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INVESTIGATION OF THE SANITARY SITUATION IN TECOLUCA, EL SALVADOR

Master thesis

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“A technician should translate between human and nature.”

– Jung H.

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Abstract

The aim of this thesis is to identify the sanitary situation in rural and urban parts of the Salvadorian municipality Tecoluca. This includes the handling of grey water, human excreta and solid waste.

Data for this research was collected by structured and semi-structured interviews, observation in the municipality and literature research. The collected information was electronically documented, analysed and implemented into a geographical information system (GIS). With the GIS it is possible to display the results together with geographical references and it is a perfect tool to continue the work by municipal personnel. Another essential part of the thesis was the cooperation with municipal personnel, residents and Salvadorian universities.

The results show that the sanitation is at an overall acceptable level in the municipality, both in rural and urban areas. A worse situation was found regarding handling of grey water and solid waste. The residents of Tecoluca contaminate their environment by discharging grey water into natural water bodies without any sort of treatment and by disposing of their solid wastes outdoors or by waste incineration.

Next steps should be further and more detailed investigations in specific villages with highest needs as well as a feasibility study on sanitation system solutions in Tecoluca Town.

Kurzzusammenfassung

Ziel dieser Arbeit ist die Erfassung der aktuellen sanitären Situation in den ländlichen und städtischen Gebieten der salvadorianischen Gemeinde Tecoluca. Dazu gehört der Umgang mit Grauwasser, menschlichen Exkrementen und feste Abfälle.

Die benötigten Daten wurden mithilfe von strukturierten und semi-strukturierten Interviews, Beobachtungen in der Gemeinde und durch Literaturrecherche erfasst. Die damit gesammelten Informationen wurden elektronisch dokumentiert, analysiert und in ein geografisches Informationssystem (GIS) integriert. Mit einem solchen System ist es möglich die Informationen georeferenziert darzustellen und es ist ein ideales Werkzeug um die Arbeiten durch Gemeindepersonal fortzuführen. Ein weiterer wichtiger Punkt des Projekts war die Zusammenarbeit mit dem Gemeindepersonal, den Einwohnern und salvadorianischen Universitäten.

Die Ergebnisse zeigen, dass die sanitären Einrichtungen, sowohl in den ländlichen Gebieten als auch in Tecoluca Stadt, im Allgemeinen auf einem akzeptablen Niveau liegen. Hingegen ist der Umgang mit Grauwasser und festen Abfälle weitaus schlechter. Die Einwohner von Tecoluca verschmutzen ihre Umwelt durch die Einleitung von unbehandelten Grauwasser in natürliche Gewässer und durch die Entsorgung von festen Abfällen im freien oder durch das Verbrennen von festen Abfällen.

Als nächste Schritte werden weitere und genauere Untersuchungen in den Dörfern in denen es am notwendigsten ist, sowie eine Studie zur Umsetzbarkeit von Sanitärsystemen für ganz Tecoluca Stadt empfohlen.

Abbreviations

ANDA	*Administración Nacional de Acueductos y Alcantarillados* National Administration for Water and Sanitation Services
BOD_5	Biochemical oxygen demand after 5 days
CNR	*Centro Nacional de Registros* National Registry Centre
COD	Chemical oxygen demand
CRIPDES	*Comité de Cristiano Pro Desplazados de El Salvador* Christian Committee for displaced persons in El Salvador
DIGESTYC	*Dirección General de Estadistica y Censos* Department of Statistics and Censuses
ENSA	*Estrategia Nacional de Saneamiento Ambiental* National Sanitation Strategy
HIBASA	*Programa higiene básica y salud en la region para central* Basic hygiene and health programme for suburban region
INTERSOL	*Verein zur Förderung Internationaler Solidarität* Association for the Promotion of International Solidarity
JMP	Joint Monitoring Programme
MINSAL	*Ministerio de Salud Pública y Asistancia Social* Ministry of Public Health and Social Welfare
MARN	*Ministerio de Medio Ambiente y Recursos Naturales* Ministry of Environment and Natural Resources
MOP	*Ministerio de Obras Públicas, Transporte, Vivienda y Desarollo Urbano* Ministry of Public Work, Transportation, Housing and Urban Development
NGO	Non-governmental organisation
USAID	United States Agency for International Development
UCSF	*Unidad Comunitaria en Salud Familiar* Community Family Health Unit
UNICEF	United Nations International Children`s Emergency Fund
WHO	World Health Organisation

1. Introduction

The treatment of wastewater is a difficult issue in El Salvador since there is a lack of a legal regulation and funding. 97% of the accumulating wastewater in El Salvador does not get any sort of treatment and directly enters natural water bodies. The remaining 3% are treated by 16 wastewater treatment plants in the country. The gap between the amount of domestic water connections compared to wastewater treatment systems is still growing, with greater emphasis on suburban and rural areas. However, El Salvador was able to increase the coverage of improved sanitation from 51% (1990) to 75% (2015).

The municipality Tecoluca, which is the target area of this thesis, does not have any treatment plant for wastewater. Instead the grey water is directly discharged into the environment with the consequence of heavily polluted natural water bodies. The most commonly used sanitation facilities in the rural parts of the municipality are latrines of any sort, such as compost latrines, pit latrines or dry latrines. Only in urban areas of the municipality the principal facilities are toilets with water flushing. 20% of the population do not have access to improved sanitation facilities and in some parts open defecation is still practiced. Tecoluca is the biggest municipality in the district of San Vicente with a total area size of almost 300 km² and nearly 27,000 inhabitants. 90% of the population live in rural areas, some in poor conditions since the region is still marked by the civil war during the 1980s.

The non-profit organisation INTERSOL has started a cooperation between the Salvadorian department San Vicente and the Austrian federal state of Salzburg in the year 2000. One of several goals of this cooperation is to push on the treatment of wastewater and to improve sanitation in the municipality Tecoluca. To achieve this, INTERSOL also initiated a cooperation with the Institute of Sanitary Engineering and Water Pollution Control at BOKU Vienna and the rationale for this thesis developed out of it.

The thesis contributes to the establishment of a local water information system and further to an improvement of the wastewater handling in the municipality. The thesis` objectives are the collection and analysis of wastewater- and solid waste-related data, a subsequent implementation of the data in a geographical information system and the cooperation with local people as well as the exchange of knowledge.

The tasks were realised by the conduction of structured and semi-structured interviews in Tecoluca Town and in selected villages of the municipality, computer aided analysis and literature research. The used literature for this thesis is mostly from Salvadorian institutions, WHO and the World Bank. Besides, literature about wastewater treatment, wastewater management and qualitative/quantitative research was used.

The entire stay in Central America was six months, of which the first two months were spent on learning Spanish in Guatemala and the remaining four months for the field work in El Salvador. For a better integration and cooperation with the community, the accommodation was located in Tecoluca Town.

The thesis is structured into four main chapters.

- In the chapter “Fundamentals” a brief overview of wastewater-related issues in general, in El Salvador and the investigation area Tecoluca in particular is given.
- In the chapter “Materials and methods” the methods used for interviews, selection of investigation sites, processing and analysis of data and the implementation in a GIS are described.
- In the chapter “Results and discussion” the findings of the investigation and observations in the municipality Tecoluca as well as the visualisation of the results with the GIS are presented.
- In the chapter “Conclusions and outlook” the results of the thesis are summarised, further required investigation in the field of wastewater and sanitation describes and an outlook for the near future is given.

2. Objectives

2.1 General objectives

The key challenges in Tecoluca are on the one hand to ensure the availability of high quality drinking water and on the other hand the treatment of accumulated wastewater.

To handle these circumstances, one objective is to **implement a water information system in which all water- and wastewater-related information of the municipality is collected**. With this system the municipality gets an overview of their current situation and is able to plan for the future. Another objective is to **expand the cooperation with Tecoluca, but also with universities of El Salvador to involve local students in this issue in order to make it a sustainable project**.

INTERSOL has initiated a cooperation with BOKU Vienna to realize these objectives with the support of several master students who shall write their master theses in Tecoluca contributing to these objectives in the course of several years.

Ultimately, the general objective of INTERSOL and the municipality of Tecoluca is to improve the sanitary situation for the municipality by evaluating the current sanitary situation in the rural parts of the municipality and eventually to implement a wastewater disposal and treatment system in Tecoluca Town.

2.2 Specific objectives

The main objective of this thesis is to form a basis for an economically and environmentally sustainable wastewater disposal and treatment system by means of the collection and analysis of wastewater-specific data as well as their integration into a geographic information system (GIS). From an environmental and hygienic point of view such a system is indispensable for a town like Tecoluca, since otherwise the consequences can be a strong pollution of the environment and in a broader sense a threat for human health.

Following works has been carried out to achieve this objective:

- Collection of wastewater and solid waste-related data via interviews and observation in Tecoluca Town as well as in rural areas (about the handling, consumption and disposal of water resp. wastewater)
- Evaluation and analysis of the collected data
- Documentation of the raw and processed data
- Implementation of the data into a GIS
- Cooperation and exchange of knowledge with the local water committees, the residents and local students in the field of civil engineering

The structured documentation of all data and the usage of a GIS for data visualisation shall assure that the information can later be used by the municipality on the one hand and by Austrian and Salvadorian students and researchers on the other hand in order to continue the work by adding and interlinking more data. It also provides a wide range of tools to edit and present the data in maps and statistics.

In addition, the thesis should serve as a basis for future master theses of students from BOKU Vienna.

3. Fundamentals

3.1 Sanitation in general

The Millennium Development Goals (MDG) arose from the UN Millennium Declaration in the year 2001 and specify eight global development goals for the year 2015 (MCARTHUR, 2014). Goal seven – Ensure environmental sustainability – includes target 7.C, which is:

"Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation". (UNITED NATIONS, 2014)

Though there was an increase in global sanitation coverage from 49% (1990) to 64% (2012), it is improbably that the MDG target of 75% of global sanitation coverage will be achieved by 2015. The lack of improved sanitation facilities is mainly a problem in rural and poor areas. In urban areas most people have access to toilets connected to canalisations. (UNITED NATIONS, 2014)

Following the MDGs, the Sustainable Development Goals (SDG) define 17 goals for a global sustainable development. Whereby goal six – "Ensure access to water and sanitation for all" – defines seven targets for the year 2030. It includes the abolishment of open defecation, access to adequate and fair sanitation, hygiene for all, reducing pollution, eliminating dumping, halving the proportion of untreated wastewater, increasing water reuse, expand international cooperation and support the participation of local communities. (UNITED NATIONS, 2016)

A sanitation facility is called "improved" when it hygienically separates the human excrements from human contact. The Joint Monitor Program (JMP) for water supply and sanitation by WHO/UNICEF has established different sanitation categories for their monitoring. Table 1 shows the defined sanitation categories from the JMP. (WHO/UNICEF, s. a.)

Table 1: Sanitation categories according JMP

Improved sanitation	**Unimproved sanitation**
• Flush toilet	• Flush/pour flush to elsewhere[1)]
• Piped sewer system	• Pit latrine without slab/open pit
• Septic tank	• Bucket
• Flush/pour flush to pit latrine	• Hanging toilet or hanging latrine
• Ventilated improved pit latrine	• Shared sanitation of any type
• Pit latrine with slab	• No facilities or bush or field
• Composting toilet	

[1)]not to piped sewer system, septic tank or pit latrine

In Central America there was an increase of sanitation coverage from 69% in the year 2000 to 80% in the year 2015. This means that the MDG target of at least 75% sanitation coverage were achieved in this region of the world.

Figure 1 shows in detail the improvement for each central American country from 2000 to 2015. El Salvador is now located in the middle field of the eight countries with a coverage of 75% in 2015. The lowest coverage is in Guatemala with 64% and the highest in Costa Rica with 95%. (THE WORLD BANK, 2016)

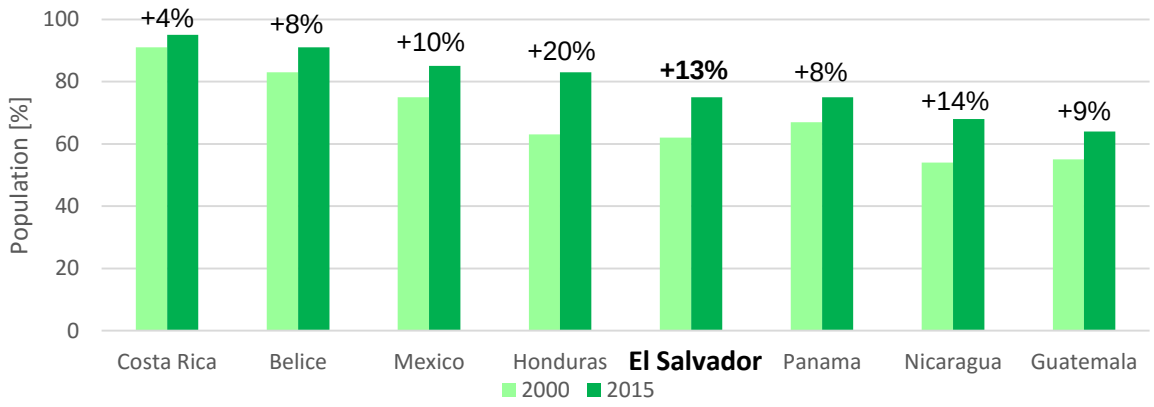


Figure 1: Access to improved sanitation in Central America

The treatment of wastewater, so the removal of organic impurities in the water, is not of high priority in Central America. Overall only 18% of the accumulating wastewater gets some sort of treatment. The other 82% entering any sort of natural environment without being treated are inducing a heavy pollution to the receiving water bodies. Mexico (54%) is the leading country in Central America when it comes to wastewater treatment. Compared to the other Central American countries El Salvador is on the very end of treating wastewater, with only 3% (Figure 2).

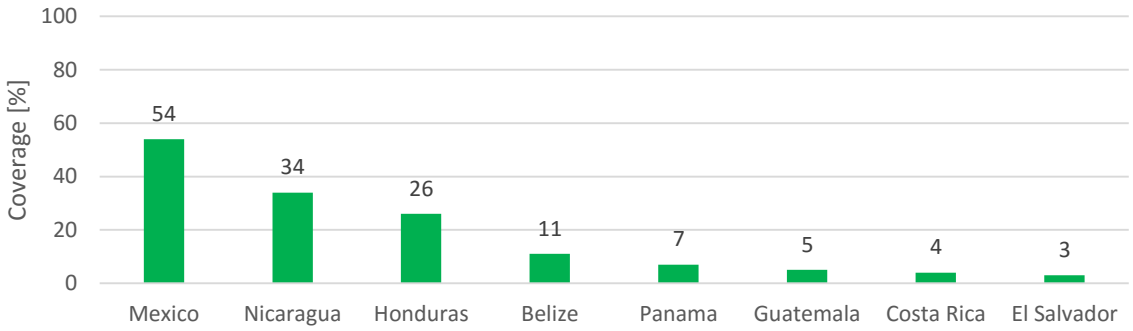


Figure 2: Percentage of treated wastewater in Central America[1]

[1] Sources: Mexico: DE LA PEÑA et al. 2013; Nicaragua: GÁMEZ, 2001; Honduras: SUAZO SUAZO and REYES OSORIO, s. a.; Belize: GRAU et al., 2013; Panama: QUIRÓS TEJEIRA, s. a.; Guatemala: SALGADO, 2009; Costa Rica: ANGULO, 2013; El Salvador: THE WORLD BANK, 2006

3.2 Sanitation in El Salvador

97% of the wastewater in El Salvador is discharged into rivers and brooks without any treatment, whereas the other 3% are treated by 16 small wastewater treatment plants, which are mostly located in the metropolitan area of San Salvador. However, the three largest cities do not treat their wastewater. During dry season only untreated wastewater flows in some creeks. These circumstances lead to the contamination of 90% of the water bodies in the country, including sources of drinking water. (THE WORLD BANK, 2006)

Figure 3 confirms the statement of the millennium development goals report (see chapter 3.1) from 2014. It shows the gap between urban and rural society in concern to the access to improved sanitation for El Salvador. The improved sanitation coverage in urban areas reaches 82% and only 60% in rural areas by 2015. But overall, 3% of the Salvadorian population still practice open defecation, mainly in the rural parts. However, the total coverage in El Salvador has increased from 51% in 1990 to 75% in 2015, which meets the target of the MDG. (WHO/UNICEF, 2015)

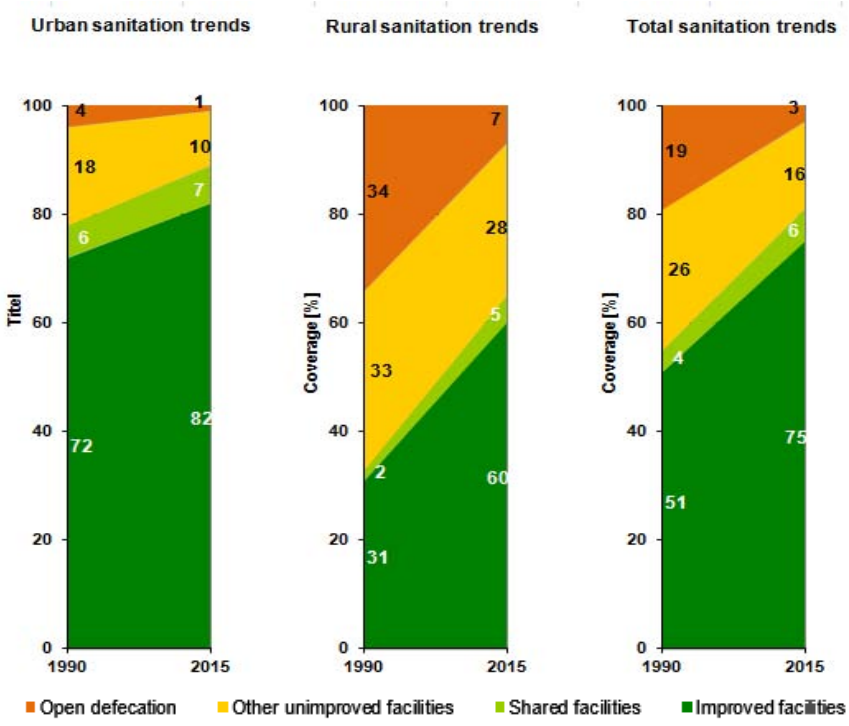


Figure 3: Sanitation trends in El Salvador 1990 – 2015 (WHO/UNICEF, 2015)

Sanitation in El Salvador is focused on canalisation systems in urban areas and latrines in rural areas. In recent years, also the management of solid waste was prioritized.

The water and sanitation sector is administrated by a large number of different service providers. That includes local providers in rural areas and small towns and the national administration for water and sanitation services (ANDA) in urban areas. There is no national agency in charge for funding or providing technical assistance of water sanitation in rural areas. Therefore, the rural

population operates systems by themselves or get help by NGOs. The government does not provide a coherent legal framework for the wastewater sector, instead there are different institutions trying to regulate this sector. (THE WORLD BANK, 2006)

Municipalities are responsible for the provision of public toilet services, cemeteries, municipal slaughterhouses, markets and regulation of economic activities, but they are not responsible for the provision of water supply services, canalisations and wastewater treatment systems. This tasks are the responsibilities of ANDA. However, due to the outdated regulatory framework, the country cannot move forward on the issue of environmental sanitation and especially on the treatment of wastewater.

In 2010 a total water consumption of 226.6 Mio m^3 was recorded, of which 187.5 Mio m^3 corresponded to managed systems by ANDA, 24.1 Mio m^3 were privately operated and 15.0 Mio m^3 belonged to decentralized systems managed by different operators. (DERAS and ROSARIO, s. a.)

3.2.1 Responsible institutions for wastewater

tn El Salvador there are four national institutions which are responsible for the incidental wastewater disposal and treatment:

- National administration for water and sanitation services (ANDA)
- Ministry of health and social welfare (MINSAL)
- Ministry of environment and natural resources (MARN)
- Ministry of public work, transportation, housing and urban development (MOP)

Their responsibilities include the implementation of legal frameworks, the sanitary technical supply, the provision of regulations and standards, the treatment of the wastewater and the authorization as well as the supervision of these installations.

3.2.1.1 ANDA

The institution is under the leadership of a president, who is nominated by the president of El Salvador and has the same rank as a minister. The president of the administration is the chairman of a board that governs ANDA, but the other members do not have much influence. It is a self-regulated institution and its budget is integrated in the ministry of public work. The institution provides services, regulations and policies for the wastewater sector and technical assistance for decentralized providers. (THE WORLD BANK, 2006)

ANDA administrates canalisations in urban areas of 84 municipalities (2010). However, there is no information about the remaining 178 of the 262 municipalities whether they have such systems. Tecoluca is one of the municipalities without a canalisation. (ANDA, 2010)

3.2.1.2 MINSAL

The ministry of health and social welfare provides designs for different domestic wastewater treatment systems (e.g. Latrine with solar drying) as well as technical standards and guidelines for different types of latrines. It is also responsible for the national health code.

MINSAL contains a unit for environmental sanitation with the mission to ensure compliance with the technical legal instruments related to basic sanitation, which prevent, reduce and control the risk factors associated with public health in El Salvador.

This unit realizes several environmental programs. One is called *"Disposición Sanitaria de Excretas" (sanitary disposal of excrements).* It promotes the use of latrines without water flushing for the disposal of excrements in areas that do not have other systems. The types of latrine that MINSAL promotes are:

- Dry latrine
- Compost latrine
- Latrine with solar drying

Another program called *"Tratamiento de Aguas Negras y Grises" (treatment of black and grey water)* promotes the use of individual septic tank systems or their components. Other prototypes of similar principle for the treatment of black and grey water in towns that do not have collective systems such as canalisations and/or wastewater treatment plants are also promoted.

The programs are realized by technical and sanitary guidelines respectively regulatory documents and are executed in coordination with the different levels of the ministry. The ministry promotes the programs nationwide. (MINSAL, s. a.c)

3.2.1.3 MARN

The ministry of environment and natural resources has started a series of strategies for the implementation of a sustainable water resource management in the course of the national environmental policy from 2012.

One of those programs is the national sanitation strategy (ENSA). It combines three fundamental key topics:

1. Integrated management for solid waste, hazardous materials and soil decontamination
2. Treatment of industrial and domestic wastewater
3. Basic sanitation for suburban and rural areas

The scopes of topic two and three are substantial for the wastewater sector in El Salvador. The priorities of the second topic are the sensitisation of industrial wastewater treatment and the education and training of domestic wastewater treatment. Furthermore, it deals with the management as well as the investigation of the reuse and recycling of treated wastewater. The third topic

aims for the expansion of sanitation coverage, the improvement of the service quality and the clean-up of public areas. (MARN, 2013)

3.2.1.4 MOP

The ministry of public work, transportation, housing and urban development understands its mission in the leading and managing of public works, housing and transportation to boost human development in an orderly and sustainable area. It integrates public and private efforts as well as ethics and transparency in a regional perspective. MOP develops national plans and legal frameworks for the sector of housing and development, but also coordinates other institutions that are necessary for development.
The ministry is relevant for wastewater since it issued the legal framework "*Marco normative para la Ventanilla Única"* which is described in chapter 3.2.2.3.

3.2.2 National legal framework

The national legal framework for wastewater and sanitation is a patchwork of different laws with no precise declaration for an economic and ecological efficient wastewater management, whether in relation of collection, treatment, disposal or reuse. The following three frameworks are relevant for the sanitation and wastewater sector in El Salvador.

3.2.2.1 Health Code (Codigo de Salud - Decreto No. 955)

The health code was edited by MINSAL and contains several articles regarding wastewater in El Salvador.

Article 56, section seven (urban and rural environmental sanitation) of the health code states, that the ministry develops environmental sanitation programs for communities with the help of regional, departmental and local health agencies. These programs include the appropriate disposal of wastewater, the disposal of solid wastes, the elimination and control of polluted drinking water, soil and air. In the same section article 59 declares that if hygiene or sanitation deficiencies are traced, the ministry will order a responsible person to correct such deficiencies.

Article 69, section nine (public sanitation facilities) prohibits the discharge of wastewater from public sanitation facilities on public roads, parks, public and private property and in places not authorized for discharge. Furthermore, article 71 states that the necessary sanitation services and facilities recommended by MINSAL (see chapter 3.2.5) shall be established in schools, barracks, markets, hotels, motels and other similar places, adjusted to the number of users and usable areas.

Finally, Article 73 declares that a regulation shall determine the technical conditions for the removal and disposal of wastewater. (Capitulo 2 - Codigo de Salud)

3.2.2.2 Special regulation for wastewater (Reglamento especial de aguas residuales - Decreto No. 39)

This decree´s aims to ensure that wastewater does not alter the quality of the receiving water bodies, which means, to contribute to the recovery, protection and sustainable utilization of water resources on the effects of pollution. It was issued by MARN in June 2000.

Furthermore, the decree states that any natural or legal, public or private owner of a work, project or activity that is responsible for producing or managing wastewater and discharge wastewater into a natural receptor, must install and operate treatment systems for wastewater to comply the provisions of the relevant legislation and the regulation. (REAR)

3.2.2.3 Policy framework for Ventanilla Única (Marco Normativo para la Ventanilla Única)

Ventanilla Única is a project of house division of social interest, intended for people with limited economic resources. It is coordinated by the department of housing and involves MINSAL, MARN, ANDA and the secretary of culture and the institute of freedom and progress. These institutions jointly perform the inspection for the projects to issue their combined corresponding decision. (MINSAL, 2015)

The objective of this Policy Framework is to establish the minimum requirements for projects to handle them in the course of *Ventanilla Única*. It will realize in the first instance the projects listed as social interests by the institute of freedom and progress, including projects that are managed within the housing program for the improvement of municipal quarters and reconstruction of houses, funded by the Inter-American Development Bank (IDB). The framework was issued in 2003 by MOP.

The object of the policy framework is to make clear general provisions for the approval of the projects realized in this program.

The set of rules established here are part of the following legal and institutional provisions:

- Technical standards by ANDA
- Regulations by MINSAL
- Law and regulations by MARN
- Law and regulation from deputy ministry of housing

Scope of application

The *Ventanilla Única* will be the responsible instance for the coordination of all permits that the government requires for the approval of housing projects, urbanization and parcelling in social interest. It shall include the improvement of informal settlements and the reconstruction of houses

at a national level. At once, the *Ventanilla Única* can interact with the municipal technical offices to issue the decisions required by the law. The deputy ministry of housing acts as a substitute in the municipalities that do not have an official technical office in order to issue permits for construction and urbanization.

Disposal of grey water

When there is no possibility for a connection to neither a canalisation nor to a septic tank for the disposal of excrements, every property must have at least a system for the handling of grey water, either individually or collectively according to the provisions of MINSAL (see chapter 3.2.5).

Disposal of excrements

When there is a possibility for a domestic drinking water connection combined with a connection to the canalisation system, a property must have at least one latrine with water flushing that needs to be built at the same time as the house. In this case the urban developer has to install a canalisation on public roads in the project area as well as a collective primary treatment such as sludge pits, prior to the connection of the canalisation. This needs to be done if the project has more than 330 properties.

When there is a possibility for a domestic drinking water connection but not for a canalisation, the project must consider an individual primary treatment system, such as septic tank or an equivalent facility, approved by MINSAL, for projects up to 660 properties. When the project exceeds 660 properties, a collective treatment system that complies with the parameters set by MINSAL concerning the quality of treated wastewater has to be implemented.

When there is no possibility for a drinking water service or only water supply through small mobile water tanks (*cantarera*) exists, every property, depending on the type of soil and hydrological conditions of the land, should have a latrine without water flushing for the disposal of excrements according to the guidelines of MINSAL, whether it is a pit latrine, compost latrine or latrine with solar drying. (Marco Normativo para la Ventanilla Única)

3.2.3 Applicable standards regarding wastewater

There are several national standards regarding wastewater in El Salvador, most of them edited by ANDA. The following standards are about the average water consumption and the permissible contaminants in domestic wastewater.

3.2.3.1 Official Salvadorian Standard: Wastewater discharged into receiving body (Norma Salvadoreña Oficiales: Aguas residuales descargadas a un cuerpo receptor)

This standard was issued in September 2009 by the national council for science and technology (CONACYT). It is an adaptation of the primary standard for wastewater that was first issued in 1996. The official Salvadorian standard for wastewater discharged into water bodies specifies the characteristics and permissible concentration of physicochemical and microbiological contaminants for wastewater, which is allowed to be discharged into natural water bodies. Table 2 shows the maximum values for domestic wastewater. (Consejo Nacional de Ciencia y Tecnologia, 9/11/2009 NSO 13.49.01:09)

In Austria the maximum permissible value for COD ranges from 75 mg/l (size class IV) to 90 mg/l (size class I) and 15 mg/l (size class IV) to 25 mg/l (size class I) for BOD_5 at 12°C (§ 1 Abs. 1 - 1. AEV für kommunales Abwasser) compared to 150 mg/l for COD and 60 mg/l for BOD_5 in El Salvador.

Table 2: Maximum permissible concentrations of contaminants in domestic wastewater to discharge in a water body

COD	BOD_5[1)]	Settleable solids	Total suspended solids	Oils and Fats	pH	Temperature[2)]
150 mg/l	60 mg/l	1 ml/l	60 mg/l	20 mg/l	5,5 - 9,0	20 – 35 °C

[1)] BOD_5 at 20 °C

[2)] In any case the temperature of the discharge should deviate less than 5 °C from the temperature of the receiving water body

3.2.3.2 Technical standards for water supply and canalisation (Normas tecnicas para abastecimiento de agua potable y alcantarillados de aguas negras)

This standard by ANDA regulates technical specification for water supply and canalisation of wastewater. It replaced the old standards for the design and construction of aqueducts and canalisation systems (established in 1967) in the year 1997. Since the rules must be integrated flexible according to scientific principles, technological progress and applied research, a new formulation was urgently needed.

The fundamental purposes of the technical standards are to reduce environmental pollution and ecological imbalance, to meet the growing demand for potable water, protect natural resources and reduce water borne diseases.

Table 3 shows the relevant values for urban areas apart from other technical specifications that are stated in the standard. ANDA does not specify in the standard what the actual size respectively number of persons of a small, medium or large household is. (ANDA, 10/9/1997).

Table 3: Specified water consumption in urban areas by ANDA

Consumer	Consumption	
Average urban resident	220	l/p/d
Small household	80 - 125	l/p/d
Medium household	125 - 175	l/p/d
Large household	175 - 350	l/p/d
Market	15	l/m²/d
Office	6	l/m²/d
Garden	1,5	l/m²/d

3.2.4 Sanitation in rural areas

There is a high diversity of sanitation facilities in rural areas of El Salvador since several different public institutions, NGO's, other organisations and private owners construct different sanitation systems in the country. The following chapters describe the most common sanitation facilities that are used in these areas.

3.2.4.1 Toilet with water flushing - "Inodoro"

This type of toilet flushes away the human excrements with water, either into:

- a pit, from where it infiltrates into the ground
- a septic tank, where it is stored
- or into a canalisation, where it is conducted to a treatment plant or directly in the environment (MINSAL, s. a.b)

In only 8% of the households in the municipality mainly in urban areas like Tecoluca Town this system is applied (UCSF TECOLUCA, 2015). But also public institutions like the town hall, the police station, the health centre, the restaurant in Parque Tehuacan, etc. use a toilet with water flushing for the disposal of excrements. A reason for this low percentage of *"Inodoros"* could be a lack of access to an improved water supply or water scarcity in the dry season. (SANABRIA, 2015). Figure 4 shows a typical toilet with water flushing in the municipality Tecoluca.

Figure 4: Inodoro - toilet with water flushing (MINSAL s. a.a)

3.2.4.2 Compost latrine (Letrina abonera seca familiar)

This type of latrine uses the principles of degradation for the disposal of human excrements. It has two bowls, each connected to a separate tank for decomposition, which are used alternately in order to maintain the degradation of the human excrements (Figure 5). Depending on the size of the household, the residents use one tank for up to one year. If a tank is full, the other bowl with its tank will be used, so that the content of the already used tank can finally degrade. After three to four months, the degraded material is removed and put on the field or in the garden as fertilizer. It should be considered that there is always a risk of contaminating bordering water bodies. (MINSAL, 2004b)

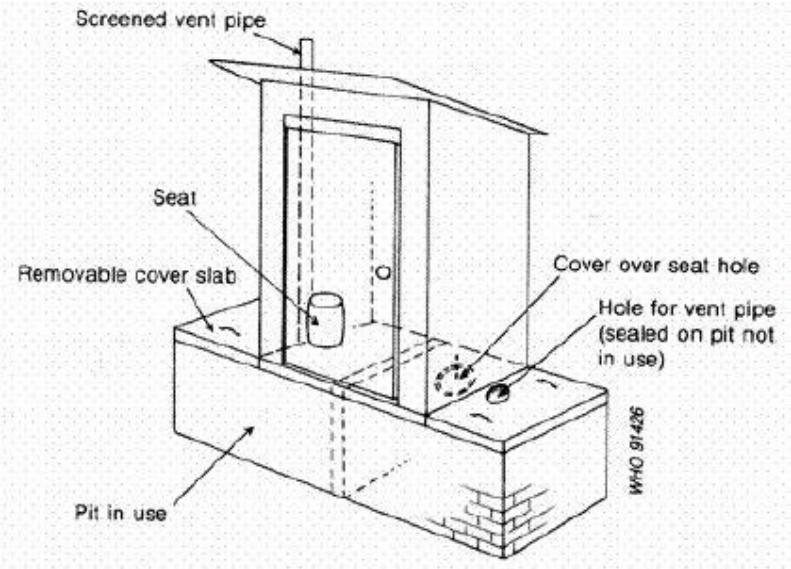


Figure 5: Example of a compost latrine with two tanks (FRANCEYS et al., 1992)

3.2.4.3 Dry latrine with solar drying (Letrina solar)

This type of latrine features a single tank with a sheet metal plate and a sink. In Figure 6 the sink with the metal plate next to the latrine can be seen. The beams of the sunlight heat up the metal plate and in turn the heat of the plate dehydrates the human excrements, thus accelerating the drying process. The latrine should be located on the sunniest spot of the available land and towards the south ensuring that the path of the sun, and therefore the beams of sunlight affect the solar collector as long as possible. The urine is collected in a detached tank to ensure the drying process of the faeces. (MINSAL, 2004b)

Figure 6: Dry latrine with solar drying (MINSAL, 2004a)

3.2.4.4 Dry latrine (Letrina seca)

Figure 7 shows a typical dry latrine that is used in rural areas in El Salvador. It is a very simple system made out of bricks or in rare cases out of corrugated metal. Inside the latrine two concrete bowls of which only one is used at a time are located. Figure 8 shows the two bowls, of which one is covered with bowls of chalk. Each bowl has its own tank for faeces. The urine is collected in a detached tank to avoid moisture during the drying process of the faeces. Depending on the number of users, one tank can be used for up to one year. If a tank is full, the other bowl is used, and the content of the previously used tank can dry out. Instead of water flushing the people put sand, ash or chalk on the excrements, in order to save water, avoid odour and to get a fertilizer for a garden or crops. The latrines are located outside of the house to avoid undesirable odour in the house.

Figure 7: Dry latrine with two chambers

Figure 8: Inside of a dry latrine

3.2.4.5 Pit latrine (Letrina de hoyo modificado)

This construction consists of a bowl connected to a simple pit, where the urine separation technique is also used, by the means of a seat having a separation device for urine and faeces. Thus also promoting dehydration of faeces, which can stabilize human excrements (Figure 9). The system should be located in areas that present no risk of landslides and in areas that are dry and therefore present no risk of floods during the rainy season. It should be ensured that there is no risk of contamination of existing water sources such as wells, surface outcrops, rivers, etc. (MINSAL, 2004b)

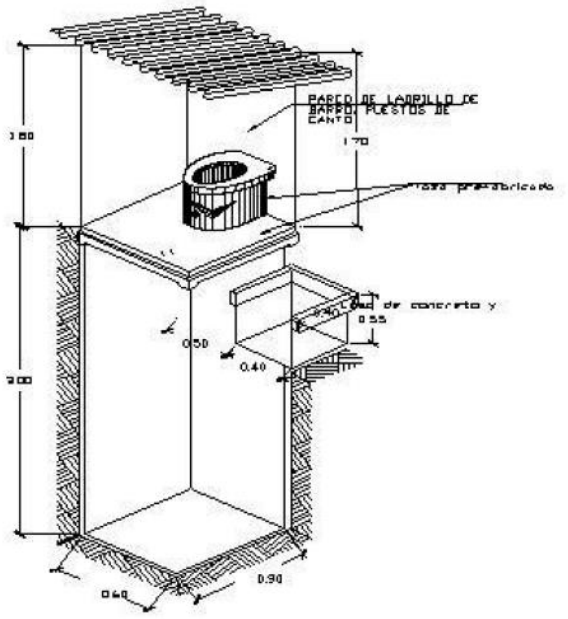


Figure 9: Example of a pit latrine

3.2.5 Individual domestic wastewater treatment system according MINSAL

The ministry of public health and social welfare provides a technical guideline for domestic wastewater treatment systems (*Gúia técnica sanitaria para la instalación y functionamiento de sistemas de tratamiento individuales de aguas negras y grises* – Technical health guideline for the installation and operation of individual wastewater treatment systems). The objective is to provide technical support to the delegates of environmental health who are responsible for decisions regarding required domestic wastewater treatment systems and to define technical criteria for the installation, operation and maintenance of domestic wastewater treatment systems.

MINSAL suggests the individual treatment of black and grey water by a septic tank system. It is composed of three elements which are a septic tank, a fat separation and an infiltration system. In the case of the infiltration system, there are three options to select, according to the technical criteria described in the guideline of the ministry, which are a drainage well, an infiltration pit or a filter sand pit (Figure 10).

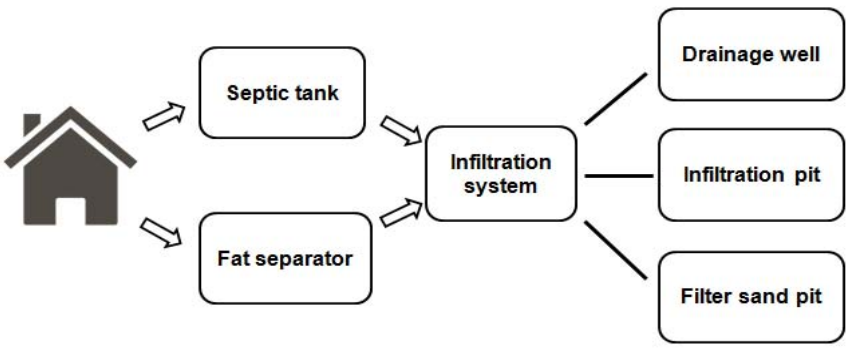


Figure 10: Schematic of the components of the domestic wastewater treatment system

3.3 Description of the study area

Tecoluca is a municipality in the Central American country El Salvador (Figure 11). It is the smallest country in Central America with 21,040 km² of which 98.5% is land and only 1.5% is covered with water. The country borders Guatemala to the north-northwest, Honduras to the north-northeast and the Pacific Ocean to the south. It is the only country in Central America that has no Caribbean coastline. El Salvador stretches 270 km from east to west and 140 km from north to south. The highest mountain is called Cerro El Pital (2.730 m) and is located on the border to Honduras. (OFICINA DEL ECONOMISTA JEFE, s. a.)

El Salvador is divided into 14 departments, which unite 262 municipalities. San Salvador, the capital of El Salvador, is the biggest city with estimated 257,754 inhabitants, while El Salvador has an estimated 6.46 million inhabitants (MINISTERIO DE ECONOMIA et al., 2014), which leads to the highest population density in Central America of 307 people/km². For comparison, Austria has a density of 102.4 people/km² (WKO, 2015).

El Salvador stretches over 3 climate zones:

- tropical zone with an elevation from 0 to 800 meters above sea level,
- temperate zone with an elevation from 800 to 1,200 m a.s.l. and
- cold zone with an elevation from 1,200 to 2,700 m a.s.l.

During the year there are only small temperature differences, the annual mean temperature is 24.8 °C. However, due to the proximity to the equator there are intense precipitation differences with an average annual precipitation of 1,784 mm, which lead to a rainy season from April to October and a dry season from November to March. The country has about 360 rivers, which are grouped into 10 hydrological regions, and an estimated amount of groundwater of about 6,155 million m³. (Tábora, Basterrechea und Candanedo)

Figure 11: Location of the municipality Tecoluca in El Salvador

3.3.1 Geography, topography and hydrology

Tecoluca is the largest municipality in the department San Vicente with 284.65 km² and combines 24 cantons. It borders the municipality San Vicente in the North, the Pacific Ocean in the South, the department Usulutan in the East and the department Zacatecoluca in the West(Figure 12). The municipal capital is also called Tecoluca and is located at an altitude of 270 m a.s.l. In the municipality humid subtropical climate with a small proportion of very humid subtropical zones in the higher parts corresponding to the volcano Chinchontepec dominates.

Figure 12: Map of the municipality Tecoluca

The municipality has an important catchment area including Rio Lempa, the largest river in the country and a series of rivers rising in the volcanic areas and the hilly areas in the southeast areas of the municipality San Vicente. The municipality contains 13 rivers with a length of more than 5 km and about 100 small brooks. There are also some lagoons in the south of Tecoluca. (GRA-JEDA et al., 1997)

3.3.2 Demography and population

Municipality Tecoluca

According to the investigation of UCSF Tecoluca the municipality Tecoluca counts 29,545 inhabitants for the year 2015. The population density is 104 people/km², three times lower than the national population density. The majority (90.1%) of the population lives in rural areas and the proportion of males to females is almost equal (Table 4). (UCSF TECOLUCA, 2015)

Table 4: Population of the municipality Tecoluca (2015)

	Males	**[%]**	**Females**	**[%]**	**Σ**	**[%]**
Urban	1367	46.8	1556	53.2	2923	9.9
Rural	13125	49.3	13497	50.7	26622	90.1
Total	14492	49.1	15053	50.9	29545	100

Tecoluca Town

According to UCSF TECOLUCA (2015) live 1935 people in 502 households in the six zones of Tecoluca Town. This leads to an average of four persons in a household, the same as in rural areas. The proportion of males and females in the town is 47 to 53. 40.2% of the households are located in Colonia San Romero (Table 5). This colony was built after a heavy earthquake in 2001, where a lot of people lost their homes. Since then prevail problematic social circumstances in this zone. (Sanabria 4/20/2015)

Table 5: Population of Tecoluca Town (2015)

Zones	**Families**	**Males**	**[%]**	**Females**	**[%]**	**Total**
Barrio Las Flores	88	179	49.7	181	50.3	360
Barrio San Jose Pasaquina	54	90	41.3	128	58.7	218
Barrio El Calvario	65	112	47.5	124	52.5	236
Barrio El Centro	48	83	44.4	104	55.6	187
Barrio Santa Tecla	45	66	54.1	56	45.9	122
Colonía San Romero	202	371	45.7	441	54.3	812
Tecoluca Town	502	901	46.6	1034	53.4	1935

3.3.3 Economy and sources of income

There is a corporate network of 328 companies located in the municipality, divided into the commercial sector with 76%, followed by the industry sector with 13% and the service sector with

11%. The agricultural sector occupies 3,367 producers, where 12% are commercial producers and 88% are small producers. (TRIGUEROS, 2012)

Table 6 shows the mean monthly salaries of the different economic sectors in El Salvador. It can be notified that people providing a service earn more than twice as much as farmers. (DIGESTYC, 2014)

Table 6: Mean monthly salary according economic sector (2013)

Economic sector	Mean monthly salary in US$
Agriculture	142.13
Industry	257.61
Commerce	293.11
Service	301.72

3.3.4 Water-related challenges in Tecoluca

In recent decades the number of domestic water connections in suburban and rural areas has increased more than the number of domestic wastewater treatment facilities. The problem is that most administrators of water systems and water supply do not invest in systems for domestic wastewater treatment. Water users do not have environmental consciousness to perceive the negative effects of untreated wastewater on health and the environment. Designers and constructors of buildings and residential subdivisions do not provide or leave enough space on the property for domestic wastewater treatment systems to be built. Many families that do have grey water treatment systems misuse them and grey water is discharged directly onto the street and into receiving water bodies contaminating water resources (water, air, soil) and impacting the environment and public health (MINSAL, 2009).

In the year 2008, the municipality of Tecoluca, with the support of INTERSOL, built a constructed wetland for the Parque Tehuacan, which is located a few kilometres outside of Tecoluca Town. It should treat the wastewater of a restaurant and five small lodges in the park. The constructed wetland includes a sedimentation shaft for the solid parts and two filter beds for the purification of the wastewater. The system was built as a 2-stage vertical flow filter.

It was planned that the proper operation of the system is checked biweekly with check list according to a pre-assembled schedule. However, in the course of a site visit in April 2015, the two basins were found in bad condition. Figure 13 shows the first basin which had an uncontrolled coverage of vegetation and some undesirable wastewater accumulations, but it was operating. The second basin was completely under water and there was no evidence that this basin was still

operating. This situation indicates that there is a lack of active operation and periodic maintenance of the constructed wetland in the park.

Figure 13: Uncontrolled vegetation on the first basin of the constructed wetland

Figure 14: Inundated basin of the constructed wetland in Parque Tehuacan

3.3.5 Sanitary situation in Tecoluca

Survey results from the UCSF TECOLUCA (2015) show that 84% of 6065 households in the municipality have access to improved sanitation facilities, 11% do not have access and for the remaining 5% no data exists (Figure 15).

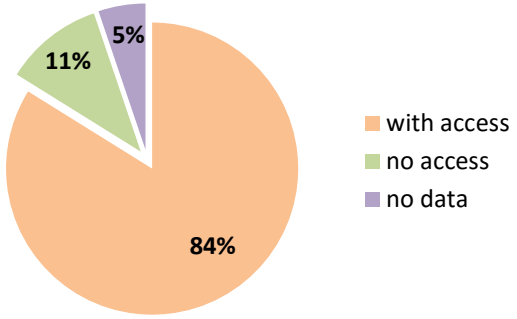


Figure 15: Household sanitation facility coverage of municipality Tecoluca

The percentage of population with access to improved sanitation for each canton in the municipality is displayed in Figure 16. The canton San Ramon Grifal in the middle of the municipality with 60% and the southernmost canton Las Mesas with 66% have the least coverage of improved sanitation.

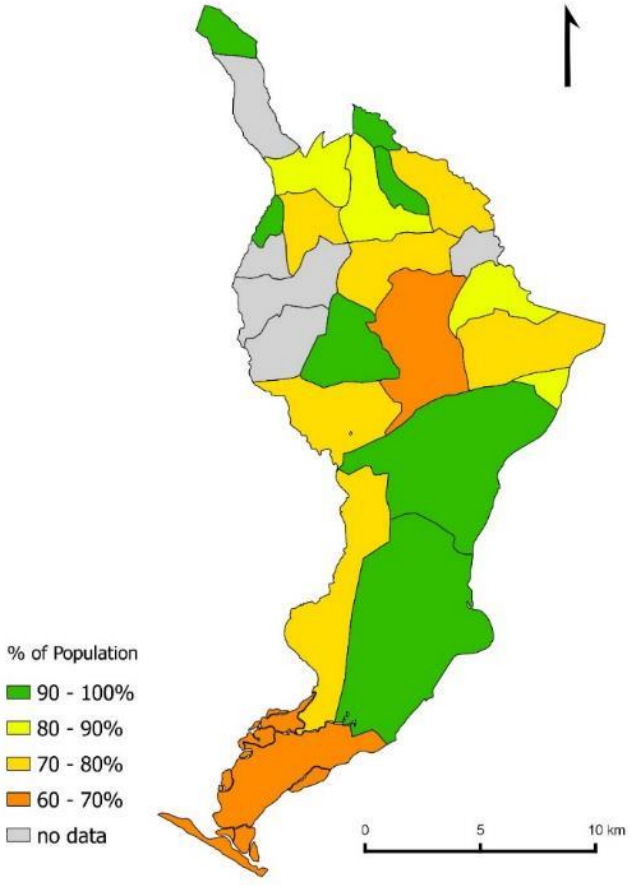


Figure 16: Percentage of population with access to improved sanitation in the municipality Tecoluca

Figure 17 shows the fraction of the different types of sanitation facilities that are used in the households that have access to such equipment. More than half of the households (58%) use compost latrines for defecation. Pit latrines are used in 27% of the households. Toilets with flushing (8%) and toilets with pit (7%) are used in a minority of the households (UCSF TECOLUCA, 2015).

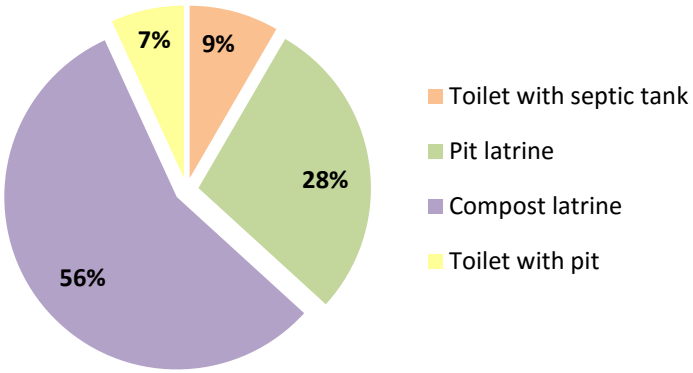


Figure 17: Types of sanitation facilities in the municipality Tecoluca

The practice regarding defecation depends on the type of the sanitation facility. At a toilet with flushing, the people use toilet paper but do not throw it in the toilet. Instead they throw it in a separate waste container next to the toilet. Therefore, no toilet paper can block the pipes or enters the environment with the black water.

At dry latrines or compost latrines the people also use toilet paper and throw it in a waste container, but in place of water for flushing, they put ash, chalk or sand on their excrements in order to prevent a displeasing smell and to enhance the drying respectively the composting process.

4. Materials and methods

This chapter describes the materials and methods used in the investigation to collect and analyse useful information from different sources. The data collection was realized by two different types of interviews. The gathered information is later digitalised, saved and analysed for presentation and further investigation. In the following subchapters the methods are explained for the urban area, Tecoluca Town, and for the rural areas of the municipality.

4.1 Investigated sites

4.1.1 Rural areas of the municipality Tecoluca

The municipality Tecoluca includes 96 communities, except Tecoluca Town. These communities have a high variety in size respectively in number of inhabitants. It ranges from only 7 households in El Paraiso to 268 households in Nueva Tehuacan. In total 8008 households are located in rural areas of Tecoluca. (UCSF TECOLUCA, 2015)

Since it was not possible to visit all of the communities in the restricted timeframe of the thesis, it was necessary to select a number of villages for the survey to get a representative result for the entire municipality.

In their guidelines for planning and designing rural water supply and sanitation programs OCK-ELFORD and REED (2002) state that this number depends on different factors such as socially, ethnically and geographically complexity of an area. If there is a high complexity of these factors in the area, more villages have to be surveyed, otherwise less villages are sufficient. The guideline provides a manual with a table and a formula for the calculation of the number of villages that need to be visited in order to get a representative result. The original table is designed for a survey in the sector of water supply and includes the following questions:

A. How many ethnic groups are there in the area? How different are these culturally?
B. How uniform is the population in socio-economic terms?
C. How geographically diverse is the region?
D. Do people rely on groundwater, surface water, or both?
E. Do some villages already have improved water supplies while others do not?
F. Are there any other complicating factors?

The formula in the manual is as follows:

$$\boldsymbol{Number\ of\ villages} = \boldsymbol{A} \times \boldsymbol{B} \times \boldsymbol{C} \times \boldsymbol{D} \times \boldsymbol{E} \times \boldsymbol{F} \qquad (4.1)$$

The letters in the formula represent the values given to the corresponding question.

The original table of the guideline from OCKELFORD and REED (2002) is in Appendix 1.

To apply the calculation for the needed number of villages to the sector of sanitation it is necessary to alter question E. Table 7 shows the adapted table for the calculation of the required villages for the survey.

Table 7: Calculation for the number of villages to be surveyed

	Question	Comment	Calculation	Value
A	How many ethnic groups are there in the area? How different are these culturally?	Mostly Christians in rural areas.	Enter a number of distinct group.	1
B	How uniform is the population in socio-economic terms?	Some differences in the source of income.	Enter 1, 2 or 3 for the range: uniform to wide diversity.	2
C	How geographically diverse is the region?	Constant topography, mostly agriculturally influenced landscape.	Enter a number of distinct areas.	1
D	Do people rely on groundwater, surface water, or both?		Enter 1 for either surface water or groundwater, or 2 if both surface water and groundwater are relied on by the same or different communities in the area.	2
E	Do some villages already have improved sanitation systems while others do not?		Enter 1 if only unimproved or only improved; enter 2 if both unimproved and improved are present.	2
F	Are there any other complicating factors?	Unpredictable factors	Enter 1 for no, 2 for yes.	2

Using the values from Table 7, the number of villages that need to be visited can be calculated as

$$A \times B \times C \times D \times E \times F = 1 \times 2 \times 1 \times 2 \times 2 \times 2 = \mathbf{16}$$

Thus, the interviews were carried out in 15 (15.6%) of 96 villages or communities all over the municipal area of Tecoluca. These 15 villages comprise 1856 households, i.e. 23.2% of the rural population of Tecoluca live in the selected villages.

Since the presence of a member of the local water committee and of the supervisor was required for the interviews, the selection of the villages to be visited depended also on the time availability of these persons.

As one can see in Figure 18, the investigated sites were located in the northern parts of Tecoluca. The reason for this is that this thesis was carried out jointly with another master`s thesis called “Establishment of a GIS database for water resources management: a case study in Tecoluca, El Salvador” by Schaidreiter V. in 2016, and due to practical and time constraints only villages in these parts were examined.

The villages are mainly composed of simple houses and dirt roads. The houses are made of bricks, corrugated metal or clay and include a small garden in which most of the families keep livestock such as pigs, fowls or even cattle.

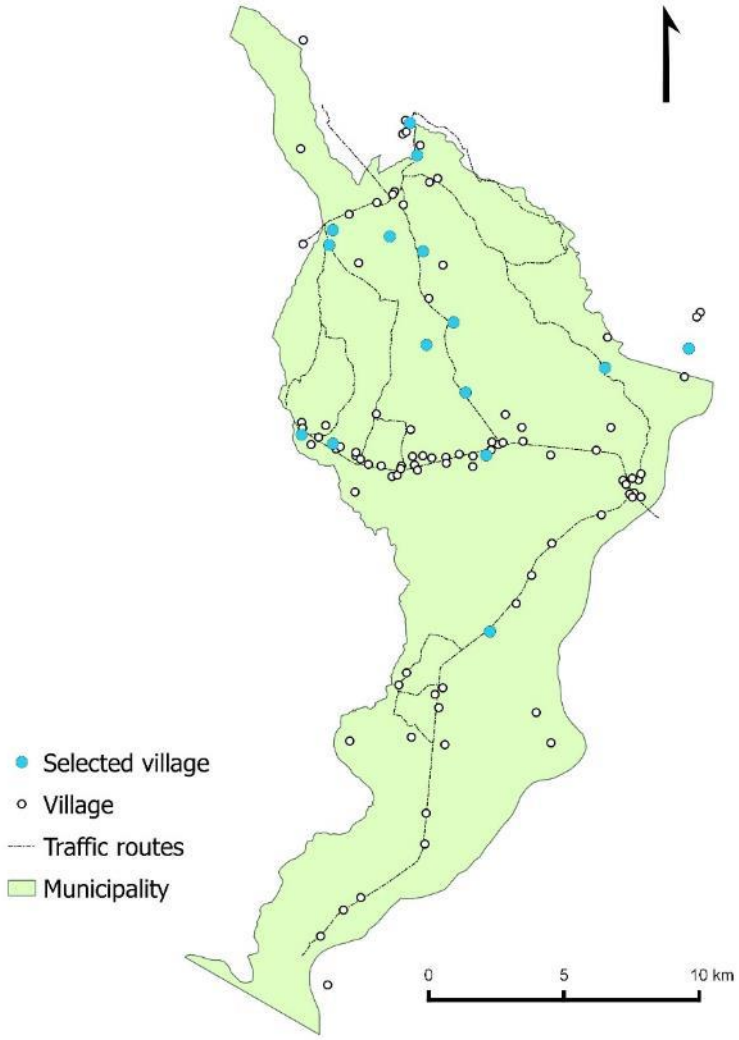


Figure 18: Investigated sites in the municipality

4.1.2 Urban area of Tecoluca (Tecoluca Town)

As shown in Figure 19, Tecoluca Town is divided into 6 zones (El Calvario, El Centro, Las Flores, San Jose Pasaquina, Santa Tecla and Colonia San Romero). The lower layer in the figure shows

the cadastre of the town provided from the municipality, however, in parts of San Romero the cadastre is not complete.

The interviews were executed in 5 different households in each zone in the town, to get an overview of the sanitary situation in the urban area. The selection of households was random, but it was taken care that these were evenly distributed over the surveyed area.

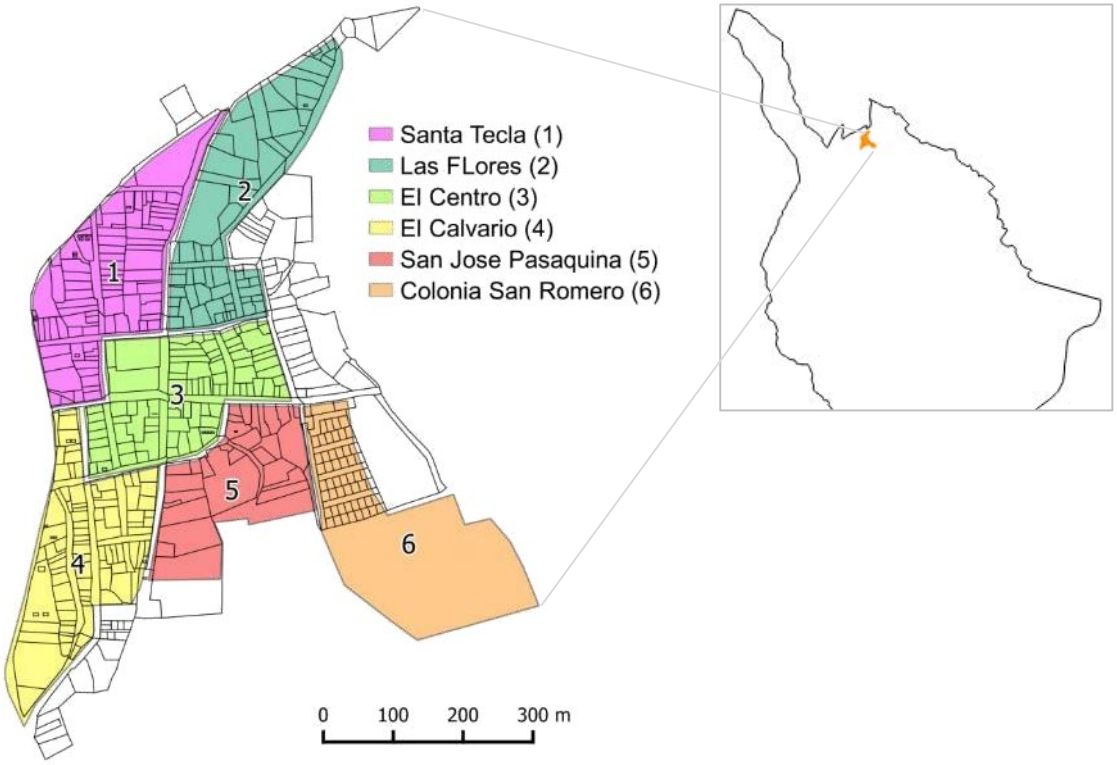


Figure 19: Surveyed zones of Tecoluca Town

4.2 Method of the interviews

4.2.1 Interviews in rural areas of the municipality Tecoluca

OCKELFORD and REED (2002) declare, that it is important to execute the interviews without prejudice and in a sensitive approach. The objective is to gather information from the interviewee`s point of view, which means that the interviewer should not contradict the answers given by the interviewee, especially when the interviewer works in the sector and may know more than the interviewee. Furthermore, the interviewer should make it clear that the interviewee`s own experience, knowledge and opinion is fundamental for the survey and should adapt the questions suitable to the interviewee`s knowledge. Lastly, the interviewer should be aware that also a false understanding or knowledge of the interviewee can contribute to the survey in the same way as a correct one.

There are three types of methods of how an interview can be executed, from structured, over semi-structured, to unstructured interviews. For the investigation in rural areas a qualitative or semi-structured method was selected. This type of interview contains a list of questions that guarantee some structure and comparable information for the interviewer, but the interviewee has more flexibility in his answers than in a structured interview. This sort of interview enables the interviewees to answer in their own terms and further dialogs and discussions can result. (EDWARDS and HOLLAND, 2013)

The meetings in the villages were always accompanied by the technical supervisor of the municipality Herberth Sanabria and the interviews were conducted with one of the local people of the community or with one member of the responsible water committee.

Since the interviews were done in cooperation with Schaidreiter V., the questionnaire for the villages contains questions for the wastewater sector and the water supply sector. The original questionnaire can be seen in Appendix 2.

The questionnaire contains 11 questions about the production, handling and disposal of wastewater and solid waste. The answers were given by a member of the responsible water committee and considered as average values for a household respectively the village. Therefore, the interviews in the different villages were held mostly in the same pattern, with a few individual adaptations for specific situations.

The questions are:

- How many families live in the village?
- How many people live in average in a household?
- How much water do you consume in one day/month?
- For what purpose you are using the water?
- What kind of detergents and/or disinfectants do you use to keep your household clean?
- How do you dispose of your grey water?
- Where is the bathroom located?
- How do you dispose of your excrements/faeces?
- What type of latrine are you using?
- Who constructed the latrines?
- How do you dispose of solid waste?

4.2.2 Interviews in the urban area (Tecoluca Town)

For the interviews in Tecoluca Town a quantitative or structured method was selected. Structured interviews are based on questionnaires with a series of questions. The questions are asked in a similar way throughout the survey, in order to gain comparable information from the interviewees. There is only little flexibility for the interviewer and the interviewee but it is a good method for examining a large number of subjects. (EDWARDS and HOLLAND, 2013)

Every interview was conducted as an individual interview with one member of the household and it was accompanied by an employee of the municipality. The attendance of the municipality was necessary to simplify the conversation in case of communicational problems and to encourage the residents to answer openly and correctly to the foreign interviewer.

The questionnaire for the urban area was slightly different from the questionnaire for the rural areas. It contained 13 questions, with a main focus on the production and the distribution of grey water over a day, but also on how the residents dispose of their excrements and whether they have a wastewater system as recommended by MINSAL, which is described in chapter 3.2.5. Depending on the interviewee, an interview took 10 to 20 minutes. The original questionnaire can be seen in Appendix 3.

The questions are:

- How much people live in the household?
- How much water do you consume during a day/month in your household?
- How is the distribution of the water use/consumption over a typical day?
- What kind of detergents and/or disinfectants do you use to keep your household clean?
- Where do you wash your clothes?
- Where is the bathroom located?
- Do you have a fat separator?
- Do you have a septic tank?
- If no, how do you dispose of the excrements?
- Do you have an infiltration system for grey water?
- If no, how do you dispose of the grey water?
- How do you dispose of solid waste?
- Could or would you pay 2 – 3 US$ per month for a future wastewater service tax?

4.3 Analysis of the collected data

4.3.1 Calculation of the domestic grey water flow

SPERLING (2007) states that in general the domestic water consumption correlates nearly with the amount of produced grey water, but a part of the consumed water can be infiltrated (e.g. watering of gardens). The fraction of the supplied water that discharges from the household is the return coefficient or return factor and it varies from 60% to 100%. A typical value for the return factor is 0.8. This means that 80% of the consumed water in the household is converted to grey water.

Besides the infiltration, other losses such as the use of water for livestock, for cleaning the house and other external uses can affect the amount of grey water. The percentage of this loss depends on different factors like the habits of the inhabitants, the characteristics of the community, the supply of water and differences in the water consumption during the year. For example, in arid areas in the USA the return factor is 0.4, whereas in suburban areas in Brazil the return factor is higher than 0.8. (ORGANIZACIÓN PANAMERICANA DE LA SALUD, 2005)

If there are no local information or studies for an estimation of the return factor, ORGANIZACIÓN PANAMERICANA DE LA SALUD (2005) recommends to assume values for the return factor between 0.8 to 0.85.

The suggested value for the return factor according to DUNCAN (2004) ranges from 0.8 to 0.9 and the domestic wastewater flow is typically calculated by using the following equation developed by him:

$$\boldsymbol{Q_{ww} = 10^{-3} \times k \times q \times P} \qquad (4.2)$$

Q_{ww} Domestic grey water flow [m³/d]

q Water consumption [l/p/d]

P Population of a village

k Return factor

Since the majority in the surveyed villages use their water also for their gardens and livestock besides the typical usages such as cooking, bathing, cleaning and drinking, 0.8 for the return factor is used to estimate the amount of grey water in rural areas. The inhabitants in the urban area do not have any livestock, only gardens, so the return factor k is assumed with 0.9 instead of 0.8 in rural areas.

4.3.2 Data analysis of the rural areas of the municipality Tecoluca

After conducting the interviews, the collected information of every village was documented and summarised in a Microsoft Word-file. The significant values for the wastewater management were entered into a Microsoft Excel-file.

Table 8 shows the entered parameters in the Microsoft Excel-file with an example of one village. The parameters “id”, “Y”, “X”, “GW_code”, “E_code” and “SW_code” are necessary for a subsequent embedment in a geographical information system (see chapter 4.4).

Table 8: Used parameters in the Microsoft Excel-file for an analysis (with example values)

Parameter	*Value*	*Comment*
id	1	Numbering of the villages
Village	Las Pampas	
Y	13.5119	Longitude
X	-88.7767	Latitude
Families	79	
Males	133	
Females	149	
Persons/hh	4	
Water use	Livestock	Water use besides the common uses (cooking, washing, bathing, drinking, cleaning)
Grey water disposal	Discharge into water body	
GW_code	1	Code for an explicit assignment
Affected water body	Rio Agua Caliente	
Excrements disposal	Compost latrine	
E_code	1	Code for an explicit assignment
Constructor of latrines	HIBASA, 1994/95	
Solid waste disposal	Incineration	
SW_code	1	Code for an explicit assignment
Water consumption per household [m³/hh/month][1)]	8	
Potentially accum. grey water [l/hh/d]	213	
Potentially accum. grey water [l/p/d]	36	
Total Potentially accum. grey water [m3/d]	14	

1) m³ per household and month

The analysis of the gathered data is performed through descriptive statistics, in order to display it in a visually appealing way.

The descriptive statistics deals with the summary of data and the presentation of meaningful indicators of a dataset. Thereby, it offers different ways to display data in a summarised and significant way. (HUG and POSCHECHNIK, 2010)

For calculating the average of the various values in the following chapters, the arithmetic mean is always used and for the visualisation histograms, pie charts or line charts are used.

4.3.3 Data analysis of the urban area (Tecoluca Town)

The collected data from Tecoluca Town was also documented in a Microsoft Excel-file for the analysis and visualisation of the results. Here, also descriptive statistics are used to present the data visually appealing, like it is described in chapter 4.3.2.

The table of the file can be seen in Appendix 4.

4.4 Data implementation in a GIS

A Geographical Information System, or GIS, helps to visualise, analyse, present and understand data in relation to geographic space (ESRI, 2015). Therefore, the collected data from the rural areas of Tecoluca is implemented in such system, with the goal to create wastewater-related maps of the municipality and to provide a tool for the municipality and students for further investigation.

4.4.1 Selection of a GIS

There is a large offer of different GIS, licensed or open-sourced, available on the market. However, since it is thought that employees of the municipality should continue working on this project and the municipality has a restricted budget, only open-source GIS are under consideration.

SCHAIDREITER (2016) did, in the course of her master´s thesis, a detailed summary of the advantages and disadvantages of different open-source GIS and came to the conclusion that the software QGIS is appropriate for the required tasks of her project.

QGIS is also appropriate for the required tasks of this work, so it is used for the data implementation. Not only the same software, but also the same QGIS-project is used in order to keep the system as simple as possible and to have water- and wastewater-related information gathered in one project.

4.4.2 Data connection between Microsoft Excel and QGIS

In order to process the same dataset from the Microsoft Excel-file also in QGIS without having to re-enter it, it is necessary to automate this step. This process is realized with a short, self-programmed macro for Microsoft Excel in Microsoft Visual Basic. In addition to the reduced amount of work for a new input of the data in QGIS it also reduces the possible failures that can occur by human input.

The macro writes the content of selected cells into a Comma-separated value file (CSV-file). By pressing the key combination “CTRL+Q”, the macro starts this process and saves the generated file in the same folder as the Microsoft Excel-file is, with the identical name of the Excel-sheet that contains the data. The CSV-file must include a column header in the first row so that QGIS can recognize the file correctly. In this case, the column header for the CSV-file is the first row of the selection in the Excel-sheet and further the table header in the attribute table. Figure 20 shows the transformation from the Microsoft Excel-file to a CSV-file and finally into an attribute table in QGIS.

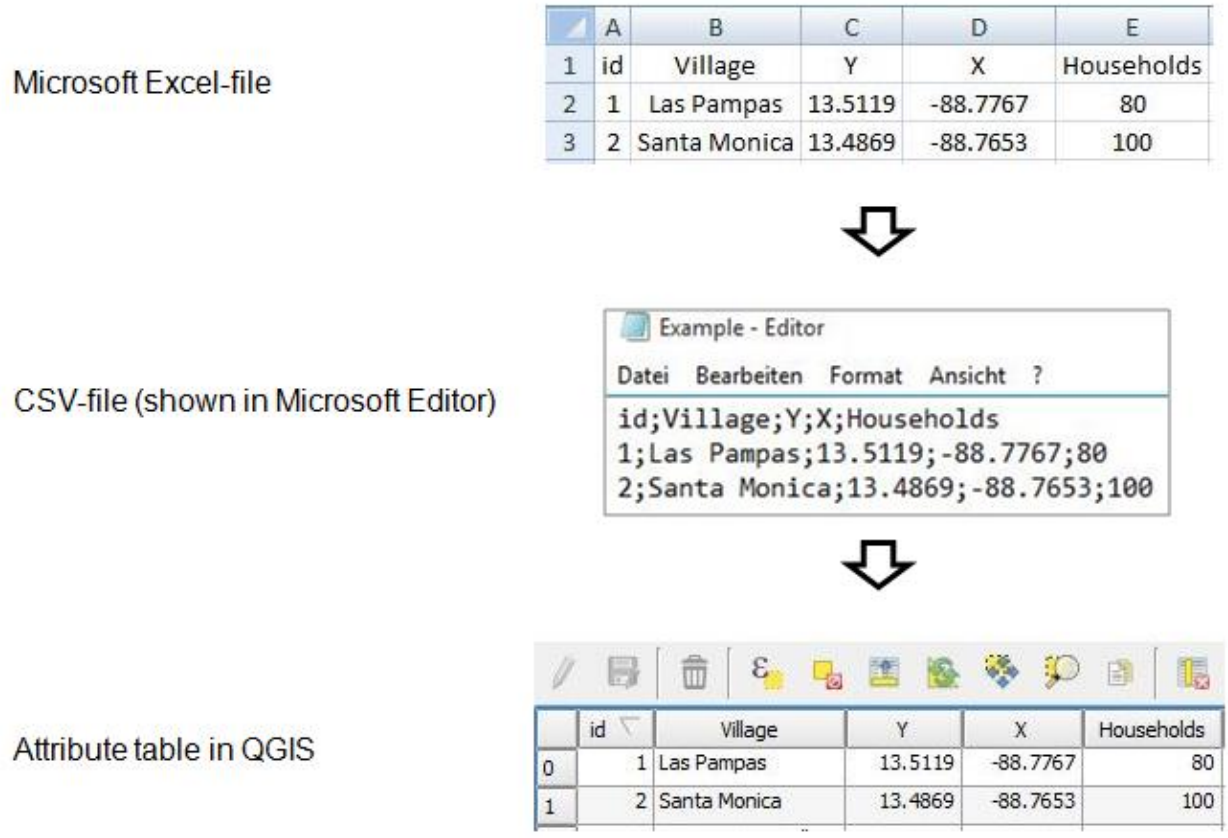


Figure 20: Example of the data transformation (Excel – CSV – QGIS)

To complete the automated process, the CSV-file needs to be loaded into the QGIS-project as a layer to create a connection between the project and the file. The attribute table of this layer then contains the data and the column header of the CSV-file. If this is done once, the attributes of the layer change automatically if the CSV-file is altered or a new CSV-file with an identical name is generated by the macro.

The created layer in the QGIS-project, named “wastewater_overall”, is now the base layer for wastewater-related layers and can be duplicated and edited.

4.4.3 Background layer for the QGIS-project

The required background layers (shape files) were provided from different sources and consist of different types as seen in Table 9. The background layers are necessary for a correct interpretation of the collected data and for geographical references. Table 9 lists the used background layers for the wastewater-related layers. The data was provided from different local persons in charge for geographical data.

Table 9: Used background layers for the QGIS-project

Layer	Source	Type
Municipality border	Freddy Cruz[1)]	Polygon
Rivers	CNR	Line
Traffic routes	CNR	Line
Communities	Schaidreiter (2015)	Point

[1)]Professor at Universidad Nacional de El Salvador

4.4.4 Analysis and visualisation in QGIS

Functions of QGIS:

The principle functions of QGIS are data - visualisation, - editing, - generation, and – management as well as the creation of maps (QGIS, 2016).

It is possible to display the comprehended data of an attribute table on a map in several ways, such as symbols, captions, histograms, pie charts or so called text diagrams. With the combination of a corresponding legend, this type of illustration is a good method to present a large amount of qualitative or quantitative data with geographical references.

Potential visualisations with the collected data:

Qualitative data, e.g. how the majority in a village dispose of their excrements, can be displayed as symbols with different styles for each method on the background layers.

Example:

The number presents the name of the village and the symbol indicates the principle method of the disposal of excrements as well as the location of the village (Figure 21).

Figure 21: Example of the usage of symbols in QGIS

Quantitative data, e.g. the potentially amount of accumulating grey water in a household, can be displayed as captions for points on the background layers. Captions are data-connected and can present different combinations, depending on what the editor wants, of the data in the attribute table.

Example:

The number presents the name of the village and the caption contains data from the attribute table (Figure 22).

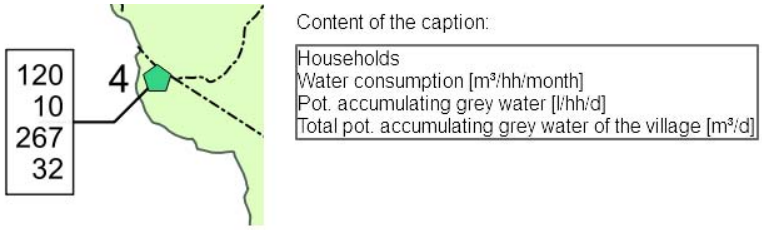


Figure 22: Example of the usage of captions in QGIS

Furthermore, it is possible to display different combinations of the layers used in a project. Figure 23 shows the principle of how layers are managed in QGIS. Depending on which layer is required for a certain purpose, layers can be added or removed for presentation.

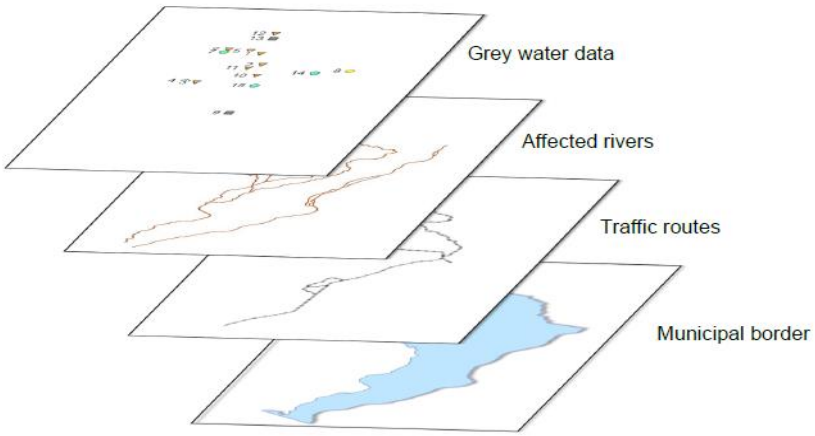


Figure 23: Example of a layer combination in QGIS

5. Results and discussion

The presented values in the following subchapters are estimated and not measured. The quantities given for the households in the communities were given in different units such as barrel/day, barrel/month, gallon/day, gallon/month, m³/day or m³/month and are considered average values for the community respectively for a household. This circumstance occurred because in their daily life the people use different units for the volume of water. In order to compare and analyse the reported data, the units were converted into consistent units of the metric system (e.g. m³/d).

5.1 Results of the interviews in the rural areas of Tecoluca

This chapter presents the results for the rural areas of the municipality, which include:

- Potentially accumulating grey water
- Final disposal of grey water, excrements and solid waste
- by QGIS created maps
- Summary of the collected data of all surveyed villages

5.1.1 Potentially accumulating grey water

The average water consumption of a household ranges from 8 m³/month in Las Pampas to 28 m³/month in Guajoyo. The overall average water consumption of a household of all surveyed villages is 15 m³/month. This value is the arithmetic mean of the 15 specified values for water consumption of each village. Considering that an average of four persons[3] live in a household, the average water consumption in rural areas is approximately 125 l/p/d[4]. Figure 24 shows the estimated quantity of water that is consumed monthly by an average household in the surveyed villages.

The interrogation was executed in the time between March and June, which is the transition period from the dry season to the rainy season.

[3] Estimated from the data of UCFS Tecoluca.

[4] This is a virtual value. Especially in the rural areas considerable amounts of water are also used for gardening and for feeding animals.

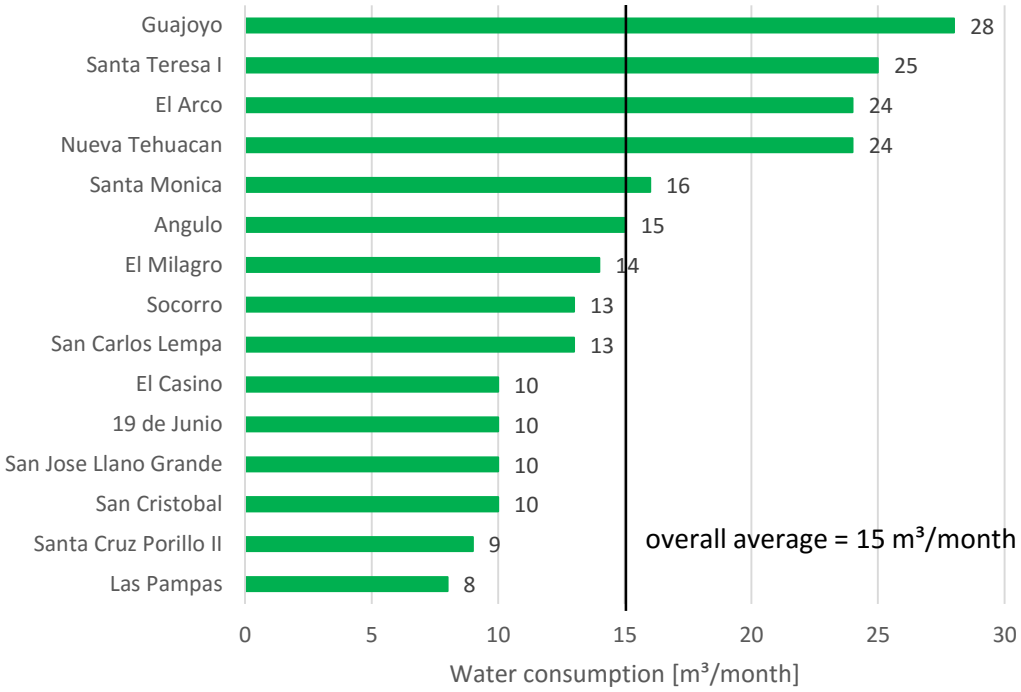


Figure 24: Average monthly water consumption of a household

Figure 25 presents the average potentially accumulating grey water that a household produces in the course of a day (displayed as strokes) and the total potentially accumulating grey water of a village (displayed as columns). The villages are in descending order from left to right according to their number of households.

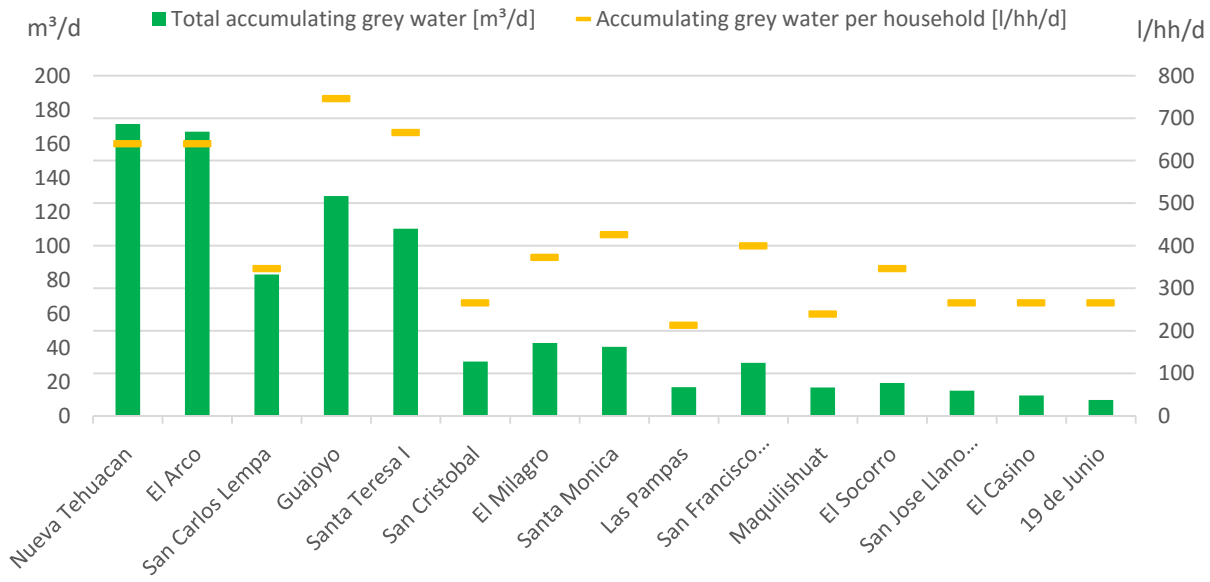


Figure 25: Potentially accumulating grey water per household for each village

The average minimum value for potentially accumulating grey water is 213 l/hh/d in Las Pampas with 79 households and the maximum value is 747 l/hh/d in Guajoyo with 173 households. The overall average value for the potentially accumulating grey water in a household is 407 litres per day. Nueva Tehuacan and El Arco produce the highest amount of grey water since these villages are the largest in the municipality with 268 and 261 households. Both villages are located in the immediate proximity of Tecoluca Town. In four of the 15 surveyed villages (Nueva Tehuacan, El Arco, Guajoyo and Santa Teresa 1) more than 100 m^3 of grey water is accumulated per day. On the opposite, in six villages (Las Pampas, Maquilishuat, El Socorro, San Jose Llano Grande, El Casino and 19 de Junio) less than 20 m^3 of grey water is accumulated per day.

Due to the data implementation in QGIS, described in chapter 4.4, it is possible to display the quantitative information collected by the interviews on a map. Figure 26 is a map of the municipality Tecoluca that displays information in captions for each village. The content of the caption is the number of households, the average monthly water consumption of a household, the potentially accumulating grey water for a household per day as well as for the whole community per day.

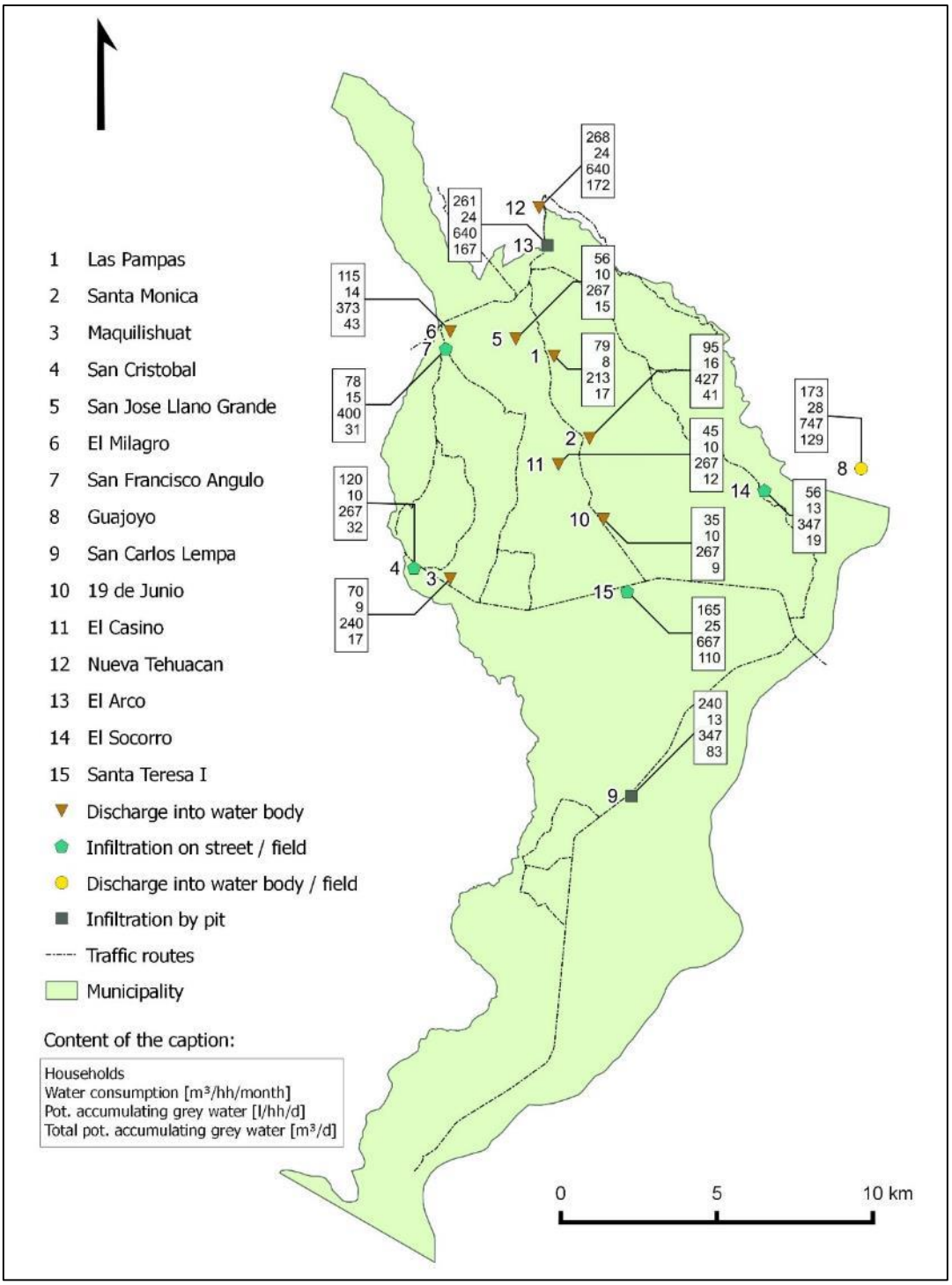


Figure 26: Map of grey water quantities in the surveyed villages

5.1.2 Final disposal of grey water

The disposal of grey water in the villages can be divided into three different procedures, shown in Figure 27.

The most common way is the discharge onto the street. This happens in 13 (87%) of the surveyed villages. If a water body is located in the vicinity of the village and a suitable topology is given, the grey water flows from the street into that water body, excluding the parts that are infiltrated on the way. This is mainly case in nine (62%) of the 15 villages. In four (25%) villages the grey water flows from the street to the open field where it infiltrates.

In two villages (13%) the majority of the households uses a separate infiltration pit on their property for the disposal of grey water.

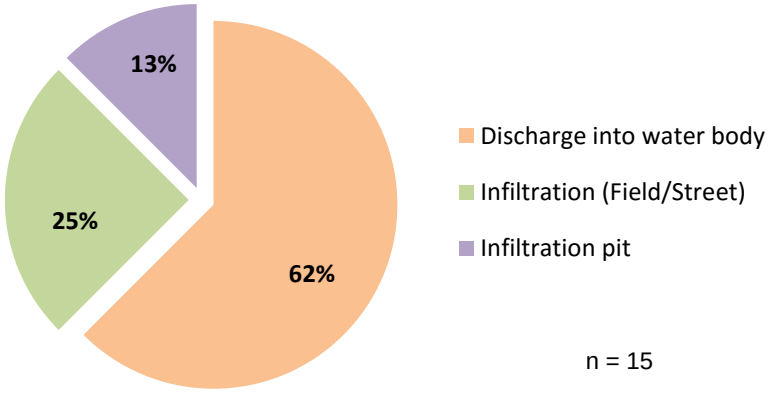


Figure 27: Disposal of grey water in rural areas

Figure 28 shows a map that displays the major procedure for grey water disposal in the surveyed villages and the rivers that are affected by the grey water. Each symbol indicates the location of the villages as well as the procedure at the same time. It can be seen that all of the affected rivers unite to one main river, called Cañon La Empalizada, in the west of the municipality. In the east of the municipality Rio Lempa is affected by Guajoyo. Both rivers end up in the Pacific Ocean.

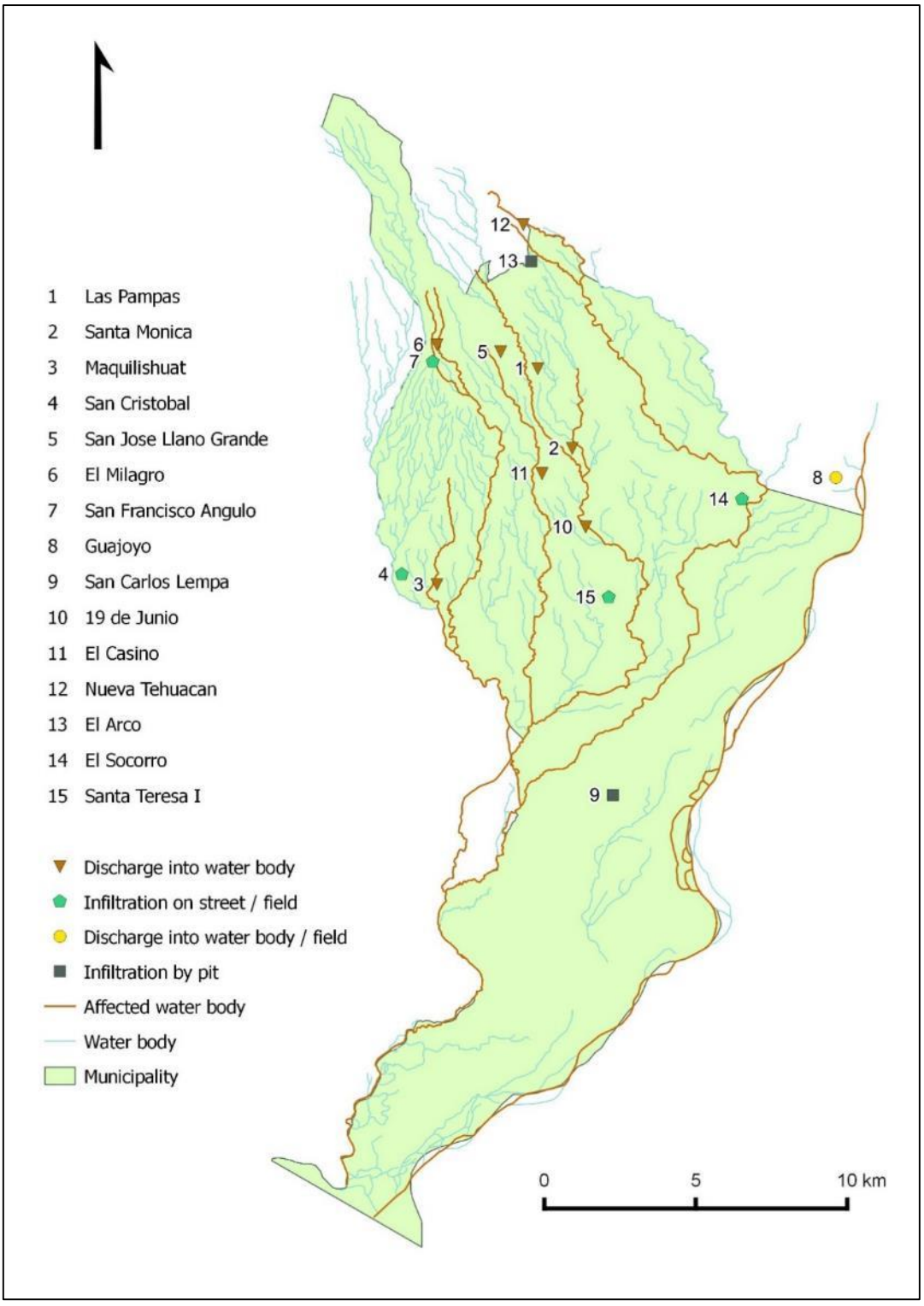


Figure 28: Map of common grey water disposal in the surveyed villages

5.1.3 Final disposal of excrements

In all surveyed villages, except for San Jose Llano Grande, the majority of the households uses latrines to dispose of their excrements.

In 10 (67%) of the 15 surveyed villages the compost latrine is the most common system and in eight of these villages, different organisations paid for the materials and in some cases also built up the compost latrines. In three villages (20%) the majority of the households uses pit latrines for excrement disposal. Dry latrines are used in one village called Maquilishuat. Figure 30 illustrates the types of latrines that are used by the majority in a village and in which villages organisations funded and/or built the latrines.

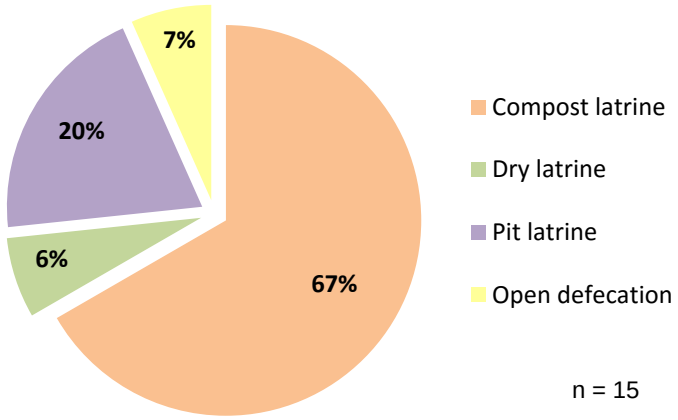


Figure 29: Disposal of excrements in rural areas

The worst situation that was investigated was in San Jose Llano Grande, where the residents put their excrements in plastic bags and afterwards threw them on the open field which is equivalent to open defecation. This means that at least one village in the municipality Tecoluca has no improved sanitation facilities like WHO/UNICEF describes it in the JMP (see chapter 3.1).

Figure 29 shows the percentage of different systems used in the surveyed villages for the disposal of excrements.

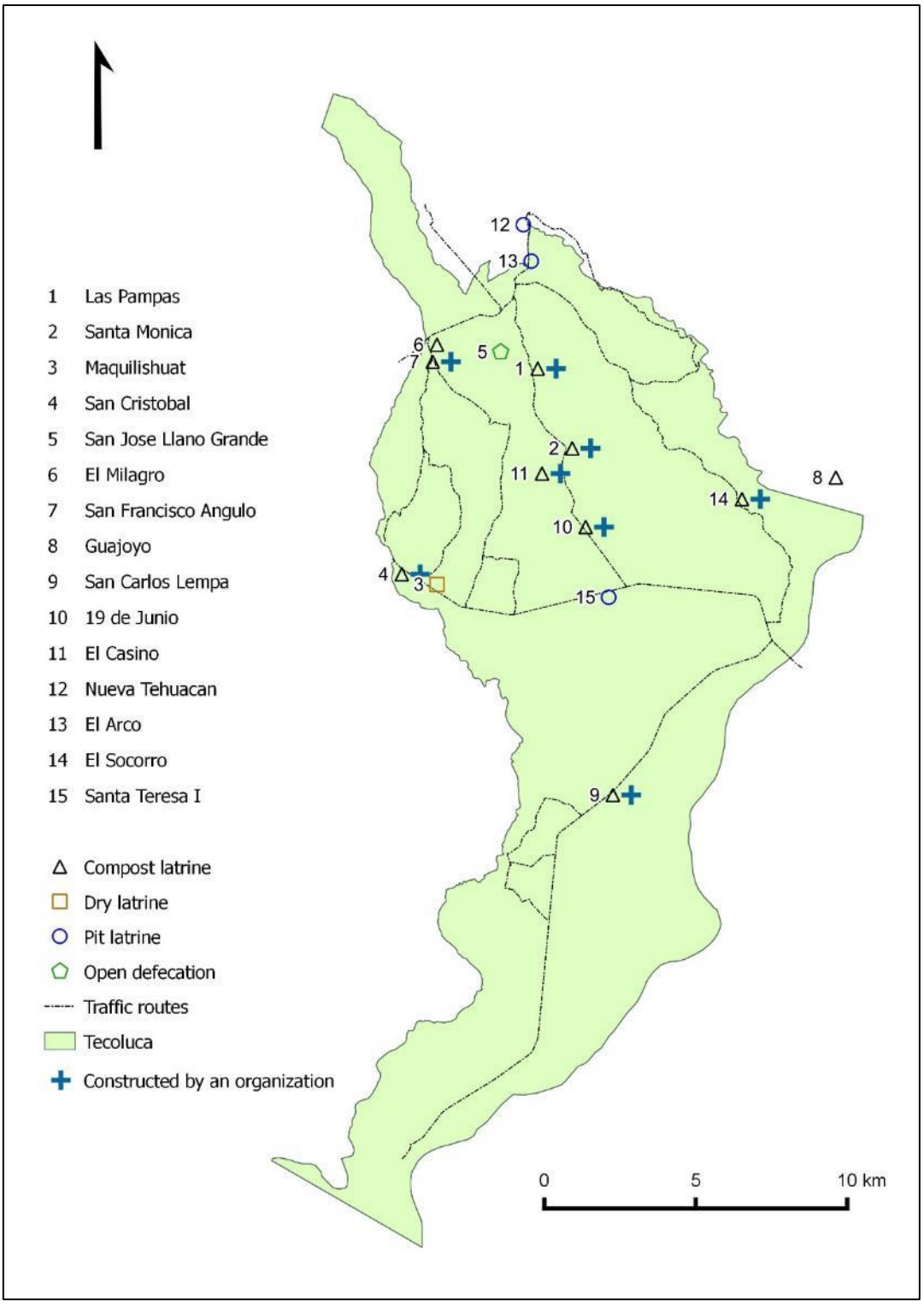


Figure 30: Map of common excrement disposal in the surveyed villages

5.1.4 Final disposal of solid waste

There is no municipal service to collect and correctly store, recycle or reuse the big amounts of organic and nonorganic materials in the villages. Therefore, the people keep the solid waste on their properties, burn it, bury it or dispose it of on the street or the open field.

In spite of the widespread incineration, a lot of solid waste contaminates the immediate environment of the settlements. Due to heavy rainfalls during the rainy season, the rubbish on the streets is transported into the rivers.

In some villages two main procedures of how the residents dispose of their solid waste exist. Figure 31 shows that in 13 (65%) of the villages the incineration of waste on the field or on the street is the common procedure. In only one village (El Argo) the community collects plastic material that is afterwards recycled, but the other waste material is just buried. In Nueva Tehuacan, which is located in the north of Tecoluca Town, one part of the community burns their solid waste. Another part of Nueva Tehuacan use waste containers, just as in Tecoluca Town (see chapter 5.2.6), which are emptied by the same garbage truck form the town and the waste is also transported to a dumpsite in Usulutan. The final disposal outdoors is commonly established in four (20%) of the surveyed villages.

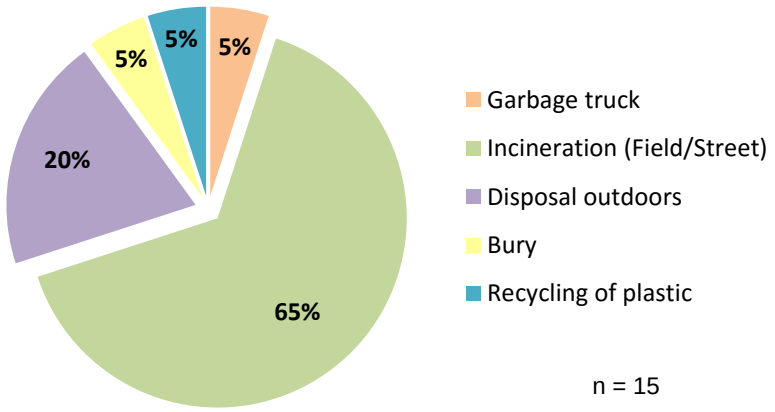


Figure 31: Disposal of solid waste in rural areas

Figure 32 shows a map of the common solid waste disposal procedures in the surveyed villages. The creation of this map is similar to the map of the grey water disposal in chapter 5.1.2.

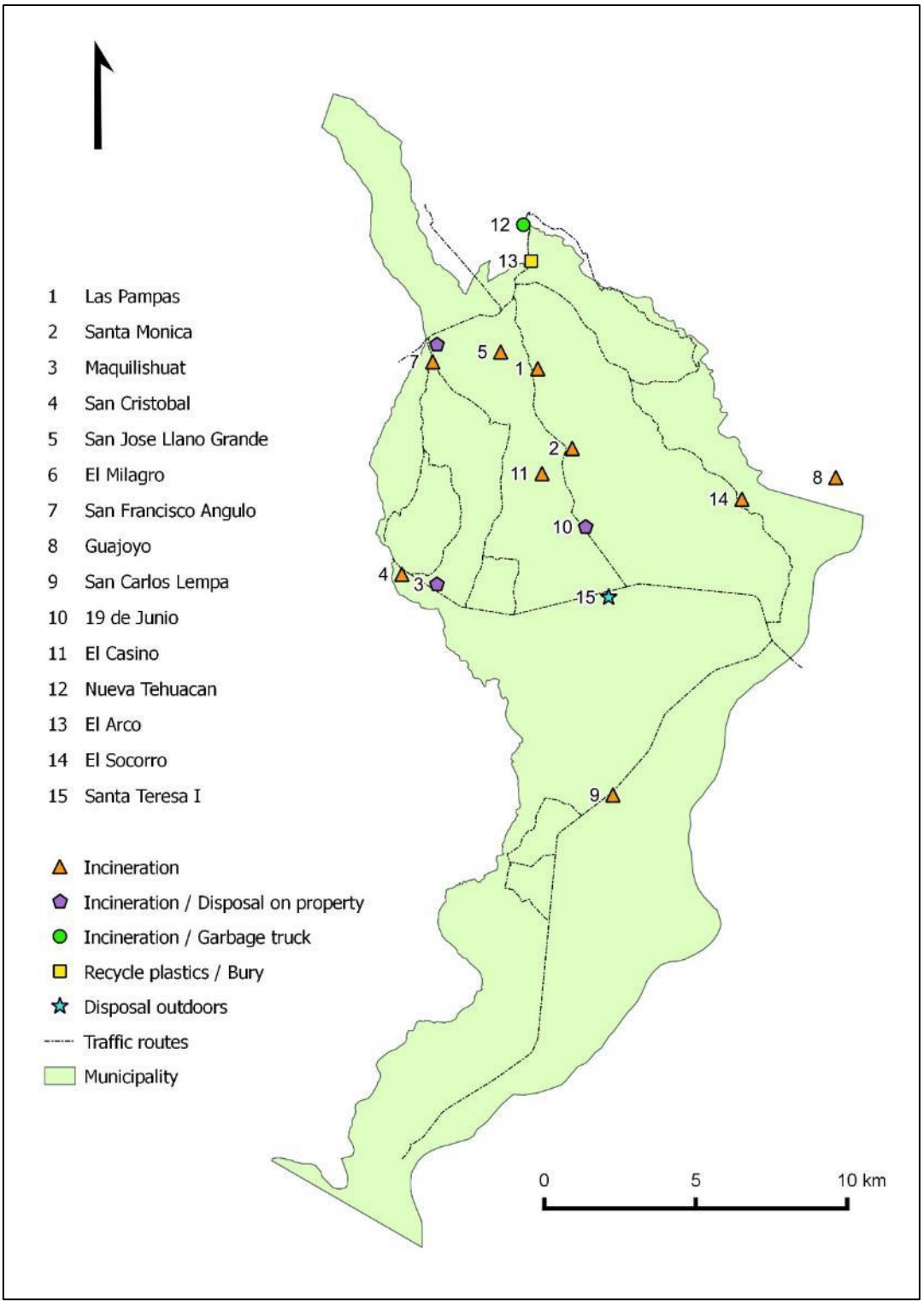


Figure 32: Map of common solid waste disposal in the surveyed villages

5.1.5 Summary of the information in the surveyed villages

Table 10 to Table 24 show a summary of the collected data combined with an aerial photo and the geographic location from the surveyed villages. This information is used in the QGIS-project. It is also documented in Spanish in order to provide the collected data for the municipality.

Table 10: Data from Las Pampas

Las Pampas | 13° 30' 42.8" N 88° 46' 36.1" W	
Families	79
Persons/household	4
Additional water use*	Livestock
Grey water disposal	Discharge into water body
Water body	Rio Agua Caliente
Excreta disposal	Compost latrine
Constructor	HIBASA, 1994/95
Solid waste	Incineration
Water consumption per household	8 m³/hh/month
Pot. accumulating grey water per household	213 l/hh/d
Pot. accumulating grey water per person	60 l/p/d
Total pot. accumulating grey water	17 m³/d

*beside cooking, washing, cleaning, drinking

Table 11: Data from Santa Monica

Santa Monica | 13° 29' 12.8" N 88° 45' 55.0" W	
Families	95
Persons/household	4
Additional water use*	Livestock and garden
Grey water disposal	Discharge into water body
Water body	Rio Jalapa, Rio Agua Caliente
Excreta disposal	Compost latrine
Constructor	Health Centre, 2004/05
Solid waste	Incineration
Water consumption per household	16 m³/hh/month
Pot. accumulating grey water per household	427 l/hh/d
Pot. accumulating grey water per person	108 l/p/d
Total pot. accumulating grey water	41 m³/d

*beside cooking, washing, cleaning, drinking

Table 12: Data from Maquilishuat

Maquilishuat | 13° 26' 39.4" N 88° 48' 19.4" W	
Families	70
Persons/household	4
Additional water use*	Livestock and garden
Grey water disposal	Discharge into water body
Water body	Rio Paso de las Yeguas
Excreta disposal	Dry latrine
Constructor	-
Solid waste	Incineration / Disposal outdoors
Water consumption per household	9 m³/hh/month
Pot. accumulating grey water per household	240 l/hh/d
Pot. accumulating grey water per person	58 l/p/d
Total pot. accumulating grey water	17 m³/d

*beside cooking, washing, cleaning, drinking

Table 13: Data from San Cristobal

San Cristobal | 13° 26' 58.2" N 88° 49' 00.4" W	
Families	120
Persons/household	4
Additional water use*	-
Grey water disposal	Infiltration on the street
Water body	-
Excreta disposal	Compost latrine
Constructor	European Union and Municipality
Solid waste	Incineration
Water consumption per household	10 m³/hh/month
Pot. accumulating grey water per household	267 l/hh/d
Pot. accumulating grey water per person	73 l/p/d
Total pot. accumulating grey water	32 m³/d

*beside cooking, washing, cleaning, drinking

Table 14: Data from San Jose Llano Grande

San Jose Llano Grande | 13° 31' 04.8" N 88° 47' 17.1" W	
Families	56
Persons/household	4
Additional water use*	Garden
Grey water disposal	Discharge into water body
Water body	Rio Limon
Excreta disposal	Open defecation
Constructor	-
Solid waste	Incineration
Water consumption per household	10 m³/hh/month
Pot. accumulating grey water per household	267 l/hh/d
Pot. accumulating grey water per person	74 l/p/d
Total pot. accumulating grey water	15 m³/d

*beside cooking, washing, cleaning, drinking

Table 15: Data from El Milagro

El Milagro | 13° 31' 06.5" N 88° 48' 23.3" W	
Families	115
Persons/household	4
Additional water use*	Livestock and garden
Grey water disposal	Discharge into water body
Water body	Rio Angulo, Rio Ismendia
Excreta disposal	Compost latrine
Constructor	-
Solid waste	Incineration / Disposal outdoors
Water consumption per household	14 m³/hh/month
Pot. accumulating grey water per household	373 l/hh/d
Pot. accumulating grey water per person	89 l/p/d
Total pot. accumulating grey water	43 m³/d

*beside cooking, washing, cleaning, drinking

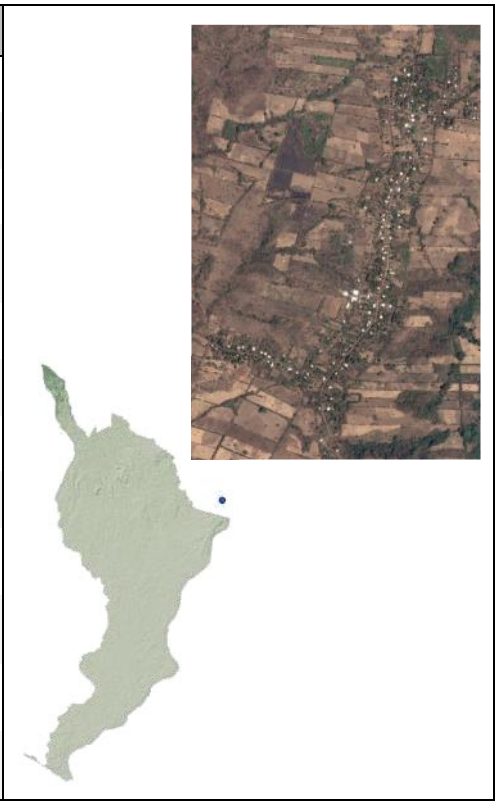
Table 16: Data from San Francisco Angulo

San Francisco Angulo | 13° 30' 49.3" N 88° 48' 25.5" W	
Families	78
Persons/household	4
Additional water use*	Livestock and garden
Grey water disposal	Infiltration on the open field
Water body	-
Excreta disposal	Compost latrine
Constructor	unknown organisation, 2001
Solid waste	Incineration
Water consumption per household	15 m³/hh/month
Pot. accumulating grey water per household	400 l/hh/d
Pot. accumulating grey water per person	104 l/p/d
Total pot. accumulating grey water	31 m³/d

*beside cooking, washing, cleaning, drinking

Table 17: Data from Guajoyo

Guajoyo | 13° 28' 55.1" N 88° 41' 02.3" W	
Families	173
Persons/household	4
Additional water use*	Livestock and garden
Grey water disposal	Discharge into water body / open field
Water body	Rio Lempa
Excreta disposal	Compost latrine
Constructor	-
Solid waste	Incineration
Water consumption per household	28 m³/hh/month
Pot. accumulating grey water per household	747 l/hh/d
Pot. accumulating grey water per person	199 l/p/d
Total pot. accumulating grey water	129 m³/d



*beside cooking, washing, cleaning, drinking

Table 18: Data from San Carlos Lempa

San Carlos Lempa | 13° 22' 55.5" N 88° 45' 09.3" W	
Families	240
Persons/household	3
Additional water use*	-
Grey water disposal	Infiltration by pit
Water body	-
Excreta disposal	Compost latrine
Constructor	Caritas, 1994
Solid waste	Incineration
Water consumption per household	13 m³/hh/month
Pot. accumulating grey water per household	347 l/hh/d
Pot. accumulating grey water per person	106 l/p/d
Total pot. accumulating grey water	83 m³/d

*beside cooking, washing, cleaning, drinking

Table 19: Data from 19 de Junio

19 de Junio | 13° 27' 48.2" N	88° 45' 39.9" W
Families	35
Persons/household	4
Additional water use*	-
Grey water disposal	Discharge into water body
Water body	Rio San Ramon
Excreta disposal	Compost latrine
Constructor	Housing project of a NGO, 2001
Solid waste	Incineration / Disposal on property
Water consumption per household	10 m³/hh/month
Pot. accumulating grey water per household	267 l/hh/d
Pot. accumulating grey water per person	66 l/p/d
Total pot. accumulating grey water	9 m³/d

*beside cooking, washing, cleaning, drinking

Table 20: Data from El Casino

El Casino | 13° 28' 45.4" N	88° 46' 27.1" W
Families	45
Persons/household	4
Additional water use*	-
Grey water disposal	Discharge into water body
Water body	Rio San Jeronimo
Excreta disposal	Compost latrine
Constructor	USAID, 2001
Solid waste	Incineration
Water consumption per household	10 m³/hh/month
Pot. accumulating grey water per household	267 l/hh/d
Pot. accumulating grey water per person	69 l/p/d
Total pot. accumulating grey water	12 m³/d

*beside cooking, washing, cleaning, drinking

Table 21: Data from Nueva Tehuacan

Nueva Tehuacan | 13° 33' 19.8" N 88° 46' 48.3" W	
Families	268
Persons/household	4
Additional water use*	-
Grey water disposal	Discharge into water body
Water body	Rio Jalapa
Excreta disposal	Pit latrine
Constructor	-
Solid waste	Incineration / Garbage truck
Water consumption per household	24 m³/hh/month
Pot. accumulating grey water per household	640 l/hh/d
Pot. accumulating grey water per person	175 l/p/d
Total pot. accumulating grey water	172 m³/d

*beside cooking, washing, cleaning, drinking

Table 22: Data from El Arco

El Arco | 13° 32' 38.4" N 88° 46' 39.7" W	
Families	261
Persons/household	3
Additional water use*	-
Grey water disposal	Infiltration by pit
Water body	-
Excreta disposal	Pit latrine
Constructor	-
Solid waste	Recycle / Bury in the open
Water consumption per household	24 m³/hh/month
Pot. accumulating grey water per household	640 l/hh/d
Pot. accumulating grey water per person	209 l/p/d
Total pot. accumulating grey water	167 m³/d

*beside cooking, washing, cleaning, drinking

Table 23: Data from El Socorro

El Socorro | 13° 28' 16.3" N 88° 42' 51.8" W	
Families	56
Persons/household	3
Additional water use*	-
Grey water disposal	Infiltration on the open field
Water body	-
Excreta disposal	Compost latrine
Constructor	CRIPDES, 2013
Solid waste	Incineration
Water consumption per household	13 m³/hh/month
Pot. accumulating grey water per household	347 l/hh/d
Pot. accumulating grey water per person	105 l/p/d
Total pot. accumulating grey water	19 m³/d

*beside cooking, washing, cleaning, drinking

Table 24: Data from Santa Teresa 1

Santa Teresa 1 | 13° 26' 28.3" N 88° 45' 10.0" W	
Families	165
Persons/household	3
Additional water use*	-
Grey water disposal	Infiltration on the street
Water body	-
Excreta disposal	Pit latrine
Constructor	-
Solid waste	Disposal outdoors
Water consumption per household	25 m³/hh/month
Pot. accumulating grey water per household	667 l/hh/d
Pot. accumulating grey water per person	226 l/p/d
Total pot. accumulating grey water	110 m³/d

*beside cooking, washing, cleaning, drinking

5.2 Results of the interviews in Tecoluca Town

This chapter presents the results of the urban area Tecoluca Town, which include:

- Potentially accumulating grey water
- Final disposal of grey water, excrements and solid waste
- Usage of detergents
- Description of the grey water path in the town

5.2.1 Potentially accumulating grey water

In total, 34 interviews were carried out in the six zones of Tecoluca Town. To assess the potentially accumulating grey water it was questioned how much water a household consumes per day and at which time the residents use their water over a day.

Figure 33 shows the average water consumption per person and the average cumulative amount of water per person over a day. The highest water use occurs in the morning during 06:00 and 08:00 am when the people start their day. The two other peaks occur at midday and in the evening at around 08:00 pm.

The average daily water consumption is 111.5 litres per person. This is a difference of 108.5 litres or 49,3% in comparison with the specified 220 litres per person in urban areas specified in the standard by ANDA (see chapter 3.2.3).

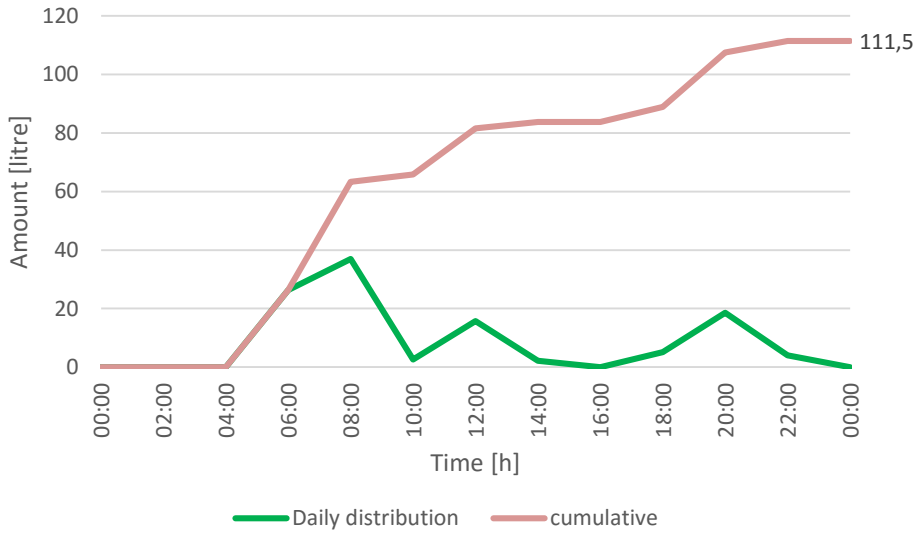


Figure 33: Daily water consumption distribution in Tecoluca Town

Figure 34 shows the estimated quantities of grey water for Tecoluca Town. It can be seen that the total potentially accumulating grey water for one day reaches a volume of 194 m³.

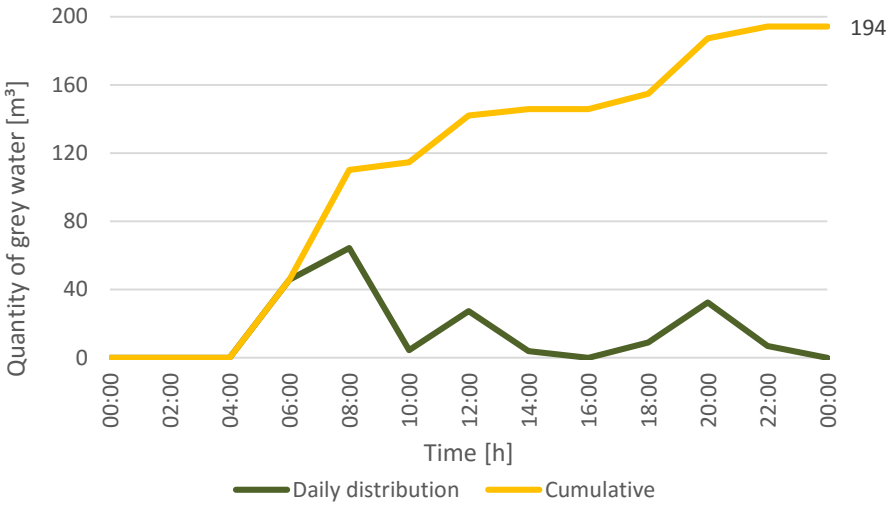


Figure 34: Daily potentially accumulating grey water in Tecoluca Town

5.2.2 Final disposal of grey water

The common disposal of grey water in private households is the discharge by a tube onto the street as seen in Figure 35. This procedure is contrary to the technique specified by MOP in the legal framework for *Ventanilla Única* (see chapter 3.2.2.3), where every household should dispose of their grey water by an infiltration system according to the treatment systems by MINSAL (see chapter 3.2.5) when there is no canalisation in place. According to an employee of the health unit in Tecoluca Town (5/5/2015) the reason for this contradiction is that after an inspection, the connection to the infiltration system for the grey water is going to be disconnected in the majority of the households, because the residents think that the pit quickly fills up and subsequently overflows. Therefore, the grey water is not infiltrated scattered in each property, but it flows onto the streets, accumulates in several main runoffs and enters a natural water body.

Only public institutions such as the town hall, the police station or the health centre discharge their grey water subterranean by sewer pipes, but in the end the grey water also flows into one of the three nearby water bodies without any treatment.

Figure 35: Typical discharge of grey water from households onto the street

5.2.3 Path of the grey water in Tecoluca Town

The accumulated grey water from a household is collected on the property and discharged by a tube onto the street. From there it flows, following the gravity, along the wayside until it finally enters one of the two brooks (Rio Agua Caliente and Rio Mano de Leon) or a small ditch (Quebrada Tejera). A part of the grey water infiltrates or evaporates on the way to a water body. South of San Fernando the brooks and the ditch unite to the river Rio San Ramon, later to Cañon La Empalizada which finally enters the Pacific Ocean at La Puntilla in the south of the municipality. Parts of the water from the river are used for irrigating fields and to supply the livestock in the dry season. Figure 36 shows a scheme of the grey water path.

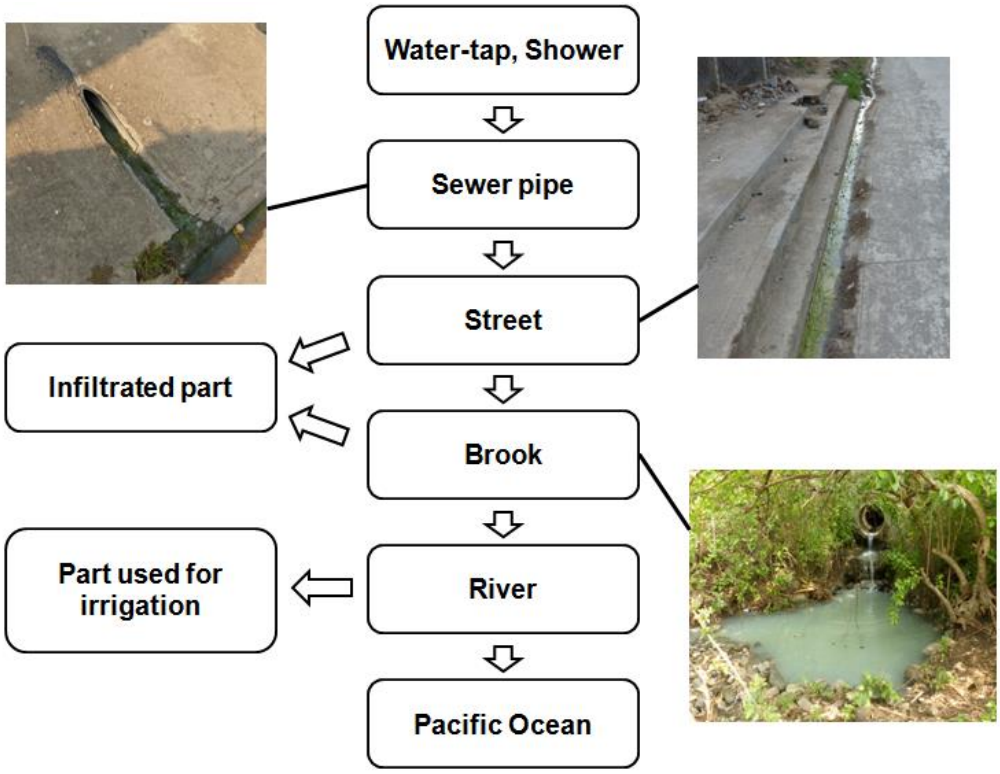


Figure 36: Schematic of the grey water path

Figure 37 shows the visited sites where grey water enters natural water bodies in Tecoluca Town. At sites 1, 2, 3 and 4 the grey water is discharged into the brook Rio Mano de Leon. At site 5 the inlet of grey water is into Rio Agua Caliente. Site 6 displays the inlet below the football ground into the ditch Quebrada Tejera. There are probably more such sites in the town, but were not visited.

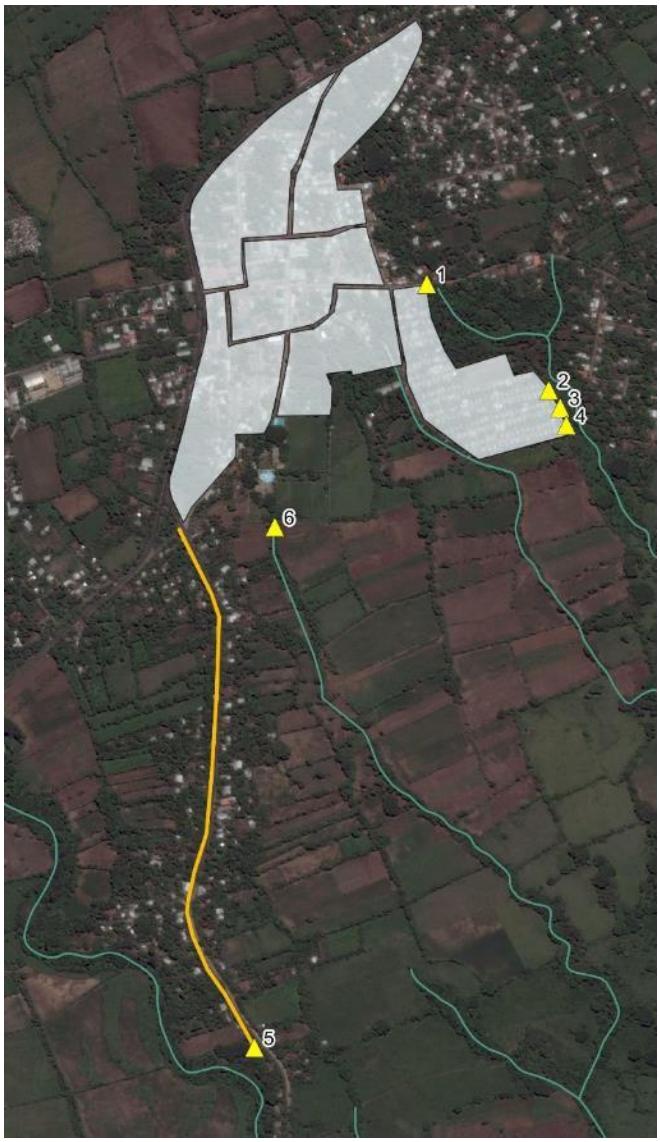


Figure 37: Sites of grey water discharge of Tecoluca Town

Quebrada Tejera

A part of the accumulated grey water in Tecoluca Town, mainly from the centre, is collected by a sewer pipe north of the football ground. This sewer pipe runs subterraneous until it reaches the southern end of the football ground, where it ends above ground. There the grey water enters the ditch (Figure 38). At the moment of the visitation (May 06, 2015) it was observable that the water had an intense turbidity. Furthermore, on the same day it was observed that the water of the ditch flows about 100 m before all of the water infiltrated into the ground. Later, after another 500 m, water occurred again in the ditch but without any turbidity.

Figure 38: Outlet of the sewer pipe beneath the football ground

Rio Mano de Leon

The brook Rio Mano de Leon is the receiving water body of the grey water from the zones Las Flores, Esperanza, Colonia San Romero, El Centro and Santa Tecla. During the visitation (June 04, 2015) were four different sites were located where grey water enters this brook. During the dry season the brook only leads grey water and no fresh water. However, throughout the year many domestic chickens fed on this water (Figure 39). A measurement with test strips for pH value shows a pH value of 8 – 9 (Figure 40) and during the visitation a slightly musty smell was noticed.

Figure 39: Polluted Rio Mano de Leon in Tecoluca Town

Figure 40: Measured pH value in Rio Mano de Leon

Rio Agua Caliente

The brook Rio Agua Caliente is the receiving water body for the grey water from the zones El Calvario and El Carao. The grey water flows in a roadside ditch to an inlet (Figure 41) where it discharges into the brook (Figure 42). During the visitation (June 17, 2015) it was observable that this brook contains less solid waste than Rio Mano de Leon. A possible reason for this is that the solid waste accumulates in the roadside ditch.

Figure 41: Top of the inlet in El Carao

Figure 42: Discharge into Rio Agua Caliente from the inlet

The two brooks have their sources in the immediate vicinity of Tecoluca Town. Rio Mano de Leon originates in the east of Tecoluca Town in Colonia San Romero, Rio Agua Caliente in the west of Tecoluca Town.

5.2.4 Usage of detergents in Tecoluca Town

The usage of detergents was questioned in order to know what the components of the produced grey water are. Figure 43 shows that detergents like bleachers, disinfectants and soap are used in almost every surveyed household. Shampoo is in use in only half of the households.

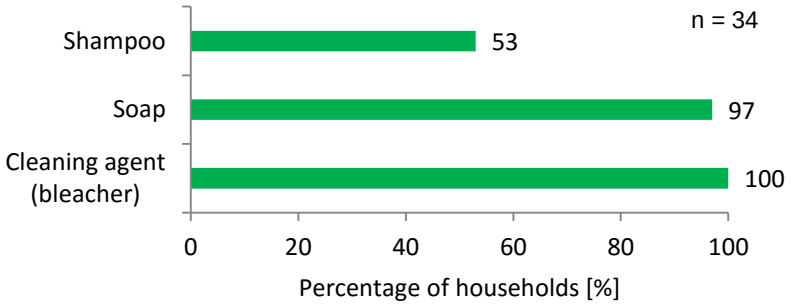


Figure 43: Usage of detergents in the households of Tecoluca Town

In Figure 44 the different bleachers and disinfectants (Rinso, Blanko Kompleto, Lejia Maxisol,…) that are mostly in use in the town can be seen. Not only the content is polluting the environment but also the packages are disposed of on the open field.

Figure 44: Empty packages of bleachers at a river bank

5.2.5 Final disposal of excrements

The common sanitary equipment for the disposal of faeces and urine in Tecoluca Town is an ordinary toilet bowl with water flushing, which is connected to a pit. Again, this is contrary to the specified system by MOP, where the households need a septic tank or an equivalent facility (see chapter 3.2.2.3). According to some informants, the pits are so deep and permeable that none of

them had to be emptied until now. The oldest pits were constructed in the year 1990, which implies no cleanout in 25 years.

5.2.6 Final disposal of solid waste

In total 85% of the solid waste in the households of Tecoluca Town is collected two times a week by a garbage truck and subsequently transported to a dumpsite in Usulutan (Figure 45). 6% of the households dispose of their solid waste outdoors, which leads to a pollution of the environment as seen in Figure 46. In the zone of Tecoluca, called Colonia San Romero, an unofficial small landfill has even formed by disposing of the solid waste at this site (Figure 47). The landfill is located just a few metres away from houses. The remaining 9% burn their solid waste.

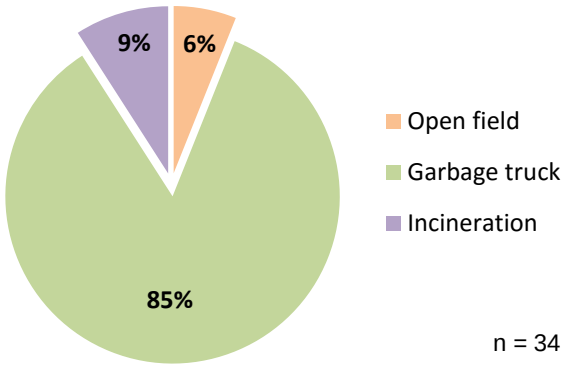


Figure 45: Disposal of solid waste in Tecoluca Town

Figure 46: Polluted brook in Tecoluca Town

Figure 47: Unofficial landfill in Colonia San Romero

5.2.7 Willingness to pay wastewater tax

The long-term goal of the municipality and INTERSOL is to implement a wastewater treatment plant for the town, where the operation and maintenance should be financed by the community for a consistent and long-term use. Therefore, the last question of the interview - if the interviewee could or would pay 2-3 US$ for a wastewater tax - was a hypothetical one. The reason why the interviewee is or is not willing to pay for such tax was not considered. The tax could be used to finance staff for an appropriate operation and maintenance of a future wastewater treatment plant.

The result was that 15 (45%) of the 34 interviewees are willing to pay for a possible wastewater tax and that the remaining 18 (55%) interviewees would not or could not pay for an additional tax (Figure 48).

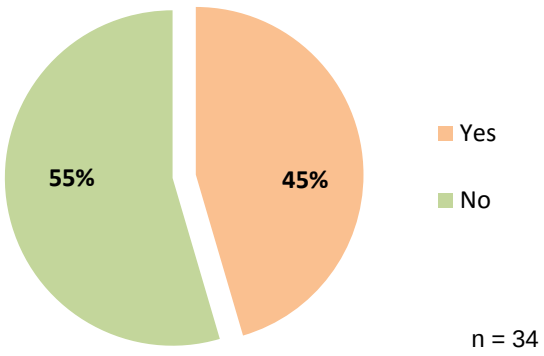


Figure 48: Willingness to pay 2-3 US$ for a wastewater tax in Tecoluca Town

5.3 Cooperation and exchange of knowledge

The social dialogue and communication with the local people is necessary to correctly perceive the goals and deficits of the investigated region (Jung 3/8/2016). It is a basic requirement for a successful and sustainable project to cooperate and interact with local people and exchange knowledge. The fundament for this study in terms of meetings with members of water committees, persons in charge for sanitation and the integration in the municipality was the support and cooperation with Herberth Sanabria, the technical manager of the municipality. He is the driving force in the municipality to push the issue of wastewater further on.

It was ensured that the involved persons get an explanation why this survey was executed, what information will be gathered, where they can find the collected data and what is the overall goal of this investigation. In return, useful information about sanitation and wastewater was provided from these people. At the end of the stay a presentation of the project was held in the town hall for the major and members of the municipality to point out the current sanitary situation in the municipality.

It was also aimed to involve local universities and students to this project. Therefore, a cooperation with Dr. Mauricio Pohl and his students form *Universidad Centroamericana "Josè Simeòn Cañas"* (UCA) was initiated in the course of this thesis. Again, a presentation of the project was held to present the efforts, methods and goals in front of about 100 students. It is thought that future students from BOKU Vienna work together with students from UCA. Another cooperation was started with the civil engineer Freddy Cruz and his students from *Universidad de El Salvador* (Figure 49).

Figure 49: Pedro (Security), Freddy Cruz, Herberth Sanabria, Oscar (Security), Bernhard Biber (left to right)

6. Conclusion and outlook

The thesis was carried out to investigate the sanitary situation in the Salvadorian municipality Tecoluca by interviewing persons in charge for the wastewater sector and local persons that live in the villages of the municipality. At the same time wastewater- and solid waste-related information was collected via research, meetings and observation. By means of these methods, the study has identified how the majority of the residents in 15 villages and the residents in the municipal capital Tecoluca Town dispose of their grey water, excrements and solid waste as well as what the common sanitary facilities in their households are. The final task of the study was to integrate the collected data into a geographical information system (GIS) for an efficient way to store and visualise the data, but also for further investigations of other students and municipal personnel. A cooperation and inclusion of local people, professors and students, besides the wastewater and solid waste-related questions, was striven from the very beginning.

The main findings of the thesis, i.e. the results of the interviews, have been summarised for rural areas of the municipality Tecoluca and Tecoluca Town, respectively.

Rural areas

The semi-structured interviews were a fast and simple solution to gather much information from only few people. This is a good way for the collection of basic data, but for a detailed insight of the common practices regarding wastewater in the villages, it is necessary to interview more people via this method or to apply other methods such as Participatory Rural Appraisal (PRA). Furthermore, the number of surveyed villages was restricted due to time and practical reasons. Although 15 villages have been visited and investigated, there are still 81 villages where it is not officially documented how the residents handle grey water, excrements and solid waste. Most of the surveyed villages are located in the hilly northern parts of Tecoluca which could lead to a misinterpretation of the results since the situation in villages near the coast can be a different.

Another challenge was the calculation of the amounts of grey water in the villages since the volumes could only be estimated because the majority of the household does not have a water meters. Also seasonal variations could not be evaluated due to time restrictions. Nevertheless, the results provide a rough estimate of the amount of accumulated grey water in the villages.

Finally, the data implementation in a GIS shall provide a planning tool for the municipality. Therefore, it has been taken to ensure that the data input and transfer is as simple as possible and was automated as far as possible. The challenge now is to teach municipal personnel the correct handling with the software and to show them the advantages of such a system. This will be realised by Austrian students who continue this project.

In general, it can be concluded that the sanitation status in the rural areas of the municipality Tecoluca is at an acceptable but still underdeveloped level for a country like El Salvador. In the sector of the handling with grey water and solid waste is the current situation definitely not acceptable. The whole municipality is polluting the streets, brooks, rivers, groundwater, air, soil, simply the entire environment, with untreated grey water and indecomposable material. The consequences of poor sanitary practices were not determined in this thesis, but if this is going on for the next decades, Tecoluca will face a “dirty” future.

Recommendation and further works

For a further improvement of the sanitary situation in the rural areas, it is essential to continue the investigation in further villages of the municipality by Austrian students in cooperation with municipal personnel and Salvadorian students. The cooperation involves the personnel and Salvadorian students in the process and shows them the precarious situation in the villages. The continuation of the GIS-database and further data input will guarantee a well-structured documentation of the findings and could play an important role in the future when the municipality decides to take actions in the handling of wastewater. Furthermore, a detailed investigation in other villages of the municipality should be executed to improve the sanitary situation where it is most needed.

Tecoluca Town

The decision to carry out structured interviews in the town was a good solution to gather a lot of information in a short period of time. This method can also be carried out by laymen since there are no noteworthy tolerances for answers, the interviewer does not need a profound knowledge and just needs to make a cross in the questionnaire. It is quite conceivable that all households of the town can be examined in the course of a larger survey.

Although, the amounts of accumulating grey water are also just estimated it can be said that the municipal capital discharges the highest amounts of untreated grey water into natural water bodies. It makes Tecoluca Town to the biggest contributor to environmental pollution in the municipality. The controversy is that most of the households have an infiltration system for grey water but do not use it. A solution can be an educational advertising for the residents about the consequences of their handling with grey water.

The handling of solid waste is better than in the rural areas since the municipality provides a collection service (garbage truck). Nevertheless, a part of the households does not make demands on this service and dispose of the solid waste outdoors. Consequences are a contamination of the environment with non-organic materials. The municipality should provide a service for solid waste to all households in order to keep the town clean.

Again, in Tecoluca Town the sanitation facilities are at an acceptable level. However. because the pits are permeable the content can drain into the soil and possibly contaminate the groundwater. In addition, the fact that the residents do not use their infiltration pits for the disposal of grey water but instead discharge it onto the streets is a problem for the environment. The handling of solid waste is better than in the rural areas because the town has a waste collection service, though in the immediate vicinity of the town, mostly in trenches, a lot of indecomposable material accumulates.

Recommendation and further works in Tecoluca Town

The next step in Tecoluca Town is to determine the demand for a wastewater treatment system and to make a feasibility study including a cost analysis for various sanitation alternatives. These tasks should answer questions whether a centralised or decentralised, intensive or extensive system or an alternative system should come to application. Another question is whether a future wastewater treatment system should collect and treat the whole accumulating wastewater or just the grey water. Furthermore, the issue of solid waste management in the town is worth another study, since in some parts of the town incineration and disposal of solid waste outdoors is still the common way.

Tecoluca has the opportunity to become a pioneering role in wastewater management in El Salvador, if the responsible persons decide to take actions. The fundament for a cleaner future is set and the people start to realise that they have to change their habits and handling with wastewater, but it is still a long way to go.

7. Summary

The aim of the thesis was to investigate the current sanitary situation in rural and urban parts of the Salvadorian municipality Tecoluca. The municipality has a cooperation with the Austrian non-profit organisation INTERSOL since 2000 with the overall goal to improve sanitation and establish a wastewater treatment system for Tecoluca Town.

The thesis shows how the majority of the residents dispose of the grey water, excrements and solid waste. Further, the collected data is implemented into a geographical information system (GIS). It is also aimed to cooperate and exchange knowledge with municipal personnel, local professors, students and residents. The practical work in El Salvador was carried out in the period from February to June 2015, which is the transition time between dry and rain season.

The essential information of the thesis is presented in four main chapters. The chapter “Fundamentals” gives an overview of the sanitation sector in general and El Salvador in particular as well as a description of the municipality Tecoluca. The next part “Materials and methods” describes the investigated sites in the rural and urban areas, the used types of interviews, the analysis of the collected data and the data implementation in a GIS. “Results and discussion” provides the actual findings of the work in Tecoluca and finally “Conclusion and outlook” summarises the findings and presents recommendations for the near future.

Two types of interviews were selected to realise the collection of the data. The first type, structured interviews, were used in the urban area, Tecoluca Town, and the second type, semi-structured interviews, in rural areas. The advantage of a structured interview is, that it is a good method for a large number of subjects but it is not very flexible. In contrast, semi-structured interviews provide some structure for the interviewer and at the same time flexibility in the answers of the interviewees. The interviews in rural areas took place in 15 different villages of the municipality in order to get representative results for the whole municipality. The selection and visitation of the villages depended on the time availability of the technical supervisor of the municipality as well as the residents of the villages. The interviews in the urban area Tecoluca town took place in 34 households even distributed over the 6 zones of the town and the results were extrapolated to the whole town. The collected data from the interviews was documented in Microsoft Excel and Microsoft Word for a subsequent analysis and visualisation of the data. The analysis in Microsoft Excel was executed by using descriptive statistics. Finally, the analysed data was transferred to an existing project of the software QGIS for a practical storage in a database and a visualisation with geographical references.

The findings of the interviews in the rural areas show that the individual households of the 15 surveyed villages generate 213 to 747 litres of grey water per day. This leads to an average

potentially accumulating grey water of 407 l/hh/d for the surveyed villages. In almost 90% of the villages is the disposal of grey water onto the street the most applied procedure. From there it enters a natural water body without any sort of treatment. In all surveyed villages, except for one, some sort of latrine is the major facility for the disposal of excrements. All used types of latrines in the surveyed villages are improved sanitation facilities according to WHO/UNICEF. The most commonly used type of latrine is the compost latrine, which is in use in 10 villages. Other common types are dry latrines and pit latrines. In the village without latrines the residents still practice open defecation. The conscientious handling of solid waste has no great significance in the rural areas. The majority simply burns the waste, dispose it of outdoors or bury it.

Due to the results of the interviews in the town it was possible to extrapolate the potentially accumulating grey water for the whole town. With an estimated volume of 194 m^3 of grey water Tecoluca Town is the biggest contributor to environmental pollution by grey water in the municipality, since all of this grey water enters natural water bodies without any sort of treatment. The disposal of excrements in the town is realised by ordinary toilet bowls with water flushing that are connected to a separate pit. These facilities are also improved sanitation facilities according to WHO/UNICEF. The handling of solid waste is better in the town than in the villages. Here, the municipality provides a garbage truck that collects the waste to times a week from 85% of the households. The remaining households dispose of the solid waste outdoors or burn it.

Ultimately, the findings of the interviews in the rural areas were put into a geographical information system project. With the help of this software were four maps created to visualise the data with geographic references and to provide maps for the municipality for future planning. The four maps contain the topics amounts of grey water, disposal of grey water, disposal of excrements and disposal of solid waste.

Summarising it can be said that the sanitary situation in Tecoluca Town but also in the rural areas is at an acceptable level for a country like El Salvador, although in some villages where open defecation is still the common practice improvements are necessary. The handling of grey water is at an unacceptable level, both in rural and urban areas. The grey water contaminates the environment of the whole municipality and puts human health at risk. Also the handling of solid waste is ruthless. Huge amounts of indecomposable material accumulate on the streets and rivers, also polluting the environment.

Further steps require more detailed investigations in the sector of wastewater, the continuation of the GIS-database and the involvement of more local people in the process.

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9. Appendix

9.1 Original calculation table for the number of villages to be surveyed

	Question	Comment	Calculation	Value
A	How many ethnic groups are there in the area? How different are these culturally?	It may be necessary to make sample surveys of each one.	Enter a number of distinct group.	
B	How uniform is the population in socio-economic terms?	A range of different conditions would need to be surveyed.	Enter 1, 2 or 3 for the range: uniform to wide diversity.	
C	How geographically diverse is the region?	The ethnic and social samples may need to be repeated for each district geographical area within the region.	Enter a number of distinct areas.	
D	Do people rely on groundwater, surface water, or both?	The ethnic and social samples may need to be repeated for each type.	Enter 1 for either surface water or groundwater, or 2 if both surface water and groundwater are relied on by the same or different communities in the area.	
E	Do some villages already have improved water supplies while others do not?	To assess the operation and maintenance issues, and the changes in hygiene behaviour, it may be necessary to survey villages with both improved and unimproved supplies.	Enter 1 if only unimproved or only improved; enter 2 if both unimproved and improved are present.	
F	Are there any other complicating factors?		Enter 1 for no, 2 for yes.	

9.2 Questionnaire for the rural areas

Communidad:
Fecha:
Hora:

Persona de Contacto:
Número de teléfono:

Interrogacion de aguas potables/negras

1. **Cuántas familias viven en el pueblo?**
   Cuántas personas viven en una familia?

2. **La poblaciòn en la communidad crece o disminue?** crece ☐ disminue ☐ igual ☐

3. **La gente tiene jardin/terreno *afuera* de la casa?** Sí ☐ No ☐

   - **Cuántos por cientos de la gente tienen terreno?**

   - **Cuántos metros cuadrados jardin tiene la gente en promedio?**

   - **De donde ustedes tienen el agua para regar el jardin?**

4. **La gente tiene animales *afuera* de la casa?** Sí ☐ No ☐

   - **Cuántos por cientos de la gente tienen animales?**
     Gallinas ☐ Cerdo ☐ Cabra ☐ Chibos ☐ Patos ☐ Otros ☐

   - **Cuántos animales tiene la gente en promedio?**
   - **De donde ustedes tienen el agua para embeber los animales?**

5. **Como la gente regan las campos de agricultura y embeben el ganado *aparte* de la casa ?**

6. **Tiene cada hogar una conexión a la red de agua potable?**

   Sí ☐ No ☐

   Cuando NO:
   - **Cuántas familias no tienen conexión al la red de agua potable?**

   - **Y porque?**

1

7. **Hay otras posibilidades para obtener agua potable en el pueblo (pozo, otros fuentes,..)?**

   - **Hay otros nacimientos/fuentes (sin captación) cerca de aqui que no son utilizado ?**

   Sí ☐
   No ☐

   - **Hay pozos?**

   Sí ☐
   No ☐

8. **Ustedes potabilizan el agua para tomar (filtrar, calentar)?**

   Sí ☐
   No ☐

9. **Se echa Cloro?**

   Sí ☐ No ☐

   Donde?
   Cuantos?
   La gente sabe que se echa Cloro? Sí ☐ No ☐

10. **Hay cisternas para recoger agua de lluvia?**

    Sí ☐
    No ☐

11. **Usted paga para el servicio de agua potable?**

    Sí ☐ No ☐

    CUANDO Sí:
    - **¿Cuanto cuesta?**
    - **¿Qué incluye el servicio?**

12. **Cuantos galónes/barriles de agua potable/ustedes gastan por dia?**

    Familia/día:
    Persona/día:

2

13. **En cual horas ustedes gastan màs agua del grifo (el mayor consumo del agua) y cuantos gallones para bañar, limpiar, lavar y regar?**

	Mañana:	Mediodía:	Tarde:
Tomar	☐	☐	☐
Cocinar	☐	☐	☐
Bañar	☐	☐	☐
Limpiar Casa	☐	☐	☐
Lavar Ropa	☐	☐	☐
Regar Jardin	☐	☐	☐
Embeber Animales	☐	☐	☐
(Váter)	☐	☐	☐

14. **Las casas tienen un contador?**

Sí ☐
No ☐

15. **Por lo que ustedes usan el agua del grifo?**

Verano:
tomar ☐ cocinar ☐ bañar ☐ limpiar ☐ lavar ☐ jardin ☐ animales ☐ otro ☐

Invierno:
tomar ☐ cocinar ☐ bañar ☐ limpiar ☐ lavar ☐ jardin ☐ animales ☐ otro ☐

16. **Hay diferencias estacionales en:**

- **la qandid de agua potable**: Sí ☐ No ☐
  suficiente en invierno:
  suficiente en verano:

- **la qalidad de agua potable**: Sí ☐ No ☐
  en invierno:
  en verano:

17. **Como evaluar su agua potable del grifo?**

GENTE	Bien	Mediocre	Mal
Color	☐	☐	☐
Sabor	☐	☐	☐
Olor	☐	☐	☐
Suciedad	☐	☐	☐
Fiabilidad	☐	☐	☐

3

18. Hay problemas con el digestión (diarrea)/la salud?

Sí ☐ No ☐

Cuando SI, usted cree que hay un relaccion con los infermos y el agua (potable)?

19. Hay análisis de agua?

Sí ☐ No ☐

CUANDO Sí:
- **Cuantos veces?**
- **Quien hace?**

20. Ustedes usan producto de limpieza?

para: bañar ☐ limpiar el hogar ☐ lavar platos/ropas ☐ No ☐
Cuando SI, que? Jabón ☐ Limpiador ☐ Shampoo ☐ Otro ☐

21. Donde ustedes lavar la ropa?

Propia casa ☐ Casa comunal ☐ Rio ☐ Otro ☐

22. A donde ustedes conducen las aguas jabónes (de bañar, cocinar, lavar)?

Calle (superficie) ☐ Calle (subterráneo) ☐ Campo abierto ☐ Fosa ☐
Otro ☐

23. Donde estan los baños?

dentro de la casa ☐ %
afuera de la casa ☐ %
no hay ☐ %

24. Cual es la disposición final de los excretas?

Calle ☐ Campo abierto ☐ Fosa ☐ Letrina ☐
Otro ☐

4

25. **Letrina**
Tipo:
Donde? dentro de la casa ☐
afuera de la casa ☐

Quien lo construyo?

Cuando?

Funcionan? Sí ☐ No ☐ porque:

Con que frecuencia se limpian? Klicken Sie hier, um Text einzugeben.

Que pasa con el abono? Klicken Sie hier, um Text einzugeben.

26. **Cual es la disposición final de la basura?**

Campo abierto ☐ Fosa ☐ Incineración ☐ Otro ☐

27. **Hay problemas con agua potable/residuales que se podría resolver fácilmente en su opinión? Cuando SI, cuales?**

5

9.3 Questionnaire for the urban area

Nr:____ Fecha: _____ Zona:_____

Interrogacion de aguas negras

1. **Cuántas personas viven en el hogar?**
2. **Cuantos galónes/barriles de agua potable/ustedes gastan por dia/mes?**
3. **En cual horas ustedes gastan màs agua del grifo (el mayor consumo del agua?**

	Mañana:	Mediodía:	Tarde:
Tomar	☐	☐	☐
Cocinar	☐	☐	☐
Bañar	☐	☐	☐
Limpiar Casa	☐	☐	☐
Lavar Ropa	☐	☐	☐
Regar Jardin	☐	☐	☐
Embeber Animales	☐	☐	☐
(Váter)	☐	☐	☐

4. **Ustedes usan productos de limpieza?**

   para: bañar ☐ limpiar el hogar ☐ lavar platos/ropas ☐ No ☐
   Cuando SI, que? Jabón ☐ Limpiador ☐ Shampoo ☐ Otro ☐

5. **Donde ustedes lavar la ropa?**

   Propia casa ☐ Casa comunal ☐ Rio ☐ Otro ☐

6. **Donde esta el baño?**

   dentro de la casa ☐
   afuera de la casa ☐
   no hay ☐

7. **Ustedes tienen un permiso de Ministerio de Salud por las aguas residuales?**

   Sí ☐ No ☐

8. **Usted tiene una trampa para grasas?**

   Sí ☐ No ☐
   Esta en uso? Sí ☐ No ☐
   Cuando NO, donde se conduce los aguas jabònes?
   Quien lo construyo/pago?
   Cuando?

1

9. Usted tiene una fosa septica?

Sí ☐ No ☐

Esta en uso? Sí ☐ No ☐
Cuando NO, cual es la disposición final de excretas?

Quien lo construyo/pago?
Cuando?

Con que frecuencia se limpian?
Que pasa con el residuos/abono?

10. Usted tiene un pozo de absorciòn?

Sí ☐ No ☐

Esta en uso? Sí ☐ No ☐
Cuando NO, donde se conduce los aguas jabònes?

Quien lo construyo/pago?
Cuando?

11. Cual es la disposición final de la basura?

Campo abierto ☐ Fosa ☐ Incineración ☐ camión de la basura ☐ Contenedor ☐ Otro ☐

12. Usted podría pagar 2$ o 3$ al mes por un servicio de aguas residuales?

Sí ☐ No ☐

2

9.4 Results of the interviews in Tecoluca Town

TECOLUCA		Person	Detergents					Lavatory				Bath			Permit		Disposal grey water					Pit				Infiltration system				Disposal solid waste				Tax	
			Soap	Bleacher	Shampoo	Other	No	own house	Community house	River	Other	indoor	outdoor	other	Yes	No	Street (surface)	Street (subsurface)	Open field	Pit	Other	Exist? Yes	Exist? No	In use? Yes	In use? No	Exist? Yes	Exist? No	In use? Yes	In use? No	Open field	Garbage truck	Incineration	Other	Yes	No
Zone / Date	Nr.	Σ 174 / Δ 5,1	33	34	18	0	0	33	0	1	0	22	12	0	0	26	33	1	0	0	0	32	2	32	2	25	8	0	33	2	28	3	0	15	18
El Calvario 19.05.2015	1	16	x	x				x				x						x					x		x										
	2	2		x				x					x			x	x					x		x		x			x		x			x	
	3	6	x	x				x				x					x					x		x		x			x		x			x	
	4	5	x	x				x					x				x					x		x		x			x		x				x
	5	6	x	x				x					x				x					x		x		x			x		x				x
	6	1	x	x				x					x				x					x		x		x			x			x			x
	7	2	x	x				x					x				x					x		x		x			x		x				x
	8	5	x	x	x			x					x				x					x		x		x			x		x				x
	9	12	x	x				x				x					x					x		x		x			x		x			x	
El Centro 16.06.2015	10	5	x	x	x			x				x				x	x					x		x			x		x		x			x	
	11	5	x	x	x			x				x				x	x						x		x		x		x		x				x
	12	7	x	x	x			x					x			x	x					x		x		x			x		x			x	
	13	4	x	x	x			x					x			x	x					x		x		x			x		x			x	
	14	7	x	x				x				x				x	x					x		x		x			x		x			x	
Barrio Santa Tecla 16.06.2015	15	2	x	x	x			x				x				x	x					x		x		x			x		x			x	
	16	5	x	x	x			x				x				x	x					x		x		x			x		x				x
	17	6	x	x	x			x				x				x	x					x		x		x			x		x			x	
	18	6	x	x				x					x			x	x					x		x			x		x		x				x
	19	3	x	x				x				x				x	x					x		x		x			x		x				x
Barrio las Flores 16.06.2015	20	4	x	x	x			x				x				x	x					x		x		x			x		x				x
	21	9	x	x				x				x				x	x					x		x		x			x		x			x	
	22	1	x	x	x			x				x				x	x					x		x		x			x		x				x
	23	5	x	x	x					x		x				x	x					x		x		x			x		x			x	
	24	4	x	x	x			x				x				x	x					x		x		x			x		x			x	
Barrio San Jose Pasaquina 17.06.2015	25	3	x	x				x				x				x	x					x		x		x			x		x				x
	26	7	x	x	x			x					x			x	x					x		x		x			x		x			x	
	27	2	x	x	x			x				x				x	x					x		x		x			x		x			x	
	28	4	x	x	x			x					x			x	x					x		x		x			x		x				x
	29	5	x	x	x			x					x			x	x					x		x		x			x		x				x
San Romero 17.06.2015	30	9	x	x				x				x				x	x					x		x			x		x	x					x
	31	6	x	x				x				x				x	x					x		x			x		x	x				x	
	32	3	x	x	x			x				x				x	x					x		x			x		x			x			x
	33	3	x	x	x			x				x				x	x					x		x			x		x		x				x
	34	4	x	x				x				x				x	x					x		x			x		x			x			x

10. Curriculum Vitae

B e r n h a r d B I B E R

born on 10 December 1989

Austrian citizen

EDUCATION

2014 / 2016

University of Natural Resources and Life Sciences, *Vienna*

Kulturtechnik und Wasserwirtschaft (Master)

Vienna

2010 / 2014

University of Natural Resources and Life Sciences, Vienna

Kulturtechnik und Wasserwirtschaft (Bachelor)

2004 / 2009

HTL St.Pölten

Mechanical Engineering

Main Focus: Automation

EXPERIENCE

02 – 06 / 2015

Master`s thesis - Investigation of the Current Sanitary Situation in Tecoluca, El Salvador

07 / 2014

Pöyry Energy GmbH – Civil Engineer (Internship)

Creation of flood protection plans, flood simulation

07 – 08 / 2011

Bitunova Baustofftechnik GmbH – Worker

Maintenance of small roads

2009 / 2010

Austrian Armed Forces (Melk) – Truck Driver

GENERAL AND SPECIFIC SKILLS

Computer Skills

- Microsoft Office
- Geographical Information Systems (ArcGIS, QGIS)
- Architecture and Design Software (AutoCAD)
- Software for Land survey
- (rmDATA, GeoSi)

Social Skills

- Willingness and Ability to learn new Things
- Open-minded and Flexibility
- Team-oriented

LANGUAGE SKILLS

German (native)	+++++
English	++++
Spanish	+++

KEY QUALIFICATIONS

- Water Ecology
- Water Supply, Wastewater Treatment and Water protection
- Hydraulic Engineering
- Geo-data and Land Management

11. Affirmation

I certify, that the master thesis was written by me, not using sources and tools other than quoted and without use of any other illegitimate support.

Furthermore, I confirm that I have not submitted this master thesis either nationally or internationally in any form.

Vienna, Austria on 23.06.2016 *Bernhard Biber, BSc*