

Practical Paper

Stakeholder perceptions, challenges, and sustainable solutions for achieving safely managed sanitation in Kazakhstan: a case study from a cold region

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ABSTRACT

In this paper, we present survey results from 30 sanitation stakeholders across the public and private sectors, professional associations, non-governmental organisations (NGOs), and households in the two coldest cities of Kazakhstan. The objectives were to identify the perceived sanitation challenges, document innovative, and traditional solutions employed by the stakeholders to manage sanitation challenges during the cold season, and to propose initiatives and policy interventions to alleviate pressing sanitation issues. Commonly encountered problems included improper installation of septic tanks (e.g. above the frost line) by non-professionals and the difficulty of households to access latrines during heavy snowfall events. Ninety-three percent of respondents expressed that foul odours and sewage overflows were their primary concerns, with only 7% reporting health impacts as a primary concern. There were significant differences in the viewpoints of the respondents regarding the extent of sanitation infrastructure maintenance or upgrades needed in the two cities, suggesting regional differences across the country rather than a uniform national situation. In the context of Kazakhstan, local NGOs were identified as playing a key role in engaging with households to co-devise affordable and sustainable sanitation solutions that are suitable for cold regions, which can then be communicated to other sanitation stakeholders, including the public sector.

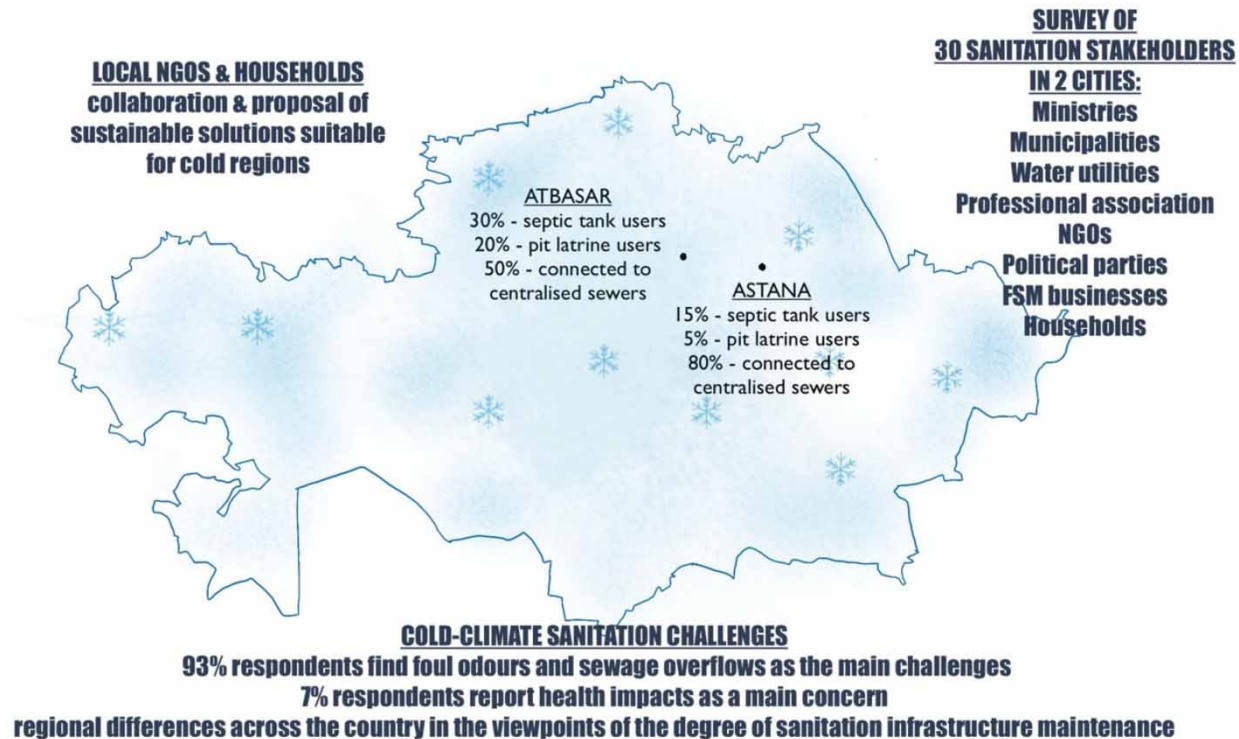
Key words: cold climate, Kazakhstan, SDG 6, sanitation, sanitation stakeholders, sustainability

HIGHLIGHTS

- The research identifies and articulates the key challenges in implementing sanitation solutions in the cold regions of Kazakhstan.
- Municipal authorities are recommended to work closely with NGOs and households to mitigate health and environmental risks and promote safely managed sanitation.
- The study can be informative for sanitation management and stakeholder engagement in other cold climate locations globally.

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GRAPHICAL ABSTRACT



INTRODUCTION

The United Nations' Sustainable Development Goal (SDG) 6 commits countries to provide safe water and sanitation for all by 2030 (United Nations 2015). SDG-aligned sanitation ensures universal adequate access to sanitation services (SDG indicator 6.2.1a), safe human waste disposal (SDG 6.2.1a), proper wastewater management (SDG 6.3.1), and the prevention of open defaecation (SDG 6.2) (United Nations 2015). The provision of access to clean water and improved sanitation is directly linked to good health and well-being (Garriga & Foguet 2013). Despite efforts to achieve the set targets, global progress needs to be quadrupled to reach the sanitation goal by 2030 (United Nations 2021). Cold regions face special challenges in meeting SDG6, many of which are distinct from the challenges faced in tropical regions, where the vast majority of sanitation research is focused.

Leblanc *et al.* (2019) define a *cold region* as a region where the average monthly temperature falls below 1 degree Celsius for at least one month a year. Accordingly, over 2.65 billion people, or around 30% of the world's population, live in cold regions and could potentially be affected by such cold weather challenges as frozen sanitation infrastructure, limited access to sanitation facilities, and impermeable soil (Leblanc *et al.* 2019; World Bank 2022, 2023). At sub-zero temperatures, the rate of aerobic and anaerobic biological processes responsible for faecal sludge degradation slows significantly, and the frozen ground becomes largely impermeable, leading to increased sludge accumulation in pits, tanks, and pipes (Buttle & Smith 2004).

In Arctic regions, the situation is further exacerbated by the high capital and operational costs associated with centralised water supply and sewer systems, which often suffer from long-term failures due to ageing and defective infrastructure not adapted to these extreme climatic conditions (Jensen *et al.* 2018). During the warmer seasons, the expansion of thawing ice and water can cause soil movement, resulting in damage to pipes, pits, and tanks, as well as sewage overflows (Leblanc *et al.* 2017). Additionally, snow blizzards and intermittent water supply have been reported to contribute to water shortages, leading to follow-on sanitation and hygiene challenges in Arctic communities (Daley *et al.* 2014).

In areas near the world's coldest capital, Ulan Baatar, Mongolia, 750,000 people rely on unimproved sanitation facilities that are unhygienic, and, although many households are willing to improve their sanitation conditions, they often lack the necessary resources and guidance to do so properly in cold climates (Leblanc *et al.* 2017). These widespread

challenges not only pose significant health and environmental risks but also undermine the efforts of cold regions to achieve SDG6.

The challenges in cold regions vary depending on the type of sanitation system employed. For instance, users of pit latrines, which are often situated outside the home, face significant challenges during the winter months. The paths leading to these facilities, as well as the surfaces of the latrine slabs within, can become dangerously slippery, hindering access and increasing the risk of accidents, particularly among vulnerable populations such as the elderly, disabled, or children.

In moderately cold climates, characterised by winter temperatures that lead to soil freezing to a depth of 1 m or less, conventional septic tanks are among the most commonly used on-site sanitation facilities (Leblanc *et al.* 2019). These systems typically consist of one or two chambers separated by a dividing wall, two manholes, and two vents, followed by a drain field for further treatment of the effluent (Nadi *et al.* 2017). The effectiveness of septic tanks is influenced by factors such as their condition, maintenance practices, the number of users, and the presence of greywater (e.g. laundry, bathing water), all of which directly affect the quality of the effluent and its environmental impact (Richards *et al.* 2016).

Households in high-income cold regions such as the United States, the United Kingdom, and the Republic of Ireland face significant problems with septic tank systems, which often fail to operate properly due to the absence of ongoing routine maintenance after installation (Withers *et al.* 2014). These issues are further exacerbated in low-income settings, where economic constraints limit access to professional installation services. As a result, many households attempt to install septic tanks themselves, often without considering critical factors such as the frost line – the depth to which the ground freezes during winter – which is crucial to prevent the system from freezing, ensure continuous waste decomposition, and avoid structural damage from freeze–thaw cycles. Additionally, common mistakes, such as inadequate insulation of the tank and pipes and incorrect siting of the drain field, can reduce infiltration efficiency in the drain field, causing the septic tank to fill more rapidly, necessitating more frequent emptying, and increasing the risk of overflows.

This study involved a survey conducted with 30 sanitation stakeholders in the two coldest cities of Kazakhstan. The survey aimed to identify specific sanitation challenges from their first-hand experience, capture innovative and traditional methods to address them during the cold season, and suggest measures to mitigate prevalent sanitation issues in cold regions. To our knowledge, this is the first time such a survey has been conducted in Kazakhstan. Our intention is that the results of the survey will be useful for practitioners and directly actionable by policymakers, municipal authorities, non-governmental organisations (NGOs), and infrastructure developers involved in implementing sustainable sanitation management strategies in such settings.

METHODS

Study setting

Kazakhstan (Republic of Kazakhstan), a Central Asian country located in the northern hemisphere, with a territory of 2.72 million kilometres, is the world's ninth-largest country by land, and with a population of 20 million people, has one of the world's lowest population densities (OECD 2016; Bureau of National Statistics 2023). The climate of the country includes arid, extremely cold winters and hot summers (Sinor *et al.* 2023). Temperatures fluctuate widely, on average from -48 to -42 °C in the north and from -5 to -1 °C in the south in January, and from 19 to 23 °C in the north and from 40 to 45 °C in the south in July (Kazhydromet 2023a; Sinor *et al.* 2023). According to WHO/UNICEF JMP (2022), 54% (10.72 million people) of the population of Kazakhstan use pit latrines, 9% (1.72 million people) – septic tanks, and the rest, 37% (7.52 million people), are connected to centralised sewers.

This study was conducted in two northern cities of Kazakhstan: Astana and Atbasar; the latter is located in the Akmola region 263 km away from Astana (Kazhydromet 2023b; Sinor *et al.* 2023) (Figure 1). The air temperature in the Akmola region can drop below -49 °C in the winter and rise to 42 °C in the summer (Kazhydromet 2023b). Astana, with a population of 1.3 million, is the world's second coldest capital (Grjibovski *et al.* 2012; Sinor *et al.* 2023). Atbasar, with a population of 34,000, holds Kazakhstan's record absolute minimum of -52 °C in the winter (Britannica 2009; Kazhydromet 2023b).

Sanitation systems in Kazakhstan

Approximately 15% of Astana and 30% of Atbasar residents use what they call 'septic tanks' (though, as will be discussed below, some of these may only be faecal sludge storage tanks rather than true septic tanks), 5 and 20% pit latrines, respectively, and the rest, 80 and 50%, respectively, are connected to centralised sewers (2GIS Mapping System 2023; Water Utility

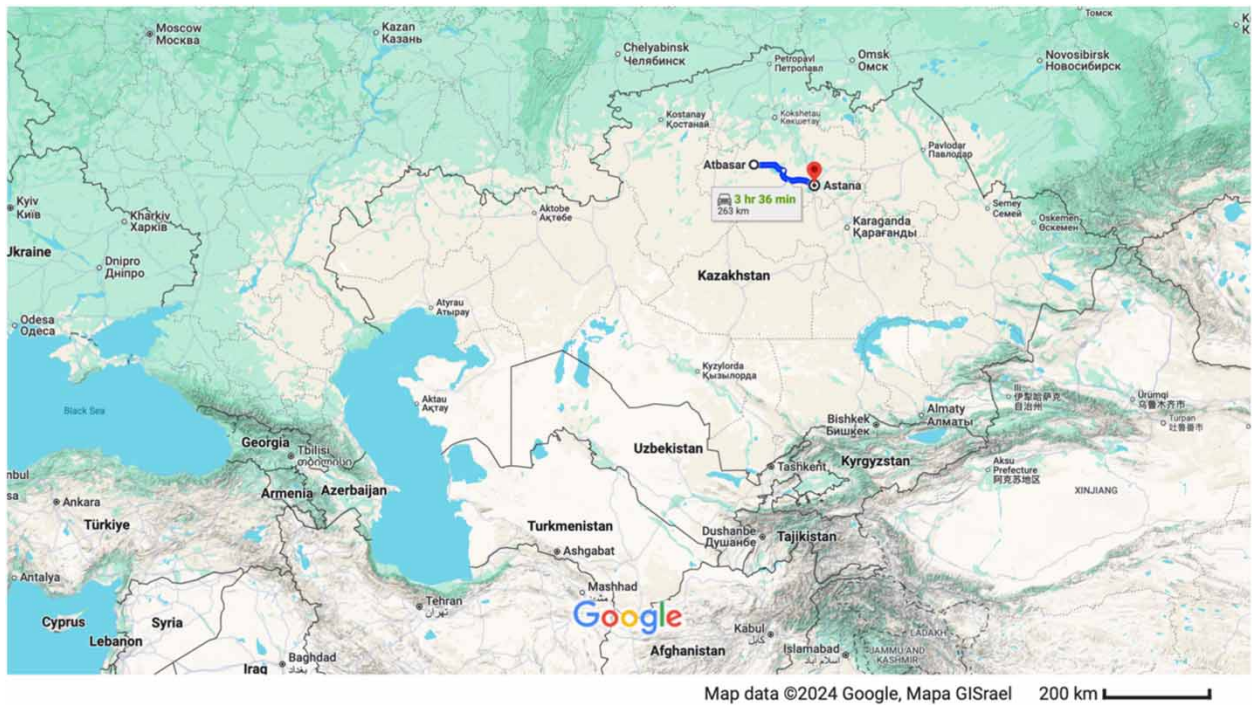


Figure 1 | Geographic illustration of the surveyed cities. *Source: Google Maps 2023.*

of Astana 2023; Water Utility of Atbasar 2023). If not connected to centralised sewers, most residents of both cities use concrete or polyethylene septic tanks or pit latrines with the slab and superstructure usually made of wood.

Survey design and execution

This study has obtained the approval from the Research Governance and Integrity Team (RGIT) and favourable opinion from the Science, Engineering and Technology Research Ethics Committee of Imperial College London (SETREC reference #6417731).

The survey was conducted in 2023 among sanitation stakeholders to explore their perspectives on the challenges faced in achieving SDG6 related to sanitation in a country with a cold climate. Based on the availability and preference of the stakeholders, 50% of the respondents were interviewed face-to-face and 50% filled out the questionnaire separately and submitted it later. Several questions in the survey were designed to qualitatively assess the respondents' perceptions of the sanitation situation in their city. Open-ended questions were also included to allow respondents to elaborate on their survey responses and discuss their additional concerns or suggestions. The full survey questionnaire can be found in Supplementary material.

In Kazakhstan, several government agencies are responsible for the water, sanitation, and hygiene sectors. Table 1 lists the main sanitation stakeholders by entity. The survey was conducted anonymously with 30 stakeholders. No personal identifiers such as respondents' names, addresses, or any other information that can directly or indirectly reveal their identity has been collected during the survey. Fifty percent of the respondents were residents of Astana and 50% of the respondents were residents of Atbasar. Fifty-three percent of the respondents were female. The respondents were in the age range of 24–68 years old: 13% of the respondents were between 24 and 30 years old, 27% between 31 and 40 years old, 30% between 41 and 50 years old, 20% between 51 and 60 years old, and 10% of the respondents were between 61 and 68 years old. The stakeholders included representatives from government agencies, political parties, NGOs, water utilities, the private sector, professional associations, and households (Table 1). All surveyed households lived in houses that are not connected to centralised sewer systems. The areas not connected to centralised sewer systems in Astana and Atbasar were provided by local utilities. Each household was assigned a unique sequential number. Five households in Astana and 10 households in Atbasar were selected using a random number generator.

Table 1 | Characteristics of the categories of the main sanitation stakeholders

Stakeholders	Main responsibilities	Number of respondents (n = 30)	
		Astana (n = 15)	Atbasar (n = 15)
Ministry of Water Resources and Irrigation	<ul style="list-style-type: none"> Development and enforcement of regulations and standards related to the use and protection of the water fund, water supply, sanitation, and irrigation. 	1	–
Ministry of Ecology and Natural Resources (Committee for Environmental Regulation and Control)	<ul style="list-style-type: none"> Monitoring compliance with environmental regulations related to water and sanitation. 	1	–
Ministry of Industry and Infrastructure Development (Committee for Construction and Housing and Communal Services)	<ul style="list-style-type: none"> Oversight of the public utilities Coordination, monitoring, and analysis of water and sanitation provision. 	1	–
Municipal authorities	<ul style="list-style-type: none"> Oversight of the publicly owned water utilities. 	1	1
Water utilities	<ul style="list-style-type: none"> Collection and management of sanitation fees Water and wastewater management Provision of centralised water and sanitation services Faecal sludge collection and management from onsite sanitation facilities. 	1	1
Association of enterprises for water supply and sanitation	<ul style="list-style-type: none"> Capacity building in water utilities Uphold the rights of water utilities. 	1	–
NGOs	<ul style="list-style-type: none"> Support environment-related initiatives (incl. sanitation and wastewater management) Raise public awareness regarding environmental issues. 	1	2
Political parties	<ul style="list-style-type: none"> Raise awareness of the water and sanitation-related problems Provide recommendations on the government legislature. 	2	–
Small-scale faecal sludge management businesses	<ul style="list-style-type: none"> Provide water and sanitation-related services (transport, collection, installation of onsite sanitation facilities, etc.). 	1	1
Households	<ul style="list-style-type: none"> Provision of timely payments for water and sanitation services Manage water resources and sanitation responsibly. 	5	10

RESULTS AND DISCUSSION

Stakeholder perceptions

The survey revealed that 20 out of 30 respondents were aware of SDG6 and had heard about national initiatives to achieve the SDGs by 2030. All respondents showed awareness of the sanitation problems related to cold weather conditions. Interestingly, the political party, NGO, private sector, and household representatives in both cities were more inclined to discuss the existing sanitation challenges than the public authorities. They expressed concerns about restricted access to adequate wastewater treatment, particularly in Atbasar, where the wastewater treatment plant fails to operate properly during the cold season due to the urgent need for renovation. A representative of a non-governmental political party highlighted the widespread issues with malfunctioning wastewater treatment facilities across the country, especially during the winter.

In terms of infrastructure reliability, 77% of respondents expressed concerns about the non-functional water infrastructure, noting that it could fail at any moment, particularly due to pipe bursts, which would directly impact sanitation facilities that rely on water for flushing (e.g. septic tanks). As one public sector representative put it, *'We just hope the pipes will not burst and get frozen during this year's winter season'*, reflecting the interconnected nature of water and sanitation infrastructure and the potential for cascading failures in these services.

Regarding on-site sanitation facilities, only two respondents evaluated their facilities as unsafe throughout the year, but 10 reported that cold weather limits their access to adequately functioning sanitation facilities. Pit latrines were

noted to be significantly impacted by the frost line, which can extend to depths of 1.5 to 2 metres or more, impeding the biological decomposition of faecal sludge and exfiltration of liquid from the pit into the surrounding soil. To manage slippery paths leading to pit latrines, households have employed various strategies, such as regularly shovelling snow, spreading sand, or installing temporary walkways made from materials that provide better traction. However, these measures are often insufficient, especially during heavy snowfalls or rapid temperature fluctuations that cause ice to form quickly.

The performance of septic tanks was also a significant concern among stakeholders in both cities. Many respondents observed a more frequent need to empty septic tanks during the cold season, with households in low-income neighbourhoods particularly affected. Due to economic constraints, these households often resort to installing single-compartment ring concrete septic tanks themselves, as they cannot afford more effective two-compartment systems made of concrete, high-density polyethylene (HDPE), or fibreglass. The survey found that in three households in Astana and seven in Atbasar, residents purchased concrete rings and installed septic tanks and drain fields themselves without hiring professional assistance. This lack of professional installation is particularly problematic in cold climates, where understanding the frost line and subsoil conditions is crucial for proper system function (Keegan *et al.* 2014). Such simple single-compartment 'septic tanks', unlike conventional two-compartment septic tanks, do not provide as effective separation of solids and liquids (Wanassen 2003). As a result, these tanks often function more like holding tanks than true septic systems, where solids can accumulate more quickly, leading to frequent solids overflows.

The condition of on-site sanitation facilities varies not only based on the quality of the initial installation but also on how well and frequently they are maintained. While professional installation is essential for setting up a functional system, ongoing maintenance, such as regular inspections and septic tank emptying, is critical to ensuring that the septic tanks and drain fields continue to operate effectively (Withers *et al.* 2014). Neglecting maintenance or conducting it improperly can lead to system degradation over time, resulting in overflows (i.e. wastewater escaping from the system into the environment) and backups (i.e. wastewater flowing back into the house).

Overall, the respondents demonstrated a general awareness of existing sanitation challenges related to cold climates (Table 2). Although only 7% of the households identified potential pathogen contamination of surrounding soil and groundwater as a major public health and environmental threat during the cold season, this concern is not unfounded. Beisenova *et al.* (2021) recently associated the presence of fungi and coliform bacteria in all groundwater samples taken 400 km south of Astana with poorly constructed septic tanks and open landfills. Contrary to the relatively low concern for health risks among respondents, 93% of the households cited foul odour and sewage overflows during the cold season as the primary reasons why sanitation facilities must be adequately managed.

The survey also identified that NGOs play a crucial role in improving sanitation infrastructure and practices, particularly in regions with challenging environmental conditions such as the cold climate of Kazakhstan. One respondent working for an NGO reported that their organisation has overseen the construction and maintenance of 10 public toilets in the surveyed cities. These toilets are strategically located in areas with high foot traffic, such as markets and parks. These public toilets face similar challenges to those reported by households. In addition to managing public toilets, the NGOs have provided

Table 2 | Stakeholder perceptions regarding the sanitation situation in the northern region of Kazakhstan

Stakeholder perceptions	Yes (%)
Are you aware of sanitation problems related to cold weather conditions?	100
Have you heard about the SDG 6?	67
Do you think your sanitation problems are addressed at the government level?	63
Is your sanitation facility connected to centralised wastewater treatment facilities?	50
Does your household have any problems with the operation and maintenance of existing sanitation infrastructure?	33
Do you have limited access to safe sanitation during the cold season? ^a	33
Do you have limited access to safe sanitation during all seasons? ^a	7

^aThe term 'limited access' is used to describe how people found it harder to physically access the latrines in the cold season than in the warm season (e.g. because of ice, snow, etc.).

technical feedback to households on the design of their onsite sanitation facilities. This guidance has focused on ensuring proper insulation and advising on the appropriate depth for installing these facilities to avoid frost line issues. Thus, NGOs often bridge the gap between households and professional services, offering critical support and expertise that many households might otherwise lack.

Challenges and barriers

All respondents identified specific sanitation challenges and barriers related to the cold weather conditions, aligning partially with the findings of [Jensen *et al.* \(2018\)](#). The primary challenges reported by users of onsite sanitation systems in cold climates were:

1. Slippery or icy paths leading to the onsite sanitation facility ([Figure 2](#)).
2. Difficulty in emptying septic tanks and pit latrines due to the frozen crust formed inside ([Figure 3](#)).
3. Freezing of septic tank manholes and pit latrine slabs ([Figure 4](#)).
4. Freezing of pipes.
5. Septic tank overflow and sewage backups.

These challenges highlight the complex, interrelated issues that households with decentralised sanitation systems face in cold climates. Addressing these barriers and challenges requires a comprehensive approach, including improvements in system design, enhanced maintenance practices, and better guidance and support for households to manage their sanitation systems effectively during the winter months.

[Table 3](#) presents the participants' responses to the survey question: *'What challenges and barriers do you consider the most important in achieving safe sanitation in the cold climate environment?'* All survey participants unanimously agreed that *'Understanding the importance of sanitation issues and their impact on drinking water quality and the environment'* is



Figure 2 | A slippery path leading to the onsite sanitation facility in Astana.



Figure 3 | Crust formed inside the septic tank.

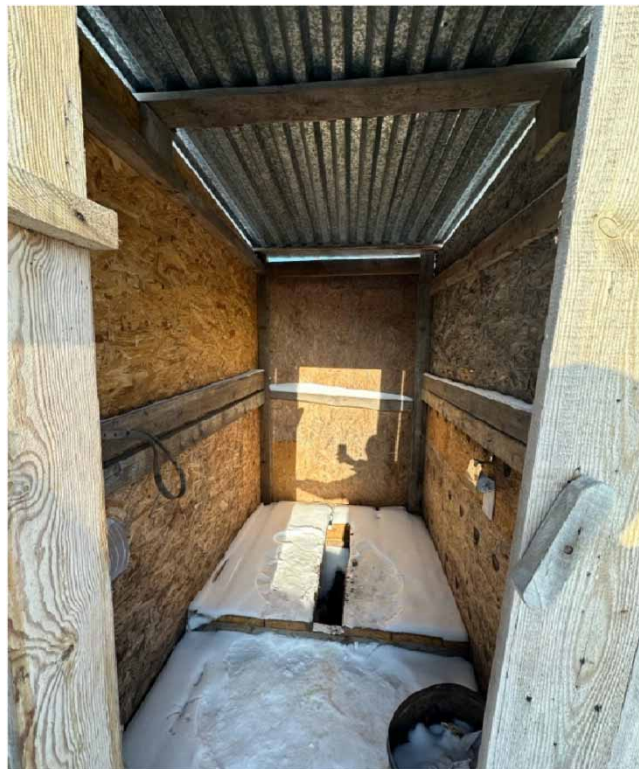


Figure 4 | A common pit latrine scene in wintertime.

Table 3 | Survey results on the sanitation challenges and barriers in cold regions of Kazakhstan

Barriers and challenges	Agree (n = 30)	%
Understanding the importance of sanitation issues and their impact on drinking water quality and the environment	30	100
Limited political support	15	50
Limited public awareness	15	50
Limited financial support	15	50
Availability of sanitation experts	14	47
Coordination of sanitation issues among stakeholders	13	43

one of the main barriers. One of them noted, *'Unfortunately, not all stakeholders understand the existing connection. If everyone had understood the importance of the bad sanitation consequences, the sanitation issues would have been solved long ago.'*

The survey revealed differing opinions on the primary barriers to achieving safe sanitation in Kazakhstan. While half of the participants identified limited political and financial support as the primary obstacle, the other half of the respondents considered limited public awareness as a more significant sanitation barrier than funding. Additionally, 13 out of 30 respondents pointed to the challenge of coordinating sanitation issues among stakeholders, indicating significant collaboration gaps within the sanitation management sector and a lack of consensus on the way forward. NGOs indicated a willingness to assist the government in monitoring the environmental impact of on-site sanitation facilities; however, they emphasised that this role would require additional funding and the delegation of certain powers to be effective.

Sustainable solutions

The proposed sustainable solutions differed for on-site and centralised (sewer-connected) sanitation infrastructure users. The public sector representatives indicated heated public restrooms and insulated water and wastewater pipes as the existing state projects that address the cold weather challenges in the sanitation management sector. The households and NGOs shared several successful cases when they worked jointly on addressing the maintenance challenges of onsite sanitation facilities in the cold season. After holding regular meetings that were documented on the NGOs' social media platforms, the NGOs together with the households have been able to propose sustainable solutions to the current cold weather sanitation problems of the on-site sanitation facilities. *'If we want safe sanitation, we need to look for sustainable solutions on our own,'* said one of the NGO representatives. Proposed solutions included:

- Emptying of tanks before the start of the cold season.
- Proper insulation of sanitation components (pipes, tanks, and superstructures) with, for example, felt or fibreglass.
- Use of durable materials that can withstand low temperatures to construct septic tanks (e.g., HDPE) (Figure 5).
- Installation of septic tanks below the frost line.
- Building a roof between the sanitation facility and house to keep the path clear from ice and snow.
- Having a cleared pit latrine ready for the cold season in case the septic tank fails to work properly.

Overall, the respondents showed general awareness of the sanitation problems in the two coldest cities of Kazakhstan. The following proposed solutions can potentially be successful and lead to safely managed sanitation:

- Emptying of tanks before the start of the cold season can potentially reduce the risks of sewage overflows due to a slower expected rate of microbiological processes during the cold season. This proposal is in line with the general practice of septic tanks maintenance in Finland, Sweden, and Norway (Laukka *et al.* 2022).
- Installing septic tanks below the frost line is aimed to help prevent freezing of the tank contents and the associated pipes, which in turn will help prevent blockages and system failures. Our survey showed that in low-income settings, septic tanks are often not buried deep enough to reduce installation cost.
- Insulation of pipes could potentially help reduce the number of cases of damages of pipes. Additionally, the use of HDPE pipes can better withstand extreme low temperatures and ground movements during frost heave (Agarwal & Gupta 2017; Nguyen *et al.* 2021).



Figure 5 | Opened first compartment of an HDPE septic tank. The photograph was taken at -27 degrees Celsius.

It is noteworthy that, although the study identifies that one of the key issues is that some so-called ‘septic tanks’ are not double-chambered, and, as a result, do not function as true septic tanks, none of the respondents proposed improved septic tank design as a potential solution. This omission likely reflects a limited understanding among respondents of the technical aspects of septic tank systems. While the inclusion of this issue in the list of proposed solutions is not suggested, it is important to acknowledge the absence of this critical consideration in their responses.

In summary, the survey revealed several sanitation challenges faced by households, including frequent septic tank overflows and sewage backups. Further investigation revealed that these problems are often linked to poor design and installation practices. While the survey identified the symptoms, follow-up inquiries and a review of current local practices highlighted that many households fail to adhere to fundamental standards for installing on-site sanitation facilities. These standards include ensuring that they are sited below the frost line, are appropriately sized to handle the household’s waste, and are constructed from materials capable of withstanding the harsh conditions of cold climates. Moreover, professional installation is essential to ensure the correct and sustainable functioning of these systems (Withers *et al.* 2014).

NGOs have made significant progress in addressing these sanitation challenges in cold climates; however, the effectiveness and sustainability of their initiatives are sometimes hampered by limited resources and insufficient coordination with local governments. To increase their impact, NGOs need to secure additional funding, strengthen their technical expertise, and strengthen partnerships with government agencies. These measures would ensure that their interventions are sustainable and scalable, contributing to long-term sanitation solutions in these regions. A collaborative approach that integrates NGO efforts with government oversight is essential for overcoming systemic barriers, ensuring all communities have access to safe and reliable sanitation services.

Participants from NGOs, along with public and private sector representatives, also highlighted the need to improve the monitoring of groundwater quality and the on-site sanitation facilities. They have emphasised that the understaffing of environmental monitoring government agencies leads to the neglect of monitoring of the environmental impact of pit latrines

and septic tanks. To address this, it is recommended that municipal authorities organise collaborative training programmes to build capacity among sanitation professionals across sectors. Research suggests that closer collaboration with local NGOs, who are well-connected to local communities, can enhance the effectiveness of sanitation projects (Pathak 1996; Thye *et al.* 2015).

Study limitations

During the development and administration of the survey, the term ‘ageing’ was used in one of the questions to describe the state of sanitation infrastructure. Upon reflection after the survey, it became apparent that this term might have been too broad or potentially misleading, as it could imply general deterioration due to age rather than specific functionality issues. Additionally, translation issues may have further compounded this ambiguity, as the term ‘ageing’ might have been interpreted differently across languages (in our survey – Kazakh, Russian, and English), leading to varied understandings among respondents. To more accurately describe the conditions observed, we have used the term ‘non-functional’ in parts of the paper where infrastructure failures were clearly due to immediate operational problems, such as breakdowns or blockages rather than simply age-related wear and tear. However, we recognise that this distinction was not made clear in the original survey, which represents a limitation of the study.

CONCLUSIONS

Our survey revealed the common cold weather-related on-site sanitation challenges facing households in two cities in Kazakhstan, some of which are due to improper design and poor installation by households. It was found that NGOs often play a key role in supporting households to cope with on-site sanitation difficulties during the cold season, with specific examples of adaptation strategies identified. Wider dissemination of knowledge and lessons learned to all stakeholders is needed in Kazakhstan to promote broader stakeholder collaboration in addressing these challenges.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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