An Explorative Study on Norwegian Users' Understandings and Practices of Vacuum Toilet Systems in Private and Semi-Private Residences

By: Amandeep Kaur Bhatti

Supervisors:
Atle Wehn Hegnes, PhD
Petter Jenssen, PhD
Elia John Mmbaga, MD, PhD

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Institute of Health and Society

Faculty of Medicine

Department of Community Medicine and Global Health

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Abstract

Sustainability and sustainable development are prominent topics of interest in the world. The sixth and eleventh targets of the Sustainable Development Goals are to have adequate clean water and hygiene and have sustainable communities, respectively. Vacuum toilet systems save water and can facilitate nutrient recovery thus they aid at sustainability at a community level. The purposes of this thesis were to 1) Describe the perceptions, knowledge, and beliefs Norwegians have of vacuum toilet systems in comparison to conventional flush toilets; 2) Explore external factors influencing routine practices towards vacuum toilet use; 3) Identify key barriers to vacuum toilet system acceptance; and 4) Identify comfort levels regarding the possible integration of the model of ecological sanitation in residences. A qualitative research study was completed through the use of in-depth interviews for data collection among vacuum toilet users in the Norwegian communities of Kaja, Ås and Torvetua, Bergen. Interview transcripts were analysed using a thematic approach to understand the practices of the vacuum toilet system and identify factors that influenced the practices and perspectives of vacuum toilet system users. Concepts rooted in the social sciences were used as analytical tools to interpret the data.

Technical aspects and personal practice were found to have influenced the users' perceptions and practice of the system, and future development of vacuum systems.

Technical complications and the blueprint of the vacuum system significantly affected users' practices and experiences. Semi-private or private residency status was a factor in the practice and perceptions of vacuum toilet systems. Noise from the vacuum toilets, and smell from the holding tanks, were reported to be the key aspects participants reported for not accepting vacuum toilet systems for future development.

The research study concludes that despite the complications and concerns, the users were overall satisfied with the vacuum toilet system. Going forward, it is important to consider the implications of the technical aspects of the vacuum toilet systems in both communities in conjunction with user practice and experience. Further improvement of the vacuum toilets should specifically be rooted in addressing noise and the technical complications with the system to enhance user compliance and acceptance.

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Abbreviations

CFS:	Conventional flush system (used interchangeably with traditional, common, or water flush)
Eco-San:	Ecological sanitation
EU:	European Union
mm:	millimetres
NMBU:	Norwegian University of Life Sciences
NIBIO:	Norwegian Institute of Bioeconomy Research
SDG:	Sustainable Development Goals
VTS:	Vacuum toilet system

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Chapter One: Introduction

Sustainability and sustainable development are prominent concepts in both developed and developing nations around the globe due to urbanization. Sustainability focuses on the needs and developments of the present with efforts to not jeopardize future needs. Sustainable development, at its core, addresses the relationships between development and the environment. Nations strive to achieve sustainable development as highlighted in the 17 Sustainable Development Goals (SDGs) in the 2030 Agenda of Sustainable Development (United Nations, 2018). The sixth target of SDGs is to have adequate and equitable sanitation and hygiene, with the eleventh target having sustainable cities and communities (United Nations, 2018). Water and other natural resources, including nutrients, are key when discussing sustainable development.

Traditionally, perspectives on the sustainable use of water have been tied to limiting water use and wastage by; turning off water taps when brushing teeth, limiting time spent in the shower, or refraining from watering lawns (Coles, 2016). Calls for action to limit excessive water consumption do not address all potential issues associated with wastewater disposal. To truly strive for sustainable living, nutrient recycling in addition to the reduction of freshwater use and consumption is fundamental (Jenssen, 2004). This dynamic interaction between society's water-saving practices may be explored through the approach of socio-hydrology (Koop, Van Dorssen, & Brouwer, 2019). The socio-hydrology approach fundamentally is to explore the dynamic interaction between water and society (Wesselink, Kooy, & Warner, 2016) which may aid in the explanation of sustainable driven behaviours in communities.

The treatment of the wastewater varies from treatment to disposal in nearby bodies of water such as rivers or oceans. In developed nations, sewage systems typically undergo wastewater treatment; the removal of pollutants from the wastewater to what is considered acceptable to release the effluent back into the environment. Reducing potable water consumption is one of many strategies implemented in striving for sustainable development through the construction of sanitation systems. A less common tactic is to extract nutrients from wastewater for utilization rather than releasing the nutrient-filled effluent into natural water bodies. The contemporary approach of ecological sanitation (Eco-San) strives to recycle these nutrients from the safe reuse of excreta in agriculture (Gardner, 1997; Langergraber & Muellegger, 2005) rather than wasting imperative nutrients in the effluent. Eco-San is an

approach towards sustainability that aims to “close the loop” between sanitation and agriculture regarding nutrients and organic matter. Significant amounts of plant nutrients are found in household wastewater (Jenssen & Skjellhaugen, 1994). Essential plant nutrients for agriculture such as phosphorous, nitrogen, and potassium are found in rich quantities in human waste (Vinnerås, 2002).

The implementation of vacuum toilet systems provides the base for minimal water consumption in a modern toilet system, using from 0.5 to 1.2 litres of water per flush systems (Jenssen, Greatorex, & Warner, 2014; Gao, Zhang, Florentino, & Liu, 2019a) compared to water flush toilets which waste anywhere from 6 to 20 litres of water per flush (Gardner, 1997). Generally, this excess water usage in present toilet systems is responsible for up to 40% of water consumption in municipalities (Gardner, 1997). Water is a vital resource biological life requires to sustain; human life cannot afford to waste such a resource on flush toilet systems (Askham, 2013). This may be indicative in socio-hydrology, where society believes fresh water should not be wasted for the mere purpose of flushing human waste out of residential spaces. Vacuum toilets are a step towards a more sustainable method of handling and treating human excreta, as well as using less freshwater for the sole purpose of disposing of human waste. Traditionally, vacuum toilets were found in water vessels and on airplanes. The introduction of vacuum toilet systems in communities and residences was an area of unfamiliarity for people as most sanitation systems were heavily based on water flush toilets in urban and peri-urban areas.

The transition in toilet system technology from a conventional flush toilet to a vacuum system toilet drastically reduces freshwater consumption. However, it also introduces physical differences in practice for users. The use of sanitation systems is inherently associated with intimate practices of users and user practice and are deeply integrated into the user’s daily life. The functionality of the system has previously been found to have relied upon the users’ compliance and acceptance of the system (Taing, 2017). Additionally, vacuum toilet systems produce a viscous sludge resulting in low volume and high nutrient concentration (Todt, 2015). This high concentration of nutrients allows for the reuse of these nutrients in agriculture safely, closing the loop between agriculture and sanitation.

Vacuum toilet systems are realistic to use when considering construction, affordability, and sustainability. However, due to the technical differences in vacuum toilets from water flush toilets, the user perspective and compliance are essential when implementing a newer sanitation

system in private residences. Flush toilet technology has been largely accepted by consumers due to the accompanying notion of "flush and forget" (Esray, Andersson, Hillers, & Sawyer, 2001) where users are not concerned about the processing and treatment of blackwater once it is flushed down the toilet bowl because it is regarded as "waste". Overall, vacuum toilet systems are sanitation systems that harbour the potential to attain sustainable development in cities and communities.

1.1 Purpose of the study

The purpose of this qualitative study was to explore and present an understanding of vacuum toilet system users' practice and perspectives and identify what factors have influenced the practice and opinions surrounding vacuum toilet system use. There is limited research for user experience and acceptance of vacuum toilet systems. User compliance and acceptance of a sanitation system is imperative; the construction of such waste management systems is futile if the user expresses discomfort and actions of noncompliance. Furthermore, the introduction of using the sludge as a resource would pose a new outlook on the sanitation system; the reuse of human waste as a resource has not been a topic deeply explored among users of particular sanitation systems. It is crucial to understand the beliefs, thoughts, and perspectives of users to determine if the population is comfortable and accepting of ecological sanitation as an approach to sustainable development and living. To strive for sustainability, the development and implementation of a circular economy model for wastewater is a vital strategy. A circular economy model is regenerative based by design; avoiding the linear model of "take, make, and dispose" where the notion of recycling and re-using is not prevalent (Esray et al., 2001; Nawab, Nyborg, Esser, & Jenssen, 2006).

This research study was conducted under the SiEUGreen project. SiEUGreen is a European Union (EU) funded project which aspires to enhance EU-China cooperation in promoting urban agriculture for smart cities ("SiEUGreen", n.d.). The project was constructed on a model of zero waste and circular economy by promoting urban agriculture for environmental sustainability ("SiEUGreen", n.d.). It is based on the notion that urban agriculture will have a positive impact on the social and economic realms of urban living as well as improving the social well-being and quality of life of the community members. The project has a total of five pilot projects in Norway, Denmark, Turkey, and two in China. This research study is specifically related to Task 2.3 which targets a social science approach to strategically study people's

adaptive practices of new technologies and institutions of environmental sustainability ("SiEUGreen", n.d.). The social science approach allowed for the exploration of adaptive practices towards novel technologies implemented to additionally identify opportunities and barriers for change in technology and practice of utilizing the technological institutions. Sanitation systems, including vacuum toilets, play an integral role in innovation and technological development for SiEUGreen.

This research specifically targeted users of vacuum toilet systems, two communities were selected, to understand any potential factors influencing the practice of vacuum toilet use to highlight what modifications can be made to enhance user compliance and acceptance. The information and knowledge produced from this explorative qualitative research study will allow other researchers and developers to use the findings for future research and improvements for sustainable toilet systems and technologies. It may also be viable and integrable information to educate members of society on the growing importance of environmental sustainability in the realm of semi-private and private residences rather than solely commercial residences.

1.2 Research questions

Two research questions have guided this study: 1) Does an environmentally sustainable vacuum toilet system serve as an acceptable toilet system for the Norwegian people?; 2) What social factors have influenced the opinions and practices of vacuum toilet system users?

The specific objectives of the research were to 1) Describe the perceptions, knowledge, and beliefs Norwegians have of vacuum toilet systems in comparison to conventional flush toilets; 2) Explore external factors influencing routine practices towards vacuum toilet use; 3) Identify key barriers to vacuum toilet system acceptance; and 4) Identify comfort levels regarding the possible integration of the model of ecological sanitation in private residences.

Given that practices and habits vary across a population, this research study used two pre-determined cases of vacuum toilet systems users in Norway to gain a broader understanding of user experience and practice. The first case researched student residents, renters, in a university dormitory compared to the second case of family residential owners to encompass practices associated with different lifestyles and stages in life. This production of knowledge from

exploring the variety of users' experiences is important to improve and continue further sustainable development in growing municipalities.

Chapter Two: Literature Review

2.1 Introduction

The fundamental principle of dry toilet technology and systems is the absence of water in the use, handling, and transport of human waste (Regmi, 2005). Historically, the use of dry toilets was seen in low-income countries, which did not have sewage systems transporting waste away from the point of excretion to the disposal or treatment facility. A conventional flush toilet system is not ecologically friendly or a sustainable system of treatment in the disposal of human excreta (Langergraber & Muellegger, 2005) due to the use of high volumes of freshwater for flushing. Water-based disposal systems have been designed and implemented on the dogma of human excreta as a waste rather than a resource (Langergraber & Muellegger, 2005) through the concept of "flush and forget" (Esray, Andersson, Hillers, & Sawyer, 2001).

These sewage systems typically use large amounts of clean drinkable water as a resource in discarding waste from toilets (Gardner, 1997). Water flushing toilets are the most commonly used in middle to high-income nations. Depending on the country or municipality, there is variation in wastewater treatment and location of disposal of wastewater in nearby bodies of water, such as rivers or oceans. Sanitation and safety are primary concerns of conventional flush toilets dismissing the concern of excessive use of water and loss of nutrients (Jenssen, 2004). Alternatively, vacuum toilet systems are a middle ground between dry toilets and water flush toilets. In these systems there is a reduction in freshwater used per flush, resulting in lower volumes of wastewater produced, and thus, creates the potential for nutrient recycling and reuse (Gardner, 1997; Jenssen, 2004).

2.2 Concept of vacuum toilets

Vacuum toilet systems are a type of flush toilet that rely on vacuum suction while using minimal water which inherently reduces flush volume (roughly 0.5-1.5 litres per flush) producing 5-7 litres of blackwater per person (Jenssen et al., 2004). Whereas conventional flush toilets produce anywhere from 6 to 15 times more blackwater than vacuum toilets due to the varying tank sizes of the toilets (Gardner 1997). Vacuum toilet systems are comprised mainly of three sections; the toilet, the piping, and the collection units (Vacuum Collection, 2021) often addressed as septic tanks. Vacuum toilets were developed in 1960 by Joel Liljendahl, a Swedish engineer, for the improvement of gravity transportation systems (Jenssen, Greatorex, & Warner, 1994). Unlike other toilet systems in which the system mechanics differ, vacuum toilet systems

work similarly to regular flush toilets as a system regarding the plumbing blueprints. The system is similar to that of conventional water flush toilets in the removal of wastewater from the toilet bowl through the pipes to, typically, a septic tank. The piping in vacuum toilet systems is smaller than traditional flush toilets; vacuum pipes are typically 50 or 63 mm in diameter (Jenssen et al., 1994) whereas traditional water flush toilets' piping is typically 76 mm but can range up to 101 mm.

Vacuum toilet systems provide for hassle-free transport of waste, as they are typically part of decentralized wastewater management systems (Jenssen et al, 2014). Wastewater systems compose of either centralized or decentralized systems. Centralized wastewater systems collect, treat, and dispose of the effluent from wastewater in larger volumes from a greater surrounding area. In comparison to decentralized systems which focus on a shorter piping distance and in smaller quantities of wastewater. Decentralized wastewater treatment reduces potable water consumption in comparison to centralized systems by collecting, treating, and redistributing clean water and wastewater from the point of use (Shehabi, Stokes, & Horvath, 2012). Vacuum toilets also differ in the volume of black water produced from 5-7 litres of blackwater a day per person compared to conventional flush toilets which produce 6-15 times more waste (Mulec, Mihelic, Walochnik, & Griessler Bulc, 2016; Jenssen et al, 2004) dependent on the particular toilet system. The blackwater produced in vacuum toilets has a higher concentration of nutrients compared to conventional flush toilets (Todt, 2015). The small volumes of waste produced is a clear advantage as the waste can be treated onsite and the nutrients extracted can be used as fertilizer and/or soil amendment due to the limited water quantity per flush (Winblad & Simpson-Hébert, 2004).

Studies regarding the bio-hazardous safety of viruses and pathogens from toilets have been conducted in the past. Pathogenic bacteria are mainly found in human vomit and feces which transfer into the toilet (Lou et al., 2020). Subsequently, flushing increases the velocity of the water in the toilet bowl and releases bioaerosols into the air resulting in the toilet serving as a mode of transmission (Li, Wang, & Chen, 2020; Lou et al., 2020). Lou et al (2020) conducted this study on conventional toilets and wastewater treatment facilities where viruses and microorganisms traveled from toilets to the wastewater management facilities. Similar research has been conducted on vacuum toilets. Li, Wang, and Chen (2020) found that vacuum toilets release fewer aerosols into the air when flushing compared to water flush toilets. Osei (2020)

recognized the hypothesis that vacuum toilets do not generate bioaerosols and have the reputation to be considered as a sanitary alternative to conventional water flush toilets. This study concluded that vacuum toilets did not produce bioaerosols or visible splashes under the same conditions as the water flush toilets (Osei, 2020). These studies suggest that vacuum toilets may serve as a sanitary alternative to water flush toilets, especially in light of the Covid-19 pandemic where there is a greater concern for virus transmission.

2.3 Ecological sanitation (Eco-San)

As mentioned, vacuum toilet systems deliver a high nutrient content due to the low production of wastewater. This product is imperative to implement the model of ecological sanitation for greater environmental sustainability. Winblad and Simpson-Hébert (2004) describe the concept of ecological sanitation as a sustainable approach that promotes the treatment of human excreta as a resource rather than waste. This is possible when human excreta itself is viewed and used as a resource; to be recycled rather than disposed of negligently (Winblad, 1998) through proper management and sanitary treatment. Fundamentally, the concept of the ecological sanitation model can be expressed as "sanitize and reuse" (Nawab, Nyborg, Esser, & Jenssen, 2006). This simply addresses the treatment of human excreta as a resource full of nutrients and therefore recycled back into the natural environment through methods of composting (Gardner, 1997). Dehydration and decomposition are the two methods to treat and sanitize human fecal matter to reuse the nutrients (Haq & Cambridge, 2012). Ecological sanitation is a sustainable model which closes the gap between sanitation and agriculture resulting in a closed system known as an ecological loop (Langergraber & Muellegger, 2005). The implementation of this model is reflective of societal understanding and acceptance of sustainable wastewater management; without societal acceptance of the model, sustainability development cannot occur.

Sanitation models have serious implications on health, the environment, and the economy (Nawab et al., 2006). Human health is subject to the sanitation and sanitary systems in place. The transmission of infectious disease from human excreta is reduced when there is a safe disposal and treatment system of human fecal matter and there is adequate protection of water bodies and supplies (Feachem, Bradley, Garelick, & Mara, 1983). With sanitation systems in place, the transmission of communicable diseases is of low prevalence. The greatest concern is argued to be the assumption that nature has an infinite capacity to store and "assimilate the waste" with

few consequences (Esray, et al., 2001). Additionally, to improve human health and well-being in the modern era with the current limitations in the natural area, natural resources must be disassociated from economic activity (Haq & Cambridge, 2012). This is achieved through the utilization of natural resources, such as water and nutrients, more efficiently and as well as returning the "waste" to the environment for re-use (Haq & Cambridge, 2012).

Ecological sanitation specifically targets the nutrient cycle by targeting nutrient recovery from human excreta in wastewater. Separating human excreta from water and composting has a high fertilizing potential with benefits to plant growth which is similar to, or exceeds, artificial mineral fertilizers in agriculture (Andreev et al., 2017; Haq & Cambridge, 2012). Similarly, Jenssen (2004) found that nutrients in wastewater hold the capacity to nearly capable of providing adequate fertilization to the crops required to feed the world population. Additionally, it has been reported that 80-90% of essential plant nutrients in wastewater are present in human excreta itself; nitrogen, phosphorous, and potassium (Vinnerås, 2002). In consideration of these reports and findings, it is essential and necessary from a sustainability standpoint to introduce the ecological sanitation model in future development as feasibility allows around the globe.

The implementation of vacuum toilets from which fertilizers and soil amendment can be produced completes the cyclical notion of the ecological loop and simultaneously maximizes sanitation by avoiding water pollution. The use of vacuum toilets allows for a shift away from the use of water operating toilets which account for 20-40% of the clean water consumed in cities (Gardner, 1997). Some high-income countries desire dry and low flush toilets for three primary reasons: saving freshwater, preventing the contamination of groundwater and other bodies of water, and composting human excreta for agriculture purposes (Winblad & Simpson-Hébert, 2004). The World Health Organization (WHO) also recognizes the use of excreta in agriculture to yield food production and sustain clean water (WHO, 2006). These reasons aim at protecting human health, preventing pollution of the environment, reducing the unnecessary use of water in sewage systems, and ultimately recycle nutrients from human waste to reduce the production of artificial fertilizers for agriculture. This is a profound step in the direction of environmental sustainability and sanitation and hygiene.

2.4 User compliance and acceptance

Sanitation systems are only as effective as the user's acceptance and compliance to using them properly. Behaviours regarding practice on past technologies form to become habits and

become barriers to compliance on newer technological systems. For example, Liernert and Larson (2010) address that the disposal of toilet paper in the feces compartment of the toilet with a flush after urinating wastes water in NoMix Technology. Rather, the users should have disposed of the paper waste in a separate bin or not flush the feces compartment of the toilet (Liernert & Larson, 2010). The user's compliance and acceptance of a toilet system are based on the requirements unique to that disposal system. A Swedish study found that users generally modified their behaviours to effectively use NoMix Toilet technology, such as modifications to flushing and disposal habits and seating (Liernert & Larson, 2010).

To learn and understand how to maximize user acceptance and compliance of vacuum toilet system technologies, the exploration of the cultural and social perceptions and norms is a vital area to explore and understand to implement or adjust existing systems for maximum acceptance and use. Without a thorough understanding of societal norms and beliefs surrounding the topic of reusing human excreta as a composted fertilizer, it is nearly impossible to ensure the sanitation system will prove to be effective. The system in itself may be sustainable and ecologically sanitary, but without user satisfaction and acceptance of the sanitation system, it is futile to draft and implement such systems.

Studies have been conducted in Europe to explore user satisfaction, acceptance, and compliance with different sanitation systems. Liernert and Larson (2010) explored user satisfaction and acceptance of source-separating toilet systems through the use of questionnaires from 2,700 participants in 7 European countries: Switzerland, Germany, Austria, Luxemburg, the Netherlands, Sweden, and Denmark. Source-separating toilets isolate the urine from fecal waste from the toilet bowl which would allow for the urine to be used as an agricultural fertilizer (Liernert & Larson, 2010). The study reported the majority of the participants were accepting of the source-separating toilets and were comfortable with the model of ecological sanitation to use in the agricultural industry through the use of fertilizer made from urine. Vacuum toilet systems are intrinsically different from source-separating toilets, therefore, the findings from European-based studies on other toilet systems cannot be applied to vacuum system users. There have been no studies conducted concerning users' experiences with vacuum toilet systems in Europe. Research on vacuum toilet systems has been primarily conducted in low to middle-income countries where sanitation remains a high priority issue in dealing with communicable diseases and sustainable development. For example, projects exploring user perceptions and acceptance

of sanitation systems in rural India (Rashid & Pandit, 2020) and other developing nations of Asia are more widely found in the literature in comparison to user acceptance and compliance in Europe. Consequently, understandings of user experience of vacuum toilet systems can only be hypothesized based on data and knowledge produced from the literature, specifically in Europe due to the differences posed in other continents and dominantly low-income countries.

Studies do highlight general human attitudes and perspectives towards elements encompassed in sanitation systems through inter-disciplinary fields. Despite these inter-disciplinary approaches there have been no studies conducted regarding users of vacuum toilet systems specifically in Norway. Typically, the subject of the user's opinions regarding ecological sanitation or comfort surrounding a particular is not a topic that is directly approached in the social sciences (Warner, 2002). The topic is manifested in subjects within the fields such as notions of purity, cleanliness, or filth, and often affiliated with religion and rituals.

2.4.1 Approaches in psychology and sociology

Literature in the fields of psychology and sociology may aid in developing an understanding of user compliance, practice, and acceptance of vacuum toilet systems. A psychological approach describes important topics that mould perceptions and practices in vacuum toilet use. People classify acts as either appropriate or inappropriate depending on their learned experiences. Individual behaviour is reflective of the learned experiences resulting in people varying in their tolerance or disgust towards human excrement. Individually learned experiences are reflected in the behaviours people exhibit and, therefore, people will vary in their tolerance or disgust towards human excrement. Templer, King, Brooner, and Corgiat (1986) developed the Body Elimination Attitude Scale to measure an individual's disgust towards human excreta. The scale does not predict behaviours directed to any particular toilet system but rather reveals the variation of people's tolerance towards human excrement (Templer et al., 1986). For instance, an individual's professional career related to sanitation show less disgust compared to individuals not working in related fields (Templer et al., 1986).

McCarthy and Shrum (1994) found that personal values do not reflect a direct relationship to recycling behaviour; they insinuated towards the topic of human excrement without directly addressing it. Values did influence personal attitudes towards recycling (McCarthy & Shrum, 1994). Primarily, the inconveniences of recycling influenced recycling behaviour (McCarthy & Shrum, 1994). If modes of recycling were deemed to be difficult or

inconvenient, an individual is less likely to partake in the recycling behaviour. Since human excreta can be a recycled resource, it is a recycling waste that McCarthy and Shrum (1994) have implicitly included in their findings.

Repulsion and disgust in human culture and behaviours have been researched and explored. Curtis and Biran (2001) explored the notion of disgust as a human universal. An individual may be more or less disgusted with human fecal matter depending on his/ her culture. (Curtis & Biran, 2001). Human feces are the primary objects of disgust for a significant portion of the human population as it contains harmful pathogens, therefore, human repulsion is a natural phenomenon for survival (Curtis & Biran, 2001).

Unfamiliarity plays another integral role in the acceptance and usage of sanitation systems. Individuals accustomed to specific toilet sanitation systems showed varying levels of acceptance or reservations to waterless toilet systems in their homes (Hennigs et al., 2019). Hennigs et al. (2019) found that individuals that used water-flush toilet systems were far less receptive and open to the idea of using waterless toilet systems in comparison to users of urine-diversion dehydration toilets. Lack of familiarity causes discomfort and therefore resistance to the unknown and is deeply rooted in psychology.

There are greater universal cultures that contribute to the way individuals react to human excrement apart from religion. Across many world cultures, the biological and physical characteristics are not always the primary what deter the majority of people from human excreta with emotions of disgust and repulsion, but rather it is the socially constructed notion of aesthetic uncleanliness (Rheinländer, Keraita, Konradsen, Samuelsen, & Dalsgaard, 2013). These emotions contribute towards perceptions that have proven to be difficult for the public acceptance of ecological sanitation (Mariwah, 2017). Mkhize, Taylor, Udert, Gounden, and Buckley (2017) convey that for dry toilet use to be accepted and used internationally, the acceptance and use of such systems must begin in developed nations where environmental concerns are on the rise. Additionally, Mariwah and Drangert (2011) suggest that open discussions in communities can aid in the successful implementation of ecological sanitation systems. Therefore, an environmental approach in combination with social enforcement will prove to be the most effective of implementing dry toilet systems with user acceptance in developed nations.

2.6 The Norwegian context

Recycling was driven by scarcity in the 20th century Norway prompted the use and reuse of materials regularly illustrating a direct link between consumption and recycling (Jørgensen, 2013). Superficially, this behaviour seems similar in the 21st century. Although, Jørgensen (2013) finds that recycling behaviours in 21st century Norway are attributed as an expression of citizenship, social norms, and expectations, as well as for the notion of contributing towards a more sustainable lifestyle. McMcarthy and Shrum (1994) found that personal values are not reflective of a direct connection to recycling behaviours, but it is rather societal norms and expectations which people inherently follow.

Recycling is attributed as an act of 'green' citizenship where consumers are mindful of the environmental impact of their consumption in the modern era (Oldenziel & Weber, 2013). For Norwegians, this occurs primarily through voluntary actions with few economic incentives encouraging 'green' behaviours (Halvorsen, 2008). This demonstrates to reflect the Norwegian societal norm of recycling; recycling is a behaviour the members of society participate in regularly through a constructed societal norm. Ecological sanitation technology is a form of recycling; the use and reuse of nutrients (Winblad,1998) through means of composting human excreta and using it as fertilizer creates an ecological loop (Jenssen, 2004; Langergraber & Muellegger, 2005). However, the recycling of human excreta for reuse has not been extensively studied in Norway.

Psychology, evolutionary adaptations, or religious norms and practices are important and relevant approaches to understand peoples' inherent and learned feelings towards human excreta and practices associated with the handling of human excreta. These various perspectives serve to deliver a holistic image of a society's attitudes and believes towards sensitive topics such as human waste. A holistic image is vital to understand Norwegian habits, preferences, and approval for particular toilet systems in their homes. Therefore, Norwegian practices and norms in recycling can provide insight into the Norwegian perspective and societal expectations. However, this cannot provide an all-inclusive understanding of Norwegian perspectives. Rather it serves to explain one aspect that can attempt to investigate Norwegian beliefs and understandings concerning comfort levels with vacuum toilet system use and for the potential implementation of Eco-San. Thus far, the literature may imply a connection between recycling perspectives and acceptance of vacuum toilet systems in a Norwegian context. Additional, and

relevant, theoretical perspectives and descriptions require research and literature development concerning the Norwegian context.

2.7 Gaps in the literature

The literature on user perception, usage, and acceptance of ecological sanitation is extensively based on studies done in lower to middle-income nations. Therefore, the exploration of developed nations' acceptance or hesitance toward the implementation of vacuum toilet systems for sustainable development is vital to move forward to reach goals as outlined in the SDGs of adequate and equitable hygiene for the world (United Nations, 2018). Additionally, the 11th target pertains to attaining sustainable cities and communities globally (United Nations, 2018) and not solely for developing nations. Social norms and expectations vary across the world and vary domestically within a region or continent. When exploring the social context of Norway, studies from other Scandinavian countries can be researched and studied to give a general idea of the Norwegian attitudes, beliefs, and practices. However, the nations do differ and there are contrasting opinions and practices. This is particular to the intimate topic of practicing vacuum toilets and the perspective of vacuum toilet users. It has the potential to further expand to general Scandinavian practices and perspectives. The literature thus far indicates the findings from this research study to be new.

Chapter Three: Study Areas and Populations

To understand the experiences and perspectives of the participants in the research study regarding the use and understanding of vacuum toilet systems in their private residences, the history of development and technicalities of the system in each community was crucial to understand and consider when collecting and analyzing the data. This information also provides detail as to why these two communities, Kaja student housing and family residences in Torvetua, were selected as the study groups for this research project.

3.1 Kaja Student Housing, Ås

Kaja Student Housing, or Kaja, at the Norwegian University of Life Sciences (NMBU) in Ås, Norway houses 48 students- a combination of couple flats and single rooms- with vacuum toilet systems on a rental contract agreed between the tenant and SiÅs. This student residence was a first-generation Eco-San system through the use of vacuum toilet technology implemented in 1997 (Jenssen, 2005). P. Jenssen (personal communication, May 9, 2021) stated that during the construction of Kaja, a local plumber from NMBU assisted in the development of the vacuum toilet system. This guided the development of the vacuum system in this community. An initial problem occurred shortly after the system start-up; Jets had initially stated that a 32mm pipe was the correct size to use (P. Jenssen, personal communication, May 9, 2021). This was changed and replaced with a larger piping size.

Changes in the system have been made over the years, and the system does not function in a circular economy. The system is and always was, decentralized from the municipal water treatment facility. The black water is collected in a holding tank at Kaja. From 1998 to 1999, blackwater was used for research purposes (P. Jenssen, personal communication, May 9, 2021). The system remained decentralized, and the blackwater waste was collected and treated and the local treatment facility (P. Jenssen, personal communication, May 9, 2021). However, blackwater has been used in a research laboratory at NMBU over the last five years (P. Jenssen, personal communication, May 9, 2021) to facilitate research, innovation, and development. This is regularly linked to the concept of Eco-San where the notion of recycling is central and relevant to concentrated wastewater; the high nutrients, low volume of blackwater is an important element of this system to work towards more efficient ways to complete the cycle of Eco-San. The separation of the greywater provides for efficient treatment and research with drinking water. The research at NMBU is centered around biogas and fertilizer production from the

blackwater. These processes will be implemented into the vacuum system in the summer of 2021, and this will serve as a demonstration for the SiEUGreen project (P. Jenssen, personal communication, May 9, 2021).

Any prevalent complications with the system or its services for Kaja student housing are addressed by SiÅs, the organization for housing as well as other services for students. The renters are not responsible for handling any maintenance or problems associated with the vacuum toilet or the system as they are not owners of the rental spaces. This aspect of ownership and notion of responsibility is a key differentiator between the student community at Kaja dormitories and the family housing in Torvetua.

3.2 Torvetua, Bergen

The community of Torvetua came into development on an environmentally friendly model, built-in 1998 after years of planning and construction ("Torvetuas historie", n.d.). The community is comprised of 41 houses, primarily housing families of two or more individuals including children of all ages. The residential properties are owned by the residents. Maintenance-related aspects with the vacuum system or toilets are the responsibility of the homeowner and not an external party or organization. The community project was conceptualized by a local politician and environmentalist, Kurt Oddekalv, for "greener development" in retaliation to a local developer, Erik Sande, who had planned to build 70 houses in that area ("Torvetuas historie", n.d.). Kurt Oddekalv was not against development in the area of Torvetua but preferred the development that "emphasizes the area's landscape character and protects the vegetation" and committed to developing the community with environmentally friendly strategies ("Torvertuas historie", n.d.). The vacuum toilet manufacturer, Jets, drafted the blueprint for the system in Torvetua (P. Jenssen, personal communication, May 9, 2021). The residences furthest from the vacuum pumps were built first started by P. Jenssen (personal communication, May 9, 2021).

The community was built in strategic ways to maintain as much of nature as possible and the implementation of a de-centralized vacuum toilet system was another aspect of making this community as environmentally friendly as possible. In other words, the treatment or handling of the wastewater was done locally; separate from the *Bergen Kommune*. The greywater was treated locally to the community and released into the lake nearby and the blackwater was collected regularly from a holding tank in the community and transported to farmlands nearby in Vestland

county (K.G. Flo, personal communication, November 11, 2020). This was done regularly and cost the community the disposal of blackwater.

In 2019, Torvetua shifted from a decentralized system to a centralized system by connecting to the wastewater treatment facility with *Bergen Kommune*'s wastewater management facilities (K.G. Flo, personal communication, November 11, 2020). The greywater and blackwater were no longer treated or collected separately in the community, but rather were merged before reaching the wastewater management facility operated by *Bergen Kommune*. The underground piping for blackwater and greywater was connected before exiting the community under the nearby lake and to *Bergen Kommune*'s wastewater management facilities (K.G. Flo, personal communication, November 11, 2020). The system as practiced today is not the model it was intended to be upon the construction of the community in the late 1990s considering the environmental benefits it was initially built for.

The relevance of researching vacuum toilet use and acceptance in both these communities is vital for a holistic understanding and finding of vacuum toilet acceptance in a Norwegian context. Considering the changes to the system as well as the similarities and differences between the two communities is fundamental to reflect upon the research.

3.3. Comparisons

Kaja and Torvetua were built in the late 1990s roughly between 1997 to 1999 with vacuum toilet systems in the residences. Both vacuum toilet systems were de-centralized from the municipal or local wastewater management facilities in the communities; the wastewater management was completed locally or utilized transportation to a secondary location. A decentralized system remains at Kaja student housing but changed at Torvetua to a centralized system with *Bergen Kommune*. The student residents at Kaja follow a hands-off approach as SiÅs holds primary responsibility for the maintenance and functioning of the wastewater system. In Torvetua, until recently, the community members and homeowners were forced to take the responsibility of maintaining and fixing all aspects related to the vacuum system they deemed essential and necessary due to the loss of funds from the initial housing development project in the late 1990s; the homeowners were compelled to be involved in problem-solving and maintenance to have a functioning system.

Additionally, Torvetua was not built or intended for use as a research site. The housing development was based on the notion of greener development in an urban area in contrast to

Kaja student housing which is a regular site for university research in Ås. An important and overlooked characteristic is the ownership status in both communities as it contributes to the importance placed on a well-functioning system in these communities. The community members took maintenance matters into their own hands from the beginning in 1999 when many of them initially moved into their new homes and personally invested in better functioning and maintained system. This is a result of personal property versus residing in rental properties, an important trait of these communities that will be discussed after.

Another key characteristic integral to the housing communities is the difference between student and family status. Kaja dormitories provide residence to students primarily between 18-30 years of age. Some of these apartments are single housing units while others are couples. All the residents are students at NMBU. In comparison, the residents in Torvetua are primarily families, many with children and others with children who moved out of the residence in the last few years. Ultimately, at some point, the residences were used by young couples, children, adolescents, and some elderly. This is related to long-term use with vacuum toilet technology for residents in Torvetua compared to a few years for students in Kaja during the period of their studies.

Younger residents, particularly those of student status encompass the residents of Kaja in comparison to relatively older homeowners in Torvetua, who are of working-class and typically reside with families long-term. This key differentiation leads to greater variance in the data collected. Therefore, the broader and more detailed understanding of the social practice of vacuum toilet system technology is possible with the differences between these two housing communities rather than a single case study which inherently would limit the scope of the research findings.

Chapter Four: Methodology

4.1 Project context

Vacuum toilet systems are a step towards sustainable development through the limited use of water per flush compared to conventional toilet systems dominating the western world. However, it is not the most sustainable wastewater system as freshwater is still introduced into the system and wasted, as reflected in a linear economy model. Vacuum toilet systems can be made into a more sustainable wastewater system when the model is improved and developed into a circular economic model. This entails the treatment and reuse of human waste through the form of fertilizers allowing the recycling of nutrients: phosphorous, potassium, and nitrogen (Vinnerås, 2002). However, the acceptance of such a circular economic model in society is imperative. To research and understand societal perspectives on the sustainable model, the Norwegian residents of Torvetua, Bergen, and residents of Kaja student housing for the Norwegian University of Life Sciences (NMBU) are potential participants for this research study. Vacuum toilet systems were built into forty-one condominium homes of the Torvetua community and served forty-eight student residents in Kaja (Jenssen, 2004).

4.2 Study design and rationale

A qualitative study design was used to explore and understand the users' experiences and perspectives toward vacuum toilet systems to determine if it is an accepted sanitation system for the Norwegian people. A qualitative methodology was deemed optimal for this study due to the nature of its holistic understanding of the broader social context and perspectives in the Norwegian population. Specifically, this study aims to explore social factors influencing the regular practice among groups of individuals regarding their use of vacuum toilet systems in their private or semi-private residences. Qualitative methods focus on exploring the subjective experiences, perceptions, and opinions of the participants (Creswell, 2013). Therefore, it was the appropriate approach for this study.

Interviews were the appropriate method of data collection to acquire data for this research study. Specifically, in-depth interviews allow for the participants to contribute and raise awareness to topics they believe are connected and important to their perspectives surrounding their practice of using vacuum toilet systems and worldview on ecological sanitation in private residences. By using a socio-hydrological approach, the researcher was able to emphasize the

practices, experiences, and perspectives (Creswell, 2013) to develop an understanding guided by the socio-hydrological approach (Wesselink, Kooy, & Warner, 2016). Overall, a qualitative methodology of interviewing was considered to be optimal for the research study as the experiences and perspectives of the participants were the key points of interest for this project.

The method of interviews was selected by eliminating other popular qualitative research methods. The use of questionnaires or surveys would limit the scope of data collected due to the directional nature of questionnaires and surveys where participants are asked to address the preconceived ideas and notions of the researcher. This method does not allow for the participant to express ideas and opinions which have not been preconceived by the researcher; the researcher's presumptions would guide the questions and content addressed in the surveys and questionnaires to lead the data collection in a particular direction. Therefore, the data would not represent a reflective and holistic image of the realities of the participants. In-depth interviews allowed for the researcher to address relevant topics; however, it is the participant who steers the discussion to what they credit to be important and relevant information to share with the researcher.

4.3 Theoretical approach

Theoretical explanations on experiences and perceptions are typically rooted in the social sciences. Theoretical explanations of water, water usage, and sustainability are often rooted in hydrology studies. The human-water dynamic interaction requires the involvement of researchers from hydrology and social science (Xu, Gober, Wheater, & Kajikawa, 2018). The theoretical approach taken to analyse the practice and perspectives of vacuum toilet systems by the users is that of socio-hydrology for analysis of this research. The foundation of socio-hydrology is that all human and natural systems are influenced by water, and, therefore, focuses on the interactions and relationships between water, water resource systems, and society (Forbes, Brozović, Franz, Lally, & Petitt, 2018; Xu et al., 2018). The involvement of social scientists and social science research highlights a focus on sustainability, adaptation, practice, and perspective in addition to hydrology's traditional focus on systems modeling (Xu et al., 2018).

The vacuum toilet system is a human system that indirectly addresses the human interaction with water and was selected to be used in the two communities: Torvetua and Kaja. Users' practices and perceptions are accounts of their interactions with a water-reducing

sanitation system. In this respect, the socio-hydrology approach could play an important role in understanding the practices, experiences, and perceptions of VTS users.

4.4 Participant recruitment

The interviews were conducted in both Torvetua and Kaja student housing. Participants were required to be regular users of vacuum toilets in their residence of Torvetua or the student dormitories in Ås and to provide informed consent to participate in the study. Both municipalities were of interest due to differences between student and working status of the participants and occupying in private or semi-private residences. Therefore, student residents were recruited from Kaja student housing, and participants from family living situations were recruited from Torvetua. The student or working status was not explicitly questioned, but rather grouped in respect to age groups on the signed consent forms. Kaja students were required to be between 18 and 30 years of age and currently retain student status. The participants in Bergen had no upper age requirement. This allowed experiences of seniors, parents, single-parents, and students in a family-living environment to be included. This addressed the factor of differences in practice and perspectives of different age groups. This was a means to develop a broader understanding of how residents use and understand vacuum toilet systems and interpret their perspectives on ecological sanitation in the private domain.

A total of 28 vacuum toilet system users were recruited and interviewed for this study. Of the 28, 18 participants were permanent residents of the community of Torvetua in Bergen, and 10 were student residents at the Kaja student dormitories in Ås. Participants from Torvetua were typically from family homes and part of the working class. Participants from Kaja were students at the Norwegian University of Life Sciences residing in couples or singles accommodations with shared washroom facilities in both.

Recruitment was a two-step process for this research study. Initially, an invitation letter with an attached informed consent form was sent to a contact resident in Torvetua inviting all potential participants in the study in advance to recruit and schedule interviews. The information documents were posted to a community social media account and shared with interested community members. In Ås, the information letter and consent form were also sent in advance to a personal contact at SiÅs who manages the Kaja student housing facility. This initial approach recruited few interested participants from Bergen and none in Ås. Therefore, in-person recruiting was essential during the fieldwork in Ås and Torvetua in October and November, respectively.

The latter method worked best at recruiting due to the general expectance of responding to interest immediately in comparison to viewing an invitation letter and choosing not to respond at all.

Unlike quantitative research, qualitative research is not ordinarily driven by calculated sample sizes (Hennik, Hutter, & Bailey, 2020). It is focused on exploring the experiences of the participants to gain a thorough understanding of their perspective on the topic of concern (Maxwell, 2010) promoting the formulation of a holistic understanding of the perspectives and experiences of the individual or community. Since there was no pre-determined number of participants to interview in Ås or Torvetua, interviews were conducted until the point of saturation; no new insights emerged from the information attained through the data collection (Mason, 2010). A point of saturation allows for the inclusion of a broader range of perspectives found in the population which provides a holistic image of the Norwegian context rather than one perspective which does not accurately reflect the target population.

4.4.1 Participant inclusion criteria

Participants in Torvetua and Kaja were asked how long they have resided in their current residence with the vacuum toilet system, were they aware of the vacuum toilet system in their residence, if they have had prior experiences with vacuum toilets, and what toilet system they used previously. A select few participants reported the relevant experience to vacuum toilet systems or sewage systems, professionally. A couple of other participants reported the occasional use of dry toilets for cabin trips in their youth with families. For the majority of participants, this was their first encounter with vacuum toilets that were not on airplanes or cruise ships. These participants reported using conventional flush toilets before vacuum toilets. This background knowledge of the participants provided the researcher with an understanding of any prior experience, acceptance, or compliance of the vacuum toilet system of the user.

4.5 In-depth interviews

Consenting participants were interviewed following an in-depth interview guideline (see Appendix E). The in-depth modality allows for participants to share information they deem relevant and important to the subject matter without the discussion deterring away from the subject matter. This ensured that preconceived notions of vacuum toilet systems and social factors are not guiding the participant's responses in a particular direction. Rather the broad and general interview questions allowed for each participant to share what they deemed as important

and relevant to the vacuum toilet system. Each participant engaged in one interview designed to last approximately 30 minutes. However, some interviews took more or less time depending on each participant. A few participants made contact with the researcher post-interview via email to provide additional information not mentioned in the recorded interview time. This information was immediately transferred in its original text to the documents of the respective transcripts.

4.6 Data collection

Interviews were conducted in October and November of 2020. Interviews typically lasted between 20 and 35 minutes. None of the participants had a relationship with the researcher before the recruitment process for the interviews. As mentioned, interviews were conducted until there was no new information emerging in the data (Weller et al., 2018).

At the beginning of each interview, the researcher provided additional information about the research study and the purpose of interviewing the participants (see Appendix D). Physical or digital informed consent forms were collected if they had not been collected before this time (see Appendices B and C) and answered all questions participants had. They were reminded that their participation is voluntary and may be drawn at any point in time during the interview or the months following so long that their data is independent and has not been analyzed collectively with other data. Participants were also reminded that they may ask the interviewer to skip any questions they were not comfortable answering. It was made clear that the interviewer was not endorsed by any particular vacuum toilet manufacturer but was a student researcher from a research team striving to understand the practicalities and views of vacuum toilet system users to better enhance, develop, and implement sustainable vacuum toilet technology for user practice and acceptance. Participants had the opportunity to decide where the interview will take place for their comfort, typically outdoors or over a digital platform which is highlighted in the recruitment letter and informed consent form (see Appendix B and C). This was largely due to the national and regional government restrictions in place at the time of the interviews in autumn of 2020.

Due to the unprecedented situation regarding the Covid-19 pandemic and infection rates in the Bergen and the Oslo region, interviews were conducted in person with infection control measures in place and on digital platforms as preferred by the respective participant. By nature of the infection rates in October in the Oslo region, many of the interviews were done in person at Kaja student housing while others were primarily over Zoom. All at the discretion of each

willing participant to choose between an interview over a digital platform at a later date or in person then. At the time of data collection for Torvetua, infection rates and stricter government control measures made it necessary to conduct the interviews in an outdoor environment or over digital platforms for the fieldwork in November. The decision to hold the interview outdoors or over a digital platform was selected by the interviewee's preference. A few outdoor interviews were arranged in advance with consideration of the weather forecast. Weather permitting, the majority of these occurred at community picnic benches within Torvetua, or under interviews were scheduled or taken upon the initial in-person meetings. Due to the weather in Bergen, some interviews were required to be conducted on a digital platform despite intentions to meet physically distanced outside in the community.

The personability factor of conducting interviews one-on-none was reduced. The researcher wore a mask for all outdoor interviews with at least 1.5 metres physically distancing to ensure minimal transmission possibility to the participant. This use of the mask may have made the interaction less personable for the participant, and therefore, the participants may have shared less information about their practice of the toilet system. Conversely, the researcher's face was visible for the digitally conducted interviews. However, the digital presence does not account for the same personability as in-person interviews. Despite the strict adherence to the Covid-19 restrictions in both communities, the possibility remained that some users and residents were hesitant and unwilling to interact with the researcher who previously had not shared close contact with them.

All collected data was audio-recorded and transcribed verbatim then stored on the researcher's password-protected electronic devices. All participants were made anonymous on audio recordings, field notes, and transcription files; any identifying information of participants was not included in the transcriptions and analysis of the research. Transcriptions were completed digitally by the researcher for thorough analysis continuously during fieldwork.

4.7 Data analysis

All the data collected during the research period was given time to be analyzed by the researcher. The researcher needed to conduct a thorough review and analysis of the data to discuss the findings and conclusion. The analysis of collected data was a continuous process that helped to guided changes in the interview guide probes for upcoming interviews during fieldwork. A thematic analysis was conducted which allowed the researcher to generate detailed

interpretations and understanding from participant narratives (Braun and Clarke, 2013). Thematic analysis is commonly used in analyzing qualitative data, especially from interview transcripts (Braun and Clark, 2013). Braun and Clarke's (2013) process for a thematic analysis was followed in the research analysis:

Familiarization: Upon transcription, all transcripts were read several times for the researcher to be familiarized with the data.

Coding: Coding was completed for each transcript in the qualitative analysis software, NVivo (NVivo, 2021). Two separate files were created, one for each community, and each file contained transcription documents that were thematically analyzed to produce codes, or "nodes" in NVivo, found in the data. These nodes were created by the researcher of reoccurring themes which surfaced in the analysis process (Clarke, Braun, & Hayfield, 2015).

Themes: Different codes generated in NVivo were grouped to create themes and subthemes. These themes were regularly reviewed and reflected upon. Changes were made throughout the analysis process.

Analysis Production: Themes were described and analyzed by the researcher.

4.8 Ethical considerations

The proposal for this research project was submitted to the *Norsk Senter for Forskningsdata* (NSD) and received approval on August 27th, 2020 (see Appendix A).

The participants' anonymity and confidentiality were guaranteed. No personal identifying information was to be made available to persons not directly involved in the research study. All physical copies of data will be destroyed upon completion of the master's thesis defence including, but not limited to the transcriptions and audio recordings. Recorded transcripts will be kept confidential for the duration of the research and destroyed as per the University of Oslo's biomedical research ethics guidelines and instructions. No persons had direct access to the data collected outside the research team.

Consent was obtained from all participants through the informed consent form (see Appendices B and C) before the data collection process. All participants were informed that they had the right to withdraw from the research study at any point in time without having to justify it. Participants were able to address any questions they have before and during data collection.

4.9 Limitations

This research study has limitations. Generalizations cannot be made across the populations of vacuum toilet users because this was explorative of two case studies in Norway. The detection and reporting of a diversity of experiences and perceptions is the goal of qualitative research (Malterud, 2001) compared to quantitative analysis which strives to achieve generalizations through statistics. Surveys and focus group discussions could have been used in the methodology to dig deeper into the themes generated in the analysis process. Therefore, the conclusions from this research study cannot be generalized for the greater population of users of vacuum toilet systems in Scandinavia. There has been limited research specifically on VTS users and their perspectives. The majority of the literature guiding this study was from the technical and practical field of VTS and theories from social science fields were drawn in addition.

Language may have been a limitation in this study as the researcher was not proficient in Norwegian. In many instances, participants used Norwegian words and terms to express the situation or feeling about their experience but faced uncertainty in translating a few of those terms into English. However, the researcher did use external sources to translate the words but the position of the interviewee during the interview may have intentionally used English terms when unable to think of an equivalent from Norwegian.

Chapter Five: Results

5.1 Introduction

This chapter provides the results of the analysis of the data collected in this study. The data from in-depth interviews, follow-up emails, information collected from one-on-one tours of the systems with recruiters, and field notes were thematically analysed with interpretations of the data on behalf of the researcher as described in section 4.7.

A total of 28 participants were interviewed for this study. Of the 28, 18 participants were permanent residents of the community of Torvetua, Bergen, and ten were student residents at the Kaja student dormitories in Ås. Participants from Torvetua were typically from family homes and part of the working class. Participants reported a range in the length of inhabitancy in the community from two to over 20 years. Many participants currently had young children and many participants had young children using the residential vacuum toilets in the past. The majority of the participants were male. In Kaja, all the participants recruited were currently enrolled as students at NMBU. The residences were couples or singles accommodations with shared washroom facilities. Participants were expected to be between 18 to 30 years of age due to student status, however, this was not explicitly questioned.

Based on information gathered from interviews with both communities, the data is presented and categorized into four major themes: technical aspects, practices of the system, personal perceptions, and social dimensions. Every theme is composed of sub-themes that were identified throughout the data analysis process and will be explored through this chapter. The data generally indicates similar technical experiences with the system, which has manifested in different perceptions of the users.

Table 1. Summary of Major Themes Emerged

Technical	Practices	Perceptions	Social
Physical properties	Cleaning practices	Knowledge	Collaboration
Complications	Prevention measures	Perspectives	Social bonding
System blueprint	Flushing behaviours	System preference	
		VTS & Eco-San	

5.2 Technical aspects

This section will address the technical and operational factors which affected the participants' practice and acceptance of the vacuum toilet system in the community. Narratives highlight user concern in three sub-themes associated with the technical properties of the vacuum toilet system: physical properties, problems with the system, preventative measures, the vacuum system blueprint. Participants were asked to "Tell me about the vacuum toilet system in your home" (see Appendix E) to which most respondents reported on the technical difficulties endured and differences with the vacuum system. Many of these difficulties lay in complications with the system as described in section 5.2.2 and have affected user experience and acceptance of the toilet.

5.2.1 Physical properties

This theme identifies the practical and physical features the participants deemed relevant or important to share with the vacuum toilet itself. Participants were questioned about their satisfaction with the appearance, seating, comfort, and sound of the vacuum toilet, as well as general comparability to conventional flush toilets. Participants generally reported an overall similarity between vacuum toilets and conventional with subtle differences in appearance and smell from the holding tank and placed great stress on the noise.

Appearances were generally reported to be 'ordinary' and comparable to that of a conventional toilet. Such as,

> *"They look very ordinary and nothing fancy. Nothing you would be ashamed of showing to your guests in any way. It looks just like (laughs) a toilet." (Participant 18)*

Although, a few participants noted some minor differences in the appearance of the vacuum toilet. For instance, vacuum toilet systems protrude out from the wall so there is no option to lean back, had shared one participant. Another participant observed the appearance of the flush button to be different from previous toilets, but not irregular. A couple of residents in Ås reported that the toilet bowls in their residences were discoloured and generally appeared to be unclean despite frequencies and all efforts of cleaning. Additionally, the general appearance of the toilet was outdated,

> *"The toilets in themselves... the look is fine. We have one of the older ones and one of the newer ones. The newer ones, of course, look better but that's the same for conventional toilets I suppose." (Participant 17)*

This was specifically regarding the flush button, which was identified as a light switch in Kaja, where a participant shared,

> *"They (people) wouldn't mind as long as the button has a different design because it has the light switch." (Participant 1)*

This may be attributed to the fact that the toilets in Kaja student housing are older models and used by numerous tenants over the years. Seating comfort was reported to be the "good" or the "same" as conventional flush. Generally, participants agreed the vacuum toilet itself is very comparable to a conventional flush regarding the appearance and seating comfort. Comparing vacuum toilets to traditional water flush toilets is suggestive of similarity between the two systems. Addressing similarity through the use of descriptors such as, "ordinary" or "same" implies the vacuum toilet has characteristics that are familiar to the user and, therefore, comfortable to some degree. However, one of the main differences recognized was the noise.

> *"The difference is that it makes a little bit more noise when it flushes, but it's faster to fill up so it's ready to use faster by another person. There's no difference in user comfort or anything. Convenience is not a problem either. It's just a regular toilet." (Participant 3)*

The emphasis on the noise or sound element of the vacuum toilet when it is flushed was described as very loud in comparison to a conventional flush toilet system.

> *"We didn't know anything about vacuum toilets. So, it came to us as a surprise in the audio sector. It kind of makes a lot of noise." (Participant 11 and 12)*

> *"The vacuum toilets, it's a more noisy than conventional toilets (…) but the noise is my biggest issue with these toilets." (Participant 13)*

Generally, participants reported that the noise is currently the greatest complaint as the overall functionality of the system has improved over time. The noise was often described as "very loud", "unpleasant", and "unusual" by the majority of participants.

> *"Well, it makes more noise. And maybe when we first moved in here, it was a bit annoying especially in the middle of the night if someone had to go to the toilet." (Participant 27)*

Additionally, the noise appeared to be a nuisance for many participants in both communities. One student resident shared the reason for her aversion to the vacuum noise.

> *"Just in, at 3:00 a.m. when I'm trying to go to the bathroom without waking my boyfriend. Yeah, but other than that, it's not it's not a problem at all*." (Participant 3)

The smell was generally differentiated by participants between the vacuum toilet itself and the vacuum system in different respects. The vacuum toilets themselves were not reported to cause smell, but rather that the smell is better with the vacuum toilet in comparison to water flush toilets.

> *"There is less odour from vacuum toilets, in my opinion." (Participant 3)*

This participant had shared professional experience with vacuum toilet systems which may have contributed to their belief that there is less smell from vacuum toilets. The dominating response on foul odour was in respect to the holding tanks in both communities. A couple of participants in Torvetua stated they were unable to sit outdoors and enjoy the natural environment due to the odour of sewage from the holding tank in the community. Most others reported the odour of sewage on days the holding tank was emptied and transported out of the community.

> *"But at that time, it (decentralized system) was a huge problem. Smell-wise, we had a lot of smell. We couldn't for very many years, in the summer, we didn't sit outside because we could smell it (…) Depending on the wind. Not every time we were outside but quite often, we smelled it." (Participant 23)*

Student participants in Kaja reported similar experiences as Torvetua. Incidents of odour ordinarily occur on days the holding tank was emptied. On the first day of interviews at Kaja, the holding tank either had a blockage in the main pipeline or was filled and the black wastewater had backed up in the pipeline and overflown in the underground chamber. This resulted in a foul odour surrounding the housing complex which the interviewer noted upon arrival. This instigated discussion on the aspect of smell with the system with a few of the participants on that day. It was revealed that on days of the holding tank being emptied, there is a considerable odour that lingers across the complex and residents are inclined to keep windows closed. A student participant shared,

> *"It smells really bad when they empty the thing (holding tank)- on the outside, but they usually do it in the middle of the day on a weekday. So, most people aren't home then. It's just sometimes when I have been here it smells really bad. But you know, it's just for barely half a day or something. And they're just emptying because I think there is a big tank or something on the other side there. There comes a huge truck, and they have this big.... thing and they just put it inside. I think they just pump it up or something. That smells really bad." (Participant 5)*

A resident of Torvetua shared,

> *"The truck that came here, it smelled a lot. Yeah, that was the 'smelly car', the kids called it." (Participant 15)*

Participants shared that the odour is only present on days the holding tank is emptied. This was reiterated with the report of the children's connection between the presence of the vehicle and foul odours from the waste. This confirms the vacuum toilet does not pose the problem of smell rather it is the holding tank.

5.2.2 Complications

Blockages, clogs, or stops, were identified as one of the most significant complications with the vacuum systems for residents. The responses in Kaja and Torvetua can be differentiated due to the practicalities of residing in semi-private or private residences. SiÅs is the organization responsible for an operational system at Kaja student housing; they are responsible for managing or repairing any maintenance-related problems with the vacuum toilets and the system. Consequently, student participants refer to blockages and maintenance collectively for the most part. Student participants reported frequent maintenance conducted on the system. SiÅs was reported to notify residents when maintenance was being conducted on the system and the toilets were not in order in the residences. This occurred for blockages, vacuum pump repairs, and general maintenance of the system.

> *"When I would wake up, I would just have a message from the people who we rent from, SiÅs, saying "your toilets are not working, don't use them". And then if you try to flush them nothing happens like the water will just fill up. It won't go out. So that- that happens sometimes. Now it's been a while since it happened. Maybe… a few months. So, it doesn't happen that often but when it does it's like you can't use the toilet." (Participant 5)*

However, some participants expressed irritability and displeasure at the occurrences of maintenance or repair work without prior notifications from SiÅs; the nearest operational restrooms were reported to be located on the university campus. There were reports of many emails and text messages with information regarding maintenance work. For example,

> *"So here it says (reads off phone), 'Don't use the toilets, the pump has stopped.' 'You will receive a message when it is back in order.' 'Please don't use the toilets, an update will come. It's out of order.' 'Temporarily out of order, we have to change a tube.' Yeah, things like that. So sometimes it's blocked, and yeah, sometimes other things. We get a lot of texts (reads off phone again) 'We have to repair a pump' Yeah, we get a lot." (Participant 2)*

Participants additionally responded that they have received numerous messages after maintenance to not participate in irregular flushing habits. Residents then presume that in those particular instances the maintenance problems were due to blockages caused by poor flushing behaviours. A distinguishing feature between Kaja and Torvetua is the responsibility of repairing and maintaining an operational system is allocated distinctively. As previously mentioned, SiÅs is the organization responsible for Kaja.

In Torvetua, the community itself is responsible to ensure an operational system. Therefore, participants in Torvetua distinguished between problems and maintenance of the system. Regarding problems, blockages also appeared to be a significant problem for the community. Participants reported that blockages had been prevalent from the beginning of inhabitancy in the community and persisted to be a problem for old and new users alike. A couple of decade long inhabitants of Torvetua reported,

> *"Yeah, the plumbing system has always been a bit of a problem because we have- sometimes the vacuum disappears due to some clog in the system." (Participant 27)*

> *"We have these blockings which have been the main problems for us. It's like you can't trust your toilet, it's not working. It's not a good...it's not functioning." (Participant 22).*

These participants and others reported that blockages and clogs posed a significant problem with the vacuum system in the community. However, participants reported varying degrees of frequency of blockages and attributed the frequency to a number of reasons ranging from technical features of the system to personal habits. The indicator of a blockage in the system is a loss of vacuum or suction. Participants have found that a loss of vacuum in one household results in a loss of vacuum in other residences,

> *"If one person loses vacuum, it's probably not just one person who lost vacuum. It's likely multiple persons losing vacuum at the same time because of the way the pipes run." (Participant 19)*

This is attributed to the fact that the piping system is connected to the problem toilet and, therefore, the blockage or loss of vacuum affects more than one household in the same branch of the pipeline. The object or composition of these blockages or clogs were reported to be typically unknown,

> *"We have no idea what's in there when it clogs because when we flush it, it's just high-pressure water that we send through the pipes and the clogging disappears. So, what causes the clog? I have no idea." (Participant 28)*

However, there were reported incidents of children flushing foreign objects, such as toys into the vacuum toilet. There was one participant who had personally seen a foreign object in the vacuum pump.

> *"We have found toys in the pump before (…) Everywhere are living little kids. They're probably having some stop because of that." (Participant 16)*

Participants also reported cases of freezing pipes in the vacuum system where outdoor temperatures dropped and excess fluid and waste which was accumulated in parts of the underground system piping would freeze.

> *"It makes kind of a reservoir within the pipeline. So when it got colder it froze in some areas, and that area stopped." (Participant 11)*

This caused blockages or a loss of vacuum in different sections of the system depending on the location of freezing. The freezing of pipes is reported to be an annual occurrence in the winter season, but the root of the problem is in the layout and blueprint of the vacuum system which has been a problem for residents, but also a significant technical aspect in its own right they have encountered. Therefore, this particular topic of the system layout and blueprint will be addressed separately as a sub-theme.

5.2.3 System blueprint

Participants residing in Torvetua have addressed an association between the degree and frequency of problems with the technical aspects of the vacuum system with the location and layout of the system pipes in the community.

> *"One of the problems we've had is there is no actual map of where the pipelines are. When we have a problem, we can only assume that a pipeline goes from this point and hopefully to this point. But we don't know if it makes a curve or it there is a joint." (Participant 1)*

There were no blueprints of the plumbing system which would help inform where the layout of the pipelines, which resulted in increased difficulty for maintenance and addressing underlying problems of the system. This resulted in assumptions of the plumbing route in attempts to localize the problem areas in the plumbing underground. Individuals would speculate where the pipes could potentially be located then proceed to excavate for physical access to the plumbing to dislodge the blockage. This was also a practice the community shouldered

community due to the limited number of inspection holes, or manholes, in the community as reported by one participant.

"They made it inaccessible several places. It's supposed to be easily accessible by not digging it so far into the ground. They should have put in much more inspection holes, or inspection possibilities to maintain the system." (Participant 4)

Engagement in the digging operations to locate the plumbing was reported to have resulted in digging in the wrong areas. Participants had reported having dug deep into the ground to realize the pipes were a few feet away in a different direction. Then proceed to dig again in hopes to locate the plumbing. Many of these areas are marked with manholes for future access to the plumbing; one participant criticized the lack of manholes built-in by developers for access to the system. A couple of participants testified instances of video examination of pipes via access of the manholes to ensure the quality of the plumbing. In the excavating occurrences, participating residents reported that in some areas the piping was relatively deep measuring from one to two metres into the ground whereas other areas had plumbing too close to the surface. Participants made a connection between the depth of the plumbing in certain areas, or branches, and freezing pipes. A few participants stated that the freezing pipes occurred where the plumbing was shallow, or closer to the surface of the ground when winter temperatures dropped below freezing point.

More commonly than freezing pipes, many participants reported problems in the angles, or bends, of the plumbing which created "weak spots" susceptible to blockages in the system.

"They made this low point that was filled up with water from two houses that blocked the vacuum for several houses here in the southern end of the system. So they made this low point flood over, and that cut out the vacuum from many houses. (Participant 4).

Participant 4 addresses inadequacies with the system layout, such as 'low points' in the system where the pipe carrying the sewage away from the residences was on an incline, where the vacuum would have to work against the force of gravity. Since there were complications with the vacuum suction on inclined piping, expectedly, there were no problems on pipelines with a negative slope.

"You know the pipes; they are moving uphill, and we here have not had so much trouble because we have downhill to the pump house. The most problems have been in the earliest houses." (Participant 16)

These low points caused blockages and ultimately a loss of vacuum to houses on the same plumbing line in that area of the community. Participants residing near this problem area reported the bends in the plumbing as reasons for many of the blockages occurring in the respective area. The bends in this low point area were reported to be up to 90 degrees. Many participants who resided in different areas of the community also reported on this low point area and addressed that the bends were as sharp as 90 degrees and were deemed as high problem areas for homes relying on the vacuum to transport waste away from their residences.

Generally, participants related certain areas of the community as high problem areas in the system plumbing. Participants did not always address the irregularities and problems with the plumbing of the low point directly but rather reported in terms of good and bad areas of residence. The majority of participants recognized certain 'branches' of the plumbing, illustrated by a line of five to six houses to be more or less concerned with blockage problems than other areas.

Some participants reported living in a good area where the blockages were of no major concern as they were in other branches of the system. Other participants reported location in terms of relative incline and decline from problem areas and the vacuum pump station.

> *"Well, I think we live in a part of the system on the high ground, I guess you could say. We have had very few problems. Problems have been related to other parts of the system. Where we live, we've had basically none." (Participant 18)*

Relatively high areas were regularly deemed as the good areas with minimal problems with the layout of the system. This was reported both ways; low area residing participants reported high area residences as relatively free of blockages due to poor plumbing design, and high ground residences generally reported their branches of the system as good and problem free in comparison to problem areas in the low points. Some participants whose residences are connected to the pipes closest to the vacuum pump reported few blockages despite being located on relatively low ground in comparison to the high ground.

> *"I'm not an engineer. But the length of the pipes, the way the pipes run, the way you have to create a vacuum, not just a fall like regular pipes. That makes it more complicated, but that's probably why there's not vacuum toilets everywhere 09:36. You actually have to create a vacuum, and the vacuum has to go all the way to the central station and then you transport it away by normal fall." (Participant 19)*

The nature of the plumbing in terms of slopes, angles of the pipeline, and depth into the earth all were contributing factors to the efficiency of the system. All these factors determined the vacuum efficacy, and arguably were the cause of blockages and loss of vacuum in the system. It was these factors that the participants had to consider and work with during the reconstruction and repairments of the system. As a result, participants expressed irritability with the reconstruction of the system piping.

> *"We fix one problem, we realize there's always been a problem in, let's say area B. I think what we've dug up two or three areas and fixed those problems. There's less problems now. We had one year where it stopped half the neighbourhood- stopped two or three or four times a week during the winter. So that was kind of gruesome. When we dug up and removed the bad decisions that were being made in the start, it started behaving better." (Participant 11)*

Participants seemingly were constantly working on technical complications with the pipeline in the community. Upon completing the repairments of one problem, the residents were summoned, so to say, to another problem in the plumbing. To ensure that the repairments remain intact, the community members arranged several examinations to ensure the utmost functionality of the system. Presumably, to prevent further complications with the plumbing or blockages due to the piping. Also, certain examinations which were conducted at community-built inspection sites allowed for a viewing of more parts of the plumbing.

> *"We have had several video examinations of the system and we see, in several stops, dips in the pipeline because of badly secured ground. Two sharp angles and bends from one area to another. There are several weak spots." (Participant # 24)*

The detailed nature of the problems faced in Torvetua reiterated the notion that the community members had the responsibility to research and determine the underlying complications in the system. Residents learned through experience and physical examination of the system and, consequentially, developed an understanding of the strengths and shortcomings of the system. Recognizably, this resulted in greater detail and understanding of the technicalities of the system. This was not possible for the participants residing in Kaja as the rental organization performed all maintenance and repair-related work on the system. Therefore, Kaja participants had less detailed information in respect to problems and maintenance of the system. The data from Kaja was heavily focused on consequences faced from scheduled and unexpected maintenance work on the system.

In summary, these findings provided an abundance of information on the routine technical aspects encountered with the vacuum toilet systems. The physical properties indicated as fairly comparable to a water flush toilet with some key differences in respect to sound and smell. The main concerns from the vacuum toilet systems were revealed to be complications with the respective systems. Kaja reported the inconveniences of a system "out of order" largely due to blockages and other maintenance work on the system by SiÅs. In Torvetua, participants predominantly focused on the vacuum system layout as an underlying issue for all the complications faced in the daily interaction with the system; blockages, loss of vacuum, and freezing pipes are some examples of common problems faced within the community. Kaja residents were found to have relied heavily upon SiÅs to ensure a functioning vacuum system whereas Torvetua residents demonstrated to be actively involved in the daily and long-term functioning of the vacuum system.

5.3 Personal practices of the system

5.3.1 Cleaning practices

The response to general cleaning practices comparability of cleaning a conventional flush and vacuum toilet did not differ significantly. The response was divided between little to no difference and some degree of difference regarding the frequency of cleaning and cleaning agents used. The majority of participants in Torvetua reported using cleaning agents provided by the manufacturer Jets. A select few participants who used the specific cleaning agents reported dissatisfaction with the product and have replaced it with cleaning agents of their preference. It was noted by some participants that the same cleaning products cannot be used on vacuum toilets as they would have used conventional toilets.

> *"Since we don't use- we can't use toilet ducts and stuff like that, or things to... those soap bars or whatever you call them because we don't use that much water." (Participant 24)*

It was recognized this was not possible due to the water quantity in the toilet bowl which would make it difficult for the cleaning product to clean the toilet. However, participants in Kaja demonstrated a greater awareness of the need to use particular cleaning agents to ensure functionality, safety, and environmentally friendly cleaning solutions.

> *"We can't put chemicals into it-there's a plaque in there (...) I had to research a bit what kind of chemicals were in the different washing stuff (products), but that was fine. I don't want to use chemicals anyways." (Participant 5).*

The recognition by this participant for certain cleaning solutions adheres to participants' reports of Jets' recommendations for cleaning substances. It also emphasizes a possible generational difference between the two communities; to actively engage in practices better suited for the environment in one community. Flushing toxic chemicals into the toilet system were avoided by many student participants and they actively search for alternatives compared to Torvetua residents who were focusing on what cleaning products were suitable for the toilet system.

Many participants reported an increased frequency of cleaning due to remanent on the toilet bowl from reduced water.

> *"It requires a bit more cleaning probably because of the amount of water that is used (...) stuff (waste) is left in the toilet because it's not much water. That's probably why it needs to be cleaned more often." (Participant 27)*

A few student participants conveyed a minor inconvenience with cleaning the vacuum toilet; reporting that the toilet brush was too large to comfortably clean the opening of the pipeline. Another student resident narrated a different approach, the regular use of the showerhead to wash away remanent in the toilet bowl.

> *"To get it clean we usually use the shower handle to sort of-if there's some feces, you know, stuck to the toilet you have to use the shower instead of just being able to flush it (...) It just seems to work better than using a brush." (Participant 10)*

Although not a prevalent cleaning practice among the participants, this case was intriguing because the participant did not report using a toilet brush as the primary method or indicate why using water from the showerhead was the primary method to rid the remanent left in the toilet bowl. Rather, water was used as a cleanser rather than cleaning agents.

5.3.2 Preventative measures

In addition to the problems faced in the technical aspects of the vacuum toilet system, participants also reported preventative measures to combat or reduce the prevalence of complications associated with the vacuum toilets and plumbing. The engagement in preventative action is a distinctive difference between the two communities; Torvetua illustrated direct involvement and responsibility for the operationality of the system compared to Kaja where SiÅs had to bear responsibility. Preventative action by the users in Kaja was generally reported to be the use of a specific toilet paper to prevent blockages in the pipelines. Residents were reported to

received specific toilet paper from SiÅs which was retrieved by residents from communal areas to the housing community.

> *"We have this special toilet paper. So, we get that from the washery (laundry) over there and use that." (Participant 7)*

> *"We have to use a different (toilet) paper. And we get it for free. While the (toilet) paper is more expensive than the normal paper so...well for being a student, I will say it will be a negative thing if we have to pay for the paper ourselves (…) We don't (pay). It's free, and it's specific." (Participant 2)*

Student participants emphasized that the toilet paper is rather expensive for purchase and would contest it if SiÅs did not provide it to the residents. The use of specific toilet paper was believed to prevent the number of blockages in the system. A few student residents described the toilet paper as "special" or "soft" versus a hard material, indicating that the use of this particular toilet paper is vital for the system that was later found to be described as 'vulnerable' for some users as indicated in section 5.4.2. Therefore, through routine use, the residents are contributing to ensuring a fully functioning system. The second measure is the perceived adherence to notices posted on the toilets themselves for appropriate flushing behaviours to minimize loss of vacuum due to foreign objects in the system.

> *"We can't put chemicals into it. It says on the- there's like a plaque in there (…) We have toilets that get blocked all the time even though there are so many, what's it called? Notes. Everything about what you can put in your toilet, what not to put in your toilet." (Participant 5)*

The notices highlighted what the residents can and cannot flush into the system. Hence it was enforced as a preventative measure.

In Torvetua, the preventative actions taken upon the community differed from those of Kaja. The participants in Torvetua were questioned what practices the participants engaged in for prevention of the problems encountered. Interestingly, one participant from Torvetua distinguished a difference between dealing with the vacuum toilet itself compared to the piping, as the external part of the system.

> *"So outside the house the whole vacuum thing has been a pain in the butt, but the toilets themselves inside, the maintenance hasn't been that bad." (Participant 17)*

This participant and others universally reported the use of a descaling liquid used for the treatment or prevention of urine stones, or struvite, that had accumulated in the "outside" part of the system, the piping. Urine stone build-up in the pipe increased the probability of a blockage in the system due to constrictions in the pipe diameter.

> *"The maintenance mostly in the home has been adding some liquid to dissolve the what's it called, urinstein (urine stones). It's the hard stuff when the urine comes in with contact with air, there will be some rock looking or hard particles that you will build up in the pipes and that needs to be some kind of acid to industrial remove it. We, of course, can't use acid as(an) environmental project so we have some more eco-friendly liquid that we put into the toilet that is supposed to dissolve this urinstein." (Participant 14)*

Majority of participants engaged in de-scaling campaigns within the community, such as participant 14. Participants reported the use of a descaler each night for a week while other participants stated the use of the descaler from three to five nights per week for each descaling period.

> *"We have de-scaling campaigns where every household gets from...the can of descaling liquid that we add each night over a period of a week maybe. That will prevent deposits to build up in the pipes." (Participant 13)*

This de-scaling gel was reported to have been used in the evening and night hours for maximum efficacy.

> "*We try to do it with the gel. We've been instructed to do it right before the household goes to sleep, so to say. So that it sits in the tubes, in the system, during the night to dissolve any (pause) build-ups or urine stones." (Participant 24)*

The frequency of descaling periods differed in participants' accounts. Some participants recount the use of a descaler every three months or so while other participants reported it to occur once a year. One participant, in particular, conveyed that in theory the descaler is meant to be utilized annually, but in practice, the descaler is used every second year due to the perception it is unnecessary to use annually. While some participants believed the use of the descaling agent for the sole purpose of preventing blockages, others perceive it as a solution or countermeasure to urine stones and build-up in the pipes.

Another preventative measure, unique to Torvetua, was the practice of pouring hot water into the toilets to "flush out" the plumbing system which many residents participated in. Flushing the system in residents' homes prevented or decreased the likelihood of future blockages.

> *"We pour lots of hot water in which we also do during the winter as well. About five buckets of hot water every evening, and that's helped a lot to keep the pipes clear." (Participant 17)*

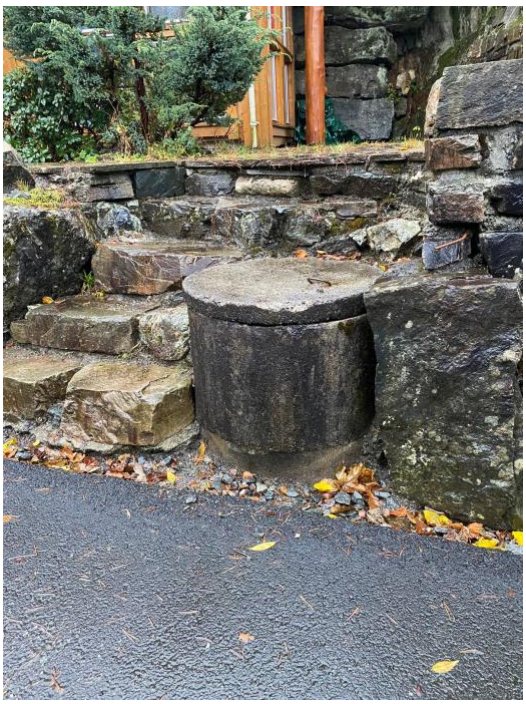
Residents who reported partaking in this practice stated varying frequencies of water flushing. Some participants reported to have engaged in this practice a couple of times a year, whereas other participants reported regular practice in the winter season, and some reported to have never participated in the practice.

> *"I know there are a couple of houses that had plumbing pipelines outside the house. Beneath the surface of the ground. They had to do it (hot water) in the wintertime to prevent frosting in the pipes." (Participant 28)*

Additionally, a few participants engaged in using a high-pressure flush directly into the system from manholes dug up in the community. These manholes were built over time where residents deemed it necessary to access the plumbing of the system. They aimed to provide quick access to dislodge blockages before a loss of vacuum to neighbouring houses. Some of the manholes in Torvetua differed from the conventional manholes in appearance. Figure 1 serves as an example of some manholes found in Torvetua where residents have quick access to the plumbing of the system for a high-pressure flush to dislodge a blockage.

Figure 1

Protruding manhole found in Torvetua



The preventative measures mentioned were aimed at dealing with minor inconveniences in the system which would ultimately lead to greater concerns or problems in the plumbing system. Therefore, addressed as preventative measures and actions. Residents also reported participating in measures that would directly affect the functionality of the system. Similar to Kaja, multiple participants in Torvetua reported the use of softer toilet paper in the vacuum toilets after discovering the sensitivity of the plumbing to 'hard' toilet paper; toilet paper that does not dissolve or become soft upon submersion in water.

> *"We had some start-up problems and especially using hard toilet paper- not one that dissolves itself easily in water. A special recycled toilet paper was problematic 'cause it's too thick and too heavy." (Participant 14)*

The use of soft toilet paper would reduce the probability of causing blockages in the piping system. This measure was not reported to have been a communal decision or finding, but rather of a select few participants who determined it to be an important factor. Although, more participants reported the presence of a sign above the toilet or toilet lid provided by the manufacturer, Jets, which discloses what materials are permissible to be flushed and foreign objects are not.

> *"So, we have signs over the toilets that say just what went through your body and toilet paper, and nothing else. So we are told every day when we go to the toilet, don't put anything else in it." (Participant 13)*

Signs adjacent to the vacuum toilet serve as reminders to prevent the disposal of foreign objects into the plumbing system, especially with house guests as reported by some participants.

> *"We have these notes on the wall. On the lid actually, on the toilet. Not to leave anything else in the toilet. I think our guests have always respected that. In this household we have been very strict with the rules." (Participant 15)*

These signs serve the same purpose as the ones in Kaja. However, the residents of Torvetua engage in various preventative measures than Kaja student housing with meticulous planning and critical thinking of the technicalities of the system.

5.3.3 Daily flushing behaviours

The most attributed cause of blockage by participants is recognized by poor flushing behaviours. Participants reported the cause of many of these blockages were attributed to foreign objects that were not intended for disposal in a vacuum toilet system. Generally, flushing behaviours were deemed relatively similar between the two communities. In Torvetua, children's toys, sanitary pads, Q-tips, hair, and food were some objects that were reported to be flushed down the toilet through community knowledge or personal admittance to habitually poor flushing behaviours.

> *"They have, you know, every once in a while, an odd toy car or something like that. You know, you have kids in the house. But as far as sanitary pads or stuff like that, I don't think we have any of that anymore." (Participant 24)*

These habits were acquired from conventional flush toilets which did not pose the same sensitivity due to foreign objects; the risk of a blockage was lower in water flush toilets than in vacuum toilets.

> *"There were a lot of new residents here. They didn't understand how to use this compared to the way you can use a conventional toilet. In conventional toilets you can't- you shouldn't flush anything else down besides human waste and toilet paper, in those either. It's more forgiving if someone puts down Q-tips or sanitary pads or such. On this kind of system if you do that you will have a blockage." (Participant 13)*

Therefore, certain flushing habits posed a greater probability of blockages in the system.

In Kaja, a similar phenomenon was found. Participants generally reported that they believed irregular flushing habits were the root of the blockages. This was due to messages and emails from SiÅs after repair or maintenance of the system was conducted and the system was not operational.

> *"I don't know if that happened every time but usually it (emails/messages) comes with a reminder after such an event, 'remember not to put tampons and pads and Q-tips in your toilet' and stuff like that." (Participant 5)*

The messages reminded residents to adhere to appropriate flushing habits as outlined on the toilets after maintenance or repair had been conducted on the system and the system. Thus, some participants had concluded the maintenance was due to poor flushing behaviours of other residents in the housing unit. No student resident reported incidents of flushing foreign objects into their residential toilet. This was not the case in Torvetua.

In both communities, participants reported knowledge of irregular flushing habits in other residences and in a few cases, their own. For instance, one participant self-reported a poor flushing decision. They admitted to having flushed food waste for disposal in the vacuum toilet which was the cause for a blockage in the plumbing soon and shared it was a reckless action that caused a blockage. A few participants reported blockages caused by hard toilet paper; toilet paper that does not dissolve easily in water and, therefore, is more susceptible to causing a clog in the plumbing.

> *"Well from time to time in particular related to the period after just moving in, there were a lot of people who either didn't know how the system worked and therefore they brought some unfortunate habits with them from conventional toilets. They put things into the toilet that shouldn't be put into any toilet, for that matter. I think that was, just say, that was the first couple of months until people realized 'oh we can't do that anymore'." (Participant 18).*

This participant in particular tackled many interconnected factors attributing to blockages caused by flushing behaviours, many of which were individually reported by other participants. They address the number of blockages induced by poor flushing behaviours at the beginning of a residency period, habits developed with previous experience with conventional flush systems, and a reform in habits to suit the vacuum system.

Other participants added that due to the reform in flushing habits, blockages caused by foreign objects decline in blockage frequencies over time. These descriptions indicate that these participants were knowledgeable and aware of how their behaviours and practices with the toilet are fundamental to the functionality of the system. That their actions will directly result in the problems and repair needed to an extent. Long-term participants also observed that poor flushing behaviours are a common cause of blockages in new users of vacuum toilets in the community more than long-term inhabitants. It is a matter of time before new residents learn the nuances and develop habits to vacuum toilets. Participants stated that blockages as a result of flushing behaviours decline over time spent using the system and learning proper use and compliance to minimize blockages. Long-term resident participants reported that blockages caused by poor flushing were significant in the late 1990s upon completion of development of the community and into the 2000s. All residents were new and had limited experience and knowledge of compliance with vacuum toilet systems. Therefore, blockages were a leading problem and have reduced the number of incidents significantly since.

Figure 2

Central vacuum pumps in Torvetua

A few participants recalled instances of children flushing toys that were found in the vacuum pumps by some community members after problems with loss of vacuum in the entire system. These central vacuum pumps of the community are shown in figure 2 to which the foreign objects made their way through the plumbing system upon being flushed.

These are all instances of flushing behaviours and practices directly involving the use of the system. Many users revealed a practice of the indirect use of the system as a form of practice; rather, the avoidance of the use of the system. Many participants avoided flushing the toilet during the night hours to prevent disturbances to others sleeping, especially with infants of children in the residence. A participant with an infant explained,

> *"It makes a lot of noise when you flush the toilet (laughs). So, I have to be careful. We have a toilet upstairs and downstairs. So when she is sleeping upstairs, her room is next to the toilet so I can't flush the toilet upstairs or use the toilet upstairs while she is sleeping. So that's how noisy it is." (Participant 19)*

Some participants reported not flushing at all, while the parents of the infant reported avoiding using the vacuum toilet in close proximity. Very few reported flushing regardless of the circumstance. The varying responses were rather intriguing when considering that the majority of participants shared that the noise of the vacuum was the greatest critique they had with the toilet at the time of the interviews. It would otherwise be presumed that many more residents would avoid flushing the toilet at night as to not cause any disturbances. It brings attention to how great of nuance the sound is if residents are incautious of it during the night. Although, some participants who shared that they do not hesitate to flush in the night mentioned that they previously refrained from flushing, but now their families are adapted to the sound.

> *"Well, it makes more noise. And maybe when we first moved in here, it was a bit annoying especially in the middle of the night if someone had to go to the toilet. It didn't take that long to get used to it. Then... well it's just sounds you get used to it. You don't hear them. You don't wake up in the middle of the night anymore." (Participant 27)*

This alluded that residents are becoming, if not are, habituated to the sound more than they believe themselves while other participants continue to avoid flushing through the night. The participants are forming habits by using vacuum toilets. Additionally, this is despite a significant number of participants revealing that the sound of the toilet has become more bearable over time but remains unpleasant. However, some participants who had admitted to avoiding the flush during the night hours did report to having evolved their practice as others became habituated to the noise and were able to sleep undisturbed. For example, a residence with two young children stated,

> *"It didn't take that long to get used to it. Then- well it's just sounds you get used to it. You don't hear them. You don't wake up in the middle of the night anymore." (Participant 17)*

This resident addressed that they became accustomed to the noise by using the phrase "you get used to it" which indicated there are degrees of habits and habituation in the community for some participants. Two participants sharing the same residence stated no hesitancy to flushing in the middle of the night; the noise had not posed a great deal of discomfort to them.

> *"We didn't have children right in the start, so we got used to it, and they never knew anything else." (Participant 12)*

This and similar experiences stressed that children, and adults, visiting the residence were generally surprised by the noise of the toilets. This addresses a key point the participants momentarily drew attention to themselves. Participants 11 and 12 had no prior experience regularly using vacuum toilets. Therefore, as stated, the noise was a nuisance but not unbearable. Their children, alternatively, were born and raised in Torvetua. The noise of the vacuum never bothered the children compared to adult residents who described that the vacuum sound was "unpleasant" or "too loud". Therefore, the exposure to the vacuum sound since childhood was the environmental factor that conditioned the children to perceive the noise as normal. Observably, the response to flushing habits was not harmonious in Torvetua.

Since the residents of this community were long-term inhabitants, there was more experience and information to share. One long-term resident of Torvetua shared,

> *"When I heard about the student apartment with these toilets (Kaja), I guess especially young people who are not responsible for their own home, they need to know about this- to not to make problems. I guess because it is always easier to understand when it gives you extra cost, yeah. A young person is not responsible for their apartment, so you wouldn't think about it in that way; how important it is not to fill toilet with stuff." (Participant 15)*

This participant addressed awareness in the differences of behaviour based on residency status and age. However, there were some behaviours between Torvetua and Kaja that were overlying, such as the use of soft toilet paper and notices near the toilet serving as a reminder to proper flushing etiquette. Practices, specifically in regard to behaviours and habits of communities at an individual level, are complex and may be explained by an array of theories and explanations as this section sought to do.

In summary, the personal practices with the system highlighted the ways in which the participants engaged with the vacuum system in respect to cleaning practices, preventative action, and flushing behaviours. Cleaning practices differed slightly between the two communities where participants from Kaja generally expressed greater concern to use

appropriate cleaning agents for compliance of the system than participants from Torvetua. Torvetua participants overall emphasized the use particular chemical agents for preventative measures rather than cleaning practices. Participants from Torvetua indicated a great deal of individual and community effort placed into preventative measures to ensure the system does not undergo any complications ranging from blockages to freezing pipes.

Kaja residents did not indicate a similar degree of involvement in preventative action as SiÅs was reported to be responsible for maintenance and repair work with the system. However, an important preventative measure was the reported regular usage of particular toilet paper provided to the residents; the particular was believed to prevent blockages in the vacuum system. Flushing behaviours were varied to an extent between the two communities. Torvetua revealed greater instances of flushing foreign objects compared to Kaja participants in addition to practices pertaining to avoiding flushing. Generally, responses from Torvetua demonstrated improvements in flushing behaviours of oneself and others with more time spent engaging with the system.

5.4 Personal perceptions

This section broadly focuses on the participants' understanding, knowledge, and acceptance of the vacuum toilet system. The implementation of a novel toilet system to largely habituated users of conventional flush toilets created an interesting setting in which the participant's understanding, acceptance, and general perceptions were imperative to a well-functioning system in the present time and the future. Questions for the participants centred around their general thoughts of the vacuum system including system preference, the future development of the systems, and the concept of ecological sanitation adopted in vacuum toilet systems.

5.4.1 Knowledge of the system

Despite long-term and intimate use of a sanitation system, participants' knowledge of the system components and functionality may differ substantially. This is apparent in the knowledge the two communities possess and is tied back to the extent that each community is responsible for the operationality of their respective vacuum systems. Since the student residents in Kaja are not responsible for the maintenance of the system, there was no importance placed on knowing the technicalities of the system. Rather these participants described key differences in vacuum toilet systems compared to conventional flush.

"I know that they consume a lot less water than-than normal toilets." (Participant 4)

Participants generally related the vacuum toilets to be environmentally friendly.

"I heard that with these toilets they are eco-friendly because they don't use that much water." (Participant 8)

Participants articulated that they knew the toilet uses less water and while others additionally added that the flush was driven by vacuum suction instead of a water flush. There was also a general understanding that the black water waste produced at the housing complex was collected in a holding tank and used for research purposes at NMBU.

"It's like in a research project right now, I know it from when we moved in I heard from others from who live here." (Participant 2)

However, the details of this knowledge and understandings of the users were rather limited regarding the process of handling the black water. Aside from these few details, participants from Kaja did not share nor indicate additional information regarding knowledge they had to the functionality of the system.

The response from Torvetua was distinctive from Kaja and the residents commonly shared their knowledge of the operation of the system without direct questioning. There were general explanations of the mechanisms of the system and variations in the system compared to traditional flush toilet systems. The most prevalent description was a reduction in water use and operation with vacuum suction rather than water flush.

"I think it's a good system because it uses less water." (Participant 25)

Some participants recognized that inhabitants of the community were generally more aware and knowledgeable about the system than average homeowners due to the substantial involvement in maintaining the functionality of the system. Many participants also understood that vacuum toilets cannot be changed in the community to water flush due to the mechanics and technicalities of the system. This was evident when participants 11 and 22 reported that another system cannot replace the existing system in the community due to the pipeline size, in diameter.

"With a system like that, you cannot go back to a normal system because of the pipelines size of course." (Participant 11)

Some participants recognized that the system was constructed specifically for vacuum toilets, this indicated there was awareness for some that the piping is specific for vacuum toilets.

> *"All the houses here were built with the purpose to have vacuum toilets. All the pipes were laid when the houses were built. You didn't have a choice; you got a vacuum toilet. That's it." (Participant 19)*
> *"Now we can't change away from this system. We would have to rip out walls and floors and put in new pipes with a different diameter if we wanted to change to a conventional system." (Participant 18)*

Majority of participants reported poor plumbing design which contributed to major blockages in the community.

> *"We have had several video examinations of the system and we see, in several stops, dips in the pipeline because of badly secured ground. Two sharp angles and bends from one area to another. There are several weak spots (…) But as far as this area, Torvetua, it was badly done to start with, and we are continuing to have problems because of that." (Participant 24)*

Additionally, they disclosed specific sections of the plumbing were susceptible and vulnerable to blockages than others due to sharp angles and inclines. This knowledge of how the system works was accumulated due to the intimate relationship inhabitants of Torvetua have had with the vacuum system. A comparison to Kaja illustrates this as the student residents are not obligated to manage the system, thus there is no intention to learn more about the vacuum system. In Torvetua, to maintain and repair the system for optimal functionality, the residents were compelled to learn the functionality of the system.

Furthermore, the majority of participants were aware of the historical development of the community, and when the system was decentralized; the treatment and disposal of the effluent were completed locally within the community.

> *"Well, we had our own water work facility, so we produced our own water. We were not connected to the local system, or the municipality system." (Participant 18)*

Interestingly, participants who were among the first inhabitants in the community in 1998-1998 reported that the community was a pilot project encouraged by a local environmentalist who was inspired to construct a sustainable community on the geographical peninsula that Torvetua is built on.

> *"This was a pilot project from one individual in Bergen who is really- you've probably heard about him, Kurt Oddekalv. He wanted the community to be more or less self-*

> *sustained as far as water and sewage and so forth. We also had our, we call it black water and grey water. So the grey water- we also had a cleaning system; a biological cleaning system before it was going back out into the lake." (Participant 24)*

This information was well known by long-term residing participants but rather limited in participants who had shifted to the community in the past decade. This contributed to their scope of knowledge of the system; how it was originally built, what changes and modifications it underwent, and what differences the community has noticed with the system over time. Many long-term residents reported emptying the holding tank from the community until the system became part of the centralized with the *Bergen Kommune* in 2018.

As some residents had reported the localized treatment of greywater, separate from blackwater collected in the holding tank, other participants revealed the change to a centralized system.

> *"The vacuum pumps suck all the black waste in one direction and still pumps it out the same pipe. The only difference is they cut off the pipe and connected it to Bergen Kommune's network instead of to the tank." (Participant 28)*

This facilitated their understanding and knowledge of the weaknesses of the system prior and they were then aware of the disadvantaged points in the system which inherently would be an important part of a functioning system. This breadth of knowledge on the community's experiences with the vacuum system may have contributed to participants' opinions about the future development of VTS and Eco-San implementation which is explored in sections 5.4.4 and 5.4.5, respectively. Furthermore, this information was well known by long-term residing participants but rather limited in participants who had shifted to the community in the past decade.

5.4.2 Opinions of the system

All respondents reported they believe a vacuum toilet system is inherently a good system in theory or as a concept.

> *"We thought it was a good concept, but it never should have been built." (Participant 28)*

> *"I think in theory it's a great idea." (Participant 17)*

A large number of student residents accredited this to the notion that the vacuum system was more environmentally friendly than convention flush toilets, therefore it was regarded as a better

system. The conservation of freshwater was a prevalent comment from participants exploring the benefits of the system. Participants were quick to comment that a water crisis was not considered to be a major concern in Norway compared to many other nations in the world.

> *"I think the overall idea is good. It uses less water, of course. Up until now there has not been a problem with clean water in Norway, but things will probably change here as well. So it's probably a good thing to waste less water in possible areas." (Participant 12)*

In addition to the benefit of freshwater conservation, the system in the complex was reported to be used for university research. There was a sense of purpose of contributing to research through one's personal yet mundane use of a sanitation system. Participants expressed that complications arose due several reasons when the concept was put into practice. Many of these participants were from Torvetua where the outcome of the implementation of such a system had been adverse in many respects. One participant from Torvetua described there was some idealism in the theory of implementing a vacuum system, and that did not translate well into practice particularly with the approach of Eco-San the system was striving for.

> *"I think there was some idealism in that. In the beginning before it opened up. Local municipal authorities decided against allowing black water because- well, one of the reasons is that you're not allowed to use human feces anywhere. You can't use it for farming as nutrients because it is not allowed to use human feces as fertilizer, in particular; not if it's ending up on your own table. So there are certain regulations that make it not a feasible solution, I would say. Ideally, well yes, it was a good idea to use it but no, it wasn't thought well through. It was just an idea, and it wasn't- well, the idea wasn't thought to the end. So you could see the consequences and obstacles you would have to deal with. That is my conclusion." (Participant 18)*

This indicates that the developers did not plan or account for all practical and legal circumstances which would arise from the implementation of relatively new technology and approach in sanitation systems. These complications informed perspectives, such as participant 18, who shared that the vacuum system and Eco-San together was not the appropriate approach at the time of construction. Especially when the vacuum system in the community proved to be a complication in itself that residents would spend years repairing and dealing with to functional standards.

> *"We have had several video examinations of the system and we see, in several stops, dips in the pipeline because of badly secured ground. Two sharp angles and bends from one area to another. There are several weak spots. But if all that would function as it should,*

> *I think it's a good idea. You use less water for each flush. But as far as this area, Torvetua, it was badly done to start with, and we are continuing to have problems because of that." (Participant 24)*

The response from Kaja remained limited to perceptions on the concept of the vacuum system itself due to the short-term living period of the residents as well as their limited interactions with the technical respect of the system.

For the functionality of the system at the time of the interviews, participants reported they are generally satisfied with the operationality of the system. Most users believe the system to be environmentally friendly compared to conventional flush toilets in regard to the reduction in water used for flushing. A few participants addressed the low volume, or "compressed waste" (concentrated black water) the system produces. Two participants highlighted what they described as the "suction of the toilet". They believed the suction of the vacuum was a positive characteristic as it drew all the waste from the toilet bowl and had no problems with rising water levels in the toilet bowls as experienced with water flush toilets.

> *"Now that I'm more used to it I noticed- I feel like this sucking function-since its much stronger than a normal toilet, it cleanses the toilet itself. So, it looks cleaner." (Participant 1)*

> *"I think it has great suction (laughs) it can take care of anything. Other toilets, you probably notice, sometimes they clog, or the water starts to rise because it cannot take care of things in the toilets, but I've never experienced these with vacuum toilets. I think they're quite actually, pretty good." (Participant 19)*

Many long-term residents at Torvetua commented that the system improved over time. This was, at times, credited to the changes in the system over time.

> *"I think it's okay now. It was quite a lot in the beginning when we moved in. And quite a lot (had) to be done since there were so many stops. But now it's okay. We don't- our area...there are not that many stops now. I think it's okay now. The maintenance, it's okay. There's not much work at all." (Participant 11)*

> *"Based on our experience, this system is maybe 20 years old and there's been some changes over those 20 years but that's been with pumps and the general system." (Participant 27)*

As some of these participants commented on the improvement as a general trend over the years, others specifically addressed the improvement as a result of the maintenance and repair of the

system, shift to a centralized wastewater system, the overall expenditure reduction, and reduced community responsibility due to the previous decentralized system.

> *"When it's the kommune you'll have professionals do it every time. It's certainly more convenient." (Participant 26)*

> *"It was also very expensive for the Torvetua area to empty the (holding) tank. It was a lot of work but also expensive, and that's why it was shut down." (Participant 21)*

Participants commonly reported of fewer difficulties to the current experience with the system in comparison to the past. A couple of participants described the overall experience with the vacuum system in a before and after experience. One participant, in particular, described it as such,

> *"We had the before experience and the after experience. Before with the old system, with pumps that was of poor quality or outdated design. And we have this latter experience, with the new pumps with today's technology. So the former experience was poor due to problems with the vacuum pumps. So, they had trouble running properly and they demanded a lot of service and had a lot of problems regarding maintenance so there was quite- not fragile but sensitive to objects. Like if you had some kind of hard paper or there were other things into the toilets that were not supposed to be there. The former experience was poorer due to poor pumps. The later experience has been good, mostly, but we had some local problems due to plumbing." (Participant 14)*

This participant describes the difference in experiences before and after improvements made to the system. This is in reflection of how the system was upon completion of development in 1998-99, modifications made to the system because of the community members, and compliance to practicing the system through the time. Additionally, participant 14 provided insight into what they deem to be the sensitivity of the vacuum system. The notion of sensitivity, or vulnerability, was reported by other participants as well. Several participants believed that the vacuum toilet is more vulnerable regarding blockages. Some users compared it to conventional flush toilets, which they described as "more forgiving" when one flushes foreign objects.

> *"In conventional toilets...it's- you shouldn't flush anything else down besides human waste and toilet paper in those either. It's more forgiving if someone puts down Q-tips or sanitary pads or such. On this kind of system if you do that, you will have a blockage." (Participant 13)*

An example of a conventional toilet that was more "forgiving" is illustrated in some users flushing Q-tips and hair with a low probability of causing a blockage in the system. One

participant indicated that even in conventional toilets only human waste and toilet paper are to be disposed of, however, it is forgiving to some foreign objects. That is simply not the case in vacuum toilets. This was reported to be apparent when new residents move into the community. Newer inhabitants are generally unaware of the sensitivity of the system that inevitably results in complications with the system which means more blockages. When there is a blockage in the system, it is plausible to cause a loss of vacuum to neighbouring residences, dependent on the location of the blockage in the system. There is also an awareness of the vulnerability of this system when participants expressed awareness that a blockage affecting one residence can result in a loss of vacuum in the residences connected by the same plumbing lines.

5.4.3 Personal preference

Upon reporting personal experiences with the vacuum system, participants shared their preference between a vacuum toilet system or that of a conventional flush. However, these responses were solely from participants in Torvetua. Interviews in Kaja were conducted before interviews in Torvetua. Due to the nature of the interviews in Kaja accommodations, the interviewer had not considered questioning the residents' preference of sanitation systems.

The responses in Torvetua were divided quite evenly between vacuum systems and water flush. Roughly half the respondents reported a willingness to use a vacuum toilet system in the future. The other half of participants reporte a preference for conventional flush toilets rather than vacuum toilets in the future.

> *"No. I would stay clear of any vacuum toilet system. The only place I would like to find them is on a cruise ship or (in) an oil rig. But not in a land-based installation." (Participant 26)*

Many participants recognized that the complications with the vacuum system could hinder willingness of future use for others, but also expressed that many of the problems had been repaired and the ones that could not be fixed were well understood to be managed in the community.

> *"Yeah, but not in the start (laughing). But now, yeah (…) Because it works better now, and we know how to maintain- how to use it. We know what to do when it stops, and we have all the neighbours; they have a good dialogue. We all know how to solve it." (Participant 11)*

Additionally, these participants were certain that vacuum toilet technology must have advanced in the previous two decades.

> *"If I had the opportunity or the chance to move into a similar little community with newer systems and third or fourth or fifth generation of these systems, I wouldn't hesitate. I find it quite tempting of having small communities that are self-sustainable in a better way or in a more self-sustainable way than it is in the general sanitary systems." (Participant 27)*

With the presumption that modern vacuum toilet technology has advanced and the problems with the system had been drastically reduced, the willing participants reported they would not be deterred from vacuum toilet systems in the future.

> *"There's nothing with our experience that would make me kind of reserve myself from moving in somewhere with a vacuum toilet." (Participant 27)*

Contrarily, the other respondents reported that the noise and complications faced with the vacuum system have deterred them from accepting vacuum toilet systems in the future. However, one participant noted no strong preference for either system; they would not be deterred or in favour of a particular system in the future.

> *"It's hard to say. I'm used to vacuum toilets and here we have vacuum toilets. So, in the beginning it was a bit weird having the vacuum toilets in our home, but right now I can't say I favour one over the other." (Participant 13)*

The divided response indicates that some participants had become habituated to the system and developed habits with long-term use of the vacuum system whereas the technical aspects affected the user

A few participants articulated their opinions and preference regarding the vacuum toilet system for the newer centralized system, with *Bergen Kommune*, rather than the previously decentralized system.

> *"I like the public best (...) it's better for us, similar for us. It's easier to think about. It's easier for us in Torvetua when it goes to the community system (kommune facility)." (Participant 25)*

> *"When it's the kommune, you'll have professionals do it every time. It's certainly more convenient." (Participant 26)*

Not all participants reported directly in preference for one system over the other but addressed the benefits of the centralized system as it is currently. Some participants have reported that since the wastewater management and treatment was switched to the municipality,

it has been less expensive for the community; there is no expenditure required for transport of the blackwater from the holding tank. Participants also reported that since the system became centralized, it is simpler and convenient since the community is no longer responsible.

> *"As long as we have a public waste system close by, I don't see the point of having trucks gathering the waste material. If it was a matter of maybe building several miles with new pipeline to connect a system like this, then maybe a truck would be the better way of handling it. But here we had trucks take once a week. It's very often. With the traffic you have- here you have the playground nearby. Earlier it was-you had the smell here which is gone now. So yeah, for our case I would not prefer trucks again." (Participant 13)*

This participant raises the point of convenience. They do not see the benefit of a decentralized system when the *kommune*'s wastewater management facility was within the community's vicinity. Therefore, they believed connecting to *Bergen Kommune* was the right decision. A few other participants reported that the problems have disappeared or reduced since the shift to a centralized system.

> *"But after we moved to the, you know offentlig (public system), when we connected to the station downhill, every problem has disappeared. I think it's better now when we have moved to the offentlig." (Participant 16)*

Figure 3

Illustration of pipeline centralizing Torvetua's vacuum system

The system was connected through a new pipeline which was constructed from where the holding tank was located on the west side of the community. The pipeline went under the lake to the wastewater treatment facility of *Bergen Kommune* as illustrated in blue on the figure on the right. The overwhelming response in Torvetua in favour of a centralized wastewater management system indicates that there are other reasons besides a centralized versus the decentralized system. Participants indicated the expenses of a decentralized system as well as convenience. With the decentralized system, the community was responsible for the expenses associated with the collection and disposal of the black water in the holding tank.

> *"It was expensive when we had the car coming and picking up. I think it was once every- I can't remember- two times in a month, maybe." (Participant 25)*

The responses also insinuated that the preference was based on where the workload and responsibility was placed. The community expressed the need and desire for an external party to repair and maintain the system. The work with the decentralized system was conducted locally as well prior to 2018 when the system became centralized with *Bergen Kommune*. When centralizing the system, the community was no longer responsible for the time and effort that went into wastewater management. Typically, this is not a realm the homeowner is responsible for and, therefore, maybe a greater factor in the preference for a centralized system over a decentralized one.

5.4.4 Future of vacuum toilet systems

Participants shared their perspectives and opinions on the advantages and disadvantages of future implementation of vacuum toilet systems, as well as what changes should be made for future development. The response varied between Torvetua and Kaja generally. Student participants from Kaja emphasized the notion of awareness in regard to vacuum toilet technology, whereas residents of Torvetua generally focused on technical improvements of the system for future use. Arguably, this is a consequence of the difference between private and semi-private residences where Torvetua residents were obligated to attend to technical problems with the system. Student participants residing in Kaja were not obligated to such tasks, therefore, their response was directed to social understandings.

Both groups of participants generally believed a vacuum toilet system is conceptually an acceptable system as it reduces the overall water required per flush and waste produced. Two participants from Kaja and Torvetua shared, respectively,

> *"I heard that with these toilets they are eco-friendly because they don't use that much water. It's easier to use." (Participant 8)*

> *"Well, as far as I know, it uses less water. So, you would probably get away with less water usage when you go with a bigger scale." (Participant 19)*

This illustrates the popular and long held belief of water conservation. With the indirect and direct approaches concerning water conservation, people may form beliefs that water conservation is a simple and minor strategy, yet quite important.

> *"In my personal opinion, I am very for it. Any sort of advances we can do to sort of tweak minor systems in our daily lives that make sort of improvements all around. Especially*

> *the ones that sort of don't really affect our lives negatively anyways, I am fully for that." (Participant 4)*

This was reflected in both groups of participants, many of whom suggested the water preservation is indicative of an environmentally friendly sanitation system.

When discussing the technical aspects that must be improved for future development, the majority of the responses were from residents of Torvetua who had substantial first-hand experience with the technical consequences of the vacuum system. A few of these participants identified vacuum systems as efficient and a space-friendly system; the plumbing was physically smaller in pipe diameter compared to traditional water flush plumbing.

> *"It's efficient and it's space friendly. You don't need to take up that much space for the technical system. It's quite easy, also, to install. The size is not big, it's about 50 mm pipes and upwards so it's quite easy to instal (…) it will take less space, it will be less expensive, and it will be- you can liberate a lot of space that you will otherwise occupy with a traditional piping to other means. To build more houses or to have more green areas for people to recreate. So, if we could find a mean to use less or take up less space, the vacuum piping could participate or be part of the solution." (Participant 14)*

This suggests the plumbing design was less invasive into the natural environment and that aligned with residents' desire to reside in environmentally built housing. This was indicated through the responses of a few participants in Torvetua, such as,

> *"The houses were built in more of an environmentally friendly way than most other conventional housing." (Participant 17)*

Although not initially clear, this participant and others indicated it was not only the community's decentralized system at the time that was an attractive environmental aspect, but also the construction of housing which was completed in an environmentally friendly manner.

> *"It was sold to us as very environmentally friendly house, and environmentally friendly group of houses and the systems." (Participant 27)*

However, the majority of the responses were superficial in nature unless further questioning provoked more details in responses. Participants revealed that the construction was completed in a manner with minimal impact on the surrounding natural environment; destruction of the surrounding vegetation and landscape was minimized by adapting to the terrain during excavation of the area. A few other environmentally friendly measures included: using fewer in-ground explosives for construction, more environmentally friendly materials, and the reduced

use of harmful chemicals used in the construction process. (“Torvetuas historie”, n.d.). It can be assumed from these details that many of the participants believed the community to be built with minimal impact on the natural environment and therefore, that is what establishes it as environmentally friendly.

Participants stated that a vacuum system may be a viable system in practice if used in compliance by the user as well as proper construction of the system by the developers.

> *“As long as people know how to- they don't flush any sanitary pads or what do you call them? As long as there is toilet paper and human waste in the system, it should work. As long as the dimensions of the pipes and the layout of the pipes are correctly made, there shouldn't be a problem at all.” (Participant 24)*

However, negative aspects for future development were addressed. Initially, participants shared from experiences that the system is reliant on electricity; electricity drives the vacuum which drives the “flush” in the system whereas traditional water flush toilets operate independently from electricity.

> *“The problem with it is if the light goes away. The electricity goes away, then you can't use it. That's-that's not good.” (Participant 25)*

From personal experience, some participants believed the cost of maintaining the system was excessive, specifically with third-party hires and materials and tools required for locally completed repairs.

> *“We will first try to fix it (problems) ourselves otherwise we will phone a company called ‘V-Tech’, and they come here and charge us a lot of money every time and fix it if we can't do it ourselves.” (Participant 23)*

> *“So there has been a significant cost for the house-owner society here.” (Participant 24)*

Some participants recognized there would be surplus expenses if VTS were to replace existing toilet technology, and thus, the disadvantage would be that only new projects could utilize vacuum toilet technology.

> *“Installing that in an already existing apartment building, I think would not be feasible. I think would be extremely expensive. But for new buildings and new projects, why not?” (Participant 24)*

The notion of public versus private sphere was also a concern and was a matter primarily raised by participants in Torvetua. They shared that in comparison to private residential settings,

compliance may be difficult to regulate in public buildings where users hold no responsibility for compliance and there is little liability for poor flushing behaviours.

> *"If you had it somewhere public where a lot of people go-I mean there would have to be, I don't know- some sort of control of what people throw in the toilet before they flush. Yeah, so I guess that might be a problem." (Participant 17)*

Additionally, participants suggest when vacuum systems are implemented in a building or community, the entire community is required to be fully compliant with the system otherwise the system does not operate to its potential.

> *"You either have to accept it and be a part of it- all of you in a certain area, or not. So if you have like 10 houses and 2 of them don't like vacuum toilets, that will be hard In think. But like this area here and when you go to new bigger areas with new houses and they're willing to do it, absolutely. So as far as when it works, it works great." (Participant 19)*

This supported the notion that semi-private residency users of vacuum toilet systems hold little accountability as their residency was not permanent; there was no long-term commitment to ensure proper operationality of the system. This may be reflective of the practices and perspectives of the temporary student users in comparison to the long-term, or permanent users, in their privately owned residences. However, the fact that the participants believed that vacuum toilet systems require maximum compliance suggested the system was quite vulnerable, a major disadvantage.

Despite the adversities and setbacks experienced with the vacuum system, Torvetua residents expressed that the system was conceptually viable.

> *"As long as the system itself is robust enough to not cause these unfortunate stops and blockages. There shouldn't be any problems with it." (Participant 24)*

This suggests that with modifications, the system may be accepted and complied with proper adherence for future community users.

> *"I don't know what technical (changes) has to be done but, of course, I wish it didn't stop that often. It shouldn't stop at all if it's perfect. It's never convenient." (Participant 26)*

Users explicitly shared what they believe is necessary to change for a better operating vacuum toilet system for users. One local participant suggested improvements in the plumbing design to be structured so gravity can be utilized rather than a layout where the plumbing works against gravity. Apartment use of vacuum systems was provided as an example.

> *"In an apartment building you usually have a big height difference. I think that might help." (Participant 26)*

A participant stated apartments would be ideal as the vacuum would not work against gravity and reported the importance and need for adequate plumbing design where bends were not sharp as to cause blockages or accumulation of waste in the plumbing.

> *"Improvements when you build the system, you need to make sure you don't have any bends that are more than 90 degrees. You have to have some people to build it that have done some piping; they have some experience with it (chuckles). So, the improvements will be to have a better solution, a better build quality." (Participant 28)*

This demonstrates that the participants encompass knowledge well beyond the daily operations of the vacuum system as many users of the sanitation system do not display similar depths of knowledge. It is the well-informed nature of these participants which has set an example of how knowledgeable users may become of the system they interact with regularly, but also have geared the discussion of the future implementation of vacuum system technology on the technical aspects. However, participants recognized their breadth of knowledge is not sufficient for future development. They reported the need for a third party that is knowledgeable of the system to deliver maximum efficiency.

> *"You would have to at least get some daily maintenance on the system. You would need to have people who can deal with it. Yeah, 24/7 actually." (Participant 18)*

The need for an external party to maintain the system was a point of commonality for participants. Many widely expressing the belief that it should not be the residents' responsibility to ensure the operationality of the system as ordinary users would not have the necessary professional training and knowledge to do so.

Another technical aspect addressed for future improvement is the need for a quieter system as the noise was unpleasant and is a deterrent for some residents when considering future acceptance of vacuum toilet systems. One long-term resident and user of the vacuum toilets stated,

> *"My only concern is the noise that it makes." (Participant 13).*

This highlights the importance placed on the vacuum noise by the users as it was their only concern about the current state of the vacuum system and future development.

Another key improvement some participants stressed the need for was proper planning of the system; to remain dedicated to the solutions and purpose of the system. One participant shared that a decentralized system should only be constructed if there are intentions and enforcements in place to ensure local treatment of the greywater and exportation for black water. Without a proper plan in place, decentralization was futile. Another participant raised another important aspect,

> *"I remember when you had these light bulbs and they should be low-energy, and you had the first light bulbs. Then it dawned on say- at least I found out 'oh actually, they contain mercury'. So, in a way you have to collect them again to prevent the mercury from getting in the environment. So yes, you saved some energy, but you created some let's say problems in the recycling system. My only point here being that if you want to take this system and apply it somewhere then you must think about the environmental benefits and think the whole thing to the end. How much are we actually benefiting the environment compared to just introducing new problems for the environment? If you have to spend a lot of energy and a lot of materials to make this a reality, then try to make the cost-benefit. Not just on the economic part but also on the environmental part. There should be more than just one economy to this. Everything has to benefit." (Participant 27)*

This participant highlights the need for a holistic approach to implement the system in a cost-benefit method; the system should not be implemented for the sole purpose of environmental sustainability, and then the cost is surplus to develop and maintain. The example of the light bulb addresses that often a new problem is developed in the process of striving for environmentally friendly solutions. There is recognition and belief that the vacuum system project in Torvetua was not constructed to its full potential. The participant questions how great of a benefit does this system contains as cost-benefits have existed in the community and emphasizes the need to consider the holistic benefits of implementing such a system.

Student participants from Kaja addressed a few social consequences of importance for the implementation of vacuum toilet systems for future use. Participants indirectly addressed the notion of familiarity bias and the acceptance of vacuum toilet technology for future use. However, familiarity bias may be explained in two ways: for the acceptance and the rejection of the system. A few participants shared that there was a similarity between a vacuum toilet and a conventional flush. For example, a student participant stated,

> *"I don't think there's a difference between that (vacuum toilet) and a normal toilet. For me, if I got the choice of choosing something that is better for the environment, I probably would." (Participant 2)*

They first addressed there is no difference between a vacuum and a conventional toilet. This suggested that the familiarity between the two toilets for this individual provided comfort to use the vacuum toilet. The participant then addressed the importance they place on selecting an option with the environment in consideration which they have deemed important. Evidently, this participant, as well as many others from Kaja, emphasized the importance and preference for an environmentally friendly sanitation system. This was not the case with all the participants. Other participants, in Torvetua, rejected the system.

> *"I would not recommend it. I think it has been a big issue here and it has cost us a lot of money and trouble. I'm quite negative." (Participant 23)*

Since the participants had limited experience with vacuum toilet systems prior to their current residence and the vast majority were long-term users of conventional toilets, many participants in Torvetua perceived the vacuum system as different. As some participants found the respective systems to be similar, others identified dissimilarities between the two systems. Often, the dissimilarity was stated to be the noise that was unfamiliar to many users especially in private residences. This dissimilarity for the user can also be rationalized by familiarity bias; since the noise was unfamiliar to many of the users, it represented what the user was not familiar with specifically in regard to their practice of a sanitation system. Therefore, their familiarity bias shaped their perspective. This was reflected when a participant stated,

> *"There should be a way to develop toilets that makes a lot less noise. More in line with conventional toilets." (Participant 28)*

This statement clearly revealed familiarity bias by likening the sound of one system to the other and their preference for the quieter one. Participants two and 18 address the two ways in which familiarity bias was represented in two ways of a similar situation.

A couple of other student participants emphasized the importance on sustainable development and suggested they are accepting of vacuum toilet systems if they are a viable option for sustainable development. This was the case of a particular participant who stated,

> *"In my personal opinion, I am very for it. Any sort of advances we can do to sort of tweak minor systems in our daily lives that make sort of improvements all around. Especially the ones that sort of don't really affect our lives negatively anyways, I am fully for that." (Participant 4)*

The context of this excerpt was in a discussion of environmental sustainability with the participant. This particular student resident has indicated that they are in favour of the necessary change individuals may need to engage for environmental sustainability which does not negatively affect the users in any form. Similar perspectives were shared among a significant number of participants from Kaja and a few from Torvetua. A few participants from Torvetua highlighted the importance of sustainability, but the discussion was heavily centered on practicalities they believed need to be addressed to enhance the system as mentioned earlier in this subsection.

5.4.5 Future implementation of ecological sanitation

The majority of participants stated that the model of ecological sanitation was a great concept. It was described as recycling due to the reuse of valuable and abundant nutrients found in the waste. Some participants viewed re-using these nutrients as beneficial for the environment. For instance, a student participant expressed support for the environmental aspect behind the approach,

> *"I'm okay with that especially if it's better for the environment. It would be a plus. It maybe sounds a little bit disgusting, but most of what we eat is from fertilizer of other animals, so I think it's no different." (Participant 7)*

This participant expressed the importance of choosing the environmentally friendly option as well as indicating there was no difference between human or animal waste. The perspective that waste produced from humans, or animals is virtually the same highlights a shift towards acceptance of the approach of Eco-San; Eco-San is reliant on the reuse of human waste as a resource. Another student participant shared,

> *"I do not see a problem with it. I can understand why some people are uncomfortable with the idea. But considering general fertilizer, something made of animal waste, there is really no difference in that sense." (Participant 3)*

This participant specified their acceptance of the implementation of an Eco-San system to utilize the nutrients potentially in the form of fertilizer yet raised the issue that they believe other people may be apprehensive to the approach. Then expressed their view that waste from a human or animal is the same and therefore it poses "no difference" to be used as a resource.

A few student participants shared that they believe Eco-San is an acceptable model to implement as long as it is scientifically proven as safe for human and environmental health

concerning hazards, such as biological pathogens. The concern for biological pathogens was recorded in both Kaja and Torvetua participants.

> *"I'm not a biologist but I know there's an easier transmission of certain diseases from human to human, stuff like that. Once again, assuming the hygiene factor is there in the sense of sort of decontamination and stuff like that, there is no negative side of that besides peoples' biases." (Participant 4)*

A long-term resident of Torvetua raised concern for what is ingested and excreted by people of which traces remain in blackwater.

> *"We used to live in farms, and you had an outdoor toilet, and you took it down- put it in the ground. You left it in the ground. I don't know, but then they didn't eat so much artificial things with all these...medicines, things in the food. All these things. I think that's part of the whole ecosystem and has to be considered, not to go back into the soil. What we eat is important (…) I'm just concerned about the wellness of this planet. I think if we can live as healthy as possible and if this is something that will do us good, I have no problem with that." (Participant 15)*

This participant discussed the environment and the "wellness of this planet", and the necessary measures that must be taken to ensure a healthy and open ecosystem. They addressed the need for a healthy planet and their approval for the approach of Eco-San if it will assist in a sustainable planet. Another factor for implementing Eco-San is premature implementation and development. Participants in Torvetua claimed the community project was premature and not planned well since waste could not be used as fertilizer as planned on fields for agricultural purposes as per biological and legal reasons.

> *"I think that that this idea- when you try to do it when it's so small and there's no plan, like they wanted to use it in the fields. There're obvious concerns about that. So, I don't think they really thought things through. When it's so uncommon to have these in Norway you can't expect to solutions to pop up by themselves (…) I think it was premature to put it here." (Participant 26)*

Participants suggested that for the future it is necessary to have a calculated plan to ensure the system will be fully operational and eliminate the need for surplus expenses to change the practicalities of the system at a later date. Some practical problems arise concerning the storage and transport of blackwater. A holding tank is an additional part of the system which is required to store the waste until it can be transported out of the community. A few participants reported spillage and smell at the site of the holding tank when the system was decentralized, and the holding tank had to be emptied.

In sharing the advantages and disadvantages of implementing the model of ecological sanitation in a vacuum system, respondents were questioned about their comfort level with the model itself. Student residents generally expressed acceptance for the implementation of Eco-San in future residential developments.

> *"I think it should be used because- it should be volunteered. It should be an alternative for people who want to contribute to the environment if it's more sustainable. But it shouldn't be forced on people, maybe." (Participant 7)*

However, the degree of individual comfort varied among participants. This was a similar case among participants from Torvetua. At the initial responses of participants, it appeared as if the majority were comfortable and accepting of Eco-San. However, with further discussion, the responses varied. It was found that despite reporting advantages of the model, some participants were only somewhat comfortable with the concept. For instance, one participant reported that ecological sanitation would be very beneficial for the environment, but also stated their discomfort when they said,

> *"I'd rather not think about it" (Participant 17).*

Generally, most participants were accepting and comfortable with the concept of ecological sanitation. For instance, the following participant shared a differing opinion from participant 17 who revealed some apprehensions to Eco-San.

> *"The thought of walking passed a green area and knowing it has been fertilized with some, well human nutrients or feces doesn't gross me or at least it's not a problem." (Participant 9)*

Some participants had claimed there is no difference between using animal waste for nutrients and human; waste is waste. However, a few participants had concerns regarding human health and the spread of disease and infection. Some of these participants recognized they were not well-informed about the approach.

> *"We don't think it's disgusting. We think it's unusual. Maybe illnesses and bad things will be transported further, but not sure about that (…) We don't know everything about it. Maybe if we were to read and learn more about it we would have a better opinion." (Participant 21)*

Thus, the process must be safe and approved for society to trust and utilize it. Overall, participants generally were accepting of the approach of Eco-San but their respective comforts with the model were diverse.

Together, the personal perceptions of the participants served as a reflection of their practice of using the vacuum toilet system and their perspectives which were in part shaped by their daily engagement with the system. Kaja participants were not familiar with the routine operation of the system as it was not their responsibility but strongly advocated for the environmental benefits of using a vacuum toilet system. Torvetua residents were responsible for the full operationality of the system which aided in the accumulation of knowledge of the vacuum toilet system that was shared often without instigation in this research study. Furthermore, this knowledge and experience contributed to the preferences participants had for the future. The response was fairly divided for preference of vacuum toilets or water flush toilets, and centralized or decentralized wastewater management systems. The majority of individuals who declared preference for water flush cited the noise or technical complications of the vacuum toilet as their deterrent. Evidently, the interaction of the participants and the vacuum system shaped the perspectives and broadened the knowledge participants had of the system. This contributed to their perspectives of future vacuum toilet system development and the implementation of Eco-San.

Generally, most participants shared advantages and disadvantages of future VTS development based off their understanding of the system through their experiences in the respective communities. Majority of student participants were very accepting of the vacuum toilet system and reported that water conservation was an important feature of it. The response was fairly divided in Torvetua where a significant number of participants cited the noise and technical complications as reasons to refrain from future development. Similarly, the response for the enforcement of Eco-San was driven by the experiences of the previous decentralized system in Torvetua compared to rather accepting perspectives by student participants, citing environmental friendliness as the central objective.

5.5 Social aspects

The fifth theme explores the experiences of the participants from a sociological perspective. Due to the nature of drastically varied interaction with the vacuum toilet system, the response differed for Torvetua and Kaja regarding social aspects. Despite the technical aspects of

the system affecting the residents as well as their perceptions and experiences, the vacuum system had affected sociality in Torvetua. Kaja participants were not reflective but addressed the potential impact of the system in a community.

This section deals largely with participants' responses deemed as social aspects despite their responses targeted as to the technically oriented questions, largely in Torvetua. Participants had differing observations to share when directly questioned in what ways if any, the vacuum toilet system has affected the community members. This section will address the directly questioned social aspects separately from the denoted responses from the participants.

5.5.1 Awareness

Since student residents were not required to engage with the vacuum system to the same extent as Torvetua residents, the reflection of the student participants did not result in a lengthy discussion of the social aspects of the toilet. The majority of student participants reported that they did not perceive any influence of the system on the Kaja community. It was only a few residents who mentioned the notion of awareness. Awareness was addressed in two ways. The first was about knowledge and societal awareness. A couple of participants indicated that individuals would become more knowledgeable of a different sanitation system through the regular interaction in the residence. Particularly a system that uses less water and is considered to be environmentally friendly which would be recognized through regular use. Secondly, it may raise awareness by demonstrating that what is considered waste can be utilized as a resource, specifically if Eco-San is implemented in the respective system.

> *"The fact that we actually use a high amount of water for just flushing down our feces in a way. So, besides that fact that maybe more of a societal awareness to these solutions, but besides that I can't really see a major influence on society from it." (Participant 4)*

5.5.2 Collaboration and collective action

As mentioned, participants in Torvetua had more details and opinions to share compared to Kaja participants. Instances of sociality in the community were largely in response to technical aspects of the vacuum toilet system. This is exemplified in the participants' responses of collaboration among residents to handle and fix the complications and technical problems posed by the vacuum toilet system. Participants reported dependency on the community in general or specified community members to assist in de-clogging blockages in the plumbing system to restore the vacuum and functionality.

> *"We had lots of blockages, and we have a group that goes out and has to open the manhole, climb down, and manually flush through with the pressure hose and stuff." (Participant 17)*

This illustrated a communal effort by the community labeled as a group to repair complications with the system and restore functionality. Some participants reported having notified neighbours when they encountered a loss of vacuum in their residences. It was often presumed that a loss of vacuum in one home would affect the neighbouring houses if it had not already. Thus, participants attested informing the neighbours and implied to rely on assistance to deal with the problem. This is a case of the individual relying on the community for assistance to manage the blockage. However, the community also relied on the individual affected by the blockage to provide a warning to the community of potentially a greater consequence of a localized blockage. This dependence and reliance brought the community together, so to speak. One participant described this phenomenon,

> *"Here we are quite a tight knit community so when some people have problems, all the neighbours just jump right into it and fix it. So, we are dependent on the neighbours here working together to maintain it and to have it functioning all the time." (Participant 19)*

They addressed the reliance and interdependence of the community members. Some participants mentioned that after residents learn how to fix complications local to their home, they offer assistance to neighbours or others in the community.

> *"With all the knowledge in the area here there is always someone who has done is before. They teach you and try to help you out, so we manage." (Participant 15)*

This behaves as a positive feedback cycle for future incidents of similar complications where the operationality of the system is dependent on individuals who have learned from their own experiences. In addition to treating blockages, the community is also dependent on collaboration to repair the mechanical aspects of the plumbing system.

Certain residents of the community were stated to have a professional background or previous professional experience with vacuum toilets or plumbing systems. Most of the residents reported no past experience with the system with the exception of aircraft and cruise ships. These individuals learned more about the system through their experience and were able to assist other community members when the same complications arose.

Many of these individuals came together with the few professionally experienced individuals and were reported to have dug a few metres into the ground to change the plumbing layout after locating the problem areas for an operational system. Group collaboration was imperative for the community to amend the poorly constructed plumbing with 90-degree bends without the financial burden of hiring a third party.

> *"But the only reason why the system is functioning here in Torvetua is based on, sort of, a community concept where you can leave everything go outside and fix the problems." (Participant 28)*

The group collaboration went beyond the amendment of the plumbing system. Participants reported collaborative efforts to deal with the loss of vacuum and blockages in the system. The existence of the practice of communal efforts was implicitly reported due to the lack of professional third-party presence in the community to attend to the dysfunctionalities of the system. The inhabitants had to rely on themselves and the community's collaboration to regain a functioning system.

5.5.3 Social bonding and unity

Social bonding occurred between community members in the collaborative efforts the community engaged in for maintenance and repairments of the system. Although similar to collective action, social bonding addresses not only the unity of the community in adverse situations with the vacuum toilet system but also the human connection. Some participants mentioned that after residents learn how to fix complications local to their home, they offer assistance to neighbours or others in the community. This behaves as a positive feedback cycle for future incidents of similar complications. One participant described this sensation with the Norwegian term, *dugnad*. They shared,

> *"Well, the community here has actually been very dugnad minded if you know the Norwegian term. Dugnad, meaning we all do things for free for the benefit of the community. We put down work, effort, etcetera." (Participant 18)*

This participant highlighted a specific Norwegian term with its connotation and understanding to explain the social context and emotion behind the action. There was also recognition and importance placed communal work to ensure a fully operational system; implying self-reliance for dealing with complications in the system is not a possibility. This was further reported indirectly by multiple participants who reported the use of a social media

platform to stay connected and address problems; residents have utilized a private group page on Facebook to notify of acute and long-term problems to coordinate a response to return to a functioning system as soon as possible.

> *"If there is a block (blockage) we will contact each other via our Facebook page." (Participant 23)*

> *"We have the Facebook page for the Torvetua and if someone doesn't have suction, vacuum or whatever you call it, they sort of write 'oh, no vacuum in 60' and then everyone responds, 'we have it (there), we have it (there)'. Then they can localize where the vacuum has gone, and then a group of them go out and do the flushing thing with the high pressure." (Participant 17)*

These very participants and others reported the formation of a community board who take leadership with maintenance and complications with the system. This has ranged from community for preventative measures communicating with external companies.

Some participants reported that there has been a negative experience in the community with the vacuum toilet system but did not state negative experiences with community residents. In comparison to a significant number of participants who stated social bonding was a positive effect on the community. Residents were believed to have had the opportunity to bond more due to the complications with the system. The commonality in the community were the obstacles which arose from the system and obligated residences to meet frequently to resolve the issues. A few participants reported that residents often remain together for company well after the task at hand has been completed. The community members know each other better due to the nature of the vacuum toilet system and its functionality in the community.

With social bonding and unity, several participants in Torvetua credited one individual in the community to a high degree. For anonymity, this individual will be addressed as Person X in this context. Person X self-reported, and testified by other community members, to be a plumber by profession. They also have been a resident of Torvetua since the construction of the community in the late 1990s. Their professional knowledge and insight were revealed to have guided the maintenance and repairments of the vacuum system in the community.

> *"For example, without [Person X] it would have been a big challenge, especially the first years because [they] knew a lot about plumbing and the system. But then after the system had been upgraded, my impression is that the scale of the problems has gone down." (Participant 27)*

Person X was believed to have contributed to the vacuum system to a large degree; the system would not have been functioning in present day if it had not been for Person X. The number of complications arising from the system declined. Crediting the functionality of the system did not seem to function independently from the notion of collaborative action. In other words, Person X's contribution were integral to the functionality of the system yet collaborative effort among the community members was also vital.

> *"And [Person X] was one of the people who did that in the very first year. I mean, I've seen [them] down there on a Christmas Eve, so you can imagine how would it work if you are to base everything on people within a community that has both competence(s) to deal with it and also, the willingness or idealism to help with it." (Participant 18)*

Nonetheless, Person X and their skillset were considered to be an imperative part of developing a better functioning system. To the extent that the individual was perceived to be rather selfless in the eyes of other community members, as described to be "*dugnad* minded".

Together these results provide important insight into the sociality aspect from the use of vacuum toilet systems in the communities. The vacuum system was believed to play a role in raising awareness of alternative toilet systems to water flush that waste large amounts of water, as well raise the acceptance of what previously was considered waste can be a resource. Collaboration and collective action were suggested to be a major outcome regarding sociality in the community. Individual residents relied heavily on the collective action of the community to ensure a fully functional system as the community relied on individuals to report and assist in repairs and maintenance, but also on particular persons who possessed professional knowledge or gained experience with the system over time. This dependence was key to an operating system in Torvetua led to greater social bonding in the community. The participants from Torvetua reported that the collaboration of the community catalysed relationships where residents became socially bonded beyond the necessary contact for maintenance of the system.

Chapter Six: Discussion

This study sought to explore and develop an understanding of vacuum toilet system users' acceptance and practice of the system, as well as identify what factors have influenced the practice and perceptions of vacuum system used in Norway. Concepts rooted in the social sciences were used as analytical tools to generate a typology to interpret the data, such as the concepts of familiarity, displeasure, and aesthetics. This research found that participants, overall, were accepting of vacuum toilet systems in semi-private and private residences with a few aspects requiring improvement from the user perspective. The emerging themes in this research were found to be key components in the users' understandings and practices of the system. Technical aspects were found to be the main theme of discourse for the majority of users. The practice, perceptions and social outcomes were determined to be heavily integrated with vacuum toilet system use in the communities.

6.1 Technicalities of the vacuum toilet systems

The results indicate that the technical complications were the prominent theme of discourse in this study. Although, smell and noise were the physical characteristics that reserved many users from accepting the vacuum toilet system as a sustainable system. Familiarity in respect to the physical characteristics of the system was universal in this study. Familiarity addresses the concept of habits. Habits are discussed to be repeated behaviours that are established through learning and use (Nilsen, Roback, Broström, & Ellström, 2012). The familiarity of the vacuum system may serve as an assurance for the user as they may continue practicing vacuum toilets based on habits formed from the use of water flush toilets. However, this is superficial as the positive response was accredited to observable features of the vacuum toilets.

The displeasure of the noise may relate to the notion of familiarity. Familiarity bias allows individuals to be comfortable with what is the preference for what is familiar for the individual and, therefore, what is unfamiliar is foreign. Arguably, with exposure arises familiarity and then the individual becomes accustomed to what was once unfamiliar. Conventional water flush toilets do not produce as much noise as vacuum toilets. This unfamiliarity with the sound results in displeasure and expected critique of the sound of the vacuum as a nuisance. However, the concept of habituation was commonly highlighted by participants regarding the noise as explored in flushing behaviours in section 5.3.3.

Research has shown that loud acoustics, generally, nearing or over the range of 85 decibels are harmful to hearing and health (National Institute on Deafness and Other Communication Disorders [NIDCD], 2021). However, these studies have not specifically researched the effects of vacuum system acoustics on human hearing. Research has found that exposure to excessive noise may lead to hearing loss, yet it is preventable (Le, Straatman, Lea, & Westerberg, 2017). On an individual level, prolonged exposure to high levels of noise may result in varying degrees of noise-induced hearing loss by damaging hair cells in the cochlea (Berkowitz, 2015). On a societal scale, noise pollution has been a growing concern as a health hazard in indoor and outdoor environments in an urbanizing world (Gupta, Gupta, Jain, & Gupta, 2018; Thakur, Batra, & Gupta, 2016). Therefore, this has become a widespread health concern in public health. Berkowitz (2015) found that the prolonged exposure to high levels of noise from public restroom hand dryers posed health hazards to human populations and the environment. Although Berkowitz (2015) was not addressing noise produced from vacuum toilet systems, the study of noise from hand dryers function as an exemplar of health implications due to environmental noise.

The National Institute on Deafness and Other Communication Disorders declares, “Long or repeated exposure to sound at or above 85 decibels can cause hearing loss.” (NIDCD, 2021). Vacuum toilet systems have been perceived to be rather noisy when used on an airplane or a water vessel. The vacuum toilets in Kaja and Torvetua are provided by the manufacturer Jets for residential use and are considered to be less noisy. However, acoustic reports conducted on Jets’ different toilet models show the noise measurements for different models of Jets vacuum toilets, including, but not limited to wall-hung Charm, Pearl, and Jade and the floor-standing model, 50M. Jets’ acoustic reports showed that the noise of the vacuum toilet varies marginally between the different models they have for residential toilets. The flush period was roughly seven seconds and multiple tests were taken for each model (Torres, 2019) and each report indicates multiple tests run with different scenarios: closed lids, open lids, with and without silencers (Brandal, 2018; Torres, 2019) and different with whether the silencer was in or outside the wall. (Brandal, 2018).

The Pearl and Charm models are borderline to the 85-decibel standard with ranges of 82 to 84 and 83 to 85 decibels, respectively (Brandal, 2018). The floor-standing model, 50M, shows a decibel range of 82 to 88 decibels (Bowden, 2015). These decibel ranges are reflective of a

situation where the vacuum toilet has a silencer, and the lid is closed during the flush. When the lid was left open, the decibel reading increased exponentially. The Charm model, with a silencer outside the wall, showed readings of 89 to 90 decibels compared to a silencer inside the wall of 80 to 81 decibels (Brandal, 2018). These reports clearly show relatively high decibel readings for all models of the Jets vacuum toilets. This indicates that people may be naturally inclined to dislike loud noises such as the vacuum flush. Therefore, the users' disapproval of noise may function as a signal of health hazards posed by the level of noise. This must be considered in the future development of vacuum toilet systems for improved public health and user approval.

The data suggested that smell was a physical characteristic prominent in the use and emptying of the holding tank in both communities. The research study did not find instances of smell with the vacuum toilets. This finding may be rationalised by other studies conducted exclusively on toilet flushing. Studies have been conducted which specifically address viruses carried in aerosol particles. Li, Wang, and Chen (2020) reported how toilet flushing can promote virus transmission and concluded that the velocity in the toilet bowl is capable of expelling particles out of the toilet bowl in aerosols. Not only do these aerosols have the potential to carry bacteria and viruses but they also, understandably, contribute to the dispersal of smell from human waste. Although not explicitly stated, it is presumed that Li, Wang, and Chen (2020) used water flushing toilets for the research when they stated, "During the flushing process, water enters the bowl from a tank under the action of pressure and mixes with the water seal. This generates turbulent motion, which drives dramatic changes in airflow." (Li et al., 2020, p. 2). A probable explanation is that while smell travels through aerosols, the vacuum of the toilet suctions releases fewer aerosols when flushing suctions all the waste rather than generating turbulent motions in the toilet bowl. This may explain the perception of the participants that vacuum toilets do not smell in Torvetua and Kaja.

The concept of familiarity was used to understand user perspectives and practices regarding the physical characteristics of VTS. Familiarity with these characteristics was found to be foundational for acceptance of the vacuum system. Previous research indicated previous experience and familiarity with a similar system revealed acceptability for the future. Hennigs et al (2019) determined that user perception and feedback were generally positive to use dry toilets but were dependent on the user's previous experience and toilet habit. Water flush toilet users were accepting of the idea of dry toilets; however, they held some reservations compared to users

who users of urine diversion dehydration toilets who were more receptive (Hennigs et al., 2019). This research study was conducted in South Africa with prototypes of non-fluid toilets (Hennigs et al., 2019). On one hand, the findings of this research study are similar to Hennigs et al (2019) when it concerns user acceptance and perception in general. Both studies found a positive response to the toilet system in question. On the other hand, the findings differ regarding Hennig et al (2019)'s regard and importance of previous toilet experience. This actively demonstrates that familiarity with the system or aspects of the system from previous experience does not indicate clear acceptance in the present or future. Rather than previous experience, the findings in this study suggested that it was the users' interaction and experiences with the vacuum toilet system itself which shaped the perceptions for future use of VTS rather than the previous experiences of toilet systems.

6.2 Complications and user practices

Technical complications forced the community members to engage in preventative action to avoid or minimize future blockages and loss of vacuum in the system. There appeared to be a connection between the practice and the technical aspects of the toilet where the participants actively engaged in particular practices of the system. Many practices were habits developed from experiences with previous toilet systems the participants continued to practice with the vacuum system. For instance, to flush foreign objects into the vacuum toilet poses a greater risk than down a conventional flush toilet. This practice may have been acquired during the use of conventional flush toilets which were deemed to be "more forgiving" than vacuum toilets which were believed to be vulnerable or sensitive. The technical aspects and practices of the system were interconnected for the user. The habits formed from previous experiences of toilet system use affected the functionality of the vacuum system, yet the existing technical aspects of the vacuum system influenced the practices users engaged in for maximum efficacy. The regular use of the technical system and practice do not operate independently from each other.

Furthermore, the perceptions of the vacuum system were related to participants' interactions with the technical aspects which affected their practice. The daily complications and general exposure to the vacuum toilet affected participants in different ways. Many community members became accustomed to the system through daily exposure, to acoustics for example. At first, the noise was loud and unpleasant but through regular exposure, it was found that numerous users familiarized the sound and increased comfort. On the other hand, a significant portion of

the communities had cited acoustics as the major drawback of the system. This influenced their perceptions of the current vacuum system as too noisy and inevitably influenced their opinions on future development.

Although cleaning practices were found to be generally accepted and overall comparable to conventional toilets, the particular case of the use of the showerhead to clean the toilet bowl was intriguing for two reasons. Firstly, the participant did not report using a toilet brush as the primary method or indicate why using water from the showerhead was the primary method to rid the remanent left in the toilet bowl. Secondly, the use of water symbolizes the notion of water as a cleaning agent. This is relevant when considering the notion of esthetic uncleanliness described by Rheinländer et al. (2019). Aesthetic uncleanliness plays the dominating role in washing away the remanent rather than concerns over biological characteristics and human health. In congruence with this notion, water would be the better cleanser and eliminate the stained remanent in the toilet versus using a toilet brush.

The use of water symbolizes the notion of water as a cleaning agent. This is relevant when considering the notion of esthetic uncleanliness described by Rheinländer et al. (2019). Aesthetic uncleanliness plays the dominating role in washing away the remanent rather than concerns over biological characteristics and human health. In congruence with this notion, water would be the better cleanser and eliminate the stained remanent in the toilet versus using a toilet brush.

While many other participants in Torvetua and Kaja found little to no difference in cleaning practices at all. They reported that normal or regular cleaning as a conventional toilet was comparable to the vacuum toilets and, thus, no additional measures were necessary. When considering aesthetic cleanliness (Rheinländer et al., 2019), it is speculated that the aesthetics of the toilet bowl are not as great of a concern for some users since they believe the cleaning practices are normal or comparable to a conventional flush. Thus, there is less concern of disgust towards aesthetical cleanliness. However, these participants largely reported the element of noise the vacuum produces when flushed as a key difference between the two systems. The array of responses regarding descaler usage can also relate to perceived cleanliness. The terms build-up and urine stones portrayed an image of grime and uncleanliness. Therefore, some users would intrinsically utilize descaler more often than others who did not reflect on imagery of uncleanliness to a similar degree.

Daily engagement with the system for the users proved to be a key determinant of the technical complications encountered. Certain actions and practices resulted in complications with technical aspects whereas others did not pose complications but rather ensured a functioning system. Users were found to have formed habits in response to practicing their vacuum system. Behaviourists consider habits as repetitive behaviours that are established through repetition and learning (Nilsen, et al., 2012). When some participants became accustomed to avoiding the flush during the night hours, it became part of a habit and they continue to believe other residents are not habituated to the sound. Furthermore, Nilsen et al. (2012) state that empirical findings suggest that repeated behaviours are difficult to change. This explains why some residents may continue to avoid any flush activity at night. However, this perspective explains behaviours and habits formed with the regular use of the VTS. Before using vacuum toilets, nearly all users were found to have limited exposure to VTS and predominately had been regular users of traditional water flush toilets. This means that users had priorly developed habits and comfort suited for conventional toilets that were incompatible with vacuum toilets.

This was evident in the cases of children in residences practicing vacuum toilets. Flushing behaviours altered to prevent disturbances to infants and children among other residents that were yet to become habituated to the vacuum system. Conversely, there some children were born and raised in Torvetua. These children whose parents reported, they "never knew anything else" revealed that the noise from the system for the children was a case of familiarity; the vacuum toilet system was the only system these children were users of regularly and did not have a comparison to conventional flush. This actively demonstrates the nature versus nurture debate on a superficial level. The nature versus nurture debate questions the biological and environmental influences on human development and behaviour (Plomin & Asbury, 2005). Although complex and highly disputed, it posed a rather interesting perspective on the behaviours and habits of the practices of participants 11 and 12 in particular. One may argue that people inherently dislike loud and unpleasant sounds while others argue that people learn to dislike certain sounds.

6.3 Practices and perceptions

Personal practice and perceptions highlighted the relationship and regular use of the system. In practice, preventative actions to prevent the complications were not only rationalised, but also perceived to become part of the routine of users in the respective communities. The practice of the system was in response to the system in respect of its unique technical

characteristics. For example, in Torvetua, participants engaged in the use of high-pressure hose flushes to respond to the inherently vulnerable pipeline layout which proved to be susceptible to blockages.

This research highlighted the complex interaction between water and people. Through the exploration of the technical and social processes of managing the vacuum toilet systems, it was visible that this interaction was inconspicuous. Many perspectives shared were indicative of a strong preference for water-saving practices. The fact that vacuum toilet systems are inherently water saving with their low water volume per flush (Jenssen et al., 2014) as modern-day notions of domestic water conservation are at the forefront and many behavioural influencing tactics are targeted to water conservation behaviours at the household level (Koop et al., 2019). These behaviours target individual practice levels. The reduction in water usage in a vacuum toilet system was the prevalent practice of water reduction in Torvetua and Kaja.

The reduction in water use contributes to the water supply and demand cycle; a simple equation widely recognized. This means high water demand is reduced when supply is increased (Butler & Memon, 2005). A vacuum toilet system can increase supply for future use by cutting the demand in the present through the limited use of water per flush. This cycle is particularly important in a Norwegian context as Statistics Norway (2021) reports the average person in Norway consumed 178 litres per day in 2019. Reducing water consumption through the use of a vacuum toilet system would reduce water consumption on an individual level to an extent through the Norwegian population and increase water supply. This would be vital for sustainable living and development in the future. The supply and demand cycle of water was addressed to an extent by the vacuum toilet users in this study.

The use of the vacuum system rationalised the communities' perception of the vacuum system as environmentally friendly by conserving the use of water for the sole purpose of waste disposal. In the 21st century, ensuring quantity of freshwater for sustaining human and animal life is a growing concern (NSF Advisory Committee for Environmental Research and Education, 2005) and that is reflective in the perception of the users of the vacuum system as an inherently "good" or environmentally friendly system. The notion of water conservation is embedded in primary and secondary education. Water-saving practices and actions are directly and indirectly taught in educational institutions to children and adults alike through an array of disciplines.

For instance, in addition to addressing water preservation activities that children can engage in, Felton et al. (2015) exemplified how water preservation is highlighted in mathematics in education institutions. Children were to understand mathematical concepts through the use of modeling; ultimately use the example of water conservation in showers compared to baths with specific water flow rates to determine which used more water. This example highlights that water conservation is not always directly discussed but it's important is also addressed in implicit ways. The importance placed on water conservation is also a transparent topic of discourse with an abundance of literature published (Coles, 2016). This reveals the notion of water as a commodity to be conserved may be rooted in education systems.

However, it was not only individual perspectives of water and water systems that affected the practice of the system. Technical aspects of the VTS made the system more vulnerable than conventional systems due to the low water quantity. The vacuum system was found by users to be more vulnerable and prone to complications such as blockages and loss of vacuum compared to their experiences with water flush toilets. From a socio-hydrology perspective, the users express immense interest and concern for water conservation that there is a willingness to adjust and accustom to the vacuum toilet system which is why their practice of the system evolves and there is participation in preventative actions.

However, many of the users who reported engaging in preventative actions had also conveyed their preference for a water flush toilet in the future. This reveals that the practices surrounding vacuum toilet system use and compliance are accepted to any extent, one which varies from user to user. The specific technical complication in these communities needs to be accounted for when considering the use of vacuum toilet systems from a socio-hydrological perspective. The technical aspects in Torvetua, where major concerns over technical complications were reported, were not found to be as substantial in Kaja. With this and evolving vacuum toilet technology, this particular case cannot be used to represent a larger population. However, it is indicative of how technical aspects of the system result in negative consequences for the community. Additionally, it demonstrates that the technical characteristics have a significant impact on the users' practices and perceptions of the vacuum toilet system. This particular finding may be beneficial going forward in sustainable development with VTS.

In going forward with the sustainable development of VTS, Eco-San is an emerging approach for sustainability. It has been assumed that cultural and societal attitudes may hinder

the approach of Eco-San (Jenssen, 2004). The participants' perspectives for the future implementation of Eco-San were relevant for two reasons. Firstly, a decentralized vacuum toilet system was implemented in Torvetua ("Torvetuas historie", n.d.) and Kaja (Jenssen, 2005), and blackwater was collected in holding tanks. For many years, In Torvetua, the aim was to utilize the blackwater as fertilizer, but the system was centralized with *Bergen Kommune* in recent years (K.G. Flo, personal communication, November 11, 2020). In Kaja, the blackwater was collected and transported to a research laboratory at NMBU for the last five years (P. Jenssen, personal communication, May 9, 2021). Both communities have had some degree of experience with the use of local waste as a resource and, therefore, are exceptional participants to share their perspectives. Secondly, the approach of Eco-San relies heavily on the acceptance of the users of the system; the technology and system can only be used to its potential if the user is accepting and compliant. Although participants were generally accepting of the approach with concerns of safety for human health, there was a degree of hesitancy in few users.

As noted, there were few acknowledgments of disgust with implementing the approach. Curtis and Biran (2001) stated a variance in disgust of human fecal waste exists across communities and cultures. A participant had discussed the environment and the wellness of the planet, and the necessary measures that must be taken to ensure a healthy and open ecosystem. They addressed the need for a healthy planet and their approval for the approach of Eco-San if it will assist in striving to attain sustainability for the planet and its people. This is reflective of the One Health approach in public health. The One Health approach is transdisciplinary by nature as it explores the interactions between animals, humans, and the environment (Zinsstag, 2020). One Health indicates that all three components are interconnected and recognize that the health of one component affects the others. The participant's concern is regarding the human to environment connection. Literature reveals that antibiotics may enter the environment through waste streams and effluents as it is poorly metabolized in the wastewater treatment processes (Chow, Ghaly, & Gillings, 2021). Antibiotics in food animals and pharmaceuticals that are ingested by humans have increased dramatically over the previous century and, subsequently, are found in blackwater (Shi et al., 2019). However, this is a phenomenon that exists independent of Eco-San. Thus, it should not be considered as a disadvantage to implementing Eco-San. However, the concerns of One Health should be considered and addressed.

Intragroup interactions were found to have occurred predominately in Torvetua due to the responsibility for the vacuum system and its functionality. The communal response to the complications with the system may be explained by Emile Durkheim's concept of organic solidarity. The concept has been a disputed one among scholars with ambiguities and contradictions in the theory. Organic solidarity was a social cohesion based on the relations between the individual and the society (Pope & Johnson,1983). In Torvetua, it is the relation between the individual participants and the community. There were apparent cases of mutual dependencies for the community and individuals. These dependencies ensured the functionality of the system. For instance, the loss of vacuum in one residence was a risk to cause a blockage and loss of vacuum for neighbouring residences. Therefore, the community relied heavily on the individual affected to notify the group. That resident also relied on the community's social cohesiveness and expected assistance from community members to aid in repairments or maintenance of the system. One actor was incapable of existing without the other.

6.4 Practices and residency status

Residency status was found to be connected to practices and opinions of vacuum toilet system users. Residency status refers to semi-private or private residency. Residents of the private residences were generally the owners of the residence, many of whom had been users of the vacuum toilets for some years if not over a couple of decades. Participants of the semi-private residences were short-term student residents and had been exposed to the vacuum system in the building from a few months up to a couple of years. The residency period and residency status resulted in greater involvement and concern for a functioning vacuum system.

The residency status of the users influenced the practice and perceptions of vacuum toilet systems. The semi-private or private residency determined the degree of repair and maintenance each community was responsible for ensuring. In Kaja, the student residents were not solely responsible for the operationality of the system. The housing organization, SiÅs, was responsible for maintenance and repair work, including blockages induced by student residents. However, the residents were found to engage in daily practice behaviour to minimize complications, such as the use of particular toilet paper and modifying flushing behaviours. This was in clear contrast with users in private residences as they were responsible for maintaining a functional vacuum system. These users were compelled to comply with the vacuum system to a greater degree than users in semi-private residences. Daily practices of behaviours and habits were modified, but

users were obligated to engage in maintenance and repair of the system unlike residents in Kaja. This engagement with the system maintenance heavily influenced the perceptions users had of the system as they were required to interact with it in differing manners from Kaja residents.

As the residency status affected user practice of the system, it further influenced the perceptions users had for future development and use. Participants in Kaja relied on SiÅs to manage all complications and maintenance on the system. Since these participants were not obligated to engage with the technicalities and preventative actions of the system as the users of Torvetua's system were, they shared rather optimistic opinions about future VTS development and use. In other words, the student participant population was more accepting of future VTS development and implementation of an Eco-San system. On the other hand, participants from Torvetua were found to be more knowledgeable of the vacuum system in the community; how to repair and prevent complications, how to engage in the technical aspects of the system. Overall, it was found that Torvetua's participants who were more involved with the functionality of the system based their perceptions on their experience. Whereas student participants generally responded from a standpoint of sustainability, particularly placing stress on water. Also, student participants were generally aware that the waste collected in the holding tank from the vacuum toilet system was used for research purposes at NMBU. This knowledge and understanding contribute towards the scarcity and shortcomings of sharing their opinions of the vacuum system. Residents of Torvetua were recognized as long-term and permanent inhabitants which is reflective in the enthusiasm and eagerness to share perspectives and experiences with the vacuum system.

When considering the acceptance of vacuum toilets, as any other technology, it often is assumed that if the technology works then it is an acceptable system. However, this is not the case. The acceptance of the users of these systems is crucial to the acceptance and compliance of new systems. Previous literature does not indicate user acceptance of vacuum toilets through practice and perception. This study addressed VTS user practices and perspectives to determine acceptance of vacuum system technology. The study concludes that the technical aspects and practices of the vacuum system are interdependent and are the key components that contribute to user acceptance of the system.

Chapter Seven: Conclusion and Recommendations

This research study sought to qualitatively explore the practice and perspectives of vacuum toilet system users to determine if vacuum toilet systems are a viable option for sustainable development in growing municipalities and communities. Drawing on insights from socio-hydrology contextualized the findings of this study for the acceptance of vacuum toilet systems among users for sustainable development. The study found that the vacuum toilet system was accepted among users in the study areas, however, compliance regarding practices was essential to a fully operational vacuum system. These included habits formed from previous extended use of water flush toilets which often resulted in blockages in the vacuum toilet systems as well as other technical and social aspects about vacuum toilet use. There was a clear connection between the users' practice of the vacuum system and the technical aspects of the vacuum system, including the complications and vacuum system blueprint. Noise from the vacuum toilet and smell from the holding tanks outside the residences were key factors of a lack of acceptance for the future development of vacuum toilet systems. This research study concludes that the relationship between technical aspects of the vacuum system and user practices was imperative to determine that the study populations were accepting of the vacuum toilet system in their residences.

This study did not aim to provide solutions to barriers and complications in vacuum toilet system use but rather focused on developing an understanding of what factors contribute to vacuum toilet system practice. These factors have been described by the participants and analyzed by the researcher in this study. The participants were restricted to current users of vacuum toilets. Additionally, the use of the two study populations, Kaja and Torvetua, broadened the understanding of vacuum system use by targeting student users residing in semi-private residences and users in family-living private residences. In addition to residency status, if working or student status was not included in the study population, the array of perspectives and experiences would not have contributed to developing a broader understanding of vacuum toilet system practice. Previous studies regarding user perspective and practices have been limited to lower and middle-income countries. Existing research in developed nations had been centered on future willingness or reservation for waterless or low-water toilet systems. This research addressed the practices and perceptions of vacuum toilet system users in a developed nation to

determine whether or not the vacuum toilet system is an acceptable sanitation system for Norwegian populations.

Technologies have been and can be improved for maximum efficiency. However, the technology is only as important as the user's willingness to accept and comply with adequate practice. Therefore, for sustainable development through the use and implementation of technologies, as the vacuum toilet system, a social science approach to understand the users' practice and perspectives are essential for the use of the system. Without user acceptance, the technology's potential is limited if not restricted. However, as previously mentioned, the vacuum toilet system in Torvetua was the first of terrestrial trials in Norway. The system blueprint and technical complications provide information for the future development of vacuum toilet systems in terrestrial communities. These technical aspects with the user experience provide a broader understanding of vacuum toilet system practice and acceptance in the study populations and, therefore, for the development acceptance of the vacuum toilet technology in the future. Additionally, since vacuum toilet systems are considered to be viable systems to implement Eco-San, understanding the user perspectives of the system is crucial for sustainable development in the future.

This study complements the existing knowledge and literature by exploring and expanding the scope of the literature on perspectives and practices of populations who had experiences with vacuum toilet systems. However, there are still many unanswered questions about the perspectives of users for future vacuum toilet system development. For maximum compliance and therefore better practice, users should be educated about the vacuum toilet system and as well of the technicalities concerning the functionality of the system. Measures to improve plumbing systems to vacuum toilet technology in newer residences and other technical problems and difficulties for the user will improve user acceptance and practice for a sustainable vacuum toilet system. Eliciting a positive user experience with the vacuum toilet system has the potential to increase the likelihood for greater acceptance of vacuum toilets in the future.

This research study was conducted in community populations with vacuum toilet technology dating over two decades old. Future research can focus on more recent toilet technology that has been implemented in a community to gain a better understanding of the Norwegian practice of vacuum toilet systems. Future studies should also broaden the participant scope to include seniors and gain perspective into practices of users under the age of majority.

Different climate environments may also be explored to understand the practices of vacuum toilet systems and the implications or benefits of use in different environmental settings for community populations. Most importantly, the relationship between technical aspects and system practices may be explored in different populations, settings, and with improved vacuum system technology.

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Appendices

Appendix A- NSD Approval

NSD NORSK SENTER FOR FORSKNINGSDATA

NSD's assessment

Project title

Norwegian Use of Vacuum Toilets and Perspectives on Ecological Sanitation

Reference number

756411

Registered

20.08.2020 av Amandeep Kaur Bhatti - amandeeb@uio.no

Data controller (institution responsible for the project)

Universitetet i Oslo / Det medisinske fakultet / Institutt for helse og samfunn

Project leader (academic employee/supervisor or PhD candidate)

Elia John Mmbaga, elia.mmbaga@medisin.uio.no, tlf: 4722850632

Type of project

Student project, Master's thesis

Contact information, student

Amandeep Bhatti, a.k.bhatti@studmed.uio.no, tlf: 4796706221

Project period

15.09.2020 - 31.05.2021

Status

27.08.2020 - Assessed

Assessment (1)

27.08.2020 - Assessed

Our assessment is that the processing of personal data in this project will comply with data protection legislation, so long as it is carried out in accordance with what is documented in the Notification Form and attachments, dated 27.08.2020, as well as in correspondence with NSD. Everything is in place for the processing to begin.

NOTIFY CHANGES
If you intend to make changes to the processing of personal data in this project it may be necessary to notify NSD. This is done by updating the information registered in the Notification Form. On our website we explain

which changes must be notified. Wait until you receive an answer from us before you carry out the changes.

TYPE OF DATA AND DURATION
The project will be processing general categories of personal data until 31.05.2021. data material with personal data will then be kept at the data controlling institution until 30.06.2021, due to examination.

LEGAL BASIS
The project will gain consent from data subjects to process their personal data. We find that consent will meet the necessary requirements under art. 4 (11) and 7, in that it will be a freely given, specific, informed and unambiguous statement or action, which will be documented and can be withdrawn. The legal basis for processing personal data is therefore consent given by the data subject, cf. the General Data Protection Regulation art. 6.1 a).

PRINCIPLES RELATING TO PROCESSING PERSONAL DATA
NSD finds that the planned processing of personal data will be in accordance with the principles under the General Data Protection Regulation regarding:

- lawfulness, fairness and transparency (art. 5.1 a), in that data subjects will receive sufficient information about the processing and will give their consent
- purpose limitation (art. 5.1 b), in that personal data will be collected for specified, explicit and legitimate purposes, and will not be processed for new, incompatible purposes
- data minimisation (art. 5.1 c), in that only personal data which are adequate, relevant and necessary for the purpose of the project will be processed
- storage limitation (art. 5.1 e), in that personal data will not be stored for longer than is necessary to fulfil the project's purpose

THE RIGHTS OF DATA SUBJECTS
Data subjects will have the following rights in this project: transparency (art. 12), information (art. 13), access (art. 15), rectification (art. 16), erasure (art. 17), restriction of processing (art. 18), notification (art. 19), data portability (art. 20). These rights apply so long as the data subject can be identified in the collected data.

NSD finds that the information that will be given to data subjects about the processing of their personal data will meet the legal requirements for form and content, cf. art. 12.1 and art. 13.

We remind you that if a data subject contacts you about their rights, the data controller has a duty to reply within a month.

FOLLOW YOUR INSTITUTION'S GUIDELINES
NSD presupposes that the project will meet the requirements of accuracy (art. 5.1 d), integrity and confidentiality (art. 5.1 f) and security (art. 32) when processing personal data.

To ensure that these requirements are met you must follow your institution's internal guidelines and/or consult with your institution (i.e. the institution responsible for the project).

FOLLOW-UP OF THE PROJECT
NSD will follow up the progress of the project at the planned end date in order to determine whether the processing of personal data has been concluded.

Good luck with the project!

Contact person at NSD: Tore Andre Kjetland Fjeldsbø
Data Protection Services for Research: +47 55 58 21 17 (press 1)

Appendix B- Recruitment Letter and Informed Consent Form (Kaja)

UiO : Institute of Health and Society
University of Oslo

Are you interested in taking part in the research project,

"Norwegian Use of Vacuum Toilets and Perspectives on Ecological Sanitation"?

This is an inquiry about participation in a research project where the main purpose is to explore the perspectives of residential vacuum toilet users in a Norwegian context. In this letter we will give you information about the purpose of the project and what your participation will involve.

This Informed Consent Form has two parts:

- **Information Sheet (to share information about the study with you)**
- **Certificate of Consent (for signatures if you choose to participate)**

Part I: Information Sheet

Purpose of the project

Environmental sustainability is a growing interest and concern for people and researchers across the globe. SiEU-Green is a European Union (EU) funded project aiming at developing and implementing sustainable technologies for a "greener" or environmentally friendly model. The project will increase food security, preserve and recycle many resources, and introduce energy efficient technologies. This research study will be conducted as a part of my master's thesis. The thesis will contribute to the SiEu-Green project by listening to your experiences and thoughts about the vacuum toilet system built in your home. Your thoughts and experiences will contribute to helping other researchers and engineers make changes to the existing technology for user satisfaction while ensuring environmental sustainability.

Who is responsible for the research project?

The University of Oslo and the Norwegian Institute of Bioeconomy Research (NIBIO) are the institutions responsible for this project.

Why are you being asked to participate?

You are invited to participate in this research because your experiences and knowledge of using vacuum toilets can contribute to our understanding of practical vacuum toilet system use. Your thoughts and experiences will also aid our researchers to develop and improve existing technologies. We are asking between 20-30 residents of the student dormitories in Ås, who are 18- 30 years old.

What does participation involve for you?

If you choose to take part in the project, this will involve your participation in an interview. The interview may take up to one hour of your time. It will include questions of your experiences with the vacuum toilet system in your residence as well as your perspectives on environmental sustainability. Your responses will be recorded electronically, and notes will be taken during the interview which will be deleted upon completion of the project.

Participation is voluntary

Participation in the project is voluntary. If you chose to participate, you may withdraw your consent at

any time without giving a reason. All the information collected from you will be deleted and will not be used in the project. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data

We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

The University of Oslo will have access to view your personal data; the electronic recording and transcription in the duration of reviewing my thesis. Elia Mmbaga and Atle Hegnes from the University of Oslo and the Norwegian Institute of Bioeconomy Research (NIBIO), respectively, will have access to your personal data through the duration of the project for supervision purposes.

The electronic recordings will be stored with password protection to ensure unauthorized persons are unable to access the collected data. I will replace your name with a code on the transcriptions which will also be stored electronically with password protection.

You as a participant will not be recognizable in publications. The age range, sex, and student status will be the only identifiers potentially mentioned in publications in addition to the dormitories of Ås being the community interviewed for this research.

What will happen to your personal data at the end of the research project?

The project is scheduled to end in June of 2021. Upon completion and approval of the thesis your personal data, including the electronic recording and transcriptions, will be permanently erased.

Your rights

As long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request to make changes to the collected data
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?

We will process your personal data based on your written consent. Based on an agreement with the University of Oslo and NSD (The Norwegian Centre for Research Data AS) has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?

If you have questions about the project, or want to exercise your rights, you may contact myself, my supervisors and NSD, respectively:

- Amandeep Kaur Bhatti, Master's student at University of Oslo a.k.bhatti@studmed.uio.no, phone: +47 96 70 62 21
- Dr. Atle Wehn Hegnes, Research Scientist at the Norwegian Institute of Bioeconomy Research Atle.hegnes@nibio.no, phone: + 47 92 89 03 19
- Dr. Elia John Mmbaga, Program Leader of International Health at the University of Oslo elia.mmbaga@medisin.uio.no, phone: +47 22 85 06 32

- NSD – The Norwegian Centre for Research Data AS, personverntjenester@nsd.no, phone: +47 55 58 21 17

Sincerely,

Amandeep Kaur Bhatti

Part II: Consent form

I have received and understood information about the project "Norwegian Use of Vacuum Toilets and Perspectives on Ecological Sanitation" and have been given the opportunity to ask questions. I give consent:

- ☐ to participate in an interview
- ☐ to be audio recoded during the interview
- ☐ for the information I share to be used in the project
- ☐ for the information I provide to be used in publications
- ☐ for my personal data to be stored until the project is completed

I give consent for my personal data to be processed until the end date of the project, approximately end of June, 2021.

Print Name of Participant _____

Signature of Participant _____

Date _____

dd/mm/yyyy

Appendix C- Recruitment Letter and Informed Consent Form (Torvetua)

UiO : Institute of Health and Society
University of Oslo

Are you interested in taking part in the research project,

"Norwegian Use of Vacuum Toilets and Perspectives on Ecological Sanitation"?

This is an inquiry about participation in a research project where the main purpose is to explore the perspectives of residential vacuum toilet users in a Norwegian context. In this letter we will give you information about the purpose of the project and what your participation will involve.

This Informed Consent Form has two parts:

- **Information Sheet (to share information about the study with you)**
- **Certificate of Consent (for signatures if you choose to participate)**

Part I: Information Sheet

Purpose of the project

Environmental sustainability is a growing interest and concern for people and researchers across the globe. SiEU-Green is a European Union (EU) funded project aiming at developing and implementing sustainable technologies for a "greener" or environmentally friendly model. The project will increase food security, preserve and recycle many resources, and introduce energy efficient technologies. This research study will be conducted as a part of my master's thesis. The thesis will contribute to the SiEu-Green project by listening to your experiences and thoughts about the vacuum toilet system built in your home. Your thoughts and experiences will contribute to helping other researchers and engineers make changes to the existing technology for user satisfaction while ensuring environmental sustainability.

Who is responsible for the research project?

The University of Oslo and the Norwegian Institute of Bioeconomy Research (NIBIO) are the institutions responsible for this project.

Why are you being asked to participate?

You are invited to participate in this research because your experiences and knowledge of using vacuum toilets can contribute to our understanding of practical vacuum toilet system use. Your thoughts and experiences will also aid our researchers to develop and improve existing technologies. We are asking between 20-30 residents of the Torvetua community who are 18 years of age and older.

What does participation involve for you?

If you choose to take part in the project, this will involve your participation in an interview. The interview may take up to one hour of your time. It will include questions of your experiences with

the vacuum toilet system in your residence as well as your perspectives on environmental sustainability. Your responses will be recorded electronically, and notes will be taken during the interview which will be deleted upon completion of the project.

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you may withdraw your consent at any time without giving a reason. All the information collected from you will be deleted and will not be used in the project. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data
We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

The University of Oslo will have access to view your personal data; the electronic recording and transcription in the duration of reviewing my thesis. Elia Mmbaga and Atle Hegnes from the University of Oslo and the Norwegian Institute of Bioeconomy Research (NIBIO), respectively, will have access to your personal data through the duration of the project for supervision purposes.

The electronic recordings will be stored with password protection to ensure unauthorized persons are unable to access the collected data. I will replace your name with a code on the transcriptions which will also be stored electronically with password protection.

You as a participant will not be recognizable in publications. Age groups and your sex will be the only identifiers potentially mentioned in publications in addition to Torvetua being the community where this research was conducted.

What will happen to your personal data at the end of the research project?
The project is scheduled to end in June of 2021. Upon completion and approval of the thesis your personal data, including the electronic recording and transcriptions, will be permanently erased.

Your rights
As long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your written consent. Based on an agreement with the University of Oslo and NSD (The Norwegian Centre for Research Data AS) has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?
If you have questions about the project, or want to exercise your rights, you may contact myself, my supervisors and NSD, respectively:

- Amandeep Kaur Bhatti, Master's student at University of Oslo
  a.k.bhatti@studmed.uio.no, phone: +47 96 70 62 21
- Dr. Atle Wehn Hegnes, Research Scientist at the Norwegian Institute of Bioeconomy Research
  Atle.hegnes@nibio.no, phone: + 47 92 89 03 19
- Dr. Elia John Mmbaga, Program Leader of International Health at the University of Oslo
  elia.mmbaga@medisin.uio.no, phone: +47 22 85 06 32
- NSD – The Norwegian Centre for Research Data AS,
  personverntjenester@nsd.no, phone: +47 55 58 21 17

Sincerely,

Amandeep Kaur Bhatti

Part II: Consent form

I have received and understood information about the project "Norwegian Use of Vacuum Toilets and Perspectives on Ecological Sanitation" and have been given the opportunity to ask questions. I give consent:

- ☐ to participate in an interview
- ☐ to be audio recoded during the interview
- ☐ for the information I share to be used in the project
- ☐ for the information I provide to be used in publications
- ☐ for my personal data to be stored until the project is completed

I give consent for my personal data to be processed until the end date of the project, approximately end of June, 2021.

Print Name of Participant _____

Signature of Participant _____

Date _____
dd/mm/yyyy

Appendix D- Pre- Interview Project Information and Verbal Consent

Hi, thank you for participating in this interview today for my master's thesis.

Before we begin the interview, I will take a moment to give you more detail about the project itself and how your time in this interview will contribute to it.

This project aims to develop an understanding of your experiences with the vacuum toilet system in your home/residence. The findings from this research will contribute towards the SiEUGreen project.

SiEuGreen is an EU-China cooperated project to promote agriculture for food security, resource efficiency, and building smart cities. Currently the project has 5 showcases; Fredrikstad hospital site, community gardens in Århus, Denmark, municipal area in Turkey and 2 urban community farms in Beijing and central China. Several researchers, scientists, engineers, social scientists, and innovators are working diligently to enhance or innovate new sustainable technologies in the showcases. An important part of this project is to re-visit technological systems previously in place, such as your vacuum toilet system.

With its low water volume and concentrated nutrient content, your vacuum toilet system could be a viable system to enhance and implement into some of the showcases. However, the adoption of such technologies should not be taken solely based on the premise of sustainability. The approval and acceptance of regular vacuum toilet system users is important due to the intimate nature of the technology. Therefore, we seek to understand how you feel and what you think about the vacuum toilet system in your home. The results of this study will help aid the future of SiEUGreen showcases and, hopefully, the future of sustainable cities.

This study is two-fold; members of the community of Torvetua and a student housing complex of the Norwegian University of Life Sciences in Ås will be interviewed.

The students' vs family communities will allow us to see and understand how different age groups and occupation (student/worker), generation/life stage understand the technology they use regularly. If it varies or is the same in order to determine the bigger picture of the Norwegian context and Norwegian perspectives to particular waste systems.

Now before we begin, there are a few housekeeping points I would like to share with you.

1. This interview is being recorded. The recording will be transcribed and analyzed; your identity will be kept confidential. Only my supervisor, Dr. Atle Hegnes, and I will have access to the recording. Do you agree to participate in this interview? (wait for verbal acknowledgement from participant)

2. There are no correct answers to these questions. If you are uncomfortable or do not want to answer a question, please let me know and we will move onto the next question.

3. This interview will take approximately half an hour, but do not feel rushed if you need more time.

Please feel free to stop me to comment, clarify, or asks questions. Do you have any questions?

Appendix E- Interview Guide

This research study aims to develop an understanding of vacuum toilet system users' acceptance and compliance of the sanitation system based on their experiences. This interview guide was used to direct the in-depth interview without leading the participant. Therefore, this guide is thematically structured and comprised of open-ended questions for the participant to share what they deem important and relevant without diverting from the aims of the research topic.
A number of probes were utilized during each interview to encourage deeper discussion, many of which are shared below. The language differed in each interview from what is presented in this guide. Additionally, some questions were disregarded after a few interviews were conducted based on the decision that some questions were not providing fulfilling responses or provided little data for the research question. This guide was not always followed in a linear fashion due to the nature of in-depth interviews.

Question 1: Tell me about the vacuum toilet system in your home.

Prompt: How many people live in this residence/use the vacuum toilets?

Prompt: How long have you been a user of vacuum toilets? Have you used conventional flush toilets in the past?

Prompt: Tell me about your satisfaction with the look, odour, and seating comfort of your vacuum toilet.

Prompt: How would you compare the look, odour and seating comfort of your vacuum toilet with that of a conventional flush toilet? Which toilet do you prefer and why?

Question 2: Are there particular aspects of your vacuum toilet system you would like to discuss?

Prompt: Have you had to address maintenance related aspects with your toilet?

Prompt: Has cleaning and maintaining your vacuum toilet been more, less or the same amount of work than you imagined it would be?

Prompt: Why or why not is the maintenance of this toilet system to your expectation and satisfaction?

~~**Question 3: What do you think about the concept of "environmental sustainability"?**~~

~~Prompt: Describe your daily practices and actions in relation to the environment. How do you handle and use natural resources such as food and water?~~

~~Prompt: Which of these actions do you consider to be sustainable behaviours? How often do you engage in these?~~

~~Prompt: What is your perspective on the possibility of a natural water shortage in the future for yourself and/or future generations?~~

Question 4: What do you think of when you hear "ecological sanitation"?

Prompt: Are you familiar with the concept of "ecological sanitation"? Could you explain it briefly? (Explain to them if they do not know)

Prompt: What do you think about sanitation systems that takes toilet water waste and composts it into a fertilizer?

Prompt: Why do you feel this particular way? (reasons for feeling this way?)

Question 5: Would you use fertilizer which is a commercial product of such a sanitation system?

Prompt: How do you feel about the use of such a fertilizer?

Prompt: Do you think such a sanitation system should be used in industrial settings and the public sector? (community gardens, government buildings, public parks)

Prompt: Would you purchase fruits and vegetables that were grown using fertilizer from these systems?

Question 6: Would you use fertilizers made from this kind of a sanitation system in your private residence/home?

Prompt: What do you think about a system where your vacuum toilet could make fertilizer for use in your garden? Why do you feel this way?

Prompt: To what extent would you personally use the fertilizer of such a sanitation system? (Eg. Only for plants versus growing fruits and vegetables for personal consumption)

Prompt: Would you spend less time, the same amount of time, or more time gardening or attending to yard work with the fertilizer?

Question 7: Do you believe vacuum toilet systems should or should not be used in urban areas? Why?

Prompt: Why or why not are larger towns and cities equipped to deal with such sanitation systems?

Prompt: What benefits and problems do you see with widespread use of vacuum toilets in cities?
Prompt: Do you think vacuum toilet systems which strive for Eco-San should or shouldn't be used in private residences?

Question 8: What do you think about the idea of using ecological sanitation in sanitation systems? Specifically, vacuum toilet systems?

Prompt: Would such a sanitation system affect your community in any way? How so?

Question 9: If you were moving into or looking for a new home, would a vacuum toilet system play a big factor in your decision? (newer question)

Question 10: Is there anything else you would like to share with me that has not been covered?