CLOSING THE LOOP:
EXPLORING STAKEHOLDER ACCEPTANCE OF WASTEWATER TREATMENT TECHNOLOGY AND WATER REUSE IN TIRUPUR, INDIA

A Thesis

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by

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ABSTRACT

This thesis seeks to explore contextual factors behind, and stakeholder perceptions on, the acceptance of wastewater treatment technology and water reuse in textile bleaching and dyeing facilities in Tirupur, India. Two main research questions are asked: 1. How has the mandatory implementation of zero liquid discharge (ZLD) technology driven physical changes in these textile facilities, and 2. How has implementation driven and shaped technology acceptance by the actors and stakeholders within these textile facilities?

Through a multi-case study approach, five textile facilities and treatment plants in Tirupur were selected and studied, that represent a maximum variation of conditions of implementation and use. Qualitative methods of data collection and analysis were used to explore and contextualize perceptions on technology acceptance.

Findings suggest that stakeholder acceptance is linked to a number of factors and themes. These factors vary from the perceived need for control over the process of treatment and reuse, to rising land and water costs. Thematic analysis indicates that, among other themes, stakeholder acceptance of ZLD technology and wastewater reuse can be linked to a shift in perspective from zero liquid discharge to zero waste, where water reuse and resource recovery are emphasized.

BIOGRAPHICAL SKETCH

A passion and concern for all things sustainable led me to this masters program at Cornell University, where I take an interdisciplinary approach towards studying sustainable design at the department of Design and Environmental Analysis, housed in the College of Human Ecology. I have a background in urban design and architecture and I love learning about and getting involved with research and projects that explore innovative strategies to environmental problems. I truly hope that this thesis is one of the first steps of many more to come.

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For their faith in me, and for their endless patience, support, and guidance throughout this research process, I first want to thank my advisor and chair, Professor Ying Hua, and my minor member, Nicholas Sanders. Their classes on the human dimensions of sustainability in the built environment and on economics and environmental policy helped me to work my way around understanding and attempting to think critically about the themes, issues, and vocabulary I needed for my thesis. Thank you both for reading through my long-winded chapters and drafts.

To my grandfather, R. Rayaprolu, for believing in higher education. To one of my many other grandfathers, G. Subrahmanyam, who came with me to Tirupur and helped me talk to so many people and translate questions when needed into Tamil. Thank you for your help, you made this research trip enjoyable and I am glad I got to spend more time with you. I also want to thank all the people I met in Tirupur, who were hospitable and helpful in assisting me with looking for case study sites and interviewees.

Thanks to my family – my mother, father, and sister, who lived my Ithaca experiences with me from India. Thank you for listening to me go on and on about my thesis and (almost) never telling me to stop being so annoying and boring. My extended family, who helped me with housing and comfort both here in the United States and at home in India, wherever and whenever I needed it. To all of my friends that I made as a part of this masters program, you were the best part of this course and experience. To all of my other friends (you know who you are), you are essential to my sanity and life, thank you for existing.

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CHAPTER 1

INTRODUCTION

1.1.Introduction

Tirupur, India, is a place of ‘decentralized textile factories’ (Chari, 2004) where, because of immense groundwater pollution problems and freshwater constraints, it is mandated that textile bleaching and dyeing factories implement and use zero liquid discharge (ZLD) technology, to treat their wastewater to the point that a maximum amount of reusable, clean water is recovered from the treatment process. This clean water could then potentially be reused back into the production process at these facilities, almost creating a closed-loop system that emphasizes treatment, recovery, and reuse.

1.1.1. What are ZLD systems?

Zero liquid discharge, or ZLD systems, are those systems that are used to treat wastewater to the point that a maximum amount of clean water is gained, and where a concentrated by-product containing all the residual waste elements, ideally in a solid form, is the separated by-product of this process. There are many issues that implementing a ZLD system seeks to address: climate water constraints and freshwater scarcity, rising water demand due to industrialization, environmental regulations and compliance, the high environmental costs of improper wastewater disposal, and corporate social responsibility (Tong & Elimelech, 2016).

Prevalent wastewater treatment technologies (Dalan, 2000) that are used to achieve zero liquid discharge are phases in the process of treatment and range from membrane processes (commonly through reverse osmosis, RO, a water purification technique) to evaporation and crystallization processes. The concentrated by-product of this technical process is usually called the concentrate or effluent (ibid). The end product of the process is called the clean stream, the permeate, distillate, condensate or filtrate, depending upon which step of the process is being discussed.

When discussing ZLD technology, a common term used to describe the performance or results of the technology is recovery, which is "*the ratio of the clean stream flow rate to the feed wastewater [initial incoming wastewater] flow rate*," (Dalan, 2000), and represents how much water is lost throughout this process. This loss factor is usually small – anywhere between 2 to 8% of water is lost due to evaporation or other reasons, and so ZLD technologies generally recover around 92 to 98 % of the water back from the treatment process. The image below (Figure 1) shows how the general concept behind ZLD operates.

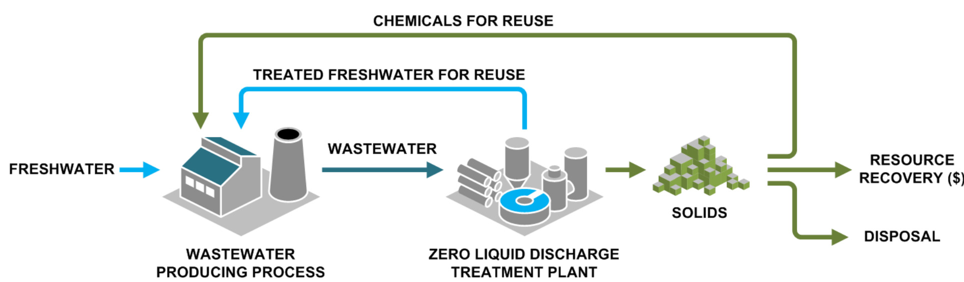


Figure 1: What is Zero Liquid Discharge? ("What is Zero Liquid Discharge & Why is it Important?" 2017).

ZLD systems are also increasingly used to recover valuable solids from the wastewater, such as salts like potassium and sodium sulfate, and critical trace elements or metals (Tong & Elimelech, 2016). This, combined with the advantages of in-house water recycling, point to how there are advantages to looking at ZLD technology as a waste management strategy in addition to as a technology. These advantages stem from viewing water efficiencies as catalysts for improvements that are elsewhere; whether on-site or off-site.

1.1.2. A brief history of ZLD as technology

ZLD's conception traces to the United States, during the 1970s (Grönwall & Jonsson, 2017b; Tong & Elimelech, 2016), where ZLD implementation occurred in, and mostly continues to occur in power plants. During the 1970s, adoption of ZLD reduced the approval period (for projects to get discharge agreements) from several years to just a few months (Tong & Elimelech, 2016), which increased its uptake amongst power plants.

Other origins of ZLD technology can be found in the history of membrane bioreactors, which use membrane filtration processes in combination with biological treatment processes (like the activated sludge process, where biological agents and aeration tanks are used to separate waste from water) to treat wastewater. While membrane bioreactors (MBR) are not the same as ZLD technology, they are often combined with further secondary and tertiary treatment steps to become ZLD. Membrane bioreactors (MBR) were first developed to treat and process wastewater on cruise ships, where freshwater was scarce (Judd & Judd, 2011 as cited in Elmer, 2014). Some 'high-value' buildings in the United States (the Falling Waters home in Chicago, the Bank of America Tower, and the Solaire Building in New York) use MBRs to recycle greywater on-site (Elmer, 2014). Membrane bioreactors are feasible in both developed as well as developing countries, as they are comparatively 'low-tech' and require less energy.

1.1.3. ZLD and environmental impacts

Tong & Elimelech (2016) point to how ZLD implementation can have serious environmental risks, such as leaching and contamination of improperly stored solid wastes and the significant GHG and carbon emissions that are consumed as part of the ZLD process. As a tertiary treatment process, ZLD is a highly technical process, especially as compared to primary and secondary wastewater treatment technologies. One main concern with ZLD is that it transfers the problem of groundwater pollution into a problem of emissions and consumption of resources, especially fossil fuels.

1.1.4. Design as potential added value of such environmental infrastructure

In addition to being a highly technical infrastructure requirement, wastewater treatment plants are also being seen as an opportunity to add ancillary value to their communities. They are designed and used as athletic fields with public walkways and bike paths (CH2M, 2017), and as state parks built on top of wastewater treatment plants as 'community green roofs' (Miller, 1994; Rodriguez, 2014). These are examples of how wastewater treatment plants were viewed as dead zones for local residents, and how that is changing. Architects, landscape architects, planners and community members participate in the process of adding community value to such dead zones together. In the case of the state park, the architect Phillip Johnson was called in to make the plans for a state park above a wastewater treatment plant (ibid). By creating community amenities out of such infrastructure, the social sustainability aspects of such infrastructure are meant to be enhanced.

1.1.5. ZLD as mitigation or adaptation strategy?

ZLD technology is considered to be a mitigating strategy in that it alleviates water quality issues, reducing the effects of groundwater pollution (Yaqub & Lee, 2019). In the case of Tirupur and other parts of India as well, ZLD is a supply-side management tool that is used to adapt to increasingly critical water quality issues.

1.2. Background and Problem Statement

Tirupur is the first example of a city that has, due to regulatory pressure, implemented ZLD technology systematically (Grönwall & Jonsson, 2017a). Tirupur's bleaching and dyeing units form a distinct, water-intensive sub-cluster of the area. These textile bleaching and dyeing factories could choose their mode of compliance with this regulation, by either opting for on-site wastewater treatment and reuse, or for off-site, distributed wastewater treatment and reuse (through joining a communal wastewater treatment plant). Both options are decentralized, non-sewered sanitation solutions, where the ‘sewer’ used to be the Noyyal river that runs through Tirupur.

Figure 2, presented below, shows a map of Tirupur’s textile bleaching and dyeing facilities and the distribution of common effluent treatment plants throughout the area. It shows how the growth of these factories has primarily been along the tributaries and banks of the Noyyal river, because of the need for clean water as a production input and flowing water as a receptacle for convenient waste output. The case studies of textile facilities and treatment plants chosen for this thesis are all located in zones shown on this map.

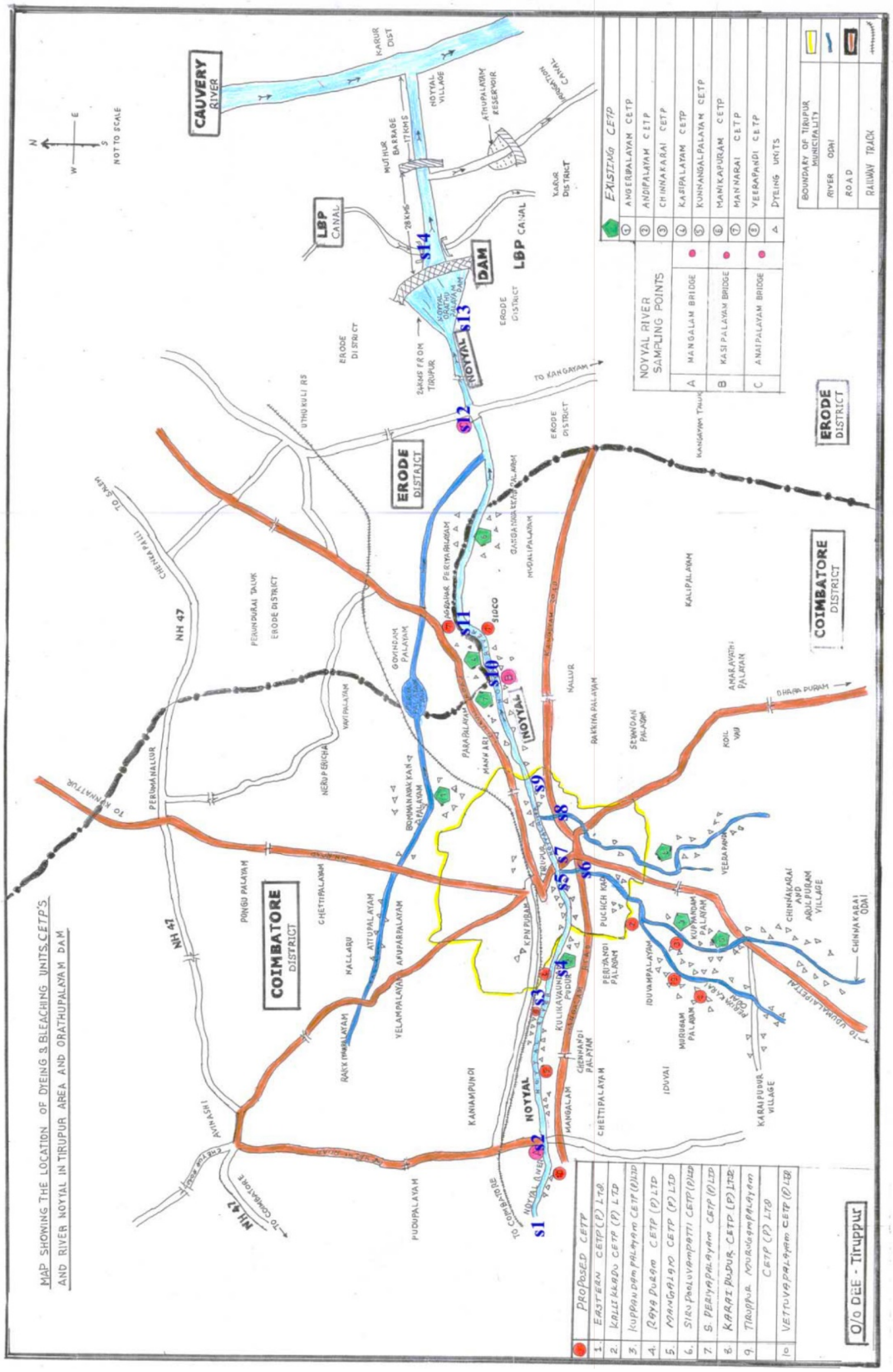


Figure 2: A map of Tirupur's textile facilities, as made by the TNPCB (Pilot Study).

Analysis of the technical specifications of ZLD as a regulation in Tirupur (Chapter 2: Background) shows how in-house water reuse is not mandated to the same level and degree of technical specifications that compliance, through the installation of ZLD technology and the prevention of effluent discharge, is. Beyond Tirupur, the idea of using ZLD technology as a regulatory requirement has recently been proposed to be made mandatory on a national scale, across different industries (Grönwall & Jonsson, 2017a), and is also one of the key means by which the government in India is proposing to clean up other rivers, and address similar pollution problems that many other parts of India are facing. This makes it a critical issue to be studied from the perspective of other disciplines as well.

Within this context of Tirupur, of water reuse not being mandated in the same way as compliance is, and of this regulation being deployed on a national scale in the future, I have chosen to focus on exploring stakeholder acceptance of wastewater treatment technology and water reuse, as acceptance is one of the many barriers towards the success of a regulation.

1.3. Research Overview

1.3.1. Research goals

The two main research goals of this thesis, that stem from the problem statement described above, are:

- To explore and identify physical or contextual factors behind the mandatory implementation of wastewater treatment technology and water reuse in Tirupur.
- To explore and identify perceptions on the acceptance of wastewater treatment technology and water reuse in Tirupur.

The first research goal helps to contextualize and situate the perceptions that the second research goal seeks to explore. Also, one of the purposes behind the first research goal was to explore what physical indicators of acceptance in these textile facilities might look like, especially since it is uncertain to this researcher whether in-house water reuse actually happens in these facilities.

The second research goal is to explore perceptions on technology acceptance, by stakeholders and actors within the setting of the textile facilities. A paper by Gaede & Rowlands (2018) broadly defines acceptance as "a *favorable or positive response (including intention, behavior and – where appropriate – use) relating to a proposed or in-situ technology or socio-technical system, by members of a given social unit (country or region, community or town and household, organization*." Both research goals are about exploring perceptions on such acceptance, through field research to collect data. Using perceptions as evidence in the social sciences can help to "*provide important insights into observations, understandings, and interpretations of the social impacts, and ecological outcomes"* (Bennett, 2016).

1.3.2. Main Research Questions

These two research objectives have been translated into the following research questions:

1. How has the mandatory implementation of wastewater reuse technology driven physical changes in textile facilities in Tirupur?

1.1. What are the different ways in which wastewater reuse has been implemented in the textile facilities?

1.2. What are the physical characteristics of these textile facilities?

2. How has the mandatory implementation of wastewater reuse technology driven technological acceptance in users and stakeholders within the textile facilities in Tirupur?

2.1. Who are the stakeholders and users within the textile facilities?

2.2. What are their perceived advantages and disadvantages of having and using this technology in the textile facilities?

2.3. What factors do they perceive to be linked to the acceptance (perceived effectiveness, ease of use, and usefulness) of this wastewater reuse technology?

The two research questions are linked in that the first question describes the context of the physical setting, and the second explores perceptions on technology acceptance by the people within the physical setting. As such, they are both complementary questions, one dealing with place, and the other, with people within the place.

1.4. Thesis structure

This thesis is structured into 6 chapters. The first chapter is an introduction, that briefly covers the background, goals, and questions of this thesis, and that introduces general concepts and themes that pertain to this thesis. The second chapter presents a more detailed overview of the background of Tirupur and covers existing research on Tirupur and the ZLD regulation, focusing specifically on water reuse. The third chapter, the literature review, covers acceptance research and frameworks, from technology acceptance to social acceptance. These three chapters together represent the pre-field research stages of this thesis. The next three chapters represent the field and post-field research stages of this thesis. Chapter 4 covers the qualitative methodology approaches chosen to answer the research questions of this thesis, and the general research plan for the collection of data. Chapter 5 covers the findings of the research process, through qualitative descriptions of the five case studies, and through descriptive details of the main factors found to be linked to acceptance. Chapter 6 discusses these findings, by situating them within the context of what existing research in Tirupur says, and by incorporating the findings into a discussion of the technology-organization-environment framework, a framework that is introduced in Chapter 3.

CHAPTER 2

BACKGROUND

2.1. Introduction

This chapter presents an overview of research in Tirupur on the ZLD regulation. While the previous chapter introduced concepts such as ZLD, zero-emissions wastewater, non-source sanitation systems and strategies, this chapter delves into the context of Tirupur and ZLD technology as regulation in Tirupur.

The chapter is structured to begin with a general introduction to the ZLD regulation, provide a brief explanatory primer to the textile industry in Tirupur, and continue into the current (as of this thesis) status of research on wastewater treatment and more specifically, on water reuse in textile units in Tirupur. At the end of this chapter, a summary providing justification for the research direction chosen for this thesis - stakeholder acceptance - is presented. The next chapter presents a literature review on acceptance research, and theories, models, and frameworks that are used in acceptance studies.

The general research aim of this background literature review is to explore and succinctly summarize the socio-economic and environmental context behind the mandatory implementation of ZLD technology in textile facilities in Tirupur, specifically focusing on what existing literature says about in-house water reuse. The focus of this research aim is primarily on textile units, even though the context of ZLD in Tirupur involves many other groups of actors, associations and other stakeholders.

There is a rich amount of interest and research on the ZLD regulation in Tirupur, from the media as well as from academic researchers, the textile industry in Tirupur itself, technical experts and the government's pollution control boards (both state and national). This background is meant to be summative, and not exhaustive, as other papers and research presented in this chapter have done a much better job of delving into the background of Tirupur and the textile cluster. Also, since much of the research is technical, stemming from civil, chemical, mechanical and environmental engineering fields, a general inclusion guideline for this chapter was to understand relevant technical terminology and only include important terminology in layman's terms.

2.1.1. An introduction to the place that is Tirupur, India.

Tirupur, India is a 'decentralized factory' (Chari, 2004) of mostly small-scale textile units, that is located in the South Indian state of Tamil Nadu. Situated along the banks of the Noyyal river, it is both the name of a city and a district that specializes in the textile and knitwear industry, dominating both the domestic markets as well as the export of cloth and knitwear (Crow & Batz, 2006).

Textile units, or factories, are of a wide variety in Tirupur. Most are small-scale (ibid), many are family-run and can trace their origins to farmers who shifted to the textile sector during the 1970s (Chari, 2004), and a few are now large-scale, highly formal, vertically-integrated corporations (Harris et al., 1999; Chari, 2004; Crow & Batz, 2006; Grönwall & Jonsson, 2017b). The small and medium-sized textile units (SMEs) tend to specialize in one or more parts of the textile production process: knitting, bleaching, dyeing, printing, or processing. Of these parts, the bleaching, dyeing and printing steps are those stages of textile production that need a large quantity of water as input in order to function as a business. These stages are called the wet processing stages, and need the most amounts of freshwater as input, ending in ever-increasing quantities of wastewater as the output.

Chari (2004) writes of how these textile factories are present everywhere in Tirupur, from residential neighborhoods with tiny, nameless units, to factories in the suburbs of Tirupur, to planned, official industrial parks. Sometimes the only signs of bleaching and dyeing units would be a cluster of smokestacks (ibid).

Tirupur used to be an agrarian town until the 1970s when the textile cluster started to grow and develop into the billion-rupee industry that it is today (Nelliyat, 2007; Jegadeesan & Fujita, 2014). Chari (2004) points to the contrast between the "*flashy marbled [Greco-Tamil] houses*" and the "*bumpy, unpaved roads [with] incoming bullock carts*" (Chari, 2004, pp. 10). Even now, there is a stark contrast between the 'state-of-art' ZLD technology that is required of textile facilities in Tirupur and the open sewer systems that still operate in the rest of Tirupur.

During the 1990s, there was a visible boom in the exports from Tirupur and overall production earnings (Jegadeesan & Fujita, 2014)). During the 1990s, there was a 230% increase in the number of firms that had 29 to 49 workers (Chari, 2004). This suggests the role that industrial decentralization and SMEs played in the boom in earnings, and in the development of Tirupur's bleaching and dyeing units as a distinct sub-cluster (Harris et al., 1999; Chari, 2004; Nelliyat, 2007).

Tirupur is also one of a hundred cities selected to be a part of India's smart cities mission, as noted by an Indian government website (GOI, 2015). In their website, under the '*What is a smart city*' section, it is noted that there is no one universal definition for a smart city and that this definition depends on the city residents, and their aspirations. Some smart city strategies are more policy-oriented, while others are more design-oriented. One role that this designation can hopefully influence in Tirupur is to look at the integration of smart city strategies that address the ethical issues that the city faces - the working conditions, the water quality, pollution levels, and health.

Tirupur is also the first example of an Indian cluster that has implemented ZLD technology systematically (Grönwall & Jonsson, 2017a), which enables water reuse of the treated water that goes through primary, secondary and tertiary treatment in a ZLD system.

2.1.2. Bleaching and dyeing textile units in Tirupur

Tirupur's bleaching and dyeing units form a distinct, water-intensive sub-cluster. While most of these units are micro, small or medium-sized (Crow & Batz, 2006), some larger units are "*dedicated, linked in dependent relations to particular exporters who are often partners in ownerships*" (Chari, 2004, pp. 67). Generally, dyeing and bleaching units send their fabric back to the knitwear companies or manufacturing companies in Tirupur. There are not many integrated manufacturing facilities, but there are vertically integrated production facilities, of exporters. There are more dyeing units than there are bleaching units, with a ratio of about 3 dyeing units for every 1 bleaching unit there is (TNPCB, 2012). Bleaching used to happen "*through antiquated open-tank systems, in which workers stand inside vats of chemical-saturated water, beating fabric against the sides of the vat*" (Chari, 2004, pp. 66). Workers were male, and of lower classes, with horrible working conditions, often working outside under the hot sun. There are gendered roles in textile units in Tirupur, where feminine workers are used for the checking and finishing stages, - unskilled, non-threatening, low-paid work as semi-skilled workers or secretaries in the administrative sections, if any (Chari, 2004, pp. 245).

2.1.3. Organizations that have major roles in the functioning of textile bleaching and dyeing units in Tirupur

Tirupur has many cluster-level organizations that work as intermediaries, facilitators and enforcers in the relationships between the textile units and the ZLD regulation. A brief overview of some of these main organizations, their acronyms, and their functions are presented here. These acronyms will be used throughout later sections of this chapter, and so they are presented succinctly here.

Banks and their roles in permits for formal bank credit – through short-term loans for equipment. Banks play a big role in how working capital between buyers and sellers flows. This is not the same set-up for all firms – smaller firms with different business connections have different degrees of bank access, and this relationship is mediated by family connections, caste memberships and other networking-based factors (Chari, 2004).

The Tamil Nadu Pollution Control Board (TNPCB) is a government department that enforces, amongst other acts, the Water Act of 1974, Environment Protection Act of 1986. Swaminathan (2014) explores the role of the board in the process of arriving at ZLD as a regulation in Tirupur, from failing to prevent groundwater pollution, to the manner in which they enforced the court directives. Much of the data on textile bleaching and dyeing units are collected and analyzed by the TNPCB, a point which Swaminathan (2014) raises when questioning the legitimacy and role of the TNPCB as inspector, enforcer, data collector, and data monitor all at once.

Organizations such as the Tirupur Dyer's Association are textile cluster-level organizations that have membership rates of 96% (Crow & Batz, 2006). They play important roles in mediating between textile units and the TNPCB, providing textile dyeing units with technical learning assistance through information and access to contractors. They are also the source of data on textile units and their locations for the TNPCB (ibid).

The New Tirupur Area Development Corporation Limited (NTADCL) is a public-private partnership that is responsible for the development of water schemes, sewage and effluent treatment plant schemes, and model industrial estate developments in Tirupur (Mahalingam, 2013). One main role that they play is in the provision of water supply to textile units in Tirupur, at a rate that they set. This water is colloquially called the L&T water (Grönwall & Jonsson, 2017b), after a major infrastructure company in India.

2.1.4. Research on health implications on the effects of water toxicity and groundwater pollution in Tirupur

The health risks and implications behind allowing unregulated, growth-oriented water-intensive industries such as the textile bleaching and dyeing cluster in Tirupur to operate freely without environmental regulations have been documented by many researchers (Furn, 2004; Nelliyat, 2007, 2012). Grönwall & Jonsson (2017b) write of how women in Tirupur's poorer areas found the water to taste different and affect cooking and washing practices. Nelliyat (2012) also writes about how health risks from industrial pollution in Tirupur affect the surrounding villages and slums in Tirupur more than other areas, who have access to alternate sources of water other than just groundwater. Furn (2004), through a soil sample and distribution study, found that land irrigated with water from the Orathupalayam Dam (which was meant to be used for irrigation by farmers, but became a toxic reservoir for colored wastewater, see Figure 3) became uncultivable and toxic, even more than four kilometers from the dam.

Figure 3: Colored wastewater in Tirupur (Matthews, 2015).

Nelliyat (2012) also writes of the ambient environment-related health risks that textile workers, especially the semi-skilled and unskilled workers employed for more physical duties, face in Tirupur. These health risks ranged from contact dermatitis to risks from copper and other metals exposure, risks of cancer from known carcinogens, and water-borne diseases. These effects of groundwater pollution by Tirupur's textile units, especially on farmers and their land became one of the main drivers that led to the inception of ZLD as a command-and-control regulation in Tirupur.

2.2. The inception of ZLD as regulation in Tirupur

The push for effluent treatment and discharge regulations in textile units in Tirupur primarily stemmed from public environmental concern, or indeed public alarm rather than just concern, at how the expanding textile cluster in Tirupur discharged their wastewater into the Noyyal river, causing high levels of toxicity and pollution issues. This toxic wastewater accumulated in the Orathupalayam dam (built on the Noyyal river in 1992), which was meant to store water for irrigation purposes and assist farmers nearby, but ended up storing highly toxic, colorful wastewater and chemicals (Swaminathan, 2014). Groups representing the farmers in and around Tirupur formed an association to litigate for effluent discharge regulations in the Indian courts, that then turned into a decades-long process of court orders, expert committee evaluations, directives, court injunctions and shut-down orders (Grönwall & Jonsson, 2017a, 2017b; Swaminathan, 2014). This litigation process started during the 1980s, and continues to date, in the form of compensation claims and other proceedings that still go through the courts.

The origin of ZLD as regulation can be traced through these government orders and directives, that initially ordered the Tamil Nadu Pollution Control Board (TNPCB) to order textile units to establish primary and secondary wastewater treatment (i.e., not complete zero liquid discharge) before discharging the wastewater into the Noyyal River. The inception of the use of common effluent treatment plants (CETP), that a group of textile units would send their wastewater to, comes from these initial directives. The first few CETPs were registered and operated (as primary wastewater treatment) during the 1990s, as private companies that had textile units as both paying members (as a flat monthly fee) as well as shareholders (Grönwall & Jonsson, 2017b). Over the course of the next two decades, compliance was tightened, effluent standards in terms of total dissolved solids (TDS, which is an indicator of the level of toxicity of wastewater) levels were made mandatory, and closure orders were handed to textile units that were guilty of non-compliance, or of free-riding with less production costs compared to those units that do comply (Grönwall & Jonsson, 2017a).

In the early 2000s, the TNPCB, in being directed by the courts to do more, and with the help of local engineers, began to advocate for ZLD - through tertiary treatment processes (through the addition of reverse osmosis technology), for the recovery of Glauber's salt (that can be reused in the production process of dyeing, or can be sold in markets) and for water recycling. After trials and pilot tests of the technologies needed to achieve ZLD, a 2006 court order mandated ZLD through a series of technical specifications, which is the first point at which the mandatory installment of ZLD technology became a regulation (ibid). ZLD was mandated through technical specifications on "*how this was to be attained through a combination of RO, RO reject management and evaporation*" (Grönwall & Jonsson, 2017b pp. 613).

This 2006 court order states: "*It is submitted that to prevent further groundwater pollution/Noyyal river pollution, the Board is instructing the functioning 729 Bleaching and Dyeing units to provide zero discharge treatment system either individually or commonly so as to ensure complete recovery* ***and reuse the water and salt*** [emphasis researcher's own] *from the wastewater discharged from their bleaching and dyeing operations,"* (Shah, 2006). The zero-discharge treatment system mentioned in this court order is then specified as additional tertiary reverse osmosis treatment. At this point, and even during subsequent notifications, the reuse of water and valuable solids is implied as part of the ZLD regulation, but is not mandated through specifications or compliance standards, in the same way that implementation of ZLD technology is.

This wastewater treatment regulation is thus either decentralized and on-site, with IETPs, or a type of distributed, satellite system (CETPs) that is independent of a main centralized system or public works facility. At this point, some CEPTs went from being private companies to ones that were operated on a public-private partnership model, between TWIC and investor-textile units.

Further court directives were issued to prevent non-compliance or less-than-satisfactory implementation of ZLD, which was an increasingly contentious issue that was also being covered by the media. This was done by directing the TNPCB to disconnect electricity to non-complying textile dyeing and bleaching units, by levying pro-rated fines to free-riding textile units that would then be used for the remediation of the river and dam, and ultimately, through a total shut-down order in 2011, ordering the closure of all textile dyeing and bleaching units in the district of Tirupur (Grönwall & Jonsson, 2017b). This shutdown order had several effects. In order to be allowed to reopen and resume business operations, textile bleaching and dyeing units had to be given permission to operate on a case-by-case basis. It took anywhere from two to five years for textile units and CETPs to be able to resume business. Many textile workers, especially semi-skilled and unskilled workers, lost their jobs (ibid), and around 100 textile units never reopened in Tirupur (ibid).

Data on micro-sized textile units, that are the nameless and mobile units that Chari (2004) found to be anywhere and everywhere in Tirupur, is lacking. This sort of data is difficult to collect, since such units don't comply with regulations, and operate informally, usually in residential neighborhoods.

In 2012, the extraction and use of groundwater was prohibited (TNPCB 2012), which meant that textile bleaching and dyeing units had to obtain their water supply from NTADCL, at the rate that NTADCL set for the industry, or from private water tankers. This prohibition order is one of many orders that used compliance specifications as the main command-and-control way of reducing groundwater pollution and wastewater discharge.

2.3. The tradeoffs of this regulation

2.3.1. Environmental costs and tradeoffs

The ZLD regulation is a "*technologically optimistic*" (Swaminathan, 2014 pp. 240) regulation that looks at technology as the most efficient means of achieving environmental sustainability, without compromising on a business-as-usual, capitalist-led development need. Discussions on the scale of exploitation and resource consumption allowed are not encompassed by this regulation (ibid).

An environmental life cycle assessment of a ZLD plant in Tirupur (Rajakumari & Kanmani, 2008) shows how the main source of carbon emissions is from the step of electricity generation, responsible for 98.5% of the carbon emissions. Other issues with a ZLD plant are that the evaporator step of the ZLD process (that is responsible for drying the sludge into a solid state) contributes towards a significantly larger amount of GWP (global warming potential) units than other steps of the treatment process (ibid). The significant amount of electricity needed and emissions generated from ZLD plants has led some researchers to question whether the issues with groundwater pollution are being traded for other environmental issues (Nelliyat, 2007).

2.3.2. ZLD versus MLD or Best Available Technology

The ZLD regulation, as specified by the courts to be the implementation of tertiary treatment through RO treatment and evaporators (Shah, 2006), is one that is the opposite of a best available technique method of approach (Grönwall & Jonsson, 2017a). A minimal liquid discharge (MLD) approach "*enables up to 95 percent liquid discharge recovery. This takes into account that attaining the final 3–5 percent of liquid elimination to achieve ZLD can nearly double the treatment cost*" (Grönwall & Jonsson, 2017a pp. 27).

An MLD approach, using a combination of low-tech and high-tech methods, has been tested in CETPs in Tirupur, through the use of solar evaporation pans to dry out the solid sludge that is the by-product of the treatment process (Mani & Madhusudanan, 2014). This method was then prohibited in a 2018 order by the TNPCB, as it was found to be a point of contamination, through seepage through the ground. So ZLD is now specified through RO treatment (recovery of as much water as possible) and evaporators (to dry out the sludge), which are both highly energy-intensive steps. The ideal solution here is unclear – but for now, the decision is to prevent groundwater contamination, rather than prevent emissions or promote water reuse.

2.4. ZLD: Selected technical specifications

2.4.1. Water reuse

During 2014, the TNPCB in a circular memo directs how inspections of the ETPs should check for the installment of electromagnetic flowmeters at - amongst other points - points where the clean, treated water (the permeate) is returned and reused, and at points where the brine solution is reused or returned to textile units. A logbook on how the permeate, brine solution and/or solid Glauber's salts are reused must be maintained. These flow meters must record data continuously, must not have a switch, and data must be sent to the local inspection offices on a regular basis. Beyond this, the circular memo is unclear on whether water is mandated to be reused in-house back into the production process, or if it can be reused for other purposes, like gardening, which Grönwall & Jonsson (2017a) call a "*popular pretense for releasing wastewater within or outside factory walls*" (Grönwall & Jonsson, 2017a pp. 27). Water reuse in textile bleaching and dyeing units is also incentivized by regulations that prohibit using groundwater for commercial purposes in Tamil Nadu ((Grönwall & Jonsson, 2017a), and with rising water costs of private water supply from the NTADCL (ibid).

2.4.2. Signs of non-compliance

Most of the directives in this circular memo relate to mandatory compliance with specified ZLD technology, to rules for disposal or discharge, and to inspections for signs of non-compliance. For example, textile units are not allowed to have any flexible hoses for inlet and outlet points in any part of the treatment plant, as hoses can be rearranged easily. Permanent, immovable pipelines are mandatory. Other signs of non-compliance include the presence of bypass pipelines in and around the ETP, that can be used to bypass treatment and discharge wastewater into the ground. The circular memo details inspection guidelines on excavation points to check for these bypass pipelines.

2.4.3. Safety measures for ambient hazards

This circular memo also states that the cleaning of ETP equipment should be through mechanized methods, rather than manual methods. Other safety measures for workers who clean and maintain the ETP include: Wearing protective clothing, safety goggles, dust masks, and rubber gloves. This circular also states that the solid sludge generated from the treatment process should be disposed of in 90 days, so that the sludge does not accumulate in CETPs and IETPs. The exact method of disposal is unclear from this memo. Swaminathan (2014) points to how evaluation committees found visible signs of the accumulation of bags of solid sludge were seen in dyeing units and along riverbanks and roads.

2.5. Choosing between CETPs, IETPs, or moving away?

As a textile cluster, textile units in Tirupur have advantages of scale due to being spatially as well as sectorally grouped. Sub-contracts and job-working in contracts, unique lending and borrowing systems, and the roles of trade associations (Chari, 2004; Crow & Batz, 2006; Swaminathan, 2014) increased inter-firm dependency (Swaminathan, 2014). Because of these factors as well as the spatial organization of textile units into small clusters, common effluent treatment plants are assumed to be the natural choice for textile units. Table 1 presents data from different sources, on the total number of bleaching and dyeing units in Tirupur, and how many chose to opt for CETPs, IETPs, or neither option.

Table 1
Showing available data on the number of textile bleaching and dyeing units in Tirupur, and the source of data.

	1999: Data collected by Peace Trust (2001) as cited by Blackman (2006).	2005: Data collected by TNPCB (Swaminathan, 2014).	2012: Data collected by TNPCB (TNPCB, 2012)
Total number of dyeing and bleaching units in Tirupur	866	737	748
Units connected to CETPs	278	281	502
Units with IETPs	424	420	156
Units with no treatment that were shut down or moved.	164	36	90

Table 1: Showing available data on the number of textile bleaching and dyeing units in Tirupur, and the source of data.

The question of why, in 2006, more textile units have chosen to install IETPs, rather than CETPs, even when CETPs offer advantages of economies of scale, of the reduced need for technical expertise, of reduced land costs, and of subsidized installation and operation is a question that Crow & Batz (2006) raise, and has influenced the research objectives of this thesis. Also, data from the TNPCB indicates that the numbers behind this choice between CETPs and IETPs changed between 2006 and 2012 (TNPCB, 2012; Swaminathan, 2014). This contradiction in data has informed one of the research objectives of this thesis, to explore implementation and water reuse through fieldwork, and collect primary data on this.

A report on the status of CEPTs, made by the TNPCB (2012), states that of the 502 dyeing units in Tirupur, 403 units are members of CETPs, while 99 have IETPs. Of the 156 bleaching units in Tirupur, 89 are members of CETPs while 67 have IETPs.

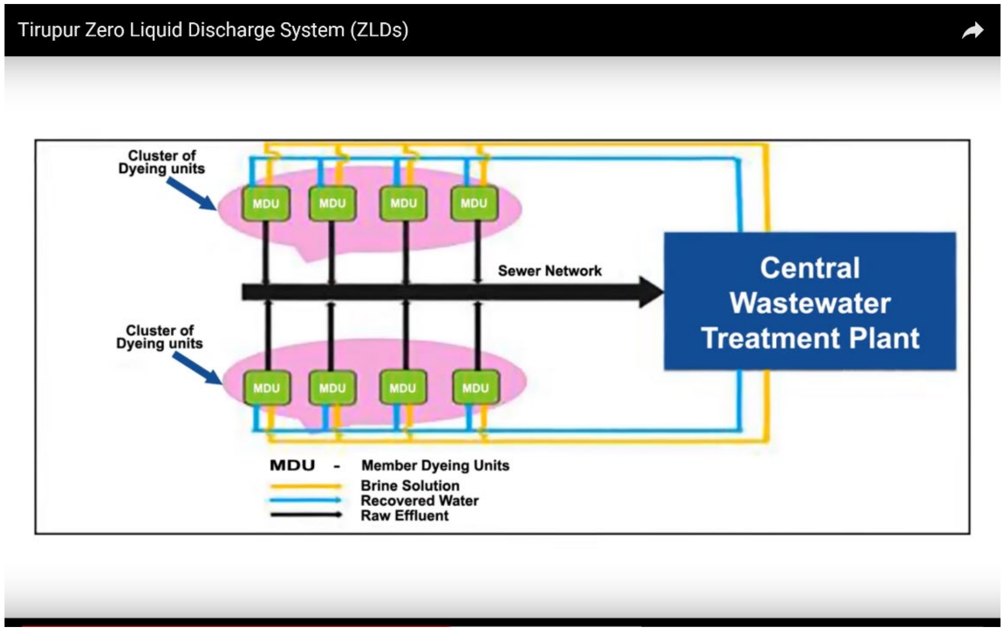


Figure 4: Showing a proposal on how a CETP functions (Veenet Technological Service, 2015).

2.5.1. Flexibility

Crow & Batz (2006) point to how giving textile units a choice in how to install wastewater treatment – via CETPs or IETPs – may have allowed more firms to stay in business, and also may have contributed to the process of diffusions of innovations within Tirupur's textile bleaching and dyeing sector.

2.5.2. Diffusion of Innovations?

The process of implementation of ZLD in Tirupur's textile dyeing and bleaching units was also informed by developments in other nearby industrial clusters, such as the tannery clusters in Tamil Nadu (Grönwall & Jonsson, 2017b). In the tannery clusters, small tanneries chose to jointly build and operate CETPs during the late 1990s, to address industrial causes of local water pollution (Kennedy, 2006). The spatial organization of this tannery cluster, into sub-clusters of small firms, also suited the organization of CETPs (ibid). The development of CETPs as a regulation to address groundwater pollution in Tirupur can be linked to developments in this cluster.

2.6. Conclusion: Further research directions for this thesis

From this background, a lot of questions related to ZLD implementation and in-house water reuse remain unanswered. Grönwall & Jonsson (2017b) point to how future research could focus on the roles that buyers' pressure and expectations - especially international, Western buyers - might play in textile units' adoption of ZLD. Such concepts, of green production and business, or eco-labeling (of the manufacturing process and not just the quality of the end-product, as noted by Nelliyat (2012)). The willingness to accept ZLD could potentially be influenced by a number of additional contextual factors and perceptions, and this is a point that Crow & Batz (2006) also raise. Within textile units, decision-makers' perceptions on the benefits and risks involved in choosing between joining a CETP, installing an IETP, or even moving to a different location could point to how a number of factors - both visible, structural factors and invisible contextual factors including attitudes and perceptions towards ZLD and water reuse - are at play here.

In choosing the research direction of this thesis to be acceptance rather than acquiescence, which is a construct that is more closely linked to adoption and implementation in mandatory environments, this thesis chose to focus less upon compliance (which is beyond the technical scope of knowledge of this researcher) and more upon signs of attitudes such as embracement, endorsement, of going beyond what is required (for example, by looking at in-house water reuse; and at cleaner production technologies that are both, as of writing this thesis, not mandated in the same way that ZLD technology implementation is) and of elements of willingness to implement and use ZLD technology. Or opposing attitudes and perceptions that may operate in Tirupur – this researcher hopes that she kept an open mind in designing the protocols used, and in data collection and analysis. In the context of Tirupur, acquiescence is a concept more closely linked to wastewater treatment as compliance, while acceptance could be a concept more closely linked to wastewater treatment as a step towards water reuse.

In addition, this background literature review shows how in-house water reuse is not mandated to the same level and degree of technical specifications compliance that installation of ZLD technology and the prevention of effluent discharge is. This is a natural outcome of the judicial pressure that made the ZLD regulation in Tirupur, where public alarm over toxic groundwater was the main driver and source of pressure on authorities to act. In-house water reuse is an important step towards closing the loop that ZLD technology implies; and changes the perspective of ZLD from an end-of-pipe treatment to a circular reuse-recycle approach (reduce is a separate, demand-side management question). This researcher hopes to add to existing knowledge on water reuse aspects of the ZLD regulation in textile facilities in Tirupur.

To conclude, this background points to how further research aims of this thesis could center around acceptance, through: 1. Physical or contextual indicators of acceptance, in terms of both implementation and usage, as well as any other signs pointing to embracement or approval of wastewater treatment technology, and 2. Perceptions on acceptance of ZLD technology and what wastewater treatment and water reuse mean.

CHAPTER 3

LITERATURE REVIEW

3.1. Introduction

In this chapter, a literature review of acceptance research is reviewed and discussed. The research covered here is situated at the intersection of two much larger bodies of literature: Firstly, the larger body of research relating to technology acceptance and social acceptance, and secondly, the social study of wastewater treatment and reuse. As such, the purpose of this literature review is to synthesize acceptance research, as it pertains to or could pertain to wastewater treatment technology and water reuse.

There are many existing theoretical frameworks and models that researchers have developed to describe the process of technology acceptance, from the perspective of the user of the technology. This thesis is informed by such user-based research on acceptance – i.e. technology acceptance. The numerous theoretical approaches towards technology acceptance and technology adoption are synthesized and summarized, with reference to wastewater reuse technology as the context. Theories on the social acceptance of technology, as conceptual frameworks for research directions, are also explored and synthesized in this literature review.

The primary aims or objectives of this literature review are to:

- Introduce acceptance as a general concept and distinguish it from similar concepts of acquiescence and adoption.
- Present an overview of technology acceptance and technology adoption, discussing main theories from both.
- Present an overview of social acceptance research, as it pertains to technology.

- Discuss current research on wastewater treatment and water reuse.
- Summarize directions for a study on acceptance in Tirupur, through defining who and what is to be studied, and through the formulation of research objectives and research questions.

From the research aims presented above, the purpose of this literature is mainly explorative and so the nature of this literature review is qualitative, and thematic, to see what alternative theoretical explanations could potentially operate in Tirupur. General inclusion criteria for theories or models presented here are: 1. Substantial applicability of the theory to other contexts and technologies, and 2. A substantial amount of research from different fields of research (such as environmental psychology, sustainability studies) on the theory in question.

Key search terms included: technology acceptance, technology adoption, social acceptance, wastewater treatment technology, water reuse, meta-analysis, review, criticism, contextual factors, perception research, psychological factors, and combinations and variations of these terms.

3.1.1. What is acceptance?

Acceptance, as a concept, is generally the act of agreeing, assenting, and acquiescing to a situation, or also approving of or embracing a situation. Opposing ideas are usually rejection, denial, avoidance, disapproval, and dissension. The concept of acceptance has many different meanings and definitions based on the situation or field of knowledge being discussed: one simple example of this is the definition of acceptance in psychology fields (as assent to the reality of a situation) versus the definition of acceptance in legal fields (as an act of agreement). As a concept, it can apply to either groups or individuals, and as a construct, it is usually constitutively defined (Kerlinger, 2000 pp. 30) by associating the definition of acceptance with other related constructs. This approach to defining acceptance is a common approach in the fields of social and information sciences. In the social sciences, acceptance can be "*behavior that enables or promotes (support) the use of a technology, rather than inhibits or demotes* *(resistance) the use of it. Support can be expressed in proclaiming the technology (for example because of its environmental benefits), or purchasing and using the technology. Resistance can be expressed in taking protesting actions against the technology, or not purchasing and using the technology*" (Huijts, Molin, & Steg, 2012).

3.1.2. Acceptance and acquiescence: Conceptual similarities and differences

Acceptance and acquiescence are similar concepts, especially in the context of a mandatory regulation. When a regulation is mandated and specified through details on implementation and compliance (See Chapter 2: Background for further information), then acquiescence in terms of compliance with the specifics of the regulation is closely linked to the idea of a compulsory acceptance of the situation. However, a transition can occur, from acquiescence (compliance with) to mandatory regulation, to acceptance (signs or perceptions pointing to a willing embracement and approval) of the regulation. An example of a study that implies this transition is one by Ghimire (2015), where the idea of approaching water supply as an engineering product (that acquiesces to technical and legal specifications) is shown to be augmented by the idea of water supply as a social good (that has to satisfy user expectations, and thus also pass certain community or user-driven acceptance criteria). In this thesis, the concept of acceptance is held to include an element of acquiescence to the mandatory ZLD regulation being studied, but also incorporates an aspect of embracement or approval (or the opposing concepts).

3.2. Technology acceptance

3.2.1. What is technology acceptance?

Technology acceptance is "*an interdisciplinary domain, that employs psychology and information systems fields of study to investigate users' attitudes towards new technologies*" (Sezgin & Yildirim, 2016). As an area of research with its roots in information systems theory, it was initially developed to assess users' attitudes towards the use of computers, which was then-nascent technology. Davis (1989), in one of the first papers to explore the determinants of user acceptance of IT, drew from many theories, including the psychology-based theory of reasoned action (TRA) and theory of planned behavior (TPB), where determinants of behavioral intention to use are usually the constructs of perceived usefulness and perceived ease of use (Marangunic & Granic, 2015). In Davis' (1989) initial conceptualization of the technology acceptance model (one of the main models to dominate acceptance research), user acceptance of technology is constitutively defined as behavioral intention to use a technology - this is the most typical dependent construct used to study technology acceptance (King & He, 2006). Some of the other dependent constructs used are behavioral expectation (Maruping, Bala, Venkatesh, & Brown, 2017); willingness to use (Marhefka, Turner, & Lockhart, 2019) and user satisfaction (Zaitul, Fanny, & Desi, 2018).

Technology acceptance research has undergone many variations, through development of the theories, modifications to the original constructs and models, and application to a wider field of technology research, that ranges from health technologies (Sezgin & Yildirim, 2016), to energy and renewables technology (Dudik, 2017), and in this thesis, to wastewater treatment technology.

3.2.2. Technology acceptance in mandatory environments

Attitudes towards the use of technology also depend upon whether implementation and usage are being mandated or not (Hwang, Al-Arabiat, & Shin, 2016). In mandatory environments, attitudes towards a technology do not necessarily affect actual use of the technology, which is of course required. However, even within mandatory contexts, the continued success of implementation and use can be affected by "*getting users' buy-in by creating positive attitudes toward the adoption of the new system being implemented*" (Hwang et al., 2016). Challenges for this thesis for studying the acceptance of wastewater treatment and reuse technology include identifying appropriate dependent constructs, definitions, and determinants to be used, while also considering the background and context.

3.2.3. Technology Acceptance and technology adoption: Conceptual similarities and differences

Acceptance and adoption are also both similar, interrelated concepts that are sometimes used interchangeably in technology research (an example of this is a paper by Autry, Grawe, Daugherty, & Richey, 2010), and at other times, are distinguished from each other. Technology adoption is generally the process of implementation and use of technology. It is generally studied in terms of its phases (of, for example, pre-and-post adoption), and adoption theories are commonly qualitative theories on the phases of the process of adoption, as seen in a paper by Renaud & van Biljon (2008). Acceptance, on the other hand, is a set of attitudes towards a technology, that act at different, specific stages of adoption (ibid). Technology acceptance is usually studied in terms of a set of factors that influence acceptance, at the level of analysis of an individual or user. Technology adoption is usually studied at the level of an organization or group, and the decision-making processes involved at this level of analysis. A common theory of the process of technology adoption is the diffusions of innovations theory (Rogers, 2003). Another common model of technology acceptance is the technology acceptance model, and its many variations and modifications (Marangunic & Granic, 2015). The table below (Table 2) shows the common differences between research on technology acceptance and research on technology adoption.

Table 2 *Showing a summary of common differences between acceptance and adoption.*	
Technology Acceptance	**Technology Adoption**
Origins in management and information systems (MIS) research.	Origins in sociology research.
From a positivist epistemology, that society shapes the individual.	From an interpretivist epistemology, that individuals shape society.
Generally quantitative methodology.	Generally qualitative methodology.
Studied in terms of factors and constructs (such as perceived ease of use, perceived usefulness).	Studied in terms of phases and contexts (such as the process of diffusions of innovations).
Examples include the Technology Acceptance Model.	Examples include the Diffusion of Innovations, the Technology-Organization-Environment Framework.
Generally studied at the level of the individual or user.	Generally studied at the level of the organization or firm.

Table 2: Showing a summary of common differences between acceptance and adoption.

While technology acceptance and adoption are usually studied separately, there are studies that attempt to integrate the two into a multi-level framework (Renaud & van Biljon, 2008; Zhou, 2008), so as to begin to understand how individual attitudes and perceptions; and firm-level factors and contexts interact with each other to form a comprehensive picture of acceptance, implementation, and use.

In the next section, two main theories of acceptance and adoption are presented. One is the technology acceptance model and its variations, and the other is the technology-organization-environment framework. Rather than choosing to review the diffusions of innovations theory, which is one of the main theories on the process of technology adoption, the TOE framework, as a more context-driven approach to adoption by firms, is reviewed instead.

3.3. The Technology Acceptance model

The technology acceptance model is a framework that models how users come to accept, and thus use a technology. Since its inception in 1989, it has come to be used in many different fields of research and has undergone many variations. Images 5, 6, and 7 show some of the variations and extensions that this model has undergone, especially with respect to the perception-based concepts of usefulness and ease of use:

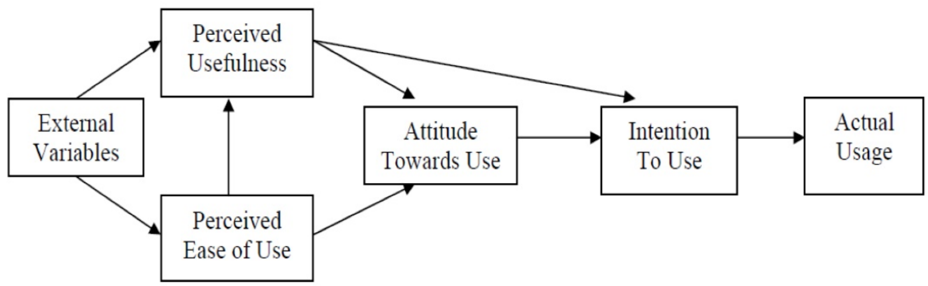


Figure 5: Showing the original Technology Acceptance Model (Davis, Bagozzi, & Warshaw, 1989).

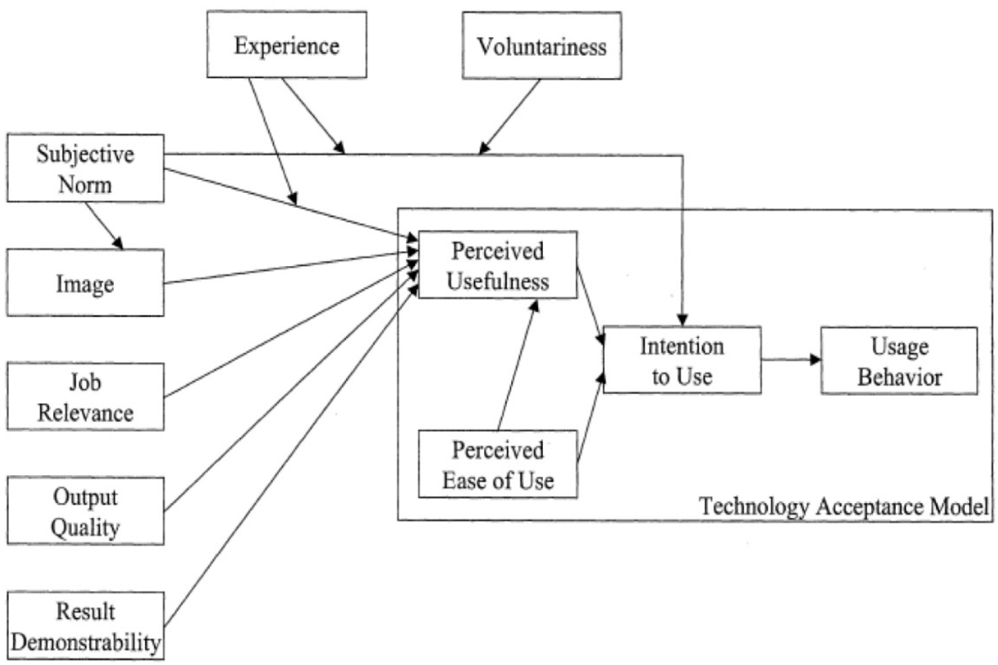


Figure 6: Showing TAM 2, which explores how other factors, notably subjective norms, deepens the concept of perceived usefulness (Venkatesh & Davis, 2000).

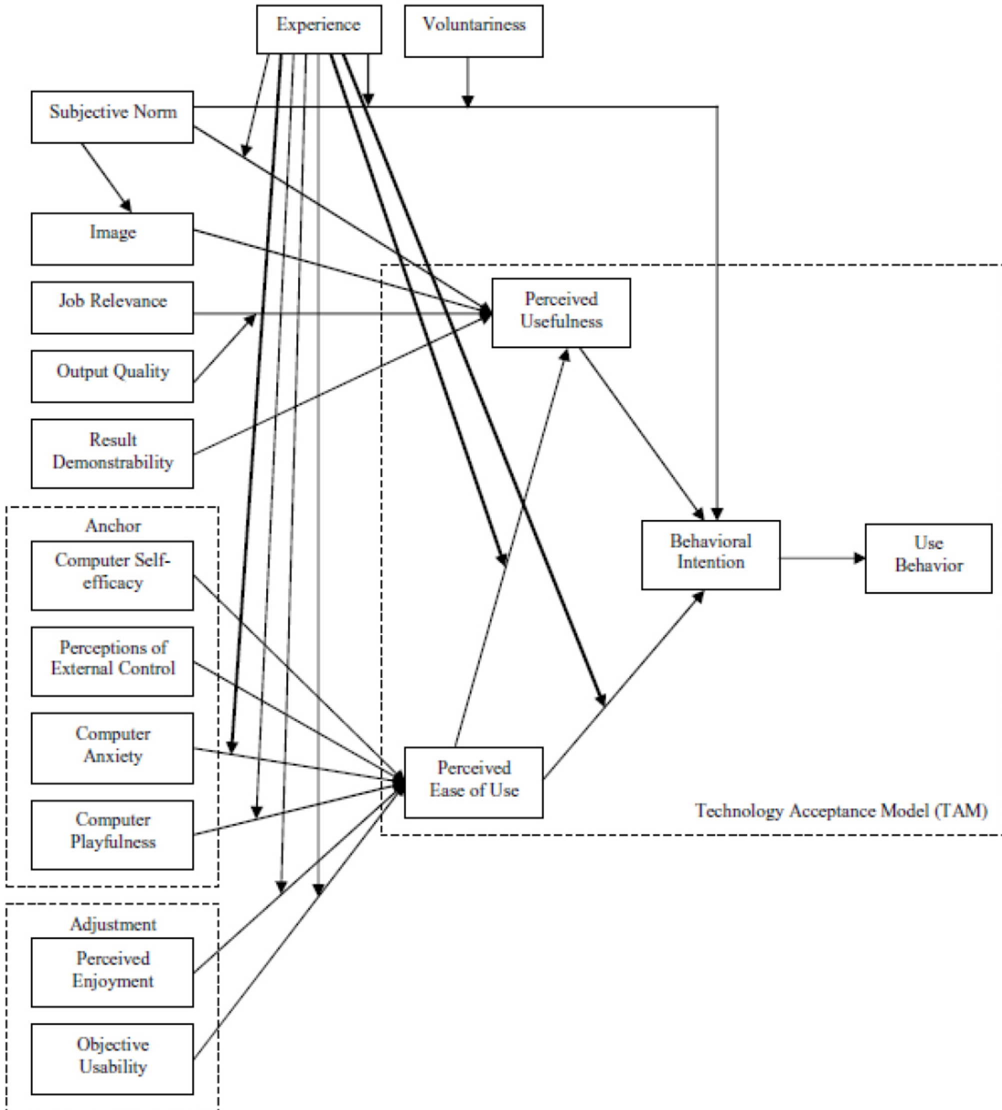


Figure 7: Showing TAM 3, and how the concept of perceived ease of use has been linked to other factors (Venkatesh & Bala, 2008).

These three figures show how the concepts of perceived ease of use and perceived usefulness were found to be influenced and linked to many other factors, most of which are specific to the information sciences field. All these figures also represent quantitative models, that are usually tested through the administration of a Likert-scale questionnaire, with statistical tests for correlation and significance used to look at linkages between different factors. In the search for the meaning of acceptance of wastewater treatment and reuse, and how it can be studied in Tirupur, it is apparent that an exploration of the factors and perceptions involved in such acceptance will not quite fit in to these models, or any of the other variations of the technology acceptance model not mentioned in this thesis, but were reviewed.

3.3.1. Determinants of technology acceptance and their definitions:

Two of the main, fundamental determinants of technology acceptance (through attitudes towards use) are perceived ease of use, and perceived usefulness (Davis, 1989). The original definitions of these two constructs are:

- Perceived usefulness: "*The degree to which a person believes that using a particular system would enhance his or her job performance*" (Davis, 1989).
- Perceived ease of use: "*The degree to which a person believes that using a particular system would be free of effort*" (Davis, 1989).

Both these definitions clearly show that they are, firstly, meant to be used in a Likert-scale-type questionnaire, where items relating to the degree of strength of a belief or perception are tested; and secondly, that they apply to the information sciences field, where the use of computer technology can be understood in terms of job performance and ease of effort needed to use a computer system. On a conceptual level, usefulness and ease of use (and the themes of usefulness or utility, and ease of use, or eases/difficulties associated with usage) are important concepts through which perceptions can be explored and examined.

3.3.1.1. Perceived ease of use

Perceptions on the ease of use, or on the amount of effort needed to implement and use a technology, are context-driven and depend upon the technology being evaluated, and the people forming the perceptions. Venkatesh (2000), in modeling how factors that determine perceived ease of use can be integrated into the technology acceptance model (see Figure 6 presented earlier in this chapter), also points to how these determinants are system-specific, field-specific, and time-specific. As an "*important driver of technology acceptance and use*" (Venkatesh, 2000, pp. 342), perceived ease of use has been studied through variables like system characteristics, training, and also control, motivation and emotion (ibid).

3.3.1.2. Perceived usefulness

The usefulness or utility of a technology can usually be directly measured by attributes such as costs and subsidies. This construct is also influenced by ease of use, since the less effort that a technology needs, the more useful it is. With perceived usefulness, determinants have been variables like subjective norms (that other people's beliefs and expectations influence the use of a technology) and voluntariness (that the technology is being used in a mandatory or non-mandatory setting) (Venkatesh & Davis, 2000).

3.3.1.3. Perceived effectiveness

In addition, a study by Fujii & Taniguchi (2010) identified perceived effectiveness as an important behavioral determinant of socially desirable behaviors, and they incorporated perceived effectiveness and perceived ease into their model of multiple pro-environmental behaviors. Perceptions on the effectiveness, success, or efficacy of a technology can help to supplement an understanding of what technology acceptance means, in terms of external factors or facilitating conditions. While perceived effectiveness as a construct is more often used to assess messages, and how persuasive they are (Dillard, 2014), it is also a concept that is used to evaluate perceptions on complex institutional systems (Lubell, Mewhirter, Berardo, & Scholz, 2017), and how efficacy is perceived as when benefits outweigh transaction costs.

3.3.2. Criticism (that applies to using it for ZLD technology in Tirupur)

The technology acceptance model and its many variations were initially developed to apply to the information sciences, and development of the constructs and their determinants reflects this. While the TAM has been studied in many other fields and contexts (Marangunic & Granic, 2015), it still reflects its origins in IS research. Determinants of technology acceptance might change under different contexts of technology, especially one like the ZLD technology, which is at the level of physical infrastructure, that involves different groups of people beyond actual ‘users’ of the technology.

The TAM is also strongly quantitative, with most studies using Likert scales to measure responses to items under each construct (Chin, Johnson, & Schwarz, 2008), making it a model on self-reported perceptions and attitudes. A mixed-methods approach towards technology acceptance is discussed in a later section of this chapter.

Another criticism of the current conceptualization of technology acceptance is that it treats technology as a foreign object that humans must either accept or refuse (Brangier, Hammes-Adelé, & Bastien, 2010). Human-technology-organization relations are more about symbiotic and inter-dependent relationships than about acceptance. In treating technology acceptance as operational acceptance (of ergonomic and usability criteria) and psycho-social acceptance (of attitudes towards usage), the human-technology relationship is assumed to be passive and static. ‘Users’ can find new uses for a technology and can actively work to appropriate a technology (Salovaaraa & Tamminenb, 2009) to get other benefits out of having and using it.

In conclusion, many authors have pointed to the simplistic concept of technology acceptance that this model presents, and also to how more complex technology involves more actors, stakeholders, and other groups that ‘users’ do not quite cover.

3.3.3. Mixed methods approach

Mixed methods approaches, or even qualitative approaches to studying user acceptance of technology (or technology acceptance by users) are mostly used to reinterpret the meaning of acceptance and the constructs involved, and to explore the drivers of acceptance in a context-based situation. “*A mixed-methods approach provides opportunities to move beyond the vague conceptualizations of "usefulness" and "ease of use" and to advance our understanding of user acceptance of technology in context”* (Wu, 2012, pp. 172). Since the TAM is over-reliant on quantitative methods (ibid), qualitative methods such as interviews and observations can be used to conceptualize context-driven meanings of technology acceptance, which can then be tested using quantitative models, or which can be used to develop quantitative models.

3.4. The Technology-Organization-Environment Framework

3.4.1. Introduction to the Technology-Organization-Environment Framework

The technology organization environment (TOE) framework is a theoretical framework used to describe how the technological, organizational and environmental context of the firm influences its decision-making processes. It is generally used to describe and explain a firm's likelihood of adoption, intent to adopt, or extent of adoption of technology, and has its origins in information systems theory, as do most frameworks that look at technology acceptance (Baker, 2012). Initially introduced by DePietro, Wiarda, & Fleischer (1990), it is a framework used to describe the process of technological innovation, using the level of analysis of a firm or organization. The main independent constructs are derived from the technological context, organizational context, and environmental context. The technological context includes those factors, such as availability and characteristics, that characterize the technology, which can range from equipment to processes. The organizational context includes those factors that characterize the firm, such as size, managerial structure, human resources, and communication processes. The environmental context includes those factors that characterize the environment (external situation) of the firm, such as the industry characteristics and market structure, the regulatory environment, and support infrastructure. The diagram below, taken from DePietro, Wiarda, & Fleischer (1990), summarizes this framework:

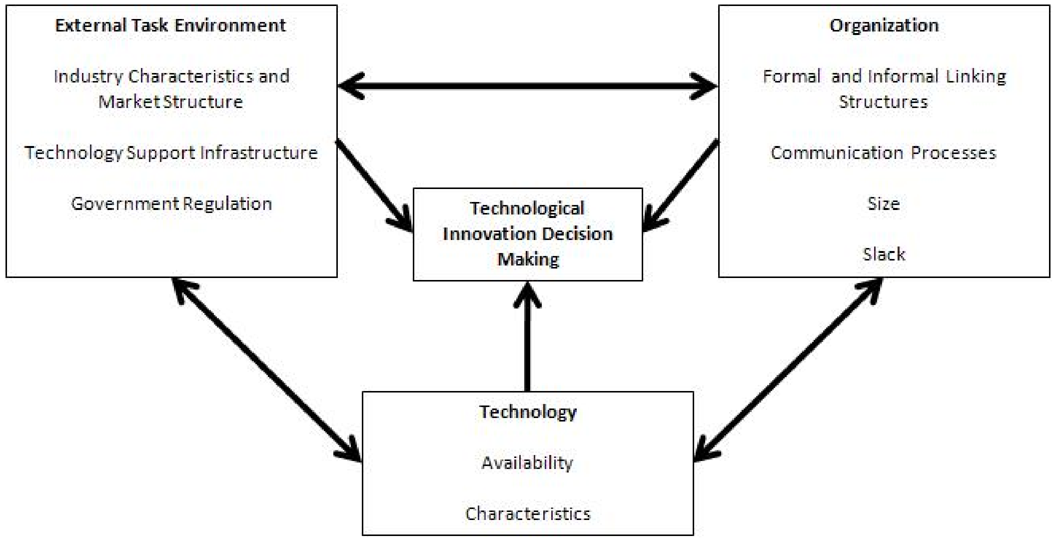


Figure 8: Image showing the TOE framework, as taken from DePietro, Wiarda, & Fleischer (1990).

These three contexts show how both constraints, as well as opportunities, act within this framework to influence the way a firm decides to adopt and implement a technological innovation. A more detailed explanation of these three contexts, based on a literature review of this framework, is provided below.

3.4.1.1. The technological context

Baker (2012) defines the technological context as one that includes all the technologies that are relevant to the firm and the process of innovation, since existing technologies limit how and when future technological changes are implemented. Baker also notes that these technologies, including those currently in use and those planned for future use, can combine in a unique way to change how technological innovation happens in firms. These technologies can also be 'competence-enhancing or competence-destroying' in that "*Competence-enhancing innovations enable firms to gradually change as they build upon their expertise, while competence-destroying innovations render many existing technologies and many types of expertise obsolete*," (Baker, 2012 Section 12.1).

3.4.1.2. The organizational context

Baker (2012) points to the many ways by which organizational context affects decisions on the adoption and implementation of a technology. Research has focused on whether features of the organization promote or inhibit technological innovation, and on specific phases (the adoption phase, the implementation phase) of the process that is targeted. On a general level, organization structure (centralized decision-making versus decentralized decision-making; defined employee roles versus fluid employee roles) has been found to be linked to specific phases of the process of technological innovation. The slack and size of a firm are two factors that are most frequently discussed within the organizational context and links to innovation (ibid).

3.4.1.3. The environmental context

The environmental context in this framework refers to supportive conditions, often external, that can affect how a firm or organization adopts or implements a technological innovation. The regulatory environment in which firms exist is a typical example of this context, sometimes (as in the case of this thesis) mandating innovation for firms. Baker (2012) points to how support infrastructure, such as the availability of skilled labor or technology service providers, can also foster or constrain innovation.

3.4.2. Discussion of the framework from prior research

As a framework that has its origins in information systems theory and organizational psychology, the TOE framework has since grown to be used in many different contexts, and across many different technologies and industries. It has been also been tested in empirical studies and is used as an explanatory mechanism in qualitative studies looking at technology adoption.

Most of the research on the TOE framework so far has accepted the three main constructs of the framework and their original definitions, without adding any more constructs to it. It is also used more to describe technological adoption, rather than technological implementation, both of which can be linked to acceptance. Baker (2012) points to how most studies using the framework tend to list the factors that are relevant to specific contexts and different technologies, and so theoretical growth of this framework has been limited to finding factors that apply to the specific context being studied. In this way, the TOE framework, as a generic theory, is both highly adaptable to different contexts, and yet unchanging in its basic structure.

In discussing the future directions for TOE research, Baker (2012) points to how the TOE framework could evolve by looking at how theories of individual behavior and adoption (covered in Chapter 3: Literature Review of this thesis) can change the way the TOE framework, an organization-level theory, is used to investigate firms' adoption and implementation of a technology, which it does not currently do. A multi-level approach to the TOE framework could then perhaps result in a theory that reflects how different levels of analysis (the individual as well as the organization, the technology, and the environment) interact with each other and form cross-level relationships.

3.5. From Technology acceptance to Social acceptance

Social acceptance, as "*a matter of public, political and regulatory acceptance*" (Carlman, 1984, as cited in Wüstenhagen, Wolsink, & Bürer, 2007a), involves looking at how there are social dimensions and constraints involved in the study of acceptance of a technology, especially technology such as renewable energy technologies. This section of the literature review explores social acceptance through existing research on renewable energy technologies, since extending a similar concept of social acceptance to wastewater treatment technology has not yet been discussed. Research on wastewater treatment and water reuse through technology could, in some ways, be similar to renewable energy technology research (on a broad conceptual level, both are technologies that respond to environmental constraints, that are often implemented because of a regulation, and that are technologies at the level of physical infrastructure).

Social acceptance research tends to be grouped more by technology (such as energy technology) than by the type of acceptance (Gaede & Rowlands, 2018). The authors raise questions: Is it that "*the problem of acceptance is unique to different technologies, actor groups, or <energy> system sectors*" making it difficult to integrate different approaches to this topic into one framework? An interdisciplinary approach attempts to "*bring together the contextual with psychological explanations of acceptance*" (Perlaviciute & Steg, 2014, as cited in Gaede & Rowlands, 2018).

Within energy technology research, social acceptance has been widely studied as a framework for research (Wüstenhagen et al., 2007a; Huijts et al., 2012; Upham, Oltra, & Boso, 2015; Friedl & Reichl, 2016; Gaede & Rowlands, 2018). According to Wüstenhagen et al., (2007) there are three dimensions of social acceptance: socio-political acceptance, community acceptance, and market acceptance (see Figure 9 below).

Figure 9: Dimensions of social acceptance, as presented by Wüstenhagen et al., (2007a).

- Socio-political acceptance is acceptance "*on the broadest, most general level*" (Wüstenhagen et al., 2007b) of general public opinions and attitudes by key stakeholders and policymakers.
- Community acceptance is the "*specific acceptance of siting decisions and renewable energy projects by local stakeholders, particularly residents and local authorities*" (ibid). Important constructs to consider here are NIMBYism, perceptions on justice and the role of public trust in authorities.
- Market acceptance is "*the process of market adoption of an innovation*" and links to decisions by consumers and investors, as well as to intra-firm acceptance of the innovation or technology.

A paper by Gaede & Rowlands (2018) also notes how research on social acceptance tends towards a simplistic conceptualization of the notions of 'public' and community in energy technology acceptance research. To address this, the authors call for "*greater interdisciplinary collaboration, and incorporation of insights from environmental psychology and the concept of place to help ground the research in social theory*" (ibid). When it comes to exploring what factors or determinants are influencing or being influenced by technology acceptance, Huijts et al., (2012) point to how exploring what the main psychological factors (and the relations between these factors) are that influence technology acceptance, can help to improve the design and implementation of a technology. Exploring what factors influence attitudes towards technology could be done through a perceived costs-risks-benefits framework, that looks at attitudes towards the costs, risks, and benefits of having and using technology (ibid). Figure 10, taken from Huijts et al., (2012), shows the conceptual model of such a framework:

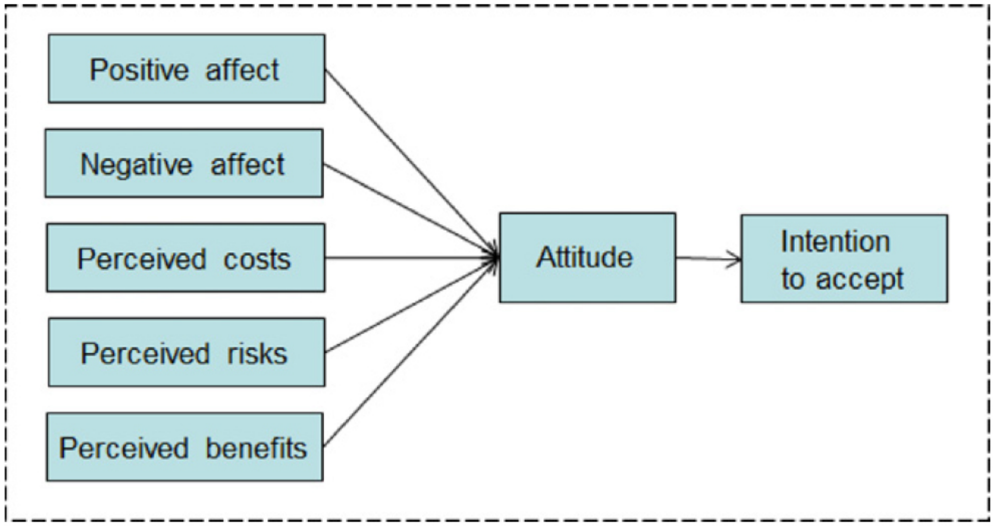


Figure 10: Showing a perceived costs-risks-benefits approach to acceptance, as presented as a framework by Huijts et al., (2012).

Figure 10 is one version of a technology acceptance framework presented by Huijts et al., (2012) – who also present a comprehensive technology acceptance framework, that incorporates roles of trust, fairness, and knowledge into the framework.

3.5.1. Conclusions

From the literature review of social acceptance, it is clear that social acceptance can be analyzed at many levels, from the micro (individual or organization) to the meso (community) to the macro (country). And at these various levels, social acceptance is a multi-actor phenomenon in that there are several different groups of people that are central to the research interest, that are doing the 'accepting': Public acceptance by consumers or citizens; stakeholder acceptance by those with an interest in the outcome; and individual acceptance, that is "*composed of attitudinal elements, behavioral intentions, and actual behaviors*" (Gaede & Rowlands, 2018). In addition, both contextual factors, that are objective characteristics of the technology in question (Perlaviciute & Steg, 2014), as well as psychological factors, that shape the acceptance of the technology in question, can be perceived differently by the various groups of actors involved.

3.6. The social acceptance of wastewater treatment and reuse: A brief overview

Wastewater reuse, and attitudes towards it, depends upon the type of wastewater being studied, and the group doing the 'accepting'. A literature review on wastewater reuse and acceptance shows that a main focus of the existing research on this topic is concerned with the public acceptance of wastewater reuse (Dolnicar, Hurlimann, & Grün, 2011; Harris-Lovett, Binz, Sedlak, Kiparsky, & Truffer, 2015; Rice, Wutich, White, & Westerhoff, 2016; Fielding, Dolnicar, & Schultz, 2018). Public acceptance here is generally by citizens or consumers, and wastewater reuse is of recycled water that is treated through water supply and wastewater treatment schemes. In breaking down acceptance and what it means in such a context, the roles of emotions, such as disgust or discomfort, are also explored in the context of acceptance of wastewater reuse (Menegaki, Mellon, Vrentzou, Koumakis, & Tsagarakis, 2009; Meehan, Ormerod, & Moore, 2013; Ross, Fielding, & Louis, 2014; Leong, 2015; Wester et al., 2015; Wester, Timpano, Çek, & Broad, 2016). Negative emotions to wastewater reuse, especially to the idea of potable wastewater reuse, play an important role in the psychological and social factors that are linked to wastewater reuse (Wester et al., 2015). These negative emotions are known as the 'yuck factor' (ibid) and are linked to gendered perceptions on the health and safety of such reuse (ibid). A paper by Menegaki et al., (2009) shows how framing wastewater reuse as 'recycled water' versus 'treated wastewater' can affect willingness to reuse wastewater, with unwillingness being linked to disgust in this study. It is unclear to this researcher whether such emotions could play a similar role in the in-house reuse of treated wastewater by textile facilities, since the water is (hopefully) being reused into the production process, and wastewater comes from the same usage, and so it is not as personal as is the concept of reusing treated wastewater for potable uses.

3.7. Conclusions: Research directions for this thesis

This thesis is concerned with the intersection of individual acceptance, by those people whose interactions with the wastewater reuse technology is a major part of their jobs and livelihoods, and stakeholder acceptance, by those decision-makers such as owners, managing directors, and chairmen of textile firms. The proposition of this thesis is that acceptance of wastewater treatment technology is linked to 1. Stakeholder acceptance, which in turn, is dependent upon 2. Individual acceptance by those who interact with the technology as a part of their daily job. As such, the outcome of this literature review here is that the TAM may not be as applicable to this situation as it has been found to be in other research on technologies and acceptance.

This qualitative study is aimed at understanding what people who experience WWT technology and interact with it as part of their livelihood think about it. It focuses on acceptance within the context of those who have real-life experience and interactions with the technology. In order to better understand the adoption of this technology, it is important to develop a better understanding of users and their interactions with it, and their perceptions of it. A paper by Bühler, Cocron, Neumann, Franke, & Krems (2014) notes that such an understanding – in the case of the paper, of electric vehicle adoption – can be attained by looking for advantages that customers are aware of, in addition to barriers and challenges that may be insurmountable. Another paper by Rahbauer, Menapace, Menrad, & Decker (2016), in a study on the adoption of green electricity by German small and medium enterprises, explored factors that influenced the SME's decisions on whether to adopt green electricity, through qualitative methods - interviews. These papers show how precedents for qualitative explorations of contextual and perception-based factors do exist. In addition, using perceptions as evidence in the social sciences can help to "*provide important insights into observations, understandings, and interpretations of the social impacts, and ecological outcomes"* as Bennett (2016) notes about environmental management.

3.8. Research Objectives and Research Questions

Even though acceptance research in the domain of water and wastewater reuse technology is relatively nascent (as compared to, for example, energy technology), it is difficult to approach the topic from a neutral theoretical perspective, that does not lean towards one of the many methods, frameworks, and paradigms that exist (Perlaviciute & Steg, 2014). The theories and frameworks presented in this literature review and the conclusions of the background review on Tirupur have informed the framing of the research objectives as:

- To explore and identify physical or contextual factors behind the mandatory implementation of wastewater treatment technology and water reuse in Tirupur.
- To explore and identify perceptions on factors linked to the acceptance of wastewater treatment technology and water reuse in textile dyeing facilities in Tirupur.

These two research objectives have been translated into the following research questions:

1. How has the mandatory implementation of wastewater reuse technology driven physical changes in textile facilities in Tirupur?

1.1. What are the different ways in which wastewater reuse has been implemented in the textile facilities?

1.2. What are the physical characteristics of these textile facilities?

2. How has the mandatory implementation of wastewater reuse technology driven technological acceptance in users and stakeholders within the textile facilities in Tirupur?

2.1. Who are the stakeholders and users within the textile facilities?

2.2. What are their perceived advantages and disadvantages of having and using this technology in the textile facilities?

2.3. What factors do they perceive to be linked to the acceptance (perceived effectiveness, ease of use, and usefulness) of this wastewater reuse technology?

The two research questions are linked in that the first question describes the context of the physical setting, and the second explores perceptions on technology acceptance by the people within the physical setting. As such, they are both complementary questions, one dealing with place, and the other, with people within the place.

3.8.1. Justification for the research questions

These questions were derived from a literature review on wastewater research in Tirupur, and on acceptance research in the context of sustainability. This literature review is broken down into two parts and chapters: One on the background and context of Tirupur and the ZLD regulation (Chapter 2: Background), and the other on acceptance research and the theories, models, and frameworks that currently comprise it (this chapter, Chapter 3: Literature Review).

A good set of research questions, as per Robson (2011), are those that are linked to current formal theory and make contributions towards the development of theory. There should be clear linkages between the questions, and they should all arise out of a common focus, or problem area. Here, the focus is on wastewater treatment and reuse in textile facilities in Tirupur, and so the research questions are centered on this issue.

3.8.1.1. Research Question One

The first research question builds off the conclusions of the background review, that there is uncertainty over whether treated wastewater is in actuality being reused in-house. This research question is also aimed at exploring physical and contextual indicators of implementation and usage, that could be linked to acceptance. The background review of Tirupur and its textile facilities points to how there is a regulatory discrepancy between treating the wastewater and reusing the treated water. From the background review, decision-makers' perceptions on the benefits and risks involved in choosing between joining a CETP, installing an IETP, or even moving to a different location could point to how a number of factors - both visible, structural factors and invisible contextual factors including attitudes and perceptions towards ZLD and water reuse - are at play here.

The question, ‘How has wastewater reuse technology driven physical changes in the built environment of Tirupur’s textile facilities?’ also its origins in a point made by Grönwall & Johnson (2017), who talk of the “*visible structural changes [that] did quite literally alter the landscape* [of Tirupur], *which became marked by artifacts in the form of treatment plants with evaporators and crystallizers towering into the air*” (Grönwall & Jonsson, 2017b). The research question presented in this thesis, on *how* these spatial changes are manifested in the built environment of Tirupur’s textile parks and facilities, builds upon the observances (ibid), and attempts to delve further into these changes, asking of them: How, why and where are such physical changes occurring?

3.8.1.2. Research Question Two

The second research question builds off the literature review presented in this chapter and focuses on stakeholders and actors within the setting of textile units in Tirupur (choosing to focus on one specific dimension of social acceptance). Sub-parts of the second research question are aimed at exploring perceptions on technology acceptance in two ways: Through exploring perceived advantages/benefits and disadvantages/risks/barriers of having and using WWT technology and water reuse, and also through exploring what factors are perceived to be linked to the ease of use, usefulness, and effectiveness of having and using WWT technology and water reuse. So, one sub-question assumes that technology acceptance can be constitutively defined through perceived ease of use, usefulness, and effectiveness; while another sub-question assumes that the meaning of technology acceptance can be explored through an advantage-disadvantage, benefit-risk approach.

3.8.2. Conclusion

Both questions are exploratory since this literature review finds that exploratory research on factors linked to the acceptance of wastewater treatment and reuse in Tirupur must be the first step of a context-driven approach to acceptance. Stake (1995) finds that issue-oriented research questions "*are not simple and clean, but intricately wired to political, social, historical, and especially personal contexts…issues draw us toward observing, even teasing out the problems of the case*" (Stake, 1995). The two research questions and their sub-questions are open-ended questions that point to how a qualitative line of inquiry (Table 3) can best answer them. The next chapter presents the qualitative methodology used to approach these research questions.

Table 3
The research questions and their purpose of inquiry, as per Robson's (2011) categories of research purposes.

Research Question	Purpose	Resulting Strategy
1. How has the mandatory use of wastewater reuse technology driven physical and spatial changes in textile 'parks' and facilities in Tirupur, India?	Descriptive & Exploratory	Pilot and Case Study – Stage 2: Field Research.
2. Has the mandatory use of wastewater technology driven technological acceptance in the people within the physical setting of the technology?	Exploratory	Case Study - Stage 2: Field Research.

Table 3: The research questions and their purpose of inquiry, as per Robson's (2011) categories of research purposes.

CHAPTER 4

METHODOLOGY

4.1. Introduction

The two research intentions of this thesis, to explore contextual factors as well as stake-holder perceptions on the acceptance of wastewater treatment technology and water reuse, are investigated through qualitative research methodology that is both exploratory and descriptive in purpose and scope. This chapter presents this research methodology, its details, and stages.

4.2. Research Process outline

A summary of the research process is presented in the table (Table 4) below:

Table 4

The various research stages, phases, and the corresponding research question and type of data source used to answer each question.

Research Phase	Corresponding Research Question/s	Type of data used
Stage 1: Pre-field research		
Literature Review		Secondary data – literature review & document and media analysis.
Research Design: Sampling strategy selection	RQ 1	Primary data – Study 1: Pilot Study & pilot test of observation and interview protocols.
Stage 2: Field research		
Data Collection	RQ1 & RQ2	Primary data –Study 2: Case Study research through observation, interview methods.
Stage 3: Post-field research		
Data Analysis	RQ1, RQ2.	Analysis of primary data. Observation schedules. Semi-structured Interviews.
Interpretation and Discussion		Integration of primary & secondary data.

Table 4: The various research stages, phases, and the corresponding research question and type of data source used to answer each question.

4.3. Research Design

4.3.1. Study One: The Pilot Study

To address the need to develop and refine the research methods, and to determine the sampling strategy conditions for the choice of case studies, a pilot study (Study 1) was conducted in Tirupur. The objectives of the pilot study are:

- To learn about the different ways in which wastewater reuse has been implemented in textile facilities in Tirupur (Research Question 1.1).
- To determine the scope and feasibility of the case study approach chosen.
    - To identify inclusion and exclusion criteria for case studies of textile dyeing facilities.
    - To identify potential case study sites.
- To identify stakeholder and user groups that act within the physical setting of a textile facility, from which respondent groups for interviews can be drawn (Research Question 2.1).
- To test and refine themes and questions for the development of the interview guide and observation guide.

4.3.1.1. Study One: Research Methods

An exploratory, unstructured pilot study guide (See Appendix A) was created to address the objectives listed above. A snowball convenience sampling method was used to approach respondents with professional/technical/working knowledge of how, where, and why wastewater reuse technology is implemented in textile dyeing facilities. At this stage, all the interviews were conducted in English, although it was noted that for further user and stakeholder interviews, the language used would, of necessity, have to be Tamil. After field interviews with a total of three respondents, three non-verbatim field memos were used in the process of open coding to find themes.

4.3.1.2. Ethical considerations

A letter of introduction was used to gain access to research participants, and permission was sought from the local officials before proceeding with the research. Since this is a qualitative inquiry into the acceptance of ZLD regulations, there were no unintended risks to which consenting participants may have been exposed, during data collection, or the course of the research process.

Research in India is not subject to a review board, as social sciences research within the country does not come under the purveyance of a formal, recognized review board. As such, international standards of conducting research were adhered to.

4.3.2. Study Two: The Case Studies

4.3.2.1. The Case study Approach

To best answer the two research questions, a qualitative study was developed using the case study approach. Qualitative research, a process of inquiry into a social or human problem, (Creswell, 1998; Yin, 2014) seemed apt for the research questions of this study. The case study approach allows the researcher to explore specific cases, to describe the setting of each case, and to provide an in-depth picture of each case (Creswell, 2018). Case studies are used to examine "*a contemporary phenomenon in-depth and in its real-world context*" (Yin, 2014, p. 237). Here, the 'case' is also the unit of observation – a textile facility. To present a more holistic picture, case studies at five sites were used. It also offered the advantage of conducting the study in the natural setting of the problem – in the textile facilities of Tirupur. Qualitative research, according to Creswell (1998), has the following characteristics:

1. The natural setting (field) is the source of data.
2. The researcher is the key instrument of data collection.

3. The outcome is a process, rather than a product.
4. Data is analysed inductively.

4.3.2.2. Sampling Strategy

The ideal sampling strategy for this qualitative study is a direction-oriented, purposeful selection of participants and cases (Creswell, 1998). In order to "*represent diverse cases to fully display multiple perspectives about the cases*" (Creswell, 1998, pp. 120), a purposeful sampling strategy of maximum variation (Miles & Huberman, 1994, p.28) was used. This maximum variation strategy allows for documentation of diverse variations, and identification of important common patterns across the cases, which is an essential analytical strategy needed to answer the second research question. The variation was recorded along two conditions: One categorical condition of wastewater treatment capacity (which is also a measure of the size of operations of the textile facility), and one of opting for individual versus common, centralized treatment facilities (a binary condition). These two conditions were determined to be the basis for the sampling strategy after a pilot study was conducted in Tirupur.

After asking six case studies of different facilities and treatment plants to be a part of this thesis, five agreed. One case, of a large textile facility that sends its wastewater for off-site treatment, refused because of scheduling issues. The following table (Table 5) presents a brief description of each case study, while the image (Figure 11) presents a not-to-scale map of the locations of each case study.

Table 5
A brief overview of each case study.

Case study	Brief Description
A	A small facility with on-site treatment
B	A large facility with on-site treatment
C	A small facility with off-site treatment
D	A small off-site treatment plant
E	A large off-site treatment plant

Table 5: A brief overview of each case study.

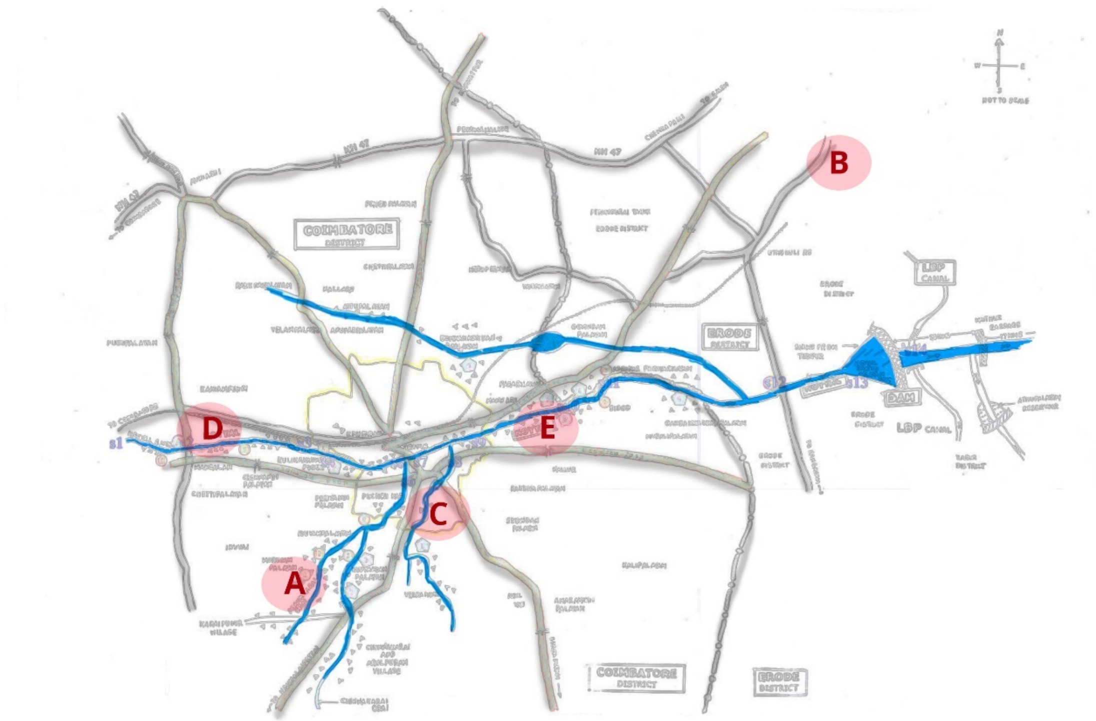


Figure 11: Map showing the general location of each case study (Pilot Study).

4.3.2.3. Study Two: Research Methods

Yin (1989) recommends the following research methods: Interviews, direct observations, participant observations, physical artefacts, documentation, and archival record analysis. These are a mixture of primary and secondary data collection methods. Data for each case study should ideally be collected through multiple methods, to better triangulate the data (Yin 2014;

Creswell 1998). Triangulation of the data allows for better accuracy and strengthens the credibility of the results.

4.3.2.3.1. The direct observation guide

Observation research can allow an exploration of the setting, and the interaction between setting and behavior, in real-time (Morgan, Pullon, Macdonald, McKinlay, & Gray, 2017). This sort of research is undertaken in its native context. If the research question is about the physical setting, as research question one is, then observation methods are an appropriate way to link the setting to the method chosen.

A clear theme from the literature review and pilot study showed that physical changes – from the sheer amount of space needed to construct a treatment plant, to allowances for inlet and outlet pipes, for wastewater reuse– are an important outcome of this regulation. As such, physical form characteristics were included as a section of the observation guide (see Appendix C), and these items were structured to include findings from the pilot study. This section is also partially based on an existing systematic observation instrument developed and tested for reliability by Paquet, Cargo, Kestens, & Daniel (2010). This instrument evaluates the physical and social characteristics of urban neighborhoods, and so, it was developed for a much different physical context. The domain of physical form characteristics was taken from this schedule. While the instrument was developed to evaluate urban neighborhoods, the attributes found under the domain of physical form characteristics were found to be similar to the categories developed from the initial pilot observation test.

The following items are some that were incorporated into the observation guide:

- Size of the facility.
- Location and size of the treatment plant within the facility (if applicable).
- Proportion of space given to the treatment plant (if applicable).
- Provision of buffer space for expansion/innovation purposes.

- Landscaping.
- Access road condition.
- Surrounding urban form (greenfield, brownfield, urban).
- Indications of disrepair/disuse, over-use, and other needs.

Another section of the of the observation guide was developed using an existing facility evaluation protocol from Elmer (2014). This section covers general questions on the treatment facility, such as on owner satisfaction, operability, maintainability and value engineering of the technology. These questions also serve to collect introductory technical data on the facility.

The observation data serves two functions: Descriptive of physical characteristics, and Indicative of acceptance. Physical indications of over-use, maintenance needs, and disrepair could be used to discern difficulties and problems being encountered. These indicators were observed as unstructured, direct observation.

Findings from the pilot study also pointed to what to include and exclude from the scope of the observation guide. For example, compliance and technical aspects were excluded as beyond the scope of this thesis. It is beyond the working & technical knowledge of this researcher to understand if water treatment and reuse happen in accordance with requirements, at all times.

The Observation Process: The researcher asked to be given a tour of the facilities of each case study. The purpose of the tour was explained as gaining an understanding of the physical setting – physical form characteristics and environmental characteristics would be noted. Observation of each case study was conducted using an observation schedule for: (1) The systematic observation of physical characteristics, and (2) The unstructured non-participant observation of people and their behaviors. Non-participant observation is where the researcher has no other relationship with the group being observed other than the role of the researcher. While the first section, the observation of physical characteristics, was conducted according to a semi-structured observation protocol (see Appendix B), the second section is based on an unstructured observation guide (see Appendix C).

Each observation process took a period of 2.5 – 5.5 hours (including the initial process of getting to know the participants, drinking tea, and introductions). All observations took place during the afternoons, over two weeks. As with the interviews, notes were recorded during the observation process, and field notes were constructed later.

4.3.2.3.2. The semi-structured interview guide

The Interview Guide: With a semi-structured interview protocol, questions are structured and grouped into themes under concepts or constructs, that are open-ended in nature, elicit detailed responses, and allow for follow-up questions. This allows for a certain degree of flexibility in the process of the conversation. "*Semi-structured interviews occupy an interesting position on the structured-unstructured continuum. Semi-structured interviews are flexible in that the interviewer can modify the order and details of how the topics are covered. At the same time, informants are asked more or less the same questions, so comparisons across interviews are still possible*". (Bernard, 2017, pp. 76).

The primary technique chosen for conducting the semi-structured interview is the face-to-face conversation. Appendix B contains the semi-structured interview protocol, a list of topics and questions that will be covered. These questions were developed from 1. The pilot study, and 2. The literature review.

The pilot study was also used to explore whether the distinctions between the following statements could be understood and explained by the researcher: 1. The usefulness (advantages, or benefits) of the technology and reuse process in realizing a goal, 2. The use of the technology and reuse process in being free of effort (or easy to implement and use), and 3. The use of the technology and reuse process in being effective (or successful) in realizing a goal. The pilot study interviewees understood the distinction, with further explanation, but one concern was whether this would be lost in translation in subsequent, more detailed interviews, some of which did not occur in English.

All the exploratory, open-ended questions in the interview guide (Appendix C) were developed to understand what factors are perceived to be linked to acceptance of the technology and reuse process. Some key questions used are:

1. In your opinion, are there any advantages, or plus points, to using this technology in the textile facility?
2. If yes, what do you think are the advantages of using this technology?
3. If no, why not?
4. In your opinion, are there any disadvantages, or minus points, to using this technology in the textile facility?
5. If yes, what do you think are the disadvantages of using this technology?
6. If no, why not? (For the full list of questions, refer to Appendix C).

The interview process:

Introductory/Grand Tour phase: The introductory phase of the interview was concerned with explaining the purpose of the study, what sort of questions would be asked, and obtaining consent for participation. Initial, open-ended questions addressed basic background information of the interviewees and the history of their interaction with the technology and reuse process. These background questions were asked with the intention of using them to assess the experience and average knowledge (cultural competence) of the informants. According to Bernard (2017, pp. 45-46) if the informants possess an average knowledge (cultural competence) value of 0.70, then just 10 informants are needed to identify the themes of the study.

The funnel phase: This phase is about open-ended questions on specifics, funneling the conversation from general questions to more specific ones. Again, since the interview method chosen was semi-structured, each informant was asked a set of similar questions, not identical ones. A variety of probes and follow-up questions were asked based on whom the interviewer was talking to.

4.3.2.4. Participants

Research participants were informed of their rights and of the purpose of this study. At the end of the field research period, of 26 participants invited to take part in the research, 19 consented.

All the interviews were conducted within the two-week period of fieldwork data collection. On average, each interview lasted about 35 minutes, with a minimum of 15 minutes and a maximum of 70 minutes (See Table 6).

Table 6
Details of Participants per case study.

Case study	Occupations of interviewees	No. of interviewees	Average spent interviewing
A	Managers, owners, engineers, workers.	5	36 mins
B	Chairmen, managers, environmental engineer, process engineer.	4	45 mins
C	Managers.	2	45 mins
D	Environmental engineers, managers, mechanical engineers.	3	42 mins
E	Manager, casual worker, mechanical engineer.	3	40 mins

Table 6: Details of Participants per case study.

4.4. Analytic Strategy

The process of deriving findings from the qualitative data collected involved the following steps of analysis:

- Running field notes (Lofland, 2006) were used to create a set of detailed field memos. Nineteen memos were created from the interviews, while five were created from each case study observation.
- Open coding: The process of arriving at coding families
    - Descriptive codes: The five observation memos, being comprised of textual data, were used to create initial categories or groups of descriptive codes, and then further sub-groups and sub-identifying descriptive codes. The main family group and sub-group of codes correspond to the main sections covered under the observation guide.
    - Pattern-finding codes: The nineteen interview memos were used to create sets of themes, to identify relevant factors that stakeholders perceive to be important to their acceptance of wastewater treatment technology and water reuse.
- Links and themes between these codes and groups were then visualized using a semantic network diagram, which helped in the descriptions of the qualitative findings. While some themes do co-occur, overlap, or abut each other (Bernard, 2017), the main use of these diagrams is to understand connections between groups and themes.

CHAPTER 5

RESULTS

5.1. Introduction

This chapter reports the results of both Study One: The Pilot Study, and Study Two: The Case Studies. First, I describe the pilot study results and how they were incorporated into the development of the observation and interview guide for study two. Then, findings from the case studies are described. Results from both studies are synthesized, and the findings for each research question are then reported.

5.2. Study One: Pilot Study

5.2.1. Objectives and corresponding results

1. The pilot study was approached with the main intention of using it to test develop the semi-structured interview guide (Appendix B) and the observation guide (Appendix C). Findings from the pilot study will be organized by these objectives: To learn about the different ways in which wastewater reuse has been implemented in textile facilities in Tirupur (Research Question 1.1).
2. To determine the scope and feasibility of the case study approach chosen.
    a. To identify inclusion and exclusion criteria for case studies of textile dyeing facilities.
    b. To identify potential case study sites.
3. To identify stakeholder and user groups that act within the physical setting of a textile facility, from which respondent groups for interviews can be drawn (Research Question 2.1)

4. To test and refine themes and questions for the development of the interview guide and observation guide.

1. Implementation, use, and acceptance.

Implementation and usage of the reuse technology occurs in these textile dyeing facilities on a continuum of options and choices. These range from outright rejection through relocation of the operations to another state, to choices between opting for self-owned, on-site treatment plant or for a common treatment plant, shared with other nearby textile dyeing facilities. The communal treatment plant would then take the responsibility of the collection of wastewater and the return of treated water to and from each textile facility. One pilot study respondent noted that "*out of 28 of the major dyeing operations in Tirupur, 14 have permanently shifted to Ahmedabad because of this requirement [to implement the technology and reuse treated water]*."

Textile dyeing facilities in Tirupur range in scale of operations and thus in size and scope. Small, informal family-owned dyeing operations were set up in residential areas and often continue to operate under the radar of the authority bodies in charge of monitoring.

Historically, textile dyeing facilities were set up on the banks of the Noyyal River and its tributaries, the main water body that runs through Tirupur. This was for ease of access to a flowing source of water, that could be used to bring in clean water and carry away dirty water. In a map provided by one of the respondents (Figure 12), it can be clearly seen how most textile dyeing facilities are currently spread around the banks of the Noyyal River. As a result, most common effluent treatment plants are now also located in a similar, path-dependent manner, to be within operating radius of existing textile dyeing facilities. This operating radius is a maximum of 13 kilometers, allowing a communal treatment plant to cater only to those facilities within the radius for ease of construction of pipes connecting the common treatment plant and the facility. There are around 20 common treatment plants in Tirupur.

New textile dyeing facilities no longer allowed to be built within 5 kilometers of the river and its tributaries. New facilities are encouraged to be planned and built as a part of industrial parks, which are parcels of land deliberately zoned and planned for heavy industrial development. Wastewater treatment and reuse would be provided as a communal amenity as a part of the perks of setting up within an industrial park. This is an attempt to move away from existing unplanned industrial activities to highly planned, zoned and regulated industries. Industrial park settings allow for shared, localized environmental controls. They help to reduce the per-business expenditure on infrastructural needs, like transportation, etc. They are often set away from residential and other urban areas, so that there is a perceived reduction in their environmental and social impact.

The pilot interviewees from the local water and sanitation departments also talked about how they are striving for a conceptual shift, from zero liquid discharge to zero waste (which includes the recovery and reuse of solid by-products of the treatment process). Sulfate-based salts that are used by textile dyeing facilities can be recovered and reused from the brine solution that comes out of the effluent treatment process. Interview respondents noted that this is a rather expensive process, and also does not apply to chloride salts or mixed salts. The final sludge that comes out of the entire process can also be sent to cement kilns and brick manufacturers, to be reused in the construction industry in and around Tirupur (this is being tested). Their ideal goal is to see the entire industry as a water neutral industry – where businesses reduce their water footprint as much as possible, and also off-set the negative externalities of the remaining footprint. While electricity and emissions costs are significantly high, solar and wind energy are being evaluated for their potential, as is cogeneration from the tons of steam produced to run the plants.

Pilot respondents also stressed that permission for borewells (to tap into groundwater aquifers), or for any transportation of materials via trucks, or for the establishment of new facilities within 5 kilometers of the river Noyyal, is not at all allowed. These additional rules were made to address complaints that the highly toxic sludge that is an output of the treatment process was being dumped into landfills or dry riverbeds. These regulations point to how compliance is the main focus of the ZLD regulation, which is a point that is discussed in Chapter 2: Background.

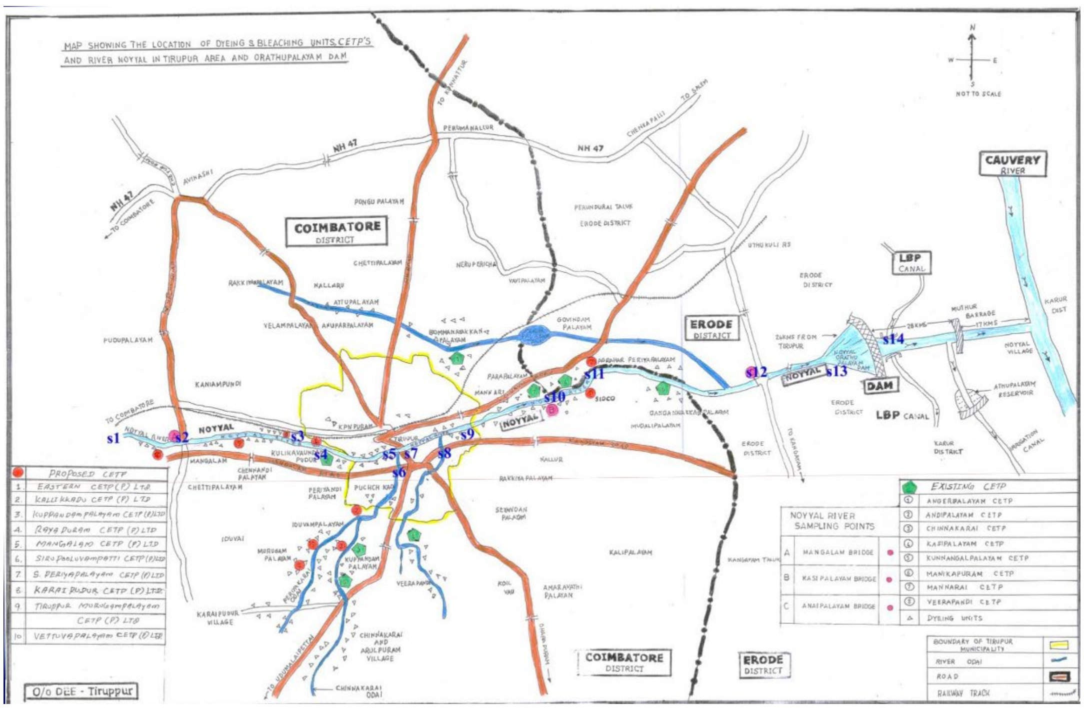


Figure 12: Map showing the location of textile dyeing facilities and common effluent treatment plants in Tirupur (Pilot Study).

2. Scope and case study sampling strategies.

Inclusion criteria: A purposive sampling strategy, with a maximum variation of conditions of implementation and use, was used to select case studies that represent a variety of implementation conditions in Tirupur. These conditions were determined using the pilot study and are detailed in Chapter 4: Methodology.

Exclusion criteria: Results from the pilot study indicated that the scope and selection of case studies would have to exclude facilities that relocated to other states, or that don't comply with the regulation. While it would have been more comprehensive to undertake case studies that also look at the antithesis of acceptance (rejection), for feasibility reasons, this is not within the scope of this thesis.

Possible case study scenarios included a single case study set-up: for example, examining just one common treatment plant, and the textile dyeing facilities connected to it. This would have allowed for a case study set-up that would have been more detailed and focused in scope. However, this would not have allowed for the capture of factors that influence the acceptance of wastewater treatment and reuse by those facilities that opt for on-site treatment, and thus was considered to not be comprehensive enough for the research objectives of this thesis

3. Stakeholder and actor groups

Within textile dyeing facilities, a number of groups of people have jobs that now directly relate to the running of the treatment processes and reuse of the water. Several new jobs were also created due to the need to operate and maintain the treatment and reuse processes. The pilot study identified the following main actor and stakeholder groups that act within textile dyeing facilities:

- Owners, chairmen and managing directors of textile dyeing businesses, that are the key decision-makers.
- Managers, at various levels, of the textile dyeing facilities that are the minor decision-makers.
- Environmental Engineers and process engineers, with specialized technical knowledge, that operate the treatment plants, and monitor the readings from flow meters.
- Formal workers, that maintain the treatment plants, and serve a variety of roles, such as line supervisors.
- Casual workers, that are usually hired seasonally or for more physical work.

Interview respondents were primarily drawn from the first three groups – those groups with decision-making power and specialized knowledge of working procedures.

4. Development of the observation and interview guide

Development of the observation and interview guides for Study two: Case Studies is presented in Chapter 4: Methodology.

5.3. Study Two: The Case Studies

Findings from both the methods of observation and interview used for each case study are presented here. One strategy for analyzing case study evidence can be about building a description of each case (Yin, 2014) and using such description to 'explain' the different ways in which ZLD technology has been implemented in these facilities. This is the strategy used in the analysis of the data collected through unstructured observation of each case study. A second strategy for analyzing case study evidence is to rely on the theoretical propositions that were developed from the literature review and that shaped the data collection protocols (ibid). This is the strategy used in the analysis of the data collected through semi-structured interviews with actors and stakeholders within each case study. Both these strategies are discussed in Chapter 4: Methodology.

5.3.1. Observation results

Data from the observation of each case study was collated into 5 observation memos. Open coding and semantic network analysis are the main qualitative analytic techniques used to develop a description of each case study from the observation. These techniques are described in more detail in the analytic strategy section of Chapter 3: Methodology.

The physical or contextual factors are represented by general descriptive codes from the open coding process. The groups of descriptive codes were broken down into three levels of groups of codes. The first level or group represents the case studies and key differences between them (on-site or off-site wastewater treatment and reuse). The second sub-group of codes categorize whether the identified physical or contextual factors fall under scale of operations, physical form characteristics, or operations and maintenance. The third sub-group of codes represent the identified physical or contextual factors of the case studies. A table (Table 7) presents the end-result of the iterative process of open thematic coding. While the first group of codes is mutually exclusive, the second and third sub-groups are linked to other codes.

A semantic network diagram that describes the links and associations between these codes is used to visually develop and display the links and relations between these codes and groups (Figure 13). The diagram is color-coded to represent main groups of themes (Pink identifies which themes and codes apply only to individual, on-site treatment and reuse; yellow identifies which themes and codes apply only to common, off-site treatment and reuse, while green identifies those themes and codes that apply to all the case studies). Links between themes and codes show how they support, contradict, and relate to one another. The main purpose of this diagram is to aid the process of presenting findings in a logical, clear manner. While this table and diagram represent the process of analysis for all five case studies (all five observation memos), cross-case comparison was not the purpose and findings do not reflect any cross-case analysis.

Table 7
Showing the groups and corresponding sub-groups of descriptive codes used in the analysis of the unstructured observations.

Main Family Group: Descriptive codes.	Sub-family group 1: Descriptive codes.	Sub-family 2: Descriptive codes.
On-site Individual effluent treatment plants: Case Studies A & B.	Scale of operations.	• Small-scaled operations. • Large-scaled operations. • Future expansion. • Current needs. • Young business. • Established business. • Current wastewater generation.

		• Anticipated future wastewater generation. • Facility planned by an architect. • Facility planned by an engineer.
	Physical Form Characteristics.	• Significant space requirement. • Surrounding urban form: greenfield. • Surrounding urban form: city. • Landscaping within textile facility. • Secondary access roads. • Main road access. • Required signage for compliance. • Double-story height structures.
	Operations and Maintenance.	• Seasonal laborers. • Dedicated staff for O & M. • Tanks for wastewater storage. • Tanks for water storage. • Dark sludge output. • Sludge storage as per guidelines. • Natural biological oxidizers (cow dung). • Pitted, chemically stained surfaces. • Health and safety procedures.
Off-site Common Effluent Treatment Plants: Case Studies C, D & E.	Scale of operations.	• Small operating radius (5km). • Large operating radius (13km). • Private land. • Government-Funded. • Privately owned companies. • Caters to a small number of textile facilities (10 – 13). • Caters to a large number of textile facilities (22 – 27).
	Physical Form Characteristics.	• Surrounding urban form: brownfield. • Surrounding urban form: city. • Main & Access roads. • Towers (12 meters and above) and structures. • Required signage for compliance. • Steam and smoke emissions from operations.

	Operations and Maintenance.	• Trial testing of new operations and processes. • Construction activities on site. • Solar drying beds in disuse. • Large technical staff required for O & M. • Technical expertise for in-house monitoring of quantities of wastewater received and water re-turned. • In-house monitoring of TDS levels, effluent, and water quality. • Maintenance of pipes between the common treatment plant and textile facilities. • Quantities of coal needed to operate the plant. • Salt recovery (recovery of solid sul-fates from the wastewater). • Reuse of treatment solutions (brine solution). • Solar energy potential. • Health and safety procedures.

Table 7: Showing the groups and corresponding sub-groups of descriptive codes used in the analysis of the unstructured observations.

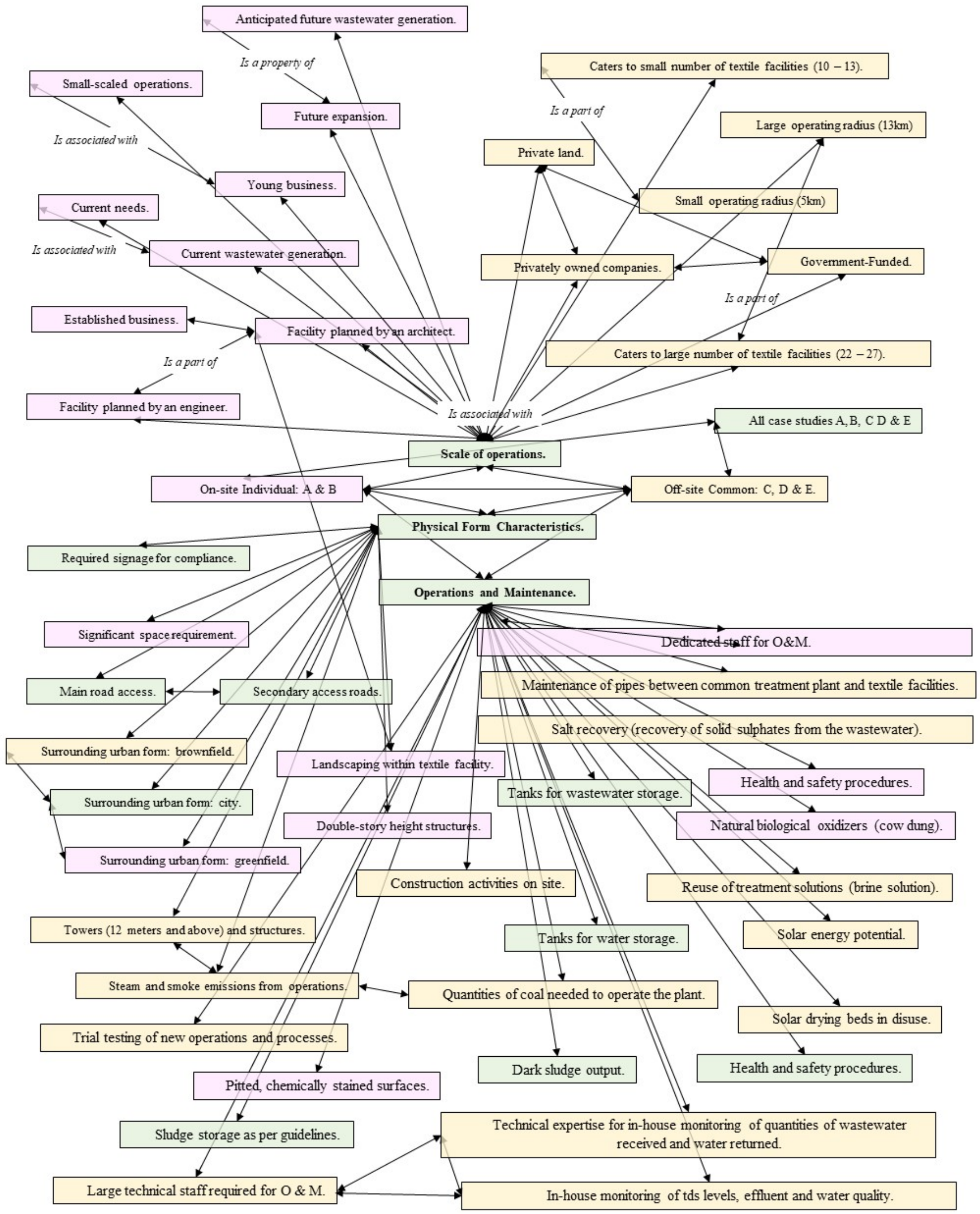


Figure 13: A semantic network diagram showing the relationship between the descriptive codes and groups from the unstructured observations.

5.3.2. Interview results

Data from interviews with actors and stakeholders within each case study was collated into 19 interview memos, one for each interview. Open coding and semantic network analysis are the main qualitative analytic techniques used to develop themes and patterns from the interview responses. These techniques are described in more detail in the analytic strategy section of Chapter 3: Methodology.

For the data collected through the interview method, the main level of analysis used was the lowest level of data collected: interviewees' responses to questions on what they thought about the ease of use, usefulness (utility) and effectiveness (success) of the wastewater treatment process. These perceptions were coded through a process of open coding, with four groups and sub-groups of codes created through this process of analysis. The first group represented whether the pattern-finding code (the perception) was seen as an advantage/opportunity/benefit, or a disadvantage/problem/risk. The second group of codes represents whether the pattern-finding code applied to all case studies, to only the on-site case studies, or to the off-site case studies. These two groups and sub-groups of codes are mutually exclusive. The third sub-group represent the pattern-finding codes that denoted sections of the text from the interview field memos. These pattern-finding codes represent interviewees' perceptions on the acceptance of wastewater treatment technology and reuse. The fourth group represents the construct to which the pattern-finding code is linked: perceived ease of use, perceived usefulness, or perceived effectiveness. Table 8 presents the end-result of the iterative process of open thematic coding used on the interview data. Thegroups and sub-groups of codes are not mutually exclusive, and so a semantic network diagram was created to understand the linkages between various codes and groups

The table of codes (Table 7) and semantic network diagram (Figure 14) represent the process of coding and analysis of 19 interview memos. The diagram is color-coded to represent main groups of themes (Pink identifies which themes and codes apply only to individual, on-site treatment and reuse; yellow identifies which themes and codes apply only to common, off-site treatment and reuse, while green identifies those themes and codes that apply to all the case studies). Links between themes and codes show how they support, contradict, and relate to one another. The main purpose of this diagram is to aid the process of presenting findings in a logical, clear manner. For this research question, a small amount of cross-case analysis occurred.

Table 8

Showing the groups and corresponding sub-groups of descriptive codes used in the analysis of the semi-structured interviews.

Main Family Group.	Family Group: Descriptive codes.	Thematic/Pattern-finding codes.	Linked Constructs.
Advantages/Opportunities/Benefits.	All case studies A, B, C D & E.	• Wastewater as resource.	Perceived usefulness.
	Off-site Common: C, D & E.	• Recovery of salts (solids).	Perceived usefulness.
	Off-site Common: C, D & E.	• Reuse of brine solution.	Perceived usefulness.
	All case studies A, B, C D & E.	• Shift from 'zero liquid discharge' to 'zero waste'.	Perceived effectiveness.
	On-site Individual: A & B.	• Buyer Satisfaction.	Perceived effectiveness.
	On-site Individual: A & B.	• Buyer Expectation.	Perceived usefulness.
	On-site Individual: A & B.	• Eco-friendly label is good for international business.	Perceived usefulness.
	All case studies A, B, C D & E.	• Public Satisfaction.	Perceived effectiveness.
	On-site Individual: A & B.	• Pride and sense of showmanship.	Perceived effectiveness.

	On-site Individual: A & B.	• Control over process.	Perceived ease of use.
	Off-site Common: C, D & E.	• Burden of proof is on CETP.	Perceived ease of use.
	Off-site Common: C, D & E.	• Burden of collection, treatment and return is on CETP.	Perceived ease of use.
	All case studies A, B, C D & E.	• Water costs.	Perceived usefulness.
	Off-site Common: C, D & E.	• Design & technology pioneers of brine treatment and reuse.	Perceived effectiveness.
Disadvantages/Problems/Risks.	On-site Individual: A & B.	• Specialized technical knowledge needed for O & M.	Perceived ease of use.
	On-site Individual: A & B.	• Specialized technical operators needed.	Perceived ease of use.
	On-site Individual: A & B.	• Specialized physical infrastructure for installation.	Perceived ease of use.
	On-site Individual: A & B.	• High costs of installation, use & maintenance.	Perceived ease of use.
	On-site Individual: A & B.	• Expensive commercial loans.	Perceived usefulness.
	All case studies A, B, C D & E.	• Energy-intensive and carbon-intensive.	Perceived effectiveness.
	Off-site Common: C, D & E.	• No distinction between 'less dirty water' and 'more dirty water'.	Perceived usefulness.
	On-site Individual: A & B.	• High level of monitoring.	Perceived usefulness.
	All case studies A, B, C D & E.	• Unfair process: Relocation – other	Perceived effectiveness.

		states or cities within the same state don't have to follow this rule.	
	Off-site Common: C, D & E.	• Uncertainty: No control over return.	Perceived ease of use.
	Off-site Common: C, D & E.	• Trust in CETP (credibility).	Perceived effectiveness.
	All case studies A, B, C D & E.	• Significant steam and smoke (from coal use) emissions.	Perceived effectiveness.
	On-site Individual: A & B.	• Future expansion plans depend on current capacity.	Perceived ease of use.
	On-site Individual: A & B.	• Non-productive asset.	Perceived usefulness.
	Off-site Common: C, D & E.	• Big expensive experiments.	Perceived effectiveness.
	All case studies A, B, C D & E.	• Ambient (Chemical, mechanical, thermal) hazards.	Perceived ease of use.
	All case studies A, B, C D & E.	• Future problems: Repair or replace.	Perceived ease of use.
	All case studies A, B, C D & E.	• Future problems: changes to technology.	Perceived ease of use.
	Off-site Common: C, D & E.	• Buyers don't care.	Perceived effectiveness.
	All case studies A, B, C D & E.	• Hazardous/Toxic solid waste.	Perceived effectiveness.
	All case studies A, B, C D & E.	• Disposal challenges.	Perceived effectiveness.
	Off-site Common: C, D & E.	• Scaling & corrosion of expensive equipment like evaporators.	Perceived ease of use.
	Off-site Common: C, D & E.	• Burden/Liability on us, not on buyers.	Perceived usefulness.

	Off-site Common: C, D & E.	• Unfair financial per-unit cost for smaller facilities.	Perceived usefulness.
	All case studies A, B, C D & E.	• River-water sharing is the main problem.	Perceived effectiveness.
Facilitating Conditions.	All case studies A, B, C D & E.	• Subsidies to set-up.	Perceived effectiveness.
	All case studies A, B, C D & E.	• Stakeholder participation in decision-making.	Perceived effectiveness.
	All case studies A, B, C D & E.	• Back-up generators for electricity-intensive process.	Perceived effectiveness.
	All case studies A, B, C D & E.	• Siting to industrial parks.	Perceived effectiveness.
	All case studies A, B, C D & E.	• Technology demonstrations and learning assistance.	Perceived effectiveness.

Table 8: Showing the groups and corresponding sub-groups of descriptive codes used in the analysis of the semi-structured interviews.

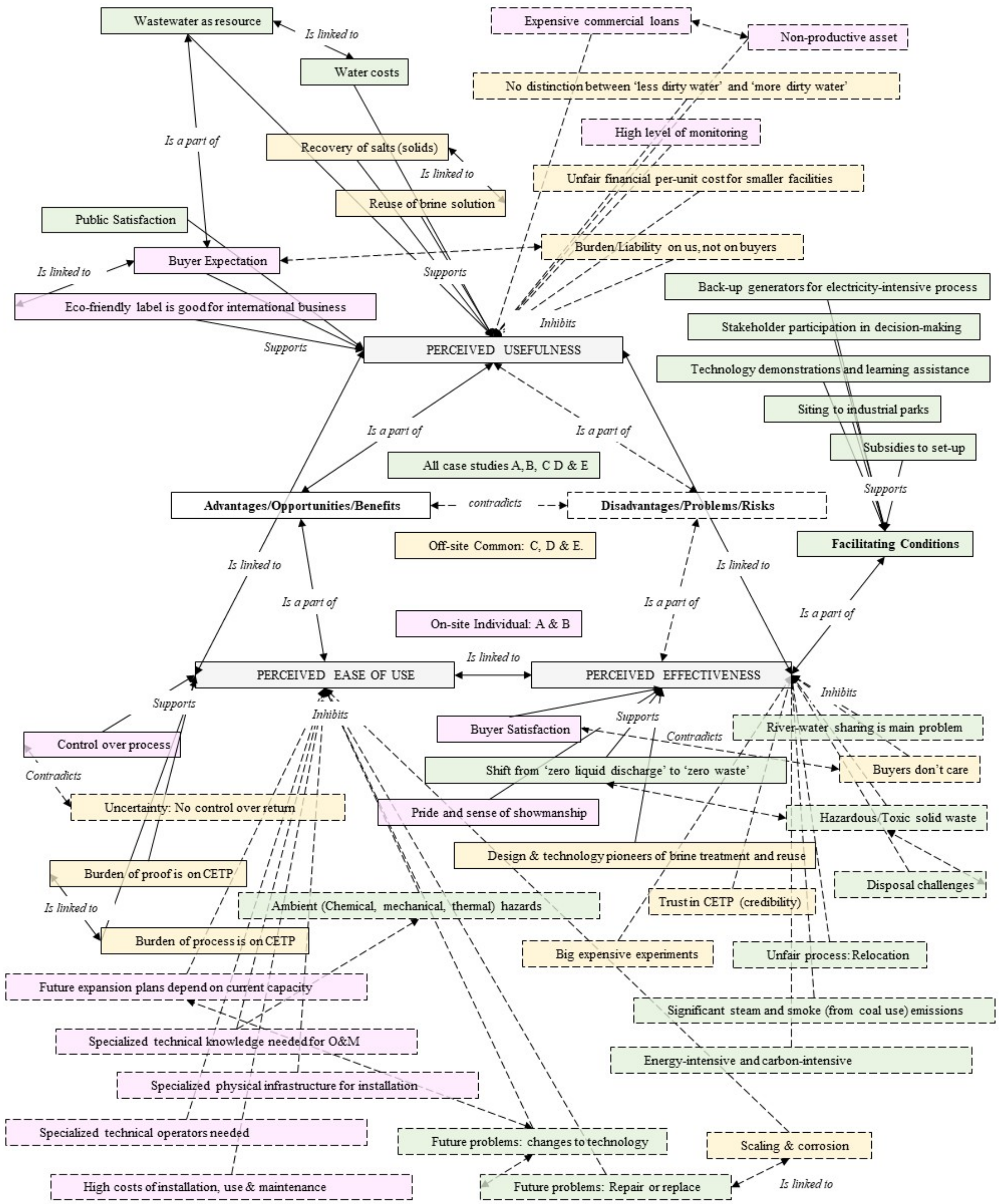


Figure 14: A semantic network diagram showing the relationship between the descriptive codes and groups from the semi-structured interviews.

5.4. Findings as per research questions

This section integrates themes and linkages from Study 1: The Pilot Study and Study 2: The Case Studies to answer each research question. Descriptions of each case study, thematic coding processes, and semantic network analysis were all used to present the findings as per each research question here.

1. How has the mandatory implementation of wastewater reuse technology driven physical changes in textile facilities in Tirupur?

1.1. What are the different ways in which wastewater reuse has been implemented in the textile facilities?

Textile facilities, due to this regulatory requirement, had the following options as a response: Relocation/Closure; Implementation of an on-site, individual scheme; or opting into a communal wastewater treatment facility with other textile units. Relocation was an inevitable response to this regulation, which is currently not required by other states or cities. One respondent noted that "out of 28 of the major dyeing operations in Tirupur, 14 have permanently shifted to Ahmedabad because of this requirement". Closure of many textile units happened immediately after the court shutdown order in 2011 (Swaminathan, 2014). Actual implementation and reuse of the wastewater can thus happen in two ways: Opting for on-site treatment, or communal off-site treatment. Of the 500 or so textile facilities that currently operate in Tirupur, around 70% of them have opted for common effluent treatment plants, while the rest chose to set up their own individual effluent treatment plants (Pilot Study).

Individual Wastewater Treatment:

In an ideal set-up, the most efficient closed-loop wastewater reuse system might be one where all the textile facilities choose to opt for communal wastewater treatment facilities, taking advantage of economies of scale and of the removal of the burden of installation, management, and maintenance. However, this does not include the significant costs, both environmental and financial, of collecting and returning the wastewater via a pipe to the CETP. Many facilities, both small and large, choose to opt for individual on-site treatment, for several reasons explained in detail later in this chapter. According to Blackman (2006), some facilities choose to opt for both the CETP as well as an IETP, having a back-up plan to one with the other. On-site treatment offers several obvious advantages of control over the rate and process of wastewater treatment, of control over a process that can significantly interrupt business operations, and of having decision-making power.

Common Wastewater Treatment: These common treatment facilities are usually managed by infrastructure developers, that are operate using a public-private-partnership (PPP) model in the water sector. These treatment facilities get back between 95 to 98% of water from the wastewater, and 75 to 80% of salts from the wastewater. They take responsibility for the technology, asset management (operations and maintenance) and value engineering of the entire process of collecting, treating, and returning the water, charging a fee to the textile facility for doing so. At a minimum, monitoring systems are set up at each 'member' textile facility to monitor TDS levels. Dedicated PVC pipes take the wastewater from the textile facility to the common effluent treatment plant. According to respondents to the interviews, a few of the larger common effluent treatment plants are now operating with profits, although it takes some years to reach this point.

1.2. What are the physical characteristics of these textile facilities?

Case Study A: The case of a small textile printing facility that aspires to expand its business operations.

Introduction:

This is currently a printing facility, a process with relatively less wet processing and wastewater generation as compared to a dyeing facility. However, the owners have ambitions of expanding the current facility to accommodate a dyeing business in the future. They have installed an individual effluent treatment plant on-site, that has the capacity to take care of their current as well as anticipated wastewater generation. This is an important case study to include, as it shows how textile firm owners now must include such considerations into their decision-making processes.

Physical Characteristics and observations:

Table 9

Showing physical characteristics and unstructured observation notes on case study A.

<table>
<tr><td>Site Diagram (Not to Scale)</td><td>Area breakdown:</td></tr>
<tr><td rowspan="4">
</td><td>Total Area: 2.8 Acres</td></tr>
<tr><td>1: IETP Area: 0.6 Acres (21.4%)</td></tr>
<tr><td>2: General Facility Area: 1.5 Acres (53.6%)</td></tr>
<tr><td>3: Buffer/Expansion Area: 0.7 Acres (25%)</td></tr>
<tr><td colspan="2">Location: 3.2 km away from the main Noyyal river, and 150 m away from a tributary.</td></tr>
<tr><td colspan="2">Duration of tour: 2 hours.</td></tr>
<tr><td colspan="2">2-year old facility.</td></tr>
<tr><td colspan="2">IETP is deliberately placed opposite to the ‘display’ building, where newer, imported equipment is showcased, and from which the tanks and treatment can be seen.</td></tr>
<tr><td colspan="2">Facility planned by: Engineers, water infrastructure specialists.</td></tr>
<tr><td colspan="2">Access Road: One primary public dirt road (4.8 m width) that cuts across the facility.</td></tr>
<tr><td colspan="2">Landscaping: No landscaping elements observed.</td></tr>
<tr><td colspan="2">Surrounding urban form: Brownfield & City.</td></tr>
<tr><td colspan="2">Total wastewater capacity: 170 kiloliters per day (KLD)</td></tr>
<tr><td colspan="2">Amount of chemical sludge generated: 200kg.</td></tr>
<tr><td colspan="2">Sludge is stored on-site on clay lining.</td></tr>
<tr><td colspan="2">Emissions generated from boiler: 15 lakh MW/hr.</td></tr>
<tr><td colspan="2">Maintenance is yearly or as needed and is sub-contracted to a third-party company (the same company that installed).</td></tr>
</table>

IETP staff: Only one technical operator has been hired so far.
IETP staff: 4 – 5 casual workers for physical work and operations.
Signage in English and Tamil detailing the chemicals used, waste generated, effluent quantities, and emissions for inspection.
Clean, treated water is stored in an overhead tank for further reuse.
The actual step of reusing the water was not observed.
Use of biological oxidizer (cow dung) in the preliminary treatment process indicates that this is a recently installed IETP.
Chemical sludge is in a solid brick form and is handled without protection by casual workers. Signage in English and Tamil, with pictures, indicates that gloves and masks are needed.
Sludge is stored on-site, as per rules. This is a growing space requirement.
Provision of buffer space for expansion of the facility, which is not adjacent to IETP so can't be used for that purpose.
Water supply for other needs is from NTADCL.
Observed 3 workers, 1 engineer, and 1 manager during a tour of the IETP.

Table 9: Showing physical characteristics and unstructured observation notes on case study A.

Case Study B: The case of the large textile dyeing facility with established operations.

Introduction:

This is one of the more established textile firms in Tirupur, operating there for over 3 decades. They supply dyed textiles to multiple countries, including the United States, Europe, China, Japan, etc. Their buyers include international brands such as GAP, H&M, Reebok, and Zara. Their production capacity, in terms of wet fabric processing (bleaching, coloring, and washing) works out to 35 tons per day of fabric. They have an on-site RO (Reverse Osmosis) treatment plant to reuse their wastewater.

As it is also situated within an industrial park, it is also representative of an effort to situate these facilities, previously allowed to be located anywhere near a water body, to planned zones. This industrial park has its own communal treatment facility, that takes in wastewater and gives back treated water to industrial units within the park. Even so, this case study chose to opt for an on-site individual effluent treatment plant, mainly for reasons of control over the entire process, ensuring that business operations would not be disrupted by external factors.

Physical Characteristics and observations:

Table 10

Showing physical characteristics and unstructured observation notes on case study B.

Site Diagram (Not to Scale)	Area breakdown:
	Total Area: 22.3 Acres
	1: IETP Area: 6.1 Acres (27.4%)
	2: General Facility Area: 12 Acres (53.8%)
	3: Buffer/Expansion Area: 4.2 Acres (18.8%)
Location: 10 km away from any point of the Noyyal. Location: Not in or near the boundary of Tirupur.	
Duration of tour: 3 hours.	
9-year old facility.	
Facility is located within a planned industrial park.	
Facility planned by: Architects and water infrastructure specialists.	
Facility provisions include hostels for textile workers, display and visitors' buildings, an administrative building, and general textile facilities.	
Entrance: One main entrance, and 2 side entrances near the IETP.	
Access Roads: Two paved access roads (7.2 m width) that border the facility.	
Internal paved 2-way roads.	
Landscaping: Presence of planned trees and shrubs around visitors' areas, the front of the workers' hostels, and on center-strip dividers of internal roads.	
Landscaping: Absence of landscaping elements towards the back of the facility, and where the IETP is located.	
Surrounding urban form: Greenfield	
Total wastewater capacity by volume: 60 lakh liters.	

Cost of sending sludge to a cement factory or incinerator: 2500 rupees per ton (potential option explored).
Provision of buffer space near IETP, for expansion/upgrades to the treatment plant.
IETP staff: 40 people, with at the most 10 casual workers.
IETP staff: Dedicated chemistry lab on-site for analysis.
IETP staff: Technical operators consist of environmental engineer-manager, mechanical engineers and electrical engineers.
Signage in English and Tamil detailing the chemicals used, waste generated, effluent quantities, and emissions for inspection.
Clean, treated water is stored in an overhead tank for further reuse at the facilities.
The actual step of reusing the water was not observed.
Established IETPs do not need biological oxidizers.
Sludge is stored on-site, in bags on lined sheets, as per rules. This is a significant space requirement, with tons of bags observed.
Sludge ('biological sludge') is generated at the rate of 1 ton per day.
'96% of water is returned' – engineer on site.
Observed chemists, engineers, managers and casual workers during the tour.

Table 10: Showing physical characteristics and unstructured observation notes on case study B.

Case Study C: The case of the medium-sized, 'typical' textile facility that recycles and reuses its water through a common effluent treatment plant.

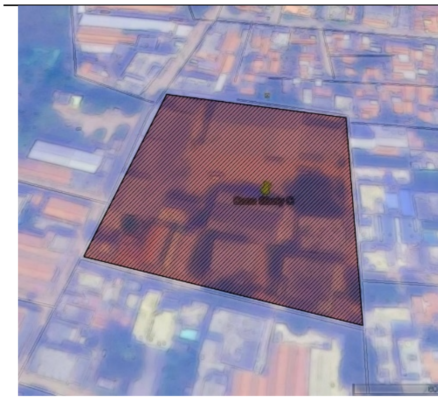
Introduction:

This case study represents one of the many medium-sized textiles dyeing facilities that pay a CETP to collect, treat and return their wastewater. This payment is based on the total volume of wastewater (in MLD) generated, but also includes a base financial equity cost to be a member. For some medium-sized and smaller facilities, the cost per unit of wastewater could be more than what it is for larger facilities. This case study is representative of the decisions that go behind the choice to opt for a communal treatment facility. Since the CETP takes care of everything -from monitoring to the maintenance of the collections pipes and returns pipes - the burdens of land and space availability, human capital, and compliance checks are removed.

Physical Characteristics and observations:

Table 11

Showing physical characteristics and unstructured observation notes on case study C.

<table>
<tr><th>Site Diagram (Not to Scale)</th><th>Area breakdown:</th></tr>
<tr><td rowspan="4"></td><td>Total Area: 2.42 Acres</td></tr>
<tr><td>1: No WWTP on-site</td></tr>
<tr><td>2: General Facility Area: 2.42 Acres (100%)</td></tr>
<tr><td>3: Buffer/Expansion Area: None</td></tr>
<tr><td colspan="2">Location: 600 m away from any point of the Noyyal or a tributary.
Location: 0.5 km away from a connecting CETP.</td></tr>
<tr><td colspan="2">Duration of tour: 1 hour.</td></tr>
<tr><td colspan="2">14-year-old facility.</td></tr>
<tr><td colspan="2">Facility planned by: Unplanned facility.</td></tr>
<tr><td colspan="2">Entrance: One main entrance, and 1 side entrance.</td></tr>
<tr><td colspan="2">Access Roads: One unpaved access road (3m width) that borders the facility.</td></tr>
<tr><td colspan="2">Landscaping: Presence of trees and shrubs that came with the site.</td></tr>
<tr><td colspan="2">Surrounding urban form: City.</td></tr>
<tr><td colspan="2">Total wastewater capacity allowed to be sent to IETP: 1 lakh liters (cap).</td></tr>
<tr><td colspan="2">Average wastewater generated: 430 KLD.</td></tr>
<tr><td colspan="2">Quantity of recycled water used: 400 KLD.</td></tr>
<tr><td colspan="2">Quantity of freshwater used: 30 KLD.</td></tr>
</table>

Quantity of fabric processed: 12 tons per day.
Wastewater, or effluent, sent by pipes to the CETP. Management of pipes is handled by the CETP.
No visitors' spaces, display elements or showcase equipment.
Little to no visitors who come to 'tour' the facilities. Visitors are limited to inspection officials and other textile unit owners. This is a 'back operations' site.
Facility consists of 2 main factory buildings where all operations take place.
Facility displays signs of age (material degradation, old equipment) with no plans for refurbishment.
No plans to upgrade equipment to more water-efficient equipment, unless perhaps if a subsidy to do so is promoted in the industry.
Signage in English and Tamil for general facility rules.
Clean, treated water is returned via a piped network (This was not observed for corroboration).
The actual step of reusing the water was not observed.
Cost of being a member of a CETP is determined based on the quantity of wastewater sent to the CETP (variable) as well as a base (fixed) cost.
"Water returned is of good, reusable quality".
"Proposed GST [Goods and Service Tax] at 12% on CETPs [and not IETPs] is a concern".
Observed: 2 textile facility managers and many workers during this tour.

Table 11: Showing physical characteristics and unstructured observation notes on case study C.

Case Study D: The case of a small-scale common effluent treatment plant.

Introduction:

This is a common wastewater treatment facility that is on the smaller end in terms of its water treatment capacity, and so also in terms of the number of individual textile businesses it caters for. This caters to a maximum of 13 textile facilities, all within a 5 km radius of the CETP. The number of textile facilities that it caters to fluctuates. It is a privately-owned common facility, that acts as a business, collecting, treating, and returning water to its customers. It employs about 40 people overall, with perhaps 20 casual laborers. There are 2 generators for back-up of the entire plant.

Physical Characteristics and observations:

Table 12

Showing physical characteristics and unstructured observation notes on case study D.

<table>
<tr><td>Site Diagram (Not to Scale)</td><td>Area breakdown:</td></tr>
<tr><td rowspan="3">
</td><td>Total Area: 9.5 Acres</td></tr>
<tr><td>1: CETP: 7.5 Acres (78.9%)</td></tr>
<tr><td>2: Buffer/Expansion Area: 2 Acres (21.1%)</td></tr>
<tr><td colspan="2">Location: 100 m away from any point of the Noyyal.</td></tr>
<tr><td colspan="2">Duration of tour: 2.5 hours.</td></tr>
<tr><td colspan="2">15-year-old facility.</td></tr>
<tr><td colspan="2">Operating radius: 5 km.</td></tr>
<tr><td colspan="2">Number of member units: 13 textile dyeing and bleaching units.</td></tr>
<tr><td colspan="2">Total wastewater capacity: 5.5 MLD.</td></tr>
<tr><td colspan="2">Current wastewater capacity: 2.5 MLD.</td></tr>
<tr><td colspan="2">Facility planned by: Water infrastructure specialists and engineers.</td></tr>
<tr><td colspan="2">CEQMS (Continuous effluent quality monitoring system) for real-time online access to data, managed by engineers.</td></tr>
<tr><td colspan="2">Entrance: One main entrance, and 1 side entrance (both can be used by trucks).</td></tr>
<tr><td colspan="2">Access Roads: One paved access road (7m width).</td></tr>
<tr><td colspan="2">Internal roads for in-site transportation of materials.</td></tr>
<tr><td colspan="2">Landscaping: None</td></tr>
</table>

Surrounding urban form: Brownfield
CETP staff: 40 people, and 20 casual workers.
CETP staff: Dedicated chemistry lab for analysis.
CETP staff: Qualified technical operators consist of environmental engineer-managers, mechanical engineers, electrical engineers, and process engineers.
Signage in English and Tamil detailing tank capacities (70-100 cu-m), names of each process and handling rules.
A brief overview of the main steps in this treatment process: Wastewater from all member facilities is mixed together in a collection tank. The mixed wastewater is homogenized so that its physical characteristics (BOD, TDS, PH levels) are all uniform. The wastewater is sent to aeration tanks to reduce the organic matter (COD, BOD): Activated Sludge. A 5-stage Reverse Osmosis plant, that is the most energy-intensive step of this process, is used to remove inorganic salts. A Mechanical evaporator removes smaller particulate matter, ending with cleaner water. A chiller and centrifuge are used to recover salts from the leftover concentrate. Rejected water from any stage is re-entered into this process, to recover as much water as possible.
3 main separate pipelines of a maximum of 5km in length are used to take in wastewater from the member facilities and return clean water. Slope of these pipes are mostly level or 0.5m, as most member units are located on the same elevation.
Incoming and outgoing flows are measured by electro-magnetic flow meter readings, which are connected to an online system.
Glauber's salt is recovered and reused by member facilities.
30 tons of solid waste generated. Of this, some (inactive through addition of lime and soda ash) is sent to a local cement plant, and the rest (hazardous) is stored on-site.
Ownership: Privately owned model.
Project costs: Loans, grants and subsidies from the government (~50%), equity shares from member units (25%), loans from banks (20%) and TWIC investment (5%).
O&M costs: 300 rupees per cubic meter of wastewater.
Observed plant managers, engineers, shift operators and casual operators during tour.
Casual workers are responsible for more physical duties that include transportation and handling of solid matter, loading and unloading of firewood and coal, and maintenance of tanks and other equipment.
Observed piles of coal and firewood near points close to boilers and chillers for use.

Observed bags of crystallized white salts that can be reused by member facilities.

Table 12: Showing physical characteristics and unstructured observation notes on case study D.

Case Study E: The case of a large-scale common effluent treatment plant.

Introduction:

This is one of the larger facilities, catering to 22 facilities (a maximum of 27 units being allowed), all within a 13 km operating radius. It employs around 100 people in total. As one of several CETPs operating through a public-private-partnership model, it is also used as the site for trial experiments with attempts to move towards more of a ‘zero waste’ approach, through testing different technology.

Physical Characteristics and observations:

Table 13
Showing physical characteristics and unstructured observation notes on case study E.

Site Diagram (Not to Scale)	Area breakdown:
	Total Area: 11.8 Acres
	1: CETP: 10.6 Acres (89.9%)
	2: Buffer/Expansion Area: 1.2 Acres (10.1%)
Location: 400 m away from any point of the Noyyal.	
Duration of tour: 3 hours.	
13-year-old facility.	
Operating radius: 13 km.	
Number of member units: 22-27 textile dyeing and bleaching units.	

Total wastewater capacity: 10 MLD.
Current wastewater capacity: 6 MLD.
Facility planned by: Water infrastructure specialists and engineers.
CEQMS (Continuous effluent quality monitoring system) for real-time online access to data, managed by plant engineers.
Entrance: One main entrance, and 2 side entrances (all 3 can be used by trucks).
Access Roads: One paved access road (7m width), 2 unpaved access roads.
Internal roads for in-site transportation of materials.
Landscaping: None
Surrounding urban form: Brownfield
CETP staff: 80 people, and 20 casual workers.
CETP staff: Qualified technical operators consist of environmental engineer-managers, mechanical engineers, electrical engineers and process engineers.
Technical operators state that they have degrees in environmental engineering, mechanical engineering. Work experience required to be a plant manager.
Signage in English and Tamil detailing tank capacities, names of each process and handling rules.
A brief overview of the main steps in this treatment process: The treatment process consists of primary, secondary and tertiary treatment. Wastewater from all member facilities is mixed together in a collection tank. The mixed wastewater is homogenized so that its physical characteristics (BOD, TDS, PH levels) are all uniform. The wastewater is sent to aeration tanks to reduce the organic matter (COD, BOD): Activated Sludge. A 5-stage Reverse Osmosis plant, that is the most energy-intensive step of this process, is used to remove inorganic salts. A Mechanical evaporator removes smaller particulate matter, ending with cleaner water.
Main separate pipelines of a maximum of 12km in length are used to take in wastewater from the member facilities and return clean water. These pipes are made of iron, with a cement mortar lining. Slope of these pipes varies from 0.5 to 6 meters.
Incoming and outgoing flows are measured by electro-magnetic flow meter readings, which are connected to an online system.
1500 tons of solid waste generated. This is dried (solar drying beds), solidified and compressed, and then secured in an on-site landfill that is layered with materials to prevent seepage.

Ownership: Public-private partnership.
Project costs: Public investment (~50%), equity shares from member units (35%), and government subsidies (15%).
O&M costs: 200 rupees per cubic meter of wastewater.
Observed plant managers, engineers, shift operators, and casual operators during the tour.
Casual workers are responsible for more physical duties that include transportation and handling of solid matter, loading and unloading of firewood and coal, and maintenance of tanks and other equipment.
Observed piles of coal and firewood near points close to boilers for steam generation (3 tons per hour).
Observed bags of crystallized white salts that can be reused by member facilities.

Table 13: Showing physical characteristics and unstructured observation notes on case study E.

2. How has the mandatory implementation of wastewater reuse technology driven technological acceptance in users and stakeholders within the textile facilities in Tirupur?

2.1. Who are the stakeholders and actors within the textile facilities?

The pilot study identified the following groups of stakeholders (defined as decision-makers within this setting) and actors (the people involved within this setting).

- Owners, chairmen and managing directors of textile dyeing businesses, that are the key decision-makers.
- Business Managers and project managers, at various levels, of the textile dyeing facilities that are the minor decision-makers.
- Environmental engineers and process, safety, chemical, and electrical engineers, with specialized technical knowledge, that operate the treatment plants, and monitor the flow meters, and readings such as TDS, BOD, PH and salt levels.
- Formal workers, that maintain the treatment plants, and serve a variety of roles, such as line supervisors, shift operators, service technicians.

- Casual workers, that are usually hired seasonally or for more physical work such as for lifting, moving and manual labor.

The table below (Table 14) shows how much human capital is currently used per each case study. While this data is presented in a tabular format, cross-case comparison is not advised, since each case study represents vastly different conditions and situations. The table is descriptive only.

Table 14
Showing current human capital requirements for wastewater treatment (WWT).

Case study Descriptions	Current no. of WWT staff	No. of 'casual' WWT workers
A: On-site small	6	4 - 5
B: On-site large	30	8 -10
C: Off-site medium	-	-
D: Common small	40	20
E: Common large	80	20

Table 14: Showing current human capital requirements for wastewater treatment (WWT).

2.2. What are their perceived advantages and disadvantages of having and using this technology in the textile facilities?

Findings for this research question are presented in the form of themes that have been found to apply more or less universally to all the case studies. Specific differences between the two main groups of case studies (Having an on-site treatment plant versus an off-site common treatment plant) are then reported under each of the two sections (Perceived Advantages and Perceived Disadvantages).

Perceived Advantages of having and using this technology:

- **Advantages across all case studies:** Across all the case studies, the following perceived advantages were found to be linked to having and using this technology:
    - Wastewater as a 'resource'

Across all the case studies, the advantages of reusing wastewater, and having it as a source of clean water for the production process, was one of the main uses listed. Because of the sporadic nature of water supply, and prohibitions against digging borewells to tap into the groundwater, most textile facilities must buy water from private suppliers, an expensive necessity. Being able to get back almost all of the water used has cut down on the amount of water that has to be bought from these private water suppliers, that often bring water in from other districts and nearby cities. It has not completely erased the need to buy water, since there are water uses such as greywater that are not required to be treated, and are thus (currently) external to this process. But it has significantly minimized the need for private water supplies.

- Recovery of solids

Another advantage of having and using this technology is that certain salts that are used in the production process of dyeing the textiles can now be recovered and reused back into the process. For textile facilities, this means that there may no longer be any reason to buy sulfate salts to use in the production process. In addition to getting back clean water, pure crystallized sulfate salts are also a recoverable resource.

- Shift from ‘zero liquid’ requirement to ‘zero waste’ perspective

In the attempt to shift away from regulations that look only at ‘zero liquid discharge’ to more of a ‘zero waste’ approach, textile facilities are finding that there are more uses and advantages that arise out of the treatment of the water. As noted above, the recovery of solid salts through new technology is an advantage that represents this shift. The ‘zero liquid discharge’ requirement has certain implications –the onus is on the textile facilities to make sure that toxic wastewater is not being leached into the groundwater, at all costs. A zero waste approach includes this but also looks at ways to close the loop and get more out of this process back to the textile facilities. It also involves looking at other external partnerships such as with the construction industry, to consider ways of reusing and repurposing other by-products of the treatment process. This shift is also linked to the development and testing of new technology and treatment processes, that can enable such a shift. The design of the brine treatment technology is an example of this.

- Public satisfaction

Textile facility stakeholders report hoping that compliance with this technology has satisfied the ‘public’ and erased the perception that they have of Tirupur’s textile units being toxic, polluting, and uncaring. Several respondents point to the signage (of how much wastewater is generated and treated, and the quantities of emissions that are generated) that their facilities now display, in addition to the actual infrastructure itself, as ‘proof’ that the public – namely the groups of farmers and petitioners whose legal efforts were successful in this regulation being enforced stringently – could be satisfied with their compliance.

- **Advantages from the on-site case studies**: Advantages that are specifically linked to having an on-site individual effluent treatment plant (IETP).

Perceived advantages or benefits of having and using on-site wastewater treatment technology are reported here. In some ways, these advantages listed below also apply to opting for off-site wastewater treatment technology as well, but they are not reported as such, firstly because they were not mentioned by respondents of the CETP case studies, and secondly, because they are more pertinent to having on-site treatment, as will be explained below.

- Buyer/Exporter Satisfaction & Expectation

Buyers, especially international buyers that belong to large-chain multi-national corporations, are increasingly expecting textile dyeing producers to follow ‘sustainable best practices’ and local compliance laws. Often, representatives come to inspect and observe how the treatment and reuse process works. Not only do they expect textile dyeing facilities to comply with regulations, but buyers also have their own internal supply chain analysts who prefer personal inspections and visits to satisfy their levels of compliance. The benefits of having on-site treatment and reuse in this scenario are clear.

- Potential of eco-friendly 'label'

While there are currently no labels or certifications associated with the implementation and use of ZLD technology (apart from the 'Consent to Establish, Consent to Operate' certificates given by the TNPCB, which don't have the same sustainable endorsement that eco-certification does), several respondents have said that these certifications would be welcomed as an added advantage of having and using this technology, that could be used to attract more international business.

- Pride and showcasing opportunities

From the interviews and observation visits, it is clear that tours of the wastewater treatment process are given to different people, for different purposes. Having on-site treatment is an opportunity to showcase and highlight how treatment and reuse of water occurs. Some respondents with little to no technical expertise in the technology have noted how they have picked up some knowledge of how the process works, because of giving so many tours. Other respondents have called their treatment plants 'model plants' that exemplify compliance.

- Control over the process

Being able to decide on the capacity of the IETP, and also run it as and when needed to suit the flow of business operations, is a major advantage of having on-site treatment. The caveat here is that the decision on the capacity of the treatment plant must remain effective for a long period of time so that returns on the installation can be recovered. One of the main considerations prior to installation is the level of current and anticipated wastewater generation.

- **Advantages from the off-site case studies:** Advantages or benefits of being a member of a common wastewater treatment plant are reported here. These perceived advantages are:

- Recovery of solids (salts) through technological innovations and tests

The recovery of sulfate salts from the wastewater treatment process was made possible through the trial testing of new technology at CETPs, where such tests, according to interview respondents, are common. Member textile units of these common treatment facilities are the first to receive the benefits, if any, of such testing procedures.

- Burden (of proof; of collection treatment and return; of O&M) is on the CETP

One of the clear advantages of being a part of off-site treatment is that the many burdens that come with installing, operating, maintaining, and managing on-site treatment are shared collectively with other textile facilities, and responsibility is given to a third party – the companies that run the CETPs. Monitoring incoming and outgoing wastewater and clean water quantities; processing, treating, and returning water for reuse; and managing every step of the process from the point of collection to the point of return involves resources – time, technical expertise, human capital, financial resources, and land. Paying a fee to 'belong' to a CETP can be considered in the light of these resources needed.

Perceived Disadvantages of having and using this technology:

- **Disadvantages across all case studies:** Across all the case studies, the following perceived disadvantages, problems, or risks were found to be linked to having and using this technology:
    - Specialized Domains

Several perceived disadvantages are linked to the issues of needing specialized knowledge, trained technical operators and highly technical infrastructure in order to treat and reuse the wastewater. The technical expertise required to run the treatment plant has reportedly resulted in a lack of sufficient technical operators for both the IETPs and CETPs. Most of the head engineers that were interviewed had degrees in fields like environmental or mechanical engineering, which is a contrast with the interviewed textile facility managers, who often had little to no further education beyond high school (it should be noted here that they do have years of working experience at these textile facilities). In addition to technical expertise, highly technical infrastructure, such as a 0.001-micron membrane filter, is required as a part of the whole regulation.

- Emissions

Emissions are also a significant problem that arises from the usage of this technology. The entire process of wastewater treatment through technology is highly energy-intensive and carbon-intensive. Electrical costs can account for anywhere between 40 to 60% of the total operating costs. In addition, since the supply of electricity is intermittent in Tirupur, electricity cuts are common, making the back-up diesel generators a critical, frequently used provision of the wastewater infrastructure. From the observation tours, it is clear that firewood and coal are commonly used as fuel sources in the CEPTs, for power-intensive equipment. Also, steam and smoke emissions from the entire process are significant and were clearly observable, even from public locations. The following image (Figure 15) is a photo of typical smoke emissions from a CEPT, taken on a bridge spanning the river Noyyal.

Figure 15: Typical smoke emissions from ZLD processes in Tirupur.

- Costs

A primary disadvantage of having and using this technology is that it has increased production costs significantly for textile dyeing facilities. One interviewee that was associated with an IETP mentioned that, per kilolitre of wastewater, the total profits from selling came up to 400 to 450 rupees, while the costs of wastewater treatment came up to 200 to 250 rupees. (These figures are to be taken with a grain of salt since with the interviewee was uncertain upon further questioning on the unit prices of cloth, and how to convert that to wastewater units

- Unfairness

Several respondents mentioned that dyeing units that simply chose to move to other states, or even to the outskirts of Tirupur (the further one goes away from the center of Tirupur, the more difficult it is for the pollution control board TNPCB to monitor facilities situated there) do not have to deal with the restrictive regulations. Informal, mobile units (that can keep changing their location and setting up shop elsewhere, as and when needed) that do not comply with the regulation were referred to by one respondent as ‘luckier units’.

When it comes to the CEPTs, respondents mentioned that smaller textile dyeing facilities end up paying more, per unit cost, to the CEPT than do larger textile dyeing facilities. This is because, in addition to being charged by the quantity of wastewater generated, textile facilities also must pay a base ‘member’ cost.

- Future Problems

Concerns or risks of having and using this technology relate to its longevity, and how textile facilities can be prepared for the future. Issues such as whether to repair or replace different equipment, or how and when changes to the technology will be needed, were all problems that relate to how much effort is going into the use of this technology. Scaling and corrosion are already concerning, especially with parts such as mechanical evaporators, or points at which solid waste is crystallized.

- Hazards

Thermal, mechanical, and physical hazards come with working with physical infrastructure that needs human labor to complete wastewater treatment processes. These hazards relate to the handling of toxic sludge, maintenance, and repairs of sensitive equipment, and even to the cleaning and maintenance of structures. While hazard signs and handling rules have to be posted at relevant points, and are usually written in both Tamil and English with graphic details - pointing to, for example, the need for gloves in necessary locations – it is doubtful as to whether the workers (referred to as casual laborers by some respondents) who are responsible for the more physical tasks follow the rules. During the observation tours, this author found no evidence of workers wearing gloves while handling the toxic sludge. This might be because of the timing of the tours, but it does point to risks associated with the use of the technology.

- External problems

Other political issues and societal conflicts were brought up in relation to problems associated with the technology. One issue is that of sharing water with a bordering state, and is a decades-old transboundary water conflict commonly called the Cauvery river water dispute, a conflict that has been explored in great detail by Anand, (2004). Since the Noyyal is a tributary of the Kaveri, some respondents place blame for the dry state of the Noyyal on this conflict. They believe that if the Noyyal had better flow, the ZLD technology would have been replaced by a less capital-intensive version and that there would be other options for wastewater reuse.

- **Disadvantages from the on-site case studies:** Disadvantages that are specifically linked to having an on-site individual effluent treatment plant (IETP):
    - Finding technical operators

The dearth of sufficient technical operators affects those facilities with IETPs more so than those who belong to CETPs. Respondents – specifically, managers – connected to IETPs mentioned that the difficulties associated with finding and hiring technical workers were some of the barriers that they faced when shifting towards having on-site wastewater treatment and reuse.

- High level of monitoring

Officials from the pollution control board (TNPCB) first approve a ‘Consent to Establish’ certificate to the facility, and then, after a year of frequent periodic inspections, approve a ‘Consent to Operate’ certificate. Both require the provision of data – showing how much sludge is generated in tonnes, how much wastewater is generated in kilolitres, and how many emissions are generated in megawatts per hour. The inspection process is more cumbersome for the officials in charge of the process, but also is a source of risk and uncertainty to textile facilities.

- Capacity matters

  Current capacities of the wastewater treatment plant, and the retention and turnover rates associated with this capacity, affect business operations and also expansion plans. Case Study A is a prime example of how this regulation has affected decision-making in textile facilities that opt for IETPs.

- 'Non-productive asset'

  While the wastewater plants do help to alleviate water costs, they are still not income-generating assets, and respondents believe that they are, to use the term used by one respondent, 'non-productive assets' that are tied to doing business in this particular industry in Tirupur.

- **Disadvantages from the off-site case studies:** Disadvantages that are specifically linked to using a common effluent treatment plant (CETP):

  - No distinction between 'less dirty' water and 'more dirty' water

While the CEPTs do monitor incoming effluent levels, this does not make a difference in how the textile units are charged. Respondents from a mid-sized textile dyeing facility believe that their wastewater may contain less effluent than wastewater from bigger units, with different equipment and different (mixed) salts. Cost breakdowns, according to the same respondents, do not reflect how 'dirty' the water is, and is based mainly on the quantities of wastewater generated. It may be that smaller units with older equipment are paying more for having older equipment, than other textile units where the equipment has been upgraded to have a lower material-to-liquid (MLR) ratio, and thus to be more water-efficient.

Figure 16: Typical pipe network to and from a CETP.

- No control over return of water

After business hours of operation, or if there are electricity cuts for a long period of time, or even if the facility reaches the maximum allowable wastewater (reportedly one hundred thousand kilolitres) respondents from the CETPs have said that they ‘lock the input’ (the in-coming wastewater) and do not take in any more wastewater until some degree of processing is finished. For textile facilities, this is a risk as it affects their business operations as well.

- Big expensive experiments

Respondents from CEPTs report feeling as though the entire process of setting up the CEPTs has been a big experiment, with many phases of trials, testing, and evaluation undergone even before permits to operate could be obtained.

  - Buyers don’t care

Respondents from CEPTs report that local buyers and bulk exporters don’t really care about pollution issues, or if their ‘brand’ – which is not much of a concern for bulk exporters – is affected by such issues. With more awareness and public concern acting as pressure on the buyers as well, this might change in the future. Right now, it is mostly the pressure that came from public litigation groups that represent farmers in surrounding areas that has acted as a driving impetus behind this regulation. There is little to no evidence of environmental concern from local companies that source their fabric from these textile dyeing facilities.

2.3. What factors do they perceive to be linked to the acceptance (perceived effectiveness, ease of use, and usefulness) of this wastewater reuse technology?

- **Perceived usefulness (PU)**

From Chapter 3: Literature review, the definition of the construct ‘perceived usefulness’ that is slightly modified for this thesis is: “*The degree to which a person believes that using wastewater treatment technology would be useful in the realization of its goals*”. Here, the goals of WWT technology are to prevent groundwater contamination, and to provide clean water for reuse. This construct is also closely linked to the idea of perceived utility, a link which other theses, such as one by Rouse (2011) have made.

The perceived usefulness of wastewater treatment technology in achieving goals of zero liquid discharge, zero waste, and water reuse is supported by direct gains or benefits it provides to the textile facility – in how wastewater can be a source of water, and how salts can be recovered and reused from the treatment process. Indirect or anticipated benefits include expectations that buyers now have, of compliance with local environmental laws, and public satisfaction with textile facilities meeting groundwater pollution prevention regulations. Another factor that supports the perceived usefulness of WWT technology is the potential for 'eco-friendly' labels or certification that is proof of compliance with ZLD and ZW standards or norms. This factor is linked to evolving buyer expectations of having a clean supply chain.

The perceived usefulness of WWT technology in achieving goals of zero liquid discharge, zero waste, and water reuse is diametrically opposed by high O&M costs and high interest rates on loans. Other factors that contradict perceived usefulness are: The degree of allowable customization within the technology with respect to how wastewater is mixed and treated with other wastewater (as opposed to a 'one size fits all' approach that common effluent treatment plants currently take); how the burden of cost is on the textile facility, and not the buyer, in order to remain competitive; how the cost is unfair for smaller facilities connected to CETPs; and how the entire process involves a high level of monitoring and inspections in order to get certificates to do business in this industry.

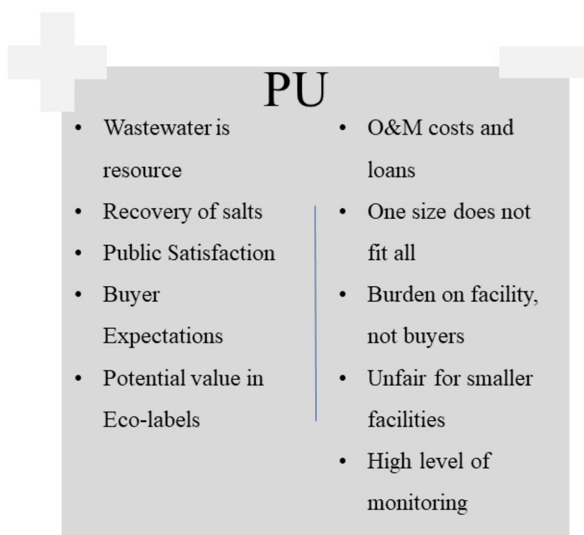


Figure 17: Summary of factors influencing the Perceived Usefulness of WWT technology.

- **Perceived ease of use (PEOU).**

From Chapter 3: Literature review, the definition of the construct ‘perceived usefulness’ that is slightly modified for this thesis is: “*The degree to which a person believes that using wastewater treatment technology would be free of effort*”. Here again, the goals of WWT technology are to prevent groundwater contamination and to provide clean water for reuse. This construct is also linked to contextualizing physical factors or characteristics that either promote or inhibit the effort required to install and use this technology.

The perceived ease of use of WWT technology is supported by factors such as the degree of perceived control over the entire process. This is a factor that influences the choice of whether to opt for on-site WWT technology or join a communal CETP. Other factors that support the perceived ease of use of this technology are those that relate to joining a CETP: that the burdens of proof and process are transferred to the CETP, making the requirement of ZLD easier to comply with.

Other considerations that contradict the perceived ease of use of the technology are considerations relating to future expansion of those textile facilities with on-site WWT; considerations relating to capacity decisions of on-site WWT; considerations of future problems such as future changes to the technology and decisions on whether to repair or replace equipment and infrastructure as and when needed. Factors that are inversely related to the perceived ease of use of WWT technology include ambient hazards for those who work daily within the infrastructure of the WWT technology; significant growing storage space requirements for hazardous biological waste; the need for technical knowledge and technical operators; the need for proximate land availability and buffer land space for future growth.

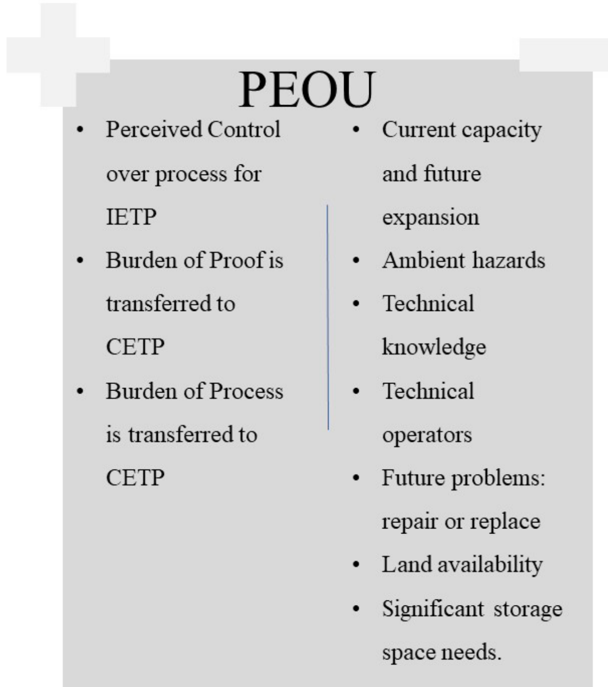


Figure 18: Summary of factors influencing the Perceived Ease of Use of WWT technology.

- **Perceived effectiveness (PE)**

From Chapter 3: Literature review, the definition of the construct ‘perceived effectiveness’ that is slightly modified for this thesis is: “*The degree to which a person believes that using wastewater treatment technology would be effective in realizing its goal*”. Here again, the goals of WWT technology are to prevent groundwater contamination and to provide clean water for reuse. This construct is also linked to facilitating conditions that are set up to address the success or effectiveness of the technology.

While there is some overlap between this construct and the other constructs PU and PEOU, the main understanding of this construct comes from those factors, often perceived to be external factors or variables, that affects the success of the technology.

The perceived effectiveness of WWT technology is directly supported by themes such as the shift from zero liquid discharge to zero waste, and the design and technology tests and pioneer status that such a shift has aided. Other factors that support the perceived effectiveness of the technology include buyer satisfaction, which is a concept that relates to buyer expectation, but includes those buyers that have already made such compliance a mandatory part of their supply chain management. Buyer satisfaction is linked to the 'showcase' status that having on-site WWT technology gives to textile facilities.

Factors that inhibit or contradict the perceived effectiveness of WWT technology in these textile facilities are: Disposal challenges of hazardous waste that are yet to be overcome; the trust or credibility of the CEPT in returning water effectively; the energy-intensive and emissions-intensive process of treatment; and proximity to the Noyyal river and/or location within the boundaries of Tirupur that influences the perception of unfairness concerns on relocation.

Facilitating conditions that aid the perceived effectiveness of the WWT technology are: the subsidies and interest-free loans provided by the government and other parties to set-up or install the technology; Stakeholder participation in the decision-making and management of the CETPs; the provision of backup generators so as not to impair business operations; the relatively new policy of siting newer facilities to industrial parks and away from the Noyyal river; and learning assistance in the form of technology demonstrations by third party industry associations.

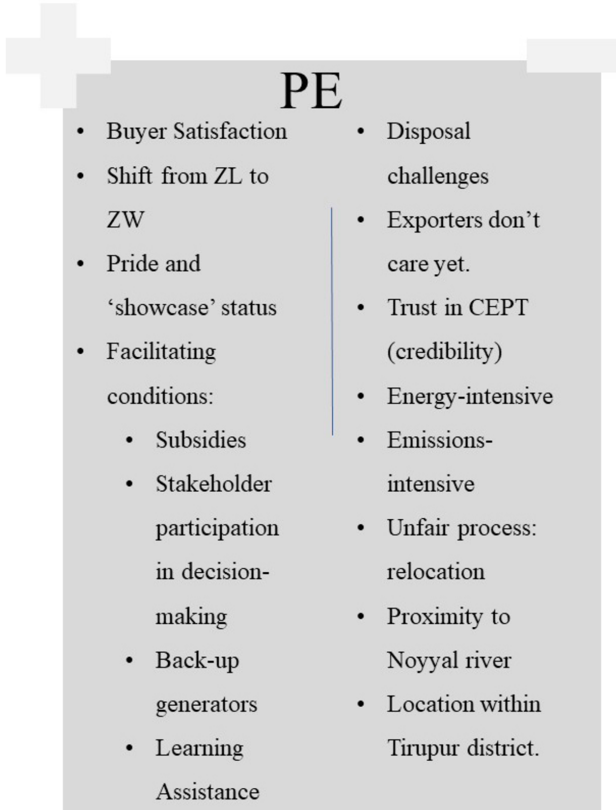


Figure 19: Summary of factors influencing the Perceived Effectiveness of WWT technology.

5.5. Conclusion

The issue of acceptance of wastewater treatment technology by textile bleaching and dyeing facilities in Tirupur is influenced by both perception-based and contextual factors, that this thesis set out to explore. Acceptance, as defined in this thesis as both acquiescence to and an embracement of wastewater treatment and reuse through technology, involves a degree of choice given to the textile facilities – a choice between whether to opt for on-site technology or join a common treatment plant. Through both observation and interview methods, findings indicate that the perceived usefulness, perceived ease of use, and perceived effectiveness of the technology (all constructs linked to the acceptance of wastewater treatment technology by textile facilities) are influenced or linked to factors varying from the perceived control by the textile facility over the treatment process to rising land and water costs. Implications of these factors, and the discussion of an appropriate theoretical explanatory model that incorporates findings from this thesis into an illustrative mechanism, are discussed in the next chapter.

CHAPTER 6

DISCUSSION

6.1. Introduction: Summary of the Findings

While findings are presented in more detail in Chapter 4: Results, a summary of the main results as per each research question is presented here again.

1. How has the mandatory implementation of wastewater reuse technology driven physical changes in textile facilities in Tirupur?

1.1. What are the different ways in which wastewater reuse has been implemented in the textile facilities?

In response to this regulation, textile facilities could: relocate or close; implement an on-site treatment and reuse scheme; or opt into a communal treatment and reuse scheme with other textile facilities. Actual implementation and reuse of the wastewater can thus happen in two ways: Opting for on-site treatment, or communal off-site treatment. Of the 500 or so textile facilities that currently operate in Tirupur, around 70% of them have opted for common effluent treatment plants, while the rest chose to set up their individual effluent treatment plants (Pilot Study).

1.2. What are the physical characteristics of these textile facilities?

Physical characteristics of textile facilities vary by the scale of operations and the set-up, and by the choice to opt for on-site or off-site treatment. Observations of the case studies indicate that location, surrounding urban form, road access, and land availability are some of the features that inform the decision-making process of how to implement wastewater treatment technology.

Within the facilities, indicators of compliance include signage, storage as per rules, continuous monitoring of data, and working conditions of the plant. Indicators of acceptance could be linked to whether other facility equipment have been upgraded to be more water-efficient.

2. How has the mandatory implementation of wastewater reuse technology driven technological acceptance in users and stakeholders within the textile facilities in Tirupur?

2.1. Who are the stakeholders and users within the textile facilities?

As stated in the previous chapter, the pilot study identified groups of stakeholders (defined as decision-makers within this setting) and actors (the users and people involved within this setting). Key groups included owners, managers, engineers and other staff. These groups are mainly drawn from those who own and manage the infrastructure, as opposed to those who design and build the infrastructure.

2.2. What are their perceived advantages and disadvantages of having and using this technology in the textile facilities?

Across all the case studies, the following perceived advantages were found to be linked to having and using this technology:

- Wastewater as a 'resource' that can be reintroduced into the production process and that can replace or minimize the need for water supply.
- Recovery of solids that can be reused back into the production process.
- A shift from 'Zero liquid' requirement to 'Zero Waste' perspective. This shift is also linked to the development and testing of new technology, treatment processes, and partnerships that can enable such a shift.
- Public satisfaction with the level of compliance that textile facilities follow..

Advantages that are specifically linked to having an on-site individual effluent treatment plant (IETP) are:

- Buyer/Exporter satisfaction, with expecting textile dyeing producers to follow 'sustainable best practices' and local compliance laws.
- The potential of eco-friendly 'label' could be welcomed as an added advantage of having and using this technology, that could be used to attract more international business.
- Pride and showcasing opportunities, because having on-site treatment is an opportunity to showcase and highlight how treatment and reuse of water occurs.
- Control over the process by being able to decide on the capacity of the IETP, and also run it as and when needed to suit the flow of business operations.

Advantages that are linked explicitly to using a common effluent treatment plant (CETP) are:

- Recovery of solids (sulfate salts) through technological innovations and trial testing of brine technology at CETPs. Member textile units of these common treatment facilities are the first to receive the benefits, if any, of such testing procedures.
- Burdens of installing, operating, maintaining, and managing on-site treatment are shared collectively with other textile facilities, and responsibility is given to a third party that runs the CETP.

Across all the case studies, the following perceived disadvantages, problems, or risks were found to be linked to having and using this technology:

- Specialized Domains of knowledge: Trained technical operators and highly technical infrastructure are needed in order to treat and reuse the wastewater. The technical expertise required to run the treatment plant has reportedly resulted in a lack of sufficient technical operators for both the IETPs and CETPs

- Emissions:. The entire process of wastewater treatment through technology is highly energy-intensive and carbon-intensive.
- Costs: A primary disadvantage of having and using this technology is that it has increased production costs significantly for textile dyeing facilities.
- Unfairness: Several respondents mentioned that dyeing units that chose to move to other states, or even to the outskirts of Tirupur, do not have to deal with the restrictive regulations.
- Future Problems: Concerns or risks of having and using this technology relate to its longevity, and how textile facilities can be prepared for the future.
- Hazards: Thermal, mechanical, and physical hazards come of working with physical infrastructure that needs human labor to complete wastewater treatment processes.

Disadvantages that are specifically linked to having an on-site individual effluent treatment plant (IETP):

- Finding technical operators: The dearth of sufficient technical operators affects those facilities with IETPs more so than those who belong to CETPs.
- High level of monitoring: The inspection process is more cumbersome for the officials in charge of the process, but also is a source of risk and uncertainty to textile facilities.
- Capacity matters: Current capacities of the wastewater treatment plant, and the retention and turnover rates associated with this capacity, affect business operations and also expansion plans. Case Study A is a prime example of how this regulation has affected decision-making in textile facilities that opt for IETPs.
- ‘Non-productive asset’: While the wastewater plants do help to alleviate water costs, they are still not income-generating assets, and respondents believe that they are, to use the term used by one respondent, ‘non-productive assets’ that are tied to doing business in this particular industry in Tirupur.

Disadvantages that are linked explicitly to using a common effluent treatment plant (CETP):

- No distinction between 'less dirty' water and 'more dirty' water: It may be that smaller units with older equipment are paying more for having older equipment, than other textile units where the equipment has been upgraded to have a lower material-to-liquid (MLR) ratio, and so to be more water-efficient.
- No control over return of water: Uncertainty over when and how much water is returned is a risk for member textile facilities, as it affects their business operations as well.
- Big expensive experiments: Respondents from CEPTs report feeling as though the entire process of setting up the CEPTs has been a big experiment, with many phases of trials, testing, and evaluation undergone even before permits to operate could be obtained.
- Buyers don't care: Respondents from CEPTs report that local buyers and bulk exporters do not really care about pollution issues, or if their 'brand' – which is not much of a concern for bulk exporters – is affected by such issues.

2.3. What factors do they perceive to be linked to the acceptance (perceived effectiveness, ease of use, and usefulness) of this wastewater reuse technology?

Perceived usefulness:

The perceived usefulness (utility) of wastewater treatment technology in achieving goals of zero liquid discharge, zero waste, and water reuse is supported by direct gains or benefits it provides to the textile facility – in how wastewater can be a source of water, and how salts can be recovered and reused from the treatment process. Indirect, or anticipated benefits include expectations that buyers now have of compliance with local environmental laws and public satisfaction with textile facilities meeting groundwater pollution prevention regulations. Another factor that supports the perceived usefulness of WWT technology is the potential for 'eco-friendly' labels or certification that is proof of compliance with zero liquid discharge and zero-waste standards or norms. This factor is linked to evolving buyer expectations of having a clean supply chain.

The perceived usefulness of WWT technology in achieving goals of zero liquid discharge, zero waste, and water reuse is contradicted by high O&M costs and high-interest rates on loans. Other factors that contradict perceived usefulness are: The degree of allowable customization within the technology with respect to how wastewater is mixed and treated with other wastewater (as opposed to a 'one size fits all' approach that common effluent treatment plants currently take); how the burden of cost is on the textile facility, and not the buyer, in order to remain competitive; how the cost is unfair for smaller facilities connected to CETPs; and how the entire process involves a high level of monitoring and inspections in order to get certificates to do business in this industry.

Perceived ease of use:

The perceived ease of use of WWT technology is supported by factors such as the degree of perceived control over the entire process. Control is a factor that influences the choice of whether to opt for on-site WWT technology or join a communal CETP. Other factors that support the perceived ease of use of this technology are those that relate to joining a CETP: that the burdens of proof and process are transferred to the CETP, making the requirement of ZLD easier to comply with.

Other considerations that contradict the perceived ease of use of the technology are considerations relating to future expansion of those textile facilities with on-site WWT; considerations relating to capacity decisions of on-site WWT; considerations of future problems such as future changes to the technology and decisions on whether to repair or replace equipment and infrastructure as and when needed. Factors that are inversely related to the perceived ease of use of WWT technology include: ambient hazards for those who work daily within the infrastructure of the WWT technology; significant growing storage space requirements for hazardous biological waste; the need for technical knowledge and technical operators and the need for proximate land availability and buffer land space for future growth.

Perceived effectiveness:

The perceived effectiveness of WWT technology is directly supported by themes such as the shift from zero liquid discharge to zero waste, and the design and technology tests and pioneer status that such a shift has aided. Other factors support the perceived effectiveness of the technology include buyer satisfaction, which is a concept that relates to buyer expectations, but includes those buyers that have already made such compliance a mandatory part of their supply chain management. Buyer satisfaction is linked to the 'showcase' status that having on-site WWT technology gives to textile facilities.

Factors that inhibit or contradict the perceived effectiveness of WWT technology in these textile facilities are: Disposal challenges of hazardous waste that are yet to be overcome; the credibility of the CEPT in returning water effectively; the energy-intensive and emissions-intensive process of treatment; proximity to the Noyyal river and/or location within the boundaries of Tirupur that influences the perception of unfairness concerns on relocation.

Facilitating conditions that aid the perceived effectiveness of the WWT technology are the subsidies and interest-free loans provided by the government and other parties to set-up or install the technology; stakeholder participation in the decision-making and management of the CETPs; the provision of backup generators so as not to impair business operations; the relatively new policy of siting newer facilities to industrial parks and away from the Noyyal river; and learning assistance in the form of technology demonstrations by third-party industry associations.

6.2. Interpretation

6.2.1. Contextual factors

This thesis attempted to delve into and describe the "*visible structural changes [that] did quite literally alter the landscape* [of Tirupur], *which became marked by artefacts in the form of treatment plants with evaporators and crystallizers towering into the air*" (Grönwall & Jonsson, 2017b). These physical changes range from the towers - crystallizers and evaporators - of the treatment plants, to massive pipes that connect the CEPTs to textile units. Through a multi-case study approach to textile facilities and treatment plants in Tirupur, physical changes and contextual factors behind the implementation and use of wastewater treatment technology were explored and qualitatively described, to understand how implementation and usage happen in these textile facilities.

One of the first objectives of the pilot study of this thesis was to ask about the different ways in which wastewater treatment and reuse have been implemented in the textile facilities. The conclusions drawn from the pilot study, about the spectrum of responses that textile facilities could opt for, fit in with what many other researchers (Crow & Batz, 2006) have also stated. Crow and Batz (2006) point to how "*firms had considerable flexibility in choosing how to comply with regulations requiring ETPs. They could join a CETP or build an IETP*." They also note how this decision-making process is made by each firm, considering factors such as land availability, financial constraints, and human capital constraints. Nelliyat (2012) writes of this choice as a policy failure, since allowing textile facilities to put up their IETPs places more burden on the state pollution control board. "*In a small-scale cluster, all or at least a majority of the units should have joined CETPs. But in Tirupur, out of 702 units, only 278 are with CETPs*" (Nelliyat, 2012).

While each case study represents a different context under which textile facilities implement and use wastewater treatment technology, there are some common observations across most of the textile facilities and common effluent treatment plants. From the qualitative observations and descriptions of each case study, physical form characteristics of these textile facilities could potentially be indicators of how these regulations are being met. Physical indicators of compliance with these regulations include signage, which detail statements such as how much wastewater, solid sludge, and emissions are generated, and how to store the solid by-products within the facility on clay lining. The location of the textile facility could also be an indicator of both age of the facility and compliance, with newer facilities being encouraged to set up shop at least five kilometers away from the river. It is unclear to this researcher whether being located downstream is more disadvantageous for textile units than compared to those textile units upstream, presumably with cleaner water. Even the quantity of wastewater generated could be used as a sign of how much business these textile units take in, and of their general size. Storage issues are a sign of uncertainty over how to properly dispose of the solid waste that is the by-product of the treatment process. Storage is also a growing space requirement in established textile facilities with on-site treatment, and in the common effluent treatment plants. While some facilities used to be allowed to send their solid waste to be burned in cement kilns, this is no longer allowed, according to the respondents of this study. This restriction is because of issues with toxic waste being dumped in unsecured, unauthorized places, where they can then leach into the groundwater.

Also, indications of textile facilities going beyond the regulation, by choosing to opt for more water-efficient equipment, were not observed or mentioned in the case studies of this research that looked at CETPs and member facilities (facilities with on-site treatment plants did mention having water-efficient equipment). This could be due to sampling issues at the case level. Other theses, such as by Koch (2016), and reports by (Winrock International India, n.d.) found that smaller and mid-sized units attached to CETPs have also upgraded their equipment to be more water-efficient, with a lower material to liquid (MLR) ratio. Winrock International

India (n.d.), in a report for the Bureau of Energy Efficiency in India, notes how benefits would include lower water treatment and operating costs, in addition to lower electricity consumption. They also point to how barriers towards efficient equipment in Tirupur include high initial costs, the low financial strength of smaller textile units, and a lack of awareness on such equipment. Cleaner production equipment, which is not required by law (as of writing this thesis) could be signs of how facilities have moved beyond acquiescence to the regulation, towards a perspective of acceptance that includes demand-side management and incorporates cleaner production technologies. Cleaner production technology is a standard recommendation for a more holistic long-term solution (Nelliyat, 2012), but is one that needs to be discussed in the context of the small-scale enterprises that make up Tirupur's textile industry, and can't afford it (ibid).

Gronwall and Jonsson (2017) write of how some Indian textile mills in the early 1900s would set up 'solar drying beds' (Ganapati et al., 1965, as cited by Grönwall & Jonsson, 2017) that were essentially beds with layers of sand through which the wastewater would percolate. Solid waste could be recovered and sold from these drying beds. Back then, textile wastewater was not made up of the dyes, salts, and metals that it is made of now. Sand filtration to clean and treat water is a simple, traditional, low-cost method used in many parts of the world. Solar drying beds are now also a feature of the common effluent treatment plants studied in this thesis. In this study, these solar drying beds, or solar evaporation pans, were observed unused, with plastic lining sheets covering the bottom of the beds. At some point, they were a feature of the CETPs that were used to concentrate the final round of sludge into solid waste in an economical manner (Mani & Madhusudanan, 2014). Due to fears of toxic chemicals leaching into the soil, this method of drying out the sludge is now forbidden. A TNPCB board order from 2018 has directed all textile facilities with IETPs to stop using solar evaporation pans, to switch to using mechanical evaporators and dryers, and to dismantle the solar evaporation pans - they do take up a large amount of space. This order notes how at least 2200 sqm of solar evaporation pan area is needed per 10KL of reject. According to this order, most CETPs and large-scale IETPs already use mechanical evaporators, and solar drying pans are lying in disuse.

The process of recovering salts used in the production process of dyeing textiles and reusing the recovered salts back into the production process, is an essential step of the treatment processes observed in the CETPs. Salt is recovered through treating the effluent wastewater through a mechanical evaporator and then a crystallizer to separate the salts. This step is known as the mechanical evaporation technique, and several respondents noted that this particular step of recovering salts is being pioneered and tested in Tirupur. It is an energy and carbon-intensive step of the process, that needs large amounts of electricity and steam (through firewood) to work. However, the value of resource recovery was mentioned by interview respondents, in connection with the perceived usefulness of wastewater treatment technology. The idea of making salt through the evaporation of brine is one that dates to the Iron and Bronze Ages, and even then it was an energy-intensive process, needing large amounts of wood to evaporate large quantities of water (Valeur, 2013). Valeur (2013) writes of *gradierwerk*, or graduation towers, which are structures used to make salt from brine solutions in Germany. These structures (Figure 19) take advantage of wind and sun to run the brine solution through the tower and separate the salt. She writes of their potential value in being a design modification to ETPs.

Figure 20: A gradierwerk in Germany (Antony, 2009).

6.2.2. Perceptions on acceptance

The decision-making process of how to implement and use wastewater treatment technology is something that each textile facility makes, based on their assessments of the costs and risks involved in the whole decision-making process (Crow & Batz, 2006). Some facilities move away, some choose to opt for on-site treatment, some for a communal treatment plant, and some facilities even decide to opt for both the CETP as well as an IETP, having a back-up plan to one with the other. The second main research objective is to look into these perceptions, and explore what stakeholder acceptance means in the context of wastewater treatment and reuse in Tirupur. This was done through exploratory, semi-structured interviews, asking both stakeholders (decision-makers) and actors within each case study what they thought about the ease of use, usefulness, and effectiveness of ZLD technology and water reuse.

Findings from these interviews suggest that water reuse and salt recovery and reuse back into the production process both play an essential role in how both the usefulness and effectiveness of this technology is perceived. By not making the wastewater treatment technology an end-of-pipe treatment that then sends treated water back into the sewage system, and thus localizing/decentralizing the water loop, there is a shift in perspective for these facilities. From complying with ZLD requirements, to articulating the benefits that a zero-waste system can have, this shift is what stakeholder acceptance in these textile facilities is based upon. This also changes the way wastewater is perceived: It becomes a resource rather than a burden, and a sense of ownership over the wastewater is more apparent. Rising water costs and the difficulties in getting continuous private water supplies have also driven this shift. However, storage and disposal issues and challenges with the toxic solid sludge show how this process has several more rounds of iterations to go through before it can achieve zero-waste status.

Another finding of this study is that respondents talked about the potential value of having eco-labels or certifications that can be used to show international buyers how water is being recycled and reused, as long as the costs of such labels are not high. Labels, to the respondents, would increase the value of having and using ZLD technology. Valeur (2013) writes of how vertically integrated textile companies in Tirupur do have some environmental management certification systems in place, and that around 25% of other stand-alone dyeing facilities also have them in place. These certifications are usually about green textiles on a more holistic level and focus on more than wastewater treatment and reuse. Valeur (2013) points to how these labels are seen as a buyers requirement for European buyers, but that there are challenges in implementing certification systems in non-integrated facilities.

Public alarm, and environmental concern, especially from farmers downstream of Tirupur, was a major driving force behind the legal enforcement of this regulation (Crow & Batz, 2006; Grönwall & Jonsson, 2017a). In talking about the usefulness of ZLD technology, respondents also mentioned how public satisfaction, buyer expectations, and satisfaction with compliance are considerations that affect how they see the value and use of ZLD technology. Findings thus suggest that public environmental concern has extended into other factors that affect how the usefulness of ZLD technology and water reuse is seen.

Factors that negatively affect how the usefulness of ZLD is perceived include high operating and maintenance costs, especially for those facilities that choose to opt to on-site treatment and reuse and smaller and mid-sized facilities connected to CETPs; how increased cost burdens can't be transferred to buyers in order to remain competitive; how smaller facilities pay more than bigger facilities to join a CETP in terms of unit cost per amount of effluent; and how continuous monitoring and inspections come with their own set of burdens. These factors have also been mentioned by other authors and researchers (Crow & Batz, 2006; Nelliyat, 2012). In particular, the unfairness of how smaller units pay more per unit of wastewater than larger facilities is something that Crow and Batz (2006) also note. They expand on this point by noting how larger facilities take on management roles and activities in CETPs, and that costs should also be a function of distance from the CETP as well as the volume of effluent. O&M costs and technical learning burdens are also why facilities choose to opt for CETPs, amongst other reasons.

Findings also indicate that having control over the decision-making process and operating process is one of the main reasons why some facilities choose to opt for on-site treatment and reuse, even when off-site treatment is a more viable option. Perceived behavioral control is a construct that is often used in individual-level acceptance research, such as in research by Huijts, Molin, & Steg (2012) and also as a construct in technology acceptance models, that has its roots in the theory of planned behavior (Taherdoost, 2018). In this situation, the construct operates differently since it is a perception that stakeholders within the facility have on the ease and difficulties that the facility as a whole might face.

Other actors within the setting of these textile facilities, such as technical as well as physical workers, work directly with wastewater treatment, and so provide perspectives on the ease of use of ZLD technology and water reuse. The burdens of process, from technical management to operations and maintenance, rest on these actors.

With textile facilities with on-site treatment and reuse, factors to consider include having enough buffer space and proximate land availability in case they need to expand or make changes to the treatment plant in the future. These are all factors that respondents perceive to be issues that could affect the ease of use at some point in the future. Other problems that are anticipated to rise in the future include issues of whether to repair or replace equipment or infrastructure as and when needed, an issue that Marchant (2018) writes about in detail as a common water infrastructure management issue.

Trust, or credibility in the CETPs, is another important factor that influences how the efficacy of ZLD technology and water reuse is perceived amongst stakeholders in facilities that choose to join CETPs. Findings from the interviews show how sometimes member facilities are 'locked' from giving any more wastewater to the CETP if their capacity is reached, or if the CETP is facing power shortages or other implementation issues.

6.3. Discussion

6.3.1. The technology-organization-environment framework

A discussion of these \ factors is organized using the technology-organization-environment (TOE) framework. The TOE framework is used to describe how the technological, organizational and environmental context of the firm influences its decision-making processes (Baker, 2012). A detailed explanation of the framework can be found in Chapter 3: Literature Review. This framework is generally used in the context of studying a firm's decision-making process of technological adoption. Dependent variables are usually the likelihood of adoption, intent to adopt, or extent of adoption of technology.

The findings of this thesis explored factors influencing acceptance by asking stakeholders and actors about their perceptions on the ease of use, usefulness, and effectiveness of this technology. These three constructs (perceived ease of use, perceived usefulness, and perceived effectiveness) are typically used when discussing individual-level technology acceptance models. Technology acceptance models generally explore attitudes and constructs that influence individual acceptance of a person's decision to use a technology. In this study, stakeholder acceptance is studied at the level of the textile facility through a case study approach. These perceptions suggest that there is an interplay between individual-level factors such as perceived behavioral control, perceived trust, public environmental concern, and firm-level factors and characteristics. An ideal framework that explains how these different factors work together to influence stakeholder acceptance has to be a multi-level framework. Rather than modifying an individual-level acceptance model, an organization-level framework like the TOE can be used to discuss these factors and incorporate an individual-level perspective on how these multi-level relationships work. This need to discuss the TOE framework in light of individual theories of behavior is something that Baker (2012) also mentions as a future direction for TOE research.

Technology: A description of the technological context of wastewater treatment and reuse in these textile facilities, and factors that characterize this technological context, is one that must be prefaced by noting that ZLD wastewater treatment technology is physical infrastructure more than it is technology. Characteristics include economic and financial factors such as fixed and variable costs, physical factors such as wastewater capacity, solid waste by-products, land, and space requirements, and physical equipment such as holding tanks, boilers, chillers, and evaporators.

Organization: A description of the organizational context of wastewater treatment and reuse in these textile facilities includes factors that describe the characteristics of the firm, from general characteristics such as the size of the firm to specific characteristics linked to treatment and reuse, such as opting for on-site or off-site treatment.

Environment: A description of the environmental context of wastewater treatment and reuse in these textile facilities includes both industry-level characteristics such as the availability of subsidies and learning assistance to set up, to external task environment factors, such as the water-stressed nature of Tirupur or the location of the facility.

Personal: Decision-makers of these textile facilities have their perceptions on individual-level factors such as having control over the process of treatment and reuse, having trust in the credibility and ability of a CETP to treat and return water on time, and the importance of public environmental concern and buyer expectations. Findings on these perceptions suggest that these factors also play a role in stakeholder acceptance of this regulation.

6.4. Limitations

This thesis considers how context (of place and setting, and of stakeholder perceptions within the setting) influences acceptance of wastewater treatment and reuse regulations. As a qualitative thesis that is broad and exploratory in scope, methodological limitations must be discussed when interpreting the findings.

6.4.1. Research Design Limitations

The research objectives of this thesis, to explore and identify physical and contextual factors behind implementation, and to explore and identify perception-based factors behind stakeholder acceptance, were formulated to look at different types of physical settings of textile facilities, and different types of stakeholders and actors across these settings. Rather than exploring such a broad overview of settings and stakeholders, if the research aims of this thesis had been narrowed to focus on one specific context (such as on-site treatment and reuse), the level of focus on the study could have been increased. This could have changed the approach from a multi-case study approach covering a variety of facilities to either a multi-case study approach covering similar facilities (in which case, cross-case comparison and synthesis could have strengthened the robustness of the findings) or even a single case study with more detail (Yin, 2014).

The sampling strategy for this thesis was, as in line with the objectives, to get maximum variation in the case studies chosen, so that an assortment of different contexts was studied. This thesis presents five case studies of two facilities with on-site treatment and reuse, one facility with off-site treatment and reuse, and two common treatment plants to which other facilities send their wastewater. Case studies of other facilities attached to CETPs are underrepresented in this sample. Ideally, at least one more case study of a textile facility with off-site treatment should have been added to this thesis, so that the study covered two cases of each main context – on-site treatment and the connected facility, off-site treatment, and off-site common treatment plants. Also, highly informal, mobile textile units that operate in residential areas under the radar of monitoring authorities were not included in this study, because this researcher could not think of ways to find and interview such textile units.

6.4.2. Research methods Limitations

6.4.2.1. Observation:

A literature review searched for systematic and/or semi-structured observation protocols for relevant observation tools, that look at both physical form characteristics as well as physical indicators of ease/difficulties faced with WWT technology. This literature search did not find any relevant tools, apart from parts of one observation tool that was developed for urban neighborhoods, not textile facilities. As such, the observation guide used in this thesis is unrated, untested, and was developed from a pilot study, and parts of an observation tool meant for a different setting. Since it was applied only once to each case study, it could not be tested or rated by this researcher. This is a major limitation of the findings of this thesis.

Another main methodological concern with observation methods is how obtrusive the technique is. This researcher told respondents what the purpose of the observation was for, and so observer effects, where people are aware of being observed, might have affected the data collection. For example, as a part of observing and asking questions on the ease/difficulties of using ZLD technology, technical workers may have downplayed any difficulties, if it relates to their job performance. Also, since the observation process took between 2.5 to 5.5 hours for each case study, the timing of the observation, even though unstructured, may have had some influence on the findings.

6.4.2.2. Semi-structured interviews:

The selection of participants for the semi-structured interviews was limited to those participants who worked in, and were directly related to, the five case studies. This may have reduced the depth of the responses and the findings because this meant that the definition of 'stakeholder' here is limited to decision-makers, technical workers, and other users. Most of the respondents are those who operate and maintain the infrastructure, rather than those who design and build infrastructure. Out of the nineteen interviewees, three were upper-level decision-makers responsible for the textile facility on a whole; five were managers at various levels, that were mostly concerned with the running of the facility, which now includes some duties related to wastewater treatment; seven were technical workers – engineers (environmental, mechanical, chemical and process) responsible for operations and maintenance; and four were physical workers hired to do the physical work of wastewater treatment. All these respondents are male – women were generally observed to work in more general sections of the textile facilities, but not in the wastewater treatment sections. At all times of observation and interviews, no children were observed to be working.

A methodological constraint with semi-structured interviews is that open-ended questions are difficult to analyze in quantitative ways. Answers from respondents can't be taken at face value; the honesty of respondents and their trustworthiness can't be guaranteed. This researcher tried to avoid issues of honesty by avoiding sensitive topics such as compliance, but even so, the trustworthiness of self-proclaimed perceptions is hard to determine.

6.4.3. Data Analysis Limitations

Triangulation: Wherever possible, this researcher attempted to triangulate the data and findings by asking for secondary data sources: documents such as maps or plans, or looking for signage with details, or asking for further details on perceptions mentioned in interviews. In the post-field research stage, findings were triangulated with existing relevant literature. However, not all findings could be triangulated, and so for some of them, structural corroboration (Eisner, 1991 as cited by Creswell, 2018) of the evidence is weak, limiting the credibility of the findings.

6.4.4. Interpretative Limitations

Qualitative researchers emphasize movement from observations and data to descriptions and patterns. The findings point to how a conceptualization of stakeholder acceptance as based solely on the constructs of PU, PEOU, and PE is a limited definition to use for stakeholder acceptance. While the TOE framework, described in Chapter 3: Literature review and discussed in an earlier section here, could act as an explanatory mechanism for stakeholder and firm-level acceptance of wastewater treatment regulations, it is typically used as a framework for adoption, not acceptance.

Maintaining an unbiased stance, especially in a study that explores perceptions through qualitative research, was difficult. Public media point to how these textile units regularly violate this regulation, even as of writing this thesis, which is in direct contrast to the positive tone that many of the respondents showed. The rounds of iterative coding that the field data went through reflect this struggle to maintain a neutral perspective towards the responses.

Literature reviews of articles on 'ZLD technology' almost invariably refer to the process of treatment of the wastewater as 'ZLD' technology. If anything, it is not just technology, but also physical infrastructure that needs a high degree of technical assistance, land requirements, and planning.

6.5. Recommendations

These observations and qualitative findings explore and describe in detail the physical context behind this regulation, and stakeholder perceptions on wastewater reuse technology. Research in Tirupur is mostly at the cluster level, or the level of the textile industry. This thesis hopes that these five detailed case studies contribute towards a facilities-level as well as a stakeholder-level understanding of what is going on.

One of the initial objectives of this thesis was to use such qualitative findings to assess the best direction and variables needed for a quantitative study on stakeholder acceptance of wastewater treatment and reuse in these textile facilities. The preliminary research plan of this thesis was to do a mixed-methods study, where qualitative findings would inform the design of either a structured questionnaire or of scale development and testing. This objective could not be met, because of time and other research constraints, issues with reaching out to interview respondents even for follow-up questions, and because of how the findings suggest that a multi-level interplay of factors and perceptions are linked to stakeholder acceptance of wastewater treatment and reuse in textile facilities. Recommendations for further research on stakeholder acceptance of wastewater treatment and reuse include taking these qualitative findings and extending them into an ecometric analysis of such acceptance, one where both systematic observation and psychometric interviews can be integrated to assess acceptance in these facilities (Raudenbush & Sampson, 1999).

6.5.1. Key Takeaways

These five case studies help to provide a background on the acceptance of ZLD technology in Tirupur. A pilot study gives a bit more backstory to these case studies, and the cases are the backstory (in that they are descriptive and somewhat inconclusive) that is my thesis, on what acceptance may mean in this context. Perceptions were collected from people within the cases, on the advantages and disadvantages of having and using ZLD technology; and of the utility, ease of use, and efficacy of doing so. Maps of Tirupur and layouts of each case facility aid in visually describing the physical and spatial changes that implementing ZLD has imposed on Tirupur.

As a supply-side management technology, that can also be called a non-sewered sanitation system that "*collects, conveys and fully treats the specific input, to allow for safe reuse and disposal of the generated output"* (ISO, n.d.), the case studies show little evidence of any demand-side improvements to water consumption, whether on-site or off-site. This ZLD approach to solving the industrial water pollution issues in Tirupur is technology-dominant, and issues of the continued scale of resource degradation and water consumption by industries remain unanswered with such an approach. The industrial pollution issues that Tirupur has and continues to face are not unique to Tirupur, but the extent of groundwater contamination, exacerbated by other issues including the poor flow of the Noyyal river and transboundary water issues, are. ZLD technology, through both on-site and off-site treatment, is increasingly seen as the main solution to water pollution issues across other parts of India as well. This thesis did not go into detail about the striking contrast between ZLD infrastructure and the water supply and sewage 'systems' that operate in the rest of Tirupur, an unequal contrast that deserves its own study.

Interviews with various stakeholders and other actors show how several factors surround the stakeholder acceptance of ZLD technology. All these perceptions are shaped by the ways in which existing political relations, financing, monitoring and governance, and maintenance mechanisms work in Tirupur. Many of the factors raised by the respondents are clearly driven by a profit motive, and so the utility, ease of use and efficacy of this technology are, to them, mostly linked to the means by which having and using ZLD affects their triple bottom line. Built into all these answers is that the easy path to profits is the best path to take. Especially for smaller textile units, this concern with profits is of critical importance.

The case studies also touch upon the design narratives – the process of developing ZLD as a solution to pollution issues in Tirupur – and design decisions that go behind the implementation and usage of ZLD. During the early 1900s, wastewater treatment in some older textile mills used to be a simple, 'low-tech' affair of constructing a solar drying bed and using natural evaporation to treat and recover some salts. With the complex dyes used now and with ZLD, it is a decision to treat the water to highly technical tertiary levels of treatment, using energy-intensive steps. Solar drying beds, which were experimented with as a potential feature of ZLD infrastructure in Tirupur, are prohibited for various reasons, and other less energy-intensive features are yet to be investigated. The energy-intensive nature of ZLD is a problem of transference, of the water pollution issue to an energy consumption one. This is a common problem when it comes to the question of the 'sustainability' of 'sustainable' infrastructure: How is this measured, and is this ultimately environmentally beneficial, or is it all just greenwash?

Studies that explore other levels of acceptance, such as public acceptance, would add to an understanding of acceptance, and the factors that influence and determine it. In the end, when it comes to closing the loop, acceptance is just one of many questions that such technology and infrastructure must answer.

6.6. Conclusion

This ZLD regulation focuses more on preventing liquid discharge but does include a 'water reuse' aspect to it. Compliance and monitoring tend to focus on the prevention side of this regulation. The findings of this thesis suggest how stakeholder acceptance could be strongly linked to water reuse, and a shift in perspective from zero liquid discharge to zero waste can only help boost stakeholder acceptance. Ultimately, acceptance is just one of the many issues that inform the way constraints are addressed, and regulations and policies are successfully designed and implemented.

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APPENDIX A

PILOT STUDY GUIDE

__/__/____

Research Study Title: Closing the Loop: Exploring factors that influence the acceptance of wastewater reuse technology in textile facilities in Tirupur, India.

What the study is about:

The purpose of this study is to understand perceptions behind the acceptance of wastewater reuse technology in textile dyeing facilities in Tirupur.

Objectives of the pilot case study:

1. To learn about the different ways in which wastewater reuse has been implemented in textile facilities in Tirupur (Research Question 1.1).

2. To determine the scope and feasibility for the case study approach chosen.

3. To identify inclusion and exclusion criteria for case studies of textile dyeing facilities.

4. To identify stakeholder and user groups that act within the physical setting of a textile facility, from which respondent groups for interviews can be drawn (Research Question 2.1)

5. To test and refine themes and questions for the development of the interview protocol and observation protocol.

Pilot Interviewee details:

Engineer with the Tamil Nadu Water Supply & Sewerage Department.

Engineer-planner with the Tamil Nadu Water Supply & Sewerage Department.

Manager of a textile facility that sent its wastewater to a common effluent treatment plant.

Exploratory Questions asked:

- How can textile dyeing facilities implement wastewater reuse processes into their operations? What are their options to do this?
- How do textile dyeing facilities choose between on-site, individual effluent treatment plants or communal effluent treatment plants?
- What are the perceived advantages and disadvantages of having to implement wastewater reuse technology?
- Do you, in your role as _____________, believe that implementing wastewater reuse technology into textile dyeing facilities is: 1. Easy? 2. Useful? 3. Effective?

APPENDIX B

SEMI-STRUCTURED INTERVIEW GUIDE

__/__/____

Research Study Title: Closing the Loop: Exploring factors that influence the acceptance of wastewater reuse technology in textile facilities in Tirupur, India.

What the study is about:

The purpose of this study is to understand perceptions behind the acceptance of wastewater reuse technology in textile dyeing facilities in Tirupur.

Role of researcher in this interview protocol:

As someone who will be asking a series of questions related to the interviewee's perceptions of wastewater reuse technology.

Role of researcher's colleague in this interview protocol: As someone who is aware of the purpose behind the questions being asked (see above), and who is assisting the researcher in asking questions, and follow-up questions.

Exploratory Questions:

Topic Being Explored	Open-ended questions/probes
Introductory Questions	1. What do you do in this facility? 2. What is your job title, if applicable? 3. For how long have you been working in this job? 4. What do you typically do as a part of your daily work activities? 5. Can you walk me through your typical day at work here?
Perceived Advantages/Opportunities/Benefits	7. In your opinion, are there any advantages, or plus points, to using this technology in the textile facility?

	8. If yes, what do you think are the advantages of using this technology? 9. If no, why not? 10. Has having this technology provided any benefits or opportunities to the firm? (repeat question for validation).
Perceived Difficulties/Problems/Risk perceptions	1. In your opinion, are there any disadvantages, or minus points, to using this technology in the textile facility? 2. If yes, what do you think are the disadvantages of using this technology? 3. If no, why not? 4. Has having this technology provided any problems to the firm?
PEOU – "the degree to which a person believes that using a particular system would be free of effort".	1. Is this wastewater reuse technology easy to use, operate and maintain? 2. How/Why?
PU "the degree to which a person believes that using a particular system would be useful in the realization of its goal".	1. Is this wastewater reuse technology useful to the textile firm? 2. How/Why?
PE – "The degree to which a person believes that using a system would be effective in realizing its goal".	1. Is this wastewater reuse technology effective in its goal of water reuse? 2. How/Why?
Conclusion	1. Do you have any questions for me, about any questions I have asked you, or the usage of any information I have gathered? 2. Thank you for giving me this tour and answering my questions. This has been very helpful for me and my research.

APPENDIX C

SEMI-STRUCTURED OBSERVATION GUIDE

__/__/____

Research Study Title: Closing the Loop: Exploring factors that influence the acceptance of wastewater reuse technology in textile facilities in Tirupur, India.

What the study is about:

The purpose of this study is to understand perceptions behind the acceptance of wastewater reuse technology in textile dyeing facilities in Tirupur.

Role of researcher in observation protocol:

- As someone to be introduced to the process of how wastewater is reused in the textile facility.
- As someone who is given a 'typical' tour of this process.

Procedure:

- Using the semi-structured observation guide, ask to be introduced to the facility and the process of water reuse, and observe how this tour is conducted.
- Make notes on people, activities, and processes observed during the tour.

Time stamp:

Duration:

Semi-structured Observations:

Questions/Prompts:

	a. Introduction: Explanation and Opening Questions	Source: Pilot case study
1.	Can you give me a tour of this facility and the water reuse process?	
2.	Can you explain to me, in detail, exactly how the water reuse process works here?	
3.	Did this facility opt for an individual, on-site effluent treatment plant or a common effluent treatment plant?	
4.	Could you go into the reasoning behind this choice (if they were an active part of the decision-making process).	
5.	Was this textile facility designed/planned by an engineer, or an architect?	
	b. General Facility and Treatment Plant Overview Questions	Elmer, 2014.
1.	Owner satisfaction: Does the treatment plant meet your expectations (in terms of cost, performance, other requirements)?	
2.	Sustainability: Has this requirement to reuse wastewater minimized water usage from other sources (groundwater, municipal supplied water)?	
3.	Value engineering: Are there less expensive methods of water reuse that could be used in this facility without impacting quality or performance?	
4.	Operability: How many people are employed to maintain and operate just the treatment plant?	
5.	Operability: What affects the ease and efficiency of operations?	
6.	Maintainability: Does the treatment plant allow for easy and cost-effective maintenance and repair?	
	c. Semi-structured Observation of Physical Form Characteristics of Textile Facility.	Paquet et al, 2010.
1.	Size in approx. square footage.	
2.	Location and size of ETP space.	
3.	Provision of buffer space for expansion/innovation purposes.	
4.	Presence of landscaped elements, such as a center divide strip, trees and shrubs along the road.	
5.	Condition of access road.	
6.	Surrounding urban form. (Greenfield, Brownfield, City).	
	d. Unstructured Observation of any factors that affects the ease/difficulties of the reuse process.	Ziesel, 2014

1.	Signs of usage, Missing traces, erosion, left-over traces.	
2.	Nature of space for each process of the treatment plant (Paved/Un-paved, Derelict/Finished).	
e. Conclusion		
1.	Do you have any questions for me, about any questions I have asked you, or the usage of any information I have gathered?	
2.	Thank you for giving me this tour and answering my questions. This has been very helpful for me and my research.	

Unstructured Descriptions:

Activities and processes listed:

Other Behaviors observed:

Physical traces:

APPENDIX D

CODE EXTRACTS FROM INTERVIEW MEMOS

Thematic, pattern-finding codes were generated from an open coding process of analyzing the non-verbatim interview memos. These memos were written by the researcher to reflect the answers of the interviewee as accurately as possible, based on field jottings. As such, the extracts presented in this section reflect the voice of the person answering the questions posed by the researcher. Each extract presented here is the typical representation of its respective code/s. Any author's comments and notes will be noted as comments made by the researcher in the memo, and not by the interviewee.

Code: [Wastewater as resource – Sub-Family (linked construct): Perceived usefulness – Family Group: All case studies A, B, C D & E – Main Family Group: Advantages/Opportunities/Benefits]

Case Study B Interviewee 3.docx

'Especially now that [private] water costs are so high; it is useful to have our own source of water for production.'

Case Study A Interviewee 1.docx

'There is maybe a 5% loss of water during the treatment process. This is 2-3% more during summer, when evaporation losses are higher. This is an 'almost zero' reuse of water. You saw how clean the water comes out of treatment – it is good to reuse back into production.'

Code: [Recovery of salts (solids) – Sub-Family (linked construct): Perceived usefulness – Family Group: Off-site Common: C, D & E - Main Family Group: Advantages/Opportunities/Benefits]

Case Study D Interviewee 2.docx

'Being able to give back brine, or Glauber's [sulphate salts] salts to our member units has helped them to reduce costs and get back even more from treatment. Pure white crystal sodium sulphate salts are recovered in 'good to sell' condition.'

Code: [Reuse of brine solution – Sub-Family (linked construct): Perceived usefulness – Family Group: Off-site Common: C, D & E – Main Family Group: Advantages/Opportunities/Benefits]

Case Study D Interviewee 2.docx

‘Brine solution is used in the production process to dye cloth. Salts are necessary to get the dyes to adhere to the cloth well, and so being able to give back brine, or Glauber’s [sulphate salts] salts to our member units has helped them to reduce costs and get back even more from treatment. Pure white crystal sodium sulphate salts are recovered in ‘good to sell’ condition.’

Code: [Shift from ‘zero liquid discharge’ to ‘zero waste’ – Sub-Family (linked construct): Perceived effectiveness – Family Group: All case studies A, B, C D & E – Main Family Group: Advantages/Opportunities/Benefits]

Case Study E Interviewee 1.docx

‘There has been a change from giving back only water, to giving back some useful solids as well. We are trying to change from ZLD technology to ZW [zero waste] technology, but this will need looking at the final sludge and how to reuse it as well.’

Code: [Buyer Satisfaction – Sub-Family (linked construct): Perceived effectiveness – Family Group: On-site Individual: A & B – Main Family Group: Advantages/Opportunities/Benefits]

Case Study B Interviewee 3.docx

‘The MNC [multinational conglomeration] companies that we sell dyed textiles to have told us that they are happy to be in business with textile units that have such compliance. They come and inspect our treatment plant as well. So, there is an added advantage to this ZLD [compliance].’

Code: [Buyer Expectation – Sub-Family (linked construct): Perceived usefulness – Family Group: On-site Individual: A & B – Main Family Group: Advantages/Opportunities/Benefits]

Case Study B Interviewee 3.docx

‘International buyers are interested in this reuse and we give some of them tours as well. It is becoming an advantage over other places and countries, especially for international buyers.’

Code: [Eco-friendly label is good for international business – Sub-Family (linked construct): Perceived usefulness – Family Group: On-site Individual: A & B – Main Family Group: Advantages/Opportunities/Benefits]

Case Study A Interviewee 2.docx

‘While we don’t have eco-friendly certificate [labels or certification], it is an advantage to be able to say, “We are reusing all our wastewater back into production, and we can show you that". This is more so for larger international buyers – some Indian buyers do ask, but most don't.'

Code: [Public Satisfaction – Sub-Family (linked construct): Perceived effectiveness – Family Group: All case studies A, B, C D & E – Main Family Group: Advantages/Opportunities/Benefits]

Case Study A Interviewee 1.docx

'It is useful to also be able to say to all the people who have been protesting, we are following the rules. Public must be satisfied with this.'

Code: [Pride and sense of showmanship – Sub-Family (linked construct): Perceived effectiveness – Family Group: On-site Individual: A & B – Main Family Group: Advantages/Opportunities/Benefits]

Case Study A Interviewee 1.docx

'This is a model plant – newly installed (2 years ago) and working perfectly. I myself [manager of the textile facility, with no engineering knowledge] give many tours to people and know how the whole process works now.'

Case Study B Interviewee 2.docx

'This entire premise has been planned by both architects and engineers. We have showcasing rooms, viewing areas and dormitory facilities for our workers. We plant trees and flowers to make it look nicer. Standards have to be met, and we have to be able to show that we have a good facility.'

Code: [Control over process – Sub-Family (linked construct): Perceived ease of use – Family Group: On-site Individual: A & B – Main Family Group: Advantages/Opportunities/Benefits]

Case Study B Interviewee 2.docx

'Being able to treat and reuse the water on our schedule is an important factor. That is the main reason why we decided to install an IETP instead of going for the CETP that is on the premises [of the industrial park].'

Code: [Burden of proof is on CETP – Sub-Family (linked construct): Perceived ease of use – Family Group: Off-site Common: C, D & E – Main Family Group: Advantages/Opportunities/Benefits]

Case Study C Interviewee 1.docx

‘All we really need to do is pay the monthly costs of treatment. Monitoring and all that [compliance] is taken care of on the side of the CETP. It is much easier for smaller units, than to install and run an IETP.’

Code: [Burden of collection, treatment and return is on CETP – Sub-Family (linked construct): Perceived ease of use – Family Group: Off-site Common: C, D & E – Main Family Group: Advantages/Opportunities/Benefits]

Case Study D Interviewee 1.docx

‘We take care of everything for our member units – even the pipes to and from each unit are managed by the PWD (public works department) and us. We monitor everything – incoming TDS (total dissolved solids) levels, quantities, outgoing quantities as well. This is the advantage we offer.’

Code: [Water costs – Sub-Family (linked construct): Perceived usefulness – Family Group: All case studies A, B, C D & E – Main Family Group: Advantages/Opportunities/Benefits]

Case Study A Interviewee 1.docx

‘Especially now that borewells are not allowed, water tankers [private companies that provide water] are so costly and are even more costly during summer. High costs of the tankers makes having this technology more useful.’

Code: [Design & technology pioneers of brine treatment and reuse – Sub-Family (linked construct): Perceived effectiveness – Family Group: Off-site Common: C, D & E – Main Family Group: Advantages/Opportunities/Benefits]

Case Study E Interviewee 2.docx

‘ZLD technology first came here from the US and Europe. But with the addition of brine reuse, we are developing and testing new technologies that haven’t been developed anywhere else in the world.’

Code: [Specialized technical knowledge needed for O&M – Sub-Family (linked construct): Perceived ease of use – Family Group: On-site Individual: A & B – Main Family Group: Disadvantages/Problems/Risks]

Case Study A Interviewee 1.docx

‘Some amount of engineering knowledge is needed to operate and run the treatment plant. As managers, we do know about some of it [the know-how] but not all the details.’

Code: [Specialized technical operators needed – Sub-Family (linked construct): Perceived ease of use – Family Group: On-site Individual: A & B – Main Family Group: Disadvantages/Problems/Risks]

Case Study B Interviewee 1.docx

‘In total we hire up to 40 people just for this treatment plant. While we are a bigger facility than most, this is still a big number. Environmental, mechanical, process engineers are needed, as are line supervisors, and operators.’

Code: [Specialized physical infrastructure for installation – Sub-Family (linked construct): Perceived ease of use – Family Group: On-site Individual: A & B – Main Family Group: Disadvantages/Problems/Risks]

Case Study B Interviewee 1.docx

‘It requires a specialized company to install the different components of the technology, and make sure that it runs well. [I think that] the company name is listed on our signage – they deal only with water treatment system installations.’

Code: [High costs of installation, use & maintenance – Sub-Family (linked construct): Perceived ease of use – Family Group: On-site Individual: A & B – Main Family Group: Disadvantages/Problems/Risks]

Case Study A Interviewee 1.docx

‘To date we have spent crores [tens of millions] of rupees in set-up and running.’

Code: [Expensive commercial loans – Sub-Family (linked construct): Perceived usefulness – Family Group: On-site Individual: A & B – Main Family Group: Disadvantages/Problems/Risks]

Case Study A Interviewee 1.docx

‘Loan costs [to install] are high – CETPs get more government subsidies than do IETPs. Moneylenders do well in Tirupur, more than businesses.’

Code: [Energy-intensive and carbon-intensive – Sub-Family (linked construct): Perceived effectiveness – Family Group: All case studies A, B, C D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study E Interviewee 1.docx

‘It takes a lot of electricity and power to run even a small individual plant, let alone [ours]. Per-month electricity costs go up to 55 lakh rupees [4 lakh kilowatts at the rate of 8.5 rupees per kw is the norm].’

Code: [No distinction between 'less dirty water' and 'more dirty water' – Sub-Family (linked construct): Perceived usefulness – Family Group: Off-site Common: C, D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study C Interviewee 1.docx

'All our water is treated the same as others, it is all mixed up together with other units. Maybe our water is cleaner and needs less treatment, and can cost less, [I don't know if there is] any difference between "less dirty water and more dirty water". Maybe this is an engineering issue.'

Code: [High level of monitoring – Sub-Family (linked construct): Perceived usefulness – Family Group: On-site Individual: A & B – Main Family Group: Disadvantages/Problems/Risks]

Case Study B Interviewee 3.docx

'You can see all the signage we have to post outside of the treatment plant – about what chemicals are used and stored on-site, about how much wastewater we generate and sludge we make, the chemicals in the sludge and the storage of the sludge. These signs are written in both English and Tamil so that anyone, even the [general public] can see them. Inspections are weekly and monthly and they do this for a year before giving us certificates, and even after that, inspections are very [frequent], to monitor the flow meter readings.'

Code: [Unfair process: Relocation – other states or cities within the same state don't have to follow this rule – Sub-Family (linked construct): Perceived effectiveness – Family Group: All case studies A, B, C D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study B Interviewee 3.docx

'I can tell you that "out of 28 of the major dyeing operations in Tirupur, 14 have permanently shifted to Ahmedabad because of this requirement [to implement the technology and reuse treated water]."

Case Study C Interviewee 1.docx

'Even in Tirupur, if your unit is on the outskirts or in another district area, then monitoring is more difficult for these [pollution board officials].'

Code: [Uncertainty: No control over return – Sub-Family (linked construct): Perceived ease of use – Family Group: Off-site Common: C, D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study C Interviewee 2.docx

‘After business hours or if full capacity [1 lakh per unit] is reached, or if the generators are also not working [if there is no electricity and no generator power to run the treatment plant] the input [wastewater] is locked and we can’t give out more.’

Code: [Trust in CETP (credibility) – Sub-Family (linked construct): Perceived effectiveness – Family Group: Off-site Common: C, D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study C Interviewee 2.docx

‘They are responsible for taking effluent and returning clean water. For all the other steps, we just pay for it but do not actually oversee it happening. In that way [I think] an IETP is useful, for more control.’

(Authors comments: Visibility of the process is a concern, mentioned by other respondents as well).

Code: [Significant steam and smoke (from coal use) emissions – Sub-Family (linked construct): Perceived effectiveness – Family Group: All case studies A, B, C D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study E Interviewee 1.docx

‘Yes, coal is used for generation. We do use a lot of coal and firewood also, to run parts of the plant. You can see [pointing to a boiler and cooling tower] how much is required right now. We generate 3 tons per hour of steam, over the whole facility. Boiler chimneys use wood – [6 tons]. Steam and smoke are a part of industries everywhere.’

Code: [Future expansion plans depend on current capacity – Sub-Family (linked construct): Perceived ease of use – Family Group: On-site Individual: A & B – Main Family Group: Disadvantages/Problems/Risks]

Case Study A Interviewee 2.docx

‘As a printing unit, we generate less wastewater than dyeing and bleaching units do. But we do want to expand into the dyeing and bleaching business in the [near] future, and so we built a bigger IETP now, to plan for this. It runs at less capacity now, of course.’

Code: [Non-productive asset – Sub-Family (linked construct): Perceived usefulness – Family Group: On-site Individual: A & B – Main Family Group: Disadvantages/Problems/Risks]

Case Study A Interviewee 2.docx

‘All the cost analyses show that this is just going to become more expensive and difficult to maintain and use, even with the recovery of water included.’

Case Study B Interviewee 4.docx

'It is a non-productive asset that we have to bear with to do work in Tirupur.'

Code: [Big expensive experiments – Sub-Family (linked construct): Perceived effectiveness – Family Group: Off-site Common: C, D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study E Interviewee 1.docx

'We are constantly building some new type of treatment unit, all to try and balance the economics of it with the technical feasibility and efficiency. [As you can see right now,] this specific area is currently under construction for upgrades [installation of a new cooling tower]. We are testing and refining this technology, especially with the new brine reuse technology system, that is proving to be hopeful. The CETPs are also places to test and pilot ways to reduce inefficiencies, but this needs a lot of capital.'

Ambient (Chemical, mechanical, thermal) hazards – Sub-Family (linked construct): Perceived ease of use – Family Group: All case studies A, B, C D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study E Interviewee 2.docx

'Yes, there are signs warning about how to work in some places [rooms and tanks and structures]. We are told what to do and what not to do [by supervisors].'

Code: [Future problems: Repair or replace – Sub-Family (linked construct): Perceived ease of use – Family Group: All case studies A, B, C D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study B Interviewee 3.docx

'We have had this treatment plant running for a few years only, so replacement has not been a worry yet. As far as possible, our engineers do minor repair and maintenance works. But as with all our actual equipment and machines, there is a newer better model from Japan or Europe available, at a cost.'

Code: [Future problems: changes to technology – Sub-Family (linked construct): Perceived ease of use – Family Group: All case studies A, B, C D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study B Interviewee 1.docx

'One issue is that upgrades and changes to phases of the treatment process are unavoidable, and so changes may become necessary in the future. There is some uncertainty with this, and how to plan for it.'

Code: [Buyers don't care – Sub-Family (linked construct): Perceived effectiveness – Family Group: Off-site Common: C, D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study C Interviewee 2.docx

'Our buyers do not care about what rules we have to follow. It may be useful to international buyers, for us to have this reuse requirement, but [I think] Indian companies are not yet at that level. The most important thing is that business not be stopped [interrupted] again.

Code: [Hazardous/Toxic solid waste – Sub-Family (linked construct): Perceived effectiveness – Family Group: All case studies A, B, C D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study B Interviewee 1.docx

'Biological solids are to be kept on site. We generate 1 ton per day, and this has to be posted on signage as per the rules. Signs about touching and handling this waste are also posted at the point where effluents are taken out of the treatment process.'

[Casual] workers, who we hire as temporary labor, do all of the moving and handling of effluents, as per guidelines. During summer, we need more such workers, so we have more then.'

Case Study A Interviewee 1.docx

'The salts are completely safe to handle – here [gives dark colored solids to this researcher to touch]. Whatever is not safe, we ask workers to follow rules.'

Code: [Disposal challenges – Sub-Family (linked construct): Perceived effectiveness – Family Group: All case studies A, B, C D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study E Interviewee 3.docx

'Trucks are not allowed at any facilities at all, so all the solid biological sludge that cannot be reused is being stored on-site for now. Several options have been discussed by the government, to make the sludge into bricks, or to burn it in an incinerator, but all that is still being discussed. This part is "not a commercial success yet".'

'We have to be very careful with these solar pans [drying beds at the facility]. They have to be lifted off the floor level with concrete, so that it is clear that there is no chance of leakage or seepage into the ground. They have to be lined with layers of rubber and plastic. And, they cannot be used anymore, as there are worries of ground contamination.'

Code: [Scaling & corrosion of expensive equipment like evaporators – Sub-Family (linked construct): Perceived ease of use – Family Group: Off-site Common: C, D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study D Interviewee 1.docx

‘We cannot control what salts our member units use. With mixed salts, there are many problems – first we can’t recover chloride salts, only sulphate ones. So we have to persuade member units to shift to sulphate salts, for recovery and reuse of the salts in the dyeing process. Mixed salts can also cause more rapid scaling in the ME [mechanical evaporators] and even the RO final stage where the last of the salts are removed.’

Code: [Burden/Liability on us, not on buyers – Sub-Family (linked construct): Perceived usefulness – Family Group: Off-site Common: C, D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study C Interviewee 1.docx

‘It is not as though these costs are being borne by our buyers in any way. We are competing with other [Indian] cities, and even other countries like Bangladesh and Vietnam where it is now cheaper than here, to produce textiles.’

Code: [Unfair financial per-unit cost for smaller facilities – Sub-Family (linked construct): Perceived usefulness – Family Group: Off-site Common: C, D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study C Interviewee 1.docx

‘We pay a base slab cost [a financial equity share] as well as costs as per how much effluent [wastewater] we make. So, costs for bigger member units are lower than what they are for smaller member units.’

Code: [River-water sharing is main problem – Sub-Family (linked construct): Perceived effectiveness – Family Group: All case studies A, B, C D & E – Main Family Group: Disadvantages/Problems/Risks]

Case Study C Interviewee 1.docx

‘The main problem here is the issue of river-water sharing with Karnataka [a bordering state], over the Cauvery river. If the water here in the river Noyyal had a better flow, the groundwater pollution would not have been so problematic. Unlike places like Surat, [a city with access to the sea and to another river] where access to water and the sea makes business easier’.

Code: [Subsidies to set-up – Sub-Family (linked construct): Perceived effectiveness – Family Group: All case studies A, B, C D & E – Main Family Group: Facilitating Conditions]

Case Study B Interviewee 3.docx

'The government does give [us textile dyeing units with IETPs] subsidies and no-interest loans to cover the cost of installing or upgrading our on-site treatment plants. This does not cover the costs of operating or maintaining the treatment plant after that, or even the costs of changing our textile dyeing and bleaching equipment and machines to be more water-efficient or energy-efficient. So mostly, it is on us and the textile unit to bear the cost of this requirement.'

Case Study E Interviewee 3.docx

'Since the CETPs are mostly PPPs (public-private-partnerships) or private-owned enterprises, we do get subsidies of 200 crore rupees to set-up and upgrade/install'.

Code: [Stakeholder participation in decision-making – Sub-Family (linked construct): Perceived effectiveness – Family Group: All case studies A, B, C D & E – Main Family Group: Facilitating Conditions]

'Since we own the treatment plant, all major decisions about operating, maintaining and upgrading are made by us, to make sure it does not interrupt the dyeing and bleaching operations. More convenient, and more control for us.'

'Member units, especially the larger ones, are encouraged to be a part of the running of the CETP, and several member units have said that from the beginning, they want to actively have a say in management of the CETP [here].'

Code: [Back-up generators for electricity-intensive process – Sub-Family (linked construct): Perceived effectiveness – Family Group: All case studies A, B, C D & E – Main Family Group: Facilitating Conditions]

Case Study D Interviewee 3.docx

'Electricity cuts are normal, mostly during summer seasons. Generators – diesel ones – are a must [necessary] otherwise we would get blamed for stalling our member unit's operations. In fact, as an environmental engineer, [I can tell you that] there is the potential for windmills, which can be installed for 10 lakh rupees. It is something that we are looking into, in addition to solar, because the generator costs are so high'.

Code: [Siting to industrial parks – Sub-Family (linked construct): Perceived effectiveness – Family Group: All case studies A, B, C D & E – Main Family Group: Facilitating Conditions]

Case Study B Interviewee 1.docx

‘For new textile dyeing and bleaching facilities, in order to get the licenses [Consent to Establish, Consent to Operate certificates] we need to be placed [situated] at least some distance away from the Noyyal – [maybe at least 5 kilometers away]. It is encouraged to set up in industrial parks [like SIPCOT]. Land allotment, common treatment facilities and other incentives are benefits of being a part of an industrial park.’

Code: [Technology demonstrations and learning assistance – Sub-Family (linked construct): Perceived effectiveness – Family Group: All case studies A, B, C D & E – Main Family Group: Facilitating Conditions]

Case Study E Interviewee 1.docx

‘We give demonstrations of how this process works to a number of different people – various people from the government; people from universities and researchers from all over the world; the owners and chairmen of our member [dyeing units]; other textile industry members wanting to learn about the process, and to students [like the researcher]. There is a lot of interest in the technology and how it works, and so we show [them] how clear the water is when it comes out of the RO [final treatment stage of reverse osmosis]. We have glasses to show what the water is like – the quality is “equal to drinking water, but not for drinking”.’

Thank you.