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Investigating the state of rural water supply in Rio Grande do Sul, Brazil

- a regional study on the implementation of United Nations Sustainable Development Goal 6.1: safe and affordable drinking water for all

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Preface

We would like to express our deepest gratitude and appreciation to Professor Antônio Benetti at *Instituto de Pesquisas Hidráulicas* (IPH) of *Universidade Federal do Rio Grande do Sul* and Professor Kenneth M Persson at the Water Resources Department of Lund University for proposing this collaboration and research topic, and for making this master thesis possible. Many thanks to all professors and students at IPH who helped us in various ways during the time in Rio Grande do Sul, and to everyone from CEVS/VIGIAGUA and the municipalities who helped us to arrange field visits and interviews.

Our 10 weeks in Rio Grande do Sul were excellent, and an invaluable experience for us. During our time at IPH we learned very much about issues related to drinking water in Brazil and Rio Grande do Sul, and we will bring this knowledge as well as many new friendships with us into our future. We also hope that the observations, discussions and conclusions put forth in this report can be of help in the future work for sustainable water supply in the region.

Finally, we would like to express our gratitude to SIDA for the support given through the Minor Field Studies (MFS) scholarship, and Sveriges Ingenjörer for the support given through Miljöfonden.

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/Joel Häggqvist and Andreas Larsson

Abstract

Access to clean drinking water is a human right and a necessity for life, yet many rely on precarious water sources across the world. The United Nations outlines a great aspiration in Agenda 2030 - that safe and affordable drinking water should be available for all by 2030. In Rio Grande do Sul (RS) in Brazil, more than one million residents rely on small-scale water supply solutions without conventional treatment. This study aims to investigate technical and socioeconomic aspects of drinking water supply in rural areas of RS, and discuss the main challenges and possible ways forward. Multiple case studies were performed, describing small-scale water supply systems through direct observations, interviews and document studies. The case studies were complemented by literature reviews and interviews with authorities, researchers and support organizations within RS. This study found that microbiological contamination constitutes the most common water quality concern. Issues with fluorine exist locally, and pesticide contamination may be widespread. In combination with lacking treatment, inadequate water source protection and deficient wastewater management, this poses a threat to rural water safety within RS. Lack of economic self-sufficiency, community scepticism towards chlorination, insufficient funding of water and sanitation projects, and limited technical and administrative capacity in municipalities constitutes the main socioeconomic and political challenges. Efforts are needed on all levels to ensure safe and affordable water for all in RS. These actions include technical improvements concerning source protection, effective treatment and wastewater management. Furthermore, a shift towards educational efforts, community participation, economic self-sufficiency through solidary water tariff structures, an effective enabling environment and increased governmental funding of water and sanitation is of utmost importance. Finally, all stakeholders need to join forces and work together to achieve safe and sustainable water services for all, and make sure that no one is left behind.

Resumo

O acesso à água potável é um direito humano e uma necessidade para a vida, no entanto, muitas pessoas dependem de fontes de água precárias em todo o mundo. Uma das grandes aspirações das Nações Unidas, por meio da Agenda 2030, é a disponibilidade de água potável, segura e acessível para todos até 2030. No Rio Grande do Sul (RS), Brasil, mais de um milhão de residentes dependem de soluções de abastecimento de água em pequena escala sem tratamento convencional. Este estudo tem o objetivo de investigar aspetos técnicos e socioeconômicos dos serviços de água nas áreas rurais do RS e discutir os principais desafios e possíveis caminhos a seguir. Diversos estudos de caso foram realizados descrevendo sistemas de abastecimento de água em pequena escala por meio de observações diretas, entrevistas e estudos de documentos. Os estudos de caso foram complementados por revisões de literatura e entrevistas com autoridades, pesquisadores e organizações de apoio no RS. Este estudo constatou que a contaminação microbiológica constitui a principal preocupação com a qualidade da água no RS. Ainda, foram observados problemas com excesso de flúor e grande potencial de contaminação por pesticidas. A falta de tratamento adequado, o gerenciamento deficiente das águas residuais e a proteção precária das fontes de água representam uma ameaça à segurança da água rural no RS. A falta de recursos econômicos, o ceticismo da comunidade em relação à cloração, o financiamento insuficiente de projetos de água e saneamento e a capacidade técnica e administrativa limitada nos municípios constituem os principais desafios socioeconômicos e políticos. São necessárias melhorias técnicas, como proteção aprimorada das fontes de água, instalação de sistemas de tratamento eficientes e gerenciamento atualizado das águas residuais. Além disso, são necessários maiores incentivos à educação ambiental e a participação da comunidade, bem como a autossuficiência econômica por meio de estruturas tarifárias solidárias e aumento do financiamento governamental destinado a água e saneamento. Finalmente, todas as partes interessadas precisam unir forças e trabalhar juntas para obter serviços de água seguros e sustentáveis para todos e garantir que ninguém seja deixado para trás.

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1. Introduction

Earth is the only planet in the universe known to have stable, liquid water bodies on its surface (NOAA 2018). Without water, life as we know it could not have developed on Earth, and water is an absolute necessity for sustaining any life on our planet. Water is essential not only for sustaining the human body, but also to sustain human societies. Access to freshwater has shaped civilization throughout human history, and has been a prerequisite for human populations to survive and thrive (National Geographic Society 2019).

Freshwater is an invaluable and indispensable resource for humanity, and is required for countless purposes in society. Access to clean drinking water and basic sanitation is crucial for all of humanity and has been declared a human right by United Nations (UN) (UN General Assembly 2010). However, about 844 million people do not have access to basic drinking water services, and 2,1 billion people lack access to safely managed drinking water services as of 2018 (UN 2018).

In the most developed countries, clean water and sanitation is widely accessible for nearly all inhabitants (UN 2018; WWAP 2019). This is not the case in many developing countries, where contamination problems often are more serious, water infrastructure and treatment systems are less developed or non-existent, and financing opportunities are more limited (UN 2018; WWAP 2019).

Studies have shown that investments in water and sanitation often give great return on investment due to savings in public health expenses. Globally, benefit-cost ratios have been estimated to reach 4,3 for combined investments in water and sanitation (Hutton, 2013). This implies that increased investments in water and sanitation not only would create great benefits for health and environment, but also deliver significant economic returns. To improve access to safe water for large amounts of people, investments in urban areas with high population density are important, and such investments are usually prioritized globally (World Bank 2017a). However, to be able to reach safely managed water and sanitation by 2030 as is the goal of UN's Agenda 2030, it is estimated that about 112 billion USD will be needed – of which 39,5 billion USD is needed for rural areas (World Bank 2017a).

The investments in water and sanitation for rural areas during the years 2000-2015 was about 5,4 billion USD (World Bank 2017a). This means that the amount spent on rural water and sanitation per year during 2015-2030 has to increase by a factor larger than seven. Rural areas and their populations are at risk of getting left behind, continuing to experience lack of access to clean water and sanitation - a very serious issue which must be addressed.

1.1 Agenda 2030 and the importance of clean water

In 2015 the UN General Assembly adopted the monumental plan "*Transforming our world: the 2030 Agenda for Sustainable Development*", after the largest, most including and most transparent consultative process in the history of the global community (UNDP 2016). The 17 Sustainable Development Goals (SDGs) are the core of the Agenda, aiming to *"stimulate action over the next 15 years in areas of critical importance for humanity and the planet"* and *"realize the human rights of all"* (UN General Assembly 2015).

The 6th goal of Agenda 2030, *SDG 6*, aims to *"ensure availability and sustainable management of water and sanitation for all*" (UN General Assembly 2015). SDG 6 is subdivided into eight targets as seen in Figure 1 below, covering all aspects of the water cycle. The eight targets within SDG 6 are interconnected and synergic in many ways, but the specific target that is in focus within this investigation and report is SDG 6.1, which is phrased as follows (UN SDSN 2019):

"By 2030, achieve universal and equitable access to safe and affordable drinking water for all"

Figure 1. The eight targets of SDG 6 (ICE 2018).

Target SDG 6.1, often shortened to "safe and affordable drinking water to all" or "safe drinking water for all", is mainly monitored by measuring the percentage of population which use safely managed drinking water services. The WHO/UNICEF Joint Monitoring Programme (JMP) defines criteria for drinking water service levels as seen in Figure 2 below. The criteria for safely managed services is clearly visualized in Figure 3 below. To be considered a safely managed service, the water must be accessible on premises, available when needed and free from contamination. For a basic water service, drinking water must be taken from an improved source, and the total collection time must be less than 30 minutes.

SERVICE LEVEL	DEFINITION
SAFELY MANAGED	Drinking water from an improved water source that is located on premises, available when needed and free from faecal and priority chemical contamination
BASIC	Drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip, including queuing
LIMITED	Drinking water from an improved source for which collection time exceeds 30 minutes for a round trip, including queuing
UNIMPROVED	Drinking water from an unprotected dug well or unprotected spring
SURFACE WATER	Drinking water directly from a river, dam, lake, pond, stream, canal or irrigation canal

Figure 2. Service level definitions for drinking water supply according to the WHO/UNICEF JMP system (UN 2018).

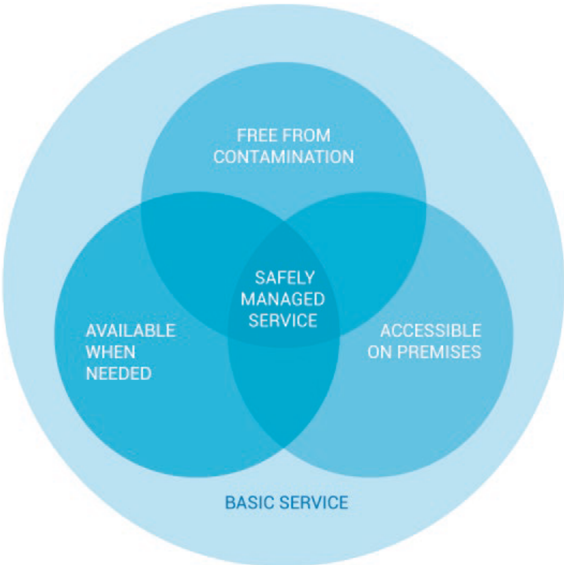

Figure 3. Visualization of criteria needed for a service to be considered safely managed (UN 2018).

If a service is to be considered a basic or safely managed, it is necessary that the water source is considered to be "improved". According to the definitions of the JMP, improved water sources include the following (WHO 2012a):

- Piped household water connections
- Public standpipes

- Boreholes
- Protected dug wells
- Protected springs
- Rainwater collection systems

While unimproved water sources include the following (WHO 2012a):

- Unprotected dug wells
- Unprotected springs
- Surface water (rivers, dams, lakes, ponds, streams, canals, irrigation channels)
- Vendor-provided water (bottled water is considered improved only when another water source is used in the household for cooking and personal hygiene)
- Tanker truck water

As of 2018, 29 % of the world population are estimated to lack safely managed drinking water supply services, meaning that about 2,1 billion people depend on unreliable and/or unsatisfactory services for their drinking water (UN 2018). About 17 % of the world population have access to basic, but not safely managed services. This leaves 12 % of the world population or 844 million people without access to even basic services, having to rely on precarious water supply solutions (UN 2018).

Even though 71 % of the world population have access to safely managed drinking water services, there is a vast difference between the urban and rural demographic groups in the world. As of 2017, it was estimated that 85 % of the urban population in the world had access to safely managed drinking water (World Bank 2017b). For the rural population in the world, the corresponding number was estimated to be 53 % (World Bank 2017c). Many countries are lagging behind in the trajectory of providing safe water for all until 2030, especially in developing countries (UN 2018). While economy of scale often may facilitate and favour water infrastructure investments in urban areas (WWAP 2019), Agenda 2030 clearly states that *"no one will be left behind"* in the attainment of the sustainable development goals (UN General Assembly 2015). This commitment calls for increased attention for groups and areas that are at risk of getting left behind. If universal and equitable access to safe and affordable drinking water truly is to be achieved for all, this means that water supply solutions for rural populations will need to be addressed and prioritized to a larger extent.

Although Agenda 2030 and the SDG's are not legally binding, all 193 countries of the UN have adopted the Agenda, meaning that they are expected to translate the goals into national frameworks and implement this plan to the fullest extent possible (UN General Assembly 2015). This means that Agenda 2030 may have the power to trigger national-level development of laws, policies and investments that can make the goals achievable - including the target of safe and affordable drinking water for all.

Brazil, which is currently transitioning into a developed country (IMF 2018), has already reached a high coverage of water supply services using *improved sources*, and 93,7 % of the population had access to piped water as of 2015 (Scott et al. 2017). However, wastewater management is lacking behind (Scott et al. 2017), which commonly causes pollution of water sources. To ensure safely managed water services, the water must be free of contamination, as seen in Figure 3 above. Brazil however lacks sufficient data for estimating the amount of people consuming water which is free from contamination, and thus the amount of people consuming safely managed water (UN 2018). In this study, the implementation of SDG 6.1 and the endeavour to reach the rural population with safe and affordable drinking water is investigated qualitatively, focusing on the situation in the southern state of Rio Grande do Sul.

1.2 Study area

Rio Grande do Sul (RS) is the southernmost state in Brazil – a relatively prosperous state with much agricultural activity (Encyclopædia Britannica 2012; IBGE 2019). In this study the implementation of SDG 6.1 in the region has been investigated through case studies of small-scale water supply solutions in the state of RS, as well as seminars and interviews with local authorities and researchers. This region was considered as a suitable study area due to its development context, which gave an opportunity to investigate how authorities are working to ensure safe and affordable water to all of its population in a region where many, but not all, have access to these services. Due to its large agricultural sector, RS was also considered an area of special interest in the light of Brazil's permissive pesticide policies, which have been considered very alarming (Canineu 2019; The Guardian 2019).

Figure 4 and Figure 5. Location of Rio Grande do Sul (RS) (Google maps 2020).

RS is situated in the very south of Brazil, bordering Argentina, Uruguay, the Brazilian state of Santa Catarina and the Atlantic Ocean, as seen in Figure 4-5 above. The state hosts a population of 11,4 million on an area of about 282 000 km^2 (IBGE 2019a). RS is a major agricultural region, and the most important crops in the state include rice, corn, wheat, soybeans, grapes and tobacco (Encyclopædia Britannica 2012; IBGE 2017).

The climate in RS is of temperate subtropical type and classified as humid mesothermal (Atlas Socioeconômico RS 2019), and precipitation in RS averages at about 1300 mm per year (Encyclopædia Britannica 2012). RS is situated in two main biome areas - the Atlantic Rainforest in the northern part and the Pampas in the southern part. Geographically, the north of RS is occupied by the Paraná Plateau while the southern part is less mountainous and encompasses flat lowland areas in the Pampas, used intensively for agriculture (Atlas Socioeconômico RS 2019).

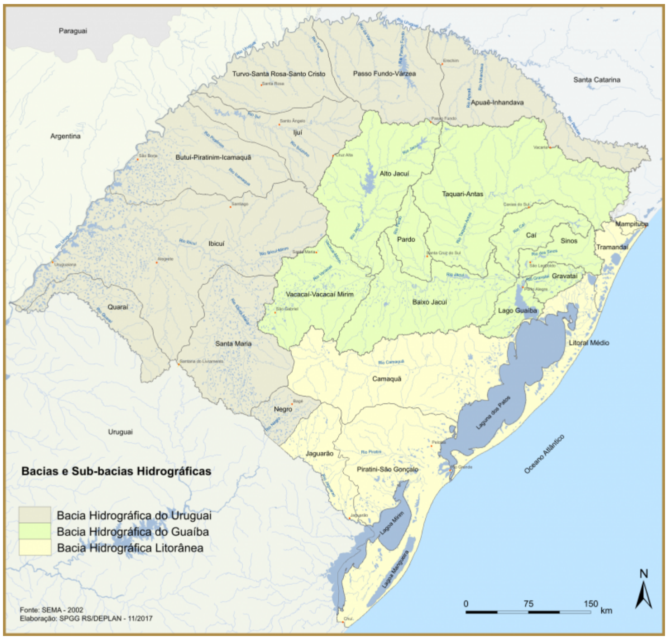

Figure 6. Hydrological basins of RS (Atlas Socioeconômico RS 2019).

Hydrologically, all of RS drains into the Atlantic Ocean, mostly through the Uruguay River basin (57 % of the state area) and the Guaíba river basin (30 % of the state area) through the lagoon Lagoa dos Patos (Atlas Socioeconômico RS 2019) (see Figure 6 above). 13 % of the state area belongs to the littoral basin, draining to the Atlantic directly or through the coastal lagoons. In all of these basins agriculture is prevalent and significant, especially in the lowlands of the Uruguay River basin (Atlas Socioeconômico RS 2019).

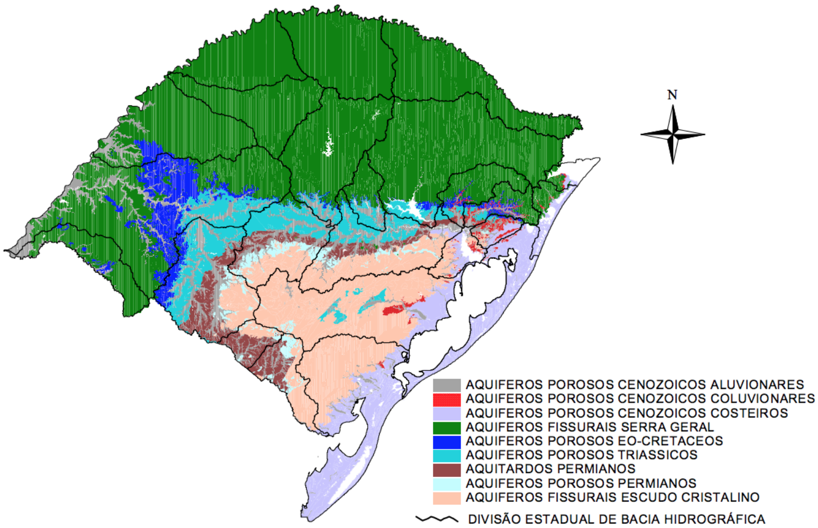

Figure 7. Hydrogeology and major aquifer systems of RS (Freitas et al. 2004).

The hydrogeology of RS and the main aquifer systems are shown in Figure 7 above. Important aquifer systems include the fractured aquifers of the basaltic Serra Geral formation and the fractured aquifer in the southern crystalline shield *(Escudo Cristalino)*. There are also aquifer systems consisting of porous sandstone formations, as well as smaller porous aquifers consisting of alluvial and colluvial deposits (Freitas et al. 2004). The enormous Guarani Aquifer System also stretches throughout large parts of the state, covered by formations such as the Serra Geral basalts, forming an integrated aquifer system over parts of RS (OAS 2009). The Guarani system is amongst the largest aquifer systems in the world, and stretches over parts of Brazil, Paraguay, Uruguay and Argentina. The formation mainly consists of sandstones from the Triassic-Jurassic age, and is used as water supply source in large parts of RS (OAS 2009).

According to the last demographic census of 2010, it was estimated that 85,3 % of the population in RS was connected to a *"public water supply system"* (Atlas Socioeconômico RS 2019). This leaves 14,7 % of the population or 1,7 million people in RS without a connection to public water supply networks, essentially meaning that these people obtain water from individual systems or through small-scale water supply solutions.

Small-scale organizations which provide water to rural communities do not generally have the same technical capacity and economic coordination as large-scale service providers. At the same time, water sources in rural areas may be especially vulnerable to contamination due to inadequate wastewater management and use of pesticides in the vicinity of water sources. An earlier study has suggested that about 60 % of small-scale water supply solutions in RS may be considered vulnerable, based on an index which consider factors such as water quantity, water quality, water treatment and distribution systems, technical capacity, financing and external support (Debiasi 2016). Based on this, RS was considered an interesting area to study the challenges in the implementation of *SDG 6.1 - safe and affordable water for all*.

2. Aim

This project aims to describe the state of drinking water supply in rural areas of RS, and discuss the current endeavour of reaching sustainable water supply and provision of clean water for all in the region. Through multiple case studies of small-scale water supply systems in RS, as well as comprehensive literature studies and interviews with authorities and researchers, the aim is to produce a holistic study where technical, socioeconomic and political aspects are taken into account in the investigation and analysis. The final purpose is to identify the main obstacles towards reaching the goal of providing clean drinking water for all in RS, and discuss possible ways forward.

The aspiration is that this project can give new aspects on the water supply challenges in rural areas and small municipalities of Rio Grande do Sul. The final report and conclusions will be distributed to people who in various ways are working in projects related to water supply within the state. Hopefully the analysis and conclusions in this study can offer new perspectives on challenges and opportunities related to rural water supply, and be useful for future work in the area.

2.1 Delimitations

The case studies performed in this project intend to serve as examples, describing how water services may be arranged in RS, and highlighting some of their main issues. They are not intended to represent all typical small-scale water solutions within the state. Furthermore, the case studies are limited to water supply systems serving more than one household, but less than 2500 people. To provide an overview of rural water supply in RS, complementary literature reviews, data analysis and interviews were used.

2.2 Research questions

1. How are water supply services generally organized in rural areas of Rio Grande do Sul, and what problems exist?
2. What issues can be observed directly through a multiple case study of rural water supply services in Rio Grande do Sul?
3. What could be possible ways forward to ensure safe and affordable water for all in Rio Grande do Sul?

3. Methodology and material

The core methodology of this project is a multiple case study of rural water supply systems in the state of RS, based on field visits to each system and interviews with local stakeholders. Literature reviews, processing of information from the database SISAGUA and interviews with researchers and authorities also contributes greatly to answer the research questions, and to provide necessary background and context. This study is mainly of qualitative character. Results related to the adequacy of the visited water supply systems are however presented in ranked forms to illustrate information more clearly and provide basis for discussion.

When the term *"rural"* is referred to in this work, this includes the central settlements of the small municipalities which were visited (which all have a population of less than 5000 each) as well as the most remote and sparsely populated countryside areas in these municipalities, unless otherwise stated.

3.1 Literature review

A large amount of literature has been used in this study; partly to provide background and overview of water supply services in the state, and partly to discuss the rural water supply services of RS in relation to international experiences and best management practices.

Political objectives and legislation related to water supply on federal and regional level is provided through analysis of official documents and laws. These sources include the constitution of Brazil, the main sanitation *Law nº 11.445/2007*, the national sanitation plan (PLANSAB), *Portaria MS nº 2914/2011* and other principal documents from authorities. The current state of water supply in the state is described based on data and documents from IBGE (*Instituto Brasileiro de Geografia e Estatística*), the socioeconomic atlas of RS, regional authorities and other relevant reports. Description of water quality and quantity issues within the state is also provided through information from regional authorities and various research articles.

Furthermore, a large body of literature was used for comparison and identification of ways forward in the discussion section. This literature relates to the observed challenges for rural water supply in various ways, and includes best management practices and guidelines found through UN, the World Health Organization (WHO), the International Water Organization (IWA) and others.

3.2 SISAGUA

During the time in RS, the authors gained access to the database SISAGUA (*Sistema de Informação de Vigilância da Qualidade da Água para Consumo*). This is a database which contains information about water supply system characteristics, water sources and water quality records for all registered drinking water supply systems in Brazil.

The data from SISAGUA was partly used to provide an overview of the registered water supply systems which exist in RS, and the characteristics of these systems. SISAGUA was also an important tool for the case studies, as it was used to access historical records of water quality for the visited water supply systems.

3.3 Case studies

The authors spent about 10 weeks in RS, based as guest students at *Instituto de Pesquisas Hidráulicas* (IPH) in Porto Alegre. During this time, field investigations through a multiple case study approach was an important part of the methodology for data collection.

Case study research aims to derive an in-depth understanding of a single or a number of "cases", set in their real-life context (Yin, 2011). In the context of this study, these "cases" are each of the eight water supply systems which have been visited and investigated. The aim of each case study was to describe:

- The configuration of the water supply system in terms of capture, treatment and distribution
- The organizational structure of the water supply service

- Which problems and challenges that exist in regards to technical, socioeconomic and cultural aspects
- How the community and authorities are working to address eventual issues

Initially, the case studies were planned to include water supply systems for rural communities around the municipality of Santa Rosa as part of an ongoing project with IPH. There were also plans to investigate rural water supply systems of *quilombola* communities using spring water sources together with the rural support organization EMATER. However, both of these plans were postponed and eventually cancelled.

Instead, a set of small municipalities with small-scale water supply systems were chosen for the case studies. As the authors did not have access to SISAGUA during the beginning of the time spent in RS, specific information regarding suitable systems to visit was limited when the field visits were arranged. The case studies were therefore decided based on recommendations from contacts in IPH; especially from *Sistema de Apoio ao Saneamento Básico* (SASB), and researchers who earlier had analysed vulnerability of small-scale water supply systems in RS. The criteria set for the case systems were the following:

- Systems situated in small municipalities with a total population < 5000
- Systems serving a maximum of 2500 people
- Systems known to have had recent issues according to SISAGUA, vulnerability assessments or commentary from SASB

In case studies, data is commonly collected in six different ways (Yin 2011); direct observations, interviews, archival records, documents, participant-observation and physical artefacts. In this study, three of these data collection methods were used; direct observations, interviews and document studies.

During each field visit, a thorough interview was performed together with the municipal representative responsible for water and sanitation in the municipality. These interviews followed the structure seen in Table 1 below. The questions often led to follow-up questions which were further discussed. The interviewing technique was thus semi-structured, an interviewing method which is commonly used and considered to offer many advantages (Adams 2015). This method was deemed appropriate since it keeps an essential structure of the interviews, while also allowing for a wider discussion of issues based on local circumstances. During each interview, the municipal representative was also asked about the future plans for water services in the municipality, and in which way they plan to address the current issues relating to water supply.

During all of the field visits, the authors were accompanied by a teacher or PhD student from *Instituto de Pesquisas Hidráulicas* (IPH), who were able to act as Portuguese-English translator. However, parts of the interviews were also performed directly in Portuguese, with translation to English performed when needed.

Table 1. Main questions of the semi-structured interviews with municipal representatives.

Indicator	**Questions, English**	**Questions, Portuguese**
Water resources availability	How often has water shortages occurred for the system?	*Com que frequência ocorreu falta de água para o sistema?*
Water source	Where is the water taken from? Is the water source protected?	*De onde é retirada a água?* *A fonte de água está protegida?*
Water quality	How is the perceived water quality? Are there known incidents where people have become sick from the drinking water?	*Como é a qualidade da água percebida?* *Existem incidentes conhecidos em que as pessoas adoeceram com a água potável?*
Level of treatment	What sort of treatment is available?	*Que tipo de tratamento está disponível?*
Distribution network	What does the water distribution system consist of?	*Em que consiste o sistema de distribuição de água?*

	How often do problems such as leaks and low tap pressure occur?	*Com que frequência ocorrem problemas como vazamentos e baixa pressão na torneira?*
Operation & maintenance	Who takes care of O&M (Operation & Maintenance)? Is O&M regular and satisfactory?	*Quem cuida da Operação e Manutenção?* *A Operação e Manutenção são regulares e satisfatórias?*
Economic sustainability	How is the water supply system financed? Is there any fee for water use and if so, is it based on consumption or flat rate? Is there any external funding?	*Como é financiado o sistema de abastecimento de água?* *Existe alguma taxa pelo uso da água? Em caso afirmativo, esta taxa é baseada no consumo ou em taxa fixa?* *Existe algum financiamento externo?*
Surveillance and monitoring	Is surveillance performed by external agents? How often?	*A fiscalização é realizada por agentes externos? Se sim, com que frequência?*
Participation of beneficiaries	Have the local population (beneficiaries) been involved in planning, budgeting, prioritization and decision-making when constructing or reconstructing the water supply system? Are the beneficiaries involved in maintenance of the system?	*A população local (beneficiários) esteve envolvida no planejamento, orçamento, priorização e tomada de decisão ao construir ou reconstruir o sistema de abastecimento de água?* *A população local está envolvida na manutenção do sistema?*

When possibilities were given during field inspections, interviews with local beneficiaries were also carried out. In these situations, the interviews did not follow a predetermined structure. Instead, the case-specific questions which were deemed most relevant were discussed.

The field visits also included a technical inspection of the water supply systems, which mainly consisted of a visual inspection on the state of source protection, wells, reservoir tanks and treatment equipment. Supporting documents such as technical reports concerning the water supply systems, including municipal basic sanitation plans, were used to complement this information, as well as water quality records from SISAGUA.

To depict the information collected about each of the cases, a set of indicators were assembled. Each of the nine indicators evaluate the adequacy of the system and services according to certain criteria, as seen in Table 2 below. This evaluation was used to illustrate the issues, and used as a supporting tool for the discussion. These evaluations do not intend to provide a final declaration of the state of the systems. The indicators which were used were inspired by and partially adapted from the study *Avaliação de vulnerabilidade dos pequenos sistemas de abastecimento de água no estado do Rio Grande do Sul* (Debiasi, 2016).

Table 2. Indicators and criteria used to evaluate adequacy of water service characteristics

Indicator	**Adequacy**	**Criteria**
Water resources availability	• Not adequate • Partially adequate • Adequate	• Annual occurrence of water scarcity • Water scarcity has occurred during the last five years • Water scarcity has not occurred during the last five years
Water source	• Not adequate • Partially adequate • Adequate	• Unprotected water source • Partially protected water source • Protected water source
Water quality	• Not adequate • Partially adequate • Adequate	• Coliforms present regularly, or levels of fluorine/turbidity regularly exceeding drinking water standards • Coliforms rarely present, but taste/odour/colour issues and/or no residual chlorine • Full compliance with water quality regulations
Level of treatment	• Not adequate • Partially adequate • Adequate	• Treatment not appropriate for given raw water quality • Treatment partially appropriate for given raw water quality • Treatment appropriate for given raw water quality
Distribution network	• Not adequate • Partially adequate • Adequate	• Interruptions due to leaks or malfunctioning equipment occurring frequently and/or no monitoring of non-revenue water • Interruptions due to leaks or malfunctioning equipment occurring intermittently and/or no monitoring of non-revenue water • Interruptions due to leaks or malfunctioning equipment occurring rarely, and non-

		revenue water is monitored
Operation & maintenance	• Not adequate • Partially adequate • Adequate	• Frequent issues due to lack of O&M • Irregular and/or insufficient O&M • Regular and sufficient O&M
Economic sustainability	• Not adequate • Partially adequate • Adequate	• Financing through tariffs not sufficient for adequate water supply • Financing through tariffs partially sufficient for adequate water supply • Financing through tariffs sufficient for adequate water supply
Surveillance and monitoring	• Not adequate • Partially adequate • Adequate	• No surveillance or monitoring • Surveillance and monitoring performed, but not in coherence with guidelines • Surveillance and monitoring performed in coherence with guidelines
Participation of beneficiaries	• Not adequate • Partially adequate • Adequate	• No community involvement in planning and decision-making regarding water supply • Some community involvement in planning and decision-making regarding water supply • Community driven planning and decision-making regarding water supply

3.4 Seminars and other interviews

During the time that the authors spent in RS, first-hand data was also collected through seminars, meetings and additional interviews. The additional sources which are brought up in this report are the following:

- Biannual seminar and meeting with the state centre of health surveillance (*Centro Estadual de Vigilância em Saúde* (CEVS)) and officials working specifically with the drinking water quality surveillance in the state (*Vigilância da Qualidade da Água para Consumo Humano* (VIGIAGUA)), 2019-10-22
- 3° State Seminar on Water and Health - Revision of drinking water standards (*3° Seminário Estadual, Água e Saúde - Revisão da Portaria de Potabilidade*), 2019-10-24

- Interviews and e-mail conversations regarding the challenges for rural water supply in RS with state authorities, the rural support agency EMATER, and professors from IPH

4. Drinking water services in Rio Grande do Sul

In this section an overview of the state of drinking water supply, water quality issues and water quantity issues in RS is provided, including a description of the political and legislative context. This section is built on literature reviews, and from analysis of data retrieved from the SISAGUA database.

The findings of this section are to be seen as results in the sense that they answer the first research question - "*How are water supply services generally organized in rural areas of Rio Grande do Sul, and what problems exist?*", while also providing context needed to answer the third research question - *"What could be possible ways forward to ensure safe and affordable water for all in Rio Grande do Sul?"*.

4.1 Politics and legislation related to water supply

4.1.1 Political background and objectives

Brazil is a federative democratic republic composed of 26 states (*estados*), 5570 municipalities (*municípios*) and the federal district (*distrito federal*) of the capital Brasília (Senado Federal 2017; OECD 2016). The municipalities are not a creation of the states, as is the case in most federations. Instead each municipality is granted the status of a federal entity at the same level as the states (Senado Federal 2017; OECD 2016). Legislative power is granted at all of these three levels - federation, state and municipality. The constitution determines certain activities which are exclusive for the federative level, and certain activities which are responsibilities of the municipalities. Municipal responsibilities include to "organize and perform essential public services of local interest" (Senado Federal 2017), which includes water and sanitation services.

The states are allowed to carry out all functions and activities which they are not explicitly excluded from according to the constitution, but the responsibilities are often shared with the federative and/or municipal levels to some extent (OECD, 2016), which also is the case for water and sanitation-related activities. Since clear responsibility division is lacking in several areas, overlap of responsibilities across government levels are frequent (OECD 2016).

Since 2007, *Law nº 11.445/2007* is the main federal law which outline policies for water and sanitation in Brazil (Lei nº 11.445/2007). This law aims to clarify responsibilities within basic water and sanitation services (*saneamento básico*), and facilitate investments and development in the sector. The law determines that municipalities are accountable for the provision of basic sanitation services. In Brazil, the term *saneamento básico* encompasses water supply, wastewater disposal, solid waste management and stormwater management (Lei nº 11.445/2007).

Even though municipalities have the main responsibility for basic sanitation services, the law also states that municipalities are allowed to outsource services to third parties such as associations or companies through formal contracts. According to the law, a basic sanitation plan (*Plano Municipal de Saneamento Básico* (PMSB)) also has to be drafted by every municipality in Brazil (Lei nº 11.445/2007). Originally, 2014 was set as deadline for the adoption of a PMSB for each municipality in Brazil. However, only 31 % of the municipalities had been able to produce a PMSB according to a review from 2015 (Akhmouch et al. 2017). This is not only an issue since sanitation problems are more likely to remain uncharted and unsolved, but also an issue since the absence of a PMSB can make the municipality unable to apply for public funding, as is the case within the state of RS (Lei nº 11.445/2007; Estado do Rio Grande do Sul 2015).

As all other nations of the UN, Brazil has adopted Agenda 2030 including SDG 6 with its goal to achieve clean water and sanitation for all. This means that Brazil also should aim to provide clean water for all until 2030, and is expected to mobilize the resources and actions needed to achieve this goal to the fullest extent possible. In Brazilian legislation, the national basic sanitation plan (*Plano Nacional de Saneamento Básico* (PLANSAB)) outlines the goals of water and sanitation since 2014 (Ministério das Cidades 2013), and relates to the targets of SDG 6 to a large extent. PLANSAB was published 2013 and put into legal force 2014, i.e. just before the UN's adoption and final enunciation of Agenda 2030, and at the end of the era of the Millennium Development Goals (MDGs). Short-term, medium-term and long-term goals (until 2018, 2023 and 2033) are set in PLANSAB. Some of the main ambitions outlined in PLANSAB, which are to be achieved until 2033, include the following (Ministério das Cidades 2013):

- Reaching 99 % of the households in Brazil with safe, piped water supply
- That 100 % of water supply services will be covered by tariff structures (aiming to ensure economically sustainable services)
- Decreasing the average water loss index (i.e. non-revenue water level) from 39 % (as of 2010) to 31 %
- Reaching 92 % of the households in Brazil with wastewater collection systems or adequate septic tank systems
- That 93 % of the wastewater that is collected will be adequately treated

4.1.2 Legislation related to water supply categorization

In Brazil, registered water supply systems are divided into three categories according to article five of *Portaria MS nº 2914/2011*. These categories are the following (Ministério da Saúde 2011):

- Water supply systems (of large scale) (*Sistemas de Abastecimento de água para consumo humano (SAA)*)
- Alternative collective solutions - *(Soluções Alternativas Coletivas de água para consumo humano (SAC))*
- Alternative individual solutions (*Soluções Alternativas Individuais de água para consumo humano (SAI)*)

The definitions of these systems are somewhat ambiguous, since they are not linked directly to the amount of households served, technical specifics or management form. However, the definitions are formulated as follows, translated from article five of *Portaria MS nº 2914/2011* (Ministério da Saúde 2011):

- SAA - "an installation composed of civil works, equipment and material, from the capture source to the building connections, for the production and collective supply of water, through a distribution network"
- SAC - "a collective water supply modality designed to provide drinking water, with groundwater or surface water abstraction, with or without plumbing and with or without a water distribution network"
- SAI - "a drinking water supply modality which serves a residential household with only one family and their household members"

The division of water supply systems to SAA, SAC and SAI have certain legal implications. According to Brazilian law, SAA and SAC systems must have disinfection and a free residual chlorine content of at least 0,2 mg/L at all points in the distribution system (Ministério da Saúde 2011), to ensure inactivation of microorganisms. The categorization of water supply systems into SAA or SAC and the amount of people served also decides the frequency of which samples must be collected for water quality surveillance and control (Ministério da Saúde 2016). This surveillance is performed through the water surveillance programme VIGIAGUA (*Vigilância da Qualidade da Água para Consumo Humano*), and in RS the municipalities are responsible for creating sampling plans and making sure that they are followed (CEVS 2019a).

4.1.3 Drinking water standards

Potability limits for drinking water are set on a national level through *Portaria MS nº 2914/2011*. The potability limits of the parameters which are deemed most relevant to this study are presented in Table 3 below (Ministério da Saúde 2011):

Table 3. Drinking water potability standards in Brazil and RS.

Parameter	Potability limit
Coliform bacteria (after treatment)	Absence in 100 ml sample
Escherichia coli (after treatment)	Absence in 100 ml sample
Fluorine	Max 1,5 mg/L*
Turbidity	Max 5 Turbidity Units (TU)
Residual chlorine	Min 0,2 mg/L in distribution system/tap Min 0,5 mg/L directly after treatment Max 5 mg/L

*In RS, the fluorine concentration has to be below 0,9 mg/L for SAA systems according to *Portaria SES/RS nº 10/1999* (Estado do Rio Grande do Sul 1999)

Comparing with drinking water standards in Sweden, bacteria such as *E. Coli* should also be absent in a 100 ml sample. The Swedish limit for fluorine is also 1,5 mg/L, and for turbidity water is classified as "potable with caution" already at 1,5 TU. There is no required minimum level of chlorine, but chlorine levels are "generally not allowed to exceed 1 mg/L" (Livsmedelsverket, 2017).

4.2 Water supply systems

4.2.1 Water supply systems - SISAGUA analysis

SISAGUA is a database in which all water supply systems in Brazil should be registered by the municipalities. Upon registration, all systems are classified as SAA, SAC or SAI. Information on all of the registered water supply systems in RS was extracted through the SISAGUA database (in November 2019), and the information was processed to generate the results which are visualized in Figure 8 and Figure 9 below.

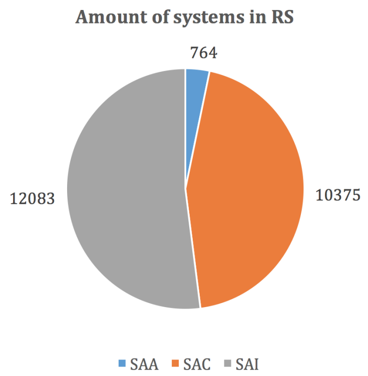

Figure 8. Number of water supply systems in RS according to system category (SISAGUA 2019).

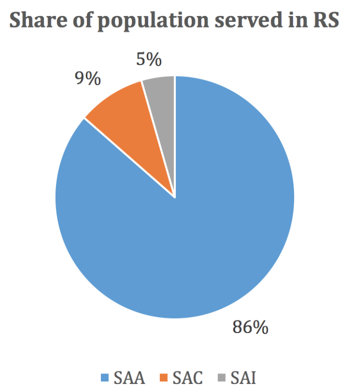

Figure 9. Share of population served by each supply category (SISAGUA 2019).

Figure 8 shows that there are a total of 23 222 (registered) water supply systems in RS. Most of these systems are small SAI systems. The 764 large-scale SAA systems are estimated to provide water to 86 % of the population in RS, or 9,8 million people. The 10 375 SAC systems are estimated to provide drinking water to 9 % of the population - roughly 1 million people.

Figure 10 below shows the amount of systems in each category that has basic water treatment installed in the form of disinfection. Even though Brazilian law stipulates that disinfection must be used, it is clearly seen that disinfection is lacking in almost all SAI systems, and in about half of the SAC systems.

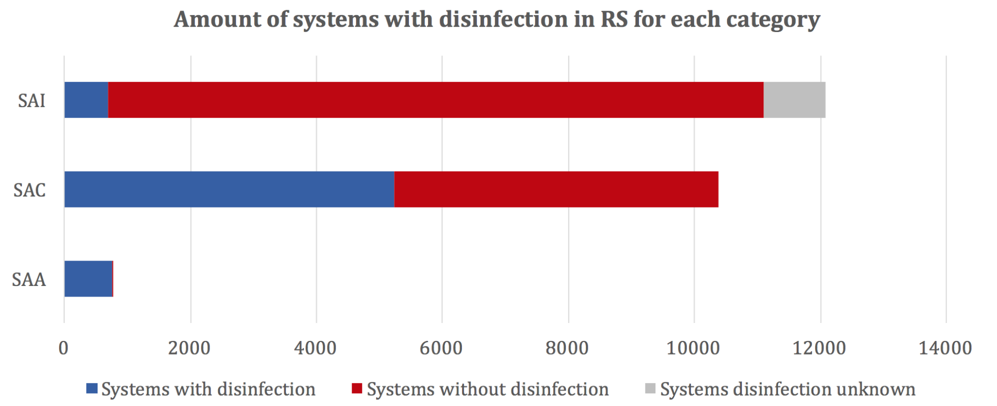

Figure 10. Amount of SAI, SAC and SAA systems with and without installed disinfection systems in RS (SISAGUA 2019).

4.2.2 Water supply systems - management and economy

In Brazil the municipalities are obligated to provide water and sanitation services to their inhabitants, but according to national law they are also allowed to outsource these responsibilities through contracts with companies and associations (Senado Federal 2017; Lei nº 11.445/2007). This means that there are several organizational forms in which SAA and SAC systems can be managed - for example directly by the municipality, by community organizations, by small local companies or by large state-level water and sanitation companies.

In RS, the state-owned water and sanitation company CORSAN is present in the 317 of the 497 municipalities (Estado do Rio Grande do Sul 2015; CORSAN 2019). Their activity is however usually limited to the central settlements of each municipality, i.e. they do not supply water to the more sparsely populated and remote rural areas in the municipalities. This means that municipalities which have a contract with CORSAN also may have SAC systems managed by community associations in the peripheral areas of the municipalities. In many of the smallest municipalities in RS, CORSAN is not active at all (Estado do Rio Grande do Sul 2015; CORSAN 2019).

In the last Brazilian census of 2010, IBGE mapped the percentage of households connected to "public water supply networks" *(rede geral de* *abastecimento de água)* for all municipalities in Brazil. The results for RS can be seen in Figure 11 below. While the term *rede geral de abastecimento de água* translates to "public water supply network", this term does not seem to correspond directly to the management form or to the SAA/SAC/SAI classification. No further explanation of the methodology used to determine if a distribution network is "public" (*geral*) is stated in the methodology notes from IBGE (IBGE 2010b). However, it seems that all SAA systems regardless of management form, as well as some of the SAC systems, have been included in the definition *rede geral de abastecimento de água* which is used in the IBGE classification.

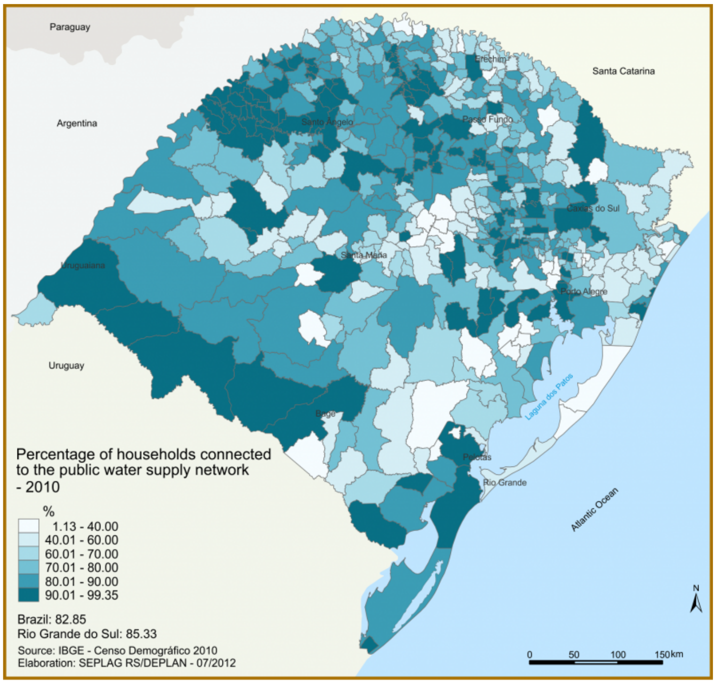

Figure 11. Percentage of households connected to a "public water supply network" (rede geral de abastecimento de água) (Atlas Socioeconômico RS 2019).

Figure 11 above shows that many municipalities have a very low number of public water supply connections, and that much of the population must rely on other solutions. In some areas the connection percentage reaches above 99 %, e.g. in the municipality of the state capital - Porto

Alegre. In this city, the *Departamento Municipal de Água e Esgotos* (DMAE) provides water and sanitation services (Atlas Socioeconômico RS 2019; Prefeitura de Porto Alegre 2020).

In Table 4 below, the distribution of water supply solutions in urban and rural areas of RS are presented respectively, also based on the last Brazilian census of 2010 (IBGE 2010a). The percentage of households estimated to be served by "public water supply networks" (which seems to include SAA systems as well as some SAC systems) is about 85 %.

Table 4. Water supply solutions for urban and rural households in RS, adapted from the last IBGE census of 2010 (IBGE 2010a).

Water supply solution	**Urban households**	**Rural households**	**Total households**
Public water supply network	2 881 428	190 287	3 071 715
Well or spring on property	164 809	240 450	405 259
Well or spring off property	24 988	78 527	103 515
Water truck	1 256	378	1 634
Rainwater harvesting with tank storage	263	841	1104
Rainwater harvesting with other storage	238	364	602
River, dam, lake or stream	277	2 178	2 455
Other form / Uncategorized	10 956	2 364	13 320
Total	**3 084 215**	**515 389**	**3 599 604**

A very important factor in the planning and construction of water supply systems is financing. In the case of small-scale solutions, public funding is usually the only prospect for financing, unless the beneficiaries possess their own economic means for initial investments. Granting of federal funds for water and sanitation projects in municipalities generally require that the municipalities have a basic sanitation plan (PMSB) (Lei nº 11.445/2007; Estado do Rio Grande do Sul 2015). However, the drafting of these plans demand great effort as well as substantial administrative and technical capacity. Many municipalities in RS still lack such plans, which is an issue in the financing of improved water and sanitation services (Lei nº 11.445/2007; Estado do Rio Grande do Sul 2015).

Some financing of water and sanitation services in RS have been supported from federal level through the *Programa de Aceleração do Crescimento* (PAC), which have channelled about 4,65 billion R$ into sanitation investments in RS between 2007-2012 (Estado do Rio Grande do Sul 2015). For rural areas, PAC funds have mainly been allocated through *Fundação Nacional de Saúde* (FUNASA), accounting for at least 170 million R$ of the investments between 2007-2014. FUNASA is the most important institution for water and sanitation funds aimed towards municipalities with less than 50 000 inhabitants and rural areas (Akhmouch et al. 2017). The investments in RS funded by FUNASA have included drilling of wells in rural areas where the population lacked suitable water supply solutions. Between 1981-2014, about 4620 new wells were drilled in RS through public funding, to provide water for rural populations (Estado do Rio Grande do Sul 2015). Although much has been done for the rural water supply in RS, there are problems left which must be addressed.

4.3 Water quality issues

4.3.1 Microbiological contamination

Microbiological contamination is a fatal but common water quality issue in many parts of the world, and especially common in locations where domestic wastewater is not adequately treated. Typical microorganisms which may contaminate drinking water include enteric bacteria such as faecal coliforms, enteric viruses, and protozoan eukaryotes such as *Cryptosporidium* and *Giardia* (Ashbolt 2015). Many of these types of microorganisms commonly give rise to gastrointestinal disease, diarrhoea and other diseases, and may reach water sources through contamination of domestic wastewater (Ashbolt 2015).

Regarding the disposal of wastewater in RS, it is estimated that 74,6 % of the households with water closets are connected to sewers or to a septic tank (Atlas Socioeconômico RS 2019). This means that 25,4 % of the population even lack such a disposal solution, instead relying on precarious solutions such as simple excavations in the ground in which wastewater is disposed (sometimes referred to as "rudimentary tanks"). For the households that have wastewater disposal solutions in rural and remote areas, septic tanks are the predominant solution (Atlas Socioeconômico RS 2019). While septic tanks often are considered to be adequate simple solutions for rural areas, these systems are also known to cause risk for environmental degradation and contamination of drinking water sources (Withers et al. 2014). Microbiological contamination from domestic wastewater which is disposed of directly into the soil or surface water recipients, or through septic tanks, therefore constitutes a significant risk for water quality in RS. Also, inadequate handling of animal waste may constitute microbiological risk in rural areas which handle livestock.

4.3.2 Pesticides

Brazil is the largest consumer of pesticides in the world, and several of the chemicals used in agriculture in Brazil are potentially carcinogenic, mutagenic and teratogenic (Rocha & Grisolia 2018). Brazil has adopted water potability limits for 27 pesticide parameters according to *Portaria MS nº 2914/2011* (Ministério da Saúde 2011), and RS has added 46 additional parameters on state-level through the *Portaria SES RS 320/2014* (CEVS 2019b; Estado do Rio Grande do Sul 2014). However, the difference in the potability limits are vast when comparing Brazil and the European Union (EU). Glyphosate, a common pesticide used in soy cultivation may be used as an example - the potability limit in Brazil is 500 µg/l according to *Portaria MS nº 2914/2011*, while the limit is 0,1 µg/l within the European Union (EU 2015) - i.e. a factor of 5000. Although this is an extreme example, it can be seen in Figure 12 below that Brazil has potability limits thousands or hundreds of times higher than the EU for several pesticides.

Figure 12. Pesticide limits for water potability in Brazil VS EU (Reporter Brazil 2017).

RS is an agricultural state, and the state uses about twice the annual amount of pesticides per inhabitant than the national average (Pessoa 2017). In RS, several studies have confirmed the presence of pesticides in water sources, including substances such as clomazone, propanil and quinclorac which are used in rice cultivation (Marchesan et al. 2007). Presence of imidacloprid and atrazine which for example are used in tobacco cultivation has also been confirmed (Bortoluzzi et al. 2006).

Even though surface water is more vulnerable to contamination, many of the pesticides used in Brazil and RS are prone to leach through soil and also contaminate groundwater - and it has been estimated that around 2,1 million people in RS receive drinking water from groundwater sources which completely lack pesticide control analyses (Zini 2016).

In Brazil, water treatment plants that use surface water as their source are obliged to perform semi-annual controls of pesticide concentrations in the drinking water (Zini 2016; Barbosa et al. 2015). However, studies have found that these pesticide analyses do not occur as often as they should, as only 9-17 % of the municipalities in Brazil have sufficient data for pesticide monitoring in SISAGUA (Barbosa et al. 2015). Furthermore, less than 10 % of the active pesticide ingredients which are legally used in the country are included in the monitoring. This means that pesticide monitoring generally is insufficient for large scale water supply solutions as well.

4.3.3 Geogenic contamination

Contamination originating from naturally occurring dissolved minerals also exist to some extent in RS. The main issue concerns elevated concentrations of fluorine in some regions of the state, which greatly exceed the potability limit of 1,5 mg/L (Luiz et al. 2016). This problem exists in different geological units in some parts of RS (Luiz et al. 2016). These problems also exist in parts of the important Guarani-Serra Geral integrated aquifer system, due to geological discontinuities with geochemical characteristics prone to cause fluoride dissolution (Filho et al. 2015).

There have also been reports of high iron and manganese levels in the groundwater in some parts of RS (Reginato et al. 2005). High levels of iron and manganese in drinking water are not dangerous to health, but can cause unpleasant odour, colour and smell (Oram 2014). It can also cause clogging of pipes due to deposits, and be unsuitable for household uses like laundry and dishwashing due to staining.

Although not a widespread problem for drinking water in the state, there are also geological structures with high arsenic content in some limited areas, a metalloid which can be very poisonous if dissolved in groundwater (Murcott 2012).

4.4 Water quantity issues

Brazil is the country with the highest volume of renewable freshwater resources in the world, and concentrates about 12 % of the world's freshwater resources (Pessoa 2017; World Atlas 2018). According to large-scale studies of global water scarcity, most parts of Brazil do not suffer from water scarcity, and the quantity problems are mainly concentrated in the northeast region of the country, as seen in Figure 13 below (Mekonnen & Hoekstra 2016).

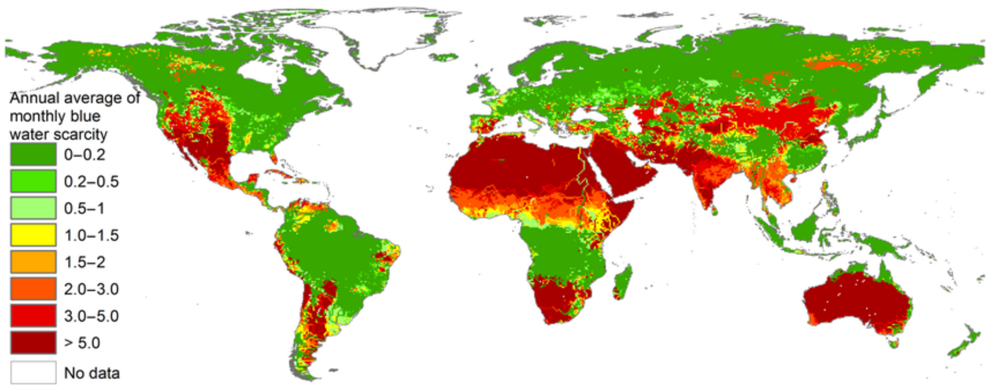

Figure 13. Water scarcity represented through annual average of monthly blue water scarcity (Mekonnen & Hoekstra 2016).

RS has a large water availability due to great density of water bodies, rivers and important subterranean reservoirs (Pessoa 2017), and an average precipitation of 1300 mm per year (Encyclopædia Britannica 2012). However, looking closely at southern Brazil and RS in Figure 13, it can be observed that blue water scarcity reaches 0,5-1,0 in many areas, and even reaches 1,0-1,5 at some locations. When the blue water scarcity index exceeds 1,0, "blue water" (fresh surface water and groundwater) availability is less than demand on average (Mekonnen & Hoekstra 2016).

Regional water scarcity in RS is largely caused by great irrigation demands, mainly for irrigation of rice which is a very water-intensive crop (Flach et al. 2016). Irrigation withdrawals have been estimated to constitute as much as 78 % of the total water abstractions in RS (Pessoa 2017). As seen in Figure 14 below, some studies have found the water stress in parts of RS to be severe due to the huge irrigation withdrawals (Flach et al. 2016).

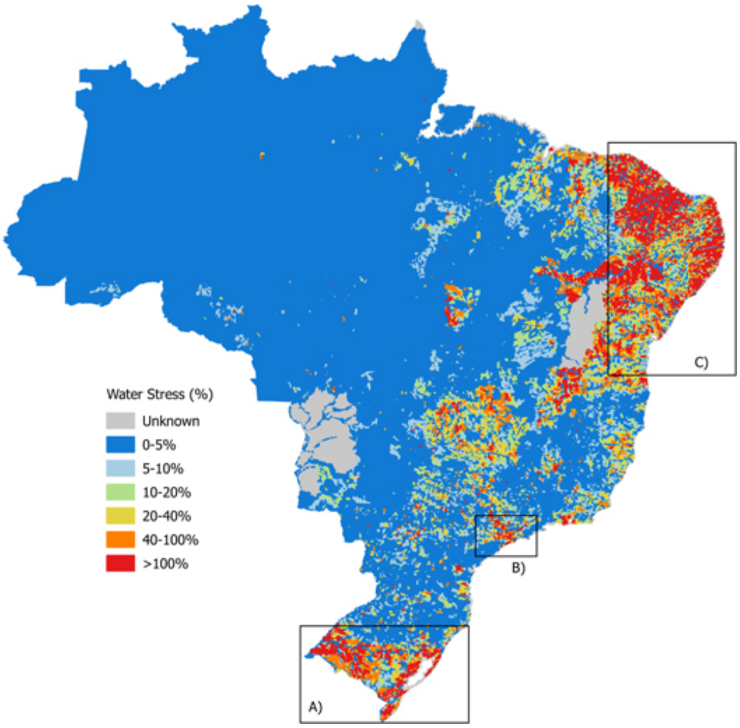

Figure 14. Water stress in Brazil, where region A) highlights the intensively irrigated rice cultivation areas in RS (Flach et al. 2016).

5. Case studies

In this section, the results from the case studies are presented. Eight small-scale water supply systems (seven SAC systems and one SAA system) were visited in four municipalities, seen in Figure 15 below. This chapter mainly aims to answer the second research question - "*What issues can be observed directly through a multiple case study of rural water supply services in Rio Grande do Sul?*". This in turn assists to answer the first and third research questions, by providing examples and in-depth understanding of the challenges encountered for rural water supply services in RS.

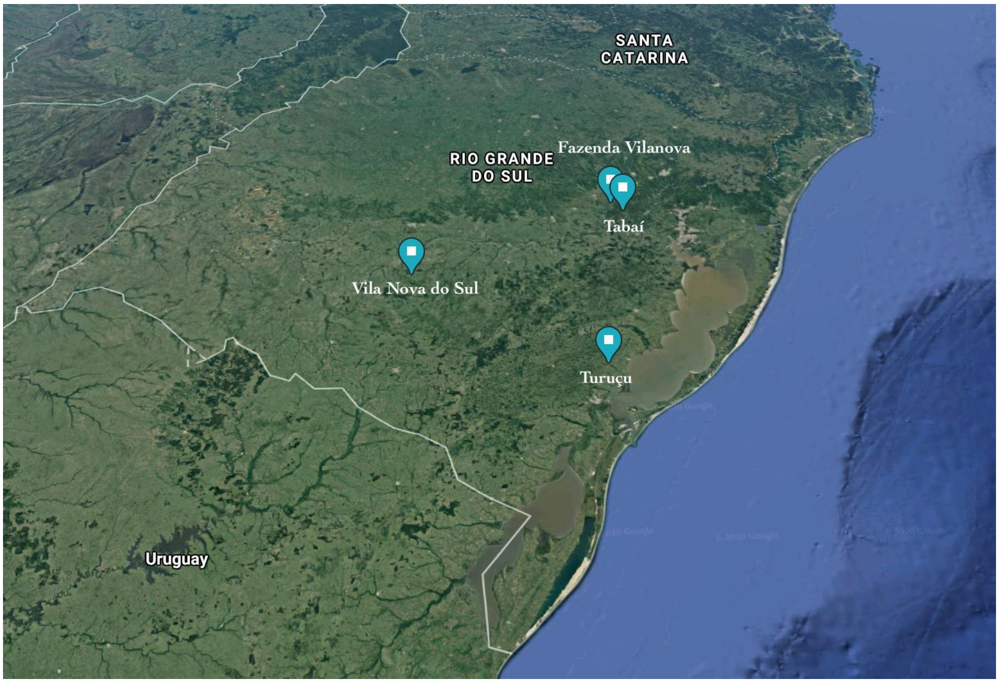

Figure 15. The municipalities which were visited during the field investigations in RS, adapted from google maps imagery (Google maps 2020).

5.1 Municipality I - Tabaí

Tabaí is a small municipality located in the central-east region of Rio Grande do Sul with 4719 inhabitants (IBGE 2019b). It is located within the *Taquari-Antas* hydrographic basin, which in turn lies within the hydrographic region of *Guaíba* (SEMA 2020). The water supply in the municipality is decentralized and not served by any SAA systems, instead drinking water is provided to the population through SAC systems managed by water supply associations or through individual SAI solutions. In the municipality there are 7 SAC systems (Interview Tabaí I 2019). Only one SAC system uses disinfection, Sociedade Abastecedora de Água Trevo Tabaí. The other systems do not use disinfection or any other treatment steps. This is alarming, considering that 45 % of the wastewater management solutions within the municipality consists of rudimentary waste disposal, which basically is an excavation in the ground in which wastewater is disposed (MJ Engenharia 2017).

Funding of about 197 500 R$ was obtained from FUNASA for the drafting of a municipal basic sanitation plan, which was performed by the technical consulting firm MJ Engenharia (Interview Tabaí I 2019). Apart from this, no further external funding from state or federal level was reported to have occurred for improvement of the water supply systems in the municipality.

During the field visit to Tabaí, two SAC water supply systems were visited and examined; Sociedade Abastecedora de Água Trevo Tabaí, the largest system of the municipality providing water for the central settlement area, and Sociedade Abastecedora de Água de Cabriúva, a small system in a village several kilometers from the central settlement area.

5.1.1 Sociedade Abastecedora de Água Trevo Tabaí

The SAC system *Sociedade Abastecedora de Água Trevo Tabaí* (SAATRE) is the largest within the municipality, serving 1571 people (SISAGUA 2019) through distribution systems in the central town of Tabaí. Groundwater is abstracted by pumping from four deep tube wells at three locations in the town area. The system consists of two wells in

Sistema Berçário, one well in *Morro do Pedro Rosa* and one well in *Élio Cardoso*. All of the wells are about 100 m deep. Two wells have functioning sanitary seals and are protected, one has a deteriorated sanitary seal and one lacks a sanitary seal altogether. The groundwater is taken from geological formations connected to the Guarani-Serra Geral integrated aquifer system (Interview Tabaí I 2019). Disinfection is performed through chlorination, and no additional treatment is installed (MJ Engenharia 2017).

Figure 16, Figure 17 and Figure 18. Elevated water reservoir, groundwater well and chlorine disinfection system belonging to Sociedade Abastecedora de Água de Trevo Tabaí.

The raw water in the wells have showed presence of coliform bacteria on several occasions (MJ Engenharia 2017). Samples have also showed concentrations of substances exceeding drinking water standards; too high fluorine levels at one of the wells in *Sistema Berçário*, and too high iron and manganese levels at the well *Élio Cardoso* (MJ Engenharia 2017). The water quality records from 2016-2019 which are available in SISAGUA reveals that 11/76 samples have shown presence of coliform bacteria (although no samples have shown presence of *Escherichia coli*), and 7/36 samples have shown residual chlorine lower than the minimum desired value of 0,2 mg/L. Turbidity levels are below the drinking water limits in all analysed samples, but fluorine levels have been high in some sample locations, reaching up to 4,9 mg/L (SISAGUA 2019).

Irregular chlorine levels have been recorded at several of the sampling locations in the system, sometimes falling under the legislated levels, explaining why disinfection at times may be insufficient to eliminate the microorganisms in the water (MJ Engenharia 2017). There are also reports of water users requesting technicians to lower the chlorine dose due to dissatisfaction with the water taste, resulting in modified operation and residual chlorine concentration below the legislated levels (Interview Tabaí I 2019).

According to the PMSB (municipal basic sanitation plan), failures lasting 5-10 days have occurred in parts of the system. This information is based on historical newspaper articles, since no logs of failures or maintenance appear to be kept by the association which runs the system, or by the municipality. Some piping and reservoir tanks were reported to be of unsatisfactory quality and damaged by oxidation, as of 2014. Water losses in the system are not well studied, but non-revenue water has been estimated to reach 42,6 % in the part of the system called Sistema Berçário (the only available estimation of non-revenue water within the municipality). Some sections of the distribution pipes are situated in stormwater drainage trenches which also receive overflow water from septic tank systems, posing a contamination risk (Interview Tabaí I 2019; MJ Engenharia 2017).

The association, SAATRE, is composed of all the users of the supply system. Association meetings are held with regular intervals, where those dependent on the system can make their voices heard regarding eventual issues and concerns (Interview Tabaí I 2019).

Water tariffs depend on the amount of water used, and the first 10 m^3 used in each residence has a lower price per m^3. According to the municipal representative, the current tariff is 45 R$ for the first 10 m^3 (Interview Tabaí I 2019).

The water tariff is collected by SAATRE, and is meant to cover the costs of operation. When more extensive maintenance is needed, the municipality have occasionally stepped in with economic support. This means that the association have problems with achieving economic self-sufficiency. External funding from state and/or federal level has not been used for direct improvement of the water supply system.

Some water quantity problems have occurred in the wells of the system during prolonged droughts, but do not occur on a yearly basis (Interview Tabaí I 2019).

In Figure 19 below, the estimated adequacy of the water supply service is shown in relation to the nine chosen indicators:

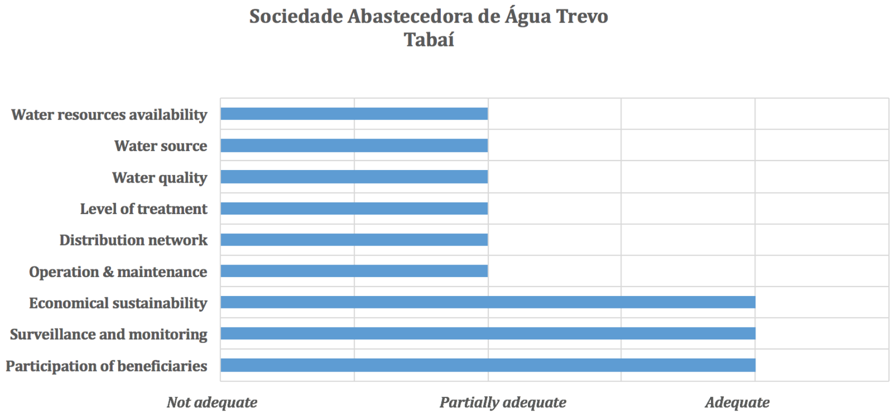

Figure 19. Bar chart showing the adequacy of the water supply system according to nine indicators, based on an interview with a municipality representative, document studies and SISAGUA data.

In conclusion the organization, economy and surveillance appear to work well, and for most of the time water of adequate quality is provided. However, faulty treatment and intermittent water quality issues still pose problems for the system. Intermittent problems with the distribution network, operation & maintenance and lack of non-revenue water monitoring are also issues for the system.

5.1.2 Sociedade Abastecedora de Água de Cabriúva

The SAC system Sociedade Abastecedora de Água de Cabriúva is located in a small village several kilometres from the municipal town centre, and serves 76 people. The water is pumped from a deep well, drilled approximately 100 meters deep. The well lacks a sanitary seal, but has a one-way valve preventing backflow as highlighted by the users upon inspection. The water is not treated and there is no disinfection system. The system has a reserve tank that holds 10 m^3, and the average daily consumption of the system is approximately 6,7 m^3.

Water samples of the system occasionally show microbiological contamination through presence of coliform bacteria (MJ Engenharia 2017). According to some members of the community the water also has problems with high iron and manganese content, and cannot be used for purposes such as car washing. This was raised as the main issue by one community member (Interview Tabaí II 2019). No water quality records exist in SISAGUA regarding Sociedade Abastecedora de Água de Cabriúva.

The community has formed an association, *Associação Abastecedora de Água Gonçalves da Silva*, and the president of the association collects water fees from the users of the system. The price for the first 10 m^3 of tap water for each household is 20 R$, and the water is more expensive per m^3 if more than 10 m^3 is consumed per household and month.

Maintenance of the system is mainly performed by the community itself. If a problem occurs which demands professional help, the municipality have provided funding in some cases. The municipality also contributed with economic assistance for the drilling of a well and construction of the distribution system for the current SAC. Earlier the village used several individual SAI systems, consisting of shallow wells which were vulnerable to droughts and contamination. In order to combat these issues, the community collectively asked for funds from the municipality to drill a deeper well, which increased the water security in the community (Interview Tabaí I 2019).

Although not considered a major issue, droughts during the summer months have sometimes caused lack of water in the system (Interview Tabaí II 2019).

Figure 20 and Figure 21. Water reservoir and groundwater well of the Cabriúva system.

In Figure 22 below, the estimated adequacy of the water supply service is shown in relation to the nine chosen indicators:

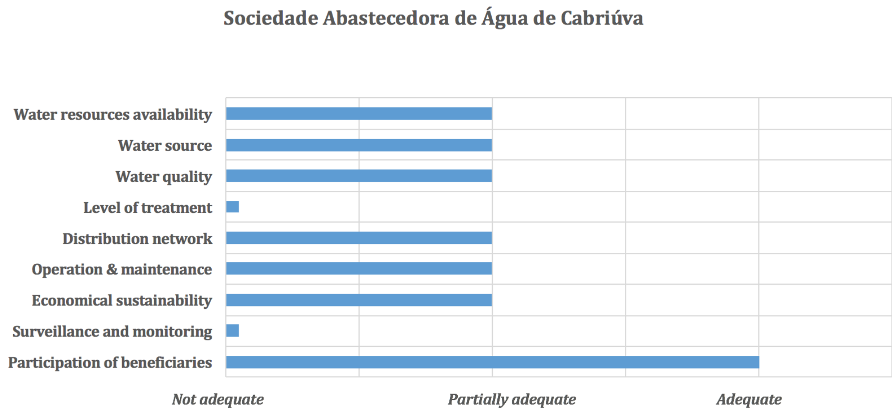

Figure 22. Bar chart showing the adequacy of the water supply system according to nine indicators, based on interviews with municipality representatives and local water users and document studies.

In conclusion, the installation of the SAC system was reported to be community-driven, there is an association and all water users appear to pay for the service. However, the water service is not economically self-sufficient, as the municipality has stepped in with economic support for maintenance when the community members have not been able to solve issues on their own. The lack of treatment poses a problem, and water quality issues are known to occur. Surveillance is lacking and water quality is not sufficiently monitored. Intermittent problems with the distribution network are reported to have occurred although not very frequently, and there is no monitoring of non-revenue water.

5.1.3 Future plans for water supply services in the municipality

In Tabaí, water supply for most of the central settlement is organized by the association of Sociedade Abastecedora de Água Trevo Tabaí (SAATRE). The rest of the municipality is served by smaller SAC systems organized in small associations, as well as individual SAI systems. According to the municipal basic sanitation plan, extension of the water distribution network belonging to SAATRE is advised, so that people who currently rely on SAC systems without treatment or SAI systems from shallow groundwater wells can get access to a safely managed water source (Interview Tabaí I 2019).

However, SAATRE lacks economic incentives to expand their network, and such an extension may require strong initiatives and investments from the potential beneficiaries and/or the municipality. Plans for extension of the SAATRE network or improved treatment in the smaller SAC systems are currently not prioritized by the municipality, mainly due to economic limitations and lack of political will (Interview Tabaí I 2019).

Cabriúva and a few other small SAC systems are too far away from the central town to be connected to the central Sociedade Abastecedora de Água Trevo Tabaí, and are instead advised to install disinfection systems and improve water source protection according to the municipality (Interview Tabaí I 2019).

5.2 Municipality II - Fazenda Vilanova

Fazenda Vilanova is a small municipality with 4120 inhabitants, located in the central-east region of Rio Grande do Sul (IBGE 2019b). It is located within the *Taquari-Antas* hydrographic basin, which in turn lies within the hydrographic region of *Guaíba* (SEMA 2020). In Fazenda Vilanova the population receive drinking water from 11 SAC systems, which are all managed by the local water supply association ASSODEC. Most of the systems have chlorine disinfection, but two of the smallest systems lack treatment (SISAGUA 2019), and all of the SAC's are reported to lack proper sanitary seals of the wells (Interview Fazenda Vilanova 2019).

ASSODEC has complete responsibility of the drinking water production in the municipality according to contract. This includes maintenance of the systems, collecting fees from the water users to cover costs and raising money for potential investments for improvements. The association does not have any professional technicians, maintenance and repairs are generally performed by contracted sanitary engineering professionals. The association holds regular meetings where water users can make their voices heard. The municipality is only involved in surveillance through the VIGIAGUA programme, performing water quality monitoring for the systems by sampling the wells each month. Fazenda Vilanova does not have a PMSB and have not accessed any external funds from state or federal level for water and sanitation improvements (Interview Fazenda Vilanova 2019).

Water scarcity has not occurred for any SAC during recent years as far as the municipality representative was aware. The municipality had no information about the amount of water losses or non-revenue water in any of the water supply systems, and explained that there is no water loss monitoring. The water tariff is equal in the whole municipality. Currently the price for tap water is 35 R$ for the first 15 m^3 per month, and 3 R$ for each further consumed m^3 of water. Fazenda Vilanova does not have a PMSB and have not accessed any external funds from state or federal level for water and sanitation improvements (Interview Fazenda Vilanova 2019).

Contact information to the ASSODEC association was given by the municipality, so that further technical information could be received through them. Unfortunately, it was not possible to interview the association during the field visit to Fazenda Vilanova, and the association never answered the questions which were sent to them by email.

5.2.1 Assodec Tristão

The SAC system Assodec Tristão is located in the central town area of the municipality and provides 757 people with water. The groundwater well is protected above ground, but has no sanitary seal. Although chlorine disinfection treatment was installed, upon inspection the hose which distributes the chlorine was cut off. The cause of this damage was unknown, but a possible explanation is that the hose was cut off with intent due to community resistance towards chlorination.

Out of the water quality records from 2016-2019 which are available in SISAGUA, 7/20 samples have shown presence of coliform bacteria, and 9/18 samples have shown total lack of residual chlorine. This means that the installed chlorination system is not used in an adequate manner. Turbidity and fluorine levels are below the drinking water limits in all analysed samples (SISAGUA 2019).

Just as the other SAC systems in Fazenda Vilanova this system is run by the association ASSODEC. The water tariff is 35 R$ for the first 15 m^3 per household each month, and 3 R$ for each m^3 above this threshold value.

Figure 23, Figure 24 and Figure 25. Chlorination hose with damage, old chlorination tank and groundwater well of the Assodec Tristão system.

In Figure 26 below, the estimated adequacy of the water supply service is shown in relation to the nine chosen indicators:

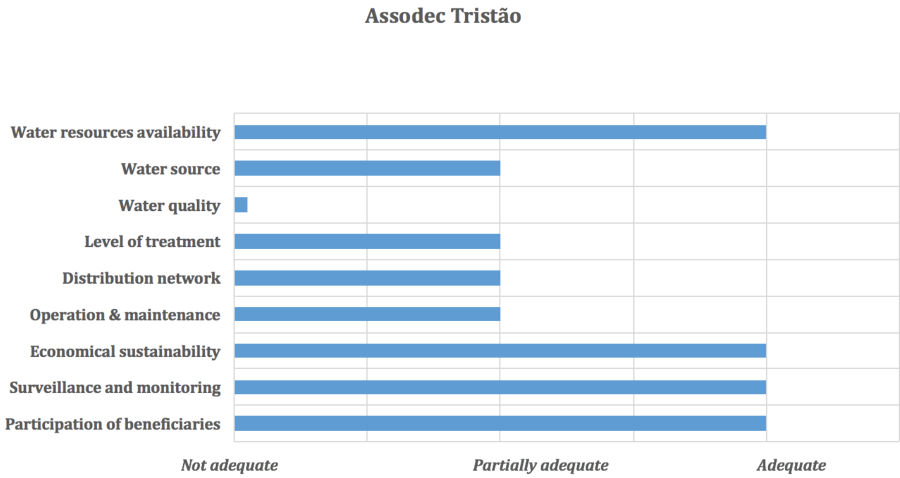

Figure 26. Bar chart showing the adequacy of the water supply system according to nine indicators, based on an interview with a municipality representative and SISAGUA data.

In conclusion, the water service appears to operate adequately in terms of organizational structure, economy and water quality surveillance and control. The system has not been affected by water scarcity as far as the municipality is aware. However, the installed chlorination system does not seem to work as intended and microbiological contamination often occurs. The distribution system does not have recurring issues, but non-revenue water is not monitored.

5.2.2 Samambaia

The SAC system of Samambaia is located slightly outside of the town area and provides water to 105 people (SISAGUA 2019). The groundwater well is placed on a platform of impermeable concrete, and is protected above ground, but has no sanitary seal. No chlorine disinfection treatment is installed in this system, and the water is pumped directly to the connected households without being stored in a reservoir. Residents typically have smaller reservoirs (*caixas d`Água*) in their homes. There are no reported issues with lack of pressure in the system according to the municipality (Interview Fazenda Vilanova 2019).

Out of the water quality records from 2016-2019 which are available in SISAGUA, 3/8 samples have shown presence of coliform bacteria. This indicates that a disinfection system would be needed to ensure safe water quality in the system. Turbidity and fluorine levels are below the drinking water limits in all analysed samples (SISAGUA 2019).

Just as the other SAC systems in Fazenda Vilanova this system is run by the association ASSODEC. The water tariff is 35 R$ for the first 15 m^3 per household each month, and 3 R$ for each m^3 above this threshold value (Interview Fazenda Vilanova 2019).

Figure 27. Groundwater well of Samambaia

In Figure 28 below, the estimated adequacy of the water supply service is shown in relation to the nine chosen indicators:

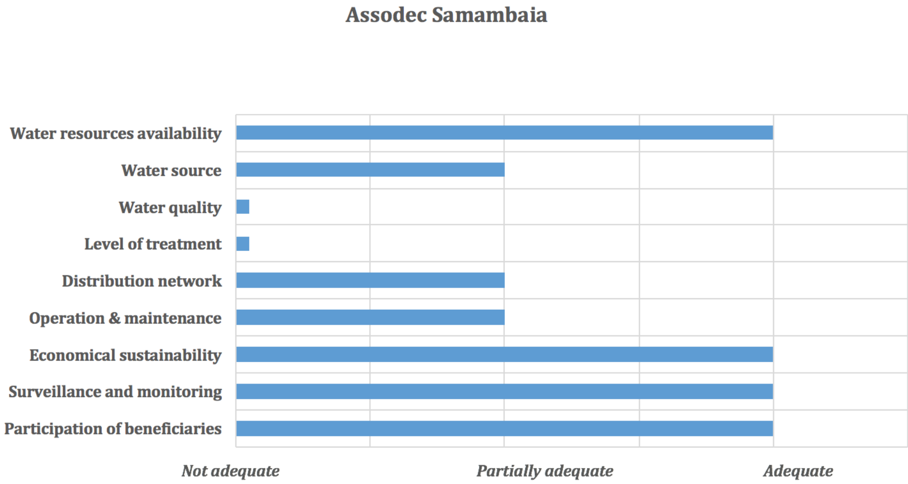

Figure 28. Bar chart showing the adequacy of the water supply system according to nine indicators, based on an interview with a municipality representative, document studies and SISAGUA data.

In conclusion, the water service appears to work adequately in terms of organizational structure, economy and water quality surveillance and control. The system has not been affected by water scarcity as far as the municipality is aware. However, there is no disinfection system, and microbiological contamination often occurs. The distribution system is not reported to have recurring issues, but non-revenue water is not monitored.

5.2.3 Future plans for water supply services in the municipality

The systems which are run by ASSODEC and possess disinfection do not always work as intended, as chlorine residual levels often are low or non-existent even in the Assodec Tristão system, and coliform bacteria are present in many samples. This needs to be addressed to ensure proper inactivation of microorganisms. Disinfection systems are also needed for Samambaia as well as the SAC system Granja Farias (which also lacks disinfection according to SISAGUA). Due to community resistance against chlorination, this is not actively encouraged by the municipality. The association ASSODEC does not have plans to install disinfection systems in these SAC systems either, unless it is demanded from the community water users or from the municipality (Interview Fazenda Vilanova 2019).

As all of the population are reported to be connected to the existing SAC systems and no one is served by SAI systems, there are no discussions of expanding the existing SAC distribution networks. The ASSODEC association appears to be economically self-sufficient and economically sustainable, since the municipality has not needed to step in with investments or maintenance costs according to the municipal representative (Interview Fazenda Vilanova 2019).

5.3 Municipality III - Vila Nova do Sul

Vila Nova do Sul is a small municipality with 4280 inhabitants in the central-west region of Rio Grande do Sul (IBGE 2019d). It is located within the hydrographic basin of *Vacacaí-Vacacaí Mirim*, which in turn lies within the hydrographic region of *Guaíba* (SEMA 2020). CORSAN runs a SAA system in the municipality, which supplies 2478 people. This system mixes treated surface water from the local Cambai river with groundwater from deep wells. The treatment plant is operated and maintained by professionals, and uses conventional treatment composed of several unit processes - coagulation, flocculation, filtration, sedimentation and disinfection. CORSAN monitors water quality and non-revenue water, and the water tariff for this system is 5,50 R$ per m^3 (Interview Vila Nova do Sul I 2019).

Apart from the CORSAN system, there are 9 SAC systems serving smaller communities (SISAGUA 2019). These are generally run by informal associations without clear responsibility delegations. Several small SAI systems also exist outside of the town area. The water quality is overall poor in the SAC and SAI systems, and many of the wells have very high fluorine levels, reaching far above drinking water standards (Interview Vila Nova do Sul II 2019). No treatment is available for these water supply solutions, except disinfection which is installed in some SAC systems (Interview Vila Nova do Sul I 2019). Non-revenue water is not monitored in these systems, and there is lack of proper well protection such as sanitary seals.

The issues with fluorine in the water has caused a large part of the population to exhibit signs of fluorosis. According to the municipal representative, 10-15 % of the population in Vila Nova do Sul suffer from fluorosis to some degree. There is also alarming testimony stating that about 8 out of 10 children were affected by fluorosis in the area, according to a municipal study from 2012 (Interview Vila Nova do Sul I 2019; Interview Vila Nova do Sul II 2019).

The wastewater in the municipality is not treated, domestic wastewater is instead directed to septic tanks or simple rudimentary tanks. According to municipal and water surveillance representatives, several of the wastewater disposal systems are old and do not work properly (Interview Vila Nova do Sul II 2019), posing a risk for microbiological contamination of water sources.

Vila Nova do Sul does not have a PMSB and has not accessed any external funds from state or federal level for water and sanitation improvements (Interview Vila Nova do Sul I 2019).

During the field visit in Vila Nova do Sul, the two SAC systems Laranjeiras and Cambai were visited and inspected, and interviews were held with users of the water supply systems.

5.3.1 Laranjeiras

The SAC system of Laranjeiras supplies water to approximately 225 people. The system uses a deep groundwater well, and the water is chlorinated through an automated system. During inspection, it was pointed out that the recently installed chlorination system has had technical problems with correct dosage since installation. The system has ongoing issues with water quality, and regularly exhibit levels of fluorine exceeding the limit set for drinking water standards (Interview Vila Nova do Sul II 2019).

According to SISAGUA, water quality analysis during 2016-2019 reveals that 14/20 samples show presence of coliform bacteria, 7/20 show presence of *Escherichia coli* and 6/20 samples show turbidity above drinking water limits, reaching up to 20,0 TU. Regarding fluorine, 20/20 samples show levels between 3,2-5,4 mg/L (clearly exceeding the drinking water limit of 1,5 mg/L and the recommended limit of 0,9 mg/L). No records of residual chlorine concentration are available in SISAGUA for this system (SISAGUA, 2019).


Figure 29 and Figure 30. Groundwater well and pumping house, and water reservoir in Laranjeiras.

The Laranjeiras system has no official association responsible for maintenance of the system and revenue collection. Instead, locals take it upon themselves to keep the well, pipes and pumps working. For this they charge no fee, as most of the households in the area have economic limitations. Furthermore, only about 40 households pay the monthly fee of 22 R$ meant to cover operational costs and energy consumption. According to SISAGUA there are currently 80 households connected to this system (SISAGUA 2019), but other sources claim that more than 100 households are connected (Interview Vila Nova do Sul I 2019).

While interviewing a local beneficiary about the quality of the water, he expressed that the water at times "*smells like wastewater*" and that he would prefer to be connected to the SAA system that CORSAN runs in the municipality (Interview Vila Nova do Sul III 2019).


Figure 31 and Figure 32. New and old chlorination system by the water reservoir in Laranjeiras.

External funding from federal or state level has not occurred for improvement of the water supply system. No water quantity problems were reported to have occurred in the system (Interview Vila Nova do Sul I 2019).

In Figure 33 below, the estimated adequacy of the water supply service is shown in relation to the nine chosen indicators:

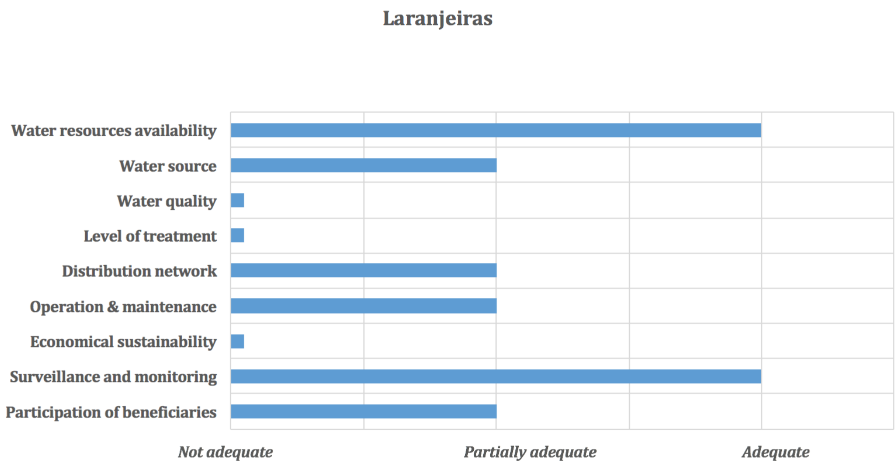

Figure 33. Bar chart showing the adequacy of the water supply system according to nine indicators, based on interviews with municipality representatives and local water users, and SISAGUA data.

In conclusion, the system appears to be adequately monitored and is not experiencing periods of water scarcity. However, contamination due to fluorine and microorganisms and the ongoing issues with chlorination pose major threats to the community. Participation is not completely satisfactory although some community members actively work with the system. The collection of fees does not cover the cost of the services provided, which makes the system economically unsustainable. Operation and maintenance works much in the same sense. Some beneficiaries do what they can to keep the system running, but the current arrangement does not guarantee water safety. The well is not properly protected, which makes it vulnerable to contamination, and the distribution network was reported to be in need of updates at the time of the interview.

5.3.2 Cambai

The SAC system of Cambai is located several kilometres outside of the town centre of the municipality, and supplies approximately 73 people with water (SISAGUA 2019). Two wells exist in the village, and these are used as the main water source. There is also a spring source of water which is used at times, especially when the water levels in the wells are low. The spring water is also channelled to one of the wells to recharge the groundwater.

Both groundwater wells have basic protection such as an elevated casing, lid and a fence keeping animals from the vicinity of the well, but no sanitary seals or proper subsurface protection. The spring water source is fenced, but is not covered in any way above ground, and is not properly protected to avoid contamination from e.g. animal faeces.



Figure 34, Figure 35 and Figure 36. Water reservoir, groundwater well and spring source in Cambai.

Water quality analysis has shown high levels of fluorine and turbidity, and presence of both coliform bacteria and *Escherichia Coli*. No disinfection or other treatment is used. An old chlorination system was seen by the water reservoir tower, but it was explained that this system was abandoned and no longer in use at the time of the visit. Chlorination is reported to be generally disliked in the village (Interview Vila Nova do Sul I 2019).

According to SISAGUA, water quality analysis during 2016-2019 reveals that 39/39 samples show presence of coliform bacteria, 26/39 show presence of *Escherichia coli*, 18/39 samples show fluorine levels between 2,2-5,2 mg/L (clearly exceeding drinking water limits) and 9/38 samples show turbidity above drinking water limits, reaching up to 13,9 TU (SISAGUA 2019).

In Cambai, there is no formal association responsible for the water supply. Community representatives collect money for maintenance at a basic rate of 10 R$ per household and month. Money is also collected separately for the energy consumption of the pumping, at a rate of about 32 R$ per household and month (Interview Vila Nova do Sul IV 2019).

One local water supply system user was interviewed regarding the current water quality and water supply system solution. Regarding the water quality, the interviewee said that he perceives the current water quality as decent in terms of taste, colour and smell. Upon asking whether the local community would prefer to be connected to the SAA system in town ran by CORSAN instead of using the local SAC system, the resident expressed satisfaction with the current supply solution, but also said that water supply from the CORSAN system would be good for the village to decrease the risk of high fluorine concentrations, under the presumption that the monthly cost of water would not increase. The resident also expressed doubt about the feasibility of the CORSAN system ever being able to expand to reach the village, due to the long distance from the town centre (Interview Vila Nova do Sul IV 2019).

External funding from federal and/or state level has not occurred for direct improvement of the water supply system in Cambai (Interview Vila Nova do Sul I 2019). Water quantity problems have occurred in the system, as the surface water source was reported to be used when water availability were low in the wells (Interview Vila Nova do Sul IV 2019). In Figure 37 below, the estimated adequacy of the water supply service is shown in relation to the nine chosen indicators:

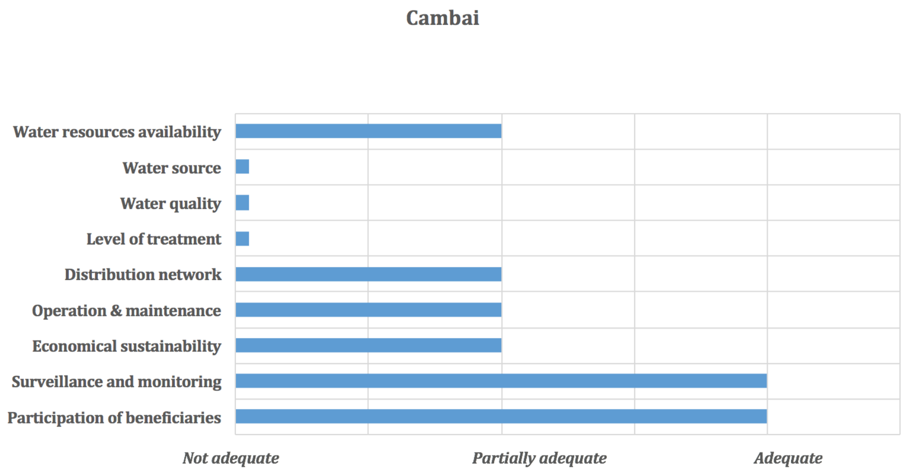

Figure 37. Bar chart showing the adequacy of the water supply system according to nine indicators, based on interviews with municipality representatives and local water users, and SISAGUA data.

In conclusion, Cambai has no formal association but the community manages to collect water fees from all households and perform basic maintenance on their own. The system is however not completely self-sufficient in terms of economy, even though there is a maintenance fee. Water scarcity has occurred, and water quality is often highly inadequate due to continual microbiological contamination, and high levels of turbidity and fluorine.

5.3.3 Future plans for water supply services in the municipality

According the municipality there are plans to expand the system of Laranjeiras by combining it with two other SAC systems, in hope that mixing could decrease fluorine levels in the produced water, and increase water security. Cambai is too remote to be connected to the SAA system in the central settlement, and state-level VIGIAGUA are currently in the process of advising residents of Cambai on how to improve protection of the spring in the village (Interview Vila Nova do Sul I 2019; Interview Vila Nova do Sul II 2019).

The CORSAN contract will be renewed within closest years, and during procurements between the municipality and CORSAN, expansion of the SAA network will be discussed. It is also possible that the upcoming procurements will result in improved wastewater collection and treatment, perhaps even through construction of a wastewater treatment plant. Since CORSAN might not profit on such an investment, it is likely that this investment would require further financing derived from cross-subsidies. This means that CORSAN would reinvests profits (usually gained in larger municipalities) into smaller systems in municipalities that lacks sufficient economy of scale (Interview Vila Nova do Sul I 2019; Interview Vila Nova do Sul II 2019).

Currently, water meters are not widely installed amongst the SAC system users meaning that the water tariff is not consumption-based. Instead a basic fee is collected by community members, meant to cover energy consumption from pumping and basic operation and maintenance. In some cases, users of SAC systems do not pay any fee for their connection to the system and water use. When disruptions occur, the municipality has stepped in with economic support for SAC systems at several occasions, paying for maintenance done by municipal technicians or contractors. This also includes basic chlorination equipment for SAC systems. In general, many SAC system users do not want to pay for water in the first place, and are thus not inclined to pay more to be connected to an improved SAA system. The municipality is currently discussing how to address these issues and increase community awareness (Interview Vila Nova do Sul I 2019; Interview Vila Nova do Sul II 2019).

5.4 Municipality IV - Turuçu

Turuçu is a small municipality located in the south-east region of Rio Grande do Sul, with a population of 3438 people (IBGE 2019e). It is located within the *Camaquã* hydrographic basin, which in turn lies within the hydrographic region of *Litorânea* (SEMA 2020). Drinking water is supplied through the municipal SAA system, and through small SAC and SAI systems (SASB 2019). According to SISAGUA there are no SAC systems in the municipality, but during the interview with the municipality it was clarified that two SAC systems actually exist; São Domingos which provides water to 10 households and Centenario which provides water to about 100 households. Several small SAI systems exist in the more remote areas.

The municipality of Turuçu has been receiving support to create a municipal basic sanitation plan during the last years from SASB, *Sistema de Apoio de Saneamento Basico*, at IPH of UFRGS, and the plan was at the last stages of completion as of November 2019.

During the field visit in Turuçu two systems were inspected, the SAA system of the municipality and the São Domingos SAC system.

5.4.1 SAA de Turuçu

The SAA system in Turuçu is located in the outskirts of the central settlements of the municipality, and it provides water to 2181 people according to data from SASB in 2019 (SISAGUA 2019; SASB 2019). It is owned and operated by the municipality of Turuçu, and produces approximately 295 000 m^3 of water yearly. The process begins with surface water being pumped up from an excavated ditch which receives water from the nearby watercourse *Arroio Turuçu*. Thereafter, treatment consists of coagulation & flocculation, decanting, rapid sand filtration and finally chlorination. Coagulation is achieved by adding aluminium sulphate and sodium bicarbonate, and after the flocs have settled the water is decanted and filtered upwards through sand layers. Before the water is sent to the reservoir and is ready for distribution, it is chlorinated with sodium hypochlorite and has its pH regulated with hydrated lime. The sludge which is produced is released back to the river. The distribution system of the SAA system was originally installed in 2001 (SASB 2019). Due to leaks, the municipality has planned to repair and update the system, but estimations of non-revenue water in the system was not available at time of inquire (Interview Turuçu 2019).

The freshwater source *Arroio Turuçu* is situated in the Camaquã River Basin, which is managed by the Camaquã River Basin Committee. The committee is responsible for the Camaquã River Basin plan, which aims to support and guide the implementation of the State Water Resources Policy, as well as the management of the water resources within the basin. The quality of the surface waters within the basin varies. Inland, within the upper and middle part of the basin, the quality is generally good but deteriorates further downstream. In the São Lourenço river, just downstream of the Turuçu river, a substantial presence of phosphorus and thermotolerant coliforms has been noted. This might be due to the wastewater which is discharged into the Turuçu river. After treatment in the SAA system however, the water quality has been deemed sufficient for human consumption (Comitê de Gerenciamento da Bacia Hidrográfica do Rio Camaquã 2008; SASB 2019).

Figure 38 and Figure 39. Arroio Turuçu and the pumping construction of the SAA system.

However, SISAGUA water quality data from 2016-2019 reveals that 33/99 samples show presence of coliform bacteria, 8/99 show presence of *Escherichia coli* and 19/78 show residual chlorine below the minimum limit of 0,2 mg/L for post-treatment tap samples (SISAGUA 2019). The potability limit for turbidity is exceeded in 3/99 samples, and there are no records of fluorine levels exceeding drinking water limits.

The fees and tariffs do not cover all of the expenses associated with the SAA treatment plant and the distribution system. This deficit makes it difficult to invest in improvements of the system. Furthermore, there is a lack of qualified personnel for operation of the treatment plant. These issues have prompted the municipality of Turuçu to initiate discussions with CORSAN about employing them for these services (SASB 2019).

Figure 40, Figure 41 and Figure 42. Water reservoir and treatment plant of the SAA system.

In Figure 43 below, the estimated adequacy of the water supply service is shown in relation to the nine chosen indicators:

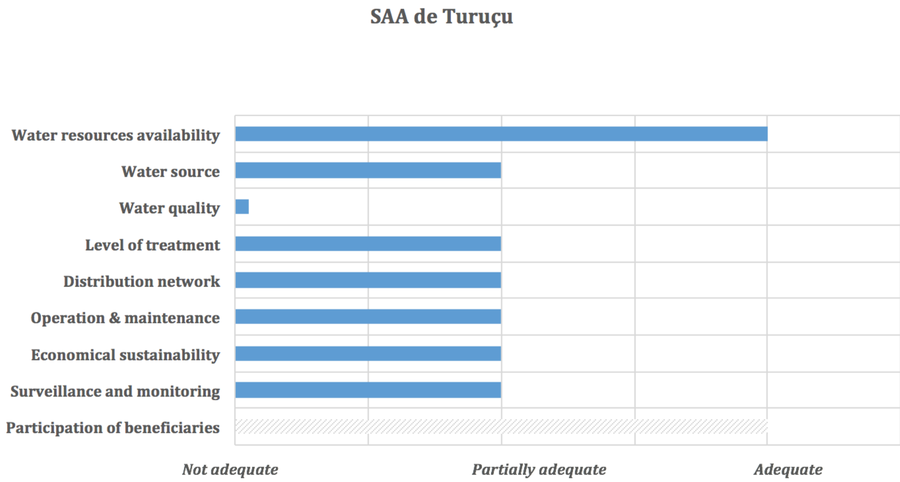

Figure 43. Bar chart showing the adequacy of the water supply system according to nine indicators, based on interviews with municipality representatives, document studies and SISAGUA data.

In conclusion, water quality is often unsatisfactory even though the treatment plant has a complete conventional treatment system. This also relates to the raw water quality, which seems to be affected from upstream pollution. The distribution system does not have frequent issues, but non-revenue water is not monitored. The water service appears to be adequately monitored, but have issues with economic self-sufficiency. As no information was retrieved regarding community involvement, the "participation of beneficiaries"-indicator was omitted from the estimation of adequacy.

5.4.2 São Domingos

The SAC system of São Domingos was installed in 2010 and serves 10 households with water. It is located a few kilometres outside of the central town in Turuçu. Water is taken from a very shallow well with a total depth of 4 m, drilled on the slope of a hill a few meters from agricultural fields, mainly cultivating soy crops (Interview Turuçu 2019). The well lacks sanitary sealing, and the lid covering the well had open cracks upon inspection. From the well, water flows to a small reservoir tank by gravity. Upon inspection, the lid of the reservoir tank revealed substantial cracks. From the reservoir tank the water is pumped to a water tower a few hundred meters away, close to the houses which are served by the system. All pipes are made of PVC. No disinfection or other treatment is used in this system (SASB 2019).

Presence of coliforms and *Escherichia coli* and has often been observed when sampling water from the system. This indication of microbiological contamination, combined with the lack of disinfection, poses a threat to the population served by the system (Interview Turuçu 2019; SASB 2019). According to SISAGUA, water quality analysis during 2016-2019 reveals that 30/33 samples show presence of coliform bacteria, 26/33 show presence of *Escherichia coli*, and 13/33 samples show turbidity above drinking water limits, reaching up to 26 TU (SISAGUA 2019). All of this indicates that the system would need both disinfection and filtration to ensure safe water quality, or a change of water source.

 

Figure 44 and Figure 45. Groundwater well and storage tank of São Domingos

There is no formal association responsible for revenue collection or operation and maintenance of this small SAC system. Instead, the municipality takes care of these tasks. Water meters are not installed in the households which are served by this system. The water tariff is therefore not based on consumption, only the electricity required for pumping. The price per month and household usually amounts to about 30 R$ (Interview Turuçu 2019).

Non-revenue water is not monitored and the rate of abstraction is not measured. According to estimations by SASB, the quantitative capacity of the system is only sufficient for 4 households although the system currently serves 10 households (as of 2019). Water scarcity occurs frequently due to the shallow depth of the well. During the summer months, mainly January and February, the households are served solely with water from water trucks, *carro-pipa*, which the municipality supplies without charge (SASB 2019).


Figure 46 and Figure 47. Water tower and water storage tank of São Domingos

In Figure 48 below, the estimated adequacy of the water supply service is shown in relation to the nine chosen indicators:

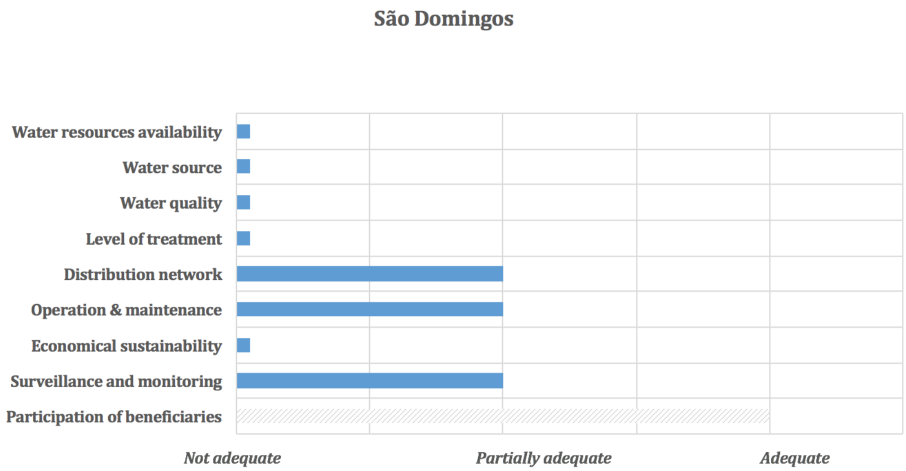

Figure 48. Bar chart showing the adequacy of the water supply system according to nine indicators, based on interviews with municipality representatives, document studies and SISAGUA data.

In conclusion, the system of São Domingos is suffering from water scarcity during summers, insufficient source protection, lack of treatment and inadequate water quality. The system is not economically self-sufficient, and although there are no reports of frequent interruptions (except for drought times in the summer when water is provided by *carro-pipa*), water losses are not monitored. As no information was retrieved regarding community involvement, the "participation of beneficiaries"-indicator was omitted from the estimation of adequacy.

5.4.3 Future plans for water supply services in the municipality

Through the work with the municipal basic sanitation plan performed by SASB, the main issues relating to water supply in Turuçu have been recognized, and improvement opportunities have been identified. The problems mainly concern lack of water quality control and effective treatment in the SAA system, and vulnerable SAC and SAI systems. This vulnerability largely is connected to the inadequate collection and disposal of wastewater within the municipality.

Areas of improvements include laboratory control of water quality, and proper instruments for flow measurement in the SAA system. For the SAC and SAI systems, investments in adequate well protection and drilling of deeper wells with proper protection (such as the case of São Domingos) will be needed to ensure water security. However, the municipality cannot currently afford any larger investments to improve the water supply in the area. When the municipal basic sanitation plan is approved, the municipality will try to access funds from external instances, e.g. through FUNASA, to implement some of the projects which are recommended in the basic sanitation plan. This could potentially help to improve the treatment plant of the SAA system and increase water security for SAC and SAI systems.

5.5 Compilation and comparison of case study results

The municipalities and water supply systems which were visited and investigated displayed both similarities and differences. A compilation of the adequacy indicators which were applied on the systems is shown in Figure 49 below. It is important to note that these rankings are estimations, and not definitive. These rankings only represent the eight systems included in the case studies, not the overall situation for rural water supply systems in RS.

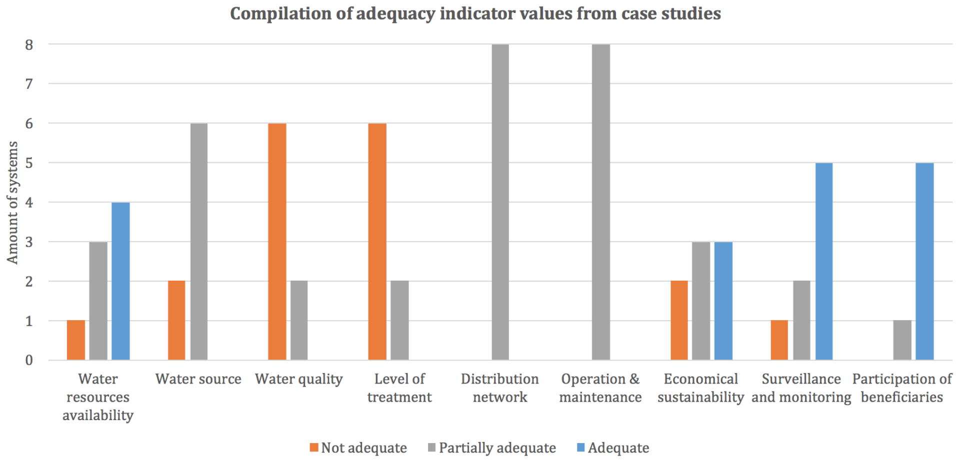

Figure 49. Compilation of adequacy indicator values from case studies. The "participation of beneficiaries"-indicator only amounts to six systems, since information was lacking for two systems.

As is seen in Figure 49 above, the *water resources availability* indicator showed mixed results. For most of the systems water scarcity was not a common issue, occurring very rarely or never. These results are however not representative for rural water supply systems in RS overall. As seen in chapter *4.4. Water quantity problems*, there are areas in RS where water stress is common due to intensive rice irrigation. Apart from the shallow well system of São Domingos in Turuçu which often experienced water scarcity, no considerable differences were detected between the visited municipalities regarding this indicator.

The *water source* indicator was mostly ranked as partially adequate. In seven out of the eight cases, groundwater was the main water source. Generally, the groundwater was extracted from drilled wells with partial protection, but without sanitary sealing. In some cases, groundwater wells were located in areas where the risk of contamination from agricultural and domestic activities was high. In one case, unprotected spring water was used as a water source and for replenishing groundwater. None of the eights systems which were visited ranked as "adequate" in this category. No considerable differences were detected between the visited municipalities regarding this indicator.

Water quality and *level of treatment* were the indicators most often ranked as "not adequate". None of the eight systems were ranked as "adequate" in these categories, since no system consistently showed water quality records in line with regulations. Many of the systems did not have any disinfection or other treatment installed, and the ones that used chlorination systems often had problems with inactivation of microorganisms, meaning that the treatment did not function as intended. Regarding these indicators, the municipality of Vila Nova do Sul displayed more serious issues due to the problems with fluorine in the groundwater, and the lack of adapted treatment which would be needed to solve this issue.

The indicators *distribution network* and *operation & maintenance* were ranked as partially adequate for all of the visited systems, based on the interviews. None of the systems had frequent issues with interruptions according to the municipal representatives, but there was no monitoring of non-revenue water for any system, and in some cases there were reports of intermittent interruptions. None of the systems were completely lacking in O&M, but since none of the water supply systems continuously produced water of adequate quality, O&M was not considered completely adequate in any of the cases. No considerable differences were detected between the visited municipalities regarding this indicator.

Economical sustainability showed mixed results. In some cases, SAC associations were reported to be economically self-sufficient and cover the costs of O&M. This was especially true for the SAC systems run by ASSODEC in the municipality of Fazenda Vilanova. In most of the other cases, associations and communities were struggling to cover the costs. This was especially true for the SAC of Laranjeiras where about half of the connected households did not pay for the water use, and the SAC of São Domingos where the community relied heavily on municipal support for water provision.

Surveillance and monitoring also showed mixed results, although most of the systems were reported to have adequate frequency of water quality surveillance and control, i.e. according to regulations. Some differences were observed between the municipalities, where the SAC systems in Fazenda Vilanova appeared to perform water surveillance and control in coherence with regulations. For some other systems, water quality monitoring was not performed as often as regulation demands. For example, no regular monitoring was performed for the SAC of Sociedade Abastecedora de Água de Cabriúva in the municipality of Tabaí,

Participation of beneficiaries mainly showed adequate results, since many of the SAC systems were reported to have associations with regular meetings, and/or informal associations with community driven planning. However, this does not necessarily mean that the water supply service is adequately managed, since scepticism towards treatment still can cause mismanagement of the water supply systems. For the systems in Turuçu this indicator was not estimated due to lack of information, otherwise no considerable differences were detected between the visited municipalities regarding this indicator.

5.5.1 Reflections regarding the case studies

The location of the case studies and dates of field visits were not confirmed as the authors arrived in RS in September 2019, and due to time constraints the case study design changed during the field period in Brazil. Since the initial case study plans (Santa Rosa and *quilombola* communities using spring sources) were cancelled, other field visits and case studies were arranged and adapted during the field period in RS, i.e. September-November 2019.

The case studies which were performed in this study mainly consisted of 1-day visits to municipalities in RS, where information was collected through interviews and direct observations. Due to limited time and information, the descriptions of the systems are not exhaustive. For example, technical details of the distribution systems were often not available. However, complementary studies were done through historical water quality records in SISAGUA and technical documents. The municipalities of Tabaí and Turuçu had PMSBs as of November 2019, which made it possible to provide more technical depth into some of the systems in these municipalities.

If the initial plan of investigating rural water supply in Santa Rosa and *quilombola* communities would have been possible to perform, the subsequent study would have had a different character. In these locations, IPH and EMATER already had ongoing projects and contacts, meaning that more in-depth technical details may have been available. Probably this would have resulted in fewer case studies, but with more technically exhaustive investigations and recommendations.

On the other hand, the current case study design with eight systems provides a broader view of small-scale water supply in rural areas of RS. This enabled a wider discussion of the challenges for rural water supply within the state, aligning with the aim of investigating the challenges in the implementation of *SDG 6.1 - safe and affordable drinking water for all*. The case studies are to be seen as the core of this study, which forms a basis of discussion for the challenges of rural water supply in RS. However, the case studies do not claim to provide a complete description of how small-scale water supply services work in RS. They are meant to serve as examples of how these services are arranged in a few cases of interest. Together with additional interviews and seminars in RS as well as literature reviews, the case studies thus enable and support the answering of the research questions.

6. Input from additional seminars, meetings and interviews

6.1 Commentary from seminars

During the time of work in Brazil, the authors participated in several seminars and discussions with state employees involved in *Vigilância da Qualidade da Água* (VIGIAGUA) i.e. the drinking water surveillance programme of the state, and others working with water and sanitation services within Rio Grande do Sul. These meetings offered much relevant commentary on the current state of rural water supply in different regions of Rio Grande do Sul, and also offered important input and reflections regarding the challenges of providing safe and affordable water for all in the state.

6.1.1 Biannual VIGIAGUA seminar

During participation in the biannual VIGIAGUA meeting on the 22nd of October 2019, about 20 participants were interviewed with the aim of providing an overview of the current issues and development of rural water supply in RS. Questions and answers are presented below (Seminar RS I 2019).

1. "Is resistance against chlorination of drinking water common in all municipalities?"

   All participants agreed that this indeed is a common and very widespread issue. One surveillance agent stated that it may be the excessively high chlorine concentration that is the main issue, not the chlorination process itself. If the systems were operating properly this resistance would be less of an issue since the taste of chlorine is not as strong at the lower end of the legislated concentration spectrum. Furthermore, several surveillance agents agreed that a lack of awareness and education regarding the importance of disinfection contributes greatly to the resistance against it. Some municipalities have worked with informing the public in various ways. However, they report that it is hard to convince people that disinfection may be needed due to local traditions and habits. There is also a lack of rigorous local-level evidence which show a clear correlation between microbiologically contaminated water and various diseases, since these studies are difficult to perform. Regarding alternative disinfection technologies, one surveillance agent stated that one municipality had completed a pilot study with UV disinfection, but that it was deemed too expensive for further implementation.

2. "Do many of the municipalities in RS actively try to access federal funding to create municipal basic sanitation plans and/or receive federal grants for implementing water and sanitation projects?"

   The participants replied that it is usually hard for the municipalities to access external funding due to lack of administrative and technical capacity. Furthermore, one agent reported that the application process to receive funds from FUNASA had recently changed, potentially becoming more complicated.

3. "Do many of the municipalities in RS have SAC systems without water tariffs?" (i.e. only symbolic fees or possibly no fee for the water supply)

   The surveillance agents confirmed that there are several municipalities in Rio Grande do Sul where such SAC systems exist. In these cases, the municipalities often have to step in with economic support for capital costs and maintenance. This however, is not in line with Brazilian legislation regarding funding and economic sustainability of drinking water systems. Several surveillance agents also agreed on that economic self-sufficiency of water and sanitation services cannot be reached for these systems without some type of water tariff.

Additional comments and points of interest which were brought up during the discussion of these questions were the following:

- Municipalities can be fined if they do not make sure that all SAC systems use chlorination. However, this is rarely enforced since it is difficult for the municipalities to implement chlorination when there is a strong resistance against it.

- There is a lack of disinfection and many errors in SISAGUA registration for many SAC's amongst several small municipalities. Some of the municipalities only have samples from SAA systems run by CORSAN and skip the surveillance of SAC systems, leading to false statements of "100 % OK water in the municipality" according to official reporting.

- High arsenic levels have led to shutdown of at least one SAC system in RS.

- Water supply in 539 schools in RS was investigated, and it was found that water quality was unsatisfactory due to microbiological contamination in several cases.

- Microbiological re-contamination of chlorinated water during storage in tanks has been observed in many systems in the state, including many SAC systems.

6.1.2 Seminar on the revision of drinking water standards in RS

The authors also participated in the 3rd state seminar on water and health on the 24th of October 2019 together with representatives from CEVS, IPH and other organizations. The main theme was the revision of drinking water standards (*Revisão da Portaria de Potabilidade*), but various wider problems relating to water supply in the state were also discussed amongst the regional water professionals. During the seminar, notes were taken regarding topics which were relevant for this study.

Some of the main points which were brought up are listed below (Seminar RS II 2019):

- A successful experience of implementing disinfection in SAC systems in the small municipality of Fagundes Varela in RS was described. In 2016, only 3/19 SAC systems in the municipality were using disinfection actively, but as of 2019 all 19 SAC systems used disinfection. During these years, technical responsibility delegations and water quality control for the systems also improved significantly. This was done through diligence from the municipality, with help from CEVS in gathering the 19 SAC association presidents for an "awareness meeting" (*momento de sensibilização*) and discussing the advantages of treatment and the requirements stipulated in law. This experience was shared as a potential source of inspiration to the many municipalities struggling to implement treatment in SAC systems.

- It was highlighted that there is a correlation between increased investments in basic sanitation and decreased hospitalizations due to diseases related to unsatisfactory sanitation (cholera, typhoid and paratyphoid fevers, shigellosis, amoebiasis, diarrhoea, gastroenteritis and other infectious intestinal diseases), in RS as well as in Brazil overall. The correlation with decreased hospitalizations due to sanitation-related diseases also holds true for investments specifically in water supply, as well as investments specifically in wastewater management.

- It was highlighted that hospitalizations due to sanitation-related diseases decreased from about 1,5/1000 inhabitants in 2009 to 0,5/1000 inhabitants in 2018 in the southern region of Brazil (including RS, Santa Catarina and Paraná). This indicates constructive progress. However, this number still amounts to many thousands of hospitalizations in RS every year due to lack of basic sanitation.

- Discussions were held regarding the integration of Water Safety Plans (WSPs) into RS state law, relating to the standard WSP framework designed by the World Health Organization (Bartram et al. 2009; WHO 2012b). This would mean increased focus and preventive risk assessment and risk management for SAA and SAC systems.

- One study which was presented showed that contaminants such as endocrine disruptors, pharmaceuticals and antibiotics which are not regularly monitored have been found in various forms in freshwater sources in RS upon analysis, calling for increased attention to these substances.

- Addition of certain pesticide compounds and metabolites to the state-level drinking water standards in RS were discussed, calling for increased attention to the use of certain pesticides within the state.

6.2 Commentary from interviews

As part of this work, professors from IPH (*Instituto de Pesquisas Hidráulicas*) with expertise in sanitation as well as water resources management, and a representative of the rural support organization EMATER were also interviewed regarding their view on the main challenges in providing sustainable water services for all in RS.

The fundamental question asked in these interviews was "*What do you believe is the biggest challenge in receiving safe and affordable water for all in Rio Grande do Sul?*", with additional follow-up questions and discussions regarding technical, socioeconomic and political-legislative aspects.

Some of the main viewpoints that were put forth in an interview with Guilherme Marques, professor of water resources management at IPH, were the following:

- The municipalities, which bear responsibility for water and sanitation services, are often ill prepared to fulfil these responsibilities. Municipalities can contract third-parties to provide these services, but they often lack staff (in quantity and capacity) who are able to prepare basic sanitation plans, terms of reference and other technical documents needed to access financing opportunities. In the remote rural areas, municipal planning is often virtually absent. Often, the inhabitants of these areas do not have economic means to hire adequate water and wastewater solutions, suffering with unreliable water supplies and risking to further pollute local streams and aquifers (Interview IPH I 2019).
- The sanitation sector in Brazil still lacks a robust finance and contract model, which hampers the development of infrastructure in poor and rural areas (and even large cities). Since infrastructure investments are sunk costs and the financial environment is not clear and safe, companies are reluctant to invest. Brazil is currently beginning to experiment with PPP's (public-private partnerships), and only time will tell how successful those changes will be (Interview IPH I 2019).
- There is a lack of integration between the sanitation sector and water resources management at the watershed levels. Water supply sources are being compromised due to water and land use decisions in the watershed, and this is beyond reach of a given municipality and its sanitation plan (Interview IPH I 2019).

Some of the main viewpoints that were put forth in an interview with Dieter Wartchow, professor of water and sanitation at IPH, were the following:

- Two main challenges exist for assuring water security in rural areas of RS. One is the cultural factor - many people have a resistance towards treatment and chlorination, and towards paying for water. People must accept measures which improve water quality, accept monitoring of water usage through installation of water meters, and agree to pay a basic water tariff to cover the costs for basic sanitation services. Educational efforts must be made to spread awareness regarding the importance of water security and basic sanitation (Interview IPH II 2019).
- The other factor regards inadequate organization and management of rural water supply services, leading to lack of sustainable tariff structures and lack of water quality control. The SAC associations often lack technical and administrative capacity. Municipalities must assist to solve these issues since they are responsible for basic sanitation services, but all municipalities do not acknowledge this responsibility (Interview IPH II 2019).
- Political and legislative changes are occurring in Brazil which favour privatization of the water and sanitation sector. This could lead to prioritization of financial gains over the right of access to safe drinking water for all. Due to political changes over the years, Brazil's water and sanitations policies have suffered from incoherency for a long time, leading to inefficient political management of water and sanitation. Due to current political decisions there are cuts in the public funding of water and sanitation services, affecting for example FUNASA funds, which may result in decreased investments for improved water services (Interview IPH II 2019).

Some of the main viewpoints that were put forth in an interview with Gabriel Ludwig Katz, representative of the rural support organization EMATER, were the following:

- There is a need for effective public water and sanitation policies where resources are aimed directly towards improving health and quality of life for the population. Basic sanitation has not been prioritized for investments in Brazil due to the medium-term to long-term results in regards to measurable indicators (Interview EMATER 2020).
- There should be an increased focus on environmental education in schools and communities. It is important that the population understands the importance of adequate water treatment, but also of water source protection. Awareness should be spread regarding the importance of preservation of springs and riparian forests, proper disposal of solid and liquid waste from households and industries, cautionary use of pesticides etc. It is also important that water is seen as a common good and not as a commodity (Interview EMATER 2020).
- Rural areas in RS have significant shortages in basic sanitation services due to their distance to areas with adequate large-scale solutions, leading to individual or small-scale solutions for water and wastewater which often are inadequate. EMATER is currently helping many rural communities with proper disposal solutions for wastewater, animal waste and solid waste in accordance with reverse logistic norms (i.e. waste management which focuses on reusing or recycling waste). These projects assist to avoid contamination of water sources, and may contribute greatly to solve water and sanitation problems in rural areas when done in a suitable way. There are many technical solutions to the problems which are commonly found for rural water and sanitation services. The biggest challenge for these solutions to reach the rural population is the lack of resources to implement them, and the environmental awareness of rural communities and families (Interview EMATER 2020).

7. Discussion

This section aims to analyse and discuss the information which was gathered through the case studies and interviews in RS. These discussions focus on the identified issues and challenges for sustainable rural water supply in RS, and discuss possible ways forward. This chapter is divided into *Technical aspects* and *Socioeconomic and political aspects*, which are discussed in separate sections.

7.1 Technical aspects

Although a multitude of technical solutions exist for purification and distribution of drinking water, the implementation of suitable solutions is not necessarily an easy task. Economic limitations and lack of awareness on the importance of water source protection and treatment appear to be limiting factors for the improvement of water supply services in rural areas of RS. Although many issues are closely tied to socioeconomic and organizational challenges within the state, several problems which were identified were also of technical nature. These issues and potential technical solutions are discussed in this section.

7.1.1 Water source protection

The level of treatment required after abstraction depends on the quality of the raw water, which in turn greatly depends on the protection of the water sources. Based on observations and interviews in RS, poor water quality in RS is most often caused by anthropogenic pollution, although natural geogenic contamination also occurs regionally. Septic and rudimentary tanks are the main wastewater disposal solutions in the rural areas of RS, and these pose a risk for contamination of groundwater sources. Untreated or insufficiently treated wastewater being discharged directly into rivers and lakes has also been identified as a source of *Escherichia coli* and faecal coliform bacteria (SASB 2019). Agricultural activities also cause risk for contamination through leakage of pesticides and faecal contamination from livestock. These are, in part, technical issues that can be solved, although careful planning and investments are required to do so.

Properly constructed and protected groundwater wells can greatly limit the risk of contamination, and two important aspects is the installation of a sanitary well cap and a grout seal, also often known as a sanitary seal. Well caps prevent rodents, birds and other vermin from accessing the water directly, and the sanitary seal protects the well from direct infiltration of potentially contaminated surface water (Swistock 2016). Most of the wells which were inspected in RS had proper well caps, although some were cracked and in need of maintenance, such as the one in São Domingos, Turuçu. Sanitary seals are commonly created by filling the annular space between the casing and the borehole wall with a mixture of cement, bentonite clay and sand. The required depth of the sanitary seal depends on the aquifer and local geology. For example, a confined aquifer will need the confining layer to be sealed after drilling, in addition to a top seal for the last 3-5 meters from the surface. Furthermore, a "well apron", effectively a concrete plateau on top of the well, is often recommended to further protect the well from intrusion of contaminated water (Ballard 2017; Van der Wal 2010). Information regarding the installation of protection such as sanitary seals was provided for all of the visited wells, either through interviews or in the PMSBs. In most cases, sanitary sealing was lacking, posing a risk for infiltration of potentially contaminated water into the wells.

Although most of the water sources from the case studies were groundwater wells, the SAC system of Cambai in Vila Nova do Sul used a spring source, and the SAA system in Turuçu used surface water from a river. Most SAI and SAC systems use groundwater, while many SAA systems use surface water due to the large quantities needed, and the ability to treat the water sufficiently in water treatment plants. In Cambai the community used a natural spring to recharge their well, effectively funnelling the spring water into the well directly. As the spring source was not properly protected, such conduct could also contaminate the groundwater source further. For the SAA of Turuçu, the river *Arroio Turuçu* serves as both the water source and recipient for untreated wastewater, constituting a risk for water safety.

Water Safety Plans (WSPs) have been highlighted as the most effective means of ensuring safe water supply, and consists of a comprehensive risk assessment and risk management approach as described in WHO's *Water Safety Plan Manual Step-by-step risk management for drinking-water suppliers* (Bartram et al. 2009). In RS, the need of such approaches and WSPs were highlighted during seminars (Seminar RS II 2019). These plans focus on identifying and addressing all threats to water safety from catchment to consumer, and largely relates to proper water source protection. Adoption of WSP approaches which focus on water source protection may be of great help for small-scale rural water supply systems, and much advice on how to implement such approaches in smaller communities can be found in WHO's *Water Safety Planning for Small Community Water Supplies - Step-by-step risk management guidance for drinking-water supplies in small communities* (WHO 2012b).

In terms of quantity, water source protection relates to watershed management and fair water allocation between stakeholders. Agricultural and industrial interests may compete with domestic use when water is scarce. However, the municipalities have priority when requesting water permits, and during periods with water scarcity domestic use is always prioritized. In RS there are several watershed committees which are comprised of water user representatives and professionals aiming to maintain sustainable management of the water sources within the catchment, in terms of both quantity and quality. However, there is a general lack of integration of the sanitation sector with water resources management at the watershed level in terms of communication and legislation (Interview IPH I 2019; Akhmouch et al. 2017). This lack of integration appears to cause water protection issues both regarding quantity and quality.

7.1.1.1 Possible ways forward

Efforts must be made to ensure adequate protection of sources which are used for drinking water production. The frequent presence of *Escherichia coli* and coliform bacteria in the water sources of RS indicates that inadequate water source protection is common. Sanitary sealing and carefully planned placement of new wells is needed to decrease vulnerability and increase the protection of many SAC and SAI water sources within RS.

Wastewater intrusion from inadequately managed septic and rudimentary tanks in rural areas are common point sources of contamination, which is known by the municipalities but rarely addressed. Carefully planned placement of these tanks could reduce the risk of contamination of groundwater sources. Reparation or updating of inadequate or malfunctioning septic tanks would also lead to decreased risk of contamination, and should be done in the vicinity of contaminated water sources. Ideally, wastewater collection and simple wastewater treatment systems such as small scale filtering systems would be used in small communities as well. Slow sand filters may be used to filtrate wastewater, and are easy to manage, relatively cheap and possible to construct with widely available materials (Thomas & Kani 2016; WHO 2000). Sand filtration could be cheaper and easier to maintain than conventional treatment which include biological unit operations such as activated sludge systems. However, installation of small scale wastewater treatment plants would first require construction of pipe networks for collection, and require substantial investments.

Spring water sources in RS are often inadequately protected, such as the one seen in Cambai. There are however relatively simple methods to protect spring water sources, such as the method developed by EMATER which can be further explored in their manual *Roteiro técnico para implantação do sistema de captação de água de nascentes e olhos d'água,* in which the spring source is covered with help of a small weir structure, geomembranes and reposition of soil (EMATER 2016).

Protection of surface water sources such as the river used in Turuçu demand catchment-level actions, and depend on wastewater management in all upstream areas. The same is true for groundwater sources overall, since these also may be contaminated over time by the surface water which is recharged into the aquifer. Since agriculture is significant throughout RS, pesticides are known to contaminate the water sources at many locations (Seminar RS II 2019). This also includes the visited municipalities which are located in the Guaíba basin and the littoral basin, and all have agricultural activity. Increased monitoring of pesticides is necessary to take appropriate actions and control that the water is free of contamination, and ensure that the water services are safely managed. Also, approaches which focus on risk management in line with WSP guidelines could be of great help for source protection and water safety in many communities in RS.

7.1.2 Water quality and water treatment

In cases where raw water quality is not appropriate for consumption, water treatment of some sort is needed if the source is to be used. Water treatment is almost always needed to secure water quality in surface water sources, and may also be needed for groundwater sources. For SAC systems in RS, disinfection through chlorination appears to be the only widespread and common treatment solution. Other disinfection methods or additional treatment steps such as filtration seem to be uncommon for SAC systems. SAA systems in small municipalities may however have simple conventional treatment in the form of coagulation, flocculation, sedimentation, filtration and disinfection such as the SAA in Turuçu (which uses surface water as source).

In Brazil, disinfection is required for all water supply systems according to *Portaria MS nº 2914/2011.* This marks a difference compared to regulations in countries such as Sweden where disinfection in private groundwater wells is discouraged by national authorities, and only recommended as a temporary solution in case of temporary issues (Socialstyrelsen 2006). If microbiological contamination is recurrent, authorities in Sweden instead advise to find a new source rather than to continually disinfect water. In Brazil, it seems as if microbiological contamination of groundwater is so common that disinfection instead is seen as a necessary precautionary measure. This may be justified since presence of indicator organisms such as total coliforms and *Escherichia coli* indeed is very widespread in SAC systems throughout Brazil and RS.

Disinfection through chlorination is disliked by many due to its taste. The taste detection level of chlorine is wide and can range from 0,3 - 5 mg/L (WHO 2003), and Brazilian legislation allows a range of 0,2-5 mg/L of chlorine in the tap according to *Portaria MS nº 2914/2011*. Often the chlorine levels are higher than needed in the SAC systems which use chlorination (as seen in SISAGUA records), and the resistance towards chlorination may depend on operational issues in some cases. Thus, improved monitoring and operation procedures are important to ensure microbiological inactivation and avoid community resistance against chlorination. Improved monitoring and operation procedures may include ensuring a proper contact time, and that chlorine dosage is based on flow pace and a residual setpoint, as pointed out in best management practice manuals (WRA 2015). This has not been achieved at all visited systems, which for example have lacked proper flow measurement, and have failed in chlorination contact time (as seen in SISAGUA records, where chlorine levels have been high while coliforms still are present).

Although chlorination is a cheap and efficient disinfection method, there are other disinfection methods which could leave the water free from unpleasant taste and offer other advantages as well. The most common of these are disinfection through UV radiation or ozone, which also can be more efficient in exterminating protozoa such as *Giardia* and *Cryptosporidium* (Tsitsifli & Kanakoudis 2018). Since UV and ozone do not leave residuals throughout the distribution network as chlorine does, the risk for recontamination may increase if UV and ozone are not combined with small amounts of residual chlorine. It could be possible to implement these types of disinfection solutions on small-scale systems, but this would likely entail higher cost and increased need for operation and maintenance, as pointed out by a VIGIAGUA state agent regarding an earlier pilot UV disinfection project in RS (Seminar RS I 2019).

Turbidity and geogenic fluorine are other water quality issues which were encountered throughout RS. Pesticides are also an alarming issue and probably present in many rural water sources, which calls for precaution even though monitoring of pesticide contamination is lacking. These issues could be addressed through small-scale water treatment solutions as well.

Turbidity can be removed through various forms of mechanical filtration or chemically through flocculation and subsequent settling of suspended material (IWA 2020). For small-scale systems, sand filtration can be a simple and efficient option which removes overall turbidity as well as some bacteria (IWA 2020), and possibly other unwanted contaminants such as pesticides and pharmaceuticals if these exist in the water. Sand filtration systems can be very simple, basically consisting of sand and gravel (which often is cheap and easy to access) in a container which the water is passed through, with regular backwashing of the sand filter. Another option is to remove turbidity through settling and decantation, with or without help from flocculation processes (i.e. addition of a flocculent and stirring prior to decantation) (IWA 2020).

Fluorine removal is possible through various treatment technologies applicable at small- and large scale, the most common being activated alumina and reverse osmosis (WHO 2006). In the case of activated alumina, treatment is performed in filter columns which are fed intermittently. This demands a control over flow rate to ensure proper contact time with the filter media, as well as storage possibilities. Although activated alumina is the most common filter media used for fluorine removal in filter columns, others such as clay and bone charcoal may also be used, if available and culturally acceptable. Reverse osmosis is another attractive option since it significantly removes almost all dissolved contaminants (WHO 2006), including pesticides. Both activated alumina filtration and reverse osmosis are however considered "high cost/high tech" due to either being relatively expensive or demanding skilled operation, which may cause difficulties in implementation (WHO 2006). However, reverse osmosis and activated alumina treatment systems commonly exist as community-sized kits and can be shipped and installed on-site according to WHO (WHO 2006). This could be suitable for communities in RS with serious fluorine issues, such as the SAC systems which were visited in Vila Nova do Sul.

Pesticides can also be removed through a plethora of different treatment solutions. The most common solutions include the above mentioned reverse osmosis, and various adsorption processes (EPA 2011). Activated carbon (in granular or particular form) is amongst the most common and efficient adsorbents used for removal of pesticides and other dissolved pollutants such as pharmaceuticals. Other possible adsorbent media include clay, zeolites and polymeric materials, and may be more suitable for certain pesticide compounds and/or local availability of adsorbent material (Marican & Durán-Lara 2017).

7.1.2.1 Possible ways forward

Disinfection should be installed in all SAC systems which currently is lacking such a solution, and these systems must be operated in a manner that is in line with best management practices. Proper operation would lead to suitable chlorine concentrations (at least 0,2 mg/L but well below 5 mg/L), which would inactivate microorganisms but avoid causing an unpleasant taste.

Best management practices for conventional water treatment should be incorporated for small water treatment plants such as the SAA in Turuçu, for example following the advice put forth in the *Handbook for the operation of water treatment works* from the Water Research Commission. The SAA of Turuçu could for example benefit from proper flow measurement installations such as parshall flumes or weirs to ensure correct chlorination dosage, in line with best management practices (Water Research Commission 2006).

A plethora of treatment solutions exists to address the problems with turbidity and fluorine, as well as unmonitored contaminants such as pesticides which are likely to exist in many water sources. Sand filters are relatively simple and cheap solutions which could assist in removal of turbidity, microorganisms and various dissolved contaminants. Activated carbon is more expensive than sand, but could also be used in simple filtration systems to remove dissolved contaminants more efficiently. High-tech solutions such as reverse osmosis could also be used at small-scale to remove fluorine as well as other dissolved contaminants, and greatly benefit the population if funding could be acquired through external or local sources.

7.1.3 Distribution networks and non-revenue water

Water loss in distribution networks is an omnipresent issue for water suppliers, and it is not possible to keep losses at 0 % (USAID 2010). However, it is very important to monitor leakage and work to decrease losses since it could save vast amounts of water and energy, and decrease the risk for contamination through infiltration of shallow groundwater. Except for identifying leakages and potential contamination sources around pipe infrastructure, network inspections are also needed to identify and address any illegal connections that might exist (Castro et al. 2009). Water which is lost through leakages (or illegal connections) is often referred to as "non-revenue water" since it will not reach paying customers and generate revenue for the supplier, of course also meaning that there are economic incentives to decrease non-revenue water (USAID 2010).

In RS, leakage and non-revenue water is not monitored in SAC systems. During the interviews with the four case study municipalities, none knew of any continual estimations of water losses in the distribution networks. Only one estimate was found in the PMSB of Tabaí, where non-revenue water in a part of the Assodec Tristão system was estimated at 42,6 % (MJ Engenharia 2017). As of 2010, the Brazilian national average was 39 % (Ministério das Cidades 2013). This number must be decreased to avoid unnecessary water abstractions, energy consumption and costs.

As pointed out in *The manager's non-revenue water handbook for Africa* accessed through IWA, a common problem is that water supply providers become stuck in a "vicious non-revenue water circle" (USAID 2010), as visualized in Figure 50 below. This means that insufficient investments in water loss reduction leads to increased investments in water production and capacity to meet customer demands, which leaves less money for operation and maintenance of distribution networks.

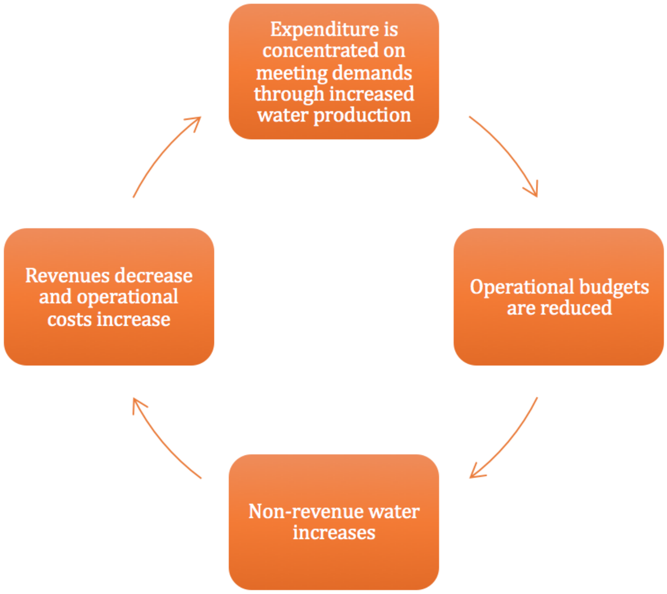

Figure 50. The "vicious non-revenue water circle", adapted from The manager's non-revenue water handbook for Africa (USAID 2010).

7.1.3.1 Possible ways forward

Leakage and non-revenue water should be monitored and managed to decrease unnecessary water abstractions, energy usage and costs. This is also needed to decrease the risk for infiltration of shallow contaminated groundwater. Increased investments in water loss reduction could instead generate a "virtuous non-revenue water circle" and generate benefits as visualized in Figure 51 below.

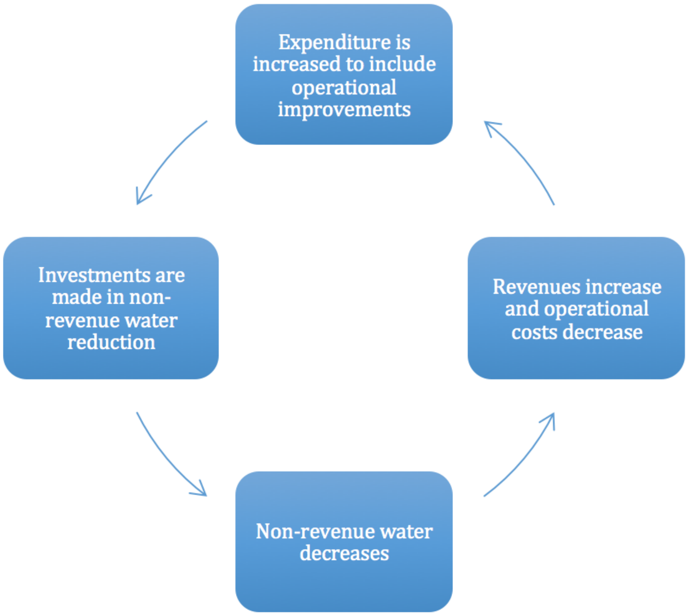

Figure 51. The "virtuous non-revenue water circle", adapted from The manager's non-revenue water handbook for Africa (USAID, 2010).

More detailed information on how to set up a non-revenue water reduction strategy including details on monitoring methods, operational approaches and reparation can be found in literature such as *The manager's non-revenue water handbook for Africa* (USAID 2010).

7.2 Socioeconomic and political aspects

While technical solutions are of fundamental importance in the provision of clean water for all, social circumstances and economic limitations often constitute the main challenges for sustainable water supply in rural areas.

Socioeconomic obstacles have been observed in several of the case studies performed in RS. The prevalence of these issues appear to be widespread throughout RS, since they have been mentioned and confirmed repeatedly in discussions with authorities, health and sanitation inspectors and researchers in the state. There are also political and macroeconomic factors which have large effects on policies and financing of water and sanitation services, and affect the development of rural water supply through a top-down pathway. In this section, the most relevant socioeconomic and political aspects are discussed.

7.2.1 Cultural attitudes and educational factors

Cultural factors affect the way in which water is perceived, valued and managed in societies (WHO 2013). This can include the belief that treatment of water does not offer any health benefits, a belief that clear water with no visible pollution always is safe to drink, a view of water-borne diseases such as diarrhoea as unavoidable and/or a non-serious health threat, and a general resistance to the change of customs in water supply and water management (Figueroa & Kincaid 2010). Some of these notions have been detected amongst several of the communities of the case studies in RS, and the widespread prevalence of these issues in RS have been confirmed through interviews with authorities and researchers in the state.

A recurrent and major issue in RS is the resistance towards chlorination in communities. In the visited municipalities there were reports of insistent resistance to chlorination, for example cases in which water users have disconnected installed chlorination systems, and cases where water users repeatedly request operators to turn off chlorination systems or decrease chlorination dosage, resulting in substandard concentrations (in the municipalities of Vila Nova do Sul, Fazenda Vilanova and Tabaí). Many of the SAC systems in RS still lack disinfection, and due to community scepticism it is very difficult for the municipalities to enforce the legal requirement of disinfection which is established in *Portaria MS nº 2914/2011*. As seen in water quality records from SISAGUA, indicator organisms such as coliform bacteria and *Escherichia coli* are often present in many SAC systems. This, in combination with lack of disinfection, results in precarious water quality. The main problem is not of technical nature, since chlorination is relatively cheap and easy to install. Instead, a crucial sociocultural obstacle is materialized in the scepticism towards disinfection.

The observed absence of adequate water source protection also has cultural pretexts. According to EMATER and state authorities, the pathways in which groundwater and surface water sources can be contaminated by anthropogenic activities are not well understood by many rural water users. The fact that domestic wastewater, animal waste and pesticides may deteriorate the water quality in local water sources is therefore not always recognized or considered in planning and construction of small-scale water and sanitation systems.

Another crucial topic concerns economy, i.e. the water tariff structures and willingness to pay. Many water service providers in RS seem to apply a water tariff structure in which the first 10 m^3 consumed per month in a household is cheaper per m^3 (compared to the additional water quantities consumed that month). This appears to be a very appropriate element in the tariff structures, since it helps poor households to afford water for essential uses more easily, while also creating an incentive against overconsumption. However, there are many rural water users in RS who maintains the notion that water usage should be free of cost, and do not pay for their water. This was for example seen in the Laranjeiras SAC system of Vila Nova do Sul which has about 80-100 households connections, but only 40 households actually pay for the water. In the SAA system of Turuçu, it was reported that several clandestine water connections exist, meaning that these connected households do not pay for water usage. Under such circumstances it becomes very difficult for associations or municipalities to cover the costs of operation and maintenance and ensure water safety, partly due to sociocultural community convictions.

7.2.1.1 Possible ways forward

Cultural customs and habits are not easy to affect, but information and education campaigns aimed towards communities and schools have yielded positive results in many cases across the globe. Such examples also exist in RS, where organizations such as EMATER have had success in such campaigns. There are also examples of educational *"awareness meetings"* regarding the importance of water quality and treatment, which have led to that SAC associations implement disinfection (Seminar RS II 2019), and cases of other municipalities which have managed to widely implement disinfection through educational initiatives (Interview IPH II 2019). Such endeavours must be reproduced throughout the state to spread this awareness.

Successful educational efforts do not appear to have a "special secret" responsible for their accomplishments, but diligence and tailoring to local circumstances are central for these efforts to generate success. More detailed advice on how to implement information and educational campaigns and can be further explored through programmes such as the *Sustainable Sanitation and Water Management Toolbox* and their resources (SSWM Toolbox 2020a). School campaigns are often highlighted for their potential to be especially effective since they can be entry points to the families and rest of the communities (SSWM Toolbox 2020b), and children may be very prone to learn if school campaigns are engaging and perceived as fun. Such campaigns should be encouraged in small municipalities and rural areas with water issues.

Unwillingness to pay causes revenue collection issues for some SAC and SAA systems in RS, and this should be addressed to ensure economic sustainability. The idea that drinking water should be free of charge (at least for basic household needs) may be righteous and equitable, and in harmony with the human right of access to clean water. However, investments in water and sanitation as well as operation and maintenance costs are not free of charge, and these costs must be covered somehow. Unless the public sector completely finances water infrastructure and its operation through other financial resources (which currently is not the case in Brazil), water users must accept that water usage has a price. One potential solution could be to modify the tariff structure further. For example, the first 5 m^3 used in a household every month could be completely free of charge, while additional quantities have a higher price than in the current structure. This could benefit the poorest water users, while creating strengthened incentives to avoid overconsumption of water.

7.2.2 Organization, community involvement and participation

According to Brazilian law (nº 11.445/2007), municipalities are responsible for the provision of water and sanitation services. However, as confirmed through interviews in RS, municipalities do not always acknowledge this role or take their responsibility (Seminar RS I 2019; Interview IPH II 2019). Many of the SAC systems used in RS, which amount to more than 10 000 (SISAGUA 2019), are run by associations with a varying degree of formality. Often the responsibility delegation between municipalities and SAC associations are unclear, resulting in lack of water quality control and economic difficulties. In many cases, the water tariff systems are dubious, and do not cover the costs needed for operation and maintenance. Thus, the SAC systems often seem to become completely dependent on municipalities for financial resources to cover maintenance costs.

According to interviews performed in RS, there seems to be a lack of communication between municipalities and SAC associations, and a general lack of municipality support and involvement in remote rural areas (Interview IPH I 2019; Interview IPH II 2019). Since there are many municipalities which are lacking in administrative and technical capacity and/or do not acknowledge their responsibility regarding basic sanitation, they do not actively work to improve the situation for inadequate SAC systems (as has been seen in some of the case studies). Lack of capacity can also make the municipalities unable to establish a basic sanitation plan (*Plano Municipal de Saneamento Básico* (PMSB)), and unable to access external funds needed for improvement of water services. At the same time, SAC users are often used to inadequate water supply solutions, and therefore communities may not actively work for improved systems or reach out to the municipality for support either (as has been seen in some of the case studies).

The organizational problems in the sector connects to the importance of community involvement and participation in decisions regarding water services. While it may be reasonable that Brazilian law calls for mandatory disinfection as well as economic self-sufficiency of SAC and SAA systems, it is also very important to avoid pure top-down enforcement processes. The community participation of beneficiaries is often highlighted as an absolute necessity to achieve success in rural development projects (Hall et al. 2016), and some comprehensive review studies have suggested that community participation the single most important factor for success in rural water supply projects (Narayan 1995). What "*participation*" conveys in this context is that the beneficiaries are involved in the projects and that their wishes are taken into account throughout all the project stages - design, implementation and construction as well as continued management and maintenance of the systems (Narayan 1995). Since the 1990's, a consensus has emerged regarding the importance of participation and the need of rural water supply projects to be demand-driven (Whittington et al. 2009).

The participation of beneficiaries has been hard to estimate during the field visits of the case studies, since there were limited opportunities to interview SAC system users directly regarding this topic. However, for some cases such as the ASSODEC association which runs the SAC systems in Fazenda Vilanova, it was confirmed that open association meetings are held regularly where water users can make their voice heard, and that this is seen as a positive element. For many other SAC cases no formal associations exist, making it more difficult to communicate about operation and maintenance, tariff systems, potential investments in treatment etc. Lack of formal associations with participatory meetings also appears to cause difficulties for the communities to communicate with the municipality as a united group, which in turn makes it harder for the municipalities to help rural SAC-dependent communities.

7.2.2.1 Possible ways forward

To ensure safe and affordable water for all, municipalities must take their responsibility and work actively to encourage proper solutions for water source protection, water treatment and water revenue collection. Municipalities must invite SAC associations to sit down together and discuss pathways to ensure water security, and determine clear responsibility delegations between the municipality and the associations. Simultaneously, precaution must be taken to avoid top-down enforcements which are not demand-driven. If there are sociocultural obstacles such as scepticism to novelties and treatment, focus must be on non-forcing educational efforts in the early stages.

Participatory approaches are important to make sure that all voices are heard and facilitate communication. Although community resistance to novelties and treatment may be expressed in participatory meetings, it is of crucial importance that generation of demand (through educational efforts etc.) precedes any project implementations. Projects which are not demand-driven are unlikely to be appreciated by beneficiaries, and likely to be unsuccessful (as seen through abandoned chlorination systems etc.). Decisions must focus on achieving the desired outcomes for the water users, while also respecting cultural rationales. More detailed advice on how to arrange participatory meetings can be found through resources such as NETSSAF's guidelines for sustainable sanitation planning through participatory approaches (NETSSAF 2008).

A main organizational flaw is the lack of technical and administrative capacity in the municipalities, resulting in lack of efforts for improved water and sanitation. More capacity is needed, but this would of course constitute a cost, and be a matter of economic prioritization for each municipality. The inability to access external funds due to absence of PMSBs are a major issue, but there are also examples of municipalities which have been able to receive FUNASA funds to draft a PMSB with help of technical consultant companies (such as the municipality of Tabaí). This is a procedure that could be reproduced by municipalities with inadequate systems who lack a PMSB, and do not have capacity or plans to draft one (such as Vila Nova do Sul).

7.2.3 Politics and external financing

Improvement of rural water services do not only depend on the local decisions and actions of communities and municipalities, but is also shaped by regional and federal political and financial systems through a top-down pathway. Sometimes these aspects are referred to as an "enabling environment" in the context of water and sanitation. The enabling environment can be said to consist of policies, legislative frameworks and financing and investment structures, together forming the “rules of the game”, which are of great importance for successful water governance (Global Water Partnership 2018).

The national plan for basic sanitation *PLANSAB* outlines high ambitions, for example that 99 % of the Brazilian population shall be served by safe, piped water by 2033. Brazil also has comprehensive legislation on water and sanitation services. However, as pointed out in studies from OECD and during interviews in RS, Brazil is suffering from disorganized governance of water and sanitation with imprecise responsibility delegations (Akhmouch et al. 2017), and a history of inconsistent water and sanitation politics and policies (Interview IPH II 2019).

Unsystematic organization of water and sanitation governance exists on federal- and state level according to reviews from OECD (Akhmouch et al. 2017). For example, as much as 8 different federal ministries managed 10 different programmes for grant funding of drinking water and sanitation investments (e.g. FUNASA) as of 2017. In the same report it is pointed out that there are no transparent criteria which federal and state-level authorities use to choose and prioritize between project funding options. Surprisingly, it even seems as if much of the federal financial resources earmarked for water and sanitation investments remain unspent and never become invested for this purpose. There have been recent periods where as much as 50 % of the water and sanitation budget have remained unspent over yearly averages. These types of backlogs occur due to lack of eligible projects (which demand a high level of technical detail), and due to problems in the implementation phase of funded projects leading to significant delays or even abandonments (Akhmouch et al. 2017). This is a very distressing issue since many people in Brazil would benefit greatly from these funds, if they were granted wisely.

Current funding remains insufficient to reach the national ambitions outlined in PLANSAB. An estimated 300 billion R$ is needed to fulfil the goals set for 2033, and the current trajectory would not reach the PLANSAB goals before 2050 (Akhmouch et al. 2017). A debate which currently is at issue in Brazil is the proposition of increased public-private partnerships (PPPs) and private investments and ownership in water and sanitation services, which potentially could funnel more financial resources to water and sanitation. Brazil has been experimenting with PPP arrangements for water and sanitation services since the 1990's (LandLinks 2011), but this remains a controversial topic where opinions diverge. As highlighted in one interview at IPH, the law and policies are currently (as of 2019) changing towards a favouring of privatization with the new national government led under *Jair Bolsonaro*, as well as the state-level political leadership in RS (Interview IPH II 2019), with potential effects on ownership and management in the water and sanitation sector. Critics such as the global union federation *Public Services Internationa*l warn that PPPs and privatization will lead to persistent prioritization of profit, and that such partnerships are incompatible with the realization of the human right to clean water and the pledge to "leave no one behind" (Karunananthan 2018). However, prominent organizations such as the World Bank and the UN often highlight the need of private capital investments as a necessary complement to accelerate development of water and sanitation infrastructure across the globe and attain SDG 6 (World Bank 2017a; UN 2018; WWAP 2019).

It may seem like the political policies on privatization may not affect water supply solutions in rural areas much, and this may be true for many cases where systems are run by small associations. However, public state-owned companies such as CORSAN adheres to political influences, and due to cross-subsidies CORSAN currently runs small water supply systems which do not yield profit, for example the small SAA system in Vila Nova do Sul (Interview Vila Nova do Sul I 2019). It is possible that services arranged under such circumstances would be affected by increased privatization of companies such as CORSAN. If a PPP would mean increased focus on profit, this could also hinder any plans to extend water distribution networks from central municipality settlements to its outskirts and rural households in the proximity. It therefore seems unlikely that poor people living in sparsely populated rural areas would benefit from a shift towards increased focus on profit (it is easier to imagine that increased private investments could lead to accelerated and positive water infrastructure development in urban areas, where prospects of profit are higher).

7.2.3.1 Possible ways forward

Currently, there are flaws in the political and financial enabling environment of water and sanitation services in Brazil. The arrangement with dispersed responsibilities for water and sanitation funding leaves room for many rationalization possibilities - elimination of duplicated responsibilities and clear and transparent prioritization criteria would likely render a more efficient funding structure.

It clearly constitutes a great loss for the Brazilian population that financial resources allocated to water and sanitation remain unspent, and this must be addressed. Since there are recurring issues with delayed and even abandoned projects, it seems as if the current lack of (transparent) selection and prioritization criteria for funding constitutes an issue. As long as eligible projects are so few that the allocated resources are not spent, remaining funds should perhaps be invested in capacity building in weak municipalities, creation of PMSBs and in educational efforts.

The debate relating to private investments is political and it is impossible to predict the outcomes of eventual scenarios. However, if CORSAN and other companies which supply water in small municipalities and rural areas would have an increased focus on profit, it is unlikely that this would offer benefits for the population in these regions. Since economy of scale is lacking in such areas, cross-subsidies may be an important and necessary tool to provide clean water for all. There might even be an obligation for an increased use of such solidary economic structures to reach the poor and vulnerable communities, and to make sure that no one gets left behind.

8. Conclusion

1. How are water supply services generally organized in rural areas of Rio Grande do Sul, and what problems exist?

Rural communities in RS are rarely connected to SAA systems with conventional treatment, and instead rely on small-scale SAC systems or individual SAI solutions. About one million people are served by SAC systems in RS. These are commonly run by community associations, with varying degrees of organizational and technical capacity. Often these associations are not economically self-sufficient, and require continuous economic assistance from the municipality. Many municipalities display a lack of administrative and technical capacity, making them unable to fulfil their responsibility and ensure safe water supply to the inhabitants, and unable to access external funding for improvement of water and sanitation services.

In rural areas, piped water is commonly accessible on premises and available when needed, although interruptions in distribution systems occur occasionally, and water scarcity has occurred in some regions. Protection of groundwater, springs and surface water sources is often inadequate, and poor wastewater solutions often cause contamination of water sources. Microbiological contamination is common in SAC systems, and disinfection is often lacking even though it is required by law. When disinfection is performed, chlorination is the predominant method. Community resistance towards chlorination is common, and a main challenge for the implementation of disinfection in SAC systems. Geogenic fluorine is a serious water quality problem in some regions of RS, known to cause fluorosis in some communities. Pesticides are likely to contaminate many water sources, although monitoring is insufficient and the magnitude of the problem remains uncharted. Still, SAC systems very rarely use filtration systems or other treatment to address these contaminants.

In terms of reaching “safely managed water services” as defined by the UN, the rural population of RS generally have water accessible on premises and available when needed. The major problem is to ensure that the water is free from contamination. As seen in RS, SAC systems as well as SAA and SAI systems struggle to ensure that the water is free from faecal and chemical contamination.

2. What issues can be observed directly through a multiple case study of rural water supply services in Rio Grande do Sul?

The issues which were highlighted in the interviews with authorities and researchers and through literature reviews were also encountered in several of the case studies. This includes widespread issues with economic self-sufficiency, including cases where beneficiaries refuse to pay for water usage (the SAC of Laranjeiras), and municipalities which struggle to support remote SAC associations (Tabaí, Vila Nova do Sul and Turuçu). Two municipalities also struggle to draft a PMSB and access external support due to lack of technical and administrative capacity (Fazenda Vilanova and Vila Nova do Sul).

Problems with water source protection and water quality issues including microbiological contamination, turbidity and/or fluorine was observed in all municipalities. In some cases, water was taken from unprotected shallow wells in close vicinity to agricultural fields (in the SAC of São Domingos), and unprotected spring water sources with consistent serious water quality issues (in the SAC of Cambai). Non-revenue water is not continuously monitored in any of the systems which were visited, and longer interruptions have occurred in some systems. In several systems, water quality control does not meet the legislated requirements. No municipalities are reported to perform continuous monitoring of pesticides, even though agricultural areas are situated close many of the water sources.

Community resistance towards chlorination was observed in all the visited municipalities. Examples of this include cut-off chlorination hoses, testimony of community members asking operators to turn off chlorination, and chlorination systems which were disconnected and abandoned after installation (in Fazenda Vilanova, Tabaí and Vila Nova do Sul).

In short, the main observed issues regarded water source protection, water quality, monitoring and surveillance of water quality, monitoring of water losses, economic self-sufficiency of services, community resistance towards chlorination, absence of PMSBs and lack of external support.

3. What could be possible ways forward to ensure safe and affordable water for all in Rio Grande do Sul?

Efforts are needed on all levels to ensure safe and affordable water for all in RS, which demands resolution from communities, municipalities, support organizations and authorities. These actions concern technical improvements, generation of a demand for safe water amongst the population, an effective enabling environment, and increased investments in water and sanitation.

In order to decrease the presence of microbiological contamination, wastewater disposal must be managed adequately. This includes collection and treatment of wastewater where possible, and modernization of septic tank systems. Groundwater wells must be properly protected using sanitary seals and well caps and freshwater springs must be protected, for example through the method developed by EMATER. Pesticides need to be monitored further to assess the health risks, and watershed committees must work to minimize dispersal of pesticides and other contaminants to water sources within the catchments.

Disinfection systems has to be installed for all SAC systems to ensure inactivation of microorganisms, and the chlorination systems must be updated and properly operated to ensure adequate concentrations and contact times, without causing excessive concentrations and an undesirable chlorine taste. Water losses in distribution networks should be monitored to decrease non-revenue water and decrease the risk of infiltration of contaminated water into pipes. Where needed, filtration or other treatment steps should be used to combat high concentrations of fluorine, turbidity and other contaminants exceeding the legislated levels.

Educational efforts such as school campaigns should be implemented to cope with community resistance against treatment and gradually generate a demand for safely managed water services. Municipalities and SAC associations must cooperate and communicate using participatory approaches to ensure that proper solutions are achieved in rural areas. Economic self-sufficiency must be ensured through solidary and sustainable tariff structures, which make sure water is affordable for all while also creating an incentive against overconsumption.

Institutional rationalization is needed to provide an effective enabling environment, where funds allocated for water and sanitation are used efficiently, focusing on cost-effective solutions in vulnerable communities. Resources must be funnelled into the municipalities which are lacking in technical and administrative capacity, to assist with the creation of PMSBs and improvement of water and sanitation systems.

Finally, all stakeholders need to join forces and work together to achieve safe and sustainable water services for all, and make sure that no one is left behind.

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