Urban Water Security in India

A case study on Udupi

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Abstract

Water is the most important natural resource on earth as it fulfills humans' basic needs to survive. As people around the world become increasingly threatened by shortages or excesses of water, the topic of water security is receiving more attention by the scientific community. Water security is not only about having enough access to water resources, but also involves water governance and risks such as floods and contamination. It can be threatened by natural factors such as droughts or anthropogenic causes such as population growth and poor management. This research is a case study on the status of water security in Udupi, India. The aim of this research was to assess the status of water security in Udupi, study how this influences people's livelihoods, and find ways to improve the current situation. During a three mond field trip qualitative data was collected in order to assess the current situation. This data was then analysed and interpreted to create recommendations for the municipality- and inhabitants of Udupi that help to move towards a state of higher water security. The data shows that although there are still challenges in water supply, the major challenge to water security in the area is water contamination. In Udupi, many of the natural water sources, as well as the domestic wells are contaminated. This has a clear impact on people's livelihoods in the area. Consequently, it is recommended to increase public awareness about pollution, improve water management practices and develop the solid- and liquid waste management infrastructure.

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1. Introduction

1.1 Problem definition

Water is regarded as the most important natural resource on earth, yet freshwater systems are increasingly being threatened by humans (Meybeck, 2003; UNESCO, 2009; Vörösmarty et al., 2005). Since 2010, the UN has acknowledged that access to clean drinking water and sanitation is a human right and that it is essential for the realisation of all human rights (UN, 2020a). They formulated Sustainable Development Goal 6, Clean Water and Sanitation, as a blueprint for more sustainable water management (UN, 2020b). It has set targets and indicators for the supply of clean drinking water, construction of sanitation, decrease of pollution, and expansion of international cooperation to guide the process of becoming more water secure. Unfortunately, human activities such as agriculture, watershed reformation (i.e. dam building, chanalization), pollution and urbanization have a negative effect on the quality and availability of freshwater systems (Vörösmarty et al., 2010). These human impacts are further exacerbated by climate change which changes weather patterns to increase the occurrence of floods and droughts (Karl et al., 2009). Vörösmarty et al. (2010) show that an estimated 80% of the worlds' population faces a high threat to water security. The threat is especially high in India, because it is struggling to provide basic water services like clean drinking water and sanitation (Vörösmarty et al., 2010), there is large scale pollution, rapid population growth in urban centres, and a lack of water recycling (Shaban & Sattar, 2011).

The state of Karnataka, in South-West India exemplifies these threats to water security. It is the second driest state of India after Rajasthan, and almost all of its districts are affected by contaminated drinking water (Kumar, 2019). There is a water demand-supply deficit that is expected to double by 2030 and an increasing demand for water because of a growing urban population (Jenkins et al., 2017). At the same time, annual rainfall levels are declining and there is limited wastewater treatment leading to pollution. Udupi is a town on the Western coast of Karnataka that faces these problems. The river Indrani that runs through the city is heavily polluted because of a lack of waste (water) management (Prabu, 2019) and runs dry during parts of the year because of decreased water inlet (Shet, 2017). The negative consequences are extensive: Declining drinking water availability because of water well contamination (Ali & Shenoy, 2015), abandoned agricultural fields because of pollution and decreased water availability, and an increase in diseases such as dengue fever and allergic skin rashes (Shet, 2017).

1.2 Scientific background

A growing water demand-supply deficit poses a threat to water security. According to Cook & Bakker (2012), water security is a growing topic of interest in the scientific community. Although the term is relatively new and becoming increasingly popular, the underlying concepts are adopted from older, similar, headings such as Integrated and Sustainable Water Resource Management (IWRM & SWRM) (Hoekstra et al., 2018). Furthermore, the concept of *urban* water

security is a sub concept of water security that focuses on water security in urban areas because these areas come with their specific challenges such as population density and the import of water and other resources from outside the area (Hoekstra et al., 2018). Hoekstra et al. (2018) find that studies on water security are often framed from a certain perspective, such as protection against hazards (engineering), supply and demand management (water resources), functions and services (environment), and power, equity and conflicts (political). They stress the need for an interdisciplinary approach that focuses on a wider array of perspectives that take into account human development, governance, food and energy security, social equity and environmental sustainability.

In order to facilitate such research, Hoekstra et al. (2018) discuss five urban water security indexes in their review paper: The City Blueprint, the Sustainable City Water Index, the Water Provision Resilience Index, the Sustainability Index for Integrated Urban Water Management, and the Urban Water Security Indices and Indicators. The Urban Water Security Indices and Indicators framework developed by Jensen & Wu (2018) is the latest model and focuses specifically on urban areas. Therefore, this framework was used to assess water security in this study. This research fills the knowledge gap on water security in Udupi, India. Although there is some research in the area into related aspects such as borewell water quality (Shenoy et al., 2017) and natural drainage (Maddodi et al., 2011b), there is no interdisciplinary research available that integrates the various dimensions of water security. Therefore, this research will consist of a thorough analysis of the three dimensions of water security (supply, risk and governance), and will link this to theory of urban/ peri-urban water security, water quality & pollution, and sustainable livelihoods. As water is the most important natural resource, this topic is inherently linked to peoples' livelihoods: A shortage of clean water or an excess in the form of floods create risks to people's lives and ways of living.

1.3 Research aim and questions

The aim of this research was to assess the status of water security in Udupi, study how this influences people's livelihoods, and find ways to improve the current situation. This aim was translated in the following research question:

"How can the challenges to improving water security in Udupi be overcome?"

This research question is further divided into three sub questions:

1. *"What are the characteristics of the current and emerging water security challenges in Udupi?"*
2. *"How does pollution impact water security in Udupi?"*
3. *"How can the status of water security in Udupi be improved?"*

To answer these questions, theory was derived from literature that helped to create a conceptual model. Then, the framework was used to assess the current situation based on information collected through interviews, a media analysis, field observations and various documents. Whenever important findings came up that did not fit the conceptual model, the model was revised. This resulted in an empirical model that contains the important aspects found in literature, as well as concepts brought forth by the data collection process. Finally, the results of this research were analysed and interpreted in order to form recommendations to enhance Udupi's water security. Figure 1 presents the research framework, a graphical representation of all these steps.

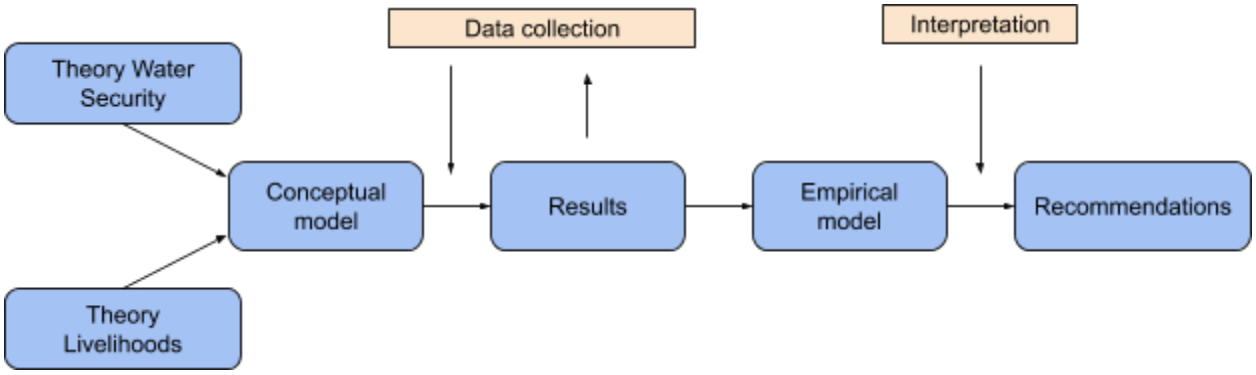


Figure 1: The research framework showing the different steps that will be taken in the proposed research. A conceptual model was made based on theory on water security and the livelihoods model. According to the results, this model was updated throughout the research to form an empirical model. Finally, this was analysed to create recommendations for improving the status of water security in Udupi.

1.4 Relevance

This study has both scientific and societal relevance. In general, this study has scientific relevance as it can be used as an example of how to conduct research in situations where data collection is difficult. During the covid-19 outbreak, qualitative data collection became very difficult because institutions were closed and people stayed at home. This research was set up in such a way that qualitative data could still be collected despite the challenges. It has demonstrated that it is still possible to conduct qualitative research in these situations by using different kinds of data sources that can mostly be found online in combination with observations and grounded visualization of the study area. This research also has scientific relevance because of its contribution to the field of Sustainable Development in general and water security specifically. Combining the concept of livelihood and the novel application of the Urban Water Security Indices and Indicators framework by Jensen & Wu (2018) resulted in a new way to study water security. This qualitative, interdisciplinary model facilitated the filling of the knowledge gap and generated new knowledge on the specific case of water security in Udupi. This study can be replicated elsewhere to get an overview of the status of water security in an area and on how people's lives are affected by water related issues.

The output of this research also has societal relevance because it can be used to meet the challenges to water security in Udupi. The research was set up in such a way that it generated recommendations for practical actions for improving how the Udupi society deals with water related issues. It successfully identified the obstructions to a more water secure Udupi and provided recommendations for policy makers and practitioners on the current challenges and possible solutions. Observation showed that there is often not much data available in the area on important water related issues. And when the data is available, it is often badly communicated. One of the contributions of this research is that it gives a clear and grounded view on the current situation. This information can be useful to all stakeholders to guide their thoughts, discussions and actions. In addition to providing data on current affairs, the study also provides recommendations for further action. These recommendations can help fasten and smoothen the transition to a more water secure Udupi. This paper can be used as the basis for reaching consensus on the current problems and the improvements that need to be made. Instead of endless discussions, stakeholders should come together, agree on what needs to happen and create a roadmap of how to get there. The results of this research can be used as a blueprint for such a roadmap to which everyone can be held accountable.

1.5 Effects of the COVID-19 lockdowns

Part of this research was a field trip to Udupi, India, in the months March, April and May of the year 2020. During this time, the coronavirus struck India and severe measures were taken by the government to contain its spread. This also had major repercussions for doing qualitative research in the area. After having switched from a quantitative to a qualitative approach because of a lack of available statistical data, the lockdown ensured that the second approach also became very difficult. People were not allowed to go outside, except to get medical supplies or other essential goods. Therefore, conducting qualitative interviews and focus groups in person became impossible. Unfortunately, it also proved impossible to snowball sample and conduct interviews over the phone; people were preoccupied with the effects of the virus and the lockdown and were very reluctant to participate. Therefore, parts of the initial research setup had to be revised. Especially the stakeholder analysis had to be scrapped as it was impossible to engage with most of the stakeholders. Other data sources were consulted, and fortunately, some of these contained the views of local people and municipal officials. This ensured that at least the qualitative approach could be followed to some extent. Another setback was the closing of the MAHE labs which made it impossible to test the quality of local water sources. Although this could have provided more detailed insight, other data sources gave a sufficient general view on the issues to answer the research questions.

1.6 Outline of this thesis

This chapter has introduced the problem of urban water security in Udupi, Karnataka, India. It also showed the scientific background in which the concepts that will be used in this research are embedded. Finally, it presented the research aim, questions and relevance. The next chapter will go further into the scientific background and explores the concept of urban water security as it will be used in this research. In the third chapter, the methodological steps that were taken to conduct this research are outlined. The fourth chapter presents the results of this

research, and in the fifth chapter the implications of these results are discussed. The sixth and final chapter presents the main conclusions of this research.

2. Theoretical framework

This chapter explains the theories and concepts that were used in this research. Theory about water security, quality, and sustainable livelihoods was combined to create a conceptual model fit for analysing the case in Udupi. As this research did not make use of any new concepts, it did not build new theory, but tested existing concepts.

2.1 Water security

A growing water demand-supply deficit poses a threat to water security. According to Cook & Bakker (2012), water security is a growing topic of interest in the scientific community. Although the term is relatively new and becoming increasingly popular, the underlying concepts are adopted from older, similar, headings such as Integrated and Sustainable Water Resource Management (IWRM & SWRM) (Hoekstra et al., 2018). Furthermore, the concept of *urban* water security focuses on water security in urban areas because these areas face unique challenges such as population density and the import of water and other resources from outside the urban area (Hoekstra et al., 2018). Hoekstra et al. (2018) stress the need for an interdisciplinary approach in water security studies so that they take into account human development, governance, food security, social equity and environmental sustainability. Consequently, it is agreed upon that research into water security should adopt a broad, integrated definition (Cook & Bakker, 2012; Jensen & Wu, 2018). The UN (2013, pp. 6) has holistically defined water security as followed:

"The capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability."

This definition shows that water security is not only about access to water, but also about its quality, and even water related risks such as floods and diseases. Jensen & Wu (2018) developed an indicator model for studying urban water security and stated that the four primary indicators are: Resources, access, risk and governance. Appendix A provides an overview of their sub indicators. As there was not sufficient quantitative data available in the area to map these indicators, the framework was used as inspiration for assessing water security qualitatively. The table in appendix A shows that the indicators resources and access both revolve around the supply and demand of water. Letting go of the quantitative indicators made the distinction between these two dimensions of water security less distinct. Therefore, it was chosen to approach this as one aspect of water security: Supply and demand. This involves the amount of water available in various sources, but also aspects like storage capacity and supply coverage and capacity. The other two dimensions, risk and governance, are more pronounced and were studied according to the aspects presented in the table in appendix A.

2.2 Peri urban water security

While Udupi city can be characterized as an urban environment, some neighbourhoods on the periphery, such as Kodavoor, are less dense and rely on agriculture Consequently, these neighbourhoods are not urban areas, nor rural areas as they are still heavily connected to the city. Therefore these areas are something in between: Peri urban. Ravetz et al. (2013) state there are no simple definitions, but characterize peri urban areas by relatively low population density compared to urban areas, scattered settlements, high dependency on transportation for commuting, fragmented communities, and a lack of spatial governance. Adam (2001) points out that a peri urban area can not be recognized as a discrete area, but rather as a diffuse area of combinations of features generated by the relation with the urban area.

Narain et al. (2013) conducted case studies in South Asian cities and villages to research water insecurity in peri urban areas in relation to neighbouring cities. They found that urbanization leads to a higher demand for water in the urban area, creating a battle for resources that peri urban residents almost always lose. The expansion of Gurgeon in India for example, caused increased water insecurity in neighbouring peri urban areas because water was extracted from the outskirts and transport to the urban area. Additionally, private lands from the surrounding villages were seized to create water treatment plants for the city (Narain et al., 2013).

Even within peri urban areas, issues and inequalities can exist. In the surrounding villages of Gurgeon, the elite use expensive technologies to pump water for their lawns and orchards, while the poor are left without any water for basic survival needs (Narain et al., 2013). In Hyderabad, presence of industries in peri urban areas caused pollution of local water sources as effluent was discharged in fields or rivers without treatment. This forced farmers to change or reduce cropping due to polluted groundwater and soils, and some of the people were forced to sell their land and seek a job in the city (Narain et al. 2013). In this way, the pollution did not only affect the water sources, but even the income and nutrition of people living in peri urban areas. The contamination of surface water and saline groundwater also increases the prevalence of waterborne diseases as cholera, diarrhea and dysentery. In the case studies, Narain et al. (2013) identified the following health implications: Skin disease, headache, cough and cold, fever, diarrhea and eye infection.

Population growth in the city thus increases urban encroachment, its environmental footprint to outside the city boundaries, competition for local groundwater sources, the water flow from peri urban to urban areas and pollution of peri urban water sources (Narain et al. 2013). These constitute the elements of water insecurity in peri urban areas. The case studies showed that these elements can have cascading effects on livelihood opportunities as people lose access to property and (free) clean water sources, experience increased health issues, and are sometimes forced to seek employment elsewhere and sell or abandon their property. Narain et al. (2013) discussed three possible interventions for dealing with these issues: (i) Lobbying with service providers to take peri urban residents into account and provide a forum for dialogue, (ii) form water management committees to improve water distribution in the area, and (iii) policy advocacy to prevent encroachment and pollution.

2.3 Water quality and pollution

After the first interviews with experts on water security in the area, it could already be concluded that the main threats to water security in the area lie with the pollution of the Indrani river and to a lesser degree with seasonal flooding. Therefore, this study shifted its main focus to the risk dimension of water security, and mainly to water pollution.

According to Chaudhry & Malik (2017), water quality is influenced by many factors such as; Precipitation, climate, soil type, vegetation, geology, flow conditions, groundwater and human activities. Natural factors such as precipitation and vegetation can influence flow conditions and thereby the self-cleaning capacity of rivers. A steady flow washes away most contaminants, but if the flow is disrupted, pollutants accumulate and contaminate the water source. Additionally, natural factors decrease the potability of water, for example the geology can create hard or acidic water, or contaminated groundwater can pollute other water sources (Shenoy et al., 2017). These natural factors then enhance the effects of human activities. Human activities can create pollutants, or: "Substances that cause undesirable effects or spoil resources when introduced to the environment" (Chaudhry & Malik, 2017, pp. 1). Pollutants can have many sources such as chemical pollution from industry or agriculture (metals, ammonia, nitrate) or bacteria from untreated sewage (e.coli). Previously performed case studies show that most water quality tests look at indicators such as heavy metal contents (Rhamanian et al., 2015), ph, conductivity, turbidity, biological- and chemical oxygen demand, chlorides, hardness (Ali & Shenoy, 2015), ammonia, nitrate, iron, total coliform bacteria and e.coli (Narain et al., 2013).

2.4 The sustainable livelihood framework

In the case studies of Narain et al. (2013) it became apparent that a threat to peri urban water security can negatively influence people's livelihoods. To assess what effects the status of water security has on its people, the sustainable livelihood framework will be used. Scoones (1998, pp. 5) defined a sustainable livelihood as:

> *"A livelihood comprises the capabilities, assets (including both material and social resources), and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stress, shocks, maintain or enhance its capabilities or access, while not undermining the resource base."*

Combining the concepts of water security and livelihood creates the possibility of finding out what water insecurity means for the way of living of the people in Udupi. The ability to pursue or maintain a certain livelihood is dependent on the resources, or capital, a person or household possesses. Scoones (1998, pp. 7-8) defined the following four capitals:

Natural capital: *"The natural resource stocks (soil, water, air etc.), and environmental services (hydrological cycle, pollution sinks etc.) from which resource flows and services useful for livelihoods are derived."*

Economic or financial capital: *"The capital base (cash, credit/debt, savings, and other economic assets including basic infrastructure and production equipment technologies) which are essential for the pursuit of any livelihood strategy."*

Human capital: *"The skills, knowledge, ability to labour, and good health and physical capability important for the pursuit of different livelihood strategies."*

Social capital: *"The social resources (networks, social claims, social relations, affiliations, associations) upon which people draw when pursuing different livelihood strategies requiring coordinated actions."*

The livelihood framework is more extended than just the capitals, it also contains concepts as context, conditions and strategies. As this research merely has the aim of describing an effect on livelihood as opposed to creating strategies on how to improve them, the inclusion of just the capitals was deemed sufficient. In this research, the effect of water (in)security related issues on the different capitals of people was mapped in order to assess how these issues affect people's lives.

2.5 The conceptual model

The previously discussed concepts can be summarized in a conceptual model. The model is visible in figure 2 and presents the concepts and their interrelatedness of this study.

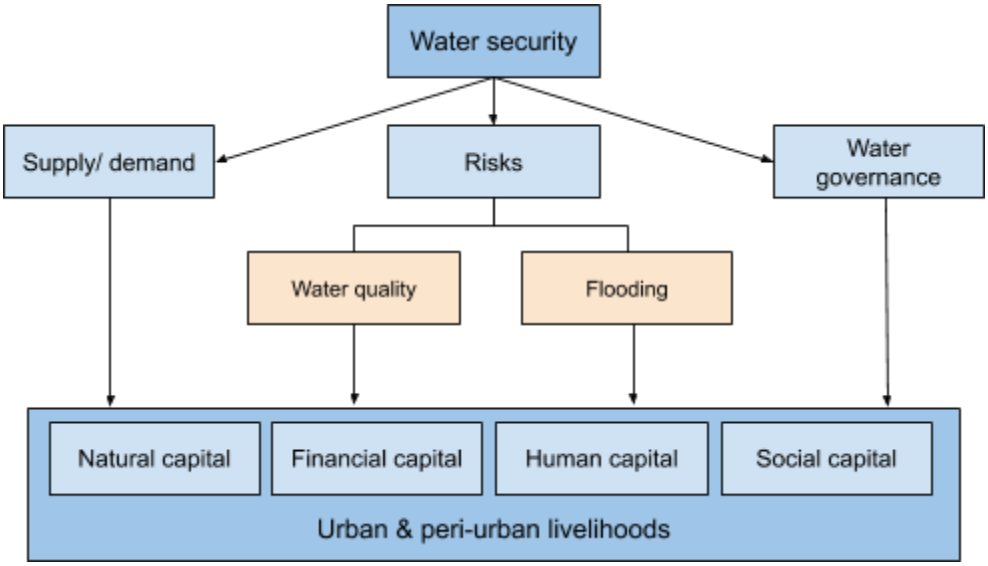


Figure 2: The conceptual model; a graphical representation of all the theoretical concepts used in this research. It shows how the concept of water security is assessed on three dimensions: Supply and demand, risk (consisting of water pollution and flooding) and water governance. Throughout the study, the effect of these dimensions on the livelihoods of people living in the urban and peri-urban areas were observed.

3. Methods

3.1 Research design

The aim of this research was to provide insight into the water security of people living in Udupi. The best research design applicable to this aim was a case study as its emphasis tends to be upon an intensive examination of one case (Bryman, 2012). A qualitative approach was used to collect data that could provide insight into the status of water security from the perspective of the people in Udupi. Different data products were used to facilitate triangulation and completeness. The use of different forms and sources of data allowed for cross-checking and thus a more coherent and complete answer to the research questions (Bryman, 2012).

3.2 Operationalization

The first sub question was mainly answered by the initial interviews at the start of the field trip. The water security indicator model designed by Jensen & Wu (2018) was used as inspiration for the development of semi-structured interview guides. These guides facilitated the initial interviews with experts on water security and treatment, waste management, and a local representative. The interview participants indicated that, although there are issues with water supply and governance, the most pressing issue was the pollution of the Indrani river. Therefore, the rest of the research focussed on pollution, waste management and the impact of pollution on the city and its inhabitants. In order to answer the second sub question, actors were interviewed in order to find out what the causes and consequences of the pollution were. Other sources such as policy documents, previous research, and media were also consulted to gain a more comprehensive view on the issues. After careful analysis of the results, an assessment was made on the current situation and the challenges to water security. Throughout the analysis of the results, specific attention was paid to the concordance of information coming from different types of data sources. Then, the last sub question was answered by providing recommendations for overcoming the challenges to water security in Udupi.

3.3 Data collection

The data collected during this study came from desk- and field research. To define the concepts that were used in this study, an initial desk research was performed. Scientific theory and literature was consulted via search engines such as Google Scholar and Scopus. Additional grey literature was consulted through various internet sources.

In order to gather qualitative data in-depth semi-structured interviews were conducted. This type of interview follows an interview guide to provide structure to the interview and focus on the concepts that need to be studied while allowing flexibility in ordering and asking the questions (Bryman, 2012). The interview guides used in this research can be found in appendix D. Purposive sampling was used to target specific interview participants. At the start of the interview, the participants were explained about the research and asked to read and sign a research information - (appendix B) and consent form (appendix C).

The data from four interviews was supplemented by data from news articles, other research conducted in the area, project- or municipal documents and observations. A complete list of all these sources can be found in appendix E. The media analysis was conducted by researching Indian newspapers on the internet such as 'The Hindu', 'Deccan Herald', and the 'Udayavani'. Some articles were in the Hindi language and translated by Google Translate. These articles provided additional insight in the status of the different dimensions of water security in general, and the problems concerning pollution specifically. Many of these articles reported the opinions of citizens and politicians and thus were very useful to understand the concepts from their perspective. The research previously conducted in the area supplied more specific information about the status of water quality and waste management in the area. And the project- and policy documents gave more insight into the measures that are in place, or being taken, to increase the water security in the area. In addition, observations were made of the important areas of the research site such as the river, lakes and neighbourhoods surrounding the river. The entire river was observed from origin to the sea to see where it runs dry, where it becomes an actual river, and especially where the major sources of pollution were. Additionally, walks in the area facilitated the observation of the waste management system, such as collection methods, but also various dumping grounds. Throughout the observation process, pictures were taken to create grounded visualization. These pictures were used as a supplementary form of data that facilitated providing proof and examples of the matters discussed throughout the research results.

3.4 Data analysis

After the data was collected, it was analysed by the framework analysis method. This is a systematic, comprehensive data analysis method that is grounded or generative; it is based in and driven by the original accounts and observations of the people it is about (Srivastava & Thomson, 2009). It follows the larger narrative from the theory, but is flexible enough to allow for concepts to emerge from the study. It is a useful method when the aim is to eventually provide recommendations and consists of 5 steps: Familiarization, identifying a thematic framework, indexing, charting, and mapping and interpretation (Srivastava & Thomson, 2009).

During the familiarization step, all data was put together and a first scan was made. This involved listening to audio tapes, reading transcripts, going out in the field, and reading summaries of the news articles, papers and documents. During this process, recurring themes were identified that could be used for the second step: Identifying a thematic framework. Part of the thematic framework was established a priori by studying water security theories, but other important issues came up during the analysis part. Important concepts that came up were the effect of water security issues on peoples' livelihoods and the role of the waste management system related to the risk dimension of water security. Once I familiarized myself with the important concepts and data, the data was indexed. First, all data was coded according to their source in order to keep track of it once the parts were taken out of context. The data products were numbered 1 to 5, and each unique source of that product was assigned a letter. For example: The first media article was coded '1a', the second '1b', and the first interview 'Interview 1' etc., the complete list of all sources can be found in appendix E. Afterwards, the data topics

were coded with colors. For example: All data related to waste management was marked orange, and everything related to livelihood impacts blue. A list of all identified data topics can be found in appendix F. During the fourth stage of the framework analysis method, charting, all data was organized based on their color, with the numeric codes after each sentence or statement to keep track of the source. The result was a completely organised data set on the basis of the research topic, with the data sources attached. This was then used to write out the results section of this research. Afterwards, the numeric codes were replaced by the correct references. In the final stage, mapping and interpretation, the key characteristics of the data were identified. This resulted in the construction of an emerging empirical model (figure 12, chapter 5) and led to the formulation of recommendations.

3.5 Research quality

The quality of this research was assessed through its internal- and external validity and its reliability.

Internal validity is defined as: *"A concern with the question of whether a finding that incorporates a causal relationship between two or more variables is sound"* (Bryman, 2012, pp. 713). So internal validity is about causality between concepts. As the literature is clear on the relationship between water security and pollution (Jensen & Wu, 2018), as well as the effect of poor water security on peoples' livelihoods (Narain et al., 2013), the internal validity of this research is expected to be high.

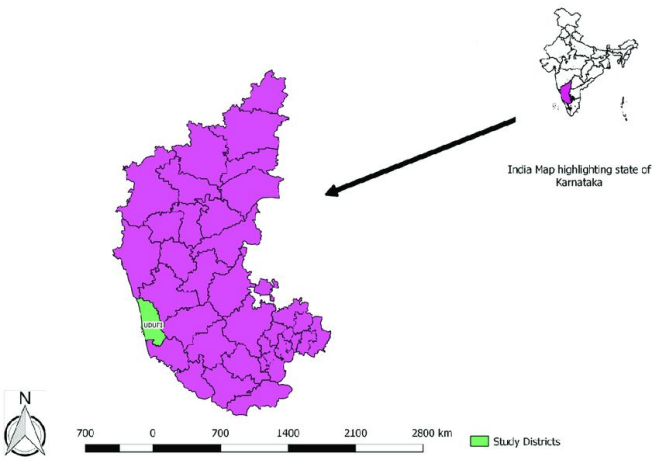
External validity is defined as: "*A concern with the question of whether the results of a study can be generalized beyond the specific research context in which it was conducted"* (Bryman, 2012, pp. 711). The research design of this study is a case study, and thus by default the results can not be generalized beyond the specific research context and area. Therefore, the external validity is low.

Reliability is defined as: *"The degree to which a measure of a concept is stable"* (Bryman, 2012, pp. 715) and is related to the concept of replication, or the degree to which results can be reproduced (Bryman, 2012). The replicability of a study is influenced by the methodological steps and data availability. As the methodological steps were explained clearly and the data came from sources that anyone can access, the reliability of this study is high.

3.6 Research site

Karnatak is one of India's 29 states, it lies in the South-West of India and is further divided into 30 districts (Sanju et al., 2019). Karnataka's capital is Bangalore, which is famous for being a major IT, biotechnology, and aerospace technology hub. Furthermore, the state the fourth largest producer of agricultural crops in India, and has a large tourism industry with famous destinations such as Hampi and Udupi (IBEF, 2020). Figure 3 shows that Udupi district lies at the Western coast of Karnataka and is home to almost 1.2 million people (Sanju et al., 2019). The district has a very high literacy rate (83%) compared to the national average (59,5%) (Udupi, 2020). In a 2011 city census, it was found that the city of Udupi has a population of

125.000 people with a literacy rate of 93,55%, showing a clear difference between the rural and urban population (COI, 2011). Furthermore, almost 84% of the cities inhabitants are Hindu, followed by 8% Muslim and 7% Christians (COI, 2011). If the outgrowths of the city are taken into account, the total population of Udupi is almost 145.000 people of which 6% live in slums (COI, 2011). The main spoken dialects are Kannada, Tulu, and Konkani (Mathews, 2012).



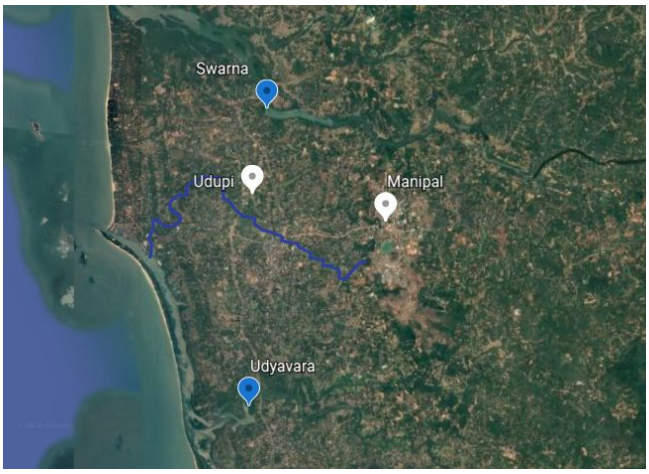


Figure 3 (Left): Map showing Udupi (green), Karnataka (purple) and India (Sanju et al., 2019).
Figure 4 (right): A map of Udupi, Manipal and the major water bodies. The blue line is the Indrani river, the Swarna river is located north of the city, and the Udyavara to the south. All three end up in the Arabian sea in the West.

Udupi has a hot and humid climate through large parts of the year. The summer ranges from March to May and is characterised by high temperatures and very little rainfall (Mathews, 2012). Afterwards, the monsoon season starts which lasts until September. The average annual rainfall is about 4200mm and there is an average of 124 rainy days a year (Mathews, 2012; Maddodi et al., 2011b). Rivers running through Udupi district originate in the Western Ghats in the east of Karnataka and end up in the Arabian sea (Maddodi et al., 2011b). Figure 4 shows those rivers: The Swarna to the north and Udyavara to the south. In Manipal, a small town to the east of Udupi, the Indrani river originates. This river runs through Udupi and also ends up in the Arabian sea. The water from this river feeds domestic water wells and was used for domestic use and agriculture. Unfortunately, the river has been severely polluted during the last decades making it impossible to use it anymore (Prabhu, 2019).

3.7 Host institute

During the field trip to Udupi, I stayed at the Manipal Academy of Higher Education (MAHE) campus in Manipal. This is a renowned university established in 1953 and now teaching over 28.000 students (MAHE, 2020). The main campus lies in Manipal, but there are also other campuses in Mangalore, Bangalore, Sikkim, Jaipur and even some abroad. It is an official partner university of dozens of universities across the world, including Utrecht University in the Netherlands. Professor Sanghamitra Roy of the Faculty of Architecture at the Manipal Institute of Technology has supervised the research during the 3 months stay at the MAHE campus.

Additionally, Professor Ajay Bailey of Utrecht University has supervised the entire research process.

3.8 Ethical considerations

Ethical considerations were made, especially because this is a partly qualitative research which is characterized by a trust relationship between the researcher and participants and the discussion of sensitive subjects (Hennink et al., 2011). When conducting interviews it is important that participants are always made aware of the fact they are participating in a research study, that they participate voluntarily and that they give informed consent. A project information sheet (Appendix B) and a consent form (Appendix C) were designed to provide information to participants and provide proof of informed consent. Furthermore, it is important that participants will not experience any negative consequences from taking part in the study so their identity had to be protected at all times. This was partly done by not asking for any personal information, but also by deleting any information from the interview transcripts that could lead to their identity. Thirdly, as India and the Netherlands are culturally very different, Professor Roy was consulted to discuss any cultural sensitive issues that need to be taken into account during the interviews. Finally, this study also made use of photography. In order to respect people's privacy, pictures were taken in such a way that there are no people in view. Of the few pictures that did contain people, permission was asked first to take the pictures. In addition, the purpose of the photographs and a brief overview of this study was explained.

4. Results

4.1 Water security

This research looked into the status of water security in Udupi. Here, the results will be presented according to the structure of the diagram shown in figure 5. This chapter will first discuss the resources, risks and governance related to water security. Then, the impacts on people's livelihoods will be discussed, as well as the differences between urban and peri-urban areas. Finally, the current challenges and the solutions proposed by various stakeholders are presented which forms the basis for the recommendations given in the next chapter.

Figure 5: Diagram showing the relation between the concepts of this study. Water security is assessed by looking at resources, risks and governance, and its impact on livelihoods. The challenges and proposed solutions regarding all these aspects are also mapped.

4.1.1 Water supply and demand

The first dimension of water security is the supply and demand of water. This section discusses the challenges to meeting the demand and current developments in increasing the supply.

Challenges to meet the demand

Udupi faces many difficulties in meeting its water demands. It lies in Karnataka, a state that is characterized by its dryness. There is a monsoon season running for four months, from June to September, but outside the season there are often water shortages. Figure 6 shows there are two relatively large rivers located outside Udupi, the Swarna in the North, and the Udyavara in the South. At present, Udupi draws water from the Swarna to meet most of the urban water needs (KUIDFC, 2018). There is one river running through the city, the Indrani, but this one is much smaller in size and is severely polluted. Unfortunately, these water sources are not enough to meet the water demand of the city. Especially in the dry season the city faces shortages and needs to ration its water supply to civilians (Moodubelle, 2020b). Currently, the water demand for Udupi and its including outgrowths and adjacent villages is estimated to be 39 million liters per day (MLD). This is expected to rise to 47 MLD in 2031 and 57 MLD in 2046 (KUIDFC, 2018). Clearly, extensive measures need to be taken to prevent extreme water shortages in the future.

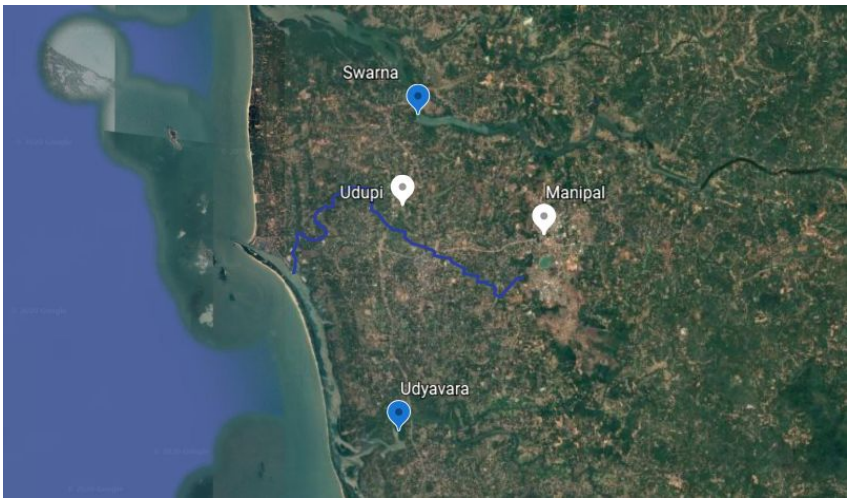


Figure 6: A map of Udupi, Manipal and the major water bodies. The blue line is the Indrani river, the Swarna river is located north of the city, and the Udyavara to the south. All three end up in the Arabian sea in the West.

The main challenges for meeting the current and future water demand are; A shortage of water sources in the dry season, increasing water demand, an old, insufficient and leaking distribution system, and a weak management system (KUIDFC, 2018; KUIDFC, 2019d) (See figure 7). Based on the interview with the water security expert and media, it becomes clear the water shortage exists because the wells are contaminated, the Indrani completely dries up, and the water stream in the Swarna is severely reduced during the dry season. The water demand is increasing because of population growth and yearly increases in tourism (COI, 2011; Udayavani, 2020c). Especially regarding the management of water related issues, there are a lot of complaints from citizens. The local representative that was interviewed was in concordance with people's complaints expressed in the media stating that water supply in the whole city is insufficient and irregular, most, if not all, water sources are polluted, and existing infrastructure is very poorly maintained. Many water wells are polluted, and it is estimated that hundreds of wells in Udupi and nearby villages are unsafe due to the threat of collapsing (Times of India, 2018). Short term solutions suggested by the water security expert and in the media are to pump up water from wells or nearby rivers, and transport this to the city by water tankers. One of the city's water sources is the Baje dam, which holds water to create a reservoir that can be tapped when necessary. Recently, the municipality has dredged the dam to increase its storage capacity in the hope this will ensure meeting the water demands of the city (Moodubelle, 2020a). The long term solution proposed by the water security expert and in the media is to tap water from another river and to revive the Indrani and urban wells.

Figure 7: The different elements that create pressure on Udupi's water resources

Developments of increasing the water supply

In order to guarantee sufficient and continuous water supply in the future, Udupi is part of a project that aims to improve water infrastructure and management. The plan is called the Karnataka Integrated Urban Water Management Investment Program (KIUWMIP), it is executed by the Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC), and funded by the government of India and the Asian Development Bank (ADP) (KUIDFC, 2019a). The project consists of two tranches, one targets the cities Byadagi, Davangere and Harihar, the second Mangalore, Kundapurra, Putur and Udupi. The total loan available for the second tranche is 110 million USD, of which 66% is provided by India and 33% by the ADB (KUIDFC, 2019a). For Udupi this means that another water source, the Varahi river, will be utilized to meet its water demand. The estimated time of completion is in 2022 and the project has three intended outputs: (i) upgrading and expanding infrastructure, (ii) improved water resource planning, monitoring and service delivery, and (iii) strengthen institutional capacity (Sanjiv, 2019; KUIDFC, 2019d). To facilitate this, 384 km of new pipelines will be laid and 7 new overhead tanks will be built (KUIDFC, 2019c). 17.000 faulty water meters will be replaced and 15.000 new connections will be created to include uncovered households in the system (KUIDFC, 2018). Additionally, training programs will be created for developing administrative and water management capacity (KUIDFC, 2019a). Initially, this project was designed to also renew the sewage infrastructure of Udupi. Unfortunately, the project costs are exceeding initial estimates. Therefore, the choice has been made that only Mangalore will receive the sewage infrastructure upgrade, the other cities just receive a water supply upgrade (KUIDFC, 2019b).

The KIUWMIP reports, and especially the consultation meeting minutes show that, although this project is a step in the right direction, still a lot of issues are not taken care of. Citizens are sceptical about the implementation time of the project, and stress the need to tackle other pressing issues (KUIDFC, 2018). The supply of a continuous stream of water to the city is vital to meet the basic needs of citizens, but this project does not solve all the issues and might even exacerbate some. One of threats pointed out in the environmental impact assessment was that increased water supply and use will increase the sewage flows, which in turn causes more pollution (KUIDFC, 2019d). It is important that these effects are not overlooked in finding long term solutions to the situation. Some citizens argue that it is better to use local sources for their freshwater supply (Udayavani, 2020h). The water security expert pointed out that almost all households have a well such as the one in picture 1, and that people don't have to rely on distant water sources once the river and wells are restored. This decreases the pressure on the municipality to provide river water to thousands of people and increases the livelihood opportunities of people living in the urban and peri urban areas as we will see later on.

Picture 1: Domestic water well. If the natural water sources are restored, Udupi's residents can become self-sufficient again.

4.1.2 Risks

Water security is not only affected by the available resources but also by the water related risks in a given area. As visible in figure 8, risks constitute potential flooding and contamination of water sources. This chapter discusses what risks Udupi faces.

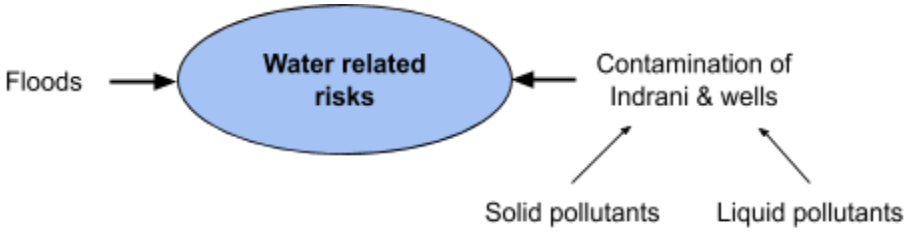


Figure 8: Water related risks in Udupi are floods and contamination.

Floods

Udupi district has developed an extensive disaster management plan in line with the Disaster Management Act of 2005 that assigns the authority for disaster management to the district level (Vishal, 2016). The responsibilities at the state level are creating policy, decision making and budget allocation, as well as monitoring through the State Emergency Operation Centre (Vishal, 2016). At sub-district level, Udupi district is further divided into three Taluks and many Panchayats (townships), each having their own disaster management plan in line with the district directives. The plans include detailed guidelines for various departments (police, fire brigade, health officers etc.) on how to act in case of any emergency. It also outlines preventive measures that need to be taken to mitigate the effects of future floodings, such as building awareness, flood embankments, deepening channels and preventing any constructions within 200 meters of the rivers (Vishal, 2016). Observations point out that the latter is definitely ignored in Udupi; all across the Indrani houses are built close to the river. A review of news articles showed that floods are very regular and cause severe damage and occasionally even casualties in the *district* during monsoon season. It also becomes clear that *the city* of Udupi is less affected, which can partly be explained by the fact that the larger rivers (Swarna & Udyavara) are flowing around the city. However, in the coastal part of Udupi city, such as the wards Kodavoor and Kalmady, there is a serious threat of flooding during the monsoon season. A local representative that was interviewed indicated that this is not an issue of serious concern to them. They are experienced with dealing with the floods and there are early warning systems in place which enables them to minimize the damage caused by the floods. In the long term, it is desirable to create more water retaining capacity in and around the city, but it is not of high priority at the moment.

Contamination

Water contamination is a serious issue in Udupi. During the interview with the water security expert, it was even named as the most important aspect of water security which becomes visible in textbox 1.

Textbox 1: The importance of pollution according to a water security expert.

> "The main problem is the pollution, once that is solved you can use the water [of the river and wells] again"

In the media, many citizens tell stories of their childhood when the Indrani was still clean, how they drank straight from the river, and swam in it, how on the riverbanks their mothers washed clothes and fathers sat fishing. Today, however the situation is very different, instead of crystal clear the water is now turned to a nasty brown color. Textbox 2 shows a quote from the interview with a local representative stating that the wells close to the river also become contaminated as the dirty water seeps into the ground. Data from the media analysis supports this statement and gives estimations of the number of polluted wells in the city that range from 300 to 700 (The Hindu, 2019a; Prabu, 2020). As almost every household possesses a well, this is a major problem, but could also be part of the solution to water supply (textbox 1). As discussed before, the majority of the citizens now receive their water either via pipelines or from water tankers that distribute the water. During the interview, the local representative pointed out that the water supplied through the pipes comes very irregular, and usually just 1 or 2 hours per day. Textbox 3 shows a quote of the interview indicating that the water they buy as an alternative is of poor quality.

> "Along the 17-18 km stretch of the river, to at least 1 km outside the riverbank the wells are polluted"

> "The trucks pump up water and sell it directly, but it is dirty water. We always treat it before we drink it"

Textbox 2 (left): The local representative speaking about the effects of the polluted river.
Textbox 3 (right): The local representative speaking about drinking water quality.

According to the water security expert, the situation of the polluted river is worsened by an increase in drainage. Observations near the source of the Indrani showed that water is pumped up in the area by private companies to be sold to citizens. Additionally, large apartment buildings, offices or university buildings create their own borewells to harvest groundwater (Shenoy et al., 2017). These two actions decrease the local water table, and thereby the water pressure that is needed to let water stream into the river and wells. The water security expert said that, because of the increased drainage, the river now falls dry for most part of the year, whereas 40 years ago it used to stream all year long. Consequently, the concentration of pollutants rises as they are no longer washed away. Additionally, the local representative indicated that, as the water comes to a stand still, pools of water form that are breeding places for mosquitos resulting in an increase of mosquito related diseases in the area. An artificial lake (Manipal lake) was created to partially combat this effect and create more pressure on the water

table. This has caused some wells to fill with water again, but is not a long term solution to the problem as it does not tackle the real causes. It is worth mentioning that the KIUWMIP studies conducted water quality tests of wells in Udupi, and found that their contamination levels were very minimum and mostly consisted of too high salt concentrations (due to seawater intrusion during dry season) (KUIDFC, 2019d), this is supported by a study by Shenoy et al., (2017). Yet, the wells that were subject of the study were deep bore wells used by large buildings, not the common wells like picture 1 most citizens have in their backyard. According to the water security expert, borewells are much less prone to contamination as they lay deeper in the ground and are often covered by not only soil, but also granite layers which are hard to penetrate by contaminants. No data on the water quality of domestic/ smaller household wells in Udupi was found.

Solid pollutants

It is clear that the pollution of the Indrani river takes place in Udupi city. At the place where the river originates, in a temple in Manipal, the water is completely clean, but the further downstream you go the dirtier it becomes. The pictures on pages 26 and 27 clearly show that the water in the Indrani increases in volume while going downstream, but also gets a foul brown/ black colour. The Indrani river is polluted by both solid and liquid waste. The types of solid waste that are mentioned most by the interview participants and in the media are; 'Garbage', plastic, vegitative components, and construction debris, but during field observations it became clear that anything can be encountered in the river or on its banks. Pictures 2 and 3 are some examples of the different types of waste encountered in, and on the banks of the Indrani.

Pictures 2 (left): This picture was taken on the border of Manipal and Udupi, thus near the start of the river. It shows the riverbed of the Indrani being full with styrofoam cases. Along the riverbed there were many of these spots that were clearly used as garbage dump.
Picture 3 (right): This picture was taken in the centre of Udupi. It shows the Indrani riverbed which is almost dry because of the dry season. It also shows different kinds of waste: Plastic bottles, metal cans and vegetation such as dead palm tree branches. This debris gradually wears down over time and releases contaminants into the water. Additionally the flow is obstructed by the waste that is thrown in and by the vegetation that is visibly growing inside the riverbed.

The sources of this waste are numerous. Based on the interviews and media analysis the following sources were identified: Locals and outsiders come to the river to dump their domestic waste, wind and rain causes tree branches and leaves to fall in the water, students litter, migrant workers live close to the river and use it as their private dust bin, and even local small scale industries, hotels and temples are reported as polluters. Between the data sources, there was some disagreement to what degree certain actors were responsible for the waste dumping. The water security expert said the main sources of pollution were not the people, but mostly the temples and small scale industries. The waste management expert said the temples used to be a big source of waste, but they have adapted after being made aware of their impact. The local representative indicated that the citizens can not be seen as a homogenous group, textbox 4 shows his observation. Although there might be some disagreement about the degree to which each actor pollutes, it is safe to say that almost everyone contributes to the problem. This was expressed by one citizen, as visible in textbox 5. The inadequacy of the government is mentioned more often. The interviews and media articles contained some accounts of polluters who come to known dumping places such as bridges, and of incidents where they gathered evidence such as pictures, but all the law enforcers did was give out warnings. The role of the government will be further discussed later on.

"The people close to the river care about it and don't throw anything in, but people from outside are coming at night and throw in their trash."

"Although the root cause of the problem is the lack of adequate drainage, the problem mainly lies with ourselves. The Indrani river problem is the inability to prosecute those who throw garbage in the water, the citizens not being organized and representatives not responding to the complaints of the locals."

Textbox 4 (left): Quote from a local representative stating his view on the source of pollution in the Indrani.
Textbox 5 (right): Quote from a media article where a citizen is stating his view on who is to blame for the current situation of the polluted Indrani (Udayavani, 2020g).

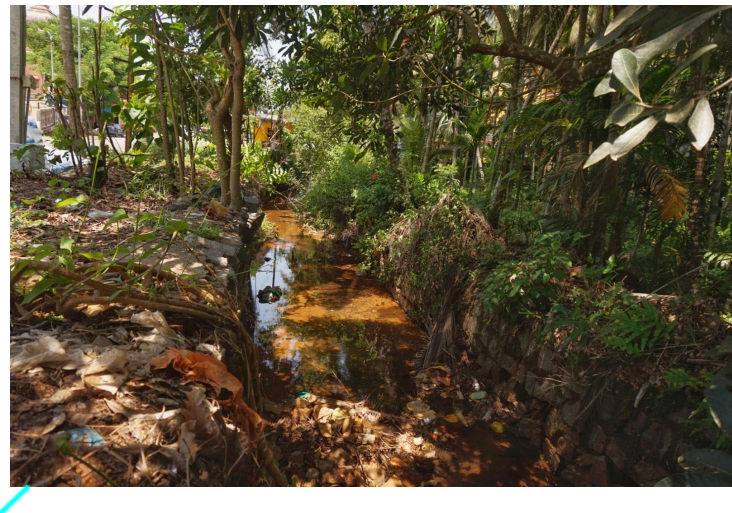
Liquid pollutants

In addition to the solid pollutants, the river is also affected by liquid waste streams. A variety of pollutants cause the groundwater, river and wells to become contaminated. From the media analysis and the interview with the water security expert, it becomes clear that sewage discharge is the main problem and some have stated that even the waste treatment plant of the city is dumping untreated sewage water into the river. In Kalmady, a ward at the end of the river stream, locals complained that the waste water from hotels, residences and hospitals are not even reaching the wastewater plant, but end up in the rivulet flowing through Kalmadi (Deccan Herald, 2011). This is all very plausible since even the government officials have stated that not more than 15% of the city is connected to the underground drainage network (Udayavani, 2020d; The Hindu, 2019b). The infrastructure is also in very poor condition. One example is that the pumps that pump the water through the pipe system regularly break because of a lack of maintenance (Udayavani, 2020a). And because it costs money to repair them every time, the

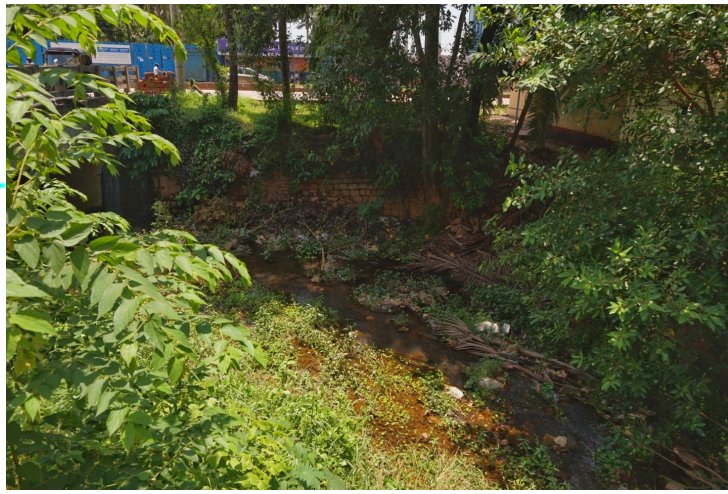
annual bill runs up. Consequently, the repairs are often postponed leaving the system broken and the wastewater to flow into the river (Udayavani, 2020a). According to the waste management expert and the KUIDFC (2019d), the groundwater in the city is not only affected by the polluted river, but also by domestic waste seepage. As many households are not connected to the sewage system, they have their own way of dealing with sewage. These ways are often not sufficient to deal with the pollutants effectively and thus add further to the contamination of the groundwater.

In an attempt to restore the freshwater sources in the area, the municipality has been making plans to completely revive the Indrani river by taking out all the contaminants (Prabu, 2020). In fact, they have already sent out tenders and made 16 lakh rupees (around 18.000 euros) available for the project (Prabu, 2020; The Hindu, 2019b). Yet, in order for this project to have a lasting effect, the *sources* of the pollution need to be exterminated. The first task of the government is to prevent the water from being contaminated, and only then can the river be cleaned (Udayavani, 2020c). According to the local representative, the government should increase pipe coverage, treatment capacity and upgrade existing treatment plants and solid waste management practices.

The next pages, 25 and 26, present pictures 4 to 16. These were taken along the Indrani river during the field trip. On page 25, a map of the upper basin of the Indrani is visible. It shows Manipal, Manipal lake (yellow), Udupi and the beginning of the Indrani. The river originates in the temple, and then flows towards Udupi. As it progresses, the river becomes wider, but also dirtier. Page 26 shows the lower basin of the Indrani. The river has much more volume in this part, especially where it meets the sea. The pictures in the right upper corner clearly show how much the river banks are polluted. And the picture on the left shows a close up of a dumping place next to a bridge over the Indrani.




Udupi
Manipal

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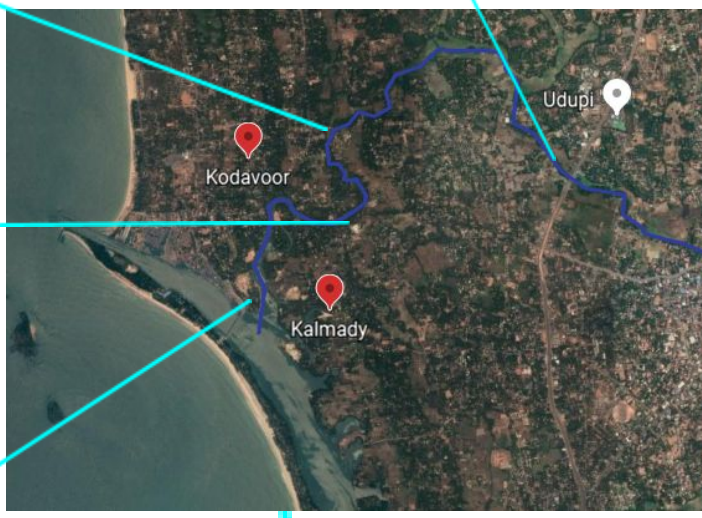

Udupi
Kodavoor
Kalmady

4.2 Waste management

An important aspect that came up during the study is waste management. Figure 9 shows the different aspects of waste management discussed in this chapter. Liquid and solid waste can both be managed in a centralised or decentralised way.

Figure 9: Centralised and decentralised solid- and liquid waste management practices in Udupi.

4.2.1 Solid waste management

The largest sources of solid waste in the river are littering locals and more large scale waste dumpers. Multiple sources indicate that the government does little more than give off warnings against the polluters. The local representative, as well as the people expressing themselves in the media, are fed up with this mentality and ask for a stricter approach in the hope that this will change people's behavior. There are no clear signs that the municipality and law enforcement have any plans for increasing their actions against waste dispersers and dumpers. It is also difficult to change people's behavior without giving them a reasonable alternative. At the moment, the waste collection infrastructure of the city still knows major shortcomings.

Pictures 17 (left) and 18 (right): These pictures were made in Manipal and show different waste collection trucks. In picture 17, workers collect waste from the little building which functions as a waste bin. In picture 18, someone is picking up waste from a condominium complex. In both cases, workers stand in the back of the truck to immediately separate the waste.

Waste collection

In Udupi, waste is collected by 18 vehicles, 16 trucks and 2 rickshaws (Maddodi et al., 2011a). Pictures 17 and 18 show different garbage collection trucks. The men standing in the back immediately separate the waste after it is loaded on the truck. The rickshaws collect domestic waste from 200-300 households per day and the trucks collect waste from stationary containers. This waste is brought to a primary collection point where it is loaded onto bigger trucks and brought to the landfill just north of the city. There, plastic bottles, aluminium and other materials that still have some value are segregated and sold by third parties (Maddodi et al., 2011a). This is a decent waste management system, were it not that its capacity is not enough to deal with the city's waste. The local representative that was interviewed estimated that waste from only 5-7 wards (of the 35) can be collected every day and that there is no fixed schedule of when a certain ward is collected. Apparently, they randomly drive around and collect waste, causing some areas to be overlooked. The local representative states that even if they did have a targeted approach, the capacity would not be enough to deal with all waste effectively. The waste management expert said the municipality distributed dust bins to households so that they can hold their waste until it is collected. Yet, in the media, one citizen remarked that there are almost no public dust bins and suggested these are installed at least every 500 meters along the Indrani riverside (Udayavani, 2020g). Field observations showed that the solution of citizens is to either dump the waste, or light it on fire such as in picture 19. In 2019, the government announced a new strategy for dealing with solid waste in the municipality (Deccan Herald, 2019b). In order to alleviate the pressure on the landfill, organic waste will be composted locally in the wards. The organic waste will be deposited in an open area and covered with earth to compost it (Deccan Herald, 2019b). This can then be given to farmers to use as soil enricher. They also asked residents, officials, flat owners, hotels, marriage halls will be asked to compost their own waste and use it for their gardens. Considering almost half of the waste in Udupi is biobased (Maddodi et al., 2010), this seems like a good idea to alleviate some of the pressure on the collection system and provide a more sustainable alternative to landfilling.

Picture 19: Locals burn organic waste and debris. This picture was taken in Manipal, but observation shows this is common practice all over India. As people do not rely on the waste management system, they regularly burn organic waste from their kitchen and garden, and sometimes also their domestic waste.

There is also a relatively new initiative for collecting and treating solid waste by the organization ‘Swachh Bharat’. The initiative is situated in the entire Udupi district and collects dry solid waste by e-rickshaws or goods-carrying vehicles (Swachh Bharat, 2019). It is then brought to newly established Solid and Liquid Resource Management (SLRM) centres, where it is separated for further use and treatment. The organization reports a change in people’s attitudes towards waste management; it is increasingly seen as an important cause and a new source of income. The project mainly employs women considering they are “more patient, reliable and better suited to communicate with women, who are usually in charge of domestic waste” (Swachh Bharat, 2019). Hereby, the project provides an opportunity for women to gain their own income or supply the household with additional income. Currently, the initiative covers 1/3rd of the district, employs 200 people and collects around 10 tonnes of waste per day (Swachh Bharat, (2019). Although this is not nearly enough to even cover the waste of Udupi city, the project is a good example of how waste management can be successfully performed by private parties.

Waste treatment

Another important part of the waste management system is how the waste is treated. Figure 10 shows the Ladder van Lansink, a picture that shows the desirability of each waste treatment option. Uncontrolled dumping is the least favorable option, followed by landfilling. Reusing materials is the most desirable. In general, Udupi performs badly because most of their waste ends up in the landfill and there are no plans to instal a waste incineration plant (Karelia, 2017). But they do separate some of the waste, and with this new plan for composting organic waste they are moving in the right direction. Combustible waste such as plastics, paper and cloth will be sent to cement factories to be used as fuel (Deccan Herald, 2019b).

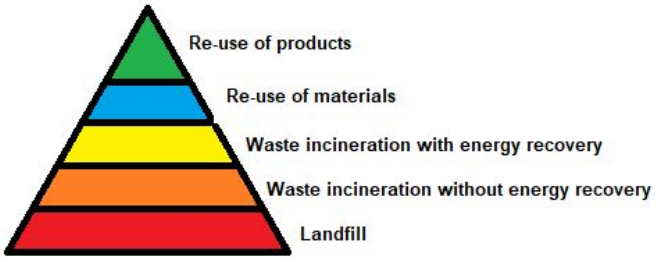


Figure 10: The ladder from Lansink, named after Ad Lansink, a Dutch politician who filed a motion in 1979 to work according to this hierarchy. This shows the hierarchy of treatment options for solid waste, the least preferred option is landfilling and the best option is to reuse products without the need for recycling.

Udupi’s landfill used to be located in (the ward) Beedinagudde, but has shifted to the edge of the city in Alevoor around ten years ago (Maddodi et al., 2011a). Maddodi et al. (2011a) conducted a study on this landfill and concluded that improvements need to be made in the operating procedures and that the capacity might not be enough in the near future. Udupi generated 8 tons of waste every day and 2 years after opening the landfill, already 12 of the 22 acres were used (Maddodi et al., 2011a). In 2017, the daily waste was reported to amount to 64 tonnes, of which 15% is recycled (Karelia, 2017). Furthermore, during the collection of waste in the municipality the trucks should be covered to prevent littering of collected waste, and on the

landfill premise, pipelines to collect effluents should be installed and the water around the landfill should be continuously monitored for water quality parameters (Maddodi et al., 2011a). By landfilling waste, especially wet waste such as organics, contaminants tend to seep into the ground and this landfill is no exception (Hallur, 2018). Actually, leachate was found in both landfills, but in Beedinagudde, the levels of most contaminants were below the required standards (Hallur, 2018). In Alevoor however, many contaminants such as heavy metals were found in the ground water with higher concentration than the standards for effluent water (Hallur, 2018). As there is no continuous monitoring and no follow up studies have been done since, it is unclear what the current situation is in terms of leaching from the landfill. Also in this regard, the new plan of the government is a step in the right direction. Keeping compostable materials of the landfill greatly reduces the pressure on its capacity, and will cause less leachate on the premise.

4.2.2 Liquid waste management

In order to create a cleaner environment and allow for reviving the river and groundwater, the liquid waste management practices in the area also need to be improved. The previous sections already briefly mentioned some aspects of this. This section discusses the different approaches to liquid waste management.

Centralised sewage treatment

Based on the interviews and media analysis, the biggest shortcomings of Udupi's sewage treatment system is the fact that only 15% of the city is covered by the underground drainage network, parts of this network are broken and sewage is discharged into the river. The system was designed for a town of 25.000 people, but today Udupi has more than 160.000 inhabitants (Deccan Herald, 2019a). The 24x7 water supply project of the KUIDFC will deal with water infrastructure, but not the underground drainage network. This is a missed opportunity, because it is a vital step in ensuring a cleaner urban area. Many sources discuss the municipal plans to create this infrastructure (Udayavani, 2020b; Udayavani, 2020d), but they are all outdated because the decision to not include this in the KIUWMIP project has been made recently. Therefore, at the moment it remains unclear if anything will be done in the near future to deal with the shortage of pipe infrastructure. In the media and interviews, the municipal water treatment plant was also heavily criticized by citizens as it is allegedly dumping untreated sewage water into the Indrani river. The municipality has acknowledged that the treatment plant is not working properly and promised it will be inspected and improved (The Hindu, 2019b).

Picture 20: A decentralised water treatment plant on the premise of an apartment building in Udupi. The water that exits the building runs through this installation in order to clean it up to water effluent standards so that it can be released into the environment.

Decentralised sewage treatment

The sewage pipelines and municipal water treatment facility are part of the centralised liquid waste management system. There are also decentralised options being utilized. The waste management expert said many households have septic tanks on their premise to deal with liquid waste. Depending on the construction of this well, the waste water can cause seepage and contaminate the groundwater. If the wells are completely made of cement, the water vaporizes because of the heat, and the pollutants are left in the bottom of the well as a residue. The local representative pointed out that there is no service to collect liquid waste from households. Larger condominiums and other buildings tend to have their own treatment system such as the one in picture 20. In Manipal, for example, there is no underground sewage system and people either have a septic tank or a treatment system. The MAHE university campus has pipelines that are connected to their own treatment plant. The treated water is used for maintaining the gardens. This is a general practice: During observation at other condominium complexes the same system was in place. Most installations are installed to clean well water before leading it to the residents inside buildings. According to the water treatment expert, the water that exits the building goes through less rigorous cleaning and is used as water for the gardens, agriculture or released to the environment. In practice however, the water is often not treated very well after it leaves the complex. The water treatment installations need continuous electricity supply (Shet, 2017). If the installation shuts off for two hours, it takes 21 days before it can be used properly again, said the water treatment expert. Power outages or blackouts can therefore severely disrupt the process. As a solution, a citizen suggested providing more generators to people using these systems (Shet, 2017). Another problem is the noise the systems produce. They are often installed on the premise, close to residential apartments where they cause a lot of disturbance. This creates an incentive for the owners to shut them off. When we arrived at the location of picture 20, the installation was shut off because of the noise.

According to the water security expert, civil servants responsible for water quality checks finding such poorly, or not at all, functioning systems are often paid to come back later.

Most large scale industries have their own effluent treatment system as well. For a long time it was very beneficial to use fresh water from the river or wells because it was much less expensive than using their own treated water. The water treatment expert said government regulation is now becoming stricter and more of these facilities are being built. Not every industry is regulated (evenly) because some industries need more extensive measures to treat their water up to standards. Not all the modern techniques are available, and if they are they are usually too big an investment. The water treatment expert's explanation is visible in textbox 4. The domestic installations are better regulated. Since a few years there are now clear building requirements which state that condominium complexes need to install their own water- and sewage treatment installation (Daiji World, 2013). The buildings that were built before this was a rule are expected to install such systems as soon as possible. For individual households the policy is that: "Households should take all possible measures to reduce the volume and load of septage on their own plot, using appropriate technology" (MDWS, 2014, pp. 30). So there is no requirement for any specific installation, but people are expected to deal with their liquid waste in a responsible manner.

"For these companies it is more difficult and expensive, they install some measures to look good enough and get away with it".

"There is an installation, but it is not run, no one knows how to run it or it breaks down and is not repaired."

"There is a tendency to invest a lot initially, but then completely fail on the maintenance and operations part".

Textbox 4 (left): The water security expert on the regulation of industries that need very rigorous water treatment.
Textbox 5 (middle): The water security expert explaining the struggles with unskilled employees.
Textbox 6 (right): The water security expert on attitudes towards maintenance and operations.

The water security expert made an interesting statement about the functioning of treatment systems, be it centralised or decentralised. In fact, it accounts to most businesses in India. There is often not enough expertise to work effectively and there is a mentality of job hopping, further increasing the problem of not having enough skilled people in the right positions. Therefore, there is not enough skilled labor for the production, installation and maintenance of treatment facilities. This sentiment is expressed in textbox 5. Something similar is stated by a citizen in the media, he points out that in the case of the maintenance of the wet wells and sewage treatment plant it is not a problem of insufficient funds, but of poor management and maintenance (Udayavani, 2020a). This comes back to the example of broken pumps. If they are regularly cleaned, they will not break down every few months (Udayavani, 2020a). But they are not cleaned and do break down, and then they are not repaired in a reasonable timeframe. According to the water security expert, this is an example of the lack of focus on operations (textbox 6).

4.3 Livelihoods

The pollution of the Indrani river impacts people's livelihoods in Udupi in multiple ways. In the media, citizens have given account of what the Indrani meant to them when it was undisturbed a few decades ago. Because of the water security issues in the area, people's natural, financial, human and social capital are negatively impacted. Figure 10 shows that livelihoods are impacted by the four different kinds of capital, and on all these aspects differences between urban & peri-urban areas can occur.

Figure 10: Livelihoods and capitals in urban and peri-urban environments.

4.3.1 Natural capital

People's natural capital consists of the natural resource stocks and environmental services from which resource flows and services useful for livelihoods are derived. In the case of water security in Udupi, this mainly means the soil and water in the area. The previous chapters already discussed the difficulties of supplying sufficient fresh water to the citizens, but that this becomes even harder because of polluted water bodies. The media articles and interviews showed that the people used to be able to rely on their own wells, or the nearby river for clean drinking water, but all of this has been contaminated now. The Indrani river had many functions like being a water source for bathing, laundry, drinking, fishing and agriculture. This natural flow has been polluted and, for parts of the year completely stopped (Deccan Herald, 2019a). The polluted water in turn pollutes the soil. This shows how this issue has affected people's natural capital in the area: Their natural resource stocks are gone and the environmental services derived from them are diminished.

4.3.2 Financial capital

Financial capital is the monetary base which is essential for the pursuit of any livelihood strategy. As the river has now been reduced to the status of a drain, agriculture and other money deriving activities have been severely impacted. Both clean soil and freshwater are needed for agriculture. 20 years ago, there was a lot of agriculture in Udupi, and the Indrani was the lifeline of the agricultural sector (Udayavani, 2020c; Daiji World, 2016; Udayavani, 2020f). Nowadays, 400 out of the previously 800 acres of farmed land are left abandoned because the soil is polluted and/ or there is not enough water to farm (Prabu, 2019). The local representative explains this in textbox 7. Coconut trees are dying because of polluted soils and a lack of water (KUIDFC, 2019c; Udayavani, 2020e). Other crops, like rice, can still be grown but only during certain parts of the year. This is a huge loss to the local communities which depended on

agriculture for their financial income. Similarly, people who relied on the river for fish or even drinking water now have diminished incomes or increased expenses. For example, 30 years ago, the river was full of fish, but today it is empty, removing a source of income for some people and for others the means to get a free meal (Udayavani, 2020c). And in the old situation, people could enjoy free drinking water, but now the water is distributed by the government or private entities, they need to pay for it.

"Agriculture of coconut has collapsed, it requires a whole year round water supply. We can't supply that anymore. First we only had to use the river, now only rainwater in the monsoon is available so we can only grow 1 crop per year instead of 3."

Textbox 7: The local representative explains how the agriculture sector has collapsed due to the polluted Indrani river.
Picture 21: An agricultural field in the dry season. This picture was taken in Kodavoor, a ward close to the sea in the peri-urban area which relied on agriculture.

4.3.3 Human capital

The human capital is mostly determined by skills, knowledge, health and the capabilities to work. The water pollution issues in Udupi do not have a direct effect on the skills and knowledge of people, but it most certainly impacts their health and abilities to work. The previous section discussed how the farming and fishing sector has taken a blow. Additionally, the media and interviews showed that the polluted water also causes health issues, especially further downstream in Kolankuru, Kodavoor, and Kalmady. In general, Udupi district has a very healthy population; there is a relatively low distribution of diseases and there are a lot of hospitals, clinics and primary health care centres (Mathews, 2012). Other factors that play a role are the high literacy rate and the socio-economic index of the district (Mathews, 2012). The coastal areas of the district however, experience higher densities of disease outbreaks, especially during the monsoon season (Mathews, 2012). Udupi city has an especially high density, but the researchers point out that although this is partly due to bad hygiene, it is also explained by its large pollution and the fact that many outsiders flock to the city for medical help (Mathews, 2012). Unfortunately, the study did not take factors such as water pollution into account. Nevertheless, other sources reported on the relation between the polluted Indrani and health issues in the city. As the Indrani runs dry during certain periods of the year, it becomes a breeding place for mosquitos. The result is an increase in mosquito related diseases like Dengue and Malaria all over town, but especially down stream where most water pools are formed (Udayavani, 2020f; Daiji World, 2016; Deccan Herald, 2019a). In addition, the local representative reports that people who come in contact with the polluted water are developing skin diseases. There are also incidents reported where solid waste dumping grounds are

attracting mosquitos and dogs (Daiji World, 2016). The dogs in turn cause road accidents which also negatively impacts human health.

4.3.4 Social capital

Even social capital, the social resources such as relations and affiliations people rely on for pursuing a livelihood strategy, is affected. A few decades ago, the river was a place where people would meet, interact and enjoy themselves during leisure activities. Kids were swimming, students were studying, parents were fishing or doing the laundry (Udayavani, 2020f). The river gave opportunities for the locals to meet together, and bond. During this research, countless testimonies were heard and read of people who especially remembered the river from their childhood as a place where they met lifelong friends. Now it is a stinking drain that has lost its attractiveness and thereby its enabling functions. On top of that, it has become a source of discontent and disagreement between citizens and municipal officials, and even citizens amongst each other. Everyone is blaming everyone for the current situation.

4.3.5 Urban & peri-urban areas

The impacts on people's livelihoods are diverse and severe. The pollution has impacted people in such a way that their way of living is under serious threat (Udayavani, 2020e). This is especially true for people living in peri-urban areas. The people living in the urban area of Udupi city are less reliant on agriculture and fishing than the people living on farms on the outskirts of the city. In Udupi, the more urban areas are also located upstream where the pollution of the river and wells is less severe than downstream. Upstream, the river is also smaller, and sometimes runs underground, whereas downstream the plain flattens, and the river volume increases. Consequently, during the transitions between dry and wet seasons, there are much more water pools formed downstream causing a larger increase in mosquitoes. Although the urban citizens still experience a significant loss in livelihoods, especially in the natural and social capitals, people whose income depends on the river are also losing financial and human capital. Throughout the data collection, different sources indicated that Kodavoor and Kalmady are the two wards most negatively impacted by the water issues, these wards lie on opposite sides of the river where it meets the sea. As discussed in the theory section, the consequence is that people can no longer depend on their old strategies for pursuing a livelihood, and might be forced to move into the city to pursue different strategies. Because of data collection limitations, this phenomenon could not be researched for these areas in this study, but it is highly likely that it exists considering the amount of fertile ground for agriculture has been reduced by 50% over the years.

Two other issues came up regarding urban & peri-urban dynamics during the 24x7 water supply project's consultation meetings. As Udupi will be withdrawing water from the Varahi river, people living downstream of that river expressed concerns about possible future water shortages. Especially the farmers around the area objected to the project (KUIDFC, 2019c). The municipality responded that of the 40 cusecs of water, 31 was for the farmers and 9,5 was left in the river, only 0,5 was taken for meeting Udupi's water demand (KUIDFC, 2019c). In addition, villages on the route of the river to the city expressed they too wanted to benefit from the project

and demanded access to the water. In response, they are allowed to tap water from the pipes. They also demanded to get treated water, but since the water treatment facility is in Udupi, they can not get it (KUIDFC, 2019c). These examples show how peri-urban areas are sometimes at a disadvantage in water related issues in relation to the urban area. But it also shows that there is room for negotiation and mutual benefit.

4.4 The municipality

The municipality of Udupi plays an important role in water security. Figure 11 shows how this section discusses the role of the municipality. The last dimension, governance is assessed by looking at their strategic planning, policies and regulations on water resources, risks and utilities (Jensen & Wu, 2018). During the field research it became clear that Udupi residents were very dissatisfied with the municipality. Therefore, this section also includes their complaints.

Figure 11: The role of the municipality in the status of water security: Water governance and citizen interaction.

4.4.1 Water governance

Jensen & Wu (2018) indicate that water governance can be mapped by looking at how the government approaches strategic water management regarding water resources (supply and demand), risk policies (floods and contamination), and utility regulation (Appendix A). In chapter 4.1.1 about water supply it already became clear that the municipality of Udupi has strategic planning in place for its water resources. The ongoing challenge to meet Udupi's water demand requires precise planning of the available sources and the distribution. During the last few decades, the municipality has tried to create a centralised distribution system for the supply of water to all households. It has constructed pipelines and water treatment centres to tap water from the river Swarna, it has created dams and lakes to create reservoirs, and many overhead water tanks to create enough pressure on the pipe system for efficient distribution (KUIDFC, 2019c). Now the demand keeps increasing, a new pipe will be made to tap water from the Varahi river (Sanjiv, 2019). Although it is still a challenge to supply enough water, it is clear that the municipality is constantly anticipating the demand and managing the supply.

When it comes to disaster management, Udupi is well prepared. For example, there is a very extensive disaster management plan for the whole district (Vishal, 2016). It includes an analysis

of the district, its vulnerabilities and capacities. It also explains what preparations and mitigations can be taken, and how the authority structures look like during disasters. Finally, it outlines response and recovery plans for various types of disasters, including standard operating procedures for all departments involved. Based on this document, it can be said that Udupi manages water related disasters well. This is confirmed by the interviews and media articles which stated that, in the case of floods, there is always enough time to prepare. On the other hand, this research has also shown that slowly emerging disasters such as the polluted Indrani river are not dealt with at all. Therefore, it can be concluded that the right policies are in place, but it remains doubtful if everything works out in practice.

Unfortunately, there is no similar document available that outlines the policies and regulations regarding water utilities. Udupi municipality communicates these matters quite poorly through its own channels. Through news articles and the KIUWMIP documents some things became more clear. At the moment, there are 16.000 water meters installed in households in Udupi which are checked by municipal employers every month. In the past, the bill was paid in cash at the municipality, but since 5 years it is also possible to pay it online via the municipal website (Mangalore Today, 2015). With the KIUWMIP project, 30.000 new meters are installed as many were reported to be broken and many households now connected for the first time (KUIDFC, 2018). There is a progressive price system in place where people pay more once they use more (The Hindu, 2016). Additionally, there are three price categories: Domestic, non-domestic and industrial. Although there was no clear policy document available, it seems the most important regulations are in place.

4.4.2 Citizen complaints

Residents point out that they fear the current state of the natural water sources in the area will have a destructive effect on biodiversity (Udayavani, 2020e), and if ignored, the next generation will be left with an immense loss (Udayavani, 2020e). This shows that reviving the Indrani river is not only a matter of reducing pollution or gaining access to water at the moment, but it is a vital step in creating a better environment and economy for all generations to come. Most agree that the problem is not the fault of anyone in particular, but that it has been ignored by all (Udayavani, 2020g). Others blame the municipality for inadequacy and inaction. The quote's in the textboxes 8, 9 and 10 illustrate their sentiment. Others are more nuanced such as in textboxes 11 and 12.

"This [sewage problem] is the result of municipal officials and representatives not making a grand decision in 20 years".

"The local government is collecting more taxes and adding extra charges every year, but the people are getting nothing in return".

The situation is the result of the city government. They are allowing multiple private complexes including multi-storey hotels and condominiums to drain the sewage into the Indrani river".

Textboxes 8 (left), 9 (middle) and 10 (right): Quotes from the media articles (8 & 10) and the interview with the local representative (9) that blame the government for the current status of the waste management system and the polluted Indrani.

"Everyone is responsible for this problem. As the city continues to grow, the Indrani river has been ignored by people, representatives and bureaucrats".	Everyone, including the municipality should try to clean up the river's pollution".

Textboxes 11 (left) and 12 (right): Quotes from citizens in the media illustrating a more nuanced opinion stating it is not only the municipality who makes mistakes.

A recurring theme in the complaints of citizens is the tendency of municipal officials to promise a lot, but then end up delivering nothing. The reports of town hall meetings are full of pledges and promises such as: "We will visit the affected areas, take action against the polluters of the Indrani, and solve the problem within a week" (Udayavani, 2020d). The following example illustrates the cause of people's disbelief: In march 2020, the papers published a government statement that this summer (dry season) there would be no water shortages in Udupi, and thus no need for water rationing (Moodubelle, 2020a). Exactly one month later, the paper published another statement saying the water reserves would be empty in 44 days, and water would need to be rationed to 6 hours per day if the monsoon did not set in quickly (Moodubelle, 2020b). This is one of the examples that pop up in the interviews, news articles and minutes of consultation meetings. It becomes obvious that the local government has often promised things it could not, or did not, deliver. This has caused a serious distrust of the people for whatever they say or do which is very harmful to the process and outcome of any undertaking, especially one that requires the cooperation of every citizen.

In March 2020, the Udyavara newspaper launched an information campaign that lasted two weeks (Udayavani, 2020a - Udayavani, 2020i). In the articles, they let experts speak about the current issues regarding the Indrani, let officials talk about what they were doing about it, and publish citizens' messages expressing their views. At the same time union and civil society organizations put pressure on the authorities (Udayavani, 2020d; Rodrigues, 2019). Afterwards, the paper concluded that there were "some positive developments" related to the pressure campaign, meaning the officials went to the sites and had taken some initiatives (Udayavani, 2020d). This shows that at least in the short term the officials can be pressurized into acting. Yet, the data shows that the long term, extensive projects are very difficult to realize. This could be because of the difficulties involved, money issues or even corruption, but this does not become clear. Part of the answer probably lies in the need for putting pressure on them. There are some examples of protest rallies in Udupi that asked for attention for the status of the river (Rodrigues, 2019), but one NGO president states that public involvement in these campaigns always quickly fizzles after initial excitement (The Hindu, 2019a). Others agree that citizens, environmentalists and social welfare organizations should not forget their pressure tactics and must constantly pressure the government to highlight its shortcomings (Udayavani, 2020d;

Udayavani, 2020h). The local representative indicated that he has been trying this for years and that this is easier said than done (textbox 13).

> "We are trying to put pressure on the politicians via the media and the municipal council. We organize local activities and mobilize locals. Thus far without much result, politicians are making promises and assurances, but they are not thinking about a permanent solution".

Textbox 13: The local representatives' experience with pressurizing the government into taking action.

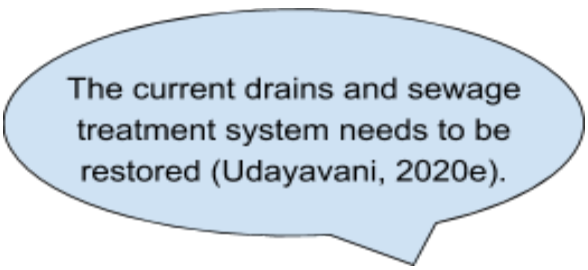
4.5 Challenges & solutions

Throughout the data collection process, many challenges and solutions were named by the various stakeholders. This section presents these challenges solutions. The Udayavani paper also prepared a list of solutions per stakeholder which can be found in appendix G. All these propositions will be used as a base for the recommendations made by this research in answering the fourth research question. Table 1 shows a summary of all the challenges identified during this research. The challenges vary in nature from natural causes to challenges caused by human action or inaction. The identified challenges are based on all the data sources.

Table 1: The challenges to a more water secure Udupi identified in this research, grouped on their water security dimension.

Resources	**Risk**	**Governance**
Drought in dry season	Minor floods in peri urban areas	Urban/ peri-urban inequalities
Dependant on distant water sources	Well & groundwater pollution	Unskilled labour
Increasing water demand	Uncontrolled waste dumping/ burning	Littering
Decreasing water table	Natural vegetation falling into the river	Corruption
Financial risks related to loss in agriculture	Insufficient solid waste collection	Moving away from landfilling
Lack of quality testing	Insufficient sewage infrastructure	Job hopping
Old, leaking water supply infrastructure	Health risks related to contamination	Functioning of the municipality
Urban/ peri-urban inequalities	Contaminated river	Maintained citizen pressure on municipality
	Uncontrolled sewage dumping (into the river)	

Throughout the data collection process, various solutions recommended by citizens were encountered. For example, during the meda analysis many accounts were given by citizens with their view on the problems and solutions. The following speech bubbles present their solutions.



The solutions coming from the data meet some of the challenges that need to be addressed. Therefore, it is recommended that they will be implemented. Nevertheless, some challenges are still unaddressed. In the discussion chapter, recommendations will be presented to address the outstanding challenges.

4.6 Concordance & discordance of statements from collected data

The data collected during this study comes from many different sources and expresses various opinions and points of view. Naturally, disagreement arises about certain issues. This chapter discusses the topics on which there is clear concordance or discordance.

In general, most concordance is reached on what is going wrong, but sometimes people disagree on who's to blame for the problems. Especially on the challenges related to water supply, there is strong concordance. People agree that the water supply in the city is seriously lacking, old water sources are polluted, and the water distributed by the government is insufficient and arrives very irregularly. There is also concordance on the reasons behind the water shortages; It is usually during the dry season when water sources become depleted, there is increasing demand and badly functioning infrastructure and management. Additionally, different sources indicated that the Indrani river runs dry parts of the year whereas in the past it would run all year long. This is supported by observations and the pictures from page 13; vegetation and waste obstruct the Indrani flow upstream. The water security- and waste management experts named a possible cause for this: Increased drainage in the upper basin of the Indrani. Although this might not be considered strong concordance on the cause of the problem, the participants were experts on the subject and their explanation is highly logical.

Similarly to the case of water supply, the issue of pollution in general, and water pollution specifically, is characterised by strong concordance. All sources report that Udupi and its surroundings are littered with trash, and that the Indrani is so polluted that it has turned to a black/ brown color. Various data sources agreed that most of the waste dumped in the river consists of garbage, vegitative components and construction debris. Additionally, it is very clear that there is a major lack of sewage treatment capacity, causing sewage to enter the river and groundwater. There is even some concordance on the statement that the sewage treatment plant is dumping untreated sewage into the river. Consequently, people also agree that at least part of the solution is to upgrade the sewage treatment infrastructure.

The pollution of the Indrani river has many consequences such as a loss of access to clean water for drinking, washing, and agriculture. In turn, this has an impact on various aspects of peoples' lives. There is overwhelming concordance on the impact of these issues on the livelihoods of the people of Udupi. No one disputes that serious issues arise in all the livelihood capitals. Many people do not know when they will have water to use at home, there is a tremendous loss of agricultural opportunities and people have even become sick of the polluted water. This shows the gravity of the situation and the importance of finding solutions to the problems. This is even more the case for the wards lying downstream, such as Kodavoor and Kalmady. They are impacted the most because they lie in peri-urban areas, where most people rely on agriculture, but also because they lie downstream, where most of the pollution accumulates.

There is not much discordance to be found in the collected data. The topic on which people are most divided is on who is to blame for the pollution. Some say all citizens are dumping their

waste in the river or on other dumping places. Others say that the people living close to the river are not doing it, but that others come from outside. Similarly, there was some discordance on whether or not the temples, shops and small scale industries play a role. Almost every person encountered in the data holds the opinion that the government is to blame for the situation. Although this can be viewed as concordance from their side, people from the municipality could not be asked for their view. It is clear that the inaction from the municipality has played a role, but without their view and opinion it is hard to say who is responsible for different parts of the problem. As one citizen remarked; It is probably not anyone's fault in particular, but everyone has some blame.

5. Discussion

The previous chapter presented the data collected during the field trip. This chapter will discuss the implications of the data with regards to the research questions that guided this research. Each chapter will discuss a sub question, and the chapter ends with discussing the limitations of this study. Throughout the data collection and analysis process, new concepts came up that altered the conceptual model. Figure 12 presents the empirical model that emerged from the data, this is a combination of the conceptual model introduced in chapter 2 and the concepts that came up later.

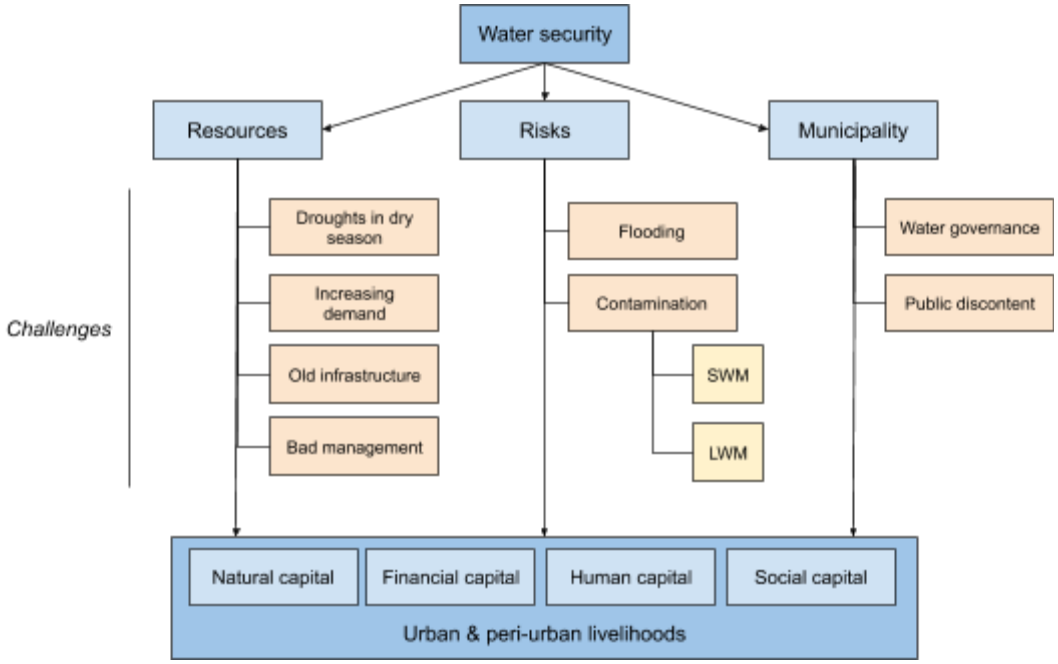


Figure 12: The empirical model containing all the studied concepts, both those derived from theory and those that emerge from the data.

5.1 Water security in Udupi

The first sub question guiding this research was: “What are the characteristics of the current and emerging water security issues of Udupi?” The last few decades, threats to water security have become increasingly severe in Udupi. As the population increases, the demand for water goes up. Most of the people used to rely on their own water sources, but this is no longer an option due to pollution. Therefore, pressure on the municipality has been increasing to find alternative water sources. This process has been going on for a long time, and water has become increasingly scarce. In the past, dams have been constructed to create artificial lakes that serve as water sources in times of need. Additionally, the river Swarna located just outside the city has been tapped for the last 10 years and in the city many borewells have been constructed to tap the groundwater. This has alleviated some of the pressure, but it was not enough. Although no one is dying of thirst in the area, there is still a great demand for more water. Households only receive water a couple of hours a day, and there is definitely not enough water anymore to

continue agriculture in the way it used to be done. Fortunately, the municipality has been working on this problem and created a solution in cooperation with the state- and national governments of India and the Asian Development Bank. The KIUWMIP project will ensure that there is a continuous supply of clean drinking water to Udupi in the next few decades. A pipeline will connect the Varahi river to Udupi, and a new pipe grid will be created in the city to supply the water to the households

The most pressing problem of supplying sufficient amounts of drinking water to the citizens seems to be addressed with this new water supply system. Although the government is notorious for taking incredible amounts of time to set up and execute such projects, it is likely that this project will be finished within a few years since construction has already started. This has solved the problem of water supply in terms of the quantity of water available. Yet, the current water supply issue is also characterised by the lack, or failing, water governance systems in place. Many problems are caused by a lack of maintenance of the pipes, pumps, and treatment plants. The KIUWMIP project supposedly also targets this problem by creating training programs and setting up guidelines and standing operating procedures, but it remains to be seen if this will be enough to ensure the functioning of the system in the future. One interview participant indicated that it is a general problem that in India the people pay less attention to the operations part, and often switch jobs so that knowledge is lost. It seems likely that this will remain a continuous challenge for the municipality. In addition, it is important to point out that the project will ensure an increase in water supply, but the way people access water has been changed. In the past, they were mostly self-sufficient; everyone had a well or took water from the river. Now, they rely on the municipality and have to pay for the water. Partly, this is inevitable as the population (density) increases there is not enough space to dig wells for everyone, and the groundwater would not be enough to meet everyone's needs. Yet, the people that already have these wells and used to rely on them have lost an important source of their livelihood.

5.2 Water contamination

As discussed in 5.1, the pollution of the Indrani has caused citizens to become dependent on the government for their domestic water needs. Therefore, it can be concluded that part of the threats to the water security dimension of supply is caused by pollution. The risk dimension however, is almost fully related to the pollution of the Indrani. The second sub question is related to the risk dimension of water security and is as follows: "How does pollution impact water security in Udupi?" Water security risks consist of floods and contamination. According to the data, floods do not pose any significant threat to Udupi city. In the rest of the district floods can cause a lot of damage and sometimes even casualties, but inside the city it seems to be manageable. Pollution and waste management however turned out to be very important issues.

50 years ago, there were far less people living in Udupi and people depended much more on organic materials than they do now. Most waste was organic and could be used as compost or thrown in the river without causing too much difficulties. Unfortunately, as the population grew and more products were made of inorganic materials, pollution became a major issue.

Additionally, the sewage system became too small to deal with all the inhabitants' sewage, and so became another source of pollution. Nowadays, the Indrani is polluted and it further contaminates the groundwater and wells in the area. This has caused a decrease in access to water for some people, it caused a decrease in agricultural output, and an increase in health issues related to contaminated water. As the water supply issue will most likely be resolved in the near future, the issue of the contaminated river and groundwater becomes the most pressing water security issue in the area. Drastic measures need to be taken to save the water bodies. Completely rejuvenating the river will not create a water source for all of Udupi, but it will rejuvenate the wells a lot of people use. Additionally, it will ensure that the people in Kalmady and Kodavoor can commit to year round agriculture again, and will most likely experience a decrease in the diseases such as skin rashes and dengue/ malaria that are present now because of the contamination. Rejuvenating the natural water sources will thus greatly increase the livelihoods of the people living in peri-urban areas.

5.3 Recommendations for the future

The final sub question of this research was: :How can the status of water security be improved in Udupi?" To answer the final subquestion recommendations were made that can lead to the improvement of water security in Udupi. The results chapter introduced many challenges that need to be addressed in order to move towards a more sustainable system. Some solutions are being implemented at the time of conducting this research, and some solutions were mentioned by stakeholders during the data collection process. This chapter presents 4 pillars of improvement based on the challenges that need to be addressed. Figure 13 shows how these recommendations for improvement target various challenges.

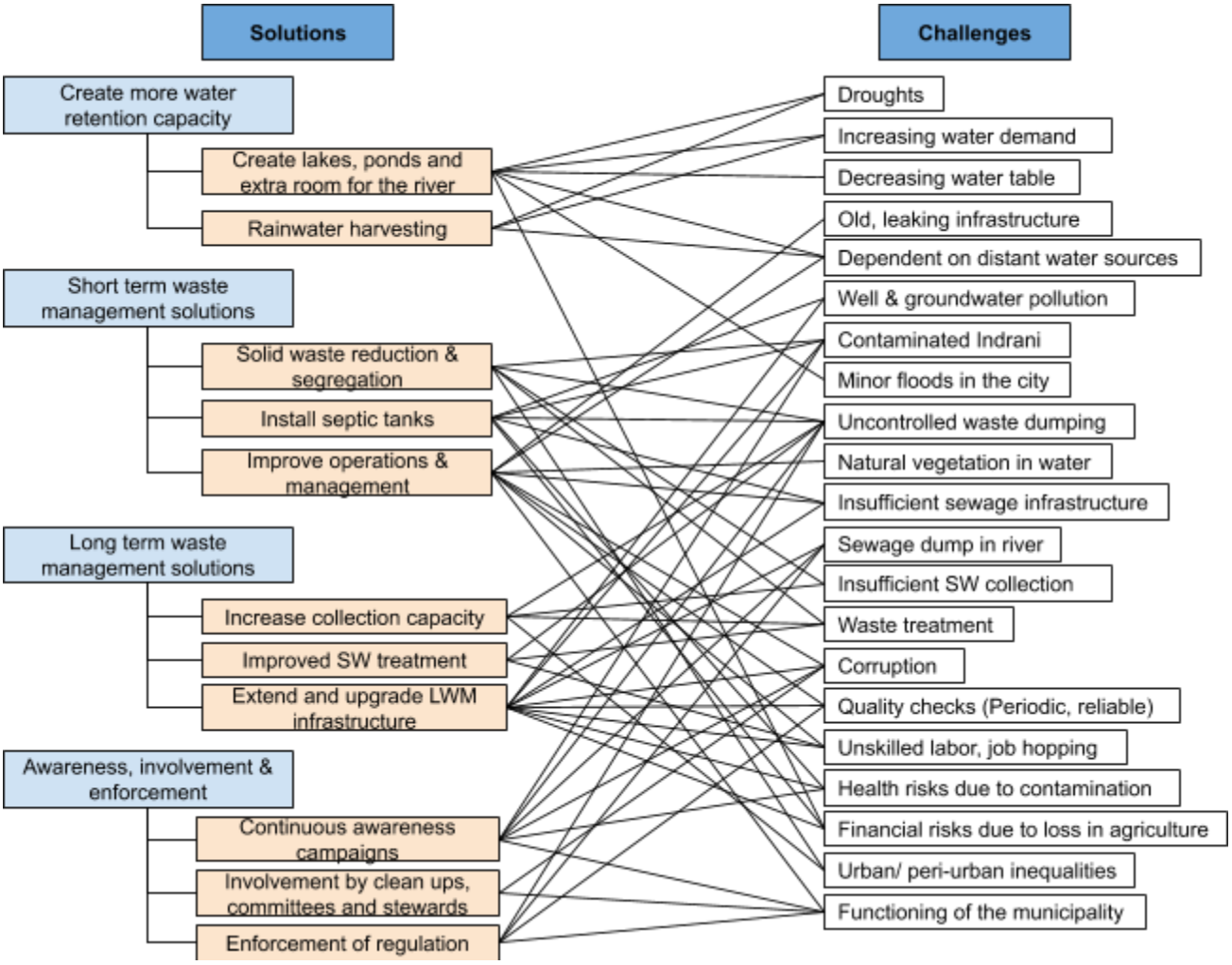


Figure 13: The challenges identified in this study and the solutions that are recommended to meet the challenges.

5.4.1 Create more water retention capacity

At this moment, Udupi still experiences great difficulty with supplying enough water to all its citizens. This is especially true during the periods outside the rainy seasons. Citizens complain about water rations of only a few hours of water per day. After the 24x7 water supply project is finished, this challenge should be solved. This should ensure that every household in Udupi is connected to the water supply network and has access to relatively clean water. Still, more can be done to make better use of local water sources, and prevent water related risks such as flooding and droughts. This study recommends creating more lakes, ponds, room for the river by dredging and widening the riverbed. Additionally, domestic rainwater harvesting should be stimulated and drainage of the water table should be prevented as much as possible. At the moment, the upper part of the Indrani runs dry during the dry season, and the lower part floods during the monsoon season. More water retention capacity can help in combating these challenges as the water reservoirs build up with excess water in the monsoon and alleviate the

droughts in the dry season. Creating more local water storages such as Manipal lake also increases pressure on the water table which is needed in order to increase the amount of water in the Indrani and neighbouring wells. This is an important step in rejuvenating the river as it will not remain clean as long as the river runs dry parts of the year; there needs to be a flow to wash away any contaminants that enter the water. In time, excess water from the Varahi river could be used to supplement water sources in the Indrani spring region, such as the lakes, Indrani and wells to further increase the water table. Additional measures to utilize water sources more effectively include selling wastewater to farmers instead of spraying it on water intensive grasses and plants in gardens and stop draining groundwater near the Indrani.

An additional measure that can already be taken to increase the flow of the Indrani river is to cut overhanging branches, and/or install nets in strategic places to prevent leaves and branches from falling in the river and making it more difficult to dump waste. In the upstream area, this will be especially feasible and necessary. It will keep out branches, leaves and litter, and give a strong signal that it is not accepted to throw anything in the river. Downstream, the river becomes too wide, but it also has less overhanging vegetation. Here, the focus should be on placing signs, bins, and creating awareness on the impacts of littering and waste dumping.

5.4.2 Short term waste management solutions

Besides dealing with water sources more effectively, a major challenge is to create a more sustainable waste management system. Before most of the water sources can be rejuvenated and utilized again, Udupi needs to ensure that the processes that lead to pollution are addressed. The short term solutions that are recommended are relatively easy to implement, but can still be very effective in meeting the challenges. In the short term, the procedures already in place should be scaled and improved. As solid waste collection already happens separated, it is important that the collection capacity is increased. This can be done by; (i) reducing the waste, (ii) separating it beforehand, and (iii) increasing the amount of people and trucks collecting it. Especially the first two options can be implemented quickly. The municipality already has a plan to create local compost spots, this will greatly reduce the volume of waste that needs to be collected. Furthermore, if waste is separated before it is picked up by citizens (now it happens on the truck), this will save the workers a lot of time and create a more efficient collection process. In Kodavoor, domestic waste bins were distributed to households with the explanation of how to segregate waste. This process needs to be scaled so that every household in Udupi separates its dry waste before collection, and deposits its own organic waste in the municipal compost piles.

The liquid waste management challenges are difficult to solve in the short term. The centralised sewage system network will take years to be sufficiently improved to deal with Udupi's sewage. Therefore, this study recommends to reduce the impact of liquid waste in the short term by stimulating the installation of septic tanks in households, improving the operations and management of the current centralised infrastructure, and improving the monitoring and enforcement of decentralised treatment facilities. As it can take decades before every household is connected to a well functioning sewage system, it is important that every

households' domestic liquid waste is being disposed of in a more sustainable way. Installing septic tanks ensures that the contaminants do not seep into the groundwater and reduces the risks of people coming in contact with contaminated water sources, thereby reducing health risk. Furthermore, it is important that the current centralised infrastructure, and any infrastructure to be built in the future, is optimally utilized. The data showed that this is not the case at the moment; There is leakage, a lack of maintenance, broken pumps and almost no quality control. People need to be trained and standard operating procedures need to be established as soon as possible so that these inefficiencies are being dealt with. The same solution is needed to optimize decentralised treatment. At the moment, the systems are too often put in place, but are then not used. A major challenge here is that the people who are sent to check the systems are bought off. One solution could be to make the owners of these systems responsible for providing periodic water quality test records, or to install automatic water samplers that can be read by a computer/ app to make the decentralised system less prone to corruption.

5.4.3 Long term waste management solutions

In the long term, solid waste collection should be 100%. In order to accomplish this, public waste bins should be installed all over the city, and especially in known waste dump locations. Additionally, more people and trucks should be employed to increase the amount of waste collected. Once solid waste collection capacity is increased, it is important that the treatment of solid waste is improved. In chapter 4.2, the Ladder van Lansink was introduced which shows the preferred treatment options. Udupi should continuously strive for reducing the amount of waste that is produced by increasing the reuse and recycling of goods and materials. The short term solutions create better segregated waste streams so that materials can easier be reused. In the long term, it is important that new initiatives/ start ups arise that use these materials to create new valuable goods. Presently, a lot of waste still ends up at the landfill or in an incineration oven. As much of the waste as possible should be reused or recycled, for some waste this is not an option. Those types of waste should be incinerated to generate energy, and at the same time be phased out of circulation. In order to facilitate a more efficient solid waste management system, the municipality should consider privatizing the waste sector as much as possible. At the moment, various layers and departments of the municipality are involved which causes a lack of accountability. The waste collection should be performed by private companies that make bids for public tenders sent out by the municipality. This creates more direct accountability and transparency.

The greatest challenge to a more sustainable waste management system in Udupi is the centralised sewage system. Although it might be more desirable in the short term to invest in decentralized treatment options, in the long term it is important to create a centralised system equipped to deal with all the sewage produced in Udupi. Decentralised systems have the advantage that they can be installed relatively easily and quickly, but as discussed before, the accountability becomes completely fragmented because all these systems need to be checked independently. In order to improve the current centralised system, the STP needs to be upgraded, and probably supplemented with a new facility. The current system was designed for only a fraction of the current population, so much higher treatment capacity is needed.

Furthermore, the pipeline infrastructure needs to be laid in the city. As the 24x7 water supply project also had to lay pipeline infrastructure, this would be the ideal time to combine the two projects and deal with all the problems at once. Unfortunately, they have decided differently. Therefore, the most pressing task of the municipality is to come up with an alternative. Like the 24x7 plan, this most likely requires the involvement of state and national government, as well as outside funders such as the Asian Development Bank. Yet, it is the responsibility of the municipality to set things in motion before another couple of decades go by without a solution.

5.4.4 Awareness, involvement and enforcement

The citizens play a very important role in the challenges Udupi faces, and therefore also need to be included into the solutions. Public or private entities can try to create change, but if the citizens of Udupi are not stimulated to change behaviour and pressurize the government into creating improvements, nothing will change. For example, before the Indrani and other water sources can be rejuvenated, more measures need to be taken to prevent further contamination. Therefore, it is important that more awareness is created. There are already civil society organizations doing this, these need to continue their work and try to increase their outreach. Furthermore, the municipality should create signs, especially around the known dumping places, that inform people littering and waste dumping is unacceptable. Finally, the information campaign of the Udyavara newspaper showed how powerful media attention can be. The news papers, and other local media channels, should continuously report on the problems, and measures being taken to keep the topic alive. It is important that creating awareness is accompanied by the implementation of previously discussed solutions. These solutions provide alternatives to the way people are used to behaving now. It would be unfair and ineffective to tell people to stop dumping waste without creating sufficient opportunities to deal with waste in a more sustainable way. A nice example of this is when the municipality went door to door in Kodavoor to hand out domestic waste bins and create awareness about the waste issue at the same time. They taught people to change their waste practices and provided them an opportunity to do so.

Involving the citizens in the solutions the water related issues can create further awareness, more support for the proposed solutions, and contribute to a more successful outcome. Citizens can be involved in many ways. For example in creating awareness, by joining awareness marches, going door to door, or talking about it to neighbours and friends, and using social media. One of the recommendations of this study is to start organizing clean ups. This can be done by the municipality, local people or civil society organizations and targeted at the city streets and/ or water bodies. Including people in the cleaning creates awareness, and sends a strong signal to the community that it is no longer accepted to pollute the city and environment. A lot of respondents of this study very quickly shifted blame towards the government when asked about the pollution issues. Although the municipality has been far from helpful and effective, there also is a role for the citizens in keeping the city clean.

Once the people have become aware, and alternatives have been created to prevent further contamination, it becomes more important to enforce already existing standards and laws. This

can be done via the police, but also via citizen involvement. One solution coming from the data was to establish local committees to oversee wetwells functioning/ maintenance and the functioning of the STP. This study recommends to also establish local committees around important waste hubs such as known dumping places and along the Indrani river that monitor the situation and report any pressing issues to the authorities. Ideally, the municipality and police function well enough so that citizens don't have to take control, but clearly that has not been the case in Udupi. The establishment of these committees can aid in developing citizen oversight and thereby decreases the need to depend on corrupt, unmotivated quality checkers or police officers. Some things cannot be enforced by citizens though, and therefore Udupi should also put more effort into upholding citizens and companies to the laws and regulations in place. There are drinking water and effluent standards, building requirements, plastic bans and fines for littering or waste dumping; they are just not enforced properly. As mentioned before, it is difficult to enforce these laws when some practices are ingrained in the culture and no alternatives are provided. Nevertheless, there are always options, and as more and more are becoming available, it is important that the enforcement will become stricter. One recommendation that needs to be added here is how to deal with illegal settlers on the river banks. Against building requirements, houses have been built quite close to the river. Officially, these people should break down their house and move elsewhere, but that will be difficult and unfair to realise. A better solution is to assign these people to be stewards of a respective area around their property so that they have the responsibility to keep the river and riverbanks clean. This is an easy way of creating accountability, and to ensure that someone is putting an effort into keeping a certain area clean. Besides creating local committees and communities to involve the citizens in solutions for the pollution problem, a special minister or government committee that is solely responsible for solving these challenges should be created. After decades without progress, the municipality needs to be more transparent and accountable. Who is working on a solution? Where is all the information regarding projects that need to solve the problems? And where is all the tax money going that is destined for these issues?

5.5 Limitations

There are certain limitations to the research that need to be addressed. The limitations all revolve around difficulties with data collection due to the coronavirus outbreak. Initially, this research was intended to collect qualitative data through interviews, but this proved to be impossible once the lockdown measures were in place. India installed a very strict lockdown that prohibited people to go outside except for getting medical supplies. Therefore, the initial research setup became very difficult to execute. This also has to do with cultural bias from the researcher. In the Netherlands, there is a more 'life goes on' mentality - I thought I could just continue the research through phone interviews or something similar. Unfortunately, the people that were contacted were only focussed on the corona outbreak, and did not have any time or attention for anything else. Many people were contacted, but almost no one responded, and the few that did were very reluctant to help, or even became irritated. Consequently, it was decided to collect data through other sources such as news articles. The results of this research would have been more robust if more interviews could be held, especially with people from the municipality. Nevertheless, the news articles and KIUWMIP documents contained some minutes

of interactions between citizens and municipal officials that provided some insight in their point of view. Another limitation is the fact that water quality testing became impossible. Due to the outbreak, the labs at MAHE were also closed. It would have been interesting to show the pollution in various parts of the river, in wells in the area, and for example to check whether the sewage treatment plant really dumps untreated sewage in the river. Although this would give more detailed information on the subject, there are no tests needed to show that the river is severely polluted.

6. Conclusion

6.1 Answer to the research question

The aim of this research was to study the impact of pollution on water security and its relation to the livelihoods of people in Udupi. Although the lockdown measures installed after the coronavirus outbreak made it difficult to collect data as intended, this research did manage to find an answer to the research question: “How can the challenges to improving water security in Udupi be overcome?”. The status of water security in Udupi is characterized by difficulties in the supply of water, high risks in terms of contamination, and poor management or governance. At the moment, pollution already has a very negative impact on water security in Udupi. Unfortunately there is still a bigger problem; the supply of enough water to the households. The first basic need of people is to have enough drinking water, once that need is met people can start to think about other measures to increase their water security. Pollution also plays a role in this issue as the supply of enough water to the city would become easier once the natural sources such as river- and groundwater would be potable. Yet, the population of the city has increased so much in recent years that this would not be enough to supply the whole city with water. Fortunately, measures are being taken to finally create an infrastructure that should be able to continuously deliver clean water to every household in Udupi. This should be finished within a few years and increase the people’s water security and livelihoods.

Once the problem of supply is solved, the issue of pollution remains. This means that in the near future the status of water security will increase, but it will be heavily impacted by pollution. Water security is threatened because of the contamination of the Indrani river and domestic water wells. This is especially true for the people living in peri-urban areas such as the wards Kalmady and Kodavoor. The people living in these areas are disproportionately affected by the pollution of these water sources as they pollute the least, but rely on the sources the most. Their way of life is threatened because they now have insufficient water to continue their agricultural practices and increasingly have to deal with water related diseases. Once the issue of supply is fixed, the urban citizens’ water security is increased heavily as they do not rely on water for their income. For the peri-urban citizens however, the problems still persist. Especially for these people, it is of vital importance that all stakeholders continue to strive for a less polluted Udupi. Before the sources can be rejuvenated, substantial improvements in the solid- and liquid waste management systems need to be implemented. This research has provided recommendations for increasing water retention capacity so that the water that falls during the rain season can be stored to be used during dry periods. This can also alleviate some of the impact of minor floods. More importantly, recommendations were provided for improving the waste management systems and creating awareness and involvement among all stakeholders. The community must come together and actively cooperate in order to combat pollution and increase water security. Many people blame the government for their inactivity, and although this is certainly an issue, in the end every citizen must take the responsibility to stop polluting, start cleaning up, and incite others to do the same.

6.2 Future research

After decades of talking it is very important that people now commit to practical actions in order to clean up the environment and eventually rejuvenate the river. Nevertheless, more research can be done to provide more insight in the causes of the problem. The largest source of discordance in the data collected revolved around the sources of pollution. One study can try to observe which actors dump waste in the river or other known dumping places in and around the city. Additionally, the study could take water samples at strategic places as this research intended to do in order to create insight in the nature and severity of the pollution of these sources. The insights of this study can be used to enforce regulation more effectively and tailor the waste management system to the places where most pollution occurs. A different study could analyse the drainage in the area. It is important to create insight in the natural drainage of the Indrani basin, as well as the contribution that human activities have. Especially in the upper basin, near the boundary between Manipal and Udupi, the water table becomes so low during parts of the year that the river runs dry. Insights from this study can be used to set limits for pumping up water in the area, which in turn can stimulate the recycling of water. This research also aimed to conduct an extensive stakeholder analysis which became impossible because of the lockdown. Once it becomes possible again to come in contact with people, it would be interesting to contact as many (different) stakeholders as possible. The study should look into the different views on the problem, the impact the problems have on these stakeholders and the relationships between the stakeholders. This information can be used to identify powerful stakeholders that can be targeted to lead the transition towards a more sustainable future. Finally, the data collected in this study showed that the potential floods do not really pose any substantial threat to the livelihoods of the people in the city. As the areas around the city reportedly suffer more from this risk, and future climate change may bring changes in sea-, river-, and precipitation levels it is important to establish current and future risks related to flooding.

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7.2 Grey literature

An extensive list of all grey literature (news articles, documents etc.) can be found in appendix E.

Appendix

Appendix A: Water security indicator framework

Table 2: Indices and indicators for measuring Urban Water Security (Jensen & Wu, 2018).

Indices and indicators for measuring Urban Water Security				
Indices	**Indicators**	**Sub-indicators**	**Metrics**	**Unit**
Resources	Availability	Water resource availability	Renewable surface water + renewable groundwater + imported water, desalinated water, reclaimed water per year per capita	M3/yr/cap
		Water storage capacity	Total volume of water stored in water reservoirs (m3) expressed as a multiple of average daily demand	No. days
	Diversity	Diversity of water resources	Contribution of alternative sources (all sources excluding the largest source) by volume to total available water resources	%
			Contribution of water transferred from another jurisdiction to total available water resources	%
	Quality	Raw water quality	Proportion of samples at intake point meeting locally applicable quality standard	%
Access	Capacity	Water supply capacity	Total water treatment capacity x (1-NRW) per day/ average demand per day	%
		Water supply coverage	Percentage of households with access to tap water supply	%
	Service sustainability	Cost recovery of water utilities	Operating expenditure/ operating revenue	Ratio
	Affordability	Water tariff	Water utility bill for monthly demand of 15m3/ average disposable household income	%
Risks	Flooding risk	Flood frequency indicator	Number of serious flooding events per year	No.
		Flood damage indicator	Economic loss caused by floods per year	Million $
			Fatalities due to floods per year	No.
	Public health risk	Access to sanitation	Proportion of households with a sewerage system connection	%
		Water contamination incidents	Number of water contamination incidents recorded by the utility per year	No.
			Proportion of drinking water samples meeting WHO standards	%
			Economic loss due to water pollution	Million $
			Proportion of households with continuous supply	%
Governance	Strategic planning		Whether the government/ institution have strategic planning towards water resources, taking into account both supply and demand	Qualitative measurement Lickert scale 1-5

	Disaster management		Whether the government/ institution have policies towards water related disaster, i.e. flooding, water contamination management such as early warning systems, compensation scheme	Lickert scale 1-5
	Regulation		Whether there is comprehensive and transparent regulation on water utilities	Lickert scale 1-5

Appendix B: Project information sheet

Project name: Urban Water Security in India: A case study on Udupi.
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Supervisors: Professor Ajay Bailey & Professor Sanghamitra Roy

This research looks into the state of water security in Udupi, Karnataka, India. The concept of water security is mapped by four indices: Resources, access, risks, and governance. These four indices are further divided in ten indicators, and fourteen sub indicators. The first step of the research is to check if all the indicators are valid, or that alterations need to be made. When the framework is tailored to fit Udupi, the indicators are mapped using quantitative and qualitative data. Quantitative metrics are included in the framework on which as much data as possible will be gathered through the consultation of information databases and reports with statistical data on these metrics. Additionally, the quantitative data will be cross checked by qualitative data resulting from semi structured interviews. The interviews will also be used to supply additional information on the indicators, especially in cases where there is insufficient quantitative data to map the indicator. The results of this research are expected to provide a sound overview on the current status of water security in Udupi. It will show what is going well, but also where the challenges lie. Therefore, the output will be an overview of the situation and recommendations for improving the situation.

The interviews will last around 30 minutes and although it is preferred that they are recorded, this is not mandatory. The participants of the interviews will remain anonymous, their names will not be taken and actions shall be undertaken to delete any information that could lead to their identity. The participants are expected to read the project information sheet and sign the consent form so that they know their rights. During the interview, the participants are expected to answer the questions truthfully, and completely to the best of their knowledge. If the participant requires any more information, the researcher, Noud Paanakker, can be contacted.

Appendix C: Consent form for interview participation

Project name: Water Security in Udupi: A stakeholder analysis.
Researcher: Noud Paanakker
Contact details: a.b.t.m.paanakker@students.uu.nl
Institutions: Utrecht University & Manipal University

1. I confirm that I have read the project information sheet and have had the opportunity to ask questions which have been answered in full.

☐

2. I understand that my participation is voluntary and I am free to withdraw at any time.

☐

3. I understand that the results of this study will be used in a research report and presentation and will be published online without the names or any identifying details of the participants.

☐

4. I agree to participate in this study.

☐

_____ _____

Signature participant Date

_____ _____

Signature researcher Date

Appendix D: Interview guides

Interview 1: Water security expert

I would like to ask you to participate in an interview that will take around 45 minutes. The information resulting from these interviews will be used in my research into water security in Udupi. We will discuss concepts such as availability, access and pollution of water. For more information about the content and the researcher of the research, I refer to the project information sheet. Please read the sheet and the consent form, and sign the latter if you are willing to participate in this interview.

Opening questions

- Please tell me what comes to mind when you think about water security in Udupi.
- According to you, what are the most important issues and challenges concerning water security in Udupi?
- I brought a list of indicators with me that I would like to look at in the research. Please have a look and tell me which are not relevant according to you. Is there anything missing?

Questions per indicator

Water resources - Availability, Diversity & Quality

- What are Udupi's water sources and is there enough water available in Udupi to meet its needs?
    - Surface, ground, imported, desalinated, reclaimed water.
- What are the water storage locations in Udupi, and what is their capacity?
- Is water coming in from other jurisdictional zones around Udupi, if so in what way?
    - Rivers, imports
- How is the water quality of the aforementioned sources? How is this tested?

Water access - Capacity, Service sustainability & Affordability

- What is the water treatment capacity of the facility(-ies) close to Udupi?
    - What are their operating costs and revenues? Are they profitable and functioning properly?
- What percentage of the households in Udupi is connected to the water grid/ have access to tap water?
- What is the price of water for households?
    - Can that be considered affordable? What is it as a proportion of income?
    - Does this differ per water source?

Water risks - Flooding & Public health risks

- Does Udupi face any flooding risk? How many floods per year?
- What is the damage related to these floods?
    - Damage in property, lost value, lives lost.
- How is the access to sanitation for households in Udupi?

    - Percentage of households with access?
- What is the state of the sewage system in Udupi?
    - What percentage of the households are connected to it? Enough capacity? Where does the sewage end up?
- What is the state of water sources in Udupi, are many contaminated?
    - Does this impact drinking water supply?
    - Are drinking water samples being taken regularly? How many of them meet the (WHO) standards?

Closing questions

We have now discussed the availability, diversity and quality of water.

- How do you think the government manages water issues?
    - Planning for water supply, disaster management, quality/ price of service.
- What do you think needs to change to increase the water security in Udupi?
- How do you see the future of water security in Udupi?
- Can I come back if I have more questions?

Thank you for your participation!

Interview 2: Waste management expert

I would like to ask you to participate in an interview that will take around 30 minutes. The information resulting from these interviews will be used in my research into water security in Udupi. We will discuss concepts such as availability, access and pollution of water. For more information about the content and the researcher of the research, I refer to the project information sheet. Please read the sheet and the consent form, and sign the latter if you are willing to participate in this interview.

Opening questions

- Please tell me a little bit about the research that you are doing.
    - What is the geographical scope?
- What are your most important findings?
- What needs to be studied more?

Questions related to water security

- Is your study related to water security issues in any way? If so, how?
- Do you also look into liquid waste management?
    - What are your most important findings there?
- Have you visited wastewater treatment plants?
    - What were your most important findings there?
    - What is the water treatment capacity of the plant close to Kodavoor?
- How is the access to sanitation for households in Udupi?
    - Percentage of households with access?
- What is the state of the sewage system in Udupi?
    - What percentage of the households are connected to it? Enough capacity? Where does the sewage end up?
- What can be done to improve the liquid waste management in Kodavoor/ Udupi?
- What are the biggest challenges?

Closing questions

- How do you think the government manages (liquid) waste management issues?
- How do you see the future of liquid waste management in Kodavoor/ Udupi?
- Do you want to add anything/ have I forgotten to ask something?

Thank you for your participation!

Interview 3: Local representative

I would like to ask you to participate in an interview that will take around 30 minutes. The information resulting from these interviews will be used in my research into water security in Udupi. We will discuss the current situation in the Kodavoor area related to the Indrani river. For more information about the content and the researcher of the research, I refer to the project information sheet. Please read the sheet and the consent form, and sign the latter if you are willing to participate in this interview.

Opening questions

- Please tell me something about what you do in relation to water security?
    - And specifically in Kodavoor?
    - How long have you been doing this?
- What have you achieved/ are there any observable changes or results?

Questions related to Kodavoor

- What are Kodavoor's water sources?
    - How do people get their water?
- What is the quality of the water?
    - Are there any recent quality tests?
- Where is the nearest water treatment plant?
    - How is it functioning? Enough capacity?
- What is the state of the Indrani river in Kodavoor?
    - How is it polluted, by whom?
- What is the state of solid and liquid waste management in the Kodavoor area?
    - Is there a sewage network that is connected to the treatment plant?
- What has been done to improve the situation?
    - What is the government doing? What is industry doing? What are the people doing?

Closing questions

- What do you think needs to change to improve the situation?
    - Who is responsible for this?
- Which places do I need to visit in the Kodavoor area to get a grasp of the situation?
- Do you want to add anything/ have I forgotten to ask something?

Thank you for your participation!

Interview 4: Water treatment expert

I would like to ask you to participate in an interview that will take around 30 minutes. The information resulting from these interviews will be used in my research into water security in Udupi. We will discuss your experience with water treatment in Udupi city. For more information about the content and the researcher of the research, I refer to the project information sheet. Please read the sheet and the consent form, and sign the latter if you are willing to participate in this interview.

Opening questions

- Can you tell me something about your activities in Udupi related to water?
    - How long have you been doing this?
- What have you achieved/ are there any observable changes or results?

Questions related to water treatment

- Can you explain how the water treatment process works?
    - What is needed?
    - What is the capacity of a plant?
- What is the capacity of installed facilities in Udupi?
    - What is the required capacity for Udupi city?
- How does the water end up at the facilities and where does it end up after treatment?
    - What is the quality after treatment? Who tests this?
- What do you think of the current situation in Udupi in terms of waste water treatment?
    - What are the biggest problems?
- What is needed to treat all waste water in Udupi?
    - What are the biggest challenges?
- How do you think locals, industry and government are dealing with these issues?
- How is water treatment regulated by the government?

Closing questions

- What are the important treatment plants I need to see?
- Do you have any contacts at treatment facilities or in the government that I could meet?
- Do you want to add anything/ have I forgotten to ask something?

Thanks for your participation!

Appendix E: List of data sources

The following table shows the data sources collected during the field trip to Udupi. It contains news articles, previous research, documents, interviews and observations.

Table 3: Information on the data products and sources collected during this study.

Code	Title	Type of source	Link/ source
1a	49 lakh for maintenance of wet wells.	News article	http://epaper.udayavani.com/EditionPage/EPpage.php?edn=Manipal&isid=UVANI_SUDP_20200302#Page/1 Udayavani, (2020a)
1b	Let us not defile the pure Indrani.	News article	http://epaper.udayavani.com/EditionPage/EPpage.php?edn=Manipal&isid=UVANI_SUDP_20200305#Page/1 Udayavani, (2020b)
1c	Our Indrani should reappear as the Thames of London!	News article	http://epaper.udayavani.com/EditionPage/EPpage.php?edn=Manipal&isid=UVANI_SUDP_20200306#Page/1 Udayavani, (2020c)
1d	Response to a series of news; Many temporary initiatives by the city council.	News article	http://epaper.udayavani.com/EditionPage/EPpage.php?edn=Manipal&isid=UVANI_SUDP_20200307#Page/1 Udayavani, (2020d)
1e	Parliament: “People need to work together.”	News article	http://epaper.udayavani.com/ArticlePage/APpage.php?edn=Manipal&articleid=UVANI_SUDP_20200308_2_1&artwidth=588px Udayavani, (2020e)
1f	The cooperation of all is necessary to keep the Indrani river clean.	News article	http://epaper.udayavani.com/EditionPage/EPpage.php?edn=Manipal&isid=UVANI_SUDP_20200309#Page/2 Udayavani, (2020f)

1g	We need to stick to Indrani's protection.	News article	http://epaper.udayavani.com/EditionPage/EPpage.php?edn=Manipal&isid=UVANI_SUDP_20200310#Page/2 Udayavani, (2020g)
1h	We need to take action for the Indrani to survive.	News article	http://epaper.udayavani.com/EditionPage/EPpage.php?edn=Manipal&isid=UVANI_SUDP_20200311#Page/2 Udayavani, (2020h)
1i	Let the people not stop fighting: Let the Indrani flow again.	News article	http://epaper.udayavani.com/EditionPage/EPpage.php?edn=Manipal&isid=UVANI_SUDP_20200312#Page/1 Udayavani, (2020i)
1j	Polluted Kalmadi makes life a living hell.	News article	https://www.deccanherald.com/content/143989/polluted-kalmadi-makes-life-living.html Deccan Herald, (2011)
1k	Udupi: Unofficial roadside garbage dump, threat of diseases feared.	News article	https://www.daijiworld.com/news/newsDisplay.aspx?newsID=401566 Daiji World, (2016)
1l	Kodavoor residents irked by untreated sewage into Indrani rivulet.	News article	https://www.thehindu.com/news/cities/Mangalore/Kodavoor-residents-irked-by-discharge-of-untreated-sewage-into-Indrani-rivulet/article17051689.ece Shet, (2017)
1m	Revive water sources like depleted wells, plead activists.	News article	https://timesofindia.indiatimes.com/city/mangaluru/revive-water-resources-like-abandoned-wells-plead-activists/articleshow/63435638.cms Times of India, (2018)
1n	Udupi: MLA blames officials for inefficient management of drinking water supply.	News article	https://www.daijiworld.com/news/newsDisplay.aspx?newsID=585958 Daiji World, (2019a)

1o	Students make device to monitor water quality.	News article	https://timesofindia.indiatimes.com/city/mangaluru/students-make-device-to-monitor-water-quality/articleshow/69509602.cms Times of India, (2019)
1p	Efforts on to save rivulet from pollution in Udupi.	News article	https://www.thehindu.com/news/cities/Mangalore/efforts-on-to-save-rivuletfrom-pollution-in-udupi/article28702918.ece Prabu, (2019)
1q	'Save Indrani river' rally launched.	News article	https://www.deccanherald.com/state/mangaluru/save-indrani-river-rally-launched-750341.html Deccan Herald, (2019a)
1r	Young minds join hands for 'Save Indrani river'.	News article	https://www.mangalorean.com/young-minds-join-hand-for-save-indrani-river/ Rodrigues, (2019)
1s	Use legal method to fight problem of pollution in rivulet: Shanbhag.	News article	https://www.thehindu.com/news/cities/Mangalore/use-legal-method-to-fight-problemof-pollution-in-rivulet-shanbhag/article28918674.ece The Hindu, (2019a)
1t	Udupi: Neglecting Indrani rivulet - Fight against CMC backed by documents.	News article	https://www.daijiworld.com/news/newsDisplay.aspx?newsID=613075 Daiji World, (2019b)
1u	Udupi city soon to get 24x7 water supply.	News article	https://timesofindia.indiatimes.com/city/mangaluru/udupi-soon-to-get-24x7-water-supply/articleshow/70776594.cms Sanjiv, (2019)
1v	Councillors raise concerns before new Udupi DC at CMC meeting.	News article	https://www.newskarnataka.com/udupi/councillors-raise-concerns-before-new-udupi-dc-at-cmc-meeting News Karnataka, (2019)

1w	Udupi municipality to clean Indrani rivulet.	News article	https://www.thehindu.com/news/cities/Mangalore/udupi-municipality-to-clean-indrani-rivulet/article30416025.ece The Hindu, (2019b)
1x	Udupi CMC sets aside 16 lakh for cleaning Indrani rivulet.	News article	https://www.thehindu.com/news/cities/Mangalore/udupi-cmc-sets-aside-16-lakh-for-cleaning-indrani-rivulet/article30813973.ece Prabu, (2020)
1y	Mangaluru: Udupi looks forward to water crisis free summer.	News article	https://timesofindia.indiatimes.com/city/mangaluru/udupi-looks-forward-to-water-crisis-free-summer/articleshow/74519103.cms Moodubelle, (2020a)
1z	Water consumption in Udupi goes up despite lockdown.	News article	https://timesofindia.indiatimes.com/city/mangaluru/water-consumption-goes-up-in-udupi-despite-lockdown/articleshow/75011426.cms Moodubelle, (2020b)
1a2	Udupi: Incessant rain creates floods, water enters houses.	News article	https://www.daijiworld.com/news/newsDisplay.aspx?newsID=607941 Daiji World, (2019c)
1b2	Karnataka floods: MAHE institute, Udupi ignores civic authorities' orders; open despite red alert.	News article	https://www.businesstoday.in/latest/trends/mahe-ignores-red-alert-over-karnataka-floods-to-students-woe/story/371645.html Khetarpal, (2020)
1c2	Dakshina Kannada, Udupi districts receive heavy rain.	News article	http://www.ptinews.com/news/10935872_Dakshina-Kannada--Udupi-districts-receive-heavy-rains.html PT News, (2014)
1d2	Decentralised waste management key in current	News article	https://www.newindianexpress.com/cities/thiruvananthapuram/2020/feb/16/decentralised-waste-management-key-in-current-scenario-say-experts-2104083.html

	scenario say experts.		New Indian Express, (2020)
1e2	Land used as dumpyard in Alevoor will be reclaimed.	News article	https://www.deccanherald.com/state/mangaluru/land-used-as-dumpyard-in-alevoor-will-be-reclaimed-777835.html Deccan Herald, (2019b)
1f2	Integrated & Sustainable SLRM in Udupi.	News article	https://sbmgramin.wordpress.com/2019/02/22/integrated-sustainable-slrm-in-udupi/ Swachh Bharat, (2019)
1g2	Adopting waste segregation as a mantra, Udupi gears up, Allots days for dry and wet garbage.	News article	https://swachhindia.ndtv.com/adopting-waste-segregation-mantra-udupi-gears-allots-days-dry-wet-garbage-7978/ Karelia, (2017)
1h2	Water tariff revised in Udupi city.	News article	https://www.thehindu.com/news/cities/Mangalore/Water-tariff-revised-in-Udupi-city/article15739600.ece The Hindu, (2016)
1i2	Udupi municipality plans online water bill payment system.	News article	http://www.mangaloretoday.com/main/Udupi-Municipality-plans-online-water-bill-payment-system.html Mangalore Today, (2015)
1j2	The human right to water and sanitation.	Website	https://www.un.org/waterforlifedecade/human_right_to_water.shtml UN, (2020a)
1k2	Ensure availability and sustainable management of water and sanitation for all.	Website	https://sdgs.un.org/goals/goal6 UN, (2020b)
1l2	Lakhs of people still have no access to safe	News article	https://timesofindia.indiatimes.com/city/bengaluru/lakhs-of-people-still-have-no-access-to-safe-drinking-water-in-karnataka/articleshow/72326537.cms Kumar, (2019)

	drinking water in Karnataka.		
1m2	Improper drainage system creates nuisance, DC warns builders	News article	https://www.daijiworld.com/news/newsDisplay.aspx?newsID=181101 Daiji World, (2013)
2a	An Evaluation of the Spatial Relation of Health, Literacy and Socio-Economic Development Index of Udupi District Using GIS Technology.	Research paper	Mathews, A. E., (2012). Manipal Institute of Technology, Department of Civil Engineering.
2b	Evaluation of leachate oddity and its contamination: A case study on Alevoor and Beedangude landfill sites deriving the best available techniques for the reclamation of the landfill site.	Research paper	Hallur, M. (2018). Manipal Institute of Technology, Department of Civil Engineering.
2c	Quality of Bore well water in Udupi Municipal area.	Research paper	Shenoy, K. N., Inchara, R., & Ananya, H. M., (2017). Indian Journal of Environmental Protection, 37(2), pp. 140-147.
2d	Influence of Solid Waste on Water Quality - A Case Study of Alevoor	Research paper	Maddodi, B. S., Udayashankar, H. N., & Prates, L. F. S., (2011). Manipal Institute of Technology, Department of Civil Engineering.

	Solid Waste Management, Udupi, India.		
2e	Computing of Udyavara Fluvial Systems - A river of Western Ghats, India: A pragmatic Inference of Runoff to Hydrological Cycle.	Research paper	Maddodi, B.S., Shankara, H. N. U., & Raghavan, B. R., (2011). Manipal Institute of Technology, Department of Civil Engineering.
2f	Municipal Solid Waste Management - A modern move towards the successful solid waste management crux on collection practices: A case study on Udupi CMC.	Research paper	Maddodi, B.S., Shreejith, K., Nayak, S., (2010). Manipal Institute of Technology, Department of Civil Engineering.
3a	IND - Karnataka Integrated Urban Water Management Investment Program Tranche 2. - Audited project financial statements.	Documents	https://www.adb.org/sites/default/files/project-documents/43253/43253-027-apfs-en.pdf (KUIDFC, 2019a)
3b	IND - Karnataka Integrated Urban Water Management	Documents	https://www.adb.org/sites/default/files/project-documents/43253/43253-027-emr-en_0.pdf (KUIDFC, 2019b)

	Investment Program Tranche 2. - Semi-annual Environmental Monitoring Report.		
3c	IND - Karnataka Integrated Urban Water Management Investment Program Tranche 2. - Semi-annual Social Monitoring Report.	Documents	https://www.adb.org/sites/default/files/project-documents/43253/43253-027-smr-en.pdf (KUIDFC, 2019c)
3d	IND - Karnataka Integrated Urban Water Management Investment Program Tranche 2. Audited project financial statements. - Resettlement plan.	Documents	http://www.kuidfc.com/ENG/uploaded_documents/jalasiri/Status%20report%20Tranch%202%2023_05_2018/Appendix%2017%20RP%20of%20Udupi%20WS%20Distribution%20Network%2014.05.18.pdf (KUIDFC, 2018)
3e	IND - Karnataka Integrated Urban Water Management Investment Program Tranche 2. - Initial Environmental Examination.	Documents	http://www.kuidfc.com/ENG/uploaded_documents/jalasiri/Status%20report/Final%20IEE%20Udupi%20WS%20(Feb%202019).pdf (KUIDFC, 2019d)

3f	Udupi Hazard Plan	Documents	https://cdn.s3waas.gov.in/s36bc24fc1ab650b25b4114e93a98f1eba/uploads/2018/07/2018073075.pdf (Vishal, 2016)
4A	Water security expert	Interview	Appendix D for interview guide
4B	Waste management expert	Interview	Appendix D for interview guide
4C	Local representative	Interview	Appendix D for interview guide
4D	Water treatment expert	Interview	Appendix D for interview guide
5A	Buildings are constructed close to the Indrani river.	Observation	-
5B	Dirty water in Indrani, becoming dirtier downstream.	Observation	-
5C	Water is full with vegetation, construction debris, plastic and other garbage.	Observation	-
5D	Loads of fires to burn waste and vegetation.	Observation	-
5E	Large amounts of water are being used to water the gardens.	Observation	-

5F	Water is pumped up from the ground, treated to create drinking water. Then treated to a lesser standard fit enough for release in the environment.	Observation	-
5G	When we arrived at the location of an apartment building with a treatment installation, the installation was shut off because of the noise.	Observation	-

Appendix F: Coding categories

Table 4: Summary of the concepts studied in this research and the findings. All findings of the concepts come from the five data product sources: Media, previous research, policy/planning documents, interviews, and observations.

Concept	Findings
Water security	Theory suggested various dimensions of water security, but the interviews showed that only one was required to be studied in depth.
Water resources	Discrepancy about the availability of fresh water to urban residents.
Water risk	Risk related to water constitutes flood and contamination risks.
Flood risk	Minor floods occur, but it is not deemed problematic.
Water pollution	The status of water quality and pollution came out as the most important topic to be studied. This study looked at the sources and effects of - and solutions to water pollution issues.
Solid pollutants	Water is mostly polluted with organic matter, plastic- and construction debris.
Liquid pollutants	Untreated sewage and effluent streams into the Indrani are the largest source of liquid pollutants. Untreated domestic sewage and the Indrani itself pollute the groundwater.
Waste management	The status of the solid - and liquid waste management infrastructure was found to be the most important impediment to water quality.
Solid waste management	Solid waste is collected by the municipality and brought to the landfill where some of the waste is separated. The capacity is not sufficient.
Liquid waste management	Liquid waste management is either centralised or decentralised. In both, the infrastructure is severely under capacitated.
Livelihood	The stories of various stakeholders documented in this research show how water pollution has affected people's livelihoods, particularly by losing access to fresh water sources and a reduction in agricultural and fishing opportunities.
Urban & peri-urban	The findings suggest some differences in impacts between the urban and peri-urban residents.
Governance	The municipal and district authorities have various plans for water governance in the future. Additionally, municipal-citizen interactions are documented.
Solutions	All sources propose various solutions to the problems in the area. This research summarizes them and builds on them to propose recommendations.

Appendix G: Solutions mentioned by the Udyavara news paper.

Municipality

1. The municipality should adequately manage the wet wells. Wastewater should not be discharged directly into the river. Arrangements should be made to avoid problems during power outages, generators should be provided wherever there is none.
2. All problems in the sewage treatment plant should be addressed so that the leaving wastewater is completely clean. Complaints from the people of the river should be addressed immediately.
3. Every three months, top officials of the municipality should visit the wet wells and the sewage treatment plant to review the performance.
4. Every wet well and sewage treatment plant management has to formulate a committee of local citizens to determine whether it is working properly. The shortcomings should be brought to the notice of the municipality and the district.
5. The river must be cleaned once a year.
6. Cleaning and supplementary work needs to be earmarked in each budget to prevent unnecessary delays.
7. The municipality should promptly provide water to households of wells that have already been polluted by the Indrani river.

Citizens and organisations

1. Wastewater should not be left in the river. Ask for a drainage system. Pitch and maintain until it arrives.
2. Pressure the municipality to install more dumpsters. Create awareness for not throwing garbage into the river.
3. The movement should be kept alive forever.

Representatives

1. Representatives of the problem areas should first conduct free health camps for river victims. Health camps should be organized at least every six months.
2. Laboratory inspection should be done once every four months to ensure that the wells in the area around the river are potable.
3. Victims should be provided with water from the municipality.
4. At each meeting of the Municipal Council, the representatives should bring up any issues of their respected area.
5. The minister in charge of the district should take note of the problem in legislative agenda programs.
6. Priority should be given to the drainage system and cleaning the Indrani.
7. The state government and the central government should seek to make a special contribution to the center’s urban development fund, which will fund the legislator’s welfare fund.

District and various departments

1. This issue should be addressed and resolved by the District Collector. The whole district can benefit if this problem is resolved.
2. Visit the problem area first and listen to the difficulty of the people.
3. The role of various departments in Indrani cleaning is essential. All departments from the Environmental Pollution Control Board should be putting pressure on the municipality for the betterment of the future. We should be careful not to spoil the Indrani river for any reason.