PATHWAYS TOWARD RAPID WASTEWATER TREATMENT RESPONSE DURING THE GLOBAL REFUGEE CRISIS

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Abstract

Pathways toward rapid wastewater treatment response during the global refugee crisis

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The aftermath of several natural and humanitarian catastrophes has demonstrated the potential for environmental impacts as displaced populations overwhelm wastewater treatment facilities in host communities. A systematic review of sanitation system operation and management revealed that there is limited academic understanding of how operators and engineers make decisions on project delivery during rapid wastewater treatment response. This dissertation aims to fill this gap in scholarship by investigating stakeholder thought processes behind advanced wastewater treatment delivery during refugee responses in Jordan and Finland in 2015-2016. The overarching research objective of this dissertation is to ***identify concepts that contribute to rapid wastewater treatment response following disasters***. While the best practices in both steady-state wastewater treatment system operation and emergency sanitation provision have received extensive academic attention, empirical research on advanced wastewater treatment process operation in dynamic or extreme conditions, such as refugee response, has been limited. The three-step research approach addresses the following hypotheses:

H1: Stakeholders' technical decisions are based on recognition-primed decision models that build on their prior experiences.

H2: Wastewater treatment system startup and performance in refugee camps is impacted by contextual and internal concepts that influence stakeholder decision-making.

H3: The concepts influencing rapid wastewater treatment delivery in disparate refugee response situations share commonalities.

The first hypothesis was tested by investigating stakeholder mental models on decision-making and wastewater treatment system project delivery at the Azraq refugee camp. The mental model constructs revealed that technical decisions were influenced by stakeholders' prior experiences, as well as six other contextual and internal concepts including "Physical location", "Resources", "Risk and uncertainty", "Personal characteristics", "Team dynamics" and "Communication". The second hypothesis was tested by constructing an Input-Mediators-Output-Input (IMOI) model that expressed the relationships between wastewater treatment system function, human evaluations of system performance and the resulting decisions for operational changes. It was discovered that mental model concepts that guided stakeholders' decision-making, such as lack of shared technical understanding and dissimilar project exceptations, delayed the startup of the advanced wastewater treatment system. Finally, the third hypothesis was tested through comparison with a distinctively different rapid wastewater treatment response case study from Finland. Several commonalities between the two extreme cases were found. The findings suggested that contextual inputs, such as the scale of refugee response, do not solely determine the quality of wastewater treatment, and that rapid response activities are supported and hindered by mediating processes in decision-making.

The most significant theoretical contribution of this dissertation is that stakeholders' decisions during rapid wastewater treatment response are based on recognition-primed decision models. As disaster context offers limited opportunities for data-driven technical decision-making, stakeholders' judgments are influenced by prior experiences, personal characteristics and team relations and dynamics. Eventually, the concepts that drive stakeholder decisions also impact wastewater treatment delivery and system performance. Based on the findings, five principles that contribute to timely refugee response in advanced WWTPs were distinguished. These principles are "creating a clear role division between agencies and stakeholders", "improving human capacity for rapid response decisions", "selecting a process that fits the regulative and operational environment", "enabling direct and fast information sharing", and "establishing fast-track permitting processes for disaster conditions". The findings of the study serve as guidelines for wastewater treatment practitioners that are involved in future disaster response operations. The two case studies that this dissertation documented can also be used as educational material for individuals that are joining rapid response teams to help them understand the specific challenges in wastewater treatment response to acute disturbances. By improving water sector practitioners' capacities for rapid response and facilitating their work during high-stress and high-uncertainty scenarios, this dissertation research and its findings can contribute to building tolerance towards the strongly emotive phenomenon of mass migration and ensure that wastewater treatment services are provided in a way that considers the needs of the host communities and displaced populations alike.

FOREWORD

This dissertation work was made possible by financial support from scholarships and research grants, a world-wide collaboration with academics and practitioners that shared my interest in wastewater treatment and humanitarian aid, and the patience and wisdom of advisors, mentors, friends and family members that provided their invaluable support during my years in graduate school.

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I would like to dedicate this dissertation to my grandpa Professor Emeritus Eero Kajosaari, whose ground-breaking work in international development and water technology has been my greatest inspiration.

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1. INTRODUCTION

1.1. OBSERVED PROBLEM

Wastewater treatment systems are critical components of urban and rural infrastructure. When designed and operated accordingly, they help prevent the spread of fecal diseases and reduce human-induced environmental pollution. Conversely, a failure to provide adequate wastewater treatment services has potential to cause irreversible adverse impacts on the environment and to danger the health of human populations. Global challenges, such as climate change and urbanization are rapidly changing the operation environment for wastewater systems (Emanuel 2005; Falkenmark and Widstrand 1992; Trevors 2005). As uncertainty in operation conditions increases and extreme events become more frequent, water infrastructure and the people who manage the systems need to have capacities to respond and endure under constant change (Butler et al. 2017; Diao et al. 2016; Pickett et al. 2013).

The decades-long research and experience-based knowledge on wastewater treatment has led to a profound understanding of the best practices in steady-state process operation (Beck 1986; Berthouex et al. 1989; Qasim 1999; Spellman 2003). Additionally, empirical research and lessons learned from prior disaster response events have resulted in guidelines that help responders with identifying the needed sanitation services (Sparkman 2012), selecting the most suitable sanitation systems, .e.g. collection and primary treatment systems (Brdjanovic et al. 2015; Fenner et al. 2007; Urich and Rauch 2014; Zakaria et al. 2015), and organizing multi-sectoral stakeholder activities (IASC 2012; WASHCluster 2009). Less is, however, known about advanced, e.g. secondary or tertiary, wastewater treatment response to acute process disturbances, such as natural disasters or large-scale population displacement (Juan-García et al. 2017; Trevors 2005). Especially, theory on concepts guiding practical decisions during rapid operational response is limited.

This dissertation identifies concepts that contribute to rapid wastewater treatment response following disasters. The objective was to use empirical data from refugee response scenarios to facilitate the development and implementation of better operation practices for future emergencies, and ultimately to improve the quality of wastewater treatment during emergency response. The socio-technical research approach was based on two prior observations in wastewater treatment efficiency and emergency response delivery. The first observation is that rapid shifts in human populations have demonstrated potential to overwhelm wastewater treatment facilities and ultimately increase environmental pollution in the areas that host displaced populations (Silcio et al. 2010). The second observation is that while human capacity for making judgments and decisions is known to be altered in high-stress environments (Hammond 2000; Lipshitz and Strauss 1997), collective decision-making and team performance can improve over time in all environments, if individuals learn to trust each other, and are aware of each other's capabilities (Ellwart et al. 2014; Murphy et al. 2000).

1.2. RESEARCH CONTEXT

The global number of forcibly displaced people is higher than ever before in the recorded history. In 2017, the estimated number of refugees around the world passed 21 million (UNHCR 2017), and 40.3 million people were internally displaced due to conflict or violence (IDMC 2017). Consequently, there is an urgent need for understanding how to best provide basic services, such as a water, food and shelter, for the displaced populations while minimizing the adverse impacts on the host communities.

One of the most notable crises that has forced millions of people to leave their homes is the Syrian civil war that started in 2011. To date, it has caused the displacement of an estimated 11.7 million people, of which over 5 million have sought asylum or protection abroad (UNHCR 2016). The Hashemite Kingdom of Jordan bordering Syria is one of the countries that has been the most impacted by the Syrian crisis. Currently, it is one of the countries hosting the largest number of refugees in relation to its national population globally (UNHCR 2017). In April 2018, 661,859 Syrian refugees were registered in Jordan (UNHCR 2018), but many sources estimate the actual number of refugees to be much higher, over 1.3 million (Ghazal 2017; Ministry of Water and Irrigation 2016). Of the registered refugees, 21% live in camp accommodations and 79% in urban and peri-urban areas (JRP 2015). Like many other countries hosting large numbers of refugees, Jordan has experienced many infrastructure related challenges due to both short- and long-term temporary residents overwhelming the existing infrastructure (UNDP 2014).

In 2015, the “Syrian refugee crisis” extended to Europe, as more than million migrants and refugees entered the European Union (Guild et al. 2015). One of the countries receiving tens of thousands of migrants over a few months was Finland (Finland 2016). With the exception of a few hundred asylum seekers who stayed with their relatives or voluntaries in host communities, Finland accommodated its 32,476 refugees and asylum seekers in refugee centers that were established rapidly in fall and winter 2015-2016. Due to the strict immigration policies and many rejections to residency and asylum applications that Finland issued over 2016 and 2017, the number of displaced people needing accommodation reduced quickly. In April 2018, the Finnish refugee center system had only 12,580 registered residents (Migri 2018).

This dissertation research focuses on rapid wastewater treatment response in temporary settlements that were established to receive refugees and people in refugee-like situations in Jordan and in Finland. In Jordan, the study explores the startup of an on-site biological wastewater treatment system at the Azraq refugee camp (est. 2014), which is one of the five official settlements that have hosted Syrian refugees in Jordan since 2011. In Finland, the study focuses on wastewater treatment delivery in three refugee centers that treated their sewage with on-site biological wastewater treatment systems.

1.3. RESEARCH APPROACH

This dissertation explores rapid wastewater treatment response to disasters in the context of large-scale population displacement. Analyses and findings are based on previously unreleased empirical field data from wastewater treatment response *case studies* in Jordan and Finland during the "global refugee crisis" in 2015-2016. A total of 24 semi-structured expert interviews were conducted over the course of 2016. In addition, water quality data was collected from the studied wastewater treatment systems. Research participants were involved in wastewater treatment response in a previously unexperienced situation in either Jordan or Finland at the time of their interview. The European refugee crisis and the resulting migrant flux to Finland was unprecedented. Respectively, Jordan is the first country to implement advanced wastewater collection and treatment systems in its refugee camps.

A scientific quest of a new phenomenon, such as advanced wastewater treatment response during refugee crisis, is by nature exploratory. As the number of data points are limited and the boundaries between the studied phenomenon and its context are not clear, exploratory topics are best approached through the case study method (Stebbins 2001; Yin 1984). The purpose of this case study research is to build a theoretical framework of the social, environmental and technical concepts that contribute to rapid wastewater treatment response during disaster response. The aim is to create testable hypotheses by. theoretical sampling, i.e. by choosing cases that are particularly suitable for illuminating issues in wastewater treatment during emergency response (Eisenhardt and Graebner 2007). In addition to their contribution to theory, well-constructed case studies of wastewater treatment during refugee response can have immediate practical implications for the design, construction and operation of advanced wastewater treatment systems during future emergency response scenarios.

In this dissertation, a three-step method is used to explore concepts that impact wastewater treatment response to refugee crises. The research hypotheses, the applied methods and the research questions in each step are summarized in Figure 1.

	Chapter 2	Chapter 3	Chapter 4
Research Hypotheses	H1: Stakeholders' technical decisions are based on recognition-primed decision models that build on their prior experiences.	H2: Advanced wastewater treatment system startup in refugee camp is impacted by contextual and internal concepts that guide stakeholder decision-making.	H3: The concepts influencing rapid wastewater treatment delivery in disparate refugee response situations share commonalities.
Case Study	Azraq refugee camp		Azraq refugee camp & Finnish refugee centers
Research Method	Mental models	Input-Mediators-Output (IMO) Model	Polar comparison of IMO models
Research Questions	Q1. Which concepts contribute to stakeholder decision-making on wastewater treatment plant project delivery during refugee response?	Q2. Which concepts impact advanced WWTS startup and operation performance in a refugee camp?	Q3. Which concepts contribute to successful wastewater treatment delivery during refugee response?

Figure 1. Summary of the research approach, research questions and the applied methods

In the first step of this research, mental model interviews were used to develop in-depth understanding of the concepts that impacted stakeholders' decisions during rapid wastewater treatment response at the Azraq refugee camp in Jordan. The mental model theory is based on the assumption that people use their existing beliefs, memories, assertions, or a mixture of the afore-mentioned things to interpret new information and to understand a new situation (Craik 1943; Johnson-Laird 2010). Mental models are "working models", which means that they are dynamic and context-dependent (Johnson-Laird 1983; Manktelow and Jones 1987; Wilson and Rutherford 1989) and thus different from other human decision and reasoning representations, e.g. cognitive maps and schemas, that model thinking processes as static structures of associations and networks (Eden 1988; Elsawah et al. 2015; Kitchin and Freundschuh 2000; Wilson and Rutherford 1989). Instead of seeing human reasoning as a process with formal rules, mental model theory defines reasoning as "a simulation of the world that is fleshed out with our knowledge" (Johnson-Laird 2010; Manktelow and Jones 1987). As such, it is ideal for investigating newly emerging situations, such as rapid wastewater treatment response to refugee crises, where stakeholders have to develop decision practices while they are working.

The second step of the research built on the findings of the mental model study. In this step, an input-mediator-output-input (IMOI) model that describes the development of the relationship between Azraq refugee camp's wastewater treatment system performance and the concepts that influenced stakeholder decisions over time was constructed. An IMOI model looks at processes as "requirements of the environment" (inputs) that become "products for the environment" (outputs) through processes or different stages (processes or mediators). It assumes that processes are cyclical, which means that the outputs from the previous cycle become inputs in the next cycle. (Ilgen et al. 2005). While this is the first application of an IMOI model to wastewater treatment system operation, IMOIs and other variations of input-process-output models have been widely used in psychological and sociological research on collective operational decision-making and team performance (Gladstein 1984; Ilgen et al. 2005; Littlepage et al. 1995; Pavitt 2014). The approach was chosen for this study in that it allows for simultaneous exploration of the wastewater treatment facility's performance and the development of decision practices within the project team.

The third and final step of this research generalized the findings from wastewater treatment response in the Azraq refugee camp by comparing that rapid response scenario with a distinctively different rapid response scenario at three Finnish refugee centers. *Polar comparison* is a standard method used in case study research that targets new phenomena that have not been previously studied in a wider context (Eisenhardt and Graebner 2007; Pettigrew 1990). The idea is to create a baseline by examining contradicting attributes between two distinctively different, polar cases. The logic is that if the polar examples share similarities, these similarities are expected to be shared with other cases that lie between the polar extremes (Pettigrew 1990). In this case, the two extremes are the Finnish and Jordanian responses. The results of the comparison were used for defining general commonalities in rapid wastewater treatment response case studies that could be used for creating a set of recommendations for facilitating wastewater treatment delivery during future refugee response scenarios.

1.4. DISSERTATION FORMAT

This dissertation follows a journal article format and is structured as follows. Chapter I introduces the motivation and scope of this dissertation work. Chapter II introduces and discusses stakeholder mental models in the Azraq refugee camp wastewater treatment plant project. Chapter III presents an Input-Mediator-Output-Input model on operational decision-making during the startup of a biological wastewater treatment plant in the Azraq refugee camp. Chapter IV extends on the work presented in Chapters II and III and introduces a comparative study on the lessons learned in two polar refugee response case studies in Jordan and Finland. Finally, Chapter V summarizes the implications of the findings of this dissertation and proposes directions for future research in the field. The middle three chapters of the dissertation are stand-alone papers that were published in, or submitted to peer-reviewed scientific journals. As all papers have their own introduction, background and method sections, some overlap in their content occurs. The dissertation appendices include IRB approvals for the study, as well as detailed information about data collection tools and the qualitative and quantitative data analysis.

2. MENTAL MODELS APPROACH TO WASTEWATER TREATMENT PLANT PROJECT DELIVERY DURING EMERGENCY RESPONSE

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ABSTRACT

Proper management of water sanitation and hygiene (WASH) services is critical in serving displaced populations. In 2015, the Azraq refugee camp in Jordan serving the displaced Syrian populations became among the first in the world to have an on-site, advanced wastewater treatment plant (WWTP). While guidelines and best-practices on proper WWTP incident management exist, evidence suggest that they are largely ineffective in providing substantial benefits when it comes to active incident management. This study applied a mental model approach to investigate Azraq WWTP project stakeholder decision practices during an active incident management phase, and to initiate work for identifying factors that influence WWTP project delivery during disaster response. Our findings show that improving practitioners' ability to recognize and address the non-technical internal concepts that impact their decision processes can positively influence wastewater treatment plant construction and operation in new and challenging project conditions. Implementable recommendations include flat communication structures, training for locating knowledge within new disaster response project groups, and increasing stakeholders' ability to create improvised solutions based on their existing professional knowledge.

KEYWORDS: disaster response, risk communications, water sanitation and hygiene (WASH), wastewater treatment, decision-making, project delivery

2.1. INTRODUCTION

The global number of refugees is higher than ever before in the recorded history. Currently, the estimated number of refugees around the world is about 21 million, with the largest share of displaced population in the Middle East at 39 percent (UNHCR 2015). Efforts to host and serve this displaced population require the prioritization of a number of services, including water, sanitation, and hygiene (WASH); food security; core relief items; health; protection; and education. Over the past decade, the sustainable provision of WASH services has received increasing attention in academic literature (Schweitzer and Mihelcic 2012; Walters and Javernick-Will 2015).

Wastewater management and recovery during disaster response are critical for ensuring protection of human health and to minimize long-term environmental consequences. The United Nations High Commissioner for Refugees (UNHCR) has recognized that large-scale population displacements can have a profound effect on the ecosystems of the host region. For the handling of wastewater, "improved sanitation technologies" such as pit toilets and latrines are among the most common recommendations when host community facilities cannot accommodate the extra flow (Fenner et al. 2007). However, these systems are not designed to treat the wastewater and can put already vulnerable populations at risk of waterborne diseases. As refugee camps and other temporary housing settlements often serve displaced populations for much longer than originally expected (UNHCR 2006), the lack of adequate on-site wastewater treatment deteriorates the quality of life in the temporary housing settlements and may eventually lead to irreversible environmental impacts in the hosting communities (Silcio et al. 2010). Thus, in order to avoid these adverse impacts, recent emergency response efforts have started to allocate more resources to providing advanced on-site wastewater treatment in temporary residential settlements.

Azraq refugee camp in Jordan serving the displaced Syrian populations is unique in that it became among the first in the world to have an on-site, advanced wastewater treatment plant (WWTP). The construction and startup of an advanced wastewater treatment plant is a complex process that demands interdisciplinary decision-making and collaboration between engineers and constructors (Culp 2011; Shane et al. 2013). In Azraq, the project delivery and decision-making is especially challenging, as the multi-stakeholder and multi-cultural project team works in rural setting with limited access to resources, harsh environmental conditions, and unprecedented nature of the wastewater quality. We hypothesized that in this context, the project team's ability to do data-driven decisions will be compromised and that instead, individual decisions will be dictated by a recognition-primed decision model that is built on each stakeholder's prior experience (Gentner and Stevens 1983; Johnson-Laird 2010; Klein 2008; Zsambok and Klein 1997).

Understanding stakeholder decision processes during wastewater treatment plant construction and operation in disaster response conditions is critical, because poor management and operational decisions can cause significant delays in WWTP construction, diminish the treatment efficiency of the WWTP, and consequently increase the potential for environmental pollution. So far, research on wastewater management has explored human factors that influence water infrastructure management under uncertainty (Frenette et al. 2010; Marlow et al. 2011; Mukheibir and Mitchell 2014), and introduced decision support and modeling tools that help wastewater and WASH professionals prepare for future emergency scenarios (Fenner et al. 2007; Urich and Rauch 2014). Additionally, a number of studies in other fields have investigated factors that influence project delivery, and team performance and decision-making during disaster response (Coles and Zhuang 2011; French et al. 2015; Mendonca et al. 2001). However, scholarly literature is yet to explore how wastewater treatment professionals' decision processes advance in active disaster response situations and identify concepts that influence individual stakeholders' decisions, and consequently the quality of wastewater treatment delivery. This study addressed this gap in research by investigating Azraq refugee camp WWTP project stakeholders' *mental models* on decision-making in both individual and group level, and by identifying concepts that influence WASH delivery and operations during an active incident management phase. The *Mental model* theory is based on the assumption that people use their existing beliefs, memories, assertions, or a mixture of the afore-mentioned things to interpret new information and to understand a new situation (Craik 1943; Johnson-Laird 2010). While this theory has few prior applications in the field of construction and infrastructure management research, it is widely applied across other research disciplines to understand and improve expert decision practices (Bruine De Bruin and Bostrom 2013; Rouse et al. 1986). Additionally, it has been identified as a one of the key methods to improve understanding of stakeholder practices during emergency response (Metcalf 2008).

The findings of the study contribute to the currently limited body of knowledge on "the stressors, properties and metrics, and examples of cases study" of wastewater treatment resiliency during disaster response or other deep uncertainty scenarios (Juan-García et al. 2017). They serve as a starting point for more detailed analysis on critical success factors in wastewater delivery during disaster response. In addition to being applicable to current refugee response scenarios world-wide, the findings of this study can benefit future disaster response, where large-scale population displacement has the potential to overwhelm wastewater treatment facilities in the hosting area. In the past, such situations were experienced in the aftermath of natural disasters, e.g. Hurricane Katrina, when displaced populations and the resulting sudden increase in wastewater flow overwhelmed wastewater treatment facilities of the hosting communities (Silcio et al. 2010). In future, such scenarios are expected to become more frequent as extreme weather events and climate-related natural and humanitarian disasters increase in both number and veracity (Adger et al. 2014).

2.2. BACKGROUND

This section reviews the relevant literature on mental model research and emergency response project delivery, and introduces the reader to the project environment in the Azraq refugee camp in Jordan.

2.2.1. MENTAL MODELS AND PROJECT DELIVERY DURING EMERGENCY RESPONSE

Mental models are internal representations that people build in their heads to make sense of the world around them. According to the mental model theory, human reasoning and decision-making does not follow formal rules of inference. Instead, it is a process where each individual envisages possibilities based on their existing beliefs and derives a conclusion by comparing the imagined outcomes, i.e. the mental models, of these different possibilities (Johnson-Laird 2010). The concept was first introduced by Craik (1943) and has since been used as a widely accepted tool in cognitive psychology to explain human reasoning and decision-making (Gentner and Stevens 1983; Johnson-Laird 1983; Johnson-Laird 2010). Outside cognitive psychology, the mental model approach has been applied, among other things, to study risk communication (Morgan et al. 2001; Morss et al. 2015), team performance and interaction (Murphy et al. 2000; Wildman et al. 2012) and human-machine and human-system interactions (Mlilo 2011; Moray 1998). The Azraq WWTP case study offers an unprecedented opportunity to investigate how wastewater treatment and construction professionals approach decision-making in a new project environment, i.e. how expert mental models on decision-making form during an emergency response scenario. It is also an opportunity to explore similarities and differences between project participants' mental models, i.e. investigate "the sharedness" of their project related understanding. Prior research on team decision-making and mental models has shown that in functioning team environments, individual mental models typically start to merge and overlap into shared mental models when team members develop shared understanding of their project or tasks (Wildman et al. 2012). Based on these prior findings and the mental model theory on decision-making, we expected to see a number of internal concepts, such as each individual's existing beliefs and prior experiences, influencing stakeholder mental models on decision-making during Azraq WWTP project delivery. Additionally, we expected to find a number of shared mental model concepts that are developed over the course of Azraq WWTP project delivery.

As mental models combine existing knowledge structures and information to simulate an unfamiliar situation, they are mostly built on "lessons learned" from prior experiences. In construction research, such lessons or learned best practices are often referred to as "critical success factors" (CSFs). Thus, the analysis on Azraq WWTP project stakeholders' mental models is a suitable method for initiating the identification of critical success factors for wastewater treatment delivery. Previous studies on CSFs in construction project delivery have determined team members' competency and prior experience in project area, team commitment, clear project objectives, sufficient managerial support, open communication, and conflict resolution capabilities as some of the key factors contributing to successful decision-making during construction project delivery (Chan et al. 2001; Chua et al. 1999; Sanvido et al. 1992). Additionally, prior findings on CSFs in disaster response have shown that clear role division, effective training, coordination and information sharing within the team contribute to successful delivery of emergency response efforts (French et al. 2015; Li 2014; Nivolianitou 2011; Zhou 2017). We anticipated finding some of the above mentioned concepts emerging from Azraq WWTP stakeholders' mental models alongside with new, previously unidentified concepts. Additionally, we anticipated to provide explanations on how they influence stakeholder decision-making during emergency response.

2.2.2. AZRAQ WASTEWATER TREATMENT PLANT

In 2016, the Azraq refugee camp in Northern Jordan was the second largest temporary housing settlement in the country with the capacity to host up to 130,000 refugees. The camp was managed by UNHCR with United Nations' Children's Fund (UNICEF) overseeing the implementation of all WASH activities in Azraq camp in coordination with Agency for Technical Co-operation and Development (ACTED) and World Vision. Azraq has been referred to as the "model refugee camp", as its facilities were designed to overcome problems that had been experienced in Zaatari refugee camp and other refugee camps around the world (Knell 2014).

Among Azraq's improved facilities was its wastewater treatment plant that is among the first in the world to provide on-site wastewater treatment in a refugee camp setting. The treatment process was a modular Moving Bed Biofilm Reactor (MBBR) that was paired with biological pre-treatment and post-chlorination. MBBRs treat wastewater with biomass that grow in biofilms on small, typically honeycomb shaped, plastic biofilm carriers, called biomedia. The use of biomedia gives the MBBR process an improved capability to respond to dynamic changes in process loading and water flows, which were expected in Azraq. While MBBR processes have been used previously for treating wastewater in remote locations (e.g. in US army bases), this is the first time MBBR technology is used in a refugee camp setting. This was also the first time this specific biological wastewater treatment technology was used in Jordan. Diagrams of the MBBR treatment units and the wastewater treatment system footprint are presented in Figure 2.

The MBBR modules of the Azraq wastewater treatment plant were originally used in an army base in a Kandahar, Afghanistan. They were delivered to Azraq in April 2015. The wastewater treatment plant construction started in March 2015 with site preparation and the construction of the in-ground concrete receiving basin and concrete support pads for the equipment. The equipment installation (e.g. plumbing and electrical) work started in August 2015 and the plant was ready for operation startup in September 2015. The wastewater treatment system start up began five months later in January 2016.

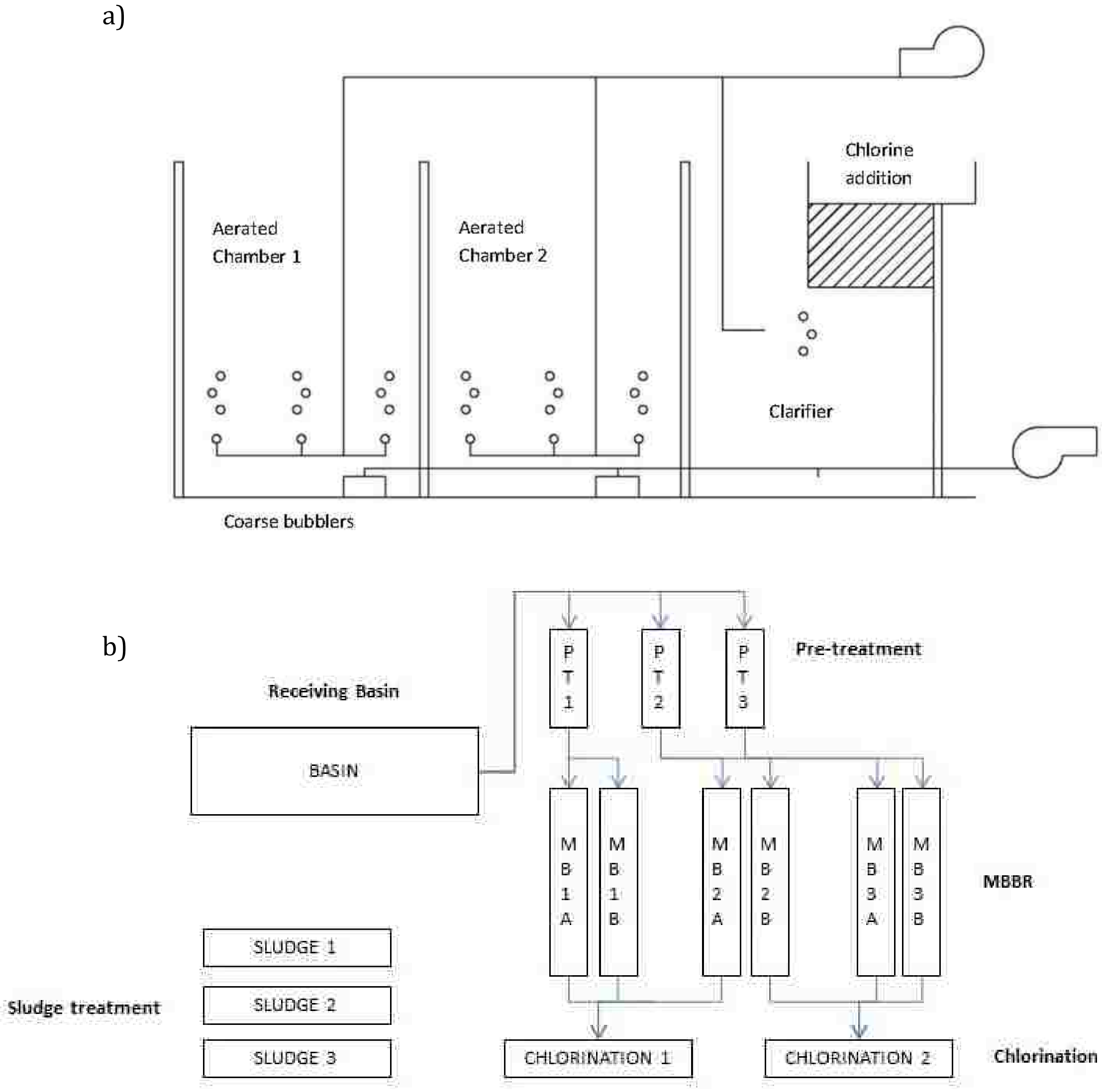

Figure 2. A diagram of a) the MBBR moving bed bioreactor and b) the wastewater treatment plant assembly at the Azraq refugee camp

2.3. RESEARCH METHODOLOGY

This study explored a unique case of building and operating an advanced wastewater treatment plant in refugee camp conditions. The objective of deep case studies such as this one is to study a single case in depth to gain profound contextual understanding of both unique and typical experiences that might later serve as base for theory development (Dalton 1959; Dyer and Wilkins 1991; Eisenhardt and Graebner 2007). While the generalizability of the findings of the current study is limited by the small non-probabilistic sample, the findings contribute to the body of knowledge by providing a rich description of the underlying dynamics of stakeholder decisions in a previously unstudied emergency response situation.

2.3.1. PARTICIPANTS

Data were collected from 11 representatives from four different professional groups involved in the wastewater treatment plant design, construction and operation at the Azraq refugee camp in Jordan. The studied sample was selective yet comprehensive, as the Azraq WWTP project only involved a limited number of people and was preceded only by the WWTP project at the Zaatari refugee camp. The study group consisted of two technical consultants, three aid organization employees, two project managers and four wastewater treatment plant operators. The participants were selected based on their level of involvement in the Azraq WWTP project as well as their ability to answer project related questions. Details about the research participants are presented in Table 1.

Table 1. Participant Details

Professional Group	Interviewee Job Role	Primary Job/ Organizational Role in WWTP[1] Project	Presence	Work Experience	Education	Experience with ER[2]
Technical Consultants	Technical Sales (CS#1)	Involved in early design and installation, providing operators and project owners consultancy on process relate & other technical issues, head of wastewater treatment process start up procedures	Mainly off-site & abroad, occasional visits to the WWTP	6 years	MS[3]	No
	Project manager (CS#2)	Head of wastewater treatment process design, involved in design and operation throughout the project, coordinating technical & operational changes with operators and project owners, consulting operators and project owners	Mainly off-site & abroad, occasional visits to the WWTP	15 years	BS[4]	No
Aid Organization Coordinators	WASH officer 1 (CR#1)	Coordinating WASH[5] initiatives in refugee camps and host communities. Liaison between all project stakeholders and representative of the project owner.	Working in several locations, visiting WWTP several times a month	12 years	MS	Yes
	WASH officer 2 (CR#3)			Yes	BS	Yes
	WASH specialist (CR#2)	Coordinating communication between project stakeholders in early design and implementation phase, overseeing WASH projects in refugee camps and host communities and acting as a focal point between aid organizations and local government	Mainly off-site but within the country, visits to the WWTP when needed	19 years	BS	Yes
Contractors	WWTP operator 1 (OP#1)	Responsible for wastewater treatment process operation on site, monitoring process performance, testing water quality and implementing operational changes when needed	On-site daily	20 years	undergoing BS	No
	WWTP operator 2 (OP#2)			23 years	Vocational training	No
	WWTP operator 3 (OP#3)			13 years	BS	No
	WWTP operators 4 (OP#4)			5 years	No training/education	No
	Construction manager (PM#1)	Project manager overseeing the construction of the wastewater treatment plant, representative of the contractor working for the consultant, communicating project delivery related issues with consultants and aid organizations	Mainly off-site but within the country, visits to WWTP when needed.	16 years	BS	No
	Operation manager (PM#2)	Supervising operation and maintenance work and observing the wastewater treatment process performance. Also supervising the operator team and following their performance.	On-site daily	Yes	BS	No

[1]WWTP = wastewater treatment plant, [2]ER = Emergency Response, [3]MS = Master in Science, [4]BS = Bachelor in Science, [5]WASH = Water, Sanitation, and Hygiene

2.3.2. DATA COLLECTION

Data were collected using on-site interviews and field observations during the site visits. The purpose of the interviews was to identify concepts that influenced project team's decision processes during emergency response wastewater treatment. In other words, the research team wanted to define the more generic knowledge sources that stakeholders draw from when they were building mental models to make sense of the new emergency operation situation. The set of 12 interviews met the requirements for conducting a reliable thematic analysis, as prior methodological research on in-depth interviewing has defined 10-15 interviews as the saturation point for the emergence of new themes (Guest et al. 2006; Morgan et al. 2001).

A narrative "storytelling" approach (Sandelowski 1991) was used to collect information about stakeholder communication practices, pre-delivery events and events related to the WWTP operation, process performance and construction. Following the recommended practices of mental models elicitation (Bruine De Bruin and Bostrom 2013; Jones et al. 2014), the mental models interviews were conducted face-to-face at interviewees' work places, and started by undirected questions, e.g. "can you tell me about your first day in the project" and "Could you tell me about some of the major activities that happened during the first process startup". Further, clarifying questions were asked based on interviewee's answers on the undirected questions when necessary, but generally researchers avoided interrupting interviewee's explanations to allow for unbiased mental model construction. The topics of the questions were selected based on prior findings in emergency response and project delivery research, as well as in wastewater treatment plant operation under shock loading scenarios. Prior to conducting the interviews, questions were pilot tested with an expert in conducting mental model interviews.

The interviews were conducted between January and May 2016. Two interviews were conducted in Arabic, two interviews in English with Arabic assistance and eight interviews in English. The translators, all native Arabic speakers, were part of the research group and have a strong technical background in water and environmental technology. All but two of the interviews were audio-recorded and transcribed. The two interviews that were not recorded were documented by hand-written notes.

Interviewers had the opportunity to spend time with the interviewees and to tour the wastewater treatment plant before the interviews. The information that was gained during tours and informal conversations was written down as reflective field observations at the end of the site visit day. The researchers also wrote descriptive notes about observed operation practices and wastewater treatment plant performance after the site visits to complement the recorded interview data. As suggested by Roth (2004), observations were used during the data analysis to make better sense of the work environment the interviewees were describing during their interviews.

2.3.3. ANALYSIS

Coding and data analysis

The qualitative data, i.e. the written narratives of the semi-structured stakeholder interviews, were analyzed and qualitatively coded through conventional content analysis. As recommended by Srivastava and Hopwood (2009), the coding was conducted as an iterative process during which the researchers revisited and re-coded the data multiple times to allow emerging insights progressively develop into deeper understandings. The Atlas.ti qualitative data analysis software was used as the coding tool throughout the process (Atlas.ti 2014). The final results of the analysis are summarized in Table 2 that presents the content of stakeholder mental models.

The data analysis started with familiarization process during which all interview material was read in detail various times. By following the practices of the conventional approach, researchers avoided using pre-existing categories or codebooks during the initial coding process and instead let concepts emerge naturally from the data (Hsieh and Shannon 2005). An example of the simultaneous and descriptive first coding round is given below. The coded quote is underlined and the code that was given is in parentheses after the quote.

"Uh, well thankfully there's not as, you know, as much of a language barrier (Language issues) *with X so we can communicate pretty well* (Communication evaluation)*. Um, we… X is very experienced and knowledgeable* (Description of team member's knowledge) *so I find that my, for lack of better term, "expertise" for the startup is not… It's been much more of a collaboration than what I am used to for normal startups* (Collaboration, comparison to normal) *um because X is very good.* (Description of team member's knowledge)*"*

The initial coding included all interview transcriptions and resulted in 184 codes. Before proceeding with the content analysis, the researchers compiled the code list by merging tags with identical meaning, e.g. "lack of documentation" and "documentation challenges". In the second step of the analysis, the initial codes were classified based on the concept they were related to. For instance, all codes that were related to communication, e.g. "description of the communication process" and "communication challenges", were classified under a larger "communication" concept. This process lead to definition of 18 initial concepts influencing stakeholder mental models that were further clustered under seven main themes presented in Figure 3.

In order to ensure that the data was assessed in a proper manner, the credibility of the qualitative analysis was tested through intercoder reliability check in two phases of the data analysis (Dewey 1983). The first test occurred after the 18 initial concepts were identified and the second one after they had been clustered under the seven main themes. The tests for intercoder reliability were completed by comparing the results of two independently working researchers. Both researchers coded one interview from each participant subgroup (coordinators, consultants and contractors).

The Cohen's kappa values were then calculated for two random sample pages of the three interview transcriptions with satisfactory results (0.6) (Hruschka et al. 2004).

Thematic and quantitative analysis

The qualitative coding process revealed seven emerging themes, e.g. groups of concepts, which influenced stakeholder decision-making processes during wastewater treatment plant construction and startup operation as shown in Figure 3. Upon closer investigation the themes could be divided into contextual and internal based on whether or not they were dependent on individual stakeholders' or stakeholder groups' input. All concepts related to "Physical location", "Resources" and "Risk and uncertainty" were considered contextual, as they were already present when stakeholders started working on the wastewater treatment plant project. Thus, rather than being included in stakeholder mental models they were defining the context in which stakeholders developed the mental models this research investigates.

All concepts that were related to stakeholders' individual characteristics were clustered under "internal" themes. These concepts were then further divided into individual or shared concepts: individual concepts were independent of other team members' views or actions whereas shared concepts were shaped by stakeholder's interaction with other team members. Consequently, shared influencing concepts were typically project specific, e.g. "pace of communication", whereas individual concepts reflected stakeholder's pre-existing knowledge and opinions, e.g. "professional experience in similar projects".

Following the thematic analysis, the quantitative content analysis included iterative re-coding of the expert interviews and quantifying how many times each concept was mentioned by each participant. During this process, many of the 18 initial concepts were renamed or divided into two or more separate concepts. The resulting 36 concepts are listed in Table 2 that presents the Azraq WWTP project stakeholders' mental models. The different columns represent different stakeholder groups (e.g. coordinators, consultants). The number in the column indicates how many participants in that group mentioned the concept during their mental model interview.

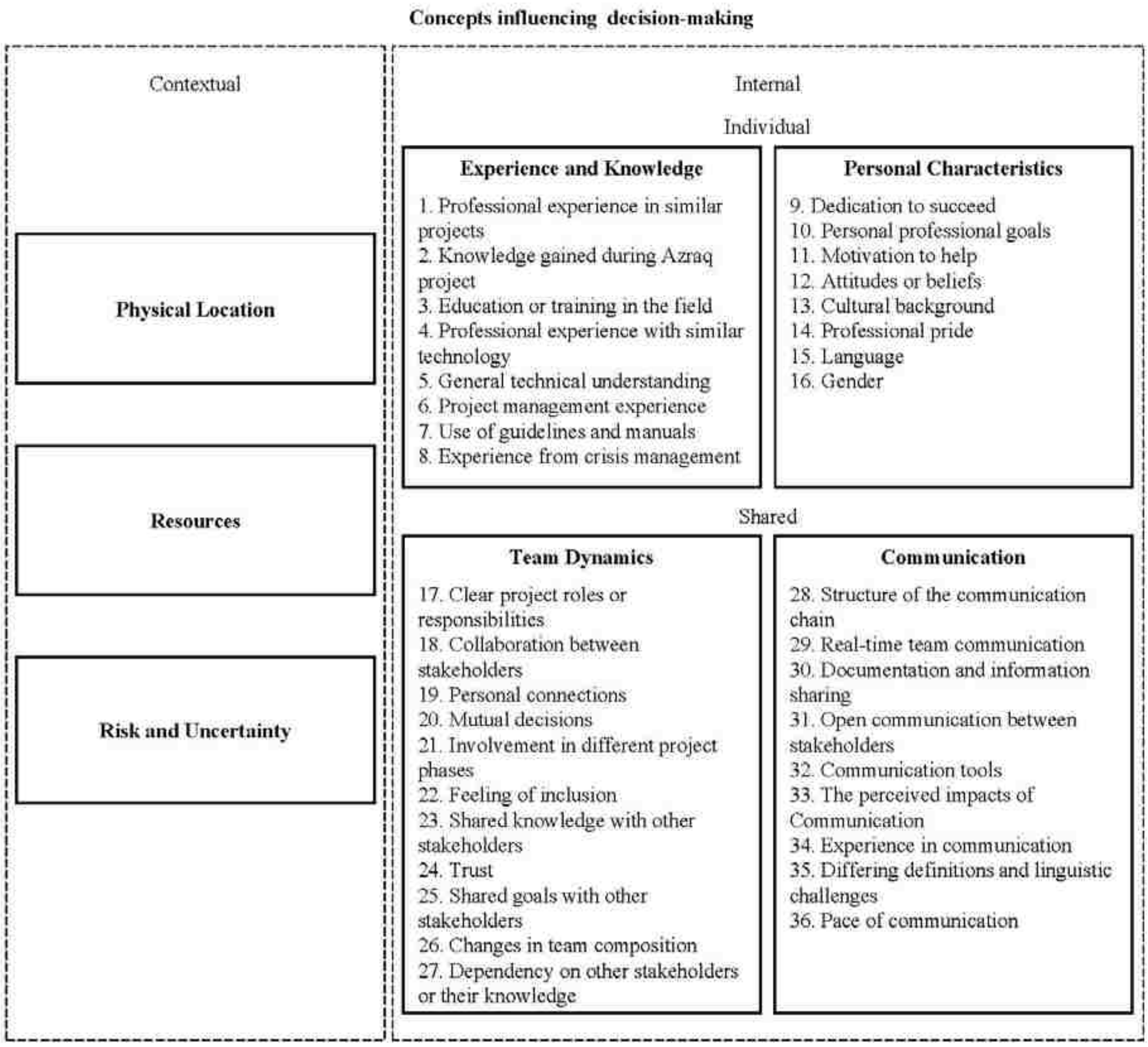

Figure 3. Concepts influencing stakeholder decision-making during wastewater treatment system startup.

2.4. RESULTS

2.4.1. STAKEHOLDER PERSPECTIVES ON OPERATIONAL DECISION-MAKING

Four themes identified from the quantitative content analysis are discussed in detail. These include, prior and relevant knowledge, personal characteristics, team dynamics, and the role of communication all relevant to the impact on team functioning. Table 2 presents the four themes and 36 concepts included in stakeholder mental models on project decision-making and summarizes how many participants from each stakeholder groups discussed them during their interviews.

Table 2. Stakeholder Mental Models

n = number of participants who mentioned the topic during interview

Experience and Knowledge	**Coordinators**	**Consultants**	**Project Managers**	**Operators**	**Total**
1. Professional experience in similar projects	3	2	2	4	11
2. Knowledge gained during Azraq project	3	2	2	4	11
3. Education or training in the field	3	2	2	3	10
4. Professional experience with similar technology	2	2	1	2	7
5. General technical understanding	2	1	1	2	6
6. Project management experience	2	2	2		6
7. Use of guidelines and manuals		2		3	5
8. Experience from crisis management	3				3
Personal Characteristics	**Coordinators**	**Consultants**	**Project Managers**	**Operators**	**Total**
9. Dedication to succeed	3	2	2	2	9
10. Personal professional goals	3	1	1	1	6
11. Motivation to help	2	1		2	5
12. Attitudes or beliefs	2	1	2		5
13. Cultural Background	2	2	1		5
14. Professional Pride	2	1		1	4
15. Language		2	1		3
16. Gender	1				1
Team Dynamics	**Coordinators**	**Consultants**	**Project Managers**	**Operators**	**Total**
17. Clear project roles or responsibilities	3	2	2	4	11
18. Collaboration between stakeholders	3	2	2	3	10
19. Personal connections	1	2	1	4	8
20. Mutual decisions	2	2	1	3	8
21. Involvement in different project phases	3	1	1	2	7
22. Feeling of inclusion		2	1	4	7
23. Shared knowledge with other team members	3	2		2	7
24. Trust	2	2		2	6
25. Shared goals with other stakeholders	3	1		1	5
26. Changes in team composition	3		1	1	5
27. Dependency on other stakeholders or their knowledge	1	2	2		5
Communication	**Coordinators**	**Consultants**	**Project Managers**	**Operators**	**Total**
28. Structure of the communication chain	3	2	2	4	11
29. Real time team communication	2	1	2	4	9
30. Documentation and information sharing	3	1	1	3	8
31. Open communication between stakeholders	2	1	1	3	7
32. Communication tools	1	2	1	2	6
33. The perceived impacts of communication	2	1	1	1	5
34. Experience in communication	2	1			3
35. Differing definitions and linguistic challenges	1	2			3
36. Pace of communication		1	1		2

Prior and relevant knowledge

All but one of the interviewees (OP#4) had received professional training in the field that they were working in, and everyone had professional experience from similar (e.g. wastewater or crisis response) projects. However, many interviewees noted that due to the specific nature of the project and the extreme operating conditions, previous work experience in similar wastewater treatment projects was not applicable in decision-making. Both consultants who had been working with several MBBR systems before stated that they had to "*change the way they saw the project*" (CS#2), adapt to a slower pace of decision processes, a "*higher number of unknowns*" (CS#1), lack of remote process control, and a longer project timeline. The operators who had work experience with wastewater treatment but not specifically with MBBR on the other hand felt like the technical knowledge they had gained from prior projects was not fully applicable to the Azraq project, but that it may have helped them in understanding the new process technology faster. The only professional group whose prior experience was fully applicable in the project was the coordinators. When asked about the reasons behind trying new processes or making changes in the dynamic project conditions, one of the coordinators (CR#2) explained that "*they know how to do these kinds of things*" because it is in their employer organization's problem mandate.

Several stakeholders (CR#1, PM#1, CR#2, CS#2, CR#3) agreed that one of the main issues delaying the startup process was that all stakeholders did not understand how the wastewater treatment system worked. Although technical information was shared between the governmental authority, consultants and project coordinators, there were a lot of misunderstandings, which could have been avoided by "*bringing the governmental authority to understand what this system is all about*" (CR#1) early in the process. When it came to the participants' personal understanding of the technology, they described feeling *"confident with the technology*" (CR#3), described the startup procedure as "*straightforward*" and "*simple process*" (CS#2) and were able to explain the basic idea behind the biological process when asked (CS#1, CR#1, OP#1, OP#2, CS#2, CR#3).

Three of the four process operators (OP#1, OP#2, OP#4) saw manuals as their primary source of information in process operation or troubleshooting. However, as one of the operators (OP#1) noted, most of the available material is targeted to different operating conditions, e.g. colder climates and different waste strength, and that for that reason the solutions they offer are not always applicable in Azraq. Both consultants (CS#1, CS#2) shared this view on the applicability of manuals and books in extreme operating conditions: while they found technical literature to be a useful tool in educating and facilitating communication with operators, they prioritized operator's prior experience and technical problem solving skills over readymade solutions.

All interviewees agreed to have gained professional knowledge and new skills over the course of the project and later used the acquired knowledge in decision-making. Operators generally mentioned learning things that were related to the process configuration or technology while coordinators, project managers and consultants were discussing topics related to project management, human resources and the physical and cultural environment. CR#1 described having gained knowledge in the form of "*different exposures*" to new project contexts, but did not feel like the project had added anything into her technical professional knowledge. Consultant CS#1 mentioned learning the importance of "*planning vis-à-vis having plans*" and consultant CS#2 had changed the format in which he shared information with other stakeholders early on in the project after learning that in a multi-lingual environment, diagrams and figures were "*worth a thousand words*".

Personal characteristics

Although personal characteristics, motivation, attitudes or beliefs were not directly addressed in the interview questions, many stakeholders discussed their impacts on the individual or team-level decision processes. Most participants (CR#1-3, CS#1-2, PM#1-2, OP#1, OP#4) mentioned situations where a thrive to succeed and perform well was guiding their decision-making. Coordinators were willing to "*stretch their capacity*" (CR#2), and "*run here and there*" (CR#1) in order to support each other under the work load and keep the projects moving forward. Some operators mentioned being motivated to expand their knowledge on wastewater treatment technologies in order to become experts and more successful in their job (OP#1, OP#4). In addition to the dedication to succeed in their role, several participants discussed having personal interest in wastewater treatment and emergency response (CR#1, CR#3, CS#2, OP#1, OP#4). For instance, CR#1 said that she "*likes to be challenged*" and was happy to join the Azraq project when she was asked. Operators OP#1 and OP#4 shared fascination towards wastewater and treatment processes and claimed to "*really enjoy*" (OP#4) their work in the Azraq wastewater treatment plant and "*see more than just the water*" (OP#1) when they work with the process.

Working in emergency response conditions was seen as a challenging task (CR#1, OP#3, CR#2) and many stakeholders took pride on being able to complete their work despite the constant uncertainty (CS#1, PM#1, PM#2, OP#3). Several participants also saw the project as a way to "*make a difference in the world*" (OP#1) and help the people in need. In order to serve the refugee population, the stakeholders were willing to work in more risky environments (CR#1, CR#3), for longer hours (CR#2, PM#1, OP#3), "*in emergency mode all the time*" (PM#1) and for lower compensation (CS#2, OP#1).

When it came to the project implementation challenges, participants had strongly differing views on the concepts that caused issues. For instance, consultants (CS#1 & CS#2) both mentioned cultural and bureaucratic differences as concepts that were hindering project delivery, whereas CR#1 specifically denied the role of cultural differences in implementation challenges. Several interviewees mentioned that the lack of mutual language had an impact on the stakeholder interaction during the construction and startup processes (CS#1, CS#2, CR#1, PM#2) and some mentioned that it had caused misunderstandings earlier in the project (CS#1, CS#2, CR#1). Interestingly, cultural and language where only discussed by consultants, coordinators and project managers: none of the operators brought up any issues related to cultural or linguistic misunderstandings.

Role of communication

Azraq WWTP project participants believed that "*open lines of communication*" (CS#1) facilitated decision-making in the startup phase and that many issues in project delivery were eventually solved by improving communication processes (CR#1, PM#1, CR#2, CS#2). Some even claimed that communication was the "*most important thing in project management*" (CS#1) and that the whole project is "*basically about the communication and not the real [treatment] process*" (CR#1). Within each stakeholder group, communication was lateral and quick as people who needed to talk to each other were typically in the same physical location and interacting with each other frequently (CS#1, OP#1, OP#2, OP#3). When describing field interactions with their colleagues, participants used words like "*collaborative*" (CS#1), "*both-sided*" (OP#1) and "*comfortable*" (OP#4) and several mentioned having a sense of "*being heard*" (CS#1, OP#1, OP#4). Communication between different stakeholder groups on the other hand was described as a hierarchic and slow process that did not fit the pace of operational decision-making in the wastewater treatment plant. Consequently, in situations that demanded immediate decisions, some of the operators and project managers had occasionally taken action without getting official authorization from their higher-ups or from the governmental authority to conduct "*the engineering work*" (PM#1) and ensure optimal process operation. However, several participants had already seen improvements in inter-group communication over the course of the project and were satisfied with the impacts that has had on the project. PM#1 explained that a change in the communication structure had helped increase the speed of interaction with the governmental authority and CS#2 found that communication had "*evolved over time*" and things were moving to a better direction after coordinators had taken "*a more active role in expressing what is possible, what is economical and what can be done*".

Several participants brought up suggestions on who should be involved in communication during different project phases. Overall, the participants seemed to agree that all stakeholders involved in project communication should have strong technical background and that only people that are "*focal for the technical implementation*" should be participating in the meetings (CR#1, PM#1, CR#2, CS#2). Some also believed that several changes in the process configuration could have been avoided, if process operators would have been brought in the conversation earlier in the design phase and their technical recommendations would have been taken into account.

As most project communication involved stakeholders from different organizations and countries, the main methods for sharing project related information were e-mail and phone calls. This was seen as a challenge by several stakeholders who believed that the lack of face-to-face discussions often led to misunderstandings as "*people from different cultures communicate differently*" (CS#1). Many participants also talked about challenges related to the language barrier (CS#1, CR#1, CS#2, PM#2) between different stakeholders and believed that it was more problematic in remote communication than during physical meetings (CS#2, CR#1). While some participants believed that the biggest breakthroughs in project progress were accomplished through face-to-face discussions (CR#1, CR#2), some considered the number of stakeholder meetings too high and would have preferred using the meeting time for "*doing the job in the field*" (PM#2).

Impact of team functioning

Several participants discussed the importance of collaboration and co-operation in successful rapid response project delivery (CS#1, CR#1, CR#2, PM#1, OP#3, CS#2, OP#1, OP#4). For participants in management positions, coordination between different stakeholders (PM#1), open feedback between partners (CR#2) and "*successful working partnerships*" (CS#2) were seen as important things in facilitating decision-making. The participants who were directly involved in wastewater treatment plant construction or operation on the other hand valued collaborative problem solving processes (CS#1) and "*comfortable*" (OP#4) and "*family-like*" (OP#1) work environment where they felt like their opinions were heard. Several participants found that collaboration had gotten easier over time as stakeholders "*built relationships with each other*" (CR#1), became more familiar with each other's skills (OP#3) and adapted their roles according to the preferences and needs of other project partners (CR#2, CS#2).

While none of the interviewees mentioned having trouble defining their personal responsibilities, some revealed having been confused over stakeholder roles at some point over the course of the project (CR#1, CS#2, PM#2). According to consultant CR#1, the misunderstandings about stakeholder responsibilities were clarified over time, and by the time the last interviews for the research were conducted, everyone was finally "*around the same objective*". All participants who discussed the issue agreed that some of the delays in project delivery could have been avoided, if the roles of the different stakeholder groups were more specific from the beginning (CR#1, CS#2, PM#2) and if all parties would have had a more active role in the beginning of the project (CR#1, OP#1, CS#2). Several participants also saw a specific role definition within each stakeholder group as an advantage (CS#1, PM#1, OP#3). For instance, consultant CS#1 believed that "*clearly defined roles*" helped the team finish construction and installation work in time and project manager PM#1went as far as to recommend that emergency response project managers should always hire people who are familiar with each other's skills and areas of expertise before starting to work together.

Aside from the confusion over some of the stakeholder roles and responsibilities, the participants were generally well aware of each other's professional skills and trusting towards other team members' judgement in decision making situations (CS#1, CR#1, CS#2, CR#3). While some participants felt like they did not need to personally know the people they work with (CR#1), others believed that personal connections helped them succeed in their work (OP#1). Some of the participants reported having friends or former colleagues help them get recruited in their current position (OP#4, OP#1) and others mentioned seeking professional advice from friends with whom they had previously worked (OP#2, CR#1, CR#3).

2.5. CONCLUSIONS

The stakeholder mental model constructs showed that decision-making during the construction and operation of the Azraq WWTP was impacted by a number of non-technical internal concepts. This was evident in every stakeholder group and on all organization levels. The findings suggest that while decision support tools, e.g. frameworks and computer-aided simulations, may be beneficial to planning and high-level organization of disaster response activities (Little et al. 2015; Pradhan et al. 2007), their value in guiding individual or group-level decision-making in wastewater treatment during disaster response is arguable as stakeholder decisions are not solely based on objective technical evaluations. Rather than investing time on developing specific tools for emergency sanitation project teams such as the one in Azraq, future research should support practitioners by improving disaster response teams' ability to recognize, share and address concepts that impact decision-making during uncertainty in project, team and individual level. Our future research will address this need by constructing an evidence-based input-mediator-output (I-M-O) model of the field decision processes during Azraq WWTP project delivery, and investigate each decision input's and mediator's relationship with the resulting quality of wastewater treatment.

Azraq WWTP project stakeholders identified inclusive communication as one of the major concepts facilitating WWTP project delivery. "Collaborative work environment" and "opportunity to get one's voice heard" were present in stakeholders' mental models on successful project delivery and many stakeholders believed that project delays could have been avoided by involving all partners in communication and decision making earlier in the WWTP design process. While effective communication is widely recognized as a critical success factor in both construction and emergency response project delivery (Chua et al. 1999; French et al. 2015; Zhou 2011), few studies have discussed best practices in field communication during construction and disaster response (Foltz and Brauer 2005; Laufer et al. 2008; Shohet and Frydman 2003). Our exploratory findings suggest that flat communication structures and careful consideration of who needs to be involved in each decision process contribute to effective project communication in WWTP construction and management during disaster response. However, more field research and case studies are needed to understand specifically how wastewater treatment professionals' field communication practices influence decision-making, WWTP project delivery and eventually wastewater treatment performance during disaster response. Through field research, researchers and practitioners could identify ways to facilitate stakeholder communication in future disaster response efforts, for instance by developing methods to improve project stakeholders' ability to share their mental models, or by developing effective and well-fitting communication and data sharing technologies.

In addition to the importance of effective field communication, the Azraq WWTP stakeholders' mental models highlight the role of shared technical knowledge and stakeholders' ability to locate knowledge within the project team. Prior research in team performance has repeatedly demonstrated how teams that have overlapping and similar understanding of the concepts related to their work perform better than teams that do not have shared concepts (Cannon-Bowers and Salas 2001; Lim and Klein 2006; Mohammed and Dumville 2001). This study is one of the first to discuss stakeholder mental models and shared knowledge in the context of emergency sanitation and wastewater treatment. Based on these findings, wastewater treatment delivery during future disaster response scenarios could be streamlined by ensuring that all stakeholders understand the opportunities and limitations related to the applied treatment technology before their involvement in the project begins, and that they are fully aware of other stakeholders' responsibilities and specific fields of expertise. Future research could explore best practices in implementing pre-project trainings to improve shared knowledge and expertise location in interdisciplinary emergency sanitation teams, and evaluate the resulting impacts on WWTP project performance during disaster response. An example would be to expand the work of Faraj and Sproull (2000) and Ellwart et al. (2014), and explore the effectiveness of different structure-oriented and perception-oriented team knowledge measurements, such as the TMM Index, in predicting and improving WWTP project team performance during disaster response.

Finally, the findings showed that project stakeholder relied heavily on their prior professional experience and "lessons learned" from similar projects when making decisions, even if this knowledge was not fully applicable to the Azraq WWTP project. Over time, stakeholders gained new skills and knowledge that helped them navigate the new project environment, but many described this process happening primarily through trial and error. To facilitate WWTP construction and operation during future disaster response efforts, future research in emergency sanitation construction and management should aim to identify and test methods that help project stakeholders utilize their prior professional experience and technical capabilities more effectively in the disaster response context. This could be accomplished through two different complementary directions of work. The first research direction, training and education, could build on the prior work of Mendonca and Fiedrich (2006), and develop and evaluate training programs that encourage individuals to apply improvisation and flexibility in operational and managerial decision-making. Specific issues that should be addressed in the context of emergency response wastewater treatment are decision-making with unreliable or limited technical information and unique regulatory restrictions. As the shift towards more flexible decision processes would also require adjustments in stakeholder roles, responsibilities and hierarchies, the second research direction should focus on investigating how existing project delivery systems could be adjusted to better respond to the needs of advanced wastewater treatment plant construction during disaster response. By building on the findings of disaster response case studies, such as the one presented here, and the existing literature on change management strategies in the engineering and construction industry (Kim et al. 2017; Lines and Vardireddy 2017), future studies should specifically aim at providing practitioners detailed guidelines on how to facilitate fast-paced project decision-making through re-distributing decision power between stakeholders.

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3. PATHWAYS TOWARD UNDERSTANDING RAPID WASTEWATER TREATMENT RESPONSE AT A LARGE REFUGEE CAMP

ABSTRACT

Wastewater treatment is increasingly affected by global challenges such as climate change, and large-scale disasters. As extreme events become more commonplace, wastewater treatment systems need to become more resilient to rapid and unpredictable operational shifts. This study contributes to the currently limited body of empirical research on wastewater treatment during disaster response by investigating the startup and operation of a modular moving bed bioreactor (MBBR) at the Azraq refugee camp in Jordan. The wastewater treatment plant is among the first to attempt modern on-site treatment in refugee camp setting. The wastewater treatment plant was initially started when the camp served around 30,000 people, and was still in start-up as the population increased to 55,000. The study introduces a novel Input-Mediators-Output-Input (IMOI) model approach for understanding the cause and consequence relationships between wastewater treatment system function, human evaluations of system performance, and the resulting decisions for operational changes. The findings suggested that disaster response scenarios would benefit from 1) prioritization of operational feasibility of the wastewater treatment system over the achievable nutrient removal rate, 2) management of stakeholder expectations related to the limitations and capacities of the applied treatment technology and project environment, and 3) re-structuring organizational decision and communication processes and resources to better support rapid decision-making on-site.

KEYWORDS: Disaster response, Resiliency, Case Study, Rapid wastewater treatment start-up

3.1. INTRODUCTION

Wastewater treatment is dynamic. Diurnal community water use, seasonal infiltration patterns and the resulting changes in the characterization on wastewater influent are well understood. Less, however, is known about sudden changes, such as in response to storms or catastrophic operation failures. As extreme weather events and climate-related natural and humanitarian disasters are predicted to increase in frequency and veracity (Adger et al. 2014; Kunkel et al. 2013; Webster et al. 2005), wastewater treatment facilities are prone to face rapid increased loadings due to unexpected regional-scale population shifts following natural disasters or political unrest. While storm events are associated with rapid increase in hydraulic loading, population shifts result in rapid increase in organic carbon loading. Events that result in rapidly increasing organic loading (i.e. biochemical oxygen demand, BOD loading) are especially challenging for process operation as they can overwhelm the microbial capacity of wastewater treatment and can lead to the discharge of untreated or partially treated sewage (Silcio et al. 2010; Tchobanoglous et al. 2003). However, because disasters generally occur with minimal advance warning, data capture for these events can be difficult. Consequently, there is little knowledge on operator responses or resources for decision support under shock-BOD loading scenarios during disaster response.

Azraq refugee camp in Jordan is among the first in the world to include on-site wastewater treatment using a secondary treatment MBBR system (Knell 2014). High BOD-loading are common in where water use is curtailed (Hammer 2001), such as in in refugee camps (Cronin et al. 2008). In addition to the high-concentration wastewater, the Azraq wastewater treatment system startup and operation is challenged by the camp's remote location in the middle of a desert, the limited access to resources and harsh environmental conditions. While guidance documents and academic literature for selecting and designing Water, Sanitation, and Health (WASH) activities in refugee camps exist (Cronin et al. 2008; Fenner et al. 2007; Zakaria et al. 2015), there are limited directions for tackling the challenges faced during operational phases. Especially, guidelines on modern wastewater treatment systems operation are missing. Similarly, while some information about wastewater conditions in hot dry climates is available (Hammer 2001), expected wastewater characteristics from refugee camp WASH pump-out stations was not available. Thus, the wastewater treatment efforts at Azraq were initiated without the benefit of knowledge typically used for successful wastewater facility engineering design.

The wastewater treatment process used at Azraq was a moving bed biofilm reactor (MBBR). MBBR are an integrated fixed film activated sludge (IFAS) technology that employ solid support structures approximately 1 to 2 cm in diameter (biomedia) to promote biofilm growth. Reactor tanks are typically filled to ~1/3 volume with the small biomedia. The end result is a combination of both biofilm and disbursed bacterial growth. Prior findings in MBBR kinetics has demonstrated the system's improved capacity to respond to changes in process loading and water flows, and to tolerate high particulate and organic loading rates and extreme temperatures (Johnson 2006 ; Lee et al. 2006; Lima et al. 2017). This is the first time an MBBR was used in a refugee camp.

The unprecedented application of MBBR technology in a refugee camp puts the Azraq wastewater treatment project team in a challenging, high-stress operation environment. While human capacity for making judgments and decisions is known to be altered in high-stress environments (Hammond 2000), collective decision-making and team performance can improve over time in all environments, if individuals learn to trust each other, and are aware of each other's capabilities (Ellwart et al. 2014; Murphy et al. 2000). The evolution of collective operational decision making and its impacts on team performance have been modeled with different variations of input-process-output models (Ilgen et al. 2005; Littlepage et al. 1995; Pavitt 2014). These models describe processes as "requirements of the environment" (inputs) that become "products for the environment" (outputs) through processes or different stages (processes or mediators) (Ilgen et al. 2005).

This study applied theories based in the psychology of team organization during a rapid start-up of a moving bed bioreactor (MBBR) secondary wastewater treatment operations at the Syrian Refugee camp in Azraq, Jordan. The unprecedented situation allows the documentation of operator decisions under adverse and previously undocumented conditions that were outside technical procedural guidance. By pairing stakeholder mental models on decision-making (Kosonen and Kim 2018) with water quality data, it introduces a novel input-mediator-output-input (IMOI) model approach for explaining the cause and consequence relationships between system function, human evaluations of system performance, and the resulting decisions for operational changes in a high-stress refugee response scenario.

3.2. MATERIALS AND METHODS

3.2.1. DATA COLLECTION

Types of Data Collected

Four types of data were collected in this study: (i) interview data, (ii) researcher observations, (iii) laboratory data collected by the research team, and (iv) data provided by treatment plant project team members.

Interview Data Collection

The interview tool is provided in Appendix 1. The questionnaire and interview process design are described in detail in (Kosonen and Kim 2018), and are described here briefly. The purpose of the interviews was to identify concepts that influenced project team's decision processes during emergency response wastewater treatment. The interviews covered stakeholders' technical understanding, resources used for decision support, procedures in communication and decision-making, and demographics. The questions were designed based on prior findings in emergency response and project delivery research, as well on current understanding of high-BOD loading scenarios at wastewater treatment plants.

Interviews were conducted between January and September 2016. All interviews, excluding one telephone interview, were conducted face-to-face at interviewees' work place. Two interviews were conducted in Arabic, three interviews in English with Arabic assistance and ten interviews in English. Translators were native Arabic speakers who were part of the research team and had a technical background in water and environmental technology. All but two of the interviews were audio-recorded and transcribed. The two interviews that were not recorded were documented by hand-written notes.

Observational Data Collection

Observational data was collected during informal interactions, during wastewater sample collection, and while interviewees provided tours of the wastewater treatment facilities. The observations and information shared was documented in written logs within 24 hours. The researchers also wrote descriptive notes about observed operational practices and wastewater treatment plant performance after the site visits to complement the recorded interview data. As suggested by Roth (2004), observations were used during the data analysis to improve interpretation of the work environment the interviewees described.

Wastewater quality data collection

Azraq employed modular MBBR units, each of which included two reaction chambers in series followed by settling chambers and a chlorine mixing tank. The reaction chambers housed the free-floating biomedia. Coarse air blowers were used for mixing and aeration. The units were gravity fed. The facility was designed for 400 m3 per day with a BOD load of 2000 mg/L.

Wastewater samples were obtained by submerging Nasco Whirl-Pak™ Stand-up sample bags 1-2 feet in the treatment tanks. Bags were double-layed with drain holes cut into the inner bag to allow on-site separation of the MBBR biomedia from the bulk solution. Sampling locations are indicated in Figure 4. After collection, the samples were stored on ice for 3 hours of travel before being transferred to a refrigerator that was set at 4°C. Water quality samples were collected during site visits in February, May, and, September 2016. Time constraints for on-site sample collection that were imposed by security measures resulted in prioritization about sample collection. Additionally, laboratory sampling processing prioritization was used due to sample holding time constraints and the limited time available for UW team member working in the JUST labs during each trip. Samples were not collected in January 2016, as the research team visited on the first day that the facility received wastewater.

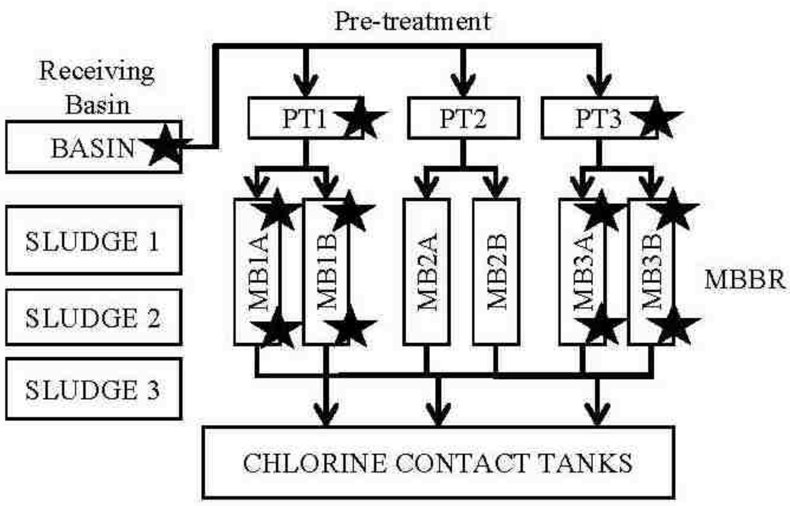

Figure 4. The layout of the Azraq wastewater treatment plant and the wastewater sample collection points.

Table 3. Participant details and interview schedule at the Azraq refugee camp

	Interviewee Job Title	Role in WWTP[1] Project	Work Location	Work Experience	Education	Experience with Emergency Response	Language	Interview Date
Phase 1 - Secondary Treatment								
Technical Consultants	Technical Sales (CS#1)	Involved in early design and installation, providing operators and project owners consultancy on process relate & other technical issues, head of wastewater treatment process start up procedures	Mainly off-site & abroad, occasional visits to the WWTP	6 years	MS[2]	No	English	Jan-16
Contractors	WWTP operator 1 (OP#1)	Responsible for wastewater treatment process operation on site, monitoring process performance, testing water quality and implementing operational changes when needed	On-site daily	20 years	undergoing BS[3]	No	English & Arabic	Feb-16
Contractors	WWTP operator 2 (OP#2)	Responsible for wastewater treatment process operation on site, monitoring process performance, testing water quality and implementing operational changes when needed	On-site daily	23 years	Vocational training	No	Arabic	Feb-16
NGO employees	WASH[4] officer 1 (CR#1)	Coordinating WASH initiatives in refugee camps and host communities. Liaison between all project stakeholders and representative of the project owner.	Working in several locations, visiting WWTP several times a month	12 years	MS	Yes	English	Feb-16
NGO employees	WASH officer 2 (CR#2)	Coordinating WASH initiatives in refugee camps and host communities. Liaison between all project stakeholders and representative of the project owner.	Mainly located in the NGO headquarters	19 years	BS	Yes	English	Feb-16
Phase 2 - Nitrification-Denitrification								
	Interviewee Job Title	Role in WWTP Project	Work Location	Work Experience	Education	Experience with Emergency Response	Language	Interview Date
Technical Consultants	Project manager (CS#2)	Head of wastewater treatment process design, involved in design and operation throughout the project, coordinating technical & operational changes with operators and project owners, consulting operators and project owners	Mainly off-site & abroad, occasional visits to the WWTP	15 years	BS	No	English	Apr-16
Contractors	WWTP operator 3 (OP#3)	Responsible for wastewater treatment process operation on site, monitoring process performance, testing water quality and implementing operational changes when needed	On-site daily	5 years	No training/education	No	Arabic	May-16
Contractors	Construction manager (PM#1)	Project manager overseeing the construction of the wastewater treatment plant, representative of the contractor working for the consultant, communicating project delivery related issues with consultants and aid organizations	Mainly off-site but within the country, visits to WWTP when needed.	16 years	BS	No	English	May-16
NGO employees	WASH officer 1 (CR#1)	Coordinating WASH initiatives in refugee camps and host communities. Liaison between all project stakeholders and representative of the project owner.	Working in several locations, visiting WWTP several times a month	12 years	MS	Yes	English	May-16
NGO employees	WASH officer 2 (CR#3)	Coordinating WASH initiatives in refugee camps and host communities. Liaison between all project stakeholders and representative of the project owner.	Working in several locations, visiting WWTP several times a month	Yes	BS	Yes	English	May-16

	Interviewee Job Title	Role in WWTP Project	Work Location	Work Experience	Education	Experience with Emergency Response	Language	Interview Date
Phase 3 - Nitrification								
Technical Consultants	WASH consultant (CR#2)	Outside consultant brought into the project to facilitate process re-configuration and technical decision-making related to the biological treatment process.	Working in the Azraq refugee camp	25 years	BS	Yes	English	Sep-16
Contractors	WWTP operator 1 (OP#1)	Responsible for wastewater treatment process operation on site, monitoring process performance, testing water quality and implementing operational changes when needed	On-site daily	20 years	undergoing BS	No	English & Arabic	Sep-16
NGO employees	WASH officer 1 (CR#1)	Coordinating WASH initiatives in refugee camps and host communities. Liaison between all project stakeholders and representative of the project owner.	Working in several locations, visiting WWTP several times a month	12 years	MS	Yes	English	Sep-16

[1]WWTP = Wastewater treatment plant, [2]MS = Master in Science, [3]BS = Bachelor in Science, [4]WASH = Water, sanitation and hygiene

3.2.2. DATA ANALYSIS

Interview data analysis and modeling

The written narratives of the interview data were analyzed using the Atlas.ti qualitative data analysis software (Atlas.ti 2014). In the first phase, researchers used conventional content analysis (Hsieh and Shannon 2005) to identify factors that impacted stakeholders' mental models, i.e. thought process constructs, during the first five months of the Azraq wastewater treatment plant project delivery. Further description of the initial thematic analysis is presented in the first section of Appendix 2. In the second phase of the data analysis, mental model interview data was combined with wastewater quality data with the purpose to build an Input-Mediator-Output-Input model to describe relationships between stakeholder decisions and wastewater treatment system performance. The methods that were applied in constructing the model are described in detail in the second section of Appendix 2.

Water quality analysis

Total suspended solids (TSS) and volatiles suspended solids (VSS) were measured utilizing standard method 2540 D and 2540 E, respectively. Chemical oxygen demand (COD) and soluble chemical oxygen demand (sCOD) of the samples were measured using Hach LCK514 (100-2000 mg/L-O_2 range) COD cuvettes that were catalyzed using a Hach DRB200 heating block. The sCOD was defined as the COD remaining in the sample after passing it through a 0.45 um cellulose acetate syringe filter (ThermoScientific F2500-15). Absorption spectroscopic measurements were made using a Hach DR5000 which returned the value of the COD for the sample. Dilutions with MilliQ water were necessary for most samples to low COD and sCOD to levels within range of the measurement kit. Hach cuvette test kits were utilized to measure the total nitrogen (LCK 138: 1-16 mg/L-N), ammonium (LCK 303: 2-47 mg/L-N), nitrate (LCK 339: 0.23-13.5 mg/L-N), and nitrite (LCK 342: 0.6-6.0 mg/L-N). The total nitrogen LCK 138 cuvettes were heated using a Hach DRB200 heating block. All samples were analyzed utilizing spectroscopic measurements made by a Hach DR5000.

3.3. RESULTS AND DISCUSSION

The temporal analysis of the interview and water quality data resulted in the development of the Input-Mediator-Output-Input (IMOI) model that presents the first 9 months of the Azraq WWTP operation. IMOI and other forms of input-process-output models are typically illustrated as three-column diagrams, where decision inputs are on the left side, mediators in the middle and the outputs on the right. Figure 6 introduces the conceptual IMOI model that uses the same format to present Azraq WWTP operation in three phases: 1 "Secondary Treatment", 2 "Nitrification-Denitrification" and 3 "Aeration process".

Since NGO employees, consultants and wastewater treatment plant operators used outcomes of the previous startup procedure to direct the next procedure, the model describes the outputs of the model at t_{n-1} as inputs to the model at t_n. Each input, mediator, and output of the decision process that, according to the interviewed stakeholders, demonstrated a positive impact on wastewater treatment delivery during refugee response is marked with a (+) sign. Respectively, those inputs, mediators, and outputs that hindered or delayed wastewater treatment delivery during refugee response are marked with a (-) sign. Other features that were neither positive nor negative are not given any sign.

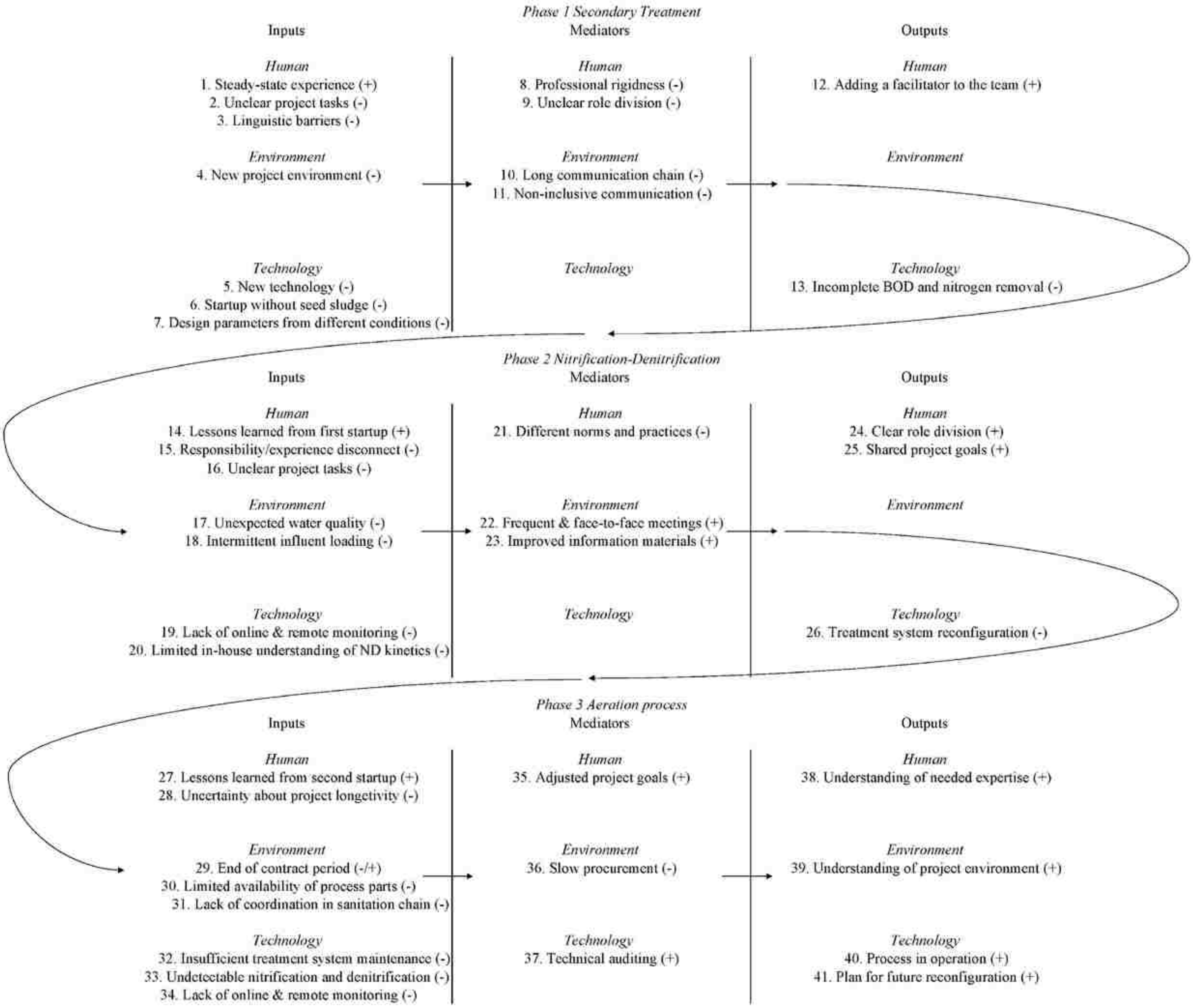

Figure 5. IMOI model describing the first 9 months of process operation in Azraq WWTP

3.3.1. PHASE 1: SECONDARY TREATMENT

This section of the full IMOI model presents stakeholder decisions and treatment system performance during the first startup of the Azraq WWTP. During this startup, the facility was configured as a secondary treatment operation. A receiving basin floated by gravity to a pre-treatment MBBR with intermittent course air flow used for mixing. Pre-treatment effluent flowed into aerated MBBR. MBBR effluent was intended to flow to chlorination contact tanks while solids were intended to flow to solids storage. During this phase, the COD influent was measured as 1940 mg/L. Details for interview data are presented in Table 3 and details for water quality testing are presented in Table 4.

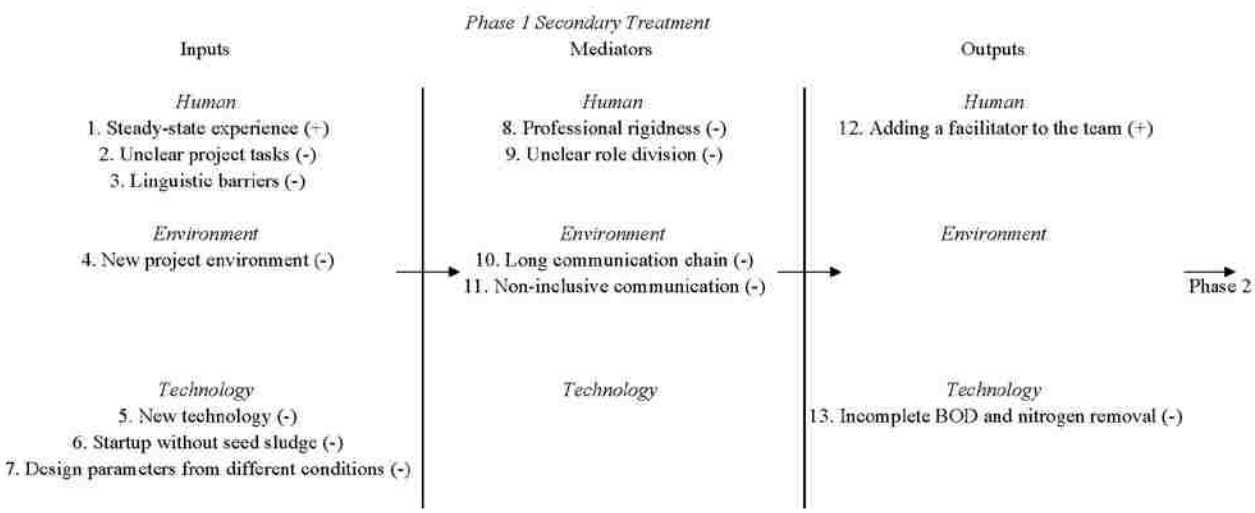

Figure 6. The IMOI model for first wastewater treatment system startup.

Decision process inputs

In phase 1, stakeholders were working in an environment where a number of factors were new (Figure 7): The MBBR system was the first ever in Jordan (#5, Fig. 7), none of the project stakeholders had previously worked together and the Azraq refugee camp was a new environment for everyone involved (#4, Fig. 7). To navigate the new project environment, stakeholders relied on their prior professional experience. Consultants and operators had prior experience from steady-state wastewater treatment process operation (#1, Fig .7), but they did not have experience from emergency response. NGO employees were the only ones who had experience from international emergency response operations. The novelty of the dynamic project conditions, along with some linguistic barriers and misunderstandings (#3. Fig, 7), led to confusion over project delivery system details and stakeholder tasks and responsibilities (#2, Fig. 7). For instance, the consultants reported to not have fully understand the role that the local governmental authority had on environmental permitting and process operation oversight. Also, they perceived that the local authorities were expecting them to provide more technical information and training about the MBBR technology than they were initially prepared to provide.

As Azraq refugee camp was still under construction when the MBBR system design and refurbishment was completed, the wastewater treatment process design parameters, such as influent wastewater characteristics and flow estimates, were received from the WWTP in the Zaatari refugee camp in Northern Jordan (#7, Fig. 7). Daily operation and process monitoring were conducted by using experience-based methods and following "steady-state" practices that stakeholders working on-site, despite their different professional backgrounds, had mutually agreed upon. When wastewater was first introduced to the system in January 2016, both pre-treatment and MBBR tanks were fully aerated to activate bacteria in the wastewater stream and provide for optimal biomass growth, as the facility was not inoculated with an activated sludge seed per local governmental authority's request (#6, Fig. 7). After initial start-up, the plan was to reduce aeration in the pre-treatment tanks to create anoxic conditions using intermittent aeration for mixing.

Decision process mediators

During Phase 1, the practices in organization-level collaboration and decision-making were for a large part emulated from prior refugee response or WWTP projects. The communication structure followed the hierarchy of the project delivery system, which also defined the relationships between different stakeholders. In general, the remote location of the Azraq WWTP and lack of internet connection made communication between stakeholders challenging. Outside of the occasions that the consultants, project owners and operators were all physically working on the project site and communicating with each other directly, the stakeholders needed to follow a three-step pattern to share project related information and data (#9, Fig. 7). The operators took samples from different process stages every eight hours, conducted on-site water quality tests and documented the results on an operation log daily. The results were shared with sub-contractor's main office by phone. From the subcontractor main office, the information would move on to the consultants and project owner via e-mail, and eventually from the project owner to the local governmental authority through e-mail, phone calls or project meetings. The long communication chain led to delays in information sharing and prevented stakeholders from having an up-to-date understanding of the process performance. By the time the process information reached the regulatory agency making the ultimate decision on whether or not the plant could start discharge, the conditions at the Azraq WWTP had already changed and operators were forced to make operational decisions with or without other stakeholders' approval.

While stakeholders working on-site reported having a mutual understanding of their task division, the division of responsibilities was reported as ambiguous on the organizational level (#11, Fig. 7). The process startup was delayed by several months due to misunderstandings related to discharge permits and acceptable startup procedures between the consulting and manufacturing company and the local governmental agency. Given that the consulting and manufacturing company had formed a contract with the acting project owner and was not aware of the fact that all water infrastructure projects in Jordan had to go through the water agency, the involvement of the water agency was a surprise to them. They perceived that the agency was expecting to have more involvement in the project from the very beginning, since it had been an active decision maker in all stages of the Zaatari WWTP project (#10, Fig. 7). Due to a high level of professional rigidness and a mentality of "sticking to what we know" (#8, Fig. 7), the issue of conflicting expectations was slow to resolve as both parties believed they were acting according to their role in the project.

Decision process outcomes

The original startup plan for the Azraq WWTP was to fill the system with tap water and introduce wastewater gradually by starting from a highly diluted influent. While the consultants who had successfully started multiple MBBR processes through this approach considered this "a common practice", this approach was new in Jordan and thus not compatible with the discharge permit requirements of the local water authority. As a result, the operators ended up following the local authority's requirements and starting the process by filling two of the three MBBR trains with undiluted wastewater and recycling it from the MBBR tanks back to the influent basin (see Azraq WWTP footprint in Figure 5). The objective of this procedure was to build up activated sludge in the MBBR tanks and gradually increase the system's BOD and nitrogen removal efficiency to the level required in the discharge permit. However, the rapid introduction of the raw wastewater with extremely high COD and ammonia concentrations (Table 5) was too intense for the volume of the aerated compartments: the biological activity in the MBBR tanks never met the discharge permit requirements, which in turn prevented the introduction of fresh wastewater and active microorganisms, and eventually led to stakeholders' mutual perception on that all microbial activity had been lost (#13, Fig. 7). As the project owner NGO and the consulting group agreed that the failure in process startup was partially a result of conflicting expectations and miscommunication between the local governmental authority and other project stakeholders, the NGO brought in a new coordinator whose primary goal was to facilitate future project conversations and "*clear the misunderstanding from contractual point of view as well as on ground*"(#12, Fig. 7).

3.3.2. PHASE 2: DENITRIFICATION-NITRIFICATION PROCESS

This section of the full IMOI model presents stakeholder decisions and treatment system performance that led to the second startup of the Azraq WWTP. During this startup, the facility was configured as a denitrification-nitrification process. A receiving basin floated by gravity to a pre-treatment MBBR with mechanic mixing in anoxic conditions. Pre-treatment effluent flowed into aerated MBBR. MBBR effluent was recycled back to the receiving basin from where it would enter the MBBR pre-treatment again. During this phase, the COD influent was measured (on average) as 1944 mg/L. Details for interview data are presented in Table 3 and details for water quality testing are presented in Table 4.

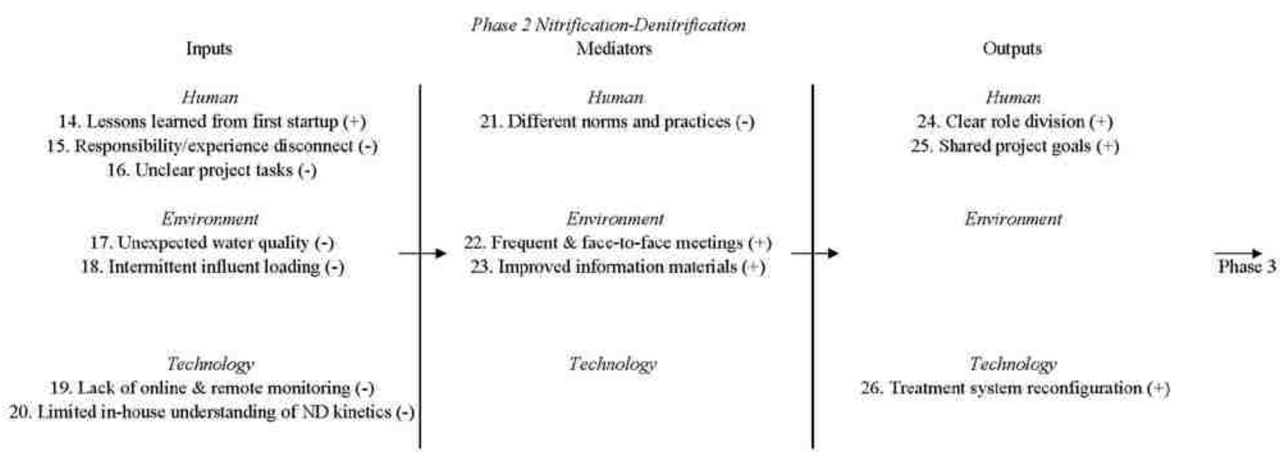

Figure 7. The IMOI model for second wastewater treatment system startup.

Decision process inputs

In the second phase, all stakeholders were more familiar with the MBBR technology and site conditions at the Azraq camp (#14, Fig. 8). The first unsuccessful startup had implicated that the designed aerated capacity of the three MBBR treatment trains was not sufficient for successful BOD and nitrogen removal with the unexpectedly high strength influent wastewater from the Azraq camp (#17, Fig. 8). While high BOD loading had been accounted for in the initial design, the wastewater treatment system capacity was not sufficient for treating the high ammonia (NH_3-N) in the influent wastewater (Table 4). In addition to the unexpected influent water quality, the treatment system capacity was challenged by the intermittent influent loading pattern (8 hours of truck delivery, 16 hours without fresh wastewater), which cause a peak in the BOD levels in the aerated MBBR tanks (#18, Fig. 8).

While understanding of the operation conditions had increased after the first phase, the interviews revealed a continuing confusion over stakeholder role and task division, especially between consultants and the local governmental authority (#16, Fig. 8). In addition to the lack of shared understanding of the local discharge permit requirements, the operational decision-making was challenged by the difficulties in establishing a working satellite or cellular data connection for remote process monitoring and control (#19, Fig. 8): The MBBR treatment units were originally designed to be overseen through a remote monitoring system, and the on-site operators were hired to run the mechanic operations. In the absence of remote monitoring, operators' role was shifted to making judgments of the biological standing of the MBBR process, which was not what they were trained to do (#15, Fig. 8). Because the camp administration was providing conflicting information about the feasibility of the remote monitoring system, the stakeholders stayed hopeful that the connection could eventually be established, and did not immediately start seeking for alternative long-term data sharing options. Instead, the treatment plant was equipped with on-site laboratory equipment for in situ water quality analysis that could be used to support treatment system operation until the remote monitoring system was set up. The plan was that the operators would conduct the analysis and share the results with the consultants overseas, who would then assist them in decision-making. However, due to the complicated, multi-step data sharing process between the project stakeholders, the water quality information reached the consultants with a 5 - 7 day lag, which restricted their timely participation in operational decision-making. With limited support for analyzing and controlling the Nitrification-Denitrification kinetics (#20, Fig. 8), the operators ended up trusting their personal judgment and visual evaluations more than on-site laboratory analysis when making operational decisions.

Decision process mediators

Many stakeholders related the unsuccessful first startup to a collective failure to practice inclusive communication from the very beginning of the project (#11, Fig. 8). Some also saw it as a result of conflicting professional cultures and different norms and practices between stakeholders (#21, Fig. 8): For instance, one of the consultants described how their company had to "*change the way the saw the project*" as they were used to more interaction with clients than what they had with the Azraq WWTP project stakeholders and to more flexible and faster decision processes than what was possible in the humanitarian relief setting. After the introduction of the new WASH coordinator in February, the consultants and NGO employees started having weekly phone conversations to share project related information with each other. At the same time, the stakeholders who were present in Jordan also shifted from having on-site meetings "when needed" to weekly routine meetings on site. While consultants and NGO employees found the frequent discussions helpful, one of the contractor representatives thought that constant face-to-face meetings were taking time away from getting the actual work done:

"*I learned that all of these organizations, they love meetings. I love practical things, I don't like to sit. You can get here and speak for two hours, why not just do the job in the field?*".

Eventually, the weekly phone conversations between consultants and NGO employees revealed a need for bringing all stakeholders together for a face-to-face discussion of the project goals and current limitations: Regardless of consultants' efforts on providing the water authority and other stakeholders explanatory materials on MBBR technology and Azraq WWTP configuration (#23, Fig. 8), the stakeholders were yet to reach an agreement about the preferred startup procedure and discharge permit requirements. Finally, four months after the initial startup, all stakeholders met up to discuss the re-startup of the Azraq WWTP (#22, Fig. 8).

Decision process outcomes

The face-to-face meeting with all stakeholders ended up being a turning point for the project and a step towards shared understanding of the project goals and role division (#24,#25, Fig. 8). The conversation helped consultants understand the local environmental regulations and how they prevented the authorities from giving the Azraq WWTP a permit to discharge before the system had demonstrated desired BOD and nitrogen removal rate in full-scale operation. Respectively, the local water authority was able to voice their concerns on the application of MBBR technology and explain their feelings of mistreatment for not being included in all of the technical decisions early on.

As a result of successful negotiations, the stakeholders decided to re-start the Azraq WWTP as a denitrification-nitrification process (DN-process) to reduce organic load and improve nitrification efficiency in the aerated process section. In the new process configuration, the pre-treatment tanks were anoxic while the MBBR tanks were aerated (#26, Fig. 8).

3.3.3. PHASE 3: AERATION PROCESS

This section of the full IMOI model presents stakeholder decisions and treatment system performance during the third startup of the Azraq WWTP. During this startup, the facility was configured as an aeration process. A receiving basin floated by gravity to a pre-treatment MBBR with intermittent course air flow used for mixing. Pre-treatment effluent flowed into aerated MBBR. MBBR effluent was discharged to a retention pool. The measured COD influent concentrations varied largely between 4724 and 432 mg/L. Details for interview data are presented in Table 3 and details for water quality testing are presented in Table 4.

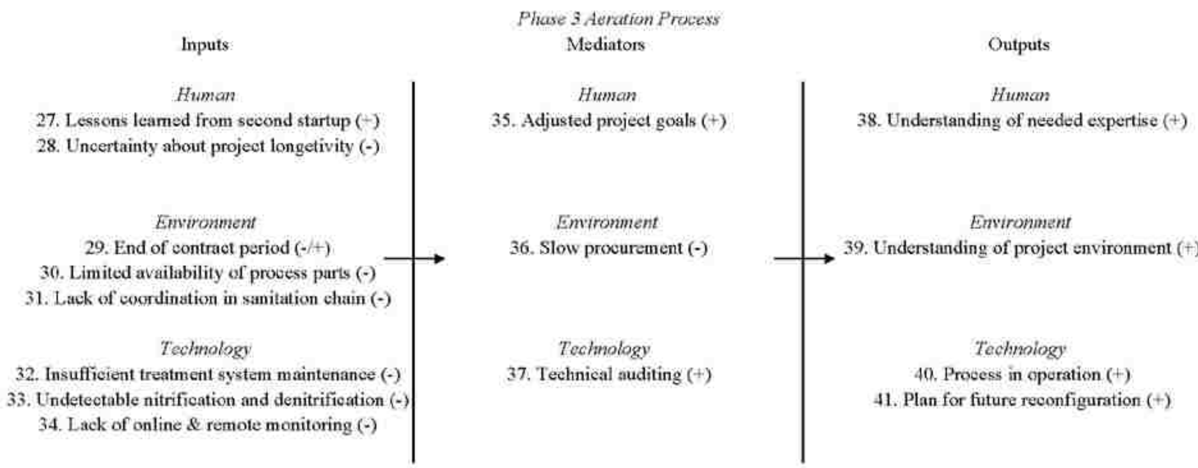

Figure 8. The IMOI model for third wastewater treatment system startup.

Decision Process Inputs

The denitrification-nitrification process that was started up in Phase 2 failed to meet the discharge permit requirements for full-scale operation. As the system was not initially designed to have denitrification, the ratio of the process capacity in pre-treatment (i.e. anoxic) and MBBR (i.e. aerobic) tanks was not optimal for nitrogen conversion reactions or BOD reduction. The water quality data reflected the non-optimal process conditions by showing unchanged total nitrogen levels and inconsistent ammonia levels between the pre-treatment and MBBR tanks (#33, Fig. 9) and no detectable patterns in suspended solids (TSS/VSS) or COD/sCOD concentrations (Table 4).

In the beginning of the third process startup, stakeholders had again increased their understanding of the project environment at the Azraq WWTP, and how its specific limitations affected process operation (#27, Fig. 9). The Azraq WWTP was run down strain by strain after two months of operation in July 2016. The stakeholders saw the treatment process failure first and foremost as a result of the non-optimal ratio between the aerated and anoxic process capacity. All stakeholders that were interviewed in the beginning of the third phase claimed that they had been aware of the process volume issue from the very beginning of the second startup, but considered the DN-process as their only feasible option to achieve a high enough BOD and nitrogen reduction, and thus wanted to try it regardless. One of the operators believed that this decision would not have been made, if all parties involved in decision-making would have been aware of the truck delivery schedules and the intermittent hydraulic loading pattern at the Azraq WWTP, and understood the limitations that it set to the denitrification-nitrification process operation. Thus, lack of coordination in the refugee camp sanitation chain was seen as a factor that challenged treatment system operation (#31, Fig. 9). In addition to the process capacity limitations, stakeholders believed that the fact that a number of process parts, such as control boards, air diffusers and generators had been severely damaged without operators' knowing during the first two startup attempts was another factor contributing to the failure of the ND-process startup (#32, Fig. 9). The air diffuser malfunctioning was seen as especially harmful for the startup success as the dissolved oxygen concentration in the aerated process parts never reached the desired level and the nitrification step of the DN-process was left incomplete. Replacing process parts was time consuming both due to the camp's remote location and project owner NGO's slow procurement processes, and in consequence operators often needed to make the most of a partially operational system (#30, Fig. 9). Additionally, Azraq WWTP operation was challenged by the continuing lack of real-time process monitoring and water quality data (#34, Fig. 9). The interviewed stakeholders discussed considering these limitations when planning future project directions, as the contract period with consultants and their sub-contractors was coming to an end with uncertainty about continuity in stakeholder involvement (#28, #29, Fig. 9).

Decision Process Mediators

In Phase 3, the experience from the two failed startups had finally convinced all stakeholders that the Azraq WWTP would not meet the original discharge permit requirements for nitrogen species (NH_3-N, NO_2-N and NO_3-N). As a result, the WWTP performance goals were adjusted (#35, Fig. 9): Instead of following the stricter environmental regulations for discharging the treated wastewater to the *wadis* (a desert valley), the effluent wastewater quality was regulated for agricultural re-use which allowed for higher ammonia concentrations (WHO 2006). Additionally, the local water authority allowed the WWTP to discharge treated wastewater, if it was able to reach the regulative requirements with one third of the system's full capacity.

The wastewater treatment system was run down strain by strain and the team replaced aerators and pipes, and emptied the tanks from biomedia. After the systematic technical auditing and refurbishment process (#37, Fig. 9), the Azraq WWTP was re-started at its original configuration with both pre-treatment and MBBR tanks aerated. At this point, all interviewed stakeholders had consensus in making the best out of the existing resources and adding process capacity in couple of months when the current contract with the consultant manufacturer was ending. While a plan for adding anoxic pre-treatment already existed, its implementation as part of the third startup was not possible due to the slow procurement and tendering procedures of the project owner NGO (#36, Fig. 9).

Decision Process Outputs

In phase 3, the Azraq WWTP was operating at one third of its full capacity and meeting the adjusted treatment requirements for ammonium nitrogen and BOD (#40, Fig. 9). The treated wastewater was discharged to a retention pool, from where it was further distributed to agricultural use in the vicinity of the refugee camp. The water quality data revealed high variability in influent wastewater quality (Table 5), which, according to the operators and NGO employees on site, was normal as trucks delivered waste from different parts of the camp one at a time. The highly varying COD and TSS levels between different MBBR tanks did not serve as strong evidence of successful activated sludge build up, but the detected levels of nitrite and nitrate nitrogen suggested the existence of active nitrifying bacteria.

Overall, the experience from the three startup processes had made the stakeholders conclude that the Azraq WWTP configuration with aerated pre-treatment and MBBR units was never a good fit for the operational conditions at the refugee camp (#39, Fig. 9). The whole facility was going to be re-designed with added anoxic capacity (#41, Fig. 9). In addition to the process design, stakeholders were looking to make changes in project team level and have more technical expertise present on site in the future: The communicational misunderstandings between different stakeholder groups along with the difficulties in establishing a real-time data sharing system had revealed a need for local experts whose assistance was readily available when WWTP operators were in need of technical support (#38, Fig. 9).

3.4. CONCLUSION

A novel qualitative Input-Mediator-Output-Input (IMOI) model was developed for presenting relationships between stakeholder decisions and wastewater treatment system performance during modular MBBR wastewater treatment system startup at Azraq refugee camp. The findings showed that the adoption of sophisticated treatment technology in extreme and remote conditions can be impacted by a number of human, environment and technology related concepts that influence operational decision-making. The lessons learned from the Azraq WWTP project can be further applied in design, construction and startup of advanced wastewater treatment facilities that operate in dynamic or unpredictable conditions similar to Azraq refugee camp.

The MBBR process was chosen for the Azraq refugee camp for its demonstrated capability to adjust to dynamic process conditions, e.g. extreme temperatures and high-organic loading scenarios (Aygun et al. 2008; Daude and Stephenson 2004). The consulting company that was hired to design the MBBR modules and oversee the plant startup process had the necessary qualifications, and while none of the other stakeholders had experience with attached growth systems, their lack of specific experience with MBBRs was initially not perceived as a challenge. However, during the system startup in Phase 1 (Figure 6), it became apparent that the limited shared technical understanding of MBBR process and its operational controlling options in refugee camp environment were strongly contributing to delays in project delivery: In regulation level, the misunderstandings about MBBR process startup procedures led to permitting restrictions that ended up contributing to the failure of the first startup. In the field, the unsuccessful remote monitoring system setup led to an unexpected shift in stakeholder role division, and forced on-site staff with limited understanding of the MBBR system to make operational decisions without real-time decision support from experts. The experience from Azraq suggests that in disaster response wastewater treatment system (WWTP) projects, the uncertainties related to the application of new treatment technologies should be carefully assessed early in the design phase. Furthermore, the findings suggest that technologies that are not familiar to the stakeholders are not introduced during rapid response scenarios when project delivery is already challenged by a number of other factors. These findings align with prior research that has shown that the complexity of the disaster response environment may overwhelm stakeholders and make them reluctant to familiarize themselves with new technologies due to inadequate training or beliefs that these technologies are too complex to be used (Jennings et al. 2015). In the context of wastewater treatment and sanitation, academic literature has previously discussed the impacts of end-users' cultural acceptance and public perception on sanitation system selection and sustainability (Kaminsky and Javernick-Will 2013; Poortvliet et al. 2018), but recommendations on refugee camp wastewater treatment system selection have thus far not included operator acceptance or familiarity in the selection criteria (Fenner et al. 2007). More case study data from rapid response events is needed for exploring in more depth, which concepts in stakeholders' shared technical understanding are critical for successful wastewater treatment system startup during rapid response.

In addition to limited familiarity with the treatment technology, stakeholder decisions were challenged by a number of factors that were related to contradictions between stakeholder expectations and the reality. Some of these factors were, for example, unclear role division and lack of shared goals. Many of the interviewed stakeholders perceived that project delays could have been avoided through effective expectation management related to the new wastewater treatment technology and project environment. In Azraq project, conflicts were eventually resolved through mediation, when the project owner (NGO) brought in a project coordinator, who was familiar with the different professional norms and technical understanding of all stakeholder groups and thus able to facilitate the development of shared project goals. However, this only happened after the WWTP design and construction were completed and the first startup had proven to be unsuccessful. To prevent unnecessary project delays, disaster response WWTP projects could set an expectation management plan in place before the initiation of the project negotiations, and aim for managing stakeholder expectations continuously throughout the project implementation, as recommended by Kwak et al. (2012) and Barker and Frolick (2003). Examples from prior infrastructure projects have shown that effective expectation management can be established through various methods, ranging from transparent project-level data sharing (Skibniewski 2009) to employee training programs (Administration 2003; Sadatsafavi et al. 2016). The findings from Azraq WWTP project demonstrate the benefits of centralizing expectation management responsibilities to a project mediator or coordinator that has prior experience from disaster response, and has enough overlapping expertise with all project stakeholders to create a trusting relationship with them (Butler 1991). However, more case study research is needed to define the best practices for expectation management program implementation as part of rapid wastewater response efforts. Additionally, we suggest that the opportunities related to Integrated Project Delivery (IPD) in advanced wastewater treatment plant construction and operation during emergency response will be explored in more detail. Many of the same issues that could be solved with expectation management could potentially be tackled through early stakeholder involvement, multi-party agreements and other IPD features that have proven to be effective in other infrastructure projects (Hanna 2016), but are yet to be discussed in academic literature on wastewater treatment plant construction and operation (Culp 2011; Shane et al. 2013).

Finally, we suggest that future academic research explores methods for increasing field staff's capacity for rapid decision-making in demanding project conditions. In Azraq WWTP project, process operation was often impacted by slow and hierarchic communication between stakeholder groups, as well as operators' inability to make autonomic decisions without confirming with other stakeholders first. To facilitate future rapid wastewater treatment response projects, academic research should identify and analyze organizational processes that would provide on-site response crews with more flexibility and autonomy in decisions related to process operation and optimization. Re-distribution of decision power during rapid response would entail that the operators that are hired to oversee advanced wastewater treatment systems under high uncertainty scenarios have an in-depth understanding of biological process kinetics, or, alternatively, have access to expert support on site. Additionally, it would entail that wastewater treatment professionals working in the field have tools to mitigate the impacts of uncertainty stressors in their personal decision-making (Hammond 2000; Kahneman 2011; Staw et al. 1981). Capacity for flexible decision-making could be improved through trainings that help create understanding of mental models on decision-making under uncertainty (Kosonen and Kim 2018), improve field staff's readiness for procedural and structural innovation during uncertainty (Somers 2009), and prepare them for taking on different roles when necessary (Webb et al. 1999). Future research should explore in more depth how such trainings could be implemented to best serve the needs of rapid wastewater treatment response teams.

In conclusion, the novel IMOI modeling approach on operational decisions was successful in documenting multiple challenges related to wastewater treatment start-up at the Azraq refugee camp. While our findings suggest that advanced wastewater treatment can contribute significantly to the long-term livability of refugee camps, we recommend that its feasibility and rationality would always be evaluated case by case based on the contextual conditions at the location of the temporary settlement. It was discovered that mental model concepts that guided stakeholders' decision-making, such as lack of shared technical understanding and dissimilar project expectations, delayed the startup of the advanced wastewater treatment system. Consequently, a successful adoption of sophisticated treatment technology in extreme and remote conditions, such as in a refugee camp, requires stakeholders' familiarity with the opportunities and challenges related to the system.

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Table 4. Water quality data from three different process phases in Azraq WWTP

Phase 1 - Secondary Treatment

	Operation		Water Quality							
	Aeration	Disharge	COD (mg/L)	sCOD (mg/L)	TSS (mg/L)	VSS (mg/L)	Total N (mg/L – N)	NH3-N (mg/L – N)	NO2-N (mg/L)*	NO3-N (mg/L)
Pretreatment 1	Yes		1940	1141	190	156		Above range	0.279	2.81
(replicate)					186	156		258	0.257	2.85
(replicate)					310	255				
MBBR 3A (chamber 1)	Yes							632	0.214	2.8
(replicate)									0.186	2.82
(replicate)									0.184	3.14
MBBR 3A (chamber 2)	Yes	No			295	245		536		
(replicate)					305	285		514		
MBBR 3B (chamber 1)	Yes		1528		345			Above range	0.173	2.72
(replicate)					315	285		490	0.198	2.7
MBBR 3B (chamber 2)	Yes		967	1002	275			586	0.102	2.55
(replicate)					325			528	0.092	Below range

* All below detectable range

Phase 2 - Denitrification-Nitrification

	Operation		Water Quality							
	Aeration	Discharge	COD (mg/L)	sCOD (mg/L)	TSS (mg/L)	VSS (mg/L)	Total N (mg/L – N)	NH3-N (mg/L – N)	NO2-N (mg/L)	NO3-N (mg/L)
Basin A	No		1978				820			
Basin B	No		1909		594	531	1440	1315		
Pretreatment 2 Front	No			508	517	263	1050	442		
Pretreatment 2 Mid	No		1081	379.6			1255	1000		
MBBR 1A (chamber 1)	Yes		3630		1271	653	1215			
MBBR 1A (chamber 2)	Yes		2290		854	608	1410			
MBBR 1B (chamber 1)	Yes									
MBBR 1B (chamber 2)	Yes				300	243				
MBBR 2A (chamber 1)	Yes		2944	2164			2240	717		
MBBR 2A (chamber 2)	Yes		1320		600	400				
MBBR 2A (clarifier)		No		1912			1205	1260		
MBBR 2B (chamber 1)	Yes			1760			1205	468		
MBBR 2B (chamber 2)	Yes		1897		553	420	1210			
MBBR 2B (clarifier)			736	1704			1100	1205		
MBBR 3A (chamber 1)	Yes			1716			1575			
MBBR 3A (chamber 2)	Yes				1700	1214	1150			
MBBR 3A (clarifier)				1344						
MBBR 3B (chamber 1)	Yes			1336						
MBBR 3B (chamber 2)	Yes									
MBBR 3B (clarifier)				2008						

Phase 3 - Nitrification

	Operation		Water Quality							
	Aeration	Discharge	COD (mg/L)	sCOD (mg/L)	TSS (mg/L)	VSS (mg/L)	Total N (mg/L – N)	NH3-N (mg/L – N)	NO2-N (mg/L)	NO3-N (mg/L)
Basin	No		4724	366	670				0.433	4.43
(replicate)			832	354	460					6.3
Basin Fresh Water	No		432	199	367				0.311	2.24
(replicate)			440		407					
Pretreatment 1	Yes		774	172	673			342	0.299	4.51
(replicate)					713					8.08
Pretreatment 3	Yes		986	281	397			408	0.402	5.32
(replicate)					380					
MBBR 1A (chamber 1)	Yes		1666	217	2005			308	0.308	8.36
(replicate)					1873				0.26	12.08
MBBR 1A (chamber 2)	Yes		424	181	355			318	1.32	3.21
(replicate)			410	181	373				0.73	6.6
MBBR 1B (chamber 1)	Yes	Yes								
MBBR 1B (chamber 2)	Yes									
MBBR 2A (chamber 1)	Yes									
MBBR 2A (chamber 2)	Yes									
MBBR 2B (chamber 1)	Yes									
MBBR 2B (chamber 2)	Yes									
MBBR 3A (chamber 1)	Yes		654	299	495			202	Above range	10.4
(replicate)					533				Above range	
MBBR 3A (chamber 2)	Yes		824	387	515			121	Above range	10.4
(replicate)			770	387	400				Above range	
MBBR 3B (chamber 1)	Yes									
MBBR 3B (chamber 2)	Yes									

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4. COMPARATIVE STUDY ON ADVANCED WASTEWATER TREATMENT DELIVERY DURING REFUGEE RESPONSE – LESSONS LEARNED FROM FINLAND AND JORDAN

ABSTRACT

Large-scale population displacement, such as the global refugee crisis, has demonstrated potential to overwhelm wastewater treatment facilities and increase enviromental pollution in the host communities. While academic research has discussed features that improve wastewater treatment systems' resiliency towards other types of disasters and rapidly changing operation conditions, concepts that contribute to successful startup, refurbishment, and operation of biological treatment systems during refugee response are yet to be identified. This study takes a novel approach to analyzing wastewater treatment system resiliency by presenting an Input-Mediator-Output (IMO) model analysis on empirical data on advanced wastewater treatment delivery during refugee response in Jordan and Finland in 2015-2016.By comparing two distinctively different case studies, the research takes initial steps in identifying principles that contribute to timely refugee response in advanced WWTPs on the dimensions of human resources, project environment, and wastewater treatment technology. These principles include 1) clear role division between agencies and stakeholders, 2) improving "human capacity" for rapid response decisions, 3) selecting a process that fits the regulative and operational environment, 4) enabling direct and fast information sharing and 5) establishing fast-track permitting processes for disaster conditions. Wastewater treatment system operators, regulative authorities and aid organizations can use these findings to support rapid decision-making in future disaster response situations.

KEYWORDS

Biological wastewater treatment, WWTP startup, emergency response, WWTP operation, large-scale population displacement

4.1. INTRODUCTION

Wastewater management and treatment are critical during disaster response for ensuring the protection of human health and minimizing long-term environmental consequences for the host community (Fenner et al. 2007; Ivers and Ryan 2006). Empirical research and lessons learned from prior disaster response events have resulted in guidelines that help responders with identifying the needed sanitation services (Sparkman 2012), selecting the most suitable sanitation systems (Brdjanovic et al. 2015; Fenner et al. 2007; Urich and Rauch 2014; Zakaria et al. 2015) and organizing multi-sectoral stakeholder activities (IASC 2012; WASHCluster 2009). However, these guidelines place little focus on the challenges faced during operational phases after the establishment of the sanitation systems. Especially, directions on emergency operations for modern wastewater treatment systems are missing.

In recent years, academic research has addressed disaster risk mitigation and preparedness of urban water systems through the concept of "resiliency". A growing body of literature has started to define the features of resilient urban wastewater systems, i.e. systems that are able to minimize the magnitude and duration of disruptive events and adapt to changing conditions (e.g. Butler et al. 2016, Johannessen & Wamsler 2017, Schoen et al. 2015, Scott et al. 2012, Xue et al. 2015). Studies to-date have focused on the response to natural phenomena (e.g., extreme weather events leading to influent flow variation) and equipment failures (e.g., power outages, aging infrastructure and mechanical issues) (Cuppens 2012; Currie et al. 2014; Schoen et al. 2015). Political and secondary disasters, such as large-scale population displacement due to natural disasters or political conflicts has received less attention. Given the specific issues related to population displacement scenarios – such as the undefined temporality (UNHCR 2006), and the multi-sectoral, highly political decision-making environment (Francis 2015; Guild et al. 2015) – there is a need to identify features that increase wastewater treatment systems' resilience towards population-displacement scenarios. Experiences from the aftermath of natural and humanitarian catastrophes, such as Hurricane Katrina and Syrian refugee crisis, have already demonstrated the potential for severe environmental impacts when displaced populations overwhelm the biological wastewater treatment facilities in host communities (Farishta 2014; Silcio et al. 2010).

This study takes a novel approach to analyzing wastewater treatment system resiliency by presenting an Input-Mediator-Output (IMO) model analysis on empirical data on advanced wastewater treatment delivery during refugee response in Jordan and Finland. IMO models are widely used in research investigating team decisions, processes, and productivity (Gladstein 1984; Pavitt 2014), but have not been previously applied in the context of wastewater treatment. IMO model describes the wastewater treatment delivery process through "requirements of the environment" (inputs) that become "products for the environment" (outputs) through processes or different stages (mediators). By comparing two distinctively different case studies, i.e., applying polar comparison method (Eisenhardt and Graebner 2007), this research takes initial steps in identifying a set of global stressors in WWTP operation during disaster response. Additionally, it proposes factors that contribute to a successful startup, refurbishment, and operation of biological treatment systems during disaster response. The findings of the study are applicable for improving resiliency and developing disaster response capacity in biological wastewater treatment system operation regarding human resources, project environment, and treatment technology. Wastewater treatment system operators, regulative authorities and aid organizations can use the given recommendations to support rapid response decision-making in future disaster response.

4.2. BACKGROUND

The Syrian Conflict has led to the displacement of over 11 million people both internally and internationally (UNHCR 2018). Ever since the beginning of the Syrian civil war in 2011, the Hashemite Kingdom of Jordan bordering Syria has been one of the countries hosting the largest number of Syrian refugees in relation to its national population (UNHCR 2016). In 2015, the "Syrian refugee crisis" became a worldwide topic as the number of people seeking for asylum in the European Union exploded unexpectedly and sparked an international crisis as countries tried to cope with the flux of people and provide shelter and basic services for everyone (Guild et al. 2015). One of the countries receiving tens of thousands of migrants over a few months was Finland (Finland 2016).The case study countries Finland and Jordan, the scale of their refugee response operations, as well as the technical specifications of the wastewater treatment systems examined in this study, are introduced in Table 5.

Table 5. Finland and Jordan in numbers regarding water, sanitation, and hygiene (WASH), and refugee response.

Water supply and services		
	Jordan	*Finland*
Access to safe drinking water service[a]	93% of the population	97% of the population
Access to safe sanitation services[a]	77% of the population	92% of the population
Renewable freshwater per capita (m^3/y)[a]	77 m^3	19,592 m^3
Refugee response		
	Jordan	*Finland*
Refugee response	Long-term (>5 years)	Short-term (<0.5 years)
Number of registered asylum seekers[b,c]	650,000	32,476
Refugee accommodation	Host community (84%), Refugee camps (16%)	Refugee centers (100%)

Case study 1: Azraq Wastewater treatment plant

The Azraq refugee camp in Northern Jordan (established in 2014) is one of the five official settlements that have hosted Syrian refugees in Jordan since 2011. The Azraq camp is located in a remote area in the middle of Jordanian desert, where temperature changes are substantial, and access restricted. With the designed capacity to serve as a temporary home for up to 130,000 refugees, it is the second largest temporary housing settlement in the country. Azraq is often referred to as the "model refugee camp", as its facilities were designed to overcome problems that Zaatari refugee camp and other refugee camps around the world have experienced (Knell 2014).

Among Azraq's improved facilities is its wastewater treatment plant (WWTP) that is one the first in the world to provide advanced treatment in a refugee camp setting. The wastewater treatment process is a moving bed biofilm reactor (MBBR) process with biological pre-treatment and post-chlorination. The initial design capacity of the treatment process was 400 m3 of wastewater per day, with an expected BOD (Biological Oxygen Demand) load of 800 kg/d. To comply to the Jordanian wastewater treatment regulations, the treated effluent from the system would have to have a BOD concentration of <60mg/L, a TSS concentration of <60mg/L and nitrate (NO_3-N) concentration of 45mg/L (WHO 2006).

Case study 2: Wastewater treatment at Finnish refugee centers

The refugees and asylum seekers that arrived in Finland during the winter of 2015-2016 stayed in refugee centers that were established rapidly in existing, often underused facilities, such as camp centers and old school buildings that were easy to empty with a rapid schedule. Many of these buildings were located in remote areas and were for that reason not connected to centralized public utility services. Instead, the facilities treated their wastewater in small de-centralized biological wastewater treatment plants. This study focuses on three refugee centers in Southern Finland with wastewater treatment system design flows of 20m3/d, 30m3/d, and 58m3/d. The expected BOD loads for the activated sludge systems with

[a] WorldBank (2018). "World Bank Open Data." <https://data.worldbank.org/>.
[b] (UNHCR), U. N. H. C. f. R. (2016). "UNHCR Syria Regional Refugee Response." <http://data.unhcr.org/syrianrefugees/country.php?id=107>. (10/9, 2016).
[c] The Ministry of the Interior, F. (2017). "Pakolainen pakenee vainoa kotimaassaan." <http://intermin.fi/maahanmuutto/turvapaikanhakijat-ja-pakolaiset>.

chemical pre-precipitation were 9.1kg/d, 10kg/d, and 14kg/d, respectively. To comply with the Finnish wastewater treatment regulations, the treated effluent from the WWTP would have to have a BOD concentration of <15mg/L. Regulations for total phosphorus concentration vary between 0.7-1.0mg/L depending on the WWTP.

4.3. METHODS

4.3.1. DATA COLLECTION

Data were collected through interviews with 21 individuals. Altogether 24 interviews were recorded as some individuals were interviewed more than once. All interviewees were involved with wastewater treatment delivery at the Azraq refugee camp in Jordan and the three refugee centers in Southern Finland. Interviews were conducted face-to-face or via telephone between January and September in 2016. In Jordan, two of the interviews were conducted in Arabic, two interviews in English with Arabic assistance and the remaining eight interviews in English. In Finland, all eight interviews were conducted in Finnish. The translators, all native Arabic or Finnish speakers, were part of the research group and had a strong technical background in water and environmental technology. Table 6 summarizes the details about interviewees.

Table 6. Participant details in Jordan and Finland

	Azraq refugee camp - Jordan						
	Interviewee Job Title	Role in WWTP Project	Work Location	Related Work Experience	Education	Experience with Emergency Response	Language
Technical Consultants	Technical Sales	Involved in early design and installation, providing operators and project owners consultancy on process relate & other technical issues, head of wastewater treatment process start up procedures	Mainly off-site & abroad, occasional visits to the WWTP	6 years	MS	N	English
	Project manager	Head of wastewater treatment process design, involved in design and operation throughout the project, coordinating technical & operational changes with operators and project owners, consulting operators and project owners	Mainly off-site & abroad, occasional visits to the WWTP	15 years	BS	N	English
Contractors	WWTP operator 1	Responsible for wastewater treatment process operation on site, monitoring process performance, testing water quality and implementing operational changes when needed	On-site daily	> 20 years	undergoing BS	N	English & Arabic
	WWTP operator 2		On-site daily	>20 years	Vocational training	N	Arabic
	WWTP operator 3		On-site daily	5 years	No training/education	N	Arabic
	Construction manager	Project manager overseeing the construction of the wastewater treatment plant, representative of the contractor working for the consultant, communicating project delivery related issues with consultants and aid organizations	Mainly off-site but within the country, visits to WWTP when needed.	16 years	BS	N	English
NGO employees	WASH officer 1	Coordinating WASH initiatives in refugee camps and host communities. Liaison between all project stakeholders and representative of the project owner.	Working in several locations, visiting WWTP several times a month	12 years	MS	Y	English
	WASH officer 2		Mainly located in the NGO headquarters	19 years	BS	Y	English
	WASH officer 3		Working in several locations, visiting WWTP several times a month	Yes	BS	Y	English
	WASH consultant	Outside consultant brought into the project to facilitate process re-configuration and technical decision-making related to the biological treatment process.	Working in the Azraq refugee camp	>20 years	BS	Y	English

Finnish refugee centers - Finland							
	Interviewee Job Title	Role in WWTP Project	Work Location	Related Work Experience	Education	Experience with Emergency Response	Language
Consultants	Consultant 1	Head of wastewater treatment process design, involved in design and operation throughout the project, coordinating technical & operational changes with operators and project owners, consulting operators and project owners	Working in several locations, visiting WWTP several times a month	5 years	MS	N	Finnish
	Consultant 2	Responsible for regulatory wastewater sampling procedure planning and analyses.	Mainly off-site, monthly visits to WWTPs	> 20 years	MS	N	Finnish
Contractors	WWTP operator / consultant	Responsible for wastewater treatment process operation on site, monitoring process performance, testing water quality and implementing operational changes when needed	Working in several locations, visiting WWTP several times a week	> 20 years	Vocational training	N	Finnish
	WWTP engineer		Working in several locations, visiting WWTP several times a week	4 years	MS	N	Finnish
NGO employees	Head of refugee center	Responsible for running the daily operations of the refugee center	Working at the refugee center	1 year	MS	N	Finnish
	Refugee center manager		Working at the refugee center	1 year	-	N	Finnish
Real estate owners	Real estate owner 1	Selecting contractors, responsible for making final decisions on procurement	Working in several locations, visiting WWTP when needed	1 year	-	N	Finnish
	Real estate owner 2		Mainly off-site, no regular site visits to WWTP	1 year	-	N	Finnish

The topics that were covered included technical understanding, resources used for decision support, procedures in communication and decision-making, and demographics. All questions were open-ended and undirected. Before interviews, the questions were pilot tested with an expert in conducting mental model interviews. Table 7 summarizes the interview topics.

Table 7. Topics covered during stakeholder interviews in Jordan and Finland

1. Background	
Demographics	
Experience with wastewater treatment and emergency response	
2. The biological wastewater treatment system	
Explanation of the current system configuration	
3. Events	
Pre-delivery events	
	Stakeholder communication prior construction
	WWTP system delivery to the site
	Events during construction and assembly
	Events during initial process startup
Recent events	
	Events related to WWTP operation and construction
	Stakeholder communication during these events
	Decision processes and stakeholder roles
4. Resources	
List of resources, including personnel and technology, used during the decision-making the process	
5. Wastewater treatment system performance	
Issues with foaming, bulking, or other problems considered system upsets	
Impacts of process upsets	
6. Operation, maintenance, and decision-making	
Procedures used when making operational changes	
Documentation of operational/assembly changes	
	The content of documents
	The use of documentation and data in decision-making
Lessons learned, expertise gained	

Face-to-face interviews were conducted at the interviewees' place of work (e.g., construction trailer office). Interviewers toured the wastewater treatment plants with the interviewees before or after the interviews. Observational information gained during conversations during tours, during site visits, and during interviews was documented in notebooks during post- tour reflections. Observational and reflective data was used as secondary data to complement the primary interview data.

Interviewees were given an option to have the interviews recorded. All but three of the interviews were audio-recorded and transcribed to text in the language they were conducted in. Hand-written notes were used to document the three interviews that were not recorded.

4.3.2. DATA ANALYSIS

The written narratives of the interview data were analyzed in two phases by using the Atlas.ti qualitative data analysis software as the analysis platform. Figure 10 summarizes the coding and data analysis process. In the first phase, researchers used conventional content analysis (Hsieh and Shannon 2005) to identify factors that impacted stakeholders' mental models, i.e., thought process constructs, during wastewater treatment delivery at Azraq camp. This analysis was based on 12 interviews that were conducted in Azraq wastewater treatment plant in January – May 2016 (Kosonen and Kim 2018). The qualitative coding process revealed seven emerging themes, e.g., groups of concepts, which influenced stakeholder decision-making processes during wastewater treatment plant construction and startup operation. The themes were further divided into contextual (Physical location, Resources, Risk, and

Uncertainty) and internal (Team dynamics, Communication, Personal characteristics and Experience and knowledge) based on whether or not they were dependent on individual stakeholders' or stakeholder groups' input (Kosonen and Kim 2018).

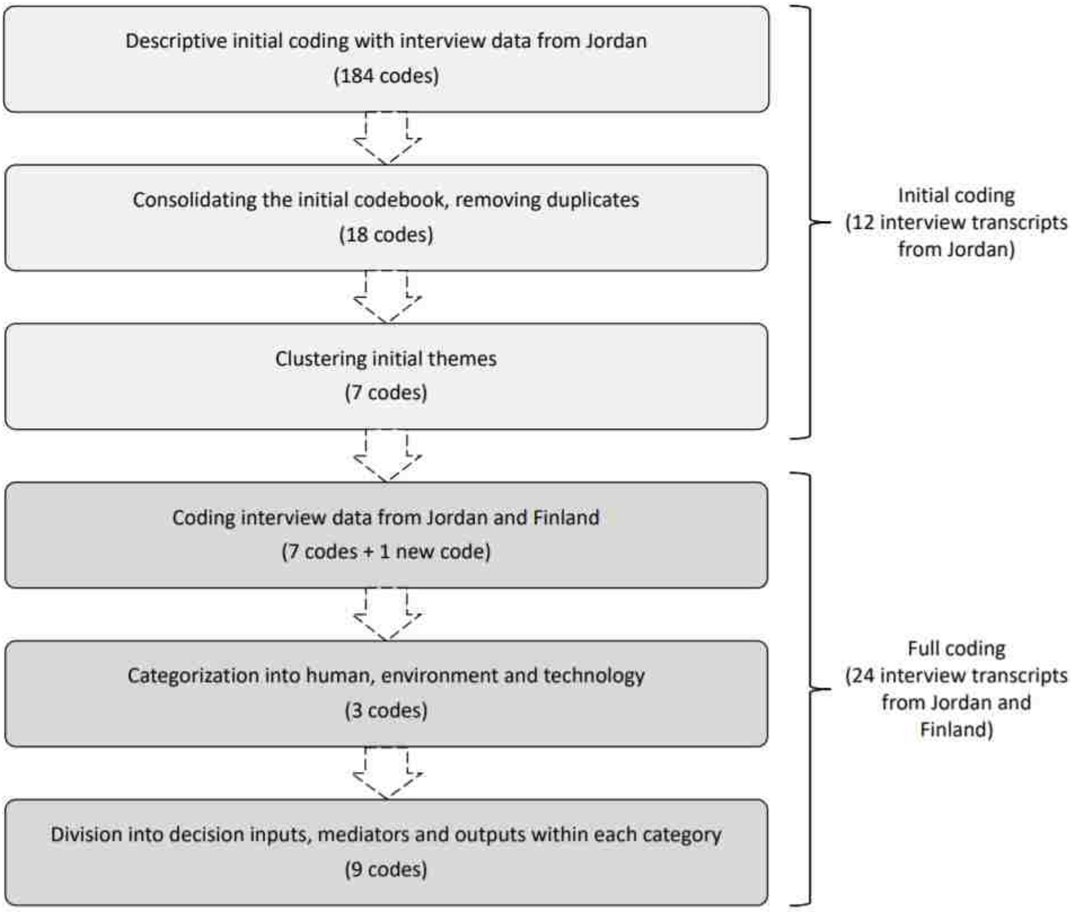

Figure 9. The qualitative coding process

In the second phase of the data analysis, the internal and contextual concepts from the first phase were used as a "codebook" for analyzing the full data set of this study. Since all identified internal concepts were related to stakeholders' personal or group resources, the group was renamed as "human resources". The contextual concept group was in turn re-named as "project environment" as all concepts were related to the environment where stakeholders made decisions about wastewater treatment. Also, a new theme "process technology" was used for all excerpts where stakeholders described wastewater treatment technology and process performance. The coded excerpts were further classified into "decision process inputs," "decision process mediators" and "decision process outcomes" based on their role in the operational decision-making process. For example, during the initial startup "new process technology" was classified as one of the decision process inputs and "the lack of inclusive communication" as one of the decision process mediators that led to the decision process outcome of "incomplete COD and nitrogen removal". Figure 11 presents the results of this analysis.

4.3.3. INPUT-MEDIATOR-OUTPUT MODEL

Input-Output models and their different variations, such as IMOI model, have been widely used in research investigating team decisions, processes, and productivity (Gladstein 1984; Pavitt 2014). IMO models describe processes as "requirements of the environment" (inputs) that become "products for the environment" (outputs) through processes or different stages (mediators). (Ilgen et al. 2005). In this study, the inputs of the IMO model were defined as the human resources, and project environment and treatment system features that existed at the beginning of the wastewater treatment delivery. Following the examples and definitions from prior studies (Ilgen et al. 2005), mediators were defined as the processes and structures through which stakeholders acted during wastewater treatment delivery. The outcomes of the IMO model describe the "state of the matters" at the end of the process, i.e., the wastewater treatment system performance and lessons learned from the refugee response process.

4.3.4. POLAR TYPES COMPARISON

This study uses a polar type comparison method to identify commonalities and distinctions in the wastewater treatment and management decision-making during refugee response in Jordan and Finland. The polar comparison is a standard method for case study research that targets new phenomena that have not been previously studied at large (Eisenhardt and Graebner 2007; Pettigrew 1990). The idea is to create a baseline by examining contradicting attributes between two distinctively different cases (Pettigrew 1990). The results of the comparison can then be used for defining general commonalities across a number of case studies; the logic is that if the extreme examples share similarities, these similarities are expected to be shared with other cases that lie between them.

Due to their distinctive differences presented in Table 7, Finland and Jordan can be considered as extreme cases for wastewater treatment delivery practices during refugee response. As all interviewees were directly involved in operation and reconstruction of biological treatment systems during the global refugee crisis in 2015-2016, the study also represents cases with "high experience-level of the phenomena", which are considered the most appropriate for polar comparison by case study theory (Pettigrew 1990, Eisenhardt and Graebner 2007).

4.4. COMPARATIVE ANALYSIS FINDINGS: COMMONALITIES AND DISTINCTIONS

This section discusses the commonalities and distinctions in wastewater treatment-related decision processes in Finland and Jordan. The first subchapter describes the decision inputs, i.e., the state of the matters when wastewater treatment began. The second subchapter describes the processes and concepts that facilitated or hindered stakeholders in amending the situation in the beginning into functioning wastewater treatment systems, and the third subchapter summarizes the outcomes of the whole process regarding accomplishments and lessons learned.

IMO and other forms of input-process-output models are typically illustrated as three-column diagrams, where inputs are on the left side, mediators in the middle and the outputs on the right. Figure 11 represents the results of the qualitative analysis in the same format. Each input, mediator, and output of the decision process that, according to the interviewed stakeholders, demonstrated a positive impact on wastewater treatment delivery during refugee response is marked with a (+) sign. Respectively, those inputs, mediators, and outputs that hindered or delayed wastewater treatment delivery during refugee response are marked with a (-) sign. Other features that were neither positive nor negative are not given any sign. The model construction process is described in detail in the second section of Appendix 2.

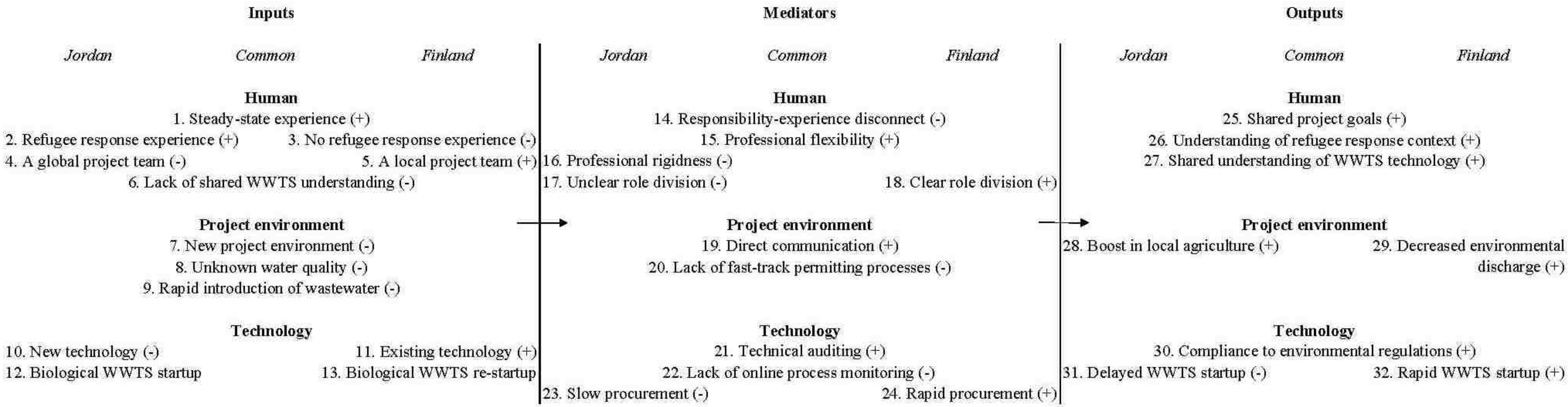

Figure 10. Comparative analysis of wastewater treatment response during refugee crisis in Jordan and Finland

4.4.1. DECISION PROCESS INPUTS

Human

In both countries, stakeholders had steady-state experience (#1, Fig. 11) from wastewater treatment system (WWTP) management. In Jordan, where refugees had started to arrive already in 2011, some stakeholders had also experience with refugee response (#2). In Finland, all stakeholders were new to refugee response context (#3).

In Azraq refugee camp, the global project team (#4) represented different nationalities and working cultures and had to thus adapt to each other's' different norms and practices. In Finland, all stakeholders were local (#5), but the project team included stakeholders with no prior exposure to wastewater treatment-related decision-making and WWTP management. The lack of shared understanding of WWTP (#6) was also experienced in Azraq camp, although all stakeholder groups consisted of individuals with prior exposure to wastewater treatment. This was mainly due to the modular MBBR technology not being previously used in Jordan, and the fact that other decision-makers did not share a technical understanding of its specifications with the consultants.

Project Environment

The project environment (#7) posed new challenges to the stakeholders that were involved in wastewater treatment-related decision-making in both countries. At the startup, stakeholders did not have adequate information on wastewater quantity and characteristics (#8). In Finland, the influent wastewater flow increased drastically overnight, but without a functioning flow meter, it was difficult to discern the amount of flow. Additionally, the stakeholders had limited information of the characteristics of the water, as water quality had only been sampled by quarterly grab samples and no real-time online quality monitoring was available at the WWTPs. In Azraq, the stakeholders had to deal with the fact that the wastewater treatment system was designed for different influent wastewater characteristics and flow patterns than was experienced during the treatment system startup. Before being hauled to the Azraq WWTP, the wastewater had been stored for up to three weeks, and it had become anoxic. Moreover, the organic load of the influent wastewater was much higher than in Za'atari refugee camp, that had been used as the base point for the process design.

The rapid introduction of wastewater (#9) was a common challenge in Finland and Jordan at the beginning of the refugee response. In Finland, the sudden change in influent flow to the WWTP was a direct result of the rushed timeline in establishing refugee centers. In Azraq WWTP, the rapid introduction of the raw wastewater was instead regulation driven: the consultants overseeing the startup process would have preferred first to fill the process with diluted wastewater and increase the concentrations gradually while the microbial communities in the aerated process compartments were building up. However, as this procedure was not compliant with the Jordanian wastewater treatment regulations, the whole treatment system was filled with untreated sewage with the intention to build microbial activity through sludge circulation.

Technology

The modular membrane bioreactor (MBBR) units in Azraq WWTP had never been operated in similar conditions. The remote location, limited access to resources and extreme temperatures put both the applied MBBR technology, as well as the consulting & manufacturer company delivering the technology in a new project environment (#10). The treatment process was started up from the beginning with no seed sludge, which slowed down the activated sludge build-up (#12). In Finland, the WWTP were already in operation at the beginning of the refugee response (#11). However, the combination of a rapid increase in influent hydraulic and organic load and malfunctioning aeration equipment had diminished the existing microbial communities that had been nitrifying in slow rates under the previously carbon-limited conditions and the processes needed to be re-started (#13)

4.4.2. DECISION MEDIATORS

Human

In both Finland and Jordan, stakeholders involved in wastewater treatment-related decision-making experienced an internal conflict between their professional experience and responsibilities during the crisis (#14). In Finland, the real-estate owners had to intervene with no prior experience with procurement decision during WWTP refurbishment. In Jordan, WWTP operators without the necessary MBBR technical familiarity had to advise on operational recommendations remotely. The adoption of new roles was facilitated by all stakeholders' professional flexibility (#15), i.e., willingness to accept tasks beyond their regular responsibilities and working extended hours to obtain new knowledge related to the startup of biological wastewater treatment systems. Stakeholders in both countries also perceived that the flexibility (#16), or the lack thereof, in regulation interpretation was beneficial for wastewater treatment delivery. Many saw this as the reason why the Finnish WWTP were reaching their permit requirements within a couple of months of the beginning of refugee response, and why Azraq WWTP was minimally achieving its effluent quality requirements with one-third of its full capacity nine months after the first startup. Additionally, the unclear role division between Azraq WWTP project stakeholders contributed to the slow progress of the startup process (#17). In Finland, stakeholder roles were quickly defined and divided, which facilitated the rapid startup of the Finnish WWTP (#18).

Project Environment

Frequent and direct communication facilitated decisions on biological wastewater treatment process operation in Jordan and Finland (#19). In Finland, "open lines of communication" were established by regulatory authority's initiative in the very beginning of the refugee response situation, but in Azraq WWTP project, the establishment of direct and frequent communication took time. In addition to helping with clarifying stakeholder roles and responsibilities, direct and frequent communication was essential in resolving issues related to contractual and regulation obscurity in both countries that was caused by the need for rapid response to refugees' needs. In both countries, stakeholders mentioned the lack of fast-track, disaster response suitable, permit processes as one of the mediating factors that challenged timely wastewater treatment delivery (#20).

Technology

The successful startup of the biological treatment processes required systematic technical auditing of the process equipment in both countries (#21). As wastewater treatment plants in Finland were already in operation when the refugee response began, the auditing was conducted as one of the first activities. In Azraq, the treatment process equipment was brand new, so there was no need for assessing its condition at the beginning of the refugee response. Only when two startup attempts had already failed, stakeholders started to suspect the buildup of biological activity was repeatedly failing due to the poor condition of mechanical equipment. The extent of the refurbishment need came as a surprise both in Finland and Azraq, as the inadequately functioning, or completely non-existing, monitoring equipment prevented stakeholders from understanding the "state of the process" through water quality characteristics (#22). The Finnish WWTPs were refurbished quickly: first process parts were replaced less than two months after the refugee centers had started their operation. The rapid reconstruction was possible because the replaced process parts were standard wastewater treatment equipment, the consultant leading the auditing and refurbishment knew local vendors and manufacturers and was able to finalize purchase decisions through an email or phone confirmation from the real estate owner (#24). In Azraq, the refurbishment was not as easy due to the remote location of the camp and the limited availability of the specific process parts needed for the MBBR process refurbishment. Also, the refurbishment process was delayed by the slow NGO procurement processes (#23) that, according to one of the project consultants, added an extra three months to any activity.

4.4.3. DECISION OUTPUTS

The biological wastewater treatment plants in Azraq refugee camp and Finnish refugee centers were eventually operating according to the environmental regulations (#30). In Finland, this happened within a few months from the beginning of the refugee response (#32), while in Azraq, the WWTP was operational 12 months after the initially scheduled startup (#31). In both cases, the successful wastewater treatment plant operation required stakeholders sharing an understanding of the project goals (#25), the refugee response context (#26), and the limitations and capabilities of the applied treatment technology (#27). In Finland, the shared goals were established in the very beginning of the project, whereas in Azraq the stakeholders developed a shared understanding of the project goals after two startup attempts had already failed. Respectively, the WWTPs in Finland were operating according to the regulations sooner than the WWTP in Azraq.

Contrary to the public reservations, the refugee response activities in Finland ended up decreasing, not increasing,wastewater-related environmental pollution in the communities that were hosting refugee centers (#29). The treatment results in the small WWTPs improved regarding effluent BOD, suspended solids and nutrient concentrations, mainly as a result of treatment equipment refurbishment and optimized process operation and all studied systems adhered to the requirements of their environmental operation permits. In Azraq, the establishment of successful wastewater treatment operation on-site enabled agricultural wastewater reuse creating potential new income opportunities for the camp residents and a boost in the local micro-economy (#28).

4.5. IMPLICATIONS

The comparative study on biological wastewater treatment startup in Finland and Jordan during refugee response revealed commonalities and distinctions between the stakeholder decision processes. Interestingly, while the refugee response context was very different in the two compared cases (Table 5), the starting points for wastewater-related decision-making shared many characteristics on human, project environment and technology dimensions. In both countries, stakeholders had limited experience from disaster response and were operating in a new project environment with limited knowledge on wastewater quality and loading patterns. Biological process activity had to be built from the beginning, which in Finland meant re-starting the processes and in Azraq, building up activity to the aerated MBBR tanks without seed sludge. In both situations, the process for enhancing microbial activity was limited by lack of adequate data on water quality, organic shock loading, and consequently process operators' limited understanding of the biological treatment process growth kinetics under these types of extreme conditions. The decision mediators, such as clear role division in Finland and unclear role division in Jordan, were on the contrary distinctively different and led to different outcomes in wastewater treatment delivery. In Jordan, the operation of the activated sludge process was delayed by several months, and treatment requirements were only partially fulfilled by the end of the study period even when the hydraulic and organic loadings stayed lower than the design values. Comparably, the studied activated sludge processes in Finland were operating with improved treatment results within two months of the beginning of the refugee response, with influent hydraulic and organic loads that exceeded the design capacity. While the generalizability of the results of the polar case study comparison is limited, these emerging findings suggest that contextual inputs, such as the scale of refugee response, are not as crucial in determining the quality of wastewater treatment as the mediating processes and structures in decision-making are. Based on these findings, we distinguished five principles that contribute to timely refugee response in advanced WWTPs on the dimensions of human agency, project environment, and wastewater treatment technology. These principles are 1) clear role division between agencies and stakeholders, 2) improving "human capacity" for rapid response decisions, 3) selecting a process that fits the regulative and operational environment, 4) enabling direct and fast information sharing and 5) establishing fast-track permitting processes for disaster conditions. The findings of this study can be applied to improve the resiliency of wastewater treatment in the face of disaster and emergencies, such as the studied case of global refugee crisis resulting from the Syrian civil war.

4.5.1. CLEAR ROLE DIVISION BETWEEN AGENCIES AND STAKEHOLDERS

Empirical evidence from Azraq and Finland suggests that clear role division facilitated interdisciplinary teams' response to the refugee crisis and helped them in continuing wastewater treatment without interruptions. In Finland, where roles were well defined from the beginning and stakeholders quickly developed mutual goals, wastewater treatment plants were operating according to the environmental permit requirements within two to three months from the beginning of the refugee response. In Azraq, where stakeholders' mutual understanding of roles and goals took more time to develop, wastewater treatment process startup was delayed by several months. The findings align with prior results from construction management research that have time and again defined the clear definition of responsibilities and roles as one of the critical success factors for project delivery in various contexts (Chan et al. 2004; Li 2014; Nivolianitou 2011; Zhou 2011). However, there are limited recommendations on how to achieve this in practice. "Selection of team leader" and "clear division of roles and responsibilities among team members" are also mentioned as two main considerations in the WHO guideline for sanitation safety planning (WHO 2015), but none of the interviewed stakeholders mentioned these plans as a resource that was used in team organization. A possible reason for the lack of SSP or guideline usage during crisis response is that these plans, too, are too general to guide decision-making in an advanced wastewater treatment process startup. Consequently, we propose that specific guidelines for communication and decision procedures during the crisis operation and startup of advanced wastewater treatment systems would be added to the country-specific SSPs. These guidelines could include detailed examples & suggestions including, but not be limited to, the party that initiates the assessment on wastewater treatment systems' capacity to respond to changed conditions, who needs to know what (e.g., do the regulatory agency or NGO employees need to understand the technology, and to what extent do operators need to understand biological wastewater treatment or project goals), and lastly, who is an "active decision-maker", i.e. people that are making decisions in the field, and who is in an advisory role.

4.5.2. IMPROVING "HUMAN CAPACITY" FOR RAPID RESPONSE ORGANIZATION AND DECISION-MAKING

In addition to research on "human agency" in emergency response wastewater treatment in team level, our preliminary findings suggest that more research is needed to understand better how wastewater treatment experts' personal, individual capacities could be improved to better align with the type of actions that are needed during crisis response. Both in Finland and in Azraq, decision-making was facilitated and accelerated by individuals who were strongly driven by their motivation to protect the environment and helping the refugees. In Finland, the governmental authority took a leading role in the very beginning of the refugee response and sought creative solutions to technical problems in collaboration with other stakeholders. In Azraq, stakeholders started to reach a mutual understanding of the project goals after two startup failures, when aid organization employees and technical consultants tightened their collaboration and took strong initiative on solving communication issues with the governmental authorities. Overall, wastewater treatment delivery was facilitated by professional flexibility and hindered by professional rigidness. These findings are supported by prior research on disaster response teams that has discovered that procedural and structural innovation, and ability to take on different roles is necessary for successful crisis operations (Somers 2009; Webb et al. 1999). They also align with Belbin's team role theory (Belbin 1996) and related research on team development in various work environments. This research suggests that teams that are under continuous change are best supported and led by individuals that display the innovative characteristics of "resource investigators", "plants" and "shapers" (Aritzeta et al. 2007). In the studied emergency situations, teams were emergent, as they were formed out of necessity, their composition was new, and they were dealing with new non-regular tasks (Dynes 1970). Still, in both cases, the leaders with "shaper" and "plant" capacities emerged and naturally claimed their role. Furthermore, the presence of a "specialist", another one of the Belbin team roles, was essential for successful plant operation both in Finland and Azraq. According to Belbin (1993), the team roles, except for the role of a "specialist" which develops through experience and knowledge, are strongly defined by individual characteristics. Thus, to facilitate future disaster response, we suggest that wastewater treatment professionals should be trained to understand and identify their characteristics, how they operate in team environments and how they make rapid decisions in disaster response conditions. Additionally, it would be beneficial for each community, country or emergency response unit to develop a roster of trusted "specialists" with extensive wastewater treatment expertise, who would guide stakeholder decision-making in wastewater treatment-related issues in future emergency situations. Capacity building for more effective response activities could be done through team role improvisation trainings that help stakeholders prepare for selecting alternative courses of action and taking on new roles (David Mendonca 2001; Rankin et al. 2013), or through Belbin team role training or similar systems that allows individuals to define their strenghts and learn to communicate and coordinate with other team members. For decision-making under high-stress, wastewater treatment professionals could be prepared by enhancing their understanding of judgments under stress (Hammond 2000; Kahneman 2011).

4.5.3. SELECTING A PROCESS THAT FITS THE REGULATIVE AND OPERATION ENVIRONMENT

Recent research on advanced wastewater treatment systems' capacity to endure dynamic organic loads has shown that MBBRs and other attached growth systems are an ideal choice for conditions, where the influent organic load can change rapidly (Aygun et al. 2008; Lee et al. 2006; Lima et al. 2017). However, at Azraq refugee camp, the MBBR system startup failed, not due to system capacity related issues, but due to a combination of factors related to stakeholder communication, obscurity in regulations, lack of process monitoring, and slow procurement and refurbishment processes. Academic literature on wastewater treatment in extreme loading conditions has so far provided very limited insights on how operable advanced treatment systems, such as MBBRs and other attached growth systems, in fact, are in dynamic organic load conditions. To our knowledge, there are few studies that have investigated the adaptation of these technologies in field conditions, as most studies have focused on testing extreme conditions in laboratory scale (Lee et al. 2006; Lima et al. 2017). Our findings provide preliminary evidence that in emergency conditions, the most optimal choices for wastewater treatment system are those that fit the regulative and operation environment. The biological performance under dynamic loading conditions is subsidiary, if treatment system startup is primarily limited by discharge regulations, slowness in procurement or stakeholders' inability to react promptly to changes in the operation environment. In Finland, stakeholder response was quick, as everyone making technical decisions was familiar with activated sludge technology, regulations for treated effluent were already set in place and system refurbishment could be done with standard equipment that was easy to procure. In Jordan, the MBBR system was new to operators and regulatory authorities, which complicated both on-site decision-making as well as regulatory decision-making, and ultimately delayed process startup. For instance the Jordanian wastewater treatment regulations prohibited process startup with seed sludge and as a result, the project team had to rely on the slower option of building up biological activity through recycling.   Furthermore, procurement was difficult in Jordan, as the needed special process parts were not readily available within the country. We propose that assessments on wastewater treatment resiliency address treatment process' ability to maintain sufficient levels of BOD and nutrient removal in dynamic conditions (e.g. based on prior research or operation data), but also include equal consideration of system vulnerability in terms of restart and repair capacity (availability of seed sludge, process parts & equipment with short notice), and expertise availability (general conspicuousness of the treatment system in the country, how likely are stakeholders to understand this system & how easy is it to get expert consultancy with short notice) in the operation context. These suggestions complement the wastewater treatment system selection criteria that has been previously presented for refugee settlements (Fenner et al. 2007) and more generally for flexible water and wastewater designs . They also provide empirical evidence on the previously identified necessity of modularity, redundancy for resilient wastewater treatment provision in disaster conditions (Currie et al. 2014; Labaka 2016; Spiller et al. 2015), and complement the previously identified set of selection criteria by introducing "expertise availability" as a key criteria for resilient wastewater treatment systems for refugee response.

4.5.4. ENABLING DIRECT AND FAST INFORMATION SHARING

The polar comparison displayed the importance of face-to-face meetings and direct communication in successful stakeholder coordination and wastewater treatment delivery during refugee response. The findings are aligned with prior research that has also recognized the need for "hi-touch" communication and direct and information interaction in dynamic project environments where conditions and team composition are changing (Hollingshead et al. 1993; Laufer et al. 2008).

Consequently, we recommend that the establishment of "open lines of communication" between all stakeholders is prioritized whenever wastewater treatment systems are brought online in similar conditions. Depending on the regulative and operation environment, the transparent and inclusive communication practices should include a set of different activities ranging from face-to-face meetings to online communication and real-time information sharing systems. In Finland, the physical proximity of all stakeholders' facilitated information sharing as communication was possible through phone conversations and all stakeholders were able to conduct site visits to the WWTPs whenever it was needed. For the international team of Azraq WWTP stakeholders, the opportunities for real-time information sharing were more limited: the consultants were supposed to provide operational support remotely, but as the remote process monitoring and operation technology were never functional due to the lack of necessary ICT infrastructure, this was not possible. While "flatness" of communication has been previously identified as a feature that enhances wastewater treatment systems recovery speed after sudden perturbations (Butler et al. 2014), academic research has not discussed the role of monitoring technology and data sharing systems in increasing the resiliency of wastewater treatment systems (Juan-García et al. 2017). Additionally, while tools have been developed for information sharing during disaster response (Little et al. 2015; Pradhan et al. 2007) and for WWTP operation during complex scenarios (Dürrenmatta and Gujera 2012; Urich and Rauch 2014), there is little empirical evidence of their applicability to disaster response. With our preliminary findings, we call for more case studies to better understand the opportunities and limitations of remote monitoring and online data management platform use in wastewater treatment plant startup and operation during disaster response. The evidence from Finland and Jordan suggests that openly accessible process monitoring data and frequent all-stakeholder discussions about its implications are key to successful and timely disaster response in wastewater treatment plants.

4.5.5. FAST-TRACK PERMITTING PROCESSES FOR DISASTER CONDITIONS

Both in Finland and in Azraq, inflexible permitting processes were hindering timely response to the refugee crisis in wastewater treatment plants. In Azraq, the MBBR startup plan was completely prevented by strict regulations that did not allow discharge from wastewater treatment plants until the required nitrification and BOD removal rates had been achieved in full scale. In Finland, slow environmental permitting process prevented quick reactions to increased influent organic load as any change in existing WWTP configuration would have required environmental permit renewal. Capacity increase was made possible only by regulative authority's deep understanding of the Finnish environmental permits and wastewater treatment, and consequently his ability to come up with creative regulative solutions. To ensure uninterrupted wastewater treatment in the future, global guidelines for permitting and controlling "emergency operation" in municipal wastewater treatment plants would be needed. Without these, the resiliency of the wastewater treatment system itself becomes irrelevant as was seen in Azraq WWTP: MBBR treatment process was a well-justified choice for a dynamic influent loading pattern, but since regulation restrictions prevented the system from functioning in the first place, response to dynamic wastewater load conditions was not possible for the first 6 months of the WWTP operation. Prior literature has introduced limited discussion on the role of legislation or permitting in preventing or enabling the resiliency of the wastewater system (Johannessen and Wamsler 2017; Juan-García et al. 2017). In their review of the "state of the art" in wastewater treatment resiliency research, Juan Garcia et al. (2017) listed all interventions that scholars had suggested for improving resiliency of wastewater systems. None of these were related to the permitting processes or environmental legislation. In another study evaluating the state of wastewater treatment resiliency, Johannessen & Wamsler (2017) identified enabling and disabling factors that influence the different resilience levels. While environmental permitting issues were not directly addressed, "Power games and political self-interest" as well as "Lack of financial and other resources to handle beyond normal" were identified as factors disabling resiliency in wastewater treatment and "interinstitutional coordination" and "micro governance arrangements" as factors enabling resiliency.

Another context where the need for expedited environmental permitting processes could have, but so far has not naturally emerged is the scholarly discussion on European refugee crisis and its policy implications. While active and extensive, this conversation has for now focused on international regulation of the movement of people and sharing of financial responsibilities (Carrera et al. 2015), not on direct implications of the rapid population increases in environmental policies at the host community level. The empirical evidence presented in this study suggests that flexible regulation is a requirement for resilient wastewater treatment during disasters. Future efforts in both academia and practice should aim to find ways to adjust wastewater related policies and permits, and their development to better fit situations of rapid response on a regional and local level without increasing the burden of disaster to the environment. References for this work could be found from numerous case studies around the world, where cities and communities have adapted expedited emergency permit processes to arrange emergency housing (Levine et al. 2007) or to avoid environmental catastrophes, such as oil spills (Pursley and Keith 2014).

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5. SUMMARY AND CONCLUSIONS

5.1. SUMMARY

Political conflicts, natural disasters, droughts and other crises have forced more people to flee their homes than ever before in the recorded history. In the future, the number of displaced people is expected to increase as a consequence of the changing climate and the resulting long-term environmental changes that will lead to loss or reduction of livelihoods of millions of people. Large-scale displacement burdens the infrastructure and natural resources in the communities that host refugees and internally displaced people, and thus becomes a political issue that has social, economic and environmental ramifications. This dissertation touched on this complicated challenge by offering insights on how the water infrastructure sector, and more specifically wastewater treatment systems, could facilitate the rapid response to future disasters that result in large-scale displacement.

The overarching research objective of this dissertation was to ***identify concepts that contribute to rapid wastewater treatment response following disasters***. While the best practices in both steady-state wastewater treatment system operation and emergency sanitation provision have received extensive academic attention, empirical research on advanced wastewater treatment process operation in dynamic or extreme conditions, such as refugee response, has been limited. The three-step research approach addressed the following hypotheses:

H1: Stakeholders' technical decisions are based on recognition-primed decision models that build on their prior experiences.

H2: Wastewater treatment system startup and performance in refugee camp is impacted by contextual and internal concepts that influence stakeholder decision-making.

H3: The concepts influencing rapid wastewater treatment delivery in disparate refugee response situations share commonalities.

The first hypothesis was tested by investigating stakeholder mental models of decision-making and wastewater treatment system project delivery at the Azraq refugee camp. Eleven people that were involved in the refugee response through project design, construction or treatment system operation were interviewed to identify the more generic knowledge sources that they used to build mental models to comprehend the new emergency operation situation. The mental model constructs revealed that technical decisions were influenced by stakeholders' prior experiences, as well as six other contextual and internal concepts including "Physical location", "Resources" and "Risk and uncertainty", and "Personal characteristics", "Team dynamics" and "Communication". The conclusion of the study was that stakeholder decisions are not solely based on objective technical evaluations. Rapid wastewater treatment response could be facilitated by improving disaster response teams' ability to recognize, share and address concepts that impact decision-making in project, team and individual level during uncertainty.

The second hypothesis was tested through a novel conceptual modeling approach that paired mental model interviews with laboratory data from the biological wastewater treatment system at the Azraq refugee camp. The Input-Mediators-Output-Input (IMOI) model expressed the relationships between the Moving Bed Bioreactor (MBBR) wastewater treatment system function, human evaluations of system performance, and the resulting decisions for operational changes. It was discovered that mental model concepts that guided stakeholders' decision-making, such as lack of shared technical understanding and dissimilar project expectations, delayed the startup of the advanced wastewater treatment system. Consequently, a successful adoption of sophisticated treatment technology in extreme and remote conditions, such as in a refugee camp, requires stakeholders' familiarity with the opportunities and challenges related to the system. While modular biological wastewater treatment technologies have potential applications in regions that are burdened with protracted refugee situations, introduction of treatment technologies that are new to the project stakeholders is not recommended during active disaster response.

Finally, the third hypothesis was tested through comparison between two distinctively different rapid wastewater treatment response case studies from Finland and Jordan. Analysis was based on 24 mental model interviews and sets of operational data from on-site biological wastewater treatment systems. Several commonalities between the two extreme cases were found. The emerging findings from the comparative analysis suggest that contextual inputs, such as the scale of refugee response, do not solely determine the quality of wastewater treatment, and that rapid response activities are supported and hindered by mediating processes in decision-making. Based on these findings, five principles that contribute to timely refugee response in advanced WWTPs were developed. These principles are "creating a clear role division between agencies and stakeholders", "improving human capacity for rapid response decisions", "selecting a process that fits the regulative and operational environment", "enabling direct and fast information sharing", and "establishing fast-track permitting processes for disaster conditions".

5.2. CONTRIBUTION TO THEORY

With previously unreleased data from active refugee response operations, this dissertation provided empirical evidence of wastewater utility management and operation during large-scale population displacement. While the influence of rapid population shifts on critical infrastructure systems has started to gain more attention in academic discussion after the European refugee crisis in 2015-2016, this research is among the first to qualitatively model the relationship between stakeholder decisions and wastewater system performance under these extreme conditions, where wastewater loading is changing rapidly and unpredictably. The applied mixed method modeling approach was developed specifically for this study and is thus a theoretical contribution itself. Additionally, this dissertation contributed to the theory by showing that stakeholders' decisions during rapid wastewater treatment response are based on recognition-primed decision models. As disaster context offers limited opportunities for data-driven technical decision-making, stakeholders' judgments are influenced by prior experiences, personal characteristics and team relations and dynamics. Eventually, the concepts that drive stakeholder decisions also impact wastewater treatment delivery and system performance. While academic research on rapid response teams and time-stressed decision scenarios (Cattermole et al. 2016; Klein et al. 2010) as well as on machine and system operations (Kaempf et al. 1996; Wickens 1992) has discussed recognition-based decision models, their influence on wastewater treatment delivery during disaster response has not been previously studied. The findings of this dissertation can be applied towards building a new theory based on the concepts that influence wastewater treatment professionals' decisions and treatment system performance in rapid response scenarios, and can ultimately improve the resilience of wastewater treatment systems.

5.3. CONTRIBUTION TO PRACTICE

The findings of this study have many practical implications. The identified decision process inputs, mediators and outputs (Chapter 3 and 4), as well as the five principles for timely wastewater treatment response (Chapter 4), serve as guidelines for practitioners that are involved in future disaster response operations. The two case studies that this dissertation documented can also be used as educational material for individuals that are joining rapid response teams to help them understand the specific challenges in wastewater treatment response to acute disturbances, such as rapid population shifts. The practical contributions of this research are noteworthy, as few disaster response operations are documented with similar detail or analytical approach. However, the practical implications can extend beyond the above case studies, and the key findings on stakeholder decision practices during rapid wastewater treatment response can start reshaping the skills and characteristics that practitioners in the water sector need for navigating their professional career. In a world where extreme weather events and unpredictable operational conditions are projected to increase, civil engineers and other professionals in the public utility sector need to have improved skills for rapid re-organization and decision-making. As the findings of this dissertation indicate, wastewater treatment resilience during crises is largely dependent on practitioners' ability to adequately respond to the quickly changing conditions (Chapter 4). Consequently, there is a need to improve practitioners' skills in recognizing, sharing and addressing concepts during uncertainty in project, team and individual level decision making. Furthermore, practitioners need guidelines for transitioning these skills to their professional practice. Training engineers and employees in governmental bodies and water utilities on effective team communication and flexible role taking practices could facilitate the development of shared understanding of the project goals and the applied treatment technology during future rapid response scenarios. In addition to continuing education programs for professionals who already work in the water sector, the findings from this research could be incorporated into higher-education curriculums either as part of existing courses or as separate classes on "engineering judgment" and "technical decision-making". Understanding how the operation environment, and prior experiences and personal characteristics shape technical decisions has applications beyond disaster response: The increased use of process automation in critical infrastructure management is shifting engineers' roles from running steady-state operations to responding to frequent disruptions and failures. It is therefore important, that future engineers have versatile skills for problem solving and are qualified to work under high uncertainty conditions.

5.4. LIMITATIONS AND FUTURE RESEARCH

The novelty of this dissertation research is reflected in the data that is collected from an unprecedented refugee response scenario, and the mixed method Input-Mediator-Output (IMO) model approach that was developed for analyzing relationships between stakeholder decisions and wastewater treatment system performance. However, as with any case study research, the findings are limited in their generalizability. For instance, although the results of the comparative study in Chapter 4 suggests that the contextual inputs, such as the scale of refugee response, are not as crucial in determining the quality of wastewater treatment as the mediating processes and structures in decision-making are, there is a possibility that the chosen case studies have unique elements that are different from other large-scale displacement scenarios that have had an impact on wastewater treatment delivery. Therefore, more empirical studies embedded in a similar context, preferably with longitudinal data collection on wastewater treatment and management during disasters and other rapid response activities, could strengthen the findings of this work. Larger, longitudinal data sets are especially important in deepening the understanding of the relationships between decision inputs, mediators, and outputs that were discussed in Chapter 3, as they would allow statistical analysis on the significance of the IMO model inputs and mediators in predicting the wastewater treatment system performance.

The need for more "*examples of case study and a comprehensive study of stressors*" has also been identified in a recent review on wastewater treatment system resiliency research (Juan-García et al. 2017). One of the reasons behind this gap in the literature is arguably the challenge of collecting data in a post-disaster context: access to post-disaster sites is typically limited, which causes hindrances to data collection, troubles with logistics and increased stress levels for researchers due to the environment that may at times be shocking and emotionally and physically stressing (Mukherji et al. 2014). This was also true with this dissertation research: the collection of qualitative field data was limited by many practical challenges that were hard to account for in advance. Furthermore, the analysis of in-depth interview data was time and resource consuming, leading to a longer delay in publishing the research results than with some other forms of qualitative study. Perhaps consequently, recent research on critical factors in water infrastructure resilience to disasters and other disruptions has been built on expert predictions and opinions (Faust and Kaminsky 2017; Johannessen and Wamsler 2017), not on real data from post-disaster operations. While expert opinions may help identifying possible challenges and themes that impact operations, their validity in predicting what will actually happen is limited (Kahneman and Klein 2009; Tetlock 2005). Thus, despite the challenges in its collection, more case study data on rapid wastewater treatment response is needed, as it has an essential, irreplaceable role in the construction of related new theory.

Finally, I hope that this dissertation sparks wider interest in the complicated challenges of rapid wastewater treatment response during disasters entails, and that it leads to academic discussion on the social, environmental and technological support mechanisms that can be put in place to facilitate future disaster response efforts. In addition to its value in improving the quality of basic services for the displaced population and protecting the public and environmental health in the host communities, academic research on wastewater management during refugee response is a way to build bridges between the displaced and hosting communities. By improving water sector practitioners' capacities for rapid response and facilitating their work during high-stress and high-uncertainty scenarios, researchers can build tolerance towards the strongly emotive phenomenon of mass migration, and ensure that wastewater treatment services are provided in a way that considers the needs of the host communities and displaced populations alike.

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APPENDIX 1. INTERVIEW GUIDE

INTEVIEW PROTOCOL

NSF RAPID: Avoiding Secondary Disasters: Wastewater Treatment Design and (Re)construction during Large-Scale Disaster Response

Interview Questions

Information for the Interviewee

Dear participant,

You are invited to assist in providing information about the decisions used to evaluate and adjust the daily operations of a wastewater treatment plant.

The goal of this study is to gather information that will help engineers and operators of wastewater treatment plants to make decisions during crisis situation, such as the response to the Syrian crisis at the Azraq Refugee Camp.

Information shared during interview with those working at the Azraq wastewater treatment plant, like you, will greatly help in collecting important data.

The information shared by each person will be confidential. All records will be kept private and no names or other information that would identify the respondent will be included in final publications or reports. The interview will be in person with 1 or 2 members of the University of Washington research team, and 1 person from the Jordan University for Science and Technology (JUST). The interview will happen at the Azraq Wastewater Treatment Plant. The interview will takes less than 1 hour. The interview will be sound recorded and written notes will be taken. These measures ensure that all the shared information is recorded and transcribed correctly. These sound files and notes will remain confidential, and will only be used by the University of Washington research team.

Your participation is voluntary. If you choose not to participate there will be no penalty or loss of benefits.

If you have any questions about the interview, please email me at hgough@uw.edu. Alternatively, you can contact my colleague, Amy Kim at amyakim@uw.edu.

Thank you.

Sincerely,

Dr. Heidi Gough, PE, PhD

Dr. Amy Kim, PhD

I. Background

1. Do you visit the Azraq wastewater treatment plant regularly? If so, how often?
2. Tell me about your role in the project.
   - Have your responsibilities or roles changed since the last interview? (Asked only during

II. Events

Initial start-up (February – April)

3. Could you tell me about major activates that happened from the beginning of the startup process (start of the recycling, January 17) until this day? Other questions might include:
- Can you tell me about any specific events (days, meetings, visits) that have happened during the startup and testing period and that were somehow important with regards to your work/process operation/project?
- How did the recycling process start? What did you do? Looking back, would you have done something differently?
- Why did you start the process by recycling? What was the end goal of the process?
- What did you expect in the beginning of the startup process? Were there some things that surprised you?
- How was the information about process operation communicated between different stakeholders during the startup?
- Did you have to make any changes to the WWTP assembly? When changes were necessary and made, how was it handled?

Re-startup (April ->)

4. The plan for the startup operation was changed recently. Can you explain why this is happening?
5. Now that you are re-starting the process, who is involved in the decision making? What are their roles?
6. Who is leading this effort right now? How are the decisions weighted between the different stakeholders?
7. What type of communication tools are the stakeholders using to exchange ideas?
8. Were you provided with any additional resources, including personnel and technology, that you can use for decision making during the re-startup? Can you share those resources with us? (e.g., manuals, diagrams, reports, and meeting minutes).
9. How are you planning to determine the effectiveness of the decisions that you make? (How do you know which process operational changes led to the desired outcome?)
10. Do you have any recommendations for decision making process improvements?

III. MBBR system performance

11. Have there been any issues with foaming, bulking, or other problems that you would consider as system upsets? Describe what situations have happened.

12. What things would you watch for in the future to avoid upsets?

13. What are some of the impacts of such upsets?

IV. Operation and maintenance and decision-making

14. Is there a new procedure you are supposed to follow when making operational changes? If so, can you describe it in detail?

15. How do you document the operational/assembly changes and what information do you include in the report? Who is this information for?

16. Do you go back and look at that information to seek help with process operational decisions? What would you include in the reports in the future?

17. What are some things you have learned during this project?

Other comments

18. Do you have anything else that you would like to share that may be pertinent for this study?

APPENDIX 2. ANALYZING CASE STUDY DATA

This appendix provides additional details about the qualitative data analysis. With descriptions of each step of the qualitative research, its goal is to provide reader confirmation of the reliability and validity of the research results. The appendix is divided under two sections. The first section summarizes the steps in qualitative coding and introduces the analytical tools that were used in the process. The second section introduces the mixed research methods behind the input-mediator-output model on rapid wastewater treatment delivery during refugee response.

SECTION 1. QUALITATIVE CODING

The qualitative coding process followed the five steps of framework analysis (Bryman and Burgess 1994; Srivastava and Thomson 2009):

1. Familiarization

2. Identifying a thematic framework

3. Indexing

4. Charting

5. Mapping and interpretation

The details of the work in each step are presented below.

1. FAMILIARIZATION

The data of this dissertation study consists of 24 interview transcripts and field observation notes. During the first step of familiarization, the interview transcripts and field notes were read through several times and initial markups and notes were made. Since interviewing, field observations and transcription were also conducted by the author, the familiarization process started simultaneously with data collection. As part of the familiarization, the author also wrote a one-page summary of each interview to highlight its prevalent themes.

2. IDENTIFYING A THEMATIC FRAMEWORK

Thematic framework is the set of themes and issues that emerge from the data after the first readthroughs. In qualitative research that is targeting a previously studied topic, some of the themes and issues may have risen a priori. However, the validity and reliability of the framework is improved if researchers let data dictate the themes and not force the data to fit the a priori issues (Bryman and Burgess 1994).

The construction of the thematic framework for this study was started by *simultaneous* and *descriptive coding* of the interviews. Simultaneous coding allows the use of multiple codes or ”tags” for a single qualitative datum, i.e. an interview segment (Saldana 2009). It is recommended for data that has content that suggests multiple meanings or describes complex interactions. As all interviewees described socio-technical interactions and decision processes with cause and consequence relationships with both descriptively and inferentially meaningful explanations of the wastewater delivery process, simultaneous coding was an appropriate choice (Glesne 2006). The coding technique was descriptive, meaning that the topic of the coded segment was summarized in a word or a short sentence (Saldana 2009).

The qualitative coding was completed by using the Atlas.ti program . The Atlas.ti program itself does not analyze the qualitative data, it is just a platform for the researcher to conduct the qualitative coding process. In other words, it is a sophisticated pdf reader that allows the user to mark different section of the document and categorize them based on the "codes" that are given for these sections. Figure 12 presents a diagram of the data organization system in Atlas.ti and clarifies through examples how interview transcripts, quotations, codes and code families are related to each other.

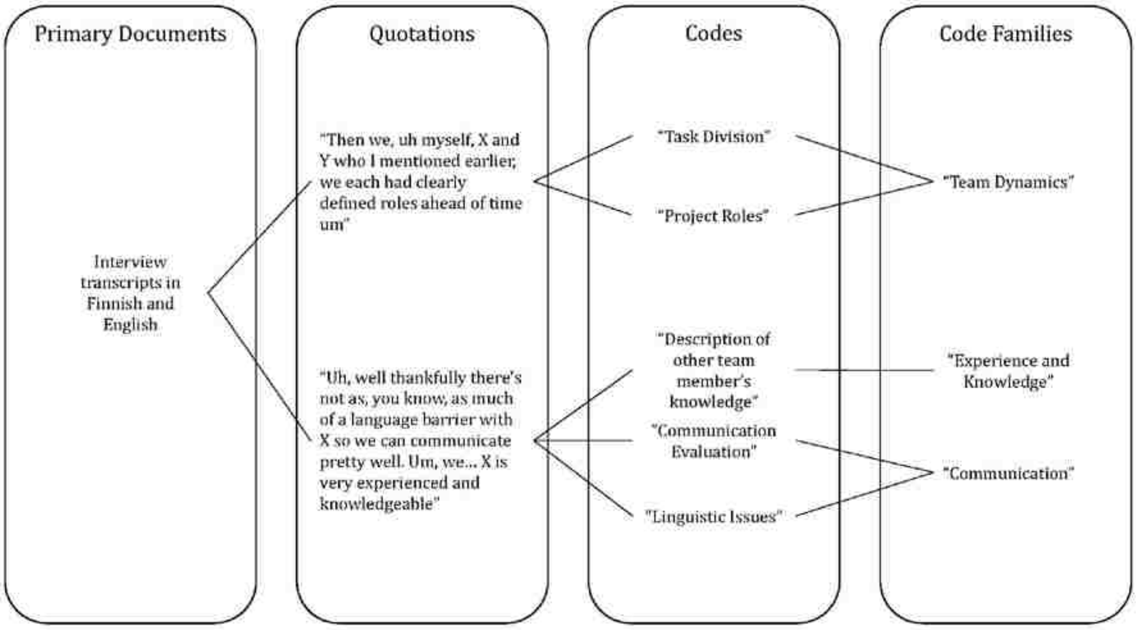

Figure A2.1 Atlas.ti data organization system

During the first round of coding, each interview transcripts was coded with descriptive codes, such as the ones presented in Figure 12. This led to the initial list of 184, which reduced to 169 codes after merging several codes with almost identical meanings. These codes are presented in Table 9. Figure 13 presents a screen shot of one of the interview transcripts in Atlas.ti after the initial, "descriptive" coding round.

Table A2.1 Results of the first descriptive coding round.

Accomplishments	Collaboration	Construction process	Decision support	Early planning
Adjustable parameters	Comfortable	Consultant	Decision-making	Easy
Advantages	Communal concept	Contract	Decisions made	Education
Adverse impacts	Communication	Contractor	Delays	Employee qualities
Age Range	Communication evaluation	Crisis avoidance	Description of other person's knowledge	Employee turnover
Azraq	Communication process description	Crisis management	Design process	Environmental pollution
Bureaucracy	Communication tools	Cultural difference	Disaster response experience	Equipment resources
Challenges	Comparaison	Cultural issues	Discoveries	Evaluation of effectiveness
Changes	Comparison to normal	Data sharing tools	Documentation	Experience in current project
Chaotic	Concerns	Decision process description	Donor involvement	
Expertise	Goals	Involvement in process selection	Make a change	Necessity
Failure	Governmental involvement	Job Description	MBBR system	Not easy
Family	Graphics	Job Title	MBBR system performance	O&M
Feeling	Group description	Key driver	Mechanical problems	Observations
Final day	Identifying stakeholders	Language issues	Mindset	Operator training
Financing	Improvement	Lessons learned	Mismatch	Opinion on interview questions
First day	Inefficiency	Limitations	Misunderstanding	Organization structure
First impressions	Initial involvement	Local community	Monitoring	Original design
Flexibility	Institutional Knowledge	Location	Motivation	Permitting
Foaming	International collaboration	Long-term plan	My idea	Personal connection
Personal feeling	Process conditions	Professional pride	Re-design	sludge recycling
Personal interest	Process configuration	Professional role	Relationship	Solution
Pictures	Process description	Project delivery	Remote location	Stakeholder education
Planning	Process monitoring	Project management	Resources	Stakeholder expectations
Policy structure	Process operation	Project Roles	Revenue system	Stakeholder involvement
Potential problem	Process parameters	Project start up	Rules	Stakeholders
Pre-construction	Process performance	Reactions	Safety	Start up process
Preparation	Process selection	Recommendations	Sampling	Successes
Privatizing	Process upsets	Recruitement	Schedule	Support
Procedure	Professional experience	Recruitment	Set backs	Sustainable development
Task division	Technical complexity	Training for this project	Upsets	WASH system
Tasks	Technical process description	Troubleshooting	Visits	Water infrastructure
Team Knowledge	Time management	Trust	Visual test	Water quality
Team members	Timeline	Unexpected situations	Warning signs	Zaatari

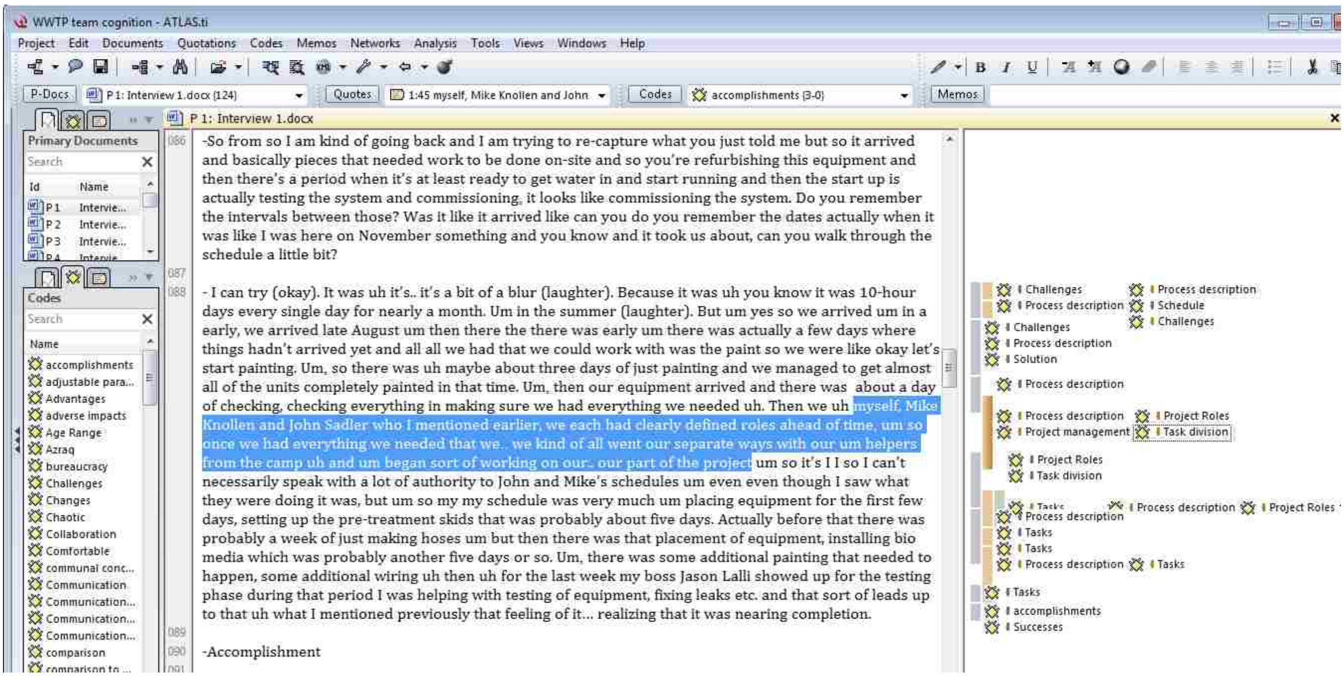

Figure A2.2 A screenshot from the Atlas.ti program during simultaneous & descriptive coding.

3. INDEXING

After the initial coding round, the next step in the data analysis was to identify themes and categories that the descriptive codes represented. This process is referred to as indexing the qualitative data. The indexing was done iteratively, through a multiple-step process where the "codebook", i.e. the index of codes, was revised heavily. First iteration led to the development of 18 initial themes that are presented in Table 10.

Table A2.2 Emerging themes after first indexing of the descriptive codes.

Broader Impact	Challenges	Operation	Culture	Decision-making	Project Delivery	Process Technology	Team
Environmental pollution	Adverse impacts	Adjustable parameters	Bureaucracy	Data sharing tools	Construction process	Adjustable parameters	Collaboration
Goals	Challenges	Failure	Communal concept	Decision-making	Consultant	Data sharing tools	Consultant
Long-term plan	Chaotic	Foaming	Cultural difference	Decision process description	Contract	MBBR system	Contractor
Solution	Concerns	Monitoring	Cultural issues	Decision support	Contractor	MBBR system performance	Description of other person's knowledge
Sustainable development	Cultural difference	O&M	International collaboration	Decisions made	Delays	Mechanical problems	Donor involvement
Water quality	Delays	Observations	Language issues	Equipment resources	Design process	Monitoring	Employee qualities
	Failure	Operator training	Local community	Evaluation of effectiveness	Early planning	Original design	Employee turnover
Recommendations	Foaming	Procedure	Motivation	Institutional Knowledge	Final day	Process conditions	Expertise
Recommendations	Inefficiency	Process monitoring	Opinion on interview questions	Key driver	Financing	Process configuration	Family
	Language issues	Process operation	Personal feeling	Make a change	First day	Process description	Governmental involvement
Comparison/Setting context	Limitations	Process performance	Personal interest	My idea	First impressions	Process monitoring	Group description
Comparaison	mechanical problems	Process upsets	Professional pride	Necessity	Goals	Process parameters	Identifying stakeholders
Comparaison to normal	Mismatch	Sampling	Relationship	Pictures	Initial involvement	Sampling	Institutional Knowledge
	Misunderstanding	sludge recycling	Trust	Policy structure	Involvement in process selection	Sludge recycling	International collaboration
Demographics	Not easy	Start up process		Process selection	Long-term plan	Start up process	My idea
Age Range	Potential problem	Troubleshooting		Resources	Permitting	Technical process description	Organization structure
Education	Process upsets	Visual test		Solution	Planning	WASH system	Personal interest
Experience in current project	Revenue system	Warning signs		Support	Policy structure	Water infrastructure	Process configuration
Job Description	Safety	Water quality		Visual test	Pre-construction		Professional role
Job Title	Set backs			Warning signs	Preparation		Project Roles
Professional experience	Technical complexity						Recruitement
	Troubleshooting						Relationship
	Unexpected situations						Rules
	Upsets						Solution

Project Preparation	Location	Personal	Successes	Uncertainty	Management Practices	Communication	Stakeholder education
Disaster response experience	Azraq	Feeling	Accomplishments	Changes	Procedure	Communication	Stakeholder expectations
Early planning	Communal concept	First impressions	Advantages	Chaotic	Project management	Communication evaluation	Stakeholder involvement
Expertise	Cultural difference	Mindset	Comfortable	Comparison to normal	Rules	Communication process description	
Goals	Cultural issues	Motivation	Discoveries	Crisis avoidance	Stakeholder education	Communication tools	
Initial involvement	Language issues	Opinion on interview questions	Easy	Crisis management	Stakeholder involvement	Data sharing tools	
Involvement in process selection	Local community	Personal connection	Improvement	Cultural difference	Time management	Documentation	
Original design	Location	Personal feeling	Lessons learned	Cultural issues	Training for this project	Graphics	
Planning	Remote location	Personal interest	Make a change	Delays	Visits	Institutional Knowledge	
Pre-construction	Zaatari	Professional pride	My idea	Flexibility		Language issues	
Preparation		Reactions	Professional pride	Misunderstanding		Misunderstanding	
Recruitment			Successes	Unexpected situations		Resources	
Training for this project							

4. CHARTING

The first round of indexing showed that descriptive codes represented different code categories. Some codes were titled based on topics or issues of interest, e.g. ”management practices” and ”cultural context”, and others were titled based on the type of quote, e.g.”recommendation” or ”process description”. As the goal of the coding was to identify ”concepts that impacted stakeholder decision-making”, the codebook was synthesized and revised to reflect this purpose. The descriptive codes were then arranged under the revised themes, as shown in Table 10.

Table A2.3 Revised codebook after two rounds of indexing and charting.

Physical Location	Risk and Uncertainty	Cultural Context	Experience and Knowledge	Motivation and Commitment	Team Dynamics	Communication
Remote location	Unexpected changes	Language barrier	Professional experience in similar projects	Dedication to complete work	Team description	Description of a communication process
Challenges in supply delivery	Dealing with crisis	Local government	Experience from crisis management	Personal interest in the topic	Team work	Challenges in communication
Communication difficulties due to location	Misinformation	Cultural differences	Knowledge gained during this project	Motivating factors behind decisions	Changes in team members	Communication tools
Climate and environmental conditions	Lack of information	Bureaucracy	Personal experiences related to construction/project management/team work	Initial involvement in the field or in the project	Collaboration between stakeholders	Any mentions related to the communication between different stakeholders
Difficulties related to geographical location/different time zone/access to IT infrastructure such as wifi	Change management	International collaboration	Education and Training	Humanitarian aid aspects and the willigness to help/ do something	Shared knowledge	Misunderstanding
	Risk management	Anything related to different cultural environment in which the project is completed	Information resources		Trust	Mutual understanding
			“Book knowledge”		Description of team member’s expertise	
					Project roles and how responsibility is divided	

INTERCODER RELIABILITY TESTING

The validity and credibility of the qualitative coding was tested in-between the indexing and charting steps. An intercoder reliability check was completed by comparing the results of two independently working researchers. Following the recommended practices of rating agreement assessments, the level of agreement was determined with a Cohen's Kappa value (Dewey 1983). Cohen's Kappa is a statistic that measures agreement between two rates as a function of observed agreement rate (identical assessments) and expected agreement rate (agreeement that happens by chance) (Cohen 1960). The formula for the calculation is provided below, with p_o being "observed agreement" and p_e "expected agreement".

$$K = \frac{p_o - p_e}{1 - p_e} = 1 - \frac{1 - p_0}{1 - p_e}$$

Both researchers coded one interview from each participant subgroup (coordinators, consultants and contractors), first by using the 18 initial themes and then by using the seven themes in the revised codebook. Once the coding was completed, a random page was selected from each coded transcript as a sample that was used for calculating the observed agreement. Every time that both researchers used, or left unused, the same code for the same text paragraph, they were seen to be in agreement. If only one of the researchers used the code, they were seen to be in disagreement. The results for each code were recorded in a four-field matrix that counts the number of agreements ("yes&yes", "no&no") and disagreements ("yes&no", "no&yes") as follows:

		Researcher 1	
		Yes	No
Researcher 2	Yes	a	b
	No	c	d

The observed proportional agreement was then calculated as :

$$\frac{a + d}{a + b + c + d} = p_o \ (observed\ agreement)$$

The expected agreement between researchers was defined as the random probability of both choosing the same code for the text paragraph. During the first round of intercoder reliability check, the expected probability was $\frac{1}{18} x \ \frac{1}{18}$, and during the second check $\frac{1}{7}\ x\ \frac{1}{7}$. The results of the second round of intercoder reliability test are presented in Table 11.

Table A2.4 Results of the intercoder reliability test

	Cohen's Kappa
Communication	1
Cultural Context	1
Experience and Knowledge	1
Motivation and Commitment	0.78
Physical Location	0.56
Risk and Uncertainty	1
Team Dynamics	1

The results of the intercoder reliability were evaluated based on guidelines that have been presented in prior literature (Hruschka et al. 2004; Landis and Koch 1977). These guidelines identify values smaller than 0 as indicating no agreement, 0–0.20 as slight agreement, 0.21–0.40 as fair agreement, 0.41–0.60 as moderate agreement, 0.61–0.80 as substantial agreement, and 0.81–1 as almost perfect agreement. Since the results from the intercoder reliability test ranged between 0.56-1.00, they were considered satisfactory.

5. MAPPING AND INTERPRETATION

The last phase of the framework analysis is data mapping and interpretation. During this step, the seven emerging themes that were identified during the indexing and charting phases were further divided into contextual and internal based on whether or not they were dependent on individual stakeholders' or stakeholder groups' input. All concepts related to "Physical location", "Resources" and "Risk and uncertainty" were considered contextual, as they were already present when stakeholders started working on the wastewater treatment plant project. Thus, rather than being included in stakeholder mental models they were defining the context in which stakeholders developed the mental models this research investigates.
All concepts that were related to stakeholders' individual characteristics were clustered under "internal" themes. These concepts were then further divided into individual or shared concepts: individual concepts were independent of other team members' views or actions whereas shared concepts were shaped by stakeholder's interaction with other team members. Consequently, shared influencing concepts were typically project specific, e.g. "pace of communication", whereas individual concepts reflected stakeholder's pre-existing knowledge and opinions, e.g. "professional experience in similar projects".

Following the thematic analysis, the quantitative content analysis included iterative re-coding of the expert interviews and quantifying how many times each concept was mentioned by each participant. During this process, many of the 18 initial concepts were renamed or divided into two or more separate concepts. The resulting 36 concepts and their definitions are listed in Table 12 as the final codebook.

Table A2.5 The final codebook with code names and descriptions.

Theme	Code Name	Description
Personal Characteristics	Dedication to succeed	The interviewee mentions something about willingness to complete the work in time, wanting to do a good job or solving problems successfully.
	Individual Goals	Note about personal objective or goal that can be, but does not have to be, related to the interviewee's role in the project
	Personal Motivation	A personal interest or motivation in the broader goal of the project, e.g. humanitarian aid or environmental protection, that is clearly driven by values
	Attitudes or beliefs	A description of someone's prejudices, doubts or positive attitude that had an impact on project delivery
	Cultural Background	A note about being or not being familiar with some cultural aspects or with a tradition of doing things in a certain way
	Professional Pride	Being proud of the quality of work or the type of work that one is doing.
	Language	Any note about linguistic difficulties or successes or issues related to translation
	Gender	Interviewee mentioning something about their gender and how it impacts their work or other people's attitudes.
Experience and Knowledge	Professional experience in similar projects	Descriptions of experience from a previous project that impacts interviewee's decision making in the current project
	Knowledge gained during the project	Any quote starting "we learned that" or "I've learned that" or any other note about increased knowledge on some issue over the course of the project
	Education or training in the field	Interviewee's professional training or education in the field of water technology or engineering
	Professional experience with similar technology	Interviewee's description of their experience or expertise with MBBR technology or advanced wastewater treatment processes in general.
	Technical understanding	Lack of or importance of interviewee's own, or some other stakeholders technical understanding.
	Project management experience	Previous experience from managing projects or people. Anything related to construction or humanitarian aid.
	Guidelines and manuals	Using guidelines or manuals to support operational decision-making, or needing them to do so. Also any quotes that talk about the content of guidelines and manuals is listed under this category.
	Experience from crisis management	Previous experience (or lack of) from crisis response or emergency response.
Communication	Structure of the communication chain	Description of the communication process. Lateral vs. Hierarchical, flat vs. not, slow vs. fast etc. and how that impacted decision-making
	Real time team communication	Quotes on how interviewees communicated with each other while performing tasks.
	Documentation and information sharing	How was everything documented? Who shared information with who and through which channels?
	Open communication between stakeholders	Notes about "easy" and open communication between other group members and how that impacted decision-making
	Communication tools	Lists of tools that were used for communication, typically mentioned when asked straight what communication methods were used.
	Impacts of communication	Interviewees mentioning how through communication something changed or how the lack of communication impacted the project delivery.
	Value of communication	Any quotes on how communication was important for the success of the project
	Experience in communication	Descriptions on how stakeholders made decisions about communication tools or processes based on their previous experience from project communication.
	Differing definitions and linguistic challenges	Communication challenges caused by language or different definitions or understanding of project related issues.
	Pace of communication	Notes on communication being too slow or fast enough compared to the advancement of the project.

	Defining project roles or responsibilities	Notes about clear role division or confusion over stakeholder roles during some project phases.
	Collaboration between stakeholders	Description of how stakeholders or team members worked together to advance project delivery. Any mentions about collaboration were put under this category.
	Personal connections	Knowing someone before the project started, getting hired through a friend, developing personal relationships.
	Mutual decisions	Making decisions together as equal partners, taking everyone's opinion into account
	Contribution in different project phases	Descriptions of how different stakeholder responsibilities were divided between different project phases, who did what on which stage etc.
Team Dynamics	Being a team member	Talking about work in a team or feeling as being one of the team members
	Shared knowledge	Talking about other team member's expertise or technical understanding or how other members trust interviewee's technical understanding or knowledge
	Trust	Notes about trust between team members or stakeholders, or any discussion about lack of trust and its impacts on decision-making
	Shared Goals	Working towards same goal or mentioning stakeholders discussing about shared goals or lack of shared goals
	Changes in team members and stakeholders	Notes about someone leaving the project or coming in while the project was already going on and how it may have impacted decision-making
	Dependency on other stakeholders	Description of a situation where interviewee was dependent on another team member or their knowledge.

SECTION 2. MIXED METHODS BEHIND IMOI MODEL

The input-mediator-output-input (IMOI) model that is presented in Chapter 3 combines qualitative mental model interview data with wastewater quality data. The purpose of the model is to describe relationships between stakeholder decisions and wastewater treatment system performance. The qualitative modeling approach was developed specifically for this study, since there are no standard practices for mixed method decision-making modeling.

The steps of the IMOI model development were as follows:

1. Initial temporal analysis of stakeholder mental models

2. Recategorizing concepts and themes influencing stakeholder decision-making

3. Narrative analysis on stakeholder descriptions on decision-making

4. Temporal pairing of mental model concepts, narratives and water quality data

5. Categorization of concepts into “decision inputs”, “decision mediators” and “decision outputs”

The details of the work in each step are presented below.

1. TEMPORAL ANALYSIS OF STAKEHOLDER MENTAL MODELS

The first step of building the Input-Mediator-Output-Input model was to conduct a temporal analysis on the stakeholder mental models that were constructed through framework analysis. By using the codebook from Table 10, all stakeholder interviews were re-coded and the frequency of each code (i.e. mental model concept) was calculated for each operational phase of the Azraq WWTP based on the timing of the interviews (described in Table 4). The results of this initial analysis are presented in Table 13.

Table A2.6 Initial temporal analysis of mental model concepts

Mental Model Concept	Startup 1	Startup 2	Startup 3
Being a team member	5	1	6
Change through communication	0	1	1
Changes in team members and stakeholders	2	4	6
Collaboration with stakeholders	19	26	45
Communication experience	3	16	19
Communication structure	11	15	26
Communication tools	5	10	15
Community involvement	4	1	5
Conflict resolution	0	11	11
Contracts	3	16	19
Contribution in different project phases	4	2	6
Crisis management experience	2	0	2
Cultural Background	3	3	6
Dedication to succeed	2	1	3
Dependency on others	0	1	1
Design issues	8	10	18
Differing definitions and linguistic challenges	2	4	6
Documentation and information sharing	7	16	23
Education or training in the field	2	3	5
Evaluation criteria	2	2	4
External conditions	17	18	35
External resources	10	4	14
Financial issues	9	7	16
Flexibility	3	6	9
Gender	0	2	2
Guidelines and manuals	12	0	12
Human resources	5	1	6
Individual Goals	1	2	3
Initial conditions	6	7	13
Initial involvement	0	3	3
Knowledge gained during project	1	10	11
Language	1	0	1
Mechanical issues	4	4	8
Mutual decisions	12	3	15
Open communication	3	2	5
Operation issues	12	5	17
Permits	2	8	10
Personal connections	4	7	11
Personal motivation	4	9	13
Process adjustments	37	24	61
Process Design	26	16	42
Process issues	10	4	14
Process performance	17	16	33
Professional Confidence	2	2	4
Professional experience in similar projects	12	16	28

Mental Model Concept	Startup 1	Startup 2	Startup 3
Professional experience with similar technology	5	3	8
Professional Pride	2	1	3
Project delivery issues	7	5	12
Project management experience	0	1	1
Project roles and responsibilities	17	34	51
Real-time communication	0	1	1
Reconstruction	2	0	2
Response time	2	8	10
Shared Goals	3	8	11
Shared knowledge	9	17	26
Technical issues	2	0	2
Technical Understanding	20	28	48
Time pressure	5	2	7
Trust	4	7	11
Uncertainty	6	5	11
Value of communication	2	0	2
TOTALS:	380	439	819

2. RECATEGORIZING CONCEPTS AND THEMES INFLUENCING STAKEHOLDER DECISION-MAKING

Similar to the mental model analysis described in Section 1, the concepts that influenced stakeholder decision-making were further synthesized into contextual (Physical location, Resources, Risk, and Uncertainty) and internal (Team dynamics, Communication, Personal characteristics and Experience and knowledge) based on whether or not they were dependent on individual stakeholders' or stakeholder groups' input. Since all identified internal concepts were related to stakeholders' personal or group resources, the group was renamed as "human resources". The contextual concept group was in turn re-named as "project environment" as all concepts were related to the environment where stakeholders made decisions about wastewater treatment.

Since, the mental model analysis described in Section 1 focused on concepts that influenced technical decisions, the details of the technical decisions themselves were not of interest and were thus not included in the final stakeholder mental model constructs (Chapter 2). However, as the purpose of the IMOI model was to show relationships between mental model concepts, technical decisions and the resulting wastewater treatment system performance, concepts related to "treatment technology" were kept in the synthesized codebook ("human resources", "project environment", "treatment technology").

3. NARRATIVE ANALYSIS ON STAKEHOLDER DESCRIPTIONS ON DECISION-MAKING

Once the synthesized codebook was formed, the interview transcripts were analyzed through narrative analysis (Sandelowski 1991). In narrative approach, the narratives or stories of different stakeholders that have experienced the same event are analyzed for common structures. All extracts of stakeholder interviews that described operational decisions or adjustments were listed and put on a timeline based on the timing of the interviews and the event described. An example of a narrative is provided below:

"So, what we attempted to do and what we have done is we redesigned the operating system such that the operators can manually type in their measured data and we were going to log in and download it every day. But now we can't do that either, because we can't get access for our parametry."

The content of each narrative was summarized with a word or few words. For instance, the narrative presented above was summarized as "lack of online monitoring". In addition, each narrative on operational adjustments or decisions was assessed based on the type of influence the concepts it described had on project delivery and treatment system performance. All narratives with concepts that had a positive influence on project delivery, e.g. "frequent face-to-face meetings" were marked with a (+). Respectively, all narratives that described an event or detail that had a negative influence on project delivery, e.g. the above mentioned "lack of online monitoring", were marked with a (-). As was expected, many of the concepts identified through narrative analysis were identical to those identified through mental model analysis. However, the narrative analysis also explained *how* the identified concepts impacted operational decision and treatment system performance.

4. TEMPORAL PAIRING OF MENTAL MODEL CONCEPTS, NARRATIVES AND WATER QUALITY DATA

The wastewater quality was analyzed during each operational phase of the Azraq wastewater treatment system by using standard methods. After identifying concepts that influenced wastewater treatment system operation in each operational stage, the qualitative findings were temporally paired with the results of the water quality analysis.

The results of the laboratory analyses were assessed qualitatively based on whether or not they showed evidence of successful nitrification, denitrification or reduction of organic load in the Azraq wastewater treatment system. The method for assessing the presence or absence of nitrification and denitrification was a simple mass balance analysis on the concentrations of different nitrogen species in the beginning of the treatment process (influent basin) and in the second chamber of the MBBR tanks (both illustrated in Figure 5). If the ammonia concentration (NH_3-N in Table 5) decreased between influent basin and the end of MBBR tanks, while the concentrations of nitrite

(NO2-N) and nitrate (NO_3-N in Table 5) increased, some level of nitrification was occurring. The chemical reactions for nitrification are given in Equations 1.1, 1.2 and 1.3.

$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O \quad (1.1)$$

$$2NO_2^- + O_2 \rightarrow 2NO_3^- \quad (1.2)$$

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O \quad (1.3)$$

In denitrification process, nitrate (NO3-) is reduced to nitrogen gas (N_2) in conditions, where oxygen is not present. Consequently, a reduction in nitrate (NO3-N in table 5) concentration between pre-treatment and second chamber of MBBR (Figure 5) was seen as an indication of some level of denitrification occurring. Denitrification happens through the three reactions given in Equations 1.4, 1.5 and 1.6.

$$6\ NO_3^- + 2CH_3OH \rightarrow 6\ NO_2^- + 2CO_2 + 4\ H_2O \quad (1.1)$$

$$6NO_2^- + 3CH_3OH \rightarrow 3N_2 + 3CO_2 + 6OH^- \quad (1.2)$$

$$6NO_3^- + 5\ CH_3OH \rightarrow 5\ CO_2 + 3\ N_2 + 7\ H_2O + 6\ OH^- \quad (1.3)$$

The reduction of organic matter was assessed through comparing the TSS and COD concentrations of the influent wastewater and in the second chamber of the MBBR tanks, If the concentrations were lower in the latter parts of the treatment system, organic matter was removed during the treatment process.

5. CATEGORIZATION OF CONCEPTS INTO "DECISION INPUTS", "DECISION MEDIATORS" AND "DECISION OUTPUTS"

By following the basic structure of Input-Mediator-Output (IMO) models, all concepts that were identified through mental model and narrative analyses were categorized into "decision inputs", "decision mediators" and "decision outputs". The classification was completed by following the descriptions presented by (Ilgen et al. 2005). The inputs of the IMO model were defined as the human resources, and project environment and treatment system features that existed at the beginning of the wastewater treatment delivery in each operational stage. Mediators were defined as the processes and structures through which stakeholders acted during wastewater treatment delivery. The outcomes of the IMO model describe the "state of the matters" at the end of the process, i.e., the wastewater treatment system performance and lessons learned from the decision process.

February 26, 2016

PI: Ms. Heta Kosonen
PhD Student
Civil & Environmental Engineering

CC: Dr. Amy Kim

RE: HSD # 51350 "Modeling Decision-Making Processes in Wastewater Treatment Plant Operation During Extreme Weather Events"

Dear Ms. Kosonen,

The University of Washington Human Subjects Division (HSD) has determined that your research qualifies for exempt status in accordance with the federal regulations under 45 CFR 46.101/ 21 CFR 56.104. Details of this determination are as follows:

Exempt category determination: **7**

If the research becomes federally funded, supported, or regulated, the researcher must immediately cease research activities until IRB approval is obtained. This will require submission of a new application.

Although research that qualifies for exempt status is not governed by federal requirements for research involving human subjects, investigators still have a responsibility to protect the rights and welfare of their subjects, and are expected to conduct their research in accordance with the ethical principles of *Justice, Beneficence* and *Respect for Persons, as* described in the Belmont Report, as well as with state and local institutional policy.

Determination Period: This exempt determination is valid for the life of the study, as long as the nature of the research activity remains the same. If there is any substantive change to the activity that has determined to be exempt, one that alters the overall design, procedures, or risk/benefit ratio to subjects, the exempt determination will no longer be valid.

Revisions: Only modifications that are deemed "minor" are allowable, in other words, modifications that do not change the nature of the research and therefore do not affect the validity of the exempt determination. **Please refer to the Guidance document for more information about what are considered minor changes.** If changes that are considered to be "substantive" occur to the research, that is, changes that alter the nature of the research and therefore affect the validity of the exempt determination, a new *Exempt Status Request* must be submitted to HSD for review and determination *prior to implementation*.

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events or any problem that may increase the risk to the human subjects and change the category of review, notify HSD promptly. Any complaints from subjects pertaining to the risk and benefits of the research must be reported to HSD.

Please use the HSD study number listed above on any forms submitted which relate to this research, or on any correspondence with the HSD office.

Good luck in your research. If we can be of further assistance, please contact us at (206) 543-0098 or via email at hsdinfo@uw.edu. Thank you for your cooperation.

Sincerely,

Galen Basse
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206.685.1211
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UNIVERSITY of WASHINGTON
HUMAN SUBJECTS DIVISION

April 6, 2016

PI: Heta Kosonen

RE: 51722
Investigating the Organization of Wastewater Treatment Operations During the Refugee Crisis in Southern Finland

Dear Dr. Kosonen:

The University of Washington Human Subjects Division (HSD) has determined that your research qualifies for exempt status in accordance with the federal regulations under 45 CFR 46.101/ 21 CFR 56.104. Details of this determination are as follows:

Exempt category determination: Category 2

Although research that qualifies for exempt status is not governed by federal requirements for research involving human subjects, investigators still have a responsibility to protect the rights and welfare of their subjects, and are expected to conduct their research in accordance with the ethical principles of *Justice, Beneficence* and *Respect for Persons, as* described in the Belmont Report, as well as with state and local institutional policy.

Determination Period: This exempt determination is valid for the life of the study, as long as the nature of the research activity remains the same. If there is any substantive change to the activity that has determined to be exempt, one that alters the overall design, procedures, or risk/benefit ratio to subjects, the exempt determination will no longer be valid.

Revisions: Only modifications that are deemed “minor” are allowable, in other words, modifications that do not change the nature of the research and therefore do not affect the validity of the exempt determination. **Please refer to the Guidance document for more information about what are considered minor changes.** If changes that are considered to be “substantive” occur to the research, that is, changes that alter the nature of the research and therefore affect the validity of the exempt determination, a new *Exempt Status Request* must be submitted to HSD for review and determination *prior to implementation*.

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events or any problem that may increase the risk to the human subjects and change the category of review, notify HSD promptly. Any complaints from subjects pertaining to the risk and benefits of the research must be reported to HSD.

Please use the HSD study number listed above on any forms submitted which relate to this research, or on any correspondence with the HSD office.

Good luck in your research. If we can be of further assistance, please contact us at (206) 543-0098 or via email at hsdinfo@uw.edu. Thank you for your cooperation.

Sincerely,

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