the water sector, human resources and organisational development, “Train the Trainer” qualification and curriculum for skills development. Prior to joining DWA, he was at the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) for several years as a Technical Advisor and a Project Manager.

Mr. Carlos A. Paillés
Fideicomiso Infraestructura Ambiental de los Valles de Hidalgo (FIAVAHI)
Hidalgo, Mexico

Mr. Paillés is the main trustee of FIAVHI. He is also the current President of the Committee of Certification of Technified Irrigation with Reclaimed Water Capacity. Mr. Paillés has years of broad experience in natural resources management and water management. Since 1999 Mr. Paillés has led many initiatives to promote safe use of wastewater in agriculture. This includes design and implementation of 29 waste-water treatment plants (WWTP) in the State of Oaxaca, Mexico. Since 2008 he has implemented 15 WWTPs in the Mezquital Valley and Tepeji Municipality as pilot projects specifically for wastewater use in agriculture.

Appendix 5: List of Participants

Participants represented different stakeholder groups, amongst them academia, federal officials, NGOs, private enterprises, municipal officials, and organisers.

Participation List Assessment Workshop Panajachel Guatemala, March 2018			
No.	**Institution**	**Name**	**Stakeholder group**
1	Universidad Rafael Landívar / URL	Joaquín Emilio Arango Aragón	Academia
2	USAC	Víctor Hugo Dardón Castillo	
3	USAC	Pablo Daniel Román Figueroa	
4	USAC	Nicolle Rabre Chacon	
5	USAC	Walter Oswaldo Sumpalaj López	
6	USAC	Gabriela Micheo	
7	USAC	Luis Arturo Lopez Quivedo	
8	USAC	Moises Méndez	
9	USAC	Edy Rodelbí Juárez González	
10	USAC Facultad de Ingeniería	Miriam Alejandra Saban Ramírez	
11	USAC Facultad de Ingeniería	Erick Arturo Mellado Cabrera	
12	USAC Facultad de Ingeniería	Gustavo Adolfo Ortiz de León	
13	USAC y Municipalidad de Panajachel	Alejandra Mejía	
14	USAC-CUNSUROC	César Ivan Rodríguez Alvarado	
15	CEA-UVG	Ovidio García	
16	Centro de Investigaciones de Ingeniería	Saulo Moisés Méndez Garza	
17	ERIS / AMSCLAE	Felix Aguilar	
18	INAB Sololá	Salomon Can Saquic	Federal officials
19	AMSCLAE	Elsa Ma. de Fátima Reyes Morales	
20	AMSCLAE	Manolo Monroy	
21	AMSCLAE	Flor Barreno Ortíz	
22	Ministerio de Ambiente y Recurso Naturales / MARN	Carlos David Aroche Quevedo	
23	Ministerio de Ambiente y Recursos Naturales / MARN	Elida Urquizú	
24	SENACYT	Efrain Paiz	
25	SENACYT	Aldo Lopez	
26	SENACYT	Melissa Guzmán	
27	SENACYT	Ericka Castillo	
28	INAB	Eduin Rolando Mendoza	
29	Agua del Pueblo	Manuel Victor Felix Racancoj Sac	NGOs
30	ANACAFE	Doris Vega	
31	ANACAFE / ANALAB	Daniel Martinez	
32	Amigos del Lago de Atitlán	Marianne Leonhardt	
33	Amigos de Lago Atitlán	Haydeé de la Paz Marroquín González	
34	Amigos del Lago de Atitlan AALA	Ana Cecilia Garcia Villeda	
35	Pura Vida Atitlan	Carlos Tambriz Chox	
36	Director PTAR Santa Cruz la Laguna / ROTARIO	Enrique Cosenza	
37	Ingeniería / Operador de la Planta de San BartoloSolola	Rodolfo Espinosa Smith	Private enterprise
38	Cementos Progreso	Oscar Gramajo	
39	Milagro del Lago S.A.	Jose Isaias Ramos Saquil	
40	Municipalidad de Panajachel	Julio Ernesto Pablo de León	Municipal officials
41	Municipalidad de Panajachel	Genaro Santiago Umul Tiguila	
42	Municipalidad de Panajachel/PTAR	Edgar Obed Alcántara Espinoza	
43	USAC	Jorge Iván Cifuentes Castillo	Organizers
44	USAC / Estudiante Jorge	Christian Marco Antonio Argueta Argueta	
45	USAC / Estudiante Jorge	Moris Uxlab Pineda Cardona	
46	USAC / Estudiante Jorge	Jennifer Paiz	
47	USAC / Estudiante Jorge	David Emanuel Girón Chávez	
48	USAC / Estudiante Jorge	Alan Josue David Martinez Catalan	
49	DWA	Roland Knitschky	
50	FIAVHI	Carlos Pailles	
51	FIAVHI	Ana Lilia Velasco	
52	FIAVHI	Emma Muñoz Alvarado	
53	FIAVHI/ UNU-FLORES	Nestor De La Paz	
54	UNU-FLORES	Laura Ferrans	
55	UNU-FLORES	Serena Caucci	
56	UNU-FLORES	Sabrina Kirschke	
57	UNU-FLORES	Lucia Benavides	
58	UNU-FLORES	Angela Hahn	
59	UNU-FLORES	Tamara Avellán	

Appendix 6: Snapshots from the Workshop







Nexus Approach
UNU-FLORES Nexus Approach
IDENTIFICAR
DATA ITEMS

UNITED NATIONS
UNIVERSITY

UNU-FLORES

The United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES) was established in Dresden, Germany in 2012 with the support of the Federal Ministry of Education and Research (BMBF) and the Ministry for Higher Education, Research and the Arts (SMWK) of the Free State of Saxony, Germany. As part of the United Nations University (UNU), the Institute helps build a bridge between the academic world and the United Nations. UNU encompasses 13 research and training institutes and programmes located in 12 countries around the world. UNU as a whole aims to develop sustainable solutions for pressing global problems of human survival and development.

UNU-FLORES develops strategies to resolve pressing challenges in the area of sustainable use and integrated management of environmental resources such as water, soil, and waste. Focusing on the needs of the UN and its Member States, particularly developing countries and emerging economies, the Institute engages in research, capacity development, advanced teaching and training, as well as dissemination of knowledge. In all activities, UNU-FLORES advances a Nexus Approach to the sustainable management of environmental resources.

Find more information at: **flores.unu.edu**

ADVANCING A NEXUS APPROACH TO THE SUSTAINABLE MANAGEMENT OF ENVIRONMENTAL RESOURCES

United Nations University
Institute for Integrated Management of Material Fluxes and of Resources
Ammonstrasse 74, 01067 Dresden, Germany
Tel.: +49 351 8921 9370 | Fax.: +49 351 8921 9389
Email: flores@unu.edu

@unuflores @UNU_FLORES

flores.unu.edu