WASTEWATER IRRIGATION IN THE MEZQUITAL VALLEY, MEXICO: SOLVING A CENTURY-OLD PROBLEM WITH THE NEXUS APPROACH

PROCEEDINGS Tepeji del Rio O Campo, Mezquital Valley, Mexico 15-17 March 2017

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Wastewater irrigation in the Mezquital Valley, Mexico: Solving a century-old problem with the Nexus Approach

Proceedings of the International Capacity Development Workshop on Sustainable Management Options for Wastewater and Sludge

Serena Caucci and Hiroshan Hettiarachchi, Editors
(UNU-FLORES)

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Fideicomiso Infraestructura Ambiental de los Valles de Hidalgo Mexico (FIAVHI), Hidalgo, Mexico; Technische Universität Dresden (TU Dresden), Dresden, Germany; Training and Demonstration Centre for Decentralized Sewage Treatment e.V BDZ, Leipzig, Germany; University of San Carlos of Guatemala (USAC), Guatemala City, Guatemala; and Municipality of Tepeji del Rio O Campo

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Background

The United Nations University for Integrated Management of Material Fluxes and of Resources (UNU-FLORES) promotes the application of an integrated and sustainable approach to managing environmental resources and furthering the concept of the water-soil-waste nexus (WSW nexus). Safe use of wastewater in agriculture (SUWA) is one excellent example that showcases this concept. UNU-FLORES has been advocating for safe use of wastewater since the inception of its research and capacity development agenda, and has worked with many other organisations and Member States to improve the current understanding and to produce new knowledge.

Mexico's Mezquital Valley is a place often cited in SUWA literature as a excellent case study due to its extent (over 90,000 hectares (ha)) and long history of wastewater use in agriculture (for over 100 years). Wastewater irrigation has given the farmers in this semi-arid region not only a solution for the problem of water scarcity but also a method to increase their crop yield. However, it has also caused many environmental, sanitary, and social issues at the same time. The State of Hidalgo, together with the Fideicomiso Infraestructura Ambiental de los Valles de Hidalgo Mexico (FIAVHI), is determined to find sustainable and long-lasting solutions to these issues.

Within this context, UNU-FLORES was pleased to join forces with FIAVHI and the Municipality of Tepeji, Mexico, to co-organise this International Capacity Development Workshop on Sustainable Management Options for Wastewater and Sludge. The UNU-FLORES team is also bringing to Mexico international members from the Technische Universität Dresden (TU Dresden), the Training and Demonstration Centre for Decentralized Sewage Treatment (BDZ e.V.), the Universidad San Carlos de Guatemala (USAC), and the University in Santiago de los Caballeros, Dominican Republic (ISA).

Both UNU-FLORES and FIAVHI have used this opportunity to lay the foundation for a long-lasting and mutually beneficial partnership. With the emblematic presence of the Mayor of Tepeji del Rio O´Campo (C.P. Moises Ramirez Tapia), FIAVHI (Carlos A. Pailles) and the President of the Council (Junta de Gobierno del Congreso del Estado de Hidalgo), MSc. Maria Luisa Pérez Perusquía, this workshop has received support for future activities in the Mezquital Valley, with special regard to the full sanitation of the region, the remediation of contaminated Raquena Lake, and improved solid waste management in the Municipality of Tepeji del Rio O´Campo.

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Section 1: Setting the Scene

1.1 Introduction

As a solution to water scarcity and groundwater abstraction, the use of reclaimed water for agricultural irrigation has been practised in arid and semi-arid countries for years, with different success rates. Wastewater today irrigates between 1.5% and 6.6% of the global irrigated area of 301 million ha (1.2 million square miles), and about 10% of the world´s food is produced using wastewater. Despite the direct benefits, health concerns around this practice are growing because the reuse of often untreated wastewater is the cause of health problems and continuous environmental pollution. Agricultural and water policies have not sufficiently addressed the inherent threats posed by the use of untreated wastewater for irrigation. Often, hazardous materials, in the form of heavy metals, organic contaminants, pathogens or antibiotic-resistant bacteria, can be found in wastewater and sludge. These accumulate in soils, crops, and groundwater, and so pass into the food chain. The experience of industrialised countries shows that even advanced wastewater treatment technologies struggle to address all of the risks. Unfortunately in many areas of the world the selection and use of sustainable technologies that provide swift responses to ensure the safety of communities have still to be addressed.

The Mezquital Valley in Hidalgo, Mexico, perfectly illustrates all of these issues. Rapid urbanisation and inadequate treatment facilities have led farmers in the valley to use untreated wastewater from Mexico City for irrigation purposes. For more than a century, this practice has helped farmers grow marketable crops at low production costs. However, these benefits might have come at the cost of the population´s health.

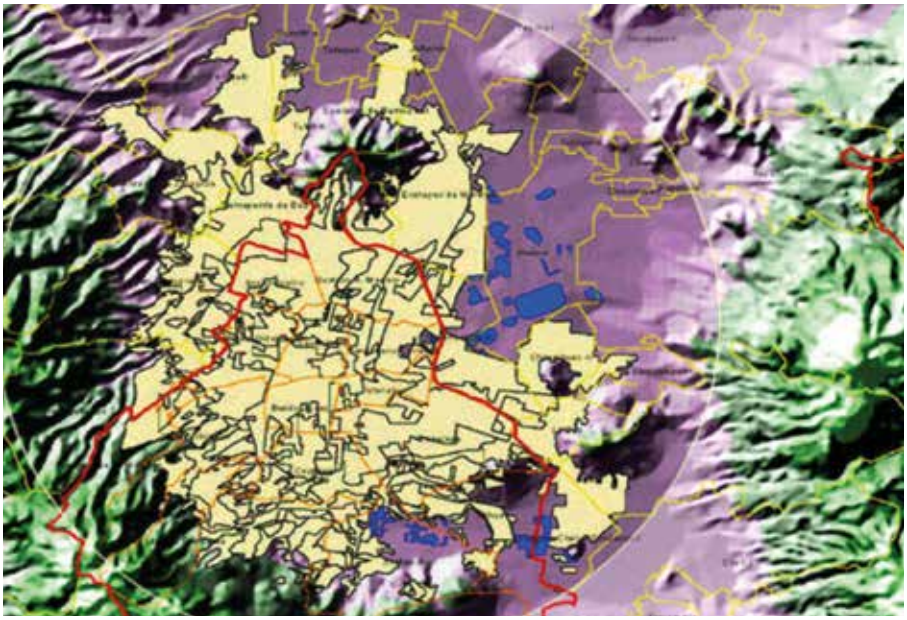


Figure 1: Actual urban area (yellow) and basin water reservoirs (blue) of Mexico City (2000) (Photo: Christina Siebe).

To ensure the safety of the population, laws and practices should ideally be pushing to reduce the problems related to unsafe wastewater usage. As this is unlikely, novel approaches that are capable of considering better management of natural resources should be developed.

The planned development of a standardised procedure for evaluating the benefits of an integrated approach under the WSW nexus will be of help to governments and local communities, which could capitalise on social pressure and force the involved stakeholders to think about the "safe use" of wastewater and long-term goal investments.

1.2 Water Reuse in Agriculture (SUWA) and the Nexus Approach

In the inaugural session, **Prof. Hiroshan Hettiarachchi (UNU-FLORES)** explained why SUWA is important for UNU-FLORES, and how it is related to the Nexus Approach – the material resources management approach advocated by UNU-FLORES.

SUWA is an excellent example that clearly illustrates the importance and benefits of integrated management of water, soil, and waste, which is defined as the Nexus Approach. The process begins in the waste sector, but a sustainable management model can make it relevant and important in relation to the other resources, such as water and soil. Proper management of wastewater provides not only a secondary source of water for some specific use, but also nutrients that can be fed back to the soils. These synergies can make an important contribution towards achieving food security as water, soil, and waste are three key environmental resources involved in crop-based food production.

Even though over 20 million hectares of land are currently irrigated with wastewater, a greater percentage of this practice is not based on any scientific criterion that ensures the "safe use" of that waste water, including in parts of the Mezquital Valley. In order to address the technical, institutional, and policy challenges of safe water reuse, places such as the Mezquital Valley need clear institutional arrangements and more skilled human resources, with a sound understanding of the opportunities and potential risks of wastewater use.

1.3 The Workshop Concept

In this workshop, new solution pathways were suggested. Knowledge on the Nexus Approach was introduced to the local stakeholders. The approach considered the management of the natural resources, namely waste soil and water, in a holistic manner. During the workshop, involved stakeholders, as well as positive and negative externalities defining the nexus, were evaluated and the factors governing the added value for the region were identified. The Nexus Approach has the capacity to demonstrate that in the long run, the benefits are higher than the costs if a sustainable reuse of wastewater is applied.

Data gathering is unfortunately one of the bottlenecks for the development of such an approach. Often, information is either not publicly available or is retained by community-based associations and/or institutions at the regional level. Similarly, technical expertise and social awareness of the benefits of the sustainable use of wastewater and sludge in agriculture have not been sufficiently spread among stakeholders. SUWA thus has to be promoted as a good practice.

In this workshop, knowledge and know-how were gathered in Tepeji del Rio O Campo, Hidalgo. Local and international experts were invited to give their perspectives on the actual and future scenarios for the Mezquital Valley. The workshop raised awareness of the benefit of the Nexus

Approach for a sustainable use of wastewater and sludge in agriculture. International experts highlighted the challenges and benefits of such practices, after having involved the audience in an open discussion.

A survey was used to gather the information necessary to demonstrate the feasibility of the Nexus Approach in the Mezquital Valley. Through the workshop, UNU-FLORES and FIAVHI aimed to shape a dedicated expert group capable of developing an econometric model to quantify the benefits of the safe use of wastewater in the Mezquital Valley, at different stakeholder levels.

No value model can drive sustainable solutions if suitable technologies are not first identified. In the workshop, improved wastewater technologies, as well as innovative irrigation options fitting the purpose of wastewater reuse, were suggested and evaluated by the participating eperts in terms of wastewater sanitation and nutrient release. Sustainable management of sludge in decentralised treatment offers the hidden potential of additional resource recovery.

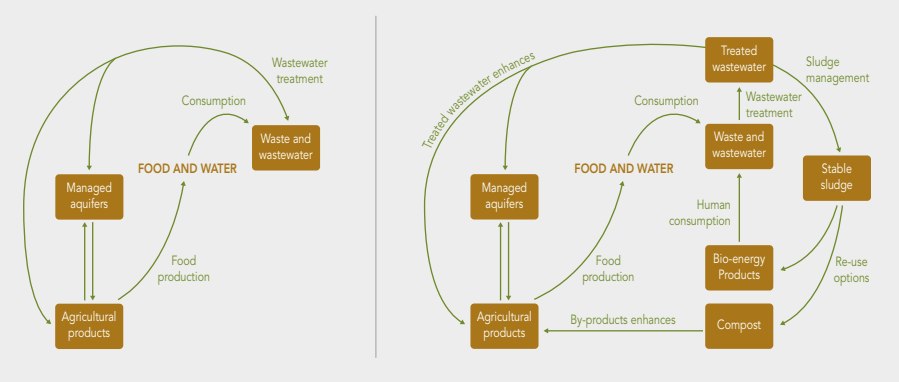


Figure 2: Schematic representation of current and suggested Nexus Approach for natural resource management in the Mezquital Valley, Mexico (Source: Serena Caucci).

Section 2: Understanding the Problem

2.1 The Mezquital Valley: Issues and Solutions in the Making

Prof. Christina Siebe (National Autonomous University of Mexico (UNAM)) introduced the current and past challenges related to the introduction of untreated wastewater as an irrigation practice in the Mezquital Valley.

The Mezquital Valley is a unique example of wastewater reuse practice in terms of area employed (90,000 ha) and temporal scale (more than 100 years). The soil-aquifer-treatment system was developed as a consequence of the drainage of the closed basin of Mexico to avoid flooding in Mexico City. It has grown in response to the increase in the city's population and wastewater discharge volumes. Wastewater is a valuable resource in the semi-arid region north of Mexico City and its reuse enables the production of mainly fodder crops and maize, thus achieving above-average yields. UNAM investigated the effects of wastewater irrigation by sampling fields irrigated

for different lengths of time, and by repeatedly monitoring single irrigation events. Results confirm that wastewater irrigation leads to consistent recharging of groundwater and increased crop yield.

Heavy metals accumulated in the first 20 cm of the soil; however, their availability to plants is small due to the alkaline pH values and the medium to large soil organic matter content. Also, pharmaceutical compounds accumulate in the topsoil, and an increase in the presence of antibiotic resistance genes was observed. Epidemiological study indicated a larger prevalence of helminth infections among children in the irrigated area compared with a nearby area where rain-fed agriculture takes place. Excess nitrogen is applied to the fields by overflow irrigation, and although the current system uses nitrogen quite efficiently the recharged groundwater is polluted with nitrate.

All of these findings give a clear indication of the need to improve wastewater reuse practices and wastewater management in the Mezquital Valley. Special attention has to be given in the first place to the hygiene measures that farmers should take. The amount of water and nutrients provided to the fields also needs to be optimised.

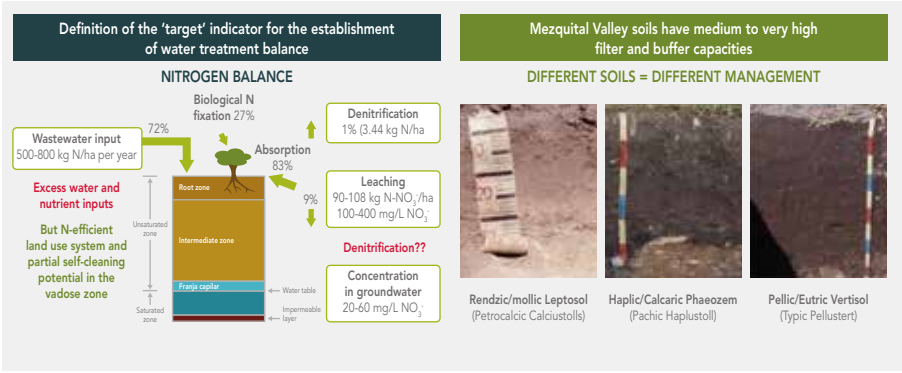


Figure 3: Nitrogen balance and suggested ad hoc soil management during wastewater reuse in the Mezquital Valley, Mexico (Source: Christina Siebe).

2.2 "Wickedness" of the Problem

Dr Tamara Avellán (UNU-FLORES) moderated a breakout session to analyse the "wickedness" of the problem of the Mezquital Valley.

Many infrastructural projects in the field of water supply and wastewater treatment have failed because of difficulties regarding 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 particular 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. From the output of the workshop, the problem of "Safe use of wastewater in the Mezquital Valley" can be considered to be highly wicked.

During the breakout session, three separate groups were formed and the participants were kindly asked to join in the group they were assigned to. A timekeeper and a rapporteur to report

back to everyone were chosen for each group. Three predefined questions were presented on a screen for all groups and the total stipulated time to write down the answers to the questions on coloured paper was 15 minutes. Nearly 10 minutes were given to discuss the answers to each question. A summary of the main outcome from this breakout session is presented below (after the figure) and details of the questions are given in Annex 3.

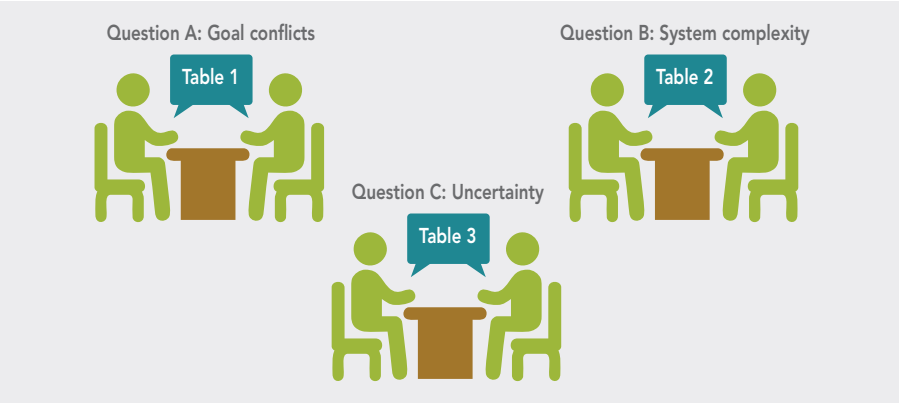


Figure 4: Schematic representation of the breakout discussion tables.

Goal conflicts ***(wickedness level: HIGH):*** The common interests of actors, especially regarding the prioritisation of economic aspects, were highlighted in the workshop. However, there is also a relevant conflict of interest between stakeholders. On the one hand, some actors are interested in the reuse of wastewater. On the other hand, different actor groups, such as farmers, consumers, and the health sector, have concerns about reusing wastewater. Farmers, for instance, refrain from changing their water use practices due to a lack of trust (officers and operations and maintenance (O&M) operators) and knowledge. By the same token, consumers feel uncertain about the irrigation of crops with wastewater. The health sector has particular concerns about epidemics, such as cholera, in the Mezquital Valley. To address these conflicting interests there need to be negotiations between all actors involved. However, politicians seem to face legal limitations in such matters and tend to prioritise other aspects.

System complexity ***(wickedness level: HIGH):*** SUWA in the Mezquital Valley is influenced by a large amount of factors: the actors involved, the management of wastewater reuse practices, the geographical location, the lack of alternative options to the untreated use of wastewater, and framework conditions. In terms of actors, the participants in the workshop highlighted interactions between groups of actors (government, farmers, and the society) that have different educational backgrounds and different interests in relation to wastewater reuse. This fact complicates the development of a common solution.

Factors influencing the application of safe wastewater reuse in agriculture in the Mezquital area are also subject to dynamic processes. In terms of actors, for instance, the continuous population growth and turnover of politicians every five years complicate planning processes. Moreover, the interconnections between factors do not make changes in agricultural practices or in policies possible. An example of an interconnection is that between crop type, irrigation techniques, and ownership of land. To understand and address the system complexity, governments and public authorities need to apply models and decision support tools. However, schools and the general public also need support and stewardship on SUWA, and more awareness of the risks connected to untreated wastewater practices.

Informational uncertainty *(wickedness level: MEDIUM):* There is a lack of information on the safe reuse of wastewater in agriculture on the part of both government and local communities. Despite the fact that certain stakeholders have knowledge of the risks connected to untreated wastewater practices and safe reuse of treated wastewater in agriculture, such information has not been shared with the relevant actors. At the same time, the available information is not used by the relevant actors because either the language used in sharing the information is too difficult to be understood by the local population or information is not specific enough to the local situation. Lack of information typically relates to information about social benefits, wastewater outflow quality, the benefits of wastewater treatment, and costs.

Nevertheless, from the workshop breakout session it appears that the diffusion of relevant information among stakeholders seems to be feasible. Information seems to be available in relevant governmental offices, among local experts and in official documents (for example, the Mezquital Valley agricultural and health census). Studies on the use of treated and untreated wastewater, as well as on wastewater technologies available for SUWA, are available but the reporting on, and diffusion of, such studies needs to be improved. Social barriers are also impeding the availability of best practice examples for implementation studies. However in spite of awareness, other issues, such as goal conflicts and system complexity, appear to be greatly responsible for slowing down the transformation of agricultural practices in the Mezquital Valley.

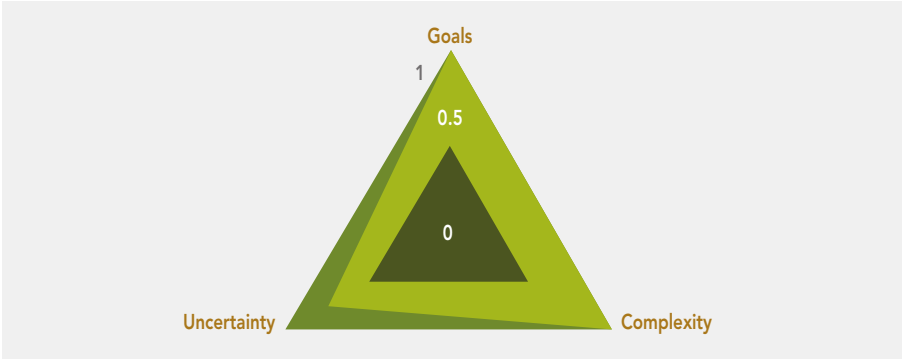


Figure 5: Wickedness of the problem of "Safe use of wastewater in the Mezquital Valley".

Section 3: Economic Aspects

3.1 Modelling the Economic Aspects of Wastewater Reuse

The importance of the economic modelling of wastewater was emphasised by **Prof. Edeltraud Günther (TU Dresden)** in her talk during the second day of the workshop.

SUWA is a crucial issue in the Mezquital Valley, involving multiple stakeholders' concerns and different solution approaches. In this lecture, Prof. Günther elaborated on the complexity of wastewater irrigation in agriculture and assessed the economic aspects related to this practice.

Stakeholder analysis and the identification of external effects, costs, barriers, and success factors of wastewater irrigation were discussed and the options of treated and untreated use of wastewater in agriculture were considered.

Identifying the core problem of the Mezquital Valley agricultural practices was vital for the development of the econometric model. Such a model cannot be developed if interactions between people and the environment are not taken into account. An organisation's impact on the natural environment is defined as the *inside-out effect,* which can be both supportive of, and harmful to, the environment, whereas people's dependency on the natural environment and environmental impacts on organisations cause the *outside-in effect*. In this context, *external effects* are defined as the use of resources. External effects also represent influences that might affect the direct utility for others and cannot be simply governed by the price mechanism, and cannot be controlled by the economic subject that is affected by the external effect. Due to circumstances, such as distance, synergies, long-term effects, diffusion, and accumulation, external effects are particularly difficult to assess.

Complex systems are characterised by behaviour that is difficult to predict

1. Nonlinearities:

    - sensitive dependence to initial conditions
    - unintended consequences
    - emergent behaviour
    - self-regulation
    - self-organisation
    - complex vs. complicated

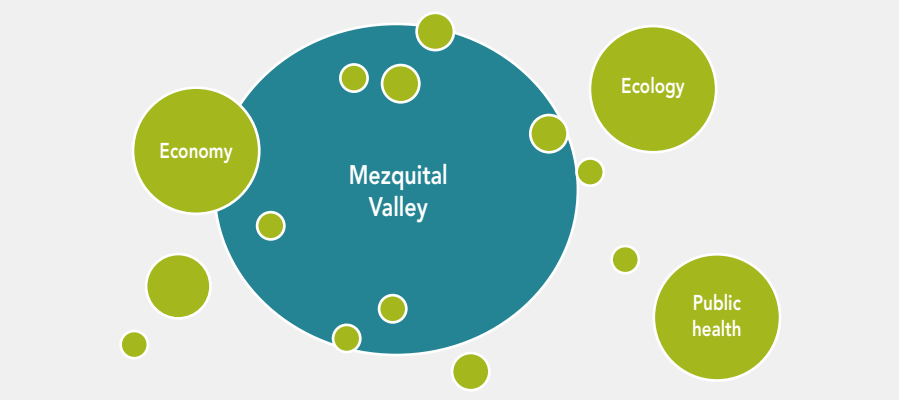


Figure 6: Schematic representation of the Mezquital system's complexity.

The corporate water stewardship seeks to capture the value of water as a socially equitable, sustainable, and economically beneficial resource. The concept proposes to engage in individual and collective actions concerning water use and treatment that benefit all stakeholders involved.

To evaluate an econometric model for the safe reuse of wastewater in agriculture in the Mezquital Valley, time-related three-step scenario evaluations have been built to discuss: (1) the *process innovation,* focusing on the construction of the wastewater treatment plants aiming at safe use of wastewater; (2) the *organisational innovation,* referring to the know-how needed to achieve the goals of sanitation and safe wastewater irrigation practices; and (3) the *product innovation,* or perhaps *marketing innovation*. Market innovation, in the context of the Mezquital Valley, relates to all ideas, product innovation, and marketing strategies that seek to encourage public acceptance of wastewater treatment.

The identification of the relevant stakeholders involved and their categorisation as regards power, legitimacy, and urgency is necessary in order to complete the scenario analysis of the Mezquital Valley case. In the context of wastewater reuse for agricultural purposes, the main actors identified were: farmers, owners of the land, the municipality, inhabitants/customers, the local municipality, the national government, FIAVHI, medical doctors, and a series of powerful organisations. A list of the stakeholders will be of help in regard to taking strategic action.

The analysis of the costs involved in the reuse of wastewater in agriculture will play a central role in defining an econometric model which will identify and quantify the benefits of SUWA. This model will thus be of help for practitioners and policymakers, who will be equipped with tools that are capable of providing solid evidence, and thus of advancing SUWA practices in the Mezquital Valley.

In general, a positive correlation between positive environmental performance and operational performance exists. With regard to: the example of the Nexus Approach, the complex cost and revenue flows of commissioning a treatment plant were approached in the workshop. The sustainable economic model should detail how the differences between the use of wastewater and use of treated wastewater in the Mezquital Valley developed and demonstrate the payoff in regard to a medium-/long-term investment.

During the investment process, the costs have been classified as *costs of action* and as *costs of inaction*. In the Mezquital Valley case study, active costs of action are supposed to avoid, reduce, substitute, recycle, and dispose. *Costs of inaction,* instead, are associated with opportunity costs, legal sanctions, and pollution rights and bargaining. Both types of costs can be passed on to participating stakeholders.

Central drivers of, and barriers to, the project have been arranged by the *External Environment Organization Individual Barrier Model,* from the perspective of a farm. For Mezquital Valley the following stakeholders are identified: owners of the land, municipality, inhabitants, the national government, FIAVHI, medical doctors, and powerful organisations. The farm is focused on the organisational level of analysis. One barrier related to the farm concerns the culture, for instance the mind-set passed on by one generation of farmers to the next generation, and one barrier related to organisational learning concerns capacity-building and the change in irrigation practices, like drip irrigation or the use of (treated) wastewater for irrigation. The individual is shaped by ability and attitude concerning the irrigation method. Change induces barriers; thus it is vital to identify these barriers, in order to reduce them and thus facilitate capacity-building and the identification and implementation of more sustainable irrigation methods in the Mezquital Valley.

Consequently, the aim of the workshop was to identify relevant stakeholders, and to identify their costs and barriers. At the end of the presentation the participants were asked to identify and discuss the externalities of the wastewater irrigation scenarios in the Mezquital Valley.

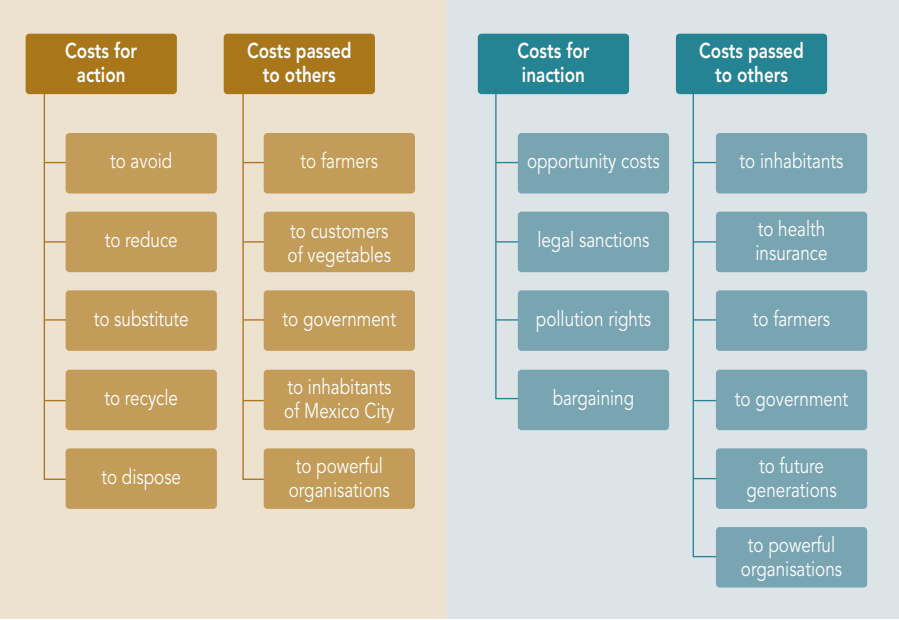


Figure 7: Schematic representation of costs identification related to the Mezquital Valley.

Figure 8: Modified from Zurek, M. B., Henrichs, T. (2007). Linking scenarios across geographical scales in international environmental assessments, *Technological Forecasting and Social Change* 74 (8): 1282–1295.

3.2 Identification of the Externalities

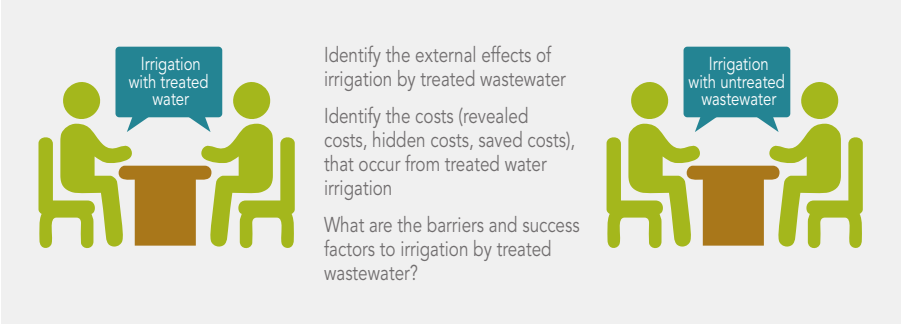


Figure 9: Questions for the session "Identification of Externalities".

Dr Ann-Karen Hüske (TU Dresden) coordinated a breakout session to identify external effects, costs, barriers, and success factors, as shown in Figure 9.

During the breakout session, separate groups were formed. A timekeeper and a rapporteur to report back to everyone were chosen for each group. The main findings from the breakout session are summarised below.

Stakeholder analysis: The analysis showed that a variety of stakeholders and stakes are involved in this question. The famers need to rethink their water reuse practices, to move from untreated to treated water irrigation. In general, the local community seems to be very concerned by health aspects as well as by the costs related to the construction of new wastewater treatment plants. The current government is seeking an intermediary solution that balances multiple stakeholder needs.

The main difficulties of the government are related to the farmers, who would like to maintain their use of untreated wastewater in agriculture, and the requests of consumers, who are negatively affected by such practices. Conflicting stakeholder interests are related to external effects. Therefore, it is important to identify the different stakes and negotiate the interests of the stakeholders. With the involvement of as many stakeholder perspectives as possible, a list of powerful stakeholders was drafted and a priority list of action strategies to be adopted was shaped.

External effects of irrigation by wastewater: The participants largely stressed the change in wastewater reuse practices, health implications, and environmental pollution as the main concern of the reuse of untreated wastewater in the Mezquital Valley. Environmental pollution has also been associated with new emerging diseases. The pollution of freshwater with heavy metals by wastewater has been claimed to be a principal cause of the increased incidence of kidney cancer among locals. Irrigation with wastewater saves fertilizer. Furthermore, the water is comparably cheap and is available in a (semi-) arid area.

Costs involved in wastewater irrigation: In terms of costs, the production costs saved by farmers who use wastewater (freshwater use and fertiliser costs) are in contrast with the health costs related to gastrointestinal infections and cancer treatments that have to be covered by both government and individuals. Additional costs are the increased environmental pollution and the remediation activities necessary to recover natural resources.

Newer irrigation methods, like drip irrigation instead of flooding irrigation, seem advisable and open up new business opportunities in the wastewater reuse crop market. Consequently, a larger variety of crops can be cultivated in compliance with the safety measures of the World Health Organization (WHO) guidelines for treated wastewater irrigation. The new irrigation method makes it possible to grow crops that promise a higher income. Larger marketability also means a bigger family income. Nevertheless, higher costs for crop production are foreseen and the need to build treatment plants adds additional costs for the operation and maintenance of the water sanitation infrastructure.

Barriers and success factors: In all areas of innovation there are always factors which might hamper, delay or block the innovation process. These factors are called barriers. Within the workshop, the retrieved costs for wastewater treatment were identified as the major barriers to be overcome. Other barriers identified were the lack of education and implementation, as well as the locals' attitudes. Identified success factors for the safe use of treated wastewater in agriculture were pollution reduction, increased wealth and health, resource recovery, improved public image, training, jobs for women, and a higher crop yield. Such factors, if promoted, can promote the change.

Section 4: Wastewater and Sludge Management

4.1 Decentralised Wastewater Treatment Options

After a brief introduction to the Training and Demonstration Centre for Decentralized Sewage Treatment e.V (BDZ) **Dr Khaja Z. Rahman (BDZ)** presented a video (nearly eight minutes in length) on his work in a severely water-scarce region in the Middle East (Jordan, Israel and Palestine), which demonstrated how international cooperation is helping in the development of decentralised wastewater treatment solutions. The strategy of having a long-term capacity development programme is also one of the key factors for successful implementation strategies. Dr Rahman focused on Jordan as a case study example. Research results from multiple pilot-scale eco-technologies (for example, innovative constructed wetlands) for treating wastewater were illustrated and the discussion of the modality adopted for the development of SUWA guidelines in Jordan helped the participants to learn from good practice examples in the field of policy implementation driven by technological implementation practices.

An example of a subsurface irrigation trench system for the treated wastewater reuse option was explained. Such technology has the advantage of avoiding elevated water loss due to evapotranspiration. Ad hoc decentralised wastewater treatment options for sewage sludge treatment in the Mezquital Valley were suggested. The pros and cons of each technology were also briefly discussed. Finally, the activities of various capacity development programmes, such as school and university education, vocational training for engineers and technicians, development of an implementation office in Jordan, and most importantly the "Water Fun – Water for Life" programme for school children, were introduced to the audience as successful stories of an educative implementation learning process.

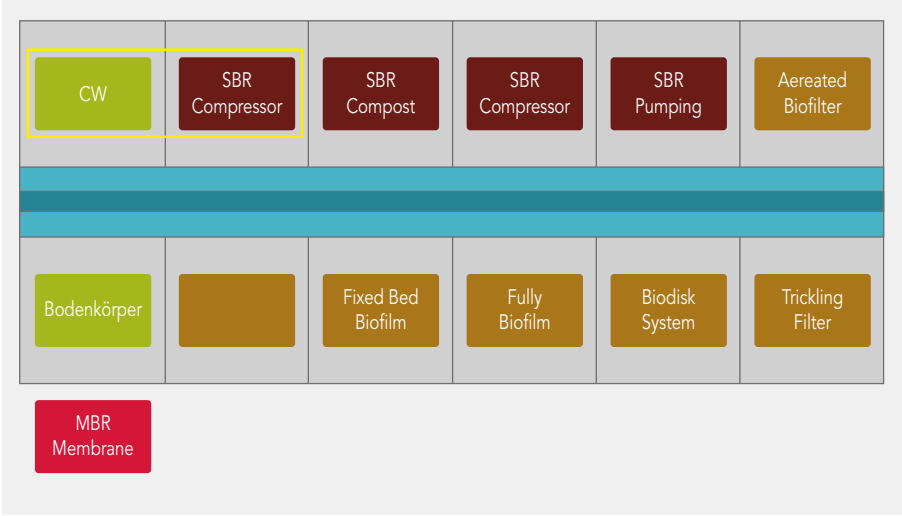


Figure 10: Decentralised wastewater treatment plant options for the treatment of wastewater in the Mezquital Valley.

4.2 Sludge Management Options

The options available for sludge management were the topic of the talk given by **Prof. Christina Dornack (TU Dresden).** She explained how sewage sludge can be a valuable material which can be reused for multiple purposes. Prof. Dornack quantified the amount of sludge produced in standard municipal wastewater treatment plants, stressing the hidden potential of sludge as a fertiliser, given the high content of nutrients and trace substances. Stabilised sludge can be good organic matter for soil amendment but it can also be a hazard. The aim of sustainable sludge treatment is to close the loop for nutrients and the reuse of natural resources for soil improvement. At the same time sustainable sludge management provides the safe disposal of hazardous material when the use of sludge is not feasible due to high concentrations of persistent pollutants (in other words, heavy metals, pharmaceuticals). In the workshop, the possible technical options for sustainable sludge management in the Mezquital Valley were discussed (reduction of biological activity, reduction of sludge amount – for example due to dewatering – reduction of pathogens by anaerobic, aerobic or thermal treatment). Alternative solutions to make reuse of sludge in a circular economy manner were provided. Due to the high energy characteristics of sewage sludge cement kilns or co-combustion plants were advised as a way of boosting the local economy.

Table 1: Amount of total solids and sludge per inhabitant produced by municipal wastewater treatment plants

Sludge amount/ihnhabitant

	Total solids	**Sludge amount**
Primary sludge	45g/inh/d	0,9 l/inh/d
Secondary sludge	35g/inh/d	5 l/inh/d
Sum	**90g/inh/d**	**2.25 l/inh/d (thickened)**

Table 2: Sludge treatment – chemical oxygen demand (COD) and energy recovery from sludge

Treatment	g/ihn/d	Energy equivalent (kwh/inh/a)
COD in influent of WWTP	120	140
COD in primary sludge	40	47
COD in secondary sludge	33	38
COD removal in activated treatment	41	48
COD in effffluent	6	7
~ 60% (85kWh/inh/a) can be used for energy recovery ~ 50% (~ 45kWh/inh/a) can be recovered by AD (th+el) ~ 30% – 80% of energy demand of WWTP		

4.3 Opportunities and Challenges

A breakout session was moderated by **Dr Khaja Z. Rahman (BDZ)** to discuss the opportunities and challenges in sludge management. The questions discussed and a brief summary of the outcomes are presented below.

Question A What do you actually do with your sewage sludge? What are you planning to do with the sludge (within the next two years/five years/20 years)?

Question B What are the opportunities for the use of stabilised sludge for soil amendment/ soil conditioner?

Question C Apart from soil amendment, what else you can do in order to reduce the amount of sludge?

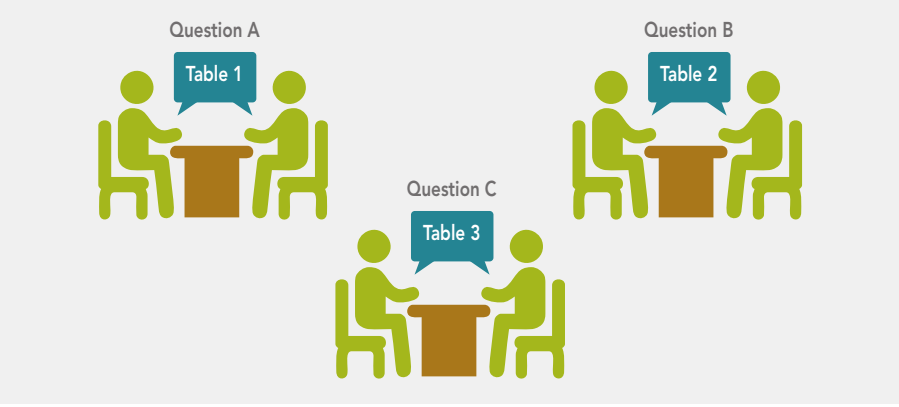


Figure 11: Schematic representation of the breakout discussion tables.

General content of the session: Sewage sludge management seemed to be an unfamiliar issue for the participants, mainly due to lack of excess sludge production within the conventional wastewater treatment plants in Mexico. However, the answers provided by the participants and overall discussions for each individual question were quite convincing and were also covered within the stipulated time period. The blend of participants from different backgrounds gave an opportunity to the rapporteur to report back with meaningful and thoughtful answers on each question. The discussions were developed in a very open and friendly atmosphere within each working group. Asking the same questions with three different groups benefited the whole session. Constructive answers were recorded from each group and those that recurred across the tables were catalogued as high interest themes.

Barriers and next steps: Based on the preparatory discussions on sludge management issues in Mexico and the experience gained by visiting several treatment plants prior to the main workshop session, it was a big challenge for the session moderators to select the questions that were finally asked of the participants. However, due to a lack of fundamental knowledge, and practical experience, of sewage sludge management among the participants, it was difficult to come up with a concrete concept or solution for how the sewage sludge should be properly handled in the near future. Several barriers need to be overcome to increase the adoption and utilisation of eco-technologies for sewage sludge management in Mexico. A well-structured and long-term capacity development programme on wastewater and sludge issues would be the first major step forward within the region in the coming days.

Section 5: Health Aspects

5.1 Wastewater Management and Health

Serena Caucci MSc (UNU-FLORES) presented on the correlation between wastewater management and health aspects in relation to the use of wastewater in agricultural practices. She highlighted the necessity of an appropriate co-design of wastewater management that would take into account health and technical expertise as well as agriculture practitioners.

In her talk Mrs Caucci highlighted how wastewater could be a resource for agriculture in a time of water scarcity, but also a risk for human safety. Farming accounts for 70% of global human water abstraction and is planned to increase with the growing needs of food security. Local communities face an urgent need to find alternative solutions to buffer scarce water availability for crop irrigation and the negative effect of this situation on their economy. One of these solutions is to apply wastewater in agriculture. The reuse of wastewater in agriculture goes beyond the single benefit of an alternative source of water provisioning. Wastewater provides an input of nutrients for plant growth and a replacement of mineral fertiliser. Unfortunately, if not properly managed wastewater can also be harmful for both humans and the environment.

The WHO has indicated that the risk of disease caused by pathogens or toxic compounds can be minimised via a reduction in farmers' and consumers' exposure to untreated wastewater. The concentrations and the nature of the contaminants in wastewater define the treatment that needs to be applied before disposal in water bodies. Traditional wastewater treatment plants have the goal of removing conventional pollutants, like organic and inorganic compounds, as well as the reduction of microbial load, but they fail to remove contaminants of emerging concern in their effluent. Antibiotic-resistant bacteria and genes (ARB&Gs) are contaminants that are of emerging concern and the phenomenon of antibiotic resistance has been highlighted by the

United Nations as the greatest challenge of our century. ARB&Gs are actively selected in human bodies as a result of high antibiotic consumption, concentrated in wastewater treatment plants, and spread through the environment via effluent in the water cycle. Such genes confer resistance to the available antibiotic treatments that aim to control bacterial infections. The reuse of poorly treated wastewater in agriculture could represent a threat to public health because resistant pathogenic bacteria could return to the human body by indirect routes, such as water irrigation practices and/or consumption of microbial contaminated crops irrigated with wastewater. Poorly treated wastewater often contains high loads of enteric pathogens that cause gastrointestinal diseases, such as *Escherichia coli*.

In the presentation, the role of wastewater treatment plants as environmental reservoirs for antibiotic-resistant and pathogenic bacteria was assessed. The likely resistance levels of bacterial communities from wastewater and wastewater-polluted environments at different geographical locations of developed (German and Switzerland), developing (Nigeria) and Latin America countries (Chile and Mexico) were assessed. Wastewater effluent is responsible for significantly high levels of ARB&Gs in the receiving environment because it is capable of introducing resistant bacteria into the freshwater system. The resistance levels differ across the seasons independently of the water sanitation. Contrary to the case in developed countries, the poor treatment of wastewater in Nigeria and Latin America has facilitated the spread of multi-drug resistant pathogens in the freshwater ecosystem. New approaches for the use of wastewater in agriculture should be tested and the persistence of resistant pathogen bacteria in crops, leaves, and agricultural soil should be further studied.

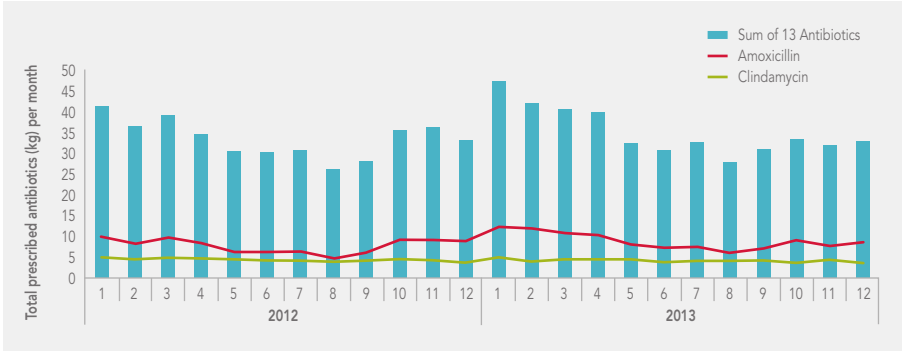


Figure 12: Antibiotic resistance can develop in wastewaters under antimicrobial pressure. Sum of monthly prescribed antibiotics (in Kg) by the AOK health insurance (Germany) in 2012 and 2013, in Dresden, Germany. Blue bars: monthly antibiotic prescriptions; yellow line: monthly clindamycin prescription (lincosamide with no marked pattern); red line: monthly amoxicillin prescription (ß-lactam with a constant prescription over the year). Modified from Caucci et al., 2016.

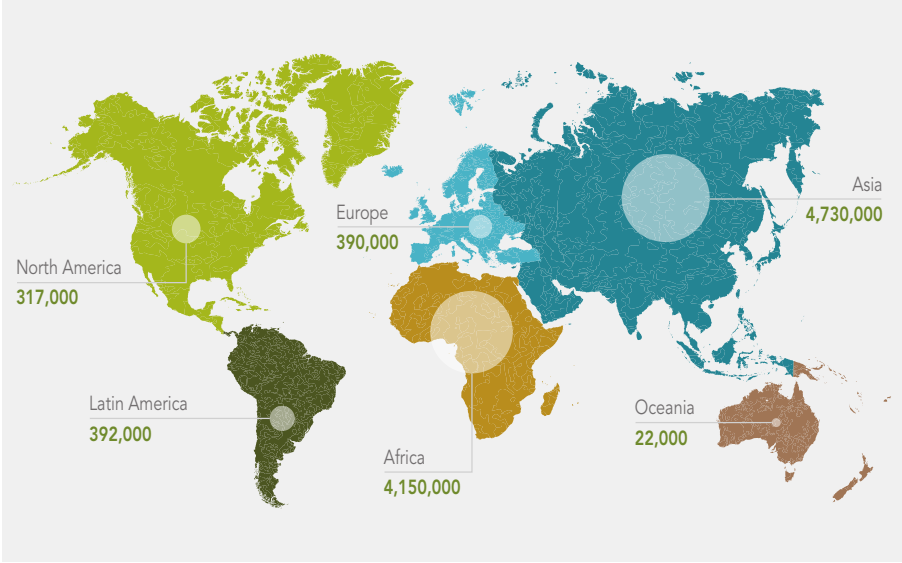


Figure 13: Projection of deaths attributable to antibiotic-resistant microorganisms worldwide (Source: WHO).

5.2 Health Policy Aspects

A breakout session on the policy aspects of health issues was moderated by **Mr Carlos Pailles (FIAVHI)**. The questions posed to the audience and a summary of the responses gathered are presented below.

Question A: What is the perception of microbial contamination in the context of water reuse? Are WHO and SUWA guidelines sufficiently widely disseminated and applied to guarantee the health of soil, humans, and crops?

Question B: Assuming the use of the nutrient content of wastewater in agriculture is important, what should be done in Mezquital to preserve health? What would you like to be included in the WHO regulations and SUWA guidelines, and why?

Question C: Are you aware of the problem of antibiotic resistance? Is there any campaign for the careful use of antibiotic treatment in Mexico?

General content of the session: The WHO and SUWA guidelines seemed to be an unfamiliar issue for the participants, mainly due to lack of diffusion of these regulations from the government offices to the population. The participants were not able to state whether the actual guidelines could be implemented, and how. Despite the demonstrated high interest in health aspects, the nutrient recovery and economic aspects were dominant in the discussion and the participants provided a clear preference on the health issue as a priority in the context of wastewater reuse. More diffusion of the WHO and SUWA guidelines is thus required. Wastewater reuse stewardship should be promoted to demonstrate that treated wastewater can provide the same benetifs as untreated wastewater (nutrients for satisfactory crop yield and water provisioning for irrigation), though avoiding the spread of epidemics and environmental pollutants.

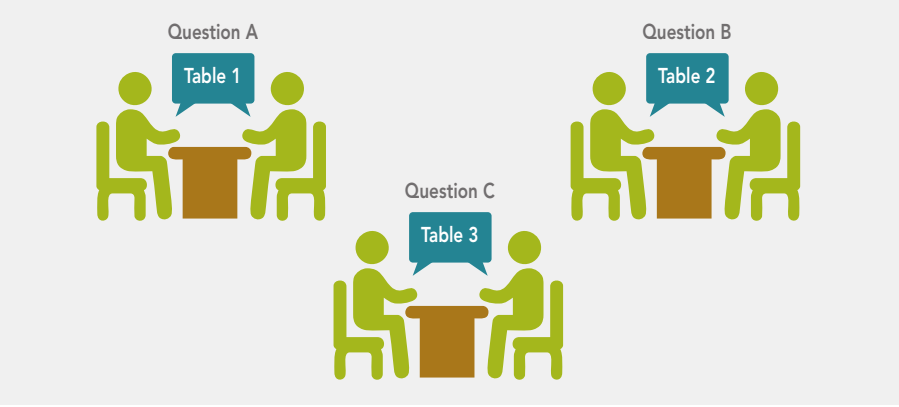


Figure 14: Schematic representation of the breakout discussion tables.

Antibiotic resistance was a new concept for the participants. Knowledge of this issue was mostly related to personal experience when the topic was addressed as "the effectiveness of medicines in relation to recurrent water-related infections". Almost all the participants had experienced antibiotic treatment failure, especially in infants and children. The problem of alternative pharmacies, which prescribe antibiotics without microbial screening analysis or proper medical assessment (farmacia similares), seems to be aggravating the situation. The use of alternative pharmacies is a popular choice among the low-income population, which often has only limited access to official practitioners due to the semi-private healthcare system in Mexico.

The problem of cross and indirect infection via crop consumption and poor sanitation was only acknowledged by a few participants. The discussions developed in a very open and friendly atmosphere within each working group.

Barriers and next steps: Due to the lack of fundamental knowledge of, and experiences of practices relating to, wastewater management and safe health practices it was difficult to come up with a concrete priority list on action to be taken or implementation of options to be considered in the existing WHO and SUWA guidelines for SUWA. Several barriers need to be overcome to increase the adoption and utilisation of safe wastewater management in Mexico. A well-structured and long-term capacity development programme on wastewater and health issues would be the first major step forward within the region. The health authorities should be involved in such programmes, as well as the educational sector, which should consider the diffusion of knowledge on overuse of antibiotics and the risks connected with antibiotic resistance, as well as promoting sanitation strategies in the rural area of the Mezquital Valley.

Section 6: The SludgeTec Project

The workshop also marked the official kick-off of the multi-partner project titled "Resource recovery from wastewater in the Americas – Assessing the water-soil-waste nexus" (SludgeTec). **Dr Tamara Avellán (UNU-FLORES)** gave an overview of the project to the workshop participants.

This presentation introduced the project under which the workshop is being hosted. The aim of the project is to *"determine and, where suitable, implement sustainable management options to the wicked problem of wastewater treatment in selected pilot areas of the Americas"*. This is intended to be achieved by applying the UNU-FLORES Nexus Approach to resource management while developing a better understanding of the bio-physical and socioeconomic and political interlinkages of water, soil, and waste. Project activities in 2017 will focus on: 1) clearly delineating the nexus problem; 2) defining the scope of the work; and 3) undertaking the necessary research to develop potential solution options. Pilot sites are set for the Mezquital Valley in Mexico, Sololá in Guatemala, and the campus facilities of ISA University in the Dominican Republic.

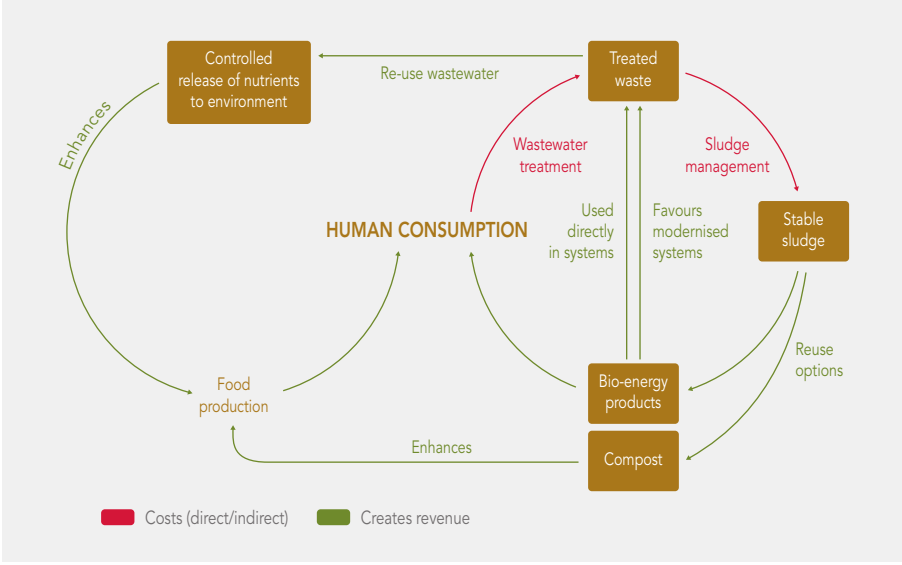


Figure 15: Closing the loop for sustainable wastewater management (Source: Caucci S. and Avellan T.).

Section 7: The Closing Session

During the closing session, the participants were offered another two opportunities to express their final thoughts: first using words and then using art.

The participants were requested to note down key stakeholders that they felt were needed or could add value to the discussions held during the previous three days. Answers ranged from national/state/federal government authorities to practitioners in diverse fields. The need for the presence of research entities in the country and diverse groups of the local population was also noted. A stakeholder group that was felt to be clearly needed was the "farmers": this group was listed most frequently (12 times), followed by the state/federal government (nine times), and the municipal government and consumers (eight times each).

The participants were then requested to draw an image of their vision of a solution to the nexus problem regarding "SUWA for sustainable development". All images had in common a people-centric approach, hence any technical solution has to take the local community, and most often the children, into account. In most drawing, wastewater treatment systems (in general, and in some cases constructed wetlands in particular) were the key technical ingredient. In some cases the sludge reuse was explicitly highlighted. In some cases the drawings were specific to the Raquena Lagoon and Tepeji del Rio; in most cases the drawings represented a generic farm area.

One participant noted the following vision statement: ***"Tepeji del Rio – Example for sustainable water."*** A few selected drawings are presented below.

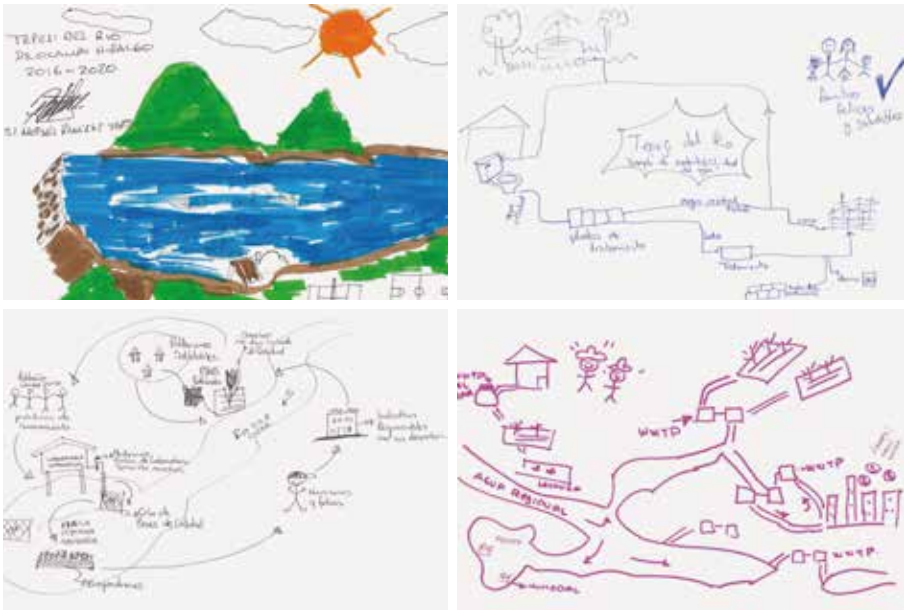


Figure 16: Selected drawings from the participants who graphically expressed their view of a sustainable solution (the one in the upper left corner was drawn by the Mayor of Tepeji del Rio O´Campo, Hon. Moises Ramirez Tapia).

In the closing session, Serena Caucci provided a brief overview of how the workshop programme unfolded. She summarised the three-day event and highlighted how the field trip had provided the international experts joining the workshop with a deep understanding of the reality in Mezquital Valley. The ad hoc presentations of the experts were possible only after listening to participants' stories and experiences. In the Mezquital Valley, economic issues take priority over the health problems related to the unsafe reuse of wastewater in agriculture. Despite the fact that health risk awareness is high, the economic revenues from such practices guarantee the survival of the locals. Reversing this situation is mandatory. Finding sustainable strategies that foster the economy and at the same time guarantee public health is the direction which must be pursued. The Nexus Approach will help to pave the way forward.

The Chair of the Congress of the State of Hidalgo, **Hon. Mrs. Maria Luisa Pérez Perusquía,** attended the closing session. She shared her vision and expectations for the future regarding the follow-up proposal on the sanitation of the Tepeji Municipality, Raquena Lake, and of the Mezquital Valley. Full support by the representatives of the Congress of the State of Hidalgo on the suggested FIAVHI-UNU-FLORES future activities was expressed. Hon. Mrs. Maria Luisa Pérez Perusquía furthermore expressed the intention of implementing a law and complementary regulations for the sustainable use of wastewater in agriculture within the State of Hidalgo, and ensuring its validity for at least 12 years.

In his closing remarks, given on behalf of the organisers, Prof. Hiroshan Hettiarachchi thanked all participants of the workshop and emphasised how the participation of members of the communities involved in the process of sanitation and wastewater reuse in the Mezquital Valley has provided a strong input in regard to understanding the problems in the Mezquital Valley. Participation by the community leader of El Caracol (Mrs Teodora Neria) was publicly appreciated. Prof. Hettiarachchi briefly explained the future research programme UNU-FLORES has envisioned for the Mezquital Valley. A memorandum of understanding on the future collaborative activities between UNU-FLORES and FIAVHI will stipulate the scope, contribution of the parties, as well as the time frame (initially a four-year collaboration) for the development of real and sustainable management of the resources (namely waste, soil, and water).

Reacting to the special request made by **Hon. Mr Moises Ramirez Tapia**, the Mayor of Tepeji del Rio O´Campo, Prof. Dr. Hettiarachchi re-emphasised UNU-FLORES' motivation in regard to being part of the process of seeking solutions to the environmental issues in the Mezquital Valley.

Representing FIAVHI, as the local host organisation, Mr Carlos Pailles concluded the event with his final expression of thanks. In his talk he mentioned the dynamic exchange of information between FIAVHI and UNU-FLORES that had made possible the event's success. He also thanked all the experts of the workshop and highlighted the professionalism of the experts, who provided last-minute changes to their presentation to accommodate the requests of the workshop participants. Mr Pailles expressed FIAVHI's satisfaction with UNU-FLORES and stated that FIAVHI is looking forward to the next phase of the collaboration on the sustainable management of the resources (namely waste, soil, and water) in the Mezquital Valley.

General Evaluation of the Workshop

Participants evaluated the workshop. The evaluators are both female (9) and male (5), and represent various stakeholder groups, namely academics (6), civil society (5), the private sector (2), and the government (1).

In a first step, participants provided numerical evaluations on a five-point scale (1 = minimum/poor and 5 = maximum/excellent). The following data represent averages rounded to one decimal place, referring to this scale. In general, the majority of participants evaluated the workshop as being excellent. This relates to the overall assessment of the workshop (mean = 4.7), as well as the organisation of the event (mean = 4.8), the balance of presentations and breakout sessions (mean = 4.6), as well as the quality of presentations (mean = 4.6) and breakout sessions (mean = 4.5). Moreover, the majority of the workshop evaluators found the workshop very useful. The workshop helped participants to understand the Nexus Approach (mean = 4.7) and the complexity of the problem (mean = 4.8), as well as in regard to identifying sustainable management options for wastewater and sludge (mean = 4.6). In addition, the majority of evaluators mentioned that they would be able to use what they had learned in their work (mean = 4.8).

In a second step, evaluators provided some 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, costs, and benefits of water reuse, or the interaction between different societal actors. In terms of future events, participants suggested adding practical cases as well as more actors, especially local people (farmers and consumers) and representatives from industries and the academic sector, in order to increase diffusion.

For more details, please see Annex 2.

ANNEXES

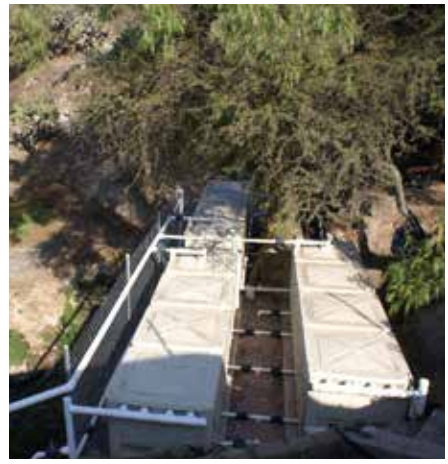
Annex 1: Field Trip to the Mezquital Valley

The trip was organised by FIAVHI and allowed participants to discuss issues related to treatment methods, agronomic practices, and health issues related to environmental pollution and microbial crop contamination with untreated wastewater. Existing and successful pilot projects on SUWA demonstrated how the valley could cope with water sanitation, water reuse, and health.

Landowner of crop fields irrigated with untreated wastewater discussing with Prof. Christina Siebe, of UNAM.

Field irrigated with untreated wastewater.

Visit to the El Caracol settlement. Mr Pailles explains the living conditions of the population before the installation of a SUWA treatment plant.



SUWA treatment plant installed near El Caracol settlement.




Decentralised SUWA treatment plant and agricultural fields irrigated with treated wastewater.


Coriander washing in the river.

Centralised wastewater treatment plant under construction in the Mezquital Valley (Photo: Christina Siebe).

Raquena Lake.

Greenhouses for cash crops production in Mezquital. The crops are irrigated with treated wastewater.

Annex 2: Survey Questionnaire and Evaluation Form Provided to the Workshop Participants

1. General information	
1.1 From the stakeholder category below, please select the one that represents you best:	
	Answers
Government official	6%
Civil society	34%
Private sector	10%
Academic	48%
Other	–
Total in %	**100**
1.2 Please indicate your sex	
	Answers
Female %	70
Male %	30
Total in %	**100**

2. General evaluation (1 = poor – 5 = excellent)					
Score	**2.1 What is your overall assessment of the workshop?**	**2.2 How do you assess the organisation of the event?**	**2.3 How do you rate the balance of presentations and breakout sessions?**	**2.4 How do you rate the quality of the presentations?**	**2.5 How do you rate the quality of the breakout sessions?**
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	3	6	3
4	16	12	12	8	24
5	50	55	50	55	40
Average score	**4.7**	**4.8**	**4.6**	**4.6**	**4.5**
A person checked both options					

3. Usefulness of the workshop (1 = no – 5 = yes)				
Score	**3.1 Did the workshop help you in understanding the Nexus Approach?**	**3.2 Did the workshop help you in understanding the complexity of the problem?**	**3.3 Did the workshop help you in identifying sustainable management options for wastewater and sludge?**	**3.4 Will you be able to use what you have learned in your work?**
1	0	0	0	0
2	0	0	0	0
3	0	0	3	0
4	16	12	12	12
5	45	55	50	50
No answer	1	0	0	1
Average score	**4.7**	**4.8**	**4.6**	**4.8**

3.5) Which two topics or aspects of the workshop did you find most interesting?

- Treated wastewater reuse. One repetition
- Training for children in schools. Information diffusion
- Wastewater and sludge management
- Sludge management and the benefits of treated water
- Use of constructed wetlands for wastewater treatment and decentralised treatments
- Interaction between different society actors
- Use of treated wastewater in agriculture and sanitation issue
- Wastewater use effects and resistance of microorganisms to antibiotics
- Eco-technologies (wetlands) and use of antibiotics (resistance)
- Treated water for irrigation, benefit–cost and use of wastewater as a resource
- Diffusion of awareness of benefits of water reuse
- Sustainable use of water and resistance genes.

3.6) Which two topics or aspects of the workshop did you find least interesting?

- There are no least interesting topics *(One repetition)*
- Everything was interesting *(Two repetitions)*
- Sludge incineration
- Wetlands, their benefits and construction
- Sludge

4.1) Please suggest improvements for future events to be held by the organisers

- Include Ejidatarios (landowners) in workshop
- Excellent workshop!
- More participation of local people (farmers and consumers) in training (One repetition)
- More participation of industry and academic sector
- Congratulations! I also suggest inviting more people for this kind of workshop
- I suggest providing more practical cases, less theory, and more field experiences. I would have liked to see the fieldwork already applied to the processes
- It was well organised and it had an excellent location
- More diffusion

Workshop Evaluation Form

Sustainable Management Options for Wastewater and Sludge

15–17 March 2017, Tepeji del Rio de Ocampo, Hidalgo, Mexico

This questionnaire aims to evaluate the workshop "Sustainable Management Opinions for Wastewater and Sludge". Please tick the correct answer or enter text in order to answer the questions. Your answers will help the organisers to improve upcoming workshops and project activities. Thank you for your collaboration!

UNU-FLORES

1. General information

1.1 From the stakeholder category below, please select the one that represents you best:

☐ Government official

☐ Civil society

☐ Private sector

☐ Academic

☐ Other

1.2 Please indicate your sex

☐ Female

☐ Male

2. General evaluation (1 = poor – 5 = excellent)

2.1 What is your overall assessment of the workshop?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

2.2 How do you assess the organisation of the event?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

2.3 How do you rate the balance of presentations and breakout sessions?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

2.4 How do you rate the quality of the presentations?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

2.5 How do you rate the quality of the breakout sessions?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

3. Usefulness of the workshop (1 = no – 5 = yes)

3.1 Did the workshop help you in understanding the Nexus Approach?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

3.2 Did the workshop help you in understanding the complexity of the problem?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

3.3 Did the workshop help you in identifying sustainable management options for wastewater and sludge?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

3.4 Will you be able to use what you have learned in your work?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

3.5 Which two topics or aspects of the workshop did you find most interesting?

_____

_____

3.6 Which two topics or aspects of the workshop did you find least interesting?

_____

_____

4. Further information

4.1 Please suggest improvements for future events held by the organisers

THANK YOU

Annex 3: Questions Provided to the Workshop Participants during the Breakout Session

Breakout session on wickedness analysis

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 the actors instead 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)?

Annex 4: List of Invitees at the International Capacity Development Workshop on Sustainable Management Options for Wastewater and Sludge, Tepeji del Rio O Campo, Hidalgo, Mexico

Affiliation	Name	Education Level/ Specialism	Profession	City – Region
FIAVHI	Almadelia Hernández	Agronomic Engineer	Production of Vegetables with Treated Wastewater	Sierra Mixteca, Oaxaca
FIAVHI	Arlette Ramírez	Environmental Engineer	WWTP O&M	Valle De Jilotepec, Edo. Mexico
FIAVHI	Ana Lilia Velasco	Graduate Student Specialising in Water Treatment	SUWA WWTP Construction	Valles Zapotecas De Oaxaca
FIAVHI	Teodomira Alvarado	Primary	Harvest and Sales of Vegetables Produced with SUWA	Sierra Totonaca Del Edo. Hidalgo
FIAVHI	Emma Muñoz	Civil Engineer	Design and Operation of WWTP for SUWA	Valles De Pachuca Hidalgo
FIAVHI	Ramón Franco	Electric and Mechanic Engineer	Responsible for SUWA WWTPS Installation	Ciudad De México
FIAVHI	Fernando Mendoza	Primary	O&M SUWA WTTPS	Valle Del Mezquital
FIAVHI	Omegar Cruz	Agronomic Engineer	Cereal Seeds Operator Responsible for Irrigation with Treated Wastewater	Sierra De San Luis Potosí
FIAVHI	Isaias Guerrero	Civil Engineer	Project Manager and Supervisor of SUWA WWTPS	Valle De Chalco
Congreso Del Estado	María Luisa Pérez Perusquia	Msc Social Science	President of the Congress of Hidalgo State	Pachuca, Hidalgo
Congreso Del Estado	Araceli Velázquez	Msc In Law	President of the Commission for Tourism (Congress State Hidalgo)	Tepeji Del Rio, Hidalgo

Affiliation	Name	Education Level/ Specialism	Profession	City – Region
Congreso Del Estado	Octavio De La Torre	Civil Engineer	President of Commission for the Environment (Congress State Hidalgo)	Zapotlán Hidalgo
UNAM	Marisa Mazari	Phd	Director of the Postgraduate Programme in Sustainability	Ciudad De México
UNAM	Gabriela Arroyo	Phd in Environmental Science	Forest Restoration Support (Restoration Irrigation Practices with SUWA	Valle De Morelia Michoacán
UNAM	Azucena	Phd in Environmental Chemistry	Application of SUWA Water in Vegetables City of Mexico	Ciudad De México
UNAM	Christina Siebe	Phd In Edafology	Evaluation of Irrigation Practices with Untreated Wastewater	Sttutgart, Germany
UNAM	Mario Cayetano	Phd in Edafology	Tests on Wastewater Irrigated Soils in Mezquital	Sierra De Guerrero
UNAM	Alma Rojas	Phd – Engineer	Design and Laboratory Testing of WWTPS for Agricultural Reuse	Ciudad De México
Itvo	Vicente Velasco	Phd Agronomy	Research Wastewater Resources	Valle De Oaxaca
Col.hgo	Edith García	Phd Economy	Regional Evaluation of Agricultural Crops	Ciudad De México
Municipio Tepeji	Moisés Ramírez	Contador Público	Major	Tepeji Del Rio
Municipio Tepeji	Gerardo Sevilla	Civil Engineer	Supervision and Approval of WWTPS	Tepeji Del Rio
Conagua	Antelmo Peña	Civil Engineer	Management of Waters, Dams and Water Bodies	Ciudad De Pachuca
Uttt	Lucina De León	Msc in Chemistry	Formation of Students in Environmental Engineering	Valle Del Mezquital

Annex 5: Team of Experts (Names in alphabetical order)

Dr Tamara Avellán
UNU-FLORES
Dresden, Germany

As a research fellow in the Water Resource Management Unit at UNU-FLORES, Dr Avellán focuses on the linkages between water, soil, and waste in 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 has worked with farmers in Uruguay to find sustainable solutions to increasing sewage loads in watersheds, which led to the installation of the first constructed wetland that uses endogenous plant species, in 2008.

Serena Caucci, MSc
UNU-FLORES
Dresden, Germany

As a researcher at UNU-FLORES, Ms Caucci contributes to the realisation of capacity development work related to multi-stakeholder projects, such as SUWA and sludge management options. Ms Caucci has worked closely with transdisciplinary partners and has 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 Technische Universität Dresden (TU Dresden) and at the Helmholtz Centre for the Environment-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 postgraduate courses such as those he runs on instrumentation and control, and 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.

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

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

Prof. Dr Edeltraud Günther
Technische Universität Dresden (TU Dresden)
Dresden, Germany

Prof. Günther specialises in business administration and conducted her doctoral research on environmental accounting at the University of Augsburg. Prof. Günther has been the Chair of Business Management and Environmental Management at TU Dresden since 1996. She has also been a visiting professor at the University of Virginia – Charlottesville, USA. She is the Founding Director of PRISMA, the Centre for Sustainability Measurement and Assessment at TU Dresden. Her current research fields are environmental performance measurement, value-based management of environmental resources, barrier analysis, and the deceleration of consumption and production processes.

Prof. Dr Hiroshan Hettiarachchi
United Nations University (UNU-FLORES)
Dresden, Germany

Prof. Hettiarachchi heads the Waste Management Unit at UNU-FLORES. His background is in civil engineering and he has conducted research and published extensively in the areas of geotechnical and geoenvironmental engineering and sustainable waste management. He is also an expert in graduate programme development and took the lead in developing the joint PhD Programme in Integrated Management of Water, Soil, and Waste offered by UNU-FLORES in partnership with TU Dresden. Prior to joining UNU, Prof. Hettiarachchi was at the Lawrence Technological University in Michigan, USA.

Dr Anne-Karen Hüske
Technische Universität Dresden (TU Dresden)
Dresden, Germany

Dr Hüske is the Scientific Managing Director of PRISMA, the Centre for Sustainability Measurement and Assessment at TU Dresden. Her research interests are in barriers to organisational change and innovation, and sustainability measurement and assessment. Dr Hüske holds a Diploma in Business Administration, obtained from TU Dresden, and a master's degree in International Management from the Université Strasbourg Ecole de Management Strasbourg in France. Her doctoral research focussed on barrier analysis.

Mr Carlos A. Paillés
Fideicomiso Infraestructura Ambiental de los Valles de Hidalgo Mexico (FIAVHI), 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 SUWA. This includes design and implementation of 29 wastewater treatment plants in the State of Oaxaca, Mexico. Since 2008 he has implemented 15 wastewater treatment plants in the Mezquital Valley and Tepeji Municipality as pilot projects specifically for wastewater reuse in agriculture.

Dr Khaja Rahman
Training and Demonstration Centre for Decentralized Sewage Treatment e.V (BDZ), Leipzig, Germany

Dr Khaja Z. Rahman is an environmental engineer. He gained a MSc. in Water Resources Engineering and a PhD in Environmental Engineering from the University of Stuttgart, Germany. Since 2008 he has been working as a Senior Research Scientist at the Helmholtz Center for Environmental Research (UFZ), in cooperation with the Demonstration Center for Decentralized Wastewater Management (BDZ e.V.), and has been involved in various national and international projects in the field of decentralised wastewater and sewage sludge management. His research interests also include removal of arsenic, heavy metals and organic micro-pollutants from sewage, and remediation of contaminated groundwater with innovative technologies.

Prof. Christina Siebe
National Autonomous University of México (UNAM)
Mexico City, Mexico

Prof. Siebe has held a permanent researcher and professor position at the Soil Science Department of the Institute of Geology, UNAM, since 1994. From 1982 till 1988 she studied Agricultural Sciences at the University of Hohenheim, Stuttgart, Germany, and got her doctorate degree in 1994 from the same university. Her main research activities are related to human impacts on soil ecological functions. Among other things, she has studied for more than 25 years the effects of long-term irrigation with untreated wastewater on soils, crops, and groundwater in the Mezquital Valley, Mexico.

Annex 6: Members of the SludgeTec Project

ISA University
Santiago, Dominican Republic
www.isa.edu.do

Established in 1964, in Santiago, Dominican Republic, ISA is a private, non-profit university. ISA offers extensive educational and research opportunities, mainly in the sectors of agriculture, livestock, and natural resources. So far over 4,000 professionals have graduated from the university. The university has a campus with 90 ha and one wastewater treatment plant (lagoons).

USAC
Guatemala City, Guatemala
http://www.usac.edu.gt

USAC is the only public university in Guatemala and was founded in 1676. With 240,000 students, 22 campuses, and 17 research centres around the country, USAC plays a prominent role in research and education in Guatemala. Its Engineering Faculty was founded in 1880, and currently has over 40,000 students in many undergraduate and graduate degree programmes.

UNU-FLORES
Dresden, Germany
https://flores.unu.edu

Founded in 2012, UNU-FLORES develops strategies to resolve pressing challenges in the area of sustainable use and integrated management of environmental resources, such as soil, water, 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 its activities, UNU-FLORES advances a Nexus Approach to the sustainable management of environmental resources.

TU Dresden
Dresden, Germany
https://tu-dresden.de

TU Dresden is a public research university, the largest institute of higher education in the State of Saxony and one of the 10 largest universities in Germany, with over 37,000 students. It is also one of the 11 "universities of excellence" in Germany. TU Dresden benefits from a strong research tradition in water management, biotechnology, and waste management.

Training and Demonstration Centre for Decentralized Sewage Treatment e.V BDZ, Leipzig, Germany
https://www.bdz-abwasser.de

BDZ is a non-profit association for the promotion and successful establishment of decentralised wastewater management through training and demonstration platforms. It offers a manufacturer-independent platform with around 100 members from the industrial, educational, and public sectors in the area of decentralised wastewater management, not only at the national but also at the international level.

Fideicomiso Infraestructura Ambiental de los Valles de Hidalgo Mexico (FIAVHI), Hidalgo, Mexico

FIAVHI is a civil society organisation founded in 1999 after the Urban Rivers Workshop, sponsored by the UN Development Programme, WHO, the Food and Agriculture Organization, and the World Bank, to find options for wastewater treatment and reuse in rural communities, following the SUWA guidelines. Since then, more than 60 projects have been implemented by FIAVHI, mainly as pilot projects, in public–private partnership (PPP) frameworks, with four-year support programmes for each one, looking to develop their autonomy and sustainability.

Annex 7: Pictures of the Workshop


SUSTAINABLE
MANAGEMENT
OPTIONS FOR
WASTEWATER AND
SLUDGE

Annex 8: Agenda of the Workshop

Day	Event	Time	Coverage
Day 1 (15 March 2017)	**Field visit**	08:30-17:30	Field visit to the Mezquital Valley SUWA sites and wastewater treatment plant
Day 2 (16 March 2017)		08:00-08:30	Registration
	Inauguration	08:30-10:30	Welcome: FIAVHI/Tepeji Municipality/ State of Hidalgo Welcome: UNU-FLORES SUWA and the Nexus Approach (Hiroshan Hettiarachchi, UNU-FLORES) Group photo
		10:30-11:00	Coffee break and networking
	Session 1	11:00-12:30	Status quo of Mezquital Valley (30) (Christina Siebe, NAUM) Breakout discussions: Nexus problem analysis (60) (Tamara Avellán, UNU-FLORES)
		12:30-14:00	Lunch break
	Session 2	14:00-15:30	Sustainable model for water reuse: economic aspects (30) (Edeltraud Günther, TUD) Breakout discussions: identification of externalities (60) (Anne-Karen Hüske, TUD)
		15:30-16:00	Coffee break and networking
	Session 3	16:00-17:30	Moderator: Jorge Cifuentes (USAC) – Report by all discussion groups (60) – Q&A discussion (30)
Day 3 (17 March 2017)	**Session 4**	08:30-10:30	Introduction to the SludgeTec Project (30) (Tamara Avellán, UNU-FLORES) Q&A discussion (45) Decentralised wastewater treatment options (45) (Khaja Rahman, BDZ)
		10:30-11:00	Coffee break and networking
	Session 5	11:00-12:30	Sludge management options (30) (Christina Dornack, TUD) Breakout discussions: opportunities and challenges (60) (Moderated by: Khaja Rahman, BDZ)
		12:30-14:00	Lunch break
	Session 6	14:00-15:30	Wastewater management and health (30) (Serena Caucci, UNU-FLORES) Breakout discussions: policy aspects of health (60) (Moderated by: Carlos Pailles, FIAVHI)
		15:30-16:00	Coffee break and networking
	Session 7	16:00-17:30	Moderator: Hiroshan Hettiarachchi (UNU-FLORES) – Report by all discussion groups (60) – Q&A discussion (30)
	Closing	17:30-18:00	Workshop wrap-up (Christina Siebe, NAUM) Words of thanks: UNU-FLORES, FIAVHI

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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

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