आवासन और शहरी कार्य मंत्रालय
भारत सरकार
MINISTRY OF HOUSING AND
URBAN AFFAIRS
GOVERNMENT OF INDIA

स्वच्छ भारत
एक कदम स्वच्छता की ओर

Swachh Bharat Mission – Urban 2.0

ADVISORY ON

OPTIONS FOR ONSITE SANITATION IN COLDER REGIONS

Central Public Health and Environmental Engineering Organization (CPHEEO)

MINISTRY OF HOUSING & URBAN AFFAIRS

Government of India

www.sbmurban.org | December 2025

आवासन और शहरी कार्य मंत्रालय
भारत सरकार
MINISTRY OF HOUSING AND
URBAN AFFAIRS
GOVERNMENT OF INDIA

स्वच्छ भारत
एक कदम स्वच्छता की ओर

Swachh Bharat Mission- Urban 2.0

Advisory

on

Options for Onsite Sanitation in Colder Regions

Central Public Health and Environmental Engineering Organization (CPHEEO)

Ministry of Housing & Urban Affairs

Government of India

www.sbmurban.org | December 2025

श्रीनिवास कटिकिथाला, भा.प्र.से.
सचिव
Srinivas Katikithala, I.A.S.
Secretary

सत्यमेव जयते

स्वच्छ भारत
एक कदम स्वच्छता की ओर

भारत सरकार
आवासन और शहरी कार्य मंत्रालय
संकल्प भवन, नई दिल्ली-110001
Government of India
Ministry of Housing and Urban Affairs
Sankalp Bhawan, New Delhi-110001

Foreword

India's colder and high-altitude regions including the Himalayan states and Union Territories present unique challenges for ensuring safe, reliable, and sustainable sanitation services. Extended winters, freezing temperatures, difficult terrain, and limited water availability often hinder the performance of conventional sewage treatment systems. Under the vision of Swachh Bharat Mission-Urban 2.0, the Ministry of Housing & Urban Affairs is committed to addressing these challenges through context appropriate, climate-resilient, and technologically sound solutions.

This Advisory on **"Options for Onsite Sanitation in Colder Regions"** has been developed to support State Governments, Urban Local Bodies, engineering departments, and practitioners working in cold impacted regions. It consolidates proven approaches, emerging technologies, and global best practices relevant to Indian conditions.

The Advisory emphasizes the importance of sustainable planning, resilient infrastructure, and climate adaptive technologies to ensure uninterrupted sanitation service delivery. It also highlights the role of simple innovations, careful system design, microbial augmentation, adequate insulation, and steady operation and maintenance practices that enable communities in colder regions to manage sanitation efficiently throughout the year.

I appreciate the efforts of CPHEEO and the Technical Support Unit of RITES under SBM-Urban 2.0. I am hopeful that this Advisory will serve as a valuable resource for all stakeholders and will further strengthen our collective mission to ensure safe sanitation for every citizen, regardless of geography or climate.

(Srinivas Katikithala)

New Delhi
December 2025

Office Address : Room No. 919, 9th Floor, Sankalp Bhawan, Pandit Ravi Shankar Shukla Lane, K.G. Marg, New Delhi-110001
Tel. : 011-23783010, 23783011; E-mail : secyurban@nic.in; Website; www.mohua.gov.in

रूपा मिश्रा
संयुक्त सचिव एवं मिशन निदेशक
ROOPA MISHRA
Joint Secretary & Mission Director
Swachh Bharat Mission - Urban

भारत सरकार
आवासन और शहरी कार्य मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF HOUSING AND URBAN AFFAIRS

सत्यमेव जयते

स्वच्छ भारत
एक कदम स्वच्छता की ओर

Preface

Temperature is one of the most critical environmental factors influencing microbial function in sewage treatment processes. Low temperatures severely inhibit microbial activity, substrate utilization rates, and cell growth, resulting in a significant reduction in treatment efficiency. Consequently, maintaining and improving sewage treatment performance in colder regions remains a considerable challenge. There is a growing need to introduce innovative approaches and technological advancements tailored for low-temperature regions.

A global evaluation of processes designed to improve sewage treatment performance in colder regions reveals that only a limited range of adaptable approaches is currently available. This advisory attempts to increase awareness among city administrators and engineers working in such conditions, enabling them to make informed decisions regarding onsite sewage treatment. It also aims to consolidate methods and strategies that enhance the performance of onsite sewage treatment systems operating under low-temperature conditions.

Onsite sewage treatment systems in colder regions face unique challenges, which must be addressed professionally through sustainable and strategic planning. Implementing appropriate solutions not only ensures that treatment facilities remain operational during severe winters but also contributes to environmental protection and public health.

I extend my sincere appreciation to all officers of CPHEEO, along with the technical team from RITES Ltd., under SBM-Urban 2.0. I am hopeful that this advisory will broaden the scope for sanitation in the colder regions.

(Roopa Mishra)

New Delhi
December 2025

Office Address: Room No. 140, C-Wing, Nirman Bhawan, New Delhi-110011
Tel.: 011-23061558, 23061300 • Email: js.sbm-mohua@gov.in

New Delhi
December 2025

Dr. V. K. Chaurasia
डॉ. वी. के. चौरसिया
Adviser (PHEE) (I/c)
सलाहकार (पीएचईई) (I/c)
Tel(O): 91-11-23061144
Email: vk.chaurasia@nic.in

आज़ादी का अमृत महोत्सव

सत्यमेव जयते

G20 भारत 2023 INDIA

स्वच्छ भारत
एक कदम स्वच्छता की ओर

भारत सरकार
आवासन और शहरी कार्य मंत्रालय
निर्माण भवन
GOVERNMENT OF INDIA
MINISTRY OF HOUSING AND URBAN AFFAIRS
NIRMAN BHAWAN

नई दिल्ली-110011, तारीख 20
New Delhi-110011, Dated 20

Acknowledgment

With focus on implementation of sanitation and UWM projects under SBM-U 2.0, Hilly states/UTs had been experiencing difficulty in identifying suitable options of domestic UWM. Low temperatures in these areas, severely inhibit microbial activity, substrate utilization rates, and cell growth, resulting in a significant reduction in treatment efficiency. Consequently, maintaining and improving sewage treatment performance in colder regions remains a considerable challenge.

Keeping in view, growing need for innovative approaches and technological advancements tailored for low-temperature operation, CPHEEO has brought out this advisory on"*Options for Onsite Sanitation in Colder Regions*," to consolidate effective processes adopted in cold-impacted regions worldwide. The advisory aims to assist administrators, engineers, and residents of habitations affected by cold temperatures in managing onsite sewage treatment efficiently, thereby improving livability. It provides guidance on their applicability in similar cold conditions in India.

I wish to express my sincere appreciation to the CPHEEO team for their dedicated efforts in preparing this advisory. I would also like to specially acknowledge Shri Sanjay Raut and Dr. Barjinder Bhalla, Technical Consultants/Experts from RITES Ltd., for their significant and valuable contributions to this important work.

Chaurasia

(Dr VK Chaurasia)

New Delhi
December 2025

Executive Summary

During the implementation of SBM-U 2.0, several technological challenges were encountered in the construction and operation of onsite sanitation systems in cold-impacted regions. In view of these challenges, this document reviews approaches and processes adopted in cold-affected areas globally and evaluates their applicability under similar conditions in India.

The advisory presents various onsite sewage treatment methodologies and management practices suitable for cold-impacted areas, highlighting their advantages, limitations, and necessary process modifications to ensure effective operation at low temperatures. Implementation strategies, including system insulation, temperature control measures, and the use of animal dung of native herbivores for bioaugmentation, are discussed to enhance treatment efficiency.

The primary objective of the document is to guide administrators, engineers, and field personnel in making informed decisions regarding selection, design, and operation of onsite sewage treatment systems in cold regions. It also aims to assist residents of these habitations in effectively managing onsite sanitation systems, thereby improving operational stability. The technologies and practices recommended are simple, practical, and reliable, providing the required level of service while safeguarding public health and the surrounding environment.

The performance of onsite sewage treatment systems in cold-impacted regions is significantly reduced due to the diminished capacity of microorganisms to degrade organic waste at low temperatures. Additionally, frost-affected soil can cause the freezing of liquid effluent, leading to blockages or damage in conveyance pipelines and disposal structures. Consequently, planning, design, and operation of onsite sewage treatment systems in cold regions shall incorporate additional considerations that are generally not required in tropical or subtropical climates, as low temperatures affect all stages of the sanitation chain, including collection, treatment, and disposal.

Sewage treatment systems relying on biological processes are particularly vulnerable to prolonged cold conditions. At approximately 10 °C, microbial growth rates, metabolic activity, and substrate utilization decrease by up to 50 percent compared to normal operating temperatures. At temperatures below 4 °C, microbial activity is largely inhibited due to dormancy, substantially reducing the efficiency of organic matter degradation. These factors shall be explicitly accounted for in the selection, design, and operation of sanitation systems in cold-impacted habitations.

The primary selection of sanitation systems in cold-impacted regions shall be between wet (water-flushed) toilets and dry toilets, based on water availability, climatic conditions, and operational feasibility. Dry toilets require little or no water for operation and may be considered in areas with limited or unreliable water supply.

Wet (water-flushed) toilet systems shall be adopted only where all components of the sanitation system are adequately protected against freezing. Such systems require an assured water supply for flushing excreta and for its conveyance through pipes to treatment units, such as a septic tank followed by an infiltration trench or soak pit, or to packaged onsite sewage treatment plants (STPs).

Globally, in cold-impacted regions, the most adopted onsite sanitation system is the conventional septic tank. In such regions, septic tanks and associated disposal systems shall be appropriately winterized using locally available insulating materials. Typical winterization measures include the placement of a 200–300 mm (8–12 inches) thick layer of mulch (straw, leaves, etc.) or other suitable insulating materials over the tank and drain field to provide protection against frost penetration.

Additional insulation measures may include the application of insulation materials such as polyurethane foam, nitrile rubber, or plastic-based pipe insulation (e.g., HDPE) to pipes, tanks, and other sewer components to prevent freezing and ensure uninterrupted system performance during cold conditions.

Flush-Tank-Haul systems and cesspool systems may be considered as alternative onsite sanitation options in cold-impacted regions, subject to site-specific conditions and environmental safeguards. In a Flush-Tank-Haul system, sewage from toilets is collected in a completely sealed underground holding tank with no outlet or seepage to the surrounding soil. The stored sewage shall be periodically evacuated using desludging or vacuum tankers and transported to an authorized treatment or disposal facility.

In cesspool systems, sewage is conveyed into a pit or chamber constructed with porous or perforated walls. The liquid fraction of the sewage percolates into the surrounding soil, while solids settle and accumulate as sludge within the pit. The accumulated sludge shall be removed at regular intervals using desludging tankers and transported for safe treatment and disposal in accordance with applicable environmental and public health regulations.

Packaged onsite wastewater treatment units, including anaerobic packaged systems and Johkasou (anaerobic–aerobic) packaged systems, provide a technically sound and sustainable alternative for cold regions. These prefabricated and self-contained units are based on established sewage treatment processes such as sedimentation, biological degradation, and filtration, and are designed for ease of installation, operation, and maintenance under challenging climatic conditions.

Enhancement of treatment performance in septic tank–based systems may be achieved through bioaugmentation by increasing the concentration of beneficial microorganisms adapted to low-temperature conditions. The introduction of cold-adapted microbial consortia can significantly improve the degradation of organic matter under reduced temperature regimes. Animal dung obtained from cattle, goats, sheep, yaks, and other native herbivores may be used as an effective bioaugmentation material, as it contains diverse psychrophilic and psychrotolerant microbial populations capable of functioning at low temperatures. These microbial groups include, inter alia, *Psychrobacter* spp., *Cryobacterium* spp., *Acinetobacter* spp., *Flavobacterium* spp., *Pseudomonas* spp., *Arthrobacter* spp., *Polaromonas* spp., *Shewanella* spp., *Planococcus* spp., *Clostridium* spp., *Methanosarcina* spp., and *Methanobacterium* spp.

Dry toilets constitute a practical and water-efficient sanitation option in areas with limited or unreliable water supply. These systems require little or no water for operation and are generally more cost-effective to install and maintain than wet sanitation systems. Traditional Himalayan households in cold regions have long utilized rudimentary dry toilets that are well suited to local climatic conditions. Existing dry toilets may be upgraded to urine-diverting dry toilets (UDDTs), which improve hygiene and treatment efficiency by separating urine and feces. In UDDTs, fecal matter shall be covered with sawdust or ash to control odor and moisture, while also facilitating the composting process and enhancing environmental sustainability.

The contents of this advisory are briefly outlined as follows:
Section 1: Provides a general overview of sanitation in cold-impacted regions, defines the criteria for identifying habitations affected by low temperatures, and discusses the specific challenges associated with sewage treatment under cold climatic conditions.
Section 2: Outlines the objectives of the advisory.
Section 3: Presents various technical options for improving onsite sanitation in cold-impacted areas, highlighting their advantages, limitations, and applicability. This section also introduces new approaches, technologies, and context-specific solutions for enhanced treatment performance.
Section 4: Details special precautions, winterization measures, and operational strategies required to enhance the performance and reliability of sewage treatment systems under cold conditions.
Section 5: Discusses the use of cold-adapted microbial inoculum for bioaugmentation to accelerate the breakdown of organic matter and improve treatment efficiency in low-temperature environments.
Section 6: Provides a concluding summary, emphasizing operational guidance, and best practices for sustainable sanitation in cold-impacted habitations.

Contents

List of Figures

Glossary

Bioaugmentation
Bioaugmentation involves adding beneficial microorganisms to accelerate the breakdown of organic waste, improve composting, or enhance biogas production.

Colder regions
The colder regions of the Indian Himalayan Region (IHR) are habituated areas where winter temperatures remain consistently low. These zones can be categorized as follows:

- Temperate Cold Himalayan zones or Middle Himalayas: Winter temperatures drop below freezing, ranging from 0 °C to -10 °C or colder.
- Alpine zones and high-altitude regions: Winter temperatures frequently drop below -10 °C to –20°C or lower.

Composting
A biological process in which microorganisms, including bacteria and fungi, aerobically decompose biodegradable organic matter to produce an earth like material, often called humus.

Composting toilet
A dry toilet facility in which organic material such as straw, grass, sawdust, or ash is added to the excreta. Special conditions are then maintained so that the material decomposes (composts) into an inoffensive earth like material called compost or humus. The latrine may or may not have a urine separation device.

Faecal sludge
Waste material that has been emptied from on-site sanitation facilities such as latrines or septic tanks. Characteristics vary. For example, sludge can be raw—that is, untreated—or partially digested. It can be a low-viscosity slurry.

Greywater
Domestic liquid waste without any excreta—that is, water from washing, bathing, laundry, or other household uses.

Improved sanitation facility
Facility that protects and promotes human health by providing a clean environment and breaking the cycle of disease. It promotes sustainability by being economically viable, socially acceptable, and technically and institutionally appropriate.

Indian Himalayan Region	The Indian Himalayan Region is spread across 13 Indian States/Union Territories (namely Jammu and Kashmir, Ladakh, Uttarakhand, Himachal Pradesh, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Assam and West Bengal.
Leach pit/soakaway/ soakpit/seepage pit/infiltration pit	A hole in the ground used for the disposal of liquids. The walls of the pit are porous so that excess liquid can soak away into the surrounding ground. In some countries, the term cesspit is also used; in other countries, a cesspit is a watertight in-ground vault.
Permafrost	A layer of soil or rock from the ground surface to the depth with in which the temperature is continuously below 0°C for two or more years.
Septage	A type of faecal sludge, usually settled solids, removed from septic tanks or holding tanks and normally of low viscosity.
Sewage sludge	Sludge that originates from a sewer-based wastewater collection and conveyance network and a centralized or semi centralized wastewater treatment plant.
Stabilization	The degradation of the sludge or liquid waste through biologic processes into more stable, less degradable organics, thereby reducing oxygen demand and odors and making the sludge easier to handle.
Sustainable sanitation	A system that is economically viable, socially acceptable, durable, and technically and institutionally appropriate. It should function properly throughout its design life, protecting the environment and natural resources.
Toilet	The receptacle into which the user defecates.
Vault	A watertight container (tank), above or below ground, used for the collection of human excreta and/or sullage. The vault is periodically emptied and the waste taken away for treatment and disposal.
VIP toilet	Ventilated improved pit toilet. A form of pit toilet that includes a ventilation pipe to reduce odors in the toilet cubicle and requires the superstructure to be kept dark to minimize problems with flies.

1. Introduction

The Swachh Bharat Mission – Urban (SBM-U), launched on October 2, 2014, has brought about a transformative impact on urban sanitation and cleanliness in India, generating widespread public health benefits. Under this initiative, a total of 63,74,355 Individual Household Latrines (IHL) and 6,36,826 Community/Public Toilets (CT/PTs) have been constructed. Sewage Treatment Plants (STPs) with a design capacity of 37,572.00 MLD and Faecal Sludge Treatment Plants (FSTPs) with a design capacity of 49,865.00 KLD have been established. In addition, Swachh Certifications have been awarded to 4,692 ODF cities, 4,314 ODF+ cities, 1,973 ODF++ cities, and 214 Water+ cities as of December 9, 2025 (sbmurban.org).

Looking ahead, SBM is entering a more comprehensive and sustainable phase, focusing on long-term sanitation solutions, including solid and liquid waste management systems, across both urban and rural areas, including habitations in cold-impacted regions.

There are limited studies on options for onsite sanitation in colder regions. In response to this sectoral need, CPHEEO has issued this advisory. The technical scope of the advisory focuses on onsite sanitation in cold-impacted regions and outlines various precautionary measures required to address the challenges posed by such conditions. However, the following documents should also be referred to by Urban Local Bodies (ULBs) in conjunction with this advisory for comprehensive guidelines on the planning, setting up, and operation of toilets and sewage treatment facilities in colder regions:

Key Reference Documents

i. CPHEEO Manual (2013), *"Sewerage and Sewage Treatment Systems"*

- Part A: Engineering
- Part B: Operation and Maintenance
- Part C: Management

Guidelines for the design, construction, O&M, and management of sewage treatment facilities.

ii. CPHEEO (2018), *"Advisory on Public and Community Toilets"*

Guidance for planning, implementation, O&M, and monitoring and evaluation of public and community sanitation facilities.

iii. CPHEEO (2020), *"Advisory on On-site and Off-site Sewage Management Practices"*

Advisory covering practices and standards for both onsite and centralized sewage management systems.

iv. BIS (GoI), *"Code of Practice for Installation of Septic Tanks"*, IS 2470 Part 1:1985 (Second Revision)

Design criteria and construction standards for septic tanks.

v. **BIS (GoI), *"Code of Basic Requirements for Water Supply, Drainage and Sanitation"*, IS 1172:1993**
Fundamental requirements and standards for water supply, drainage, and sanitation systems.

vi. **BIS (GoI), *"Packaged Sewage Treatment Plant – Specifications"*, IS 18797:2024**
Specifications for packaged sewage treatment plants, including performance and design requirements.

A cold-impacted place may be defined as a region where cold climate, snow, frost, or freezing conditions significantly affect daily life, infrastructure, agriculture, and sanitation systems, thereby requiring special adaptations. Consequently, such areas require process modifications for effective onsite sewage management and treatment.

Approximately 30% of the global population—around 2.4 billion people—lives in countries that include cold or cold-mountain regions where the average monthly temperature can fall below 1°C or more per year (based on UN and global climate datasets). These areas may be considered cold-impacted and are often affected by challenges such as frozen sanitation infrastructure, limited access to sanitation facilities, and reduced soil permeability.

Several major countries, including Canada, Greenland, the United States (partially), Northern European nations, Russia, Mongolia, and India (particularly the Himalayan regions), contain extensive cold-impacted territories.

Approximately 16.2% of India's total geographical area lies within colder, mountainous high-altitude zones, primarily encompassing the Indian Himalayan Region (IHR). The IHR extends for about 2,500 km in length, with a width ranging from 200 to 400 km, and spans, from Jammu & Kashmir to Arunachal Pradesh. The altitude within this region varies significantly—from about 500 m to nearly 8,000 m above mean sea level.

The IHR is home to an estimated 52–55 million people, constituting roughly 4–5% of India's total population. Projections based on 2011 Censes trends and decadal urban expansion indicate that by 2021, approximately 30–35% of residents were living in urban areas, while the remaining 65–70% live in rural settings, including remote villages and high-altitude settlements. The higher-altitude districts—such as Ladakh, Lahaul–Spiti, Kinnaur, and parts of Chamoli and Uttarkashi—collectively host fewer than 1–2 million people, reflecting extremely sparse and predominantly rural habitation with very low population densities.

The States and Union Territories falling within the IHR include Himachal Pradesh, Uttarakhand, Ladakh (UT), and Jammu & Kashmir (UT), Sikkim, Meghalaya, Nagaland, Arunachal Pradesh, Assam, Tripura, Mizoram, Manipur, West Bengal.

The geography and topography of colder regions are unique and pose significant challenges for the technical feasibility of onsite sanitation solutions. Such habitations include urban local bodies (ULBs) at high-altitude settlements across:

- **Ladakh:** Leh, Kargil
- **Himachal Pradesh:** Lahaul & Spiti (Keylong, Kaza), Kinnaur, Chamba (Bharmour), Kullu
- **Uttarakhand:** Uttarkashi and Chamoli (Gangotri, Yamunotri, Harsil, Auli, Joshimath, Badrinath, etc.)
- **Jammu & Kashmir:** Northern districts such as Baramulla, Kupwara, Bandipora, and Ganderbal
- **Arunachal Pradesh:** Tawang, Bomdila
- **Sikkim:** Gangtok
- **High ranges of Nagaland and Meghalaya**

These areas, due to their cold climate, remoteness, terrain complexity, and limited population density, require specially adapted and feasible onsite sanitation approaches.

The colder regions of the Indian Himalayan Region (IHR) are habituated areas where winter temperatures remain consistently low. These zones can be categorized as follows:

- Temperate Cold Himalayan zones or Middle Himalayas: Winter temperatures drop below freezing, ranging from 0 °C to -10 °C or colder.
- Alpine zones and high-altitude regions: Winter temperatures frequently drop below -10 °C to –20°C or lower.

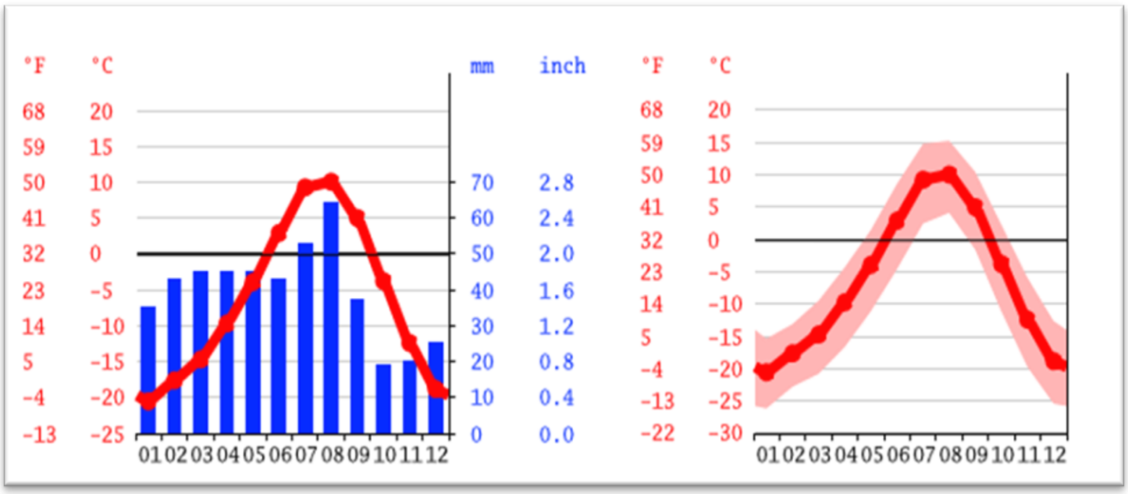
These regions are distinguished not only by their cold climate but also by the presence of:

- Seasonal or perennial snow cover
- Frost events
- Frequent freeze–thaw cycles, which significantly influence soil structure, vegetation, and microbial activity.

These high-altitude, hilly regions experience a cold climate with heavy snowfall, typically persisting from October to March, often resulting in snow-covered landscapes. For instance, in Leh (Ladakh), mean air temperatures in the coldest months can fall to –20 °C or lower, accompanied by substantial snow accumulation. A typical graph showing average annual temperature variations across months for a cold-impacted

ULB (Leh) is given in **Fig. 1.1.**

Under cold conditions, the biological processes responsible for waste degradation slow down significantly, sometimes nearly coming to a standstill. Microbial growth rate, metabolism and substrate affinities reduce to 50% at 10˚C as compared to normal temperature and practically come to a standstill (attain dormancy) when temperature goes below 4˚C. Additionally, the frozen ground becomes largely impermeable, leading to increased accumulation of undigested sludge in shallow pits, septic tanks, and connecting pipes. These technical challenges in colder regions have a substantial impact on sanitation infrastructure.



Source: Climate-data.org

Fig.1.1: A typical Average Annual Temperature variation graph in Cold Impacted ULB (Leh)

Onsite sewage treatment systems are employed in areas where households are not connected to a municipal sewerage network. In cold-impacted regions, these systems require a tailored approach due to extreme weather conditions, frozen ground, limited water availability, and hilly terrain. A fundamental requirement for any onsite sewage treatment system designed for cold regions is its ability to sustain effective treatment performance over extended periods at low temperatures.

Sewage treatment systems that rely on biological processes are particularly vulnerable to low temperatures, which strongly affect microbial growth rates, substrate utilization, and overall metabolic activity. In hilly and undulating terrains with low population density, these challenges are compounded by the high per capita capital and operational costs associated with centralized water supply and sewerage systems. As a result, onsite sewage treatment systems often emerge as the most viable option, particularly for small and medium-sized habitations. Additionally, populations in cold-impacted areas often experience high seasonal variability, further limiting the feasibility of centralized systems.

Globally, in cold-impacted areas, the most used onsite sanitation system is a subsurface septic tank followed by a soak pit or drain field (permeable infiltration structure). This system is favored for its simplicity, low cost, and independence from centralized sewer networks. However, in high-altitude, colder, and water-scarce regions—such as Ladakh, Lahaul-Spiti, and Uttarkashi—septic tanks are prone to freezing, and the anaerobic digestion process slows considerably at low temperatures. In such conditions, dry composting toilets, locally known as *Ladakhi toilets*, are preferred. These toilets are widely used across high-altitude areas including Leh and Kargil (Ladakh), Lahaul-Spiti and Kinnaur (Himachal Pradesh), Upper Uttarakhand (Chamoli, Uttarkashi), and the highlands of Sikkim and Arunachal Pradesh.

In traditional Himalayan households located in colder interior regions, dry toilets are widely used. Although rudimentary, these systems are well-adapted to the local climate. In Ladakh, composting or dry toilets, such as those illustrated in **Fig.1.2**, are often constructed inside traditional houses to ensure usability during extreme cold conditions.

Source: ETV

Fig. 1.2: A two-storey Ladakhi Traditional Dry Compost Toilet

The toilet's upper unit, locally called Dechot or Sengchot, is typically built on the upper floor. After use, a mixture of ash and mud is added to the hole. The space below functions as a collection or decomposition chamber and is completely sealed and insulated. While it is not entirely airtight, it must always include a dedicated vertical vent pipe to allow gas movement. Without this vent, gas pressure, odours, and moisture cannot escape. The rising warm air naturally creates an upward draft, facilitating ventilation. The lower chamber is accessible from the exterior of the house for cleaning and maintenance purposes.

Urine-Diverting Dry Toilets (UDDTs) are increasingly being adopted across the Himalayan region as a modern and improved version of traditional dry toilets. They are particularly suitable for cold, high-altitude, water-scarce areas where septic tanks and soak pits often fail due to freezing temperatures, poor soil infiltration, and limited water availability. UDDTs are hygienic, odor-free, waterless, and eco-friendly. In these systems, faeces are treated with sawdust or ash to control odor and moisture and to facilitate composting, making them an effective alternative to both traditional dry toilets and water-based systems prone to freezing.

This approach is being piloted by CSIR-NEERI in parts of Lahaul & Spiti (Himachal Pradesh). The project emphasizes the use of compost boosters and the recovery of fertilizer from human urine, promoting sustainable practices and circular economy principles in the Himalayan region (Patent: 202311006904). The initiative is jointly implemented by CSIR-NEERI and CSIR-IHBT. A demonstration of the Dry Toilet System with Faeces-Urine Separation and Treatment (DToi-FUrST) at CeHAB, CSIR-IHBT, Lahaul, and in five-gram panchayats (Moolings, Keylong, Thorang, Marble, Gandla) of Lahaul district, Himachal Pradesh, is shown in **Fig. 1.3.**

Source: CSIR-NEERI

Fig. 1.3: Dry toilet System with Faeces-Urine Seperation and Treatment (DToi-FUrST) at CeHAB, CSIR-IHBT, Lahaul

Flush-Tank-Haul System and Cesspool System are alternative onsite sanitation options. In a Flush-Tank-Haul System, wastewater from toilets is collected in a completely sealed underground holding tank. The tank has no outlet or seepage to the soil, and the stored wastewater is periodically removed through pumping and transported to a permissible disposal site. In a Cesspool System, wastewater enters a chamber or pit constructed with porous or perforated walls. The liquid portion of the wastewater seeps into the surrounding soil, while the solids settle at the bottom as sludge. The accumulated sludge is periodically removed by desludging tankers and transported for safe disposal at approved locations.

Packaged onsite sewage treatment units, such as Anaerobic Packaged Systems and

Johkasou Decentralized Wastewater Treatment Systems (based on both anaerobic and aerobic processes), offer a sustainable solution for colder, hilly regions. These prefabricated, self-contained units are designed using proven sewage treatment processes, including sedimentation, biological degradation, and filtration. Further technical details on these systems are provided in the subsequent sections of this document.

1.1 Challenges of Sewage Treatment in Colder Regions

Freezing air temperatures primarily affect above-ground infrastructure, while freezing soil impacts in-ground installations such as pipelines, pits, and tanks. The depth and duration of soil freezing are influenced by factors including the length and severity of the cold season, the amount of snowfall, hydrogeological conditions, and vegetative cover. Low temperatures also slow down the biological processes involved in sewage treatment, which in turn affect the design, construction, and operation of sanitation systems. Some of the key challenges in cold-impacted areas include the following:

1.1.1 Sewage Infrastructure Freezing

One of the most critical issues in colder regions is the potential freezing of essential sewage infrastructure components, including pipelines **(Fig. 1.4)**, pumps, and tanks. As temperatures drop, sewage within these components can freeze, causing clogs and operational difficulties.

Fig. 1.4: Frozen Sewer Pipe in Colder Region

Sewer systems are feasible mainly in urban areas with adequate water supply to maintain flow and prevent freezing. In colder regions, it is essential to maintain the thermal balance of sewage during conveyance to prevent excessive heat loss, which can result in pipe blockages. This is particularly important for long pipelines with low flow rates, where heat loss is more significant. Once sewage freezes, it can obstruct pipes and is difficult to thaw.

1.1.2 Reduced Microbial Activity

Microbial activity is essential for the breakdown of organic matter in sewage, but low temperatures significantly slow the metabolic rates of microorganisms involved in sewage treatment. This reduction affects various biological processes, leading to slower decomposition of organic matter. Although psychrophilic bacteria can function efficiently at low temperatures, their low prevalence is insufficient to compensate for the reduced growth of mesophilic bacteria, which predominantly govern conventional sewage treatment systems.

1.1.3 Energy Consumption

Sewage treatment in cold regions often requires additional energy to heat water and maintain operational temperatures, protecting both the biological processes and equipment from freezing. Consequently, operating costs increase, adding to the technical and financial challenges of maintaining sanitation systems in colder environments.

2. Objectives

The range of sustainable and proven sewage treatment systems suitable for colder regions in India is limited. Many designs and processes that perform well in hot climatic zones require modification to operate effectively under the harsh conditions of alpine and high-altitude environments.

The objectives of this advisory are as follows:

- To identify suitable onsite sanitation technologies for hilly, cold-impacted regions not connected to a sewer network, including their advantages and limitations.
- To present new approaches and effective implementation strategies to enhance sewage treatment efficiency in colder regions.
- To provide operational and maintenance guidance to address the unique challenges of cold environments and ensure stability in treatment processes.

3. Options for Onsite Sanitation in Colder Regions

The selected technologies should be simple, reliable, and capable of providing the required level of service to users while ensuring the protection of human health and the environment. The primary choice lies between a wet water-flushed toilet and a dry toilet, which requires no water for use.

Both options allow for multiple variations: for instance, urine can either be mixed with faecal matter or diverted separately using a urine-diverting dry toilet, where it can be treated independently.

Wet toilets operate effectively only when all components of the system are protected from freezing. They require adequate water to flush excreta and convey it through pipes to treatment units such as septic tanks, holding tanks, or other containment and treatment facilities.

In habitations experiencing significant winter migration to warmer areas, it is common practice to shut off the piped water supply to prevent pipes from freezing and bursting due to intermittent use. In such cases, the remaining residents must rely on alternative water sources, including the melting and heating of snow or ice.

3.1 Wet Toilets

All water-flush toilet options offer the advantage of indoor placement, enhancing user convenience, satisfaction, and overall hygiene. In cold regions, it is essential that flush toilets be located inside the house or within a heated enclosure to ensure reliable operation.

Cold Climate Considerations

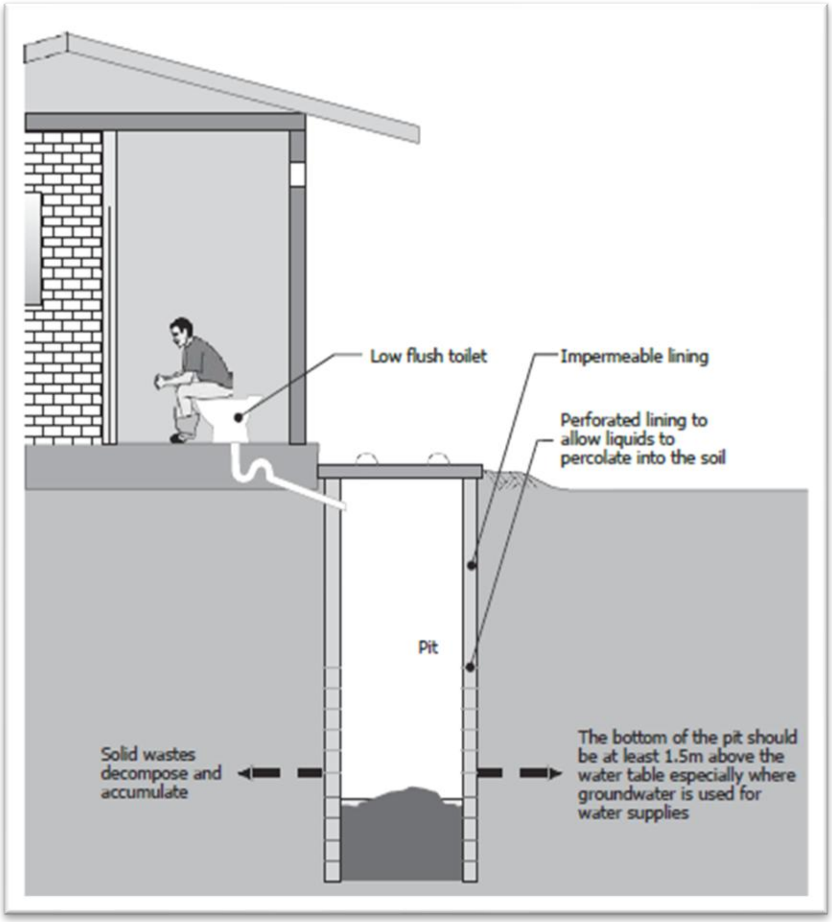
Flush toilets can function effectively in cold regions if the following precautions are observed:

- The toilet fixture and trap must be in a heated space to prevent freezing of water.
- The sewer pipe connecting the toilet to the external tank or pit should be short, insulated, or heated to prevent ice or frozen waste buildup.
- The slope of the sewer line must be designed to allow a single flush to carry solids through the pipe, minimizing the risk of blockages or frozen waste.
- If the soak pit cannot be protected from freezing, it should have sufficient empty capacity at the start of winter to accommodate all wastewater generated during the cold season.

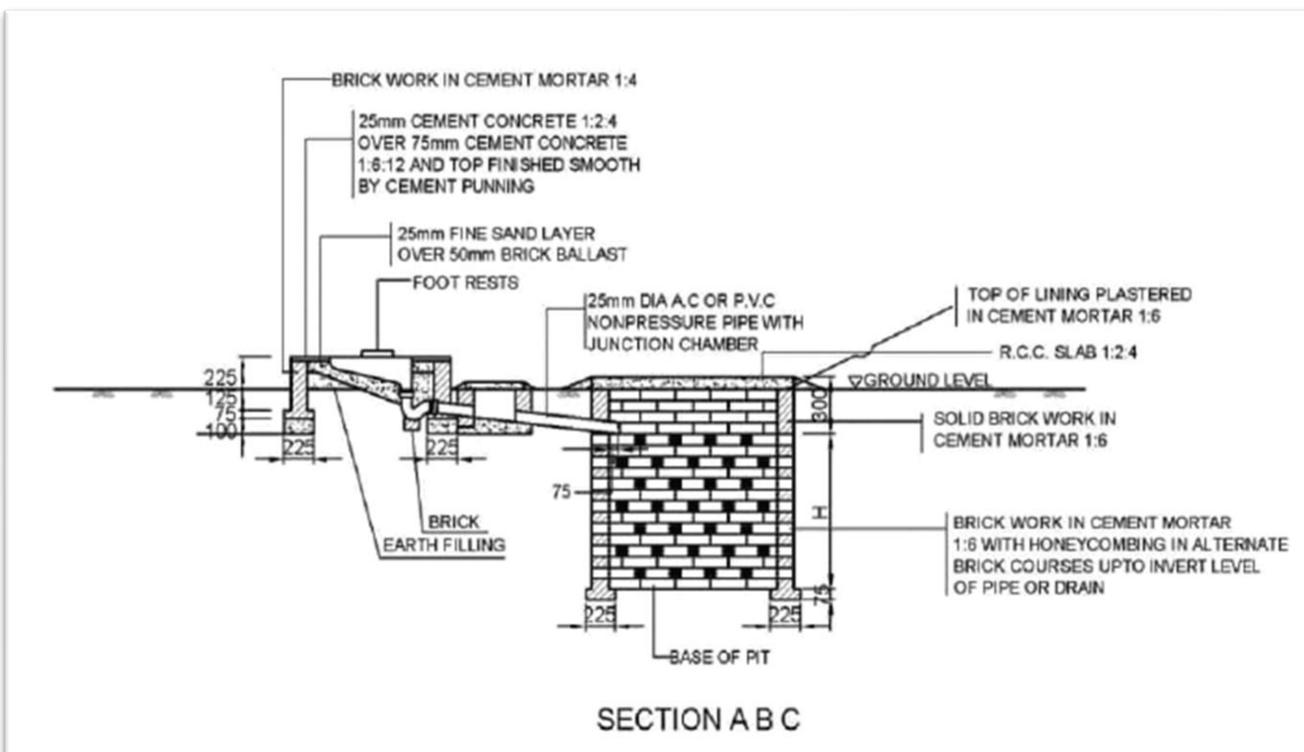
Onsite wet toilet options include the following:

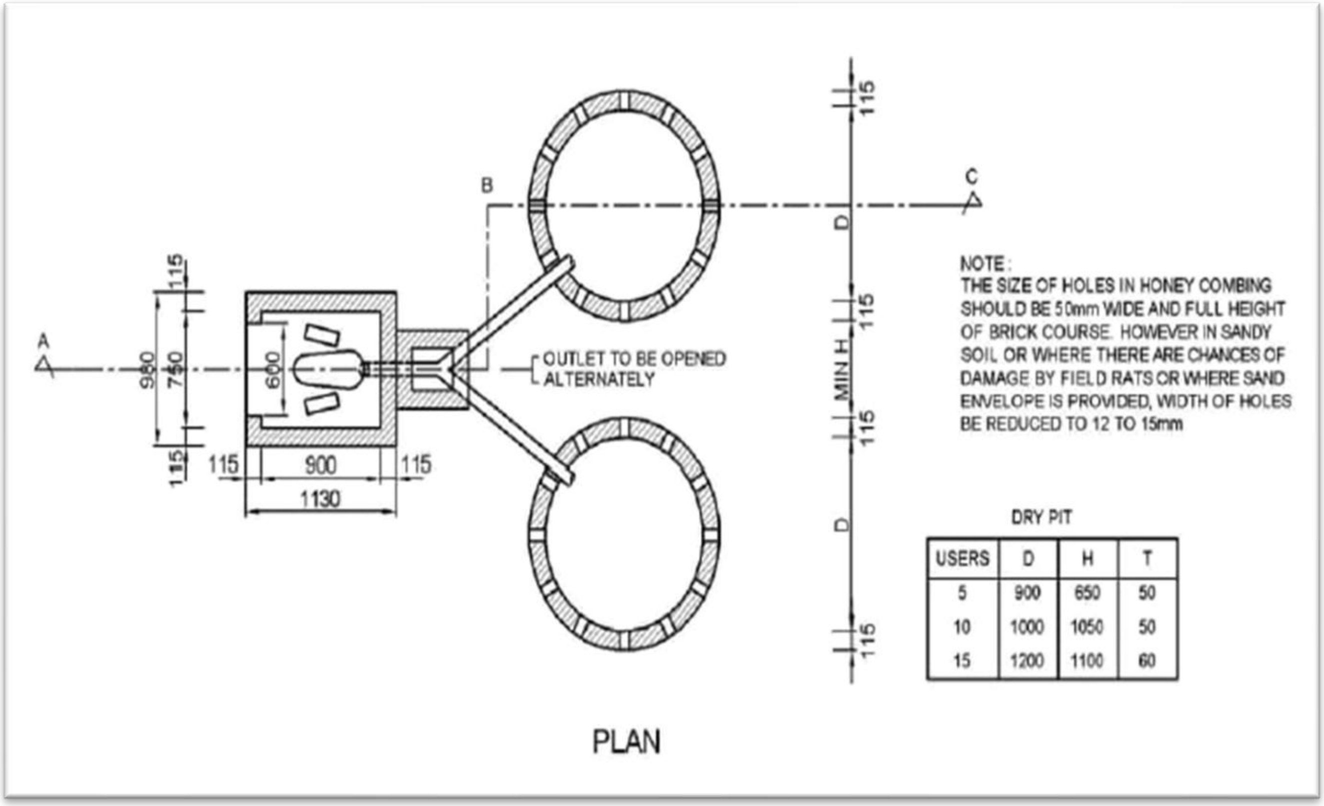
3.1.1 Low-flush toilet with Soakpit

Low-flush toilets use a small amount of water to convey excreta through sewer pipes, typically directing it to a soak pit. An example of a low-flush toilet connected to a Soak Pit is shown in **Fig. 3.1.**



Source: World Bank, 2019





Source: Manual on Sewerage and Sewage Treatment Systems (Part – A on 'Engineering), 2013

Fig. 3.1: Low-flush Toilet with Soakpits

These toilets are suitable for users with access to at least 15–25 liters per capita per day (lpcd) of water.

The soak pit also referred to as a soakaway, infiltration pit, or leach pit is a covered chamber connected to the toilet fixture by pipes. In cold climates, the pit volume must be larger than in moderate climates and should be designed based on the number of users and the desired operational life before filling. On average, an individual produces 200–500 g of faeces and 0.6–1.1 liters of urine per day, which should be considered during sizing.

Soak pits are typically 1.5 to 4 meters deep and may be lined or unlined. Lining supports the pit cover and prevents structural failure. Brick lining using 1:6 cement mortar is commonly employed. To prevent collapse, at least the top 0.5 meter of the pit should be lined up and made impermeable. If the soil is unstable, the entire pit must be lined. The lower portion of the lining should remain porous to allow infiltration of liquid into the surrounding soil while solids remain contained.

Users must ensure an adequate supply of water to operate low-flush latrines, which typically require 1.5 to 3 liters per flush. The flushing water does not need to be clean;

greywater from bathing or laundry can be used effectively. In cold regions, the pipe connecting the toilet fixture to the soak pit should be kept as short as possible, ideally 1 to 2 meters to minimize the chance of freezing. The pipe should also have a steep slope to allow rapid movement of waste. Longer pipes or pipes laid at shallow gradients increase flushing water requirements and raise the risk of wastewater remaining in the line and freezing, leading to blockages.

The advantages and disadvantages of this option are summarized below:

Advantages

- Effectively controls odors and insects and is easy to clean.
- The soak pit can accommodate small quantities of greywater.

Disadvantages

- The toilet fixture and connecting pipework must be adequately protected from freezing.
- There is a potential risk of groundwater contamination if the soak pit is not properly designed or maintained.

Operational Requirements

- Periodic removal and safe disposal of accumulated sludge.
- Adequate measures must be taken to prevent freezing of the toilet components, connecting pipes, and the soak pit.

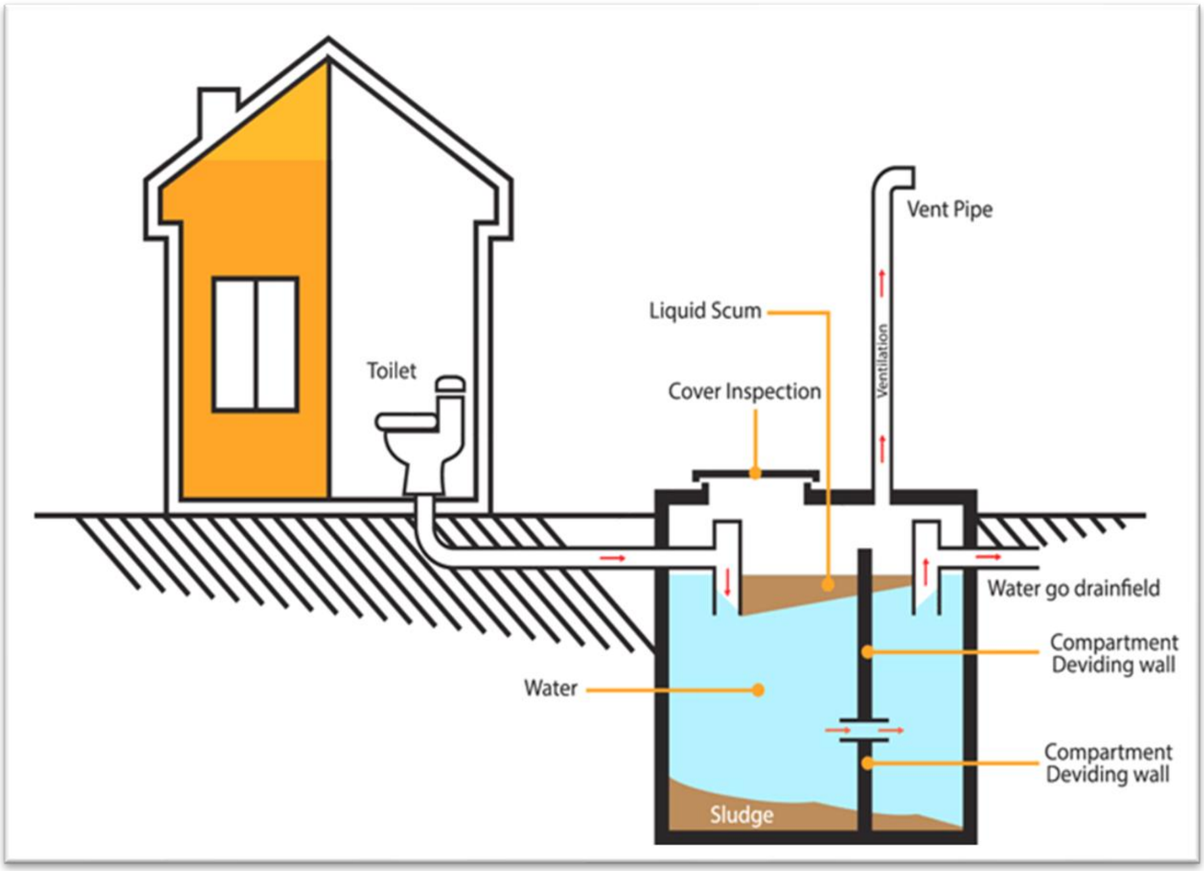
3.1.2 Flush Toilet to Septic Tank with Infiltration Trench or Soakpit

A flush toilet with a septic tank is a common onsite sanitation option in many cold-impacted regions. In this system, solids settle inside the septic tank and undergo partial digestion before being removed for further treatment or safe disposal, while the liquid effluent is discharged into the soil through an infiltration trench or soak pit.

This option is suitable for households with adequate and reliable water availability and for users who are prepared to undertake the required operation and maintenance, including periodic desludging. A typical arrangement of a flush toilet connected to a septic tank is shown in **Fig. 3.2 and Fig. 3.3**.

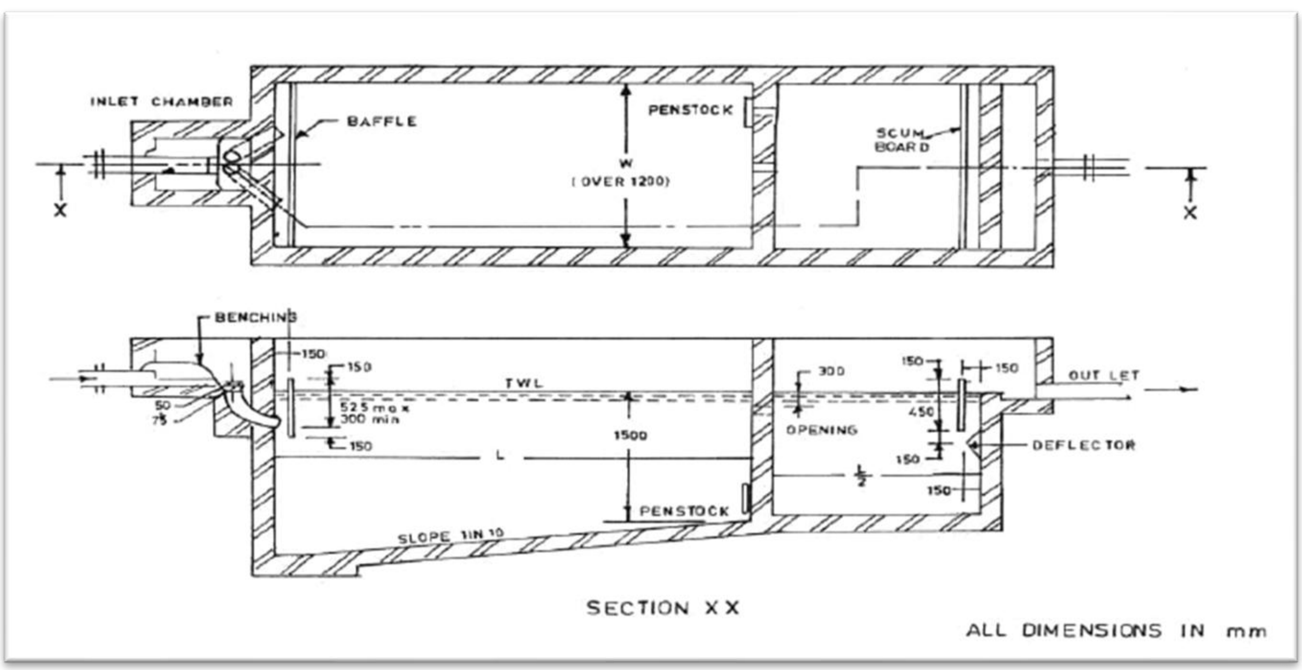
Septic tanks are typically rectangular in shape and may be constructed as either a single-chamber or double-chamber unit. In a double-chamber system, the effluent contains significantly fewer suspended solids because most settling and digestion occur in the first chamber, which is generally twice the size of the second.

The liquid depth in septic tanks usually ranges from 1 to 2 meters, and the recommended length-to-breadth ratio is 2:1 to 3:1 to ensure efficient flow and sedimentation.



Source: World Bank, 2019

Fig. 3.2: Flush Toilet with Septic Tank



Source: Manual on Sewerage and Sewage Treatment Systems (Part – A on 'Engineering), 2013

Fig. 3.3: Structure of two compartment Septic Tank for population over 50

Recommended sizes of septic tanks for individual households (up to **20 users**) and for housing colonies (up to **300 users**) are provided below. These sizes are based on standard design practices that account for daily wastewater generation, retention time, sludge accumulation, and safe operational performance.

Recommended size of Septic Tank up to 20 users

No. of Users	Length (m)	Breath (m)	Liquid depth (m) (cleaning interval of)	
			2 years	3 years
5	1.5	0.75	1.0	1.05
10	2.0	0.90	1.0	1.40
15	2.0	0.90	1.3	2.00
20	2.3	1.10	1.3	1.80

Source: Manual on Sewerage and Sewage Treatment Systems (Part – A on 'Engineering), 2013

Note 1: The capacities are recommended on the assumption that discharge from only WC will be treated in the septic tank

Note 2: A provision of 300 mm should be made for free broad.

Note 3: The sizes of septic tank are based on certain assumptions on peak discharges, as estimated in IS: 2470 (part 1) and while choosing the size of septic tank exact calculations shall be made.

Recommended size of Septic Tank up to 300 users

No. of Users	Length (m)	Breath (m)	Liquid depth (m) (cleaning interval of)	
			2 years	3 years
50	5.0	2.00	1.0	1.24
100	7.5	2.65	1.0	1.24
150	10.0	3.00	1.0	1.24
200	12.0	3.30	1.0	1.24
300	15.0	4.00	1.0	1.24

Source: Manual on Sewerage and Sewage Treatment Systems (Part – A on 'Engineering), 2013

Note 1: A provision of 300 mm should be made for free board.

Note 2: The sizes of septic tanks are based on certain assumptions on peak discharges, as estimated in IS: 2470 (Part 1) and while choosing the size of septic tank exact calculations shall be made.

Note 3: For population over 100, the tank may be divided into independent parallel chambers of maintenance and cleaning.

For the **detailed design and construction** of septic tanks and associated soaking arrangements, the methodology provided in **Chapter 9: On-site Sanitation** of the *Manual on Sewerage and Sewage Treatment Systems* (CPHEEO, Ministry of Housing & Urban Affairs, November 2013) may be referred to.

With respect to the **emptying and transportation of faecal sludge and septage**, the procedures to be followed for the safe cleaning of septic tanks—including recommended emptying frequency, operational protocols, and specifications for equipment, machinery, and desludging vehicles—are comprehensively detailed in the **Ministry's *Standard Operating Procedure (SOP) for Cleaning of Sewers and Septic Tanks, 2018***.

These units are typically winterized using locally available materials—such as a thick layer of mulch (8–12 inches of straw, leaves, etc.) or additional insulating materials such as foam, rubber, or plastic. This insulation is applied over the septic tank and drain field to enhance thermal protection and prevent frost penetration.

Dispersion Trenches

Dispersion trenches **(Fig. 3.4)** are relatively narrow and shallow, typically 0.5–1 m deep and 0.3–1 m wide, excavated with a slight gradient of approximately 0.25%. Open-jointed earthenware or concrete pipes, 80–100 mm in diameter, are laid in the trenches over a 15–25 cm bed of washed gravel or crushed stone. The tops of the pipes are then covered with coarse gravel or crushed stone to a minimum depth of 15 cm, and the remaining trench depth is backfilled with excavated soil. A thick layer of mulch or insulating material is applied on top to provide thermal insulation and prevent frost penetration.

Effluent from the septic tank is directed into a small distribution box, from which multiple dispersion trenches can radiate outward.

The total length of the dispersion trench required shall be calculated using **Equation (3.1)**. The number of trenches is determined based on a maximum length of 30 m per trench, with a minimum spacing of 2 m between adjacent trenches. Parallel distribution should be designed such that one distribution box serves 3 to 4 trenches.

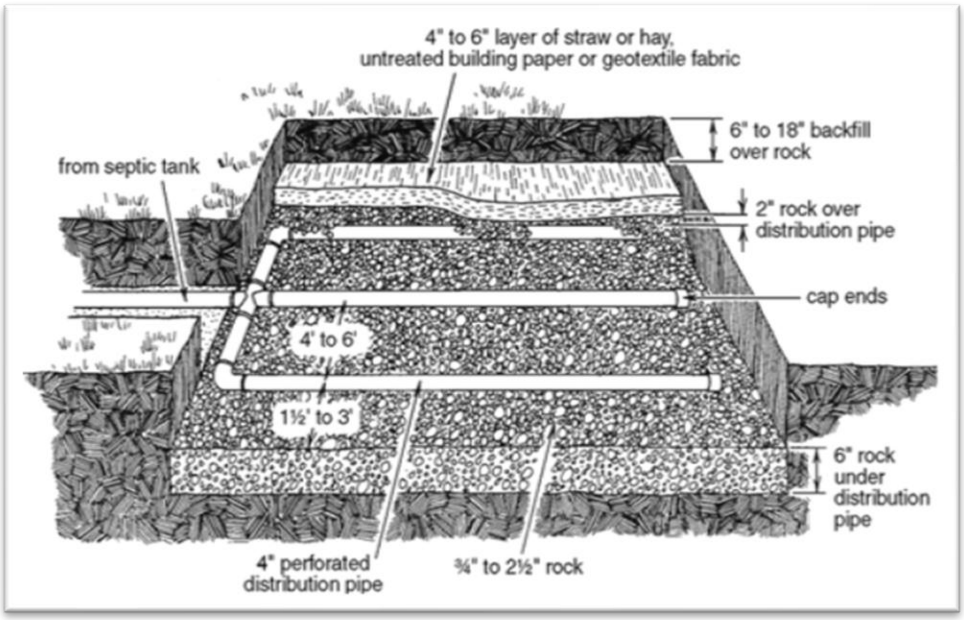
Percolation tests must be conducted to assess the suitability of the site and provide the basis for design.

The total subsurface soil area required for soak pits or dispersion trenches can be estimated using the following empirical relation:

$Q = 130\sqrt{t}$.. Eq 3.1

Where:

Q = Maximum rate of effluent application (L/day/m² of leaching surface)
t = Standard percolation rate of the soil (minutes)

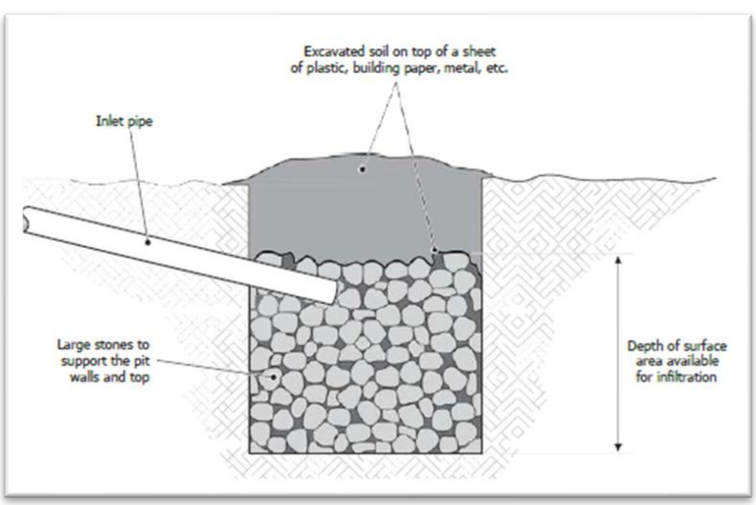


Source: NDSU

Fig. 3.4: Infiltration Trench

Soak Pit

A **soak pit (Fig. 3.5)** should be preferred primarily when land availability is limited or when a porous layer underlies an impervious top layer, allowing vertical percolation of effluent rather than horizontal dispersion, as in the case of dispersion trenches.



Source: WEDC, Loughborough University

Fig.3.5: Soakpit

The advantages and disadvantages are given below:

Advantages

- Provides a high level of service.
- Controls odors and insects; easy to maintain and clean.
- Can handle small amounts of greywater.

Disadvantages

- Requires expert design and construction.
- All components, including underground parts, must be protected from freezing.
- Poor maintenance may lead to system failure.

Operational Requirements

- Regular emptying of solids.
- Ensure no part of the system freezes.

3.1.3 Flush-Tank-Haul System and Cesspool System

In these systems, sewage is retained on-site for a short period in a holding tank or container and then transported ("hauled") to an offsite treatment facility for proper disposal **(Fig. 3.6).** Here is a clear summary of the differences:

Flush-Tank-Haul System

- Wastewater is collected in a sealed, watertight underground tank.
- No seepage into soil; no outlet.
- Entire wastewater (liquid + solids) must be pumped out and hauled away.

Cesspool System

- Wastewater enters a porous pit or chamber.
- Liquid seeps into the surrounding soil.
- Solids settle at the bottom as sludge.

Source: World Bank, 2019

Fig. 3.6: Flush-tank-haul System

The advantages and disadvantages are given below.

Advantages

- Efficient and rapid waste removal.
- Enhances hygiene and user comfort.

Disadvantages

- Requires regular collection and transportation, which can be logistically challenging.
- Relatively higher operational costs due to pumping and transport.
- Risk of spillage or contamination during handling and transport.

3.1.4 Packaged Onsite Sewage Treatment Units

Packaged units, such as Anaerobic Packaged Systems and Johkasou Packaged Sewage Treatment Units (combining anaerobic and aerobic processes), offer a sustainable solution for onsite sewage treatment in colder regions of India. These prefabricated units are fully functional and based on proven sewage treatment processes, including sedimentation, biological degradation, and filtration.

Key Points:

- **Sustainability:** Efficient operation even under cold conditions, with proper insulation and temperature management.
- **Ease of Installation:** Prefabricated units reduce onsite construction complexity.
- **Operational Requirements:** Periodic monitoring, sludge removal, and temperature control measures.
- **Initial Investment:** Higher than conventional septic tanks or dry toilets, but long-term benefits include reliability, environmental protection, and reduced maintenance.

Details of the processes are as below:

3.1.4.1 Anaerobic Packaged System or Improved Septic Tank

Anaerobic Packaged System or Improved Septic Tank **(Fig. 3.7)** uses anaerobic digestion to reduce organic load, suitable for smaller communities or individual households.

This system generally consists of the following components:

- **Settler** – Allows solids to settle out from the sewage.
- **Fluidized Baffled Reactor (FBR)** – Provides anaerobic digestion of the organic matter in the sewage.
- **Fixed Film Reactor (FFR)** – Further degrades organic matter and stabilizes the sewage.

Key Features and Benefits:

- **Energy Efficient:** Operates without wasting scarce energy resources.
- **Biogas Production:** Generates energy in the form of biogas during anaerobic digestion.
- **Low Maintenance:** Requires minimal operational effort compared to conventional systems.
- **Effluent Disposal:** Treated water can be safely disposed of into a soak pit or infiltration system.
- **Cold Climate Adaptation:** A properly insulated tank and careful usage prevent freezing and maintain microbial activity.

This system is particularly suitable for cold regions due to its energy-efficient design and ability to operate under low-temperature conditions with minimal intervention.

Source: CPHEEO Ready Reckner, 2022

Fig. 3.7: Anaerobic Packaged System with Floating Media

Anaerobic Packaged System – Typical Parameters

Parameter	Specification

Capacity	0.5-3.0 KLD
Dimensions	2.4 m x 1.2 m x 2.2 m to 13.5 m x 4.0 m x 2.2 m
Treatment Efficiency	BOD < 20 mg/l
Cost	CAPEX: Rs. 60,000-80,000
	OPEX: Rs. 1500-3000/year

Source: CPHEEO Ready Reckner, 2022

Here's a clear table showing the recommended volume of Anaerobic Packaged System based on the number of users:

No. of Persons	Volume of Anaerobic Packaged System (m^3)
5	1.0
10	1.5
15	2.0
25	3.0
50	5.0
100	10.0
150	15.0

Additional Cost:

- 10–20% extra for cold-resistant measures

Cold-Region Modifications:

- **Tank Burial:** Bury tanks below the frost line (0.8–1.2 m in high-altitude areas) to reduce heat loss.
- **Insulation:** Use Polyurethane Foam (PUF) sheets (25–50 mm) or similar materials for reactor walls and roof.
- **Heating:** Employ electric or solar heating coils where water or wastewater heating is required.
- **Hydraulic Retention Time (HRT):** Increase HRT to around 12 hours to maintain treatment efficiency in low temperatures.

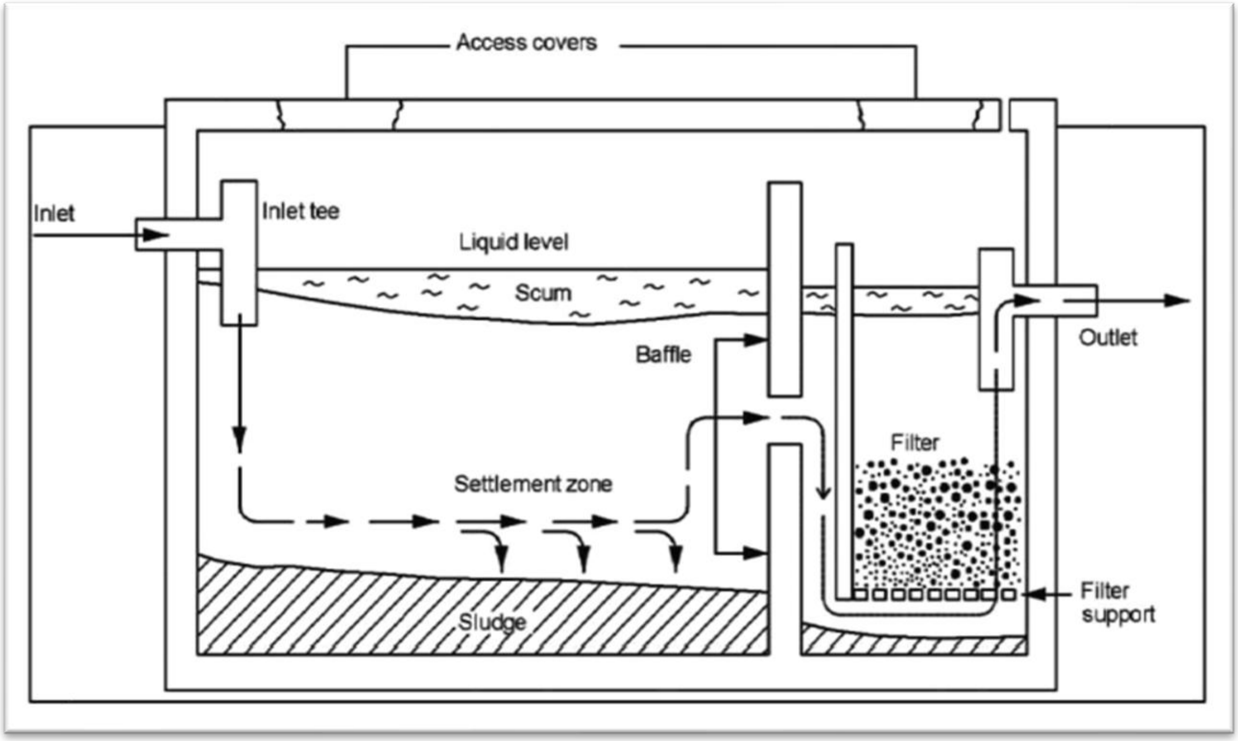
These measures help maintain **continuous operation, biological activity, and treatment efficiency** even in cold conditions.

Anaerobic Packaged System / Improved Septic Tank / Multi-Chamber Septic Tank

- Designed to prevent sludge carryover and improve treatment efficiency.
- Should contain a minimum of two partition (baffle) walls, creating three chambers with approximate volume ratios of 4:3:3.
- The chamber containing the inlet pipe should occupy roughly 40% of the total tank volume.

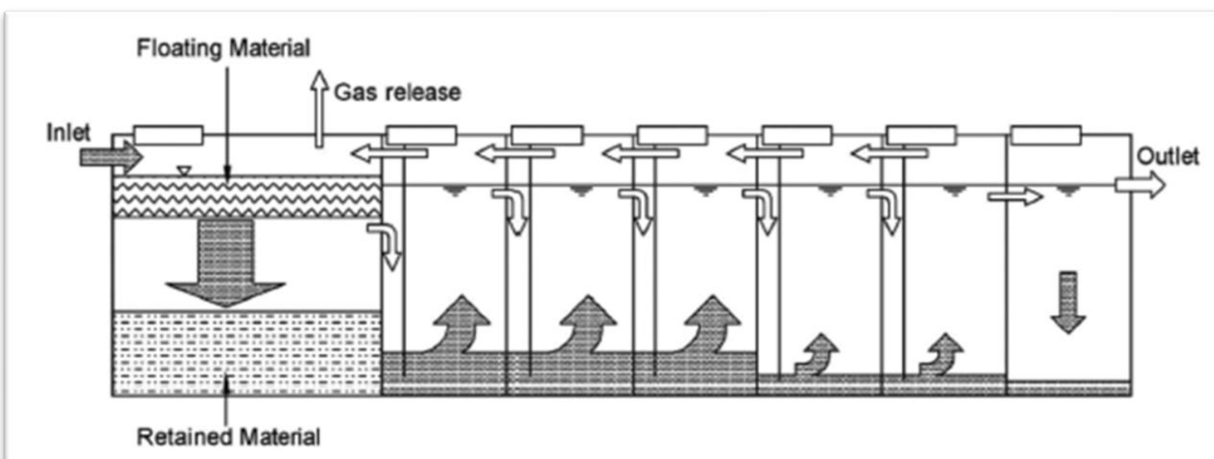
- Schematic diagrams of the **Anaerobic Filter**, **Anaerobic Baffled Reactor**, and **Multi-Chamber Anaerobic Filter** are shown in **Fig. 3.8, Fig. 3.9, and Fig. 3.10**, respectively.

These design features help ensure efficient settling of solids, reduced carryover, and improved overall treatment performance.



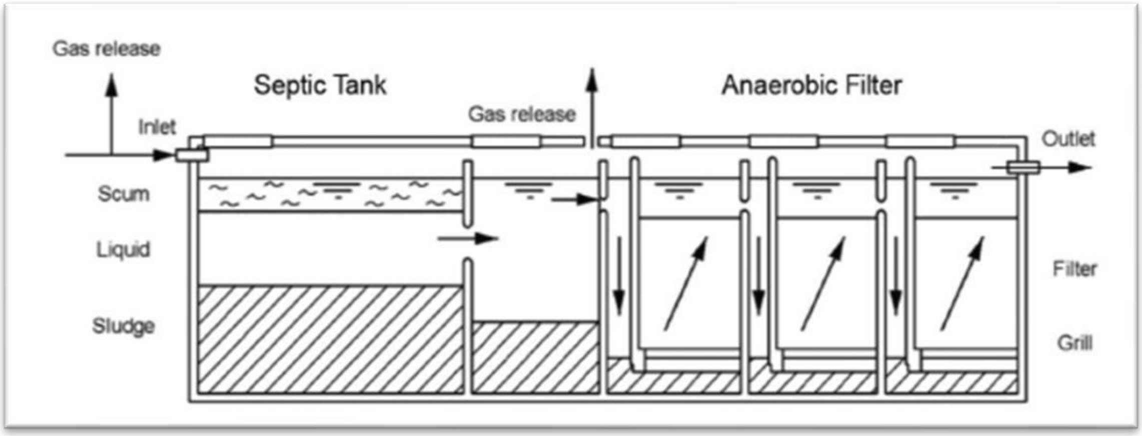
Source: Manual on Sewerage and Sewage Treatment Systems (Part – A on 'Engineering), 2013

Fig. 3.8: Anaerobic Filter



Source: Manual on Sewerage and Sewage Treatment Systems (Part – A on 'Engineering), 2013

Fig. 3.9: Anaerobic Baffled Reactor



Source: Manual on Sewerage and Sewage Treatment Systems (Part – A on 'Engineering), 2013

Fig. 3.10: Multi Chamber Anaerobic Filter

The advantages and disadvantages are given below:

Advantages

- **Eco-friendly and Cost-effective:** Reduces dependence on conventional sewage infrastructure.
- **Wide Temperature Tolerance:** Functions effectively across a broad temperature range, providing sanitation solutions in high-altitude and inaccessible areas such as Siachen and Ladakh.
- **Biogas Generation:** Produces biogas; temperature can be maintained around 25–30 °C using insulation, heating coils, or solar collectors.

Disadvantages

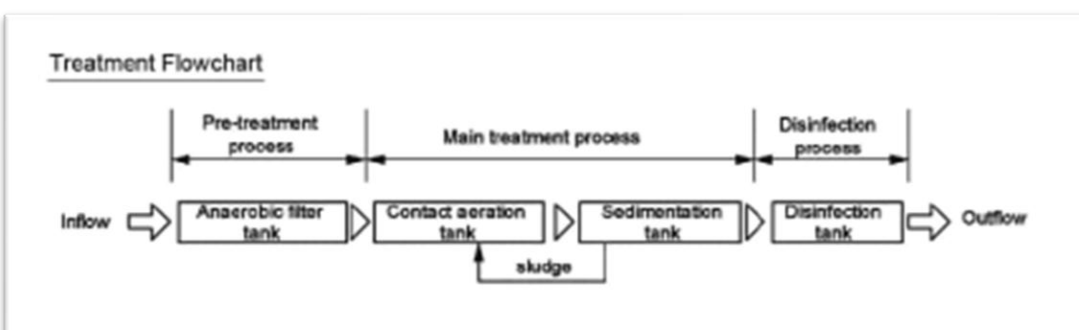
- **Gas Accumulation Risk:** Potential hazard if the venting system is blocked.
- **Higher Initial Cost:** Requires investment for prefabricated units, insulation, and optional heating.
- **Maintenance Requirements:** Needs regular monitoring of sludge levels, vents, and heating systems to prevent operational failure.
- **Technical Expertise:** Installation, operation, and troubleshooting may require trained personnel.
- **Cold Sensitivity:** Without proper insulation or heating, system performance can decline in extreme cold.
- **Limited Capacity:** Individual units may only serve small to medium communities; scaling up requires multiple units or larger systems.

3.1.4.2 Johkasou Packaged Sewage Treatment Unit

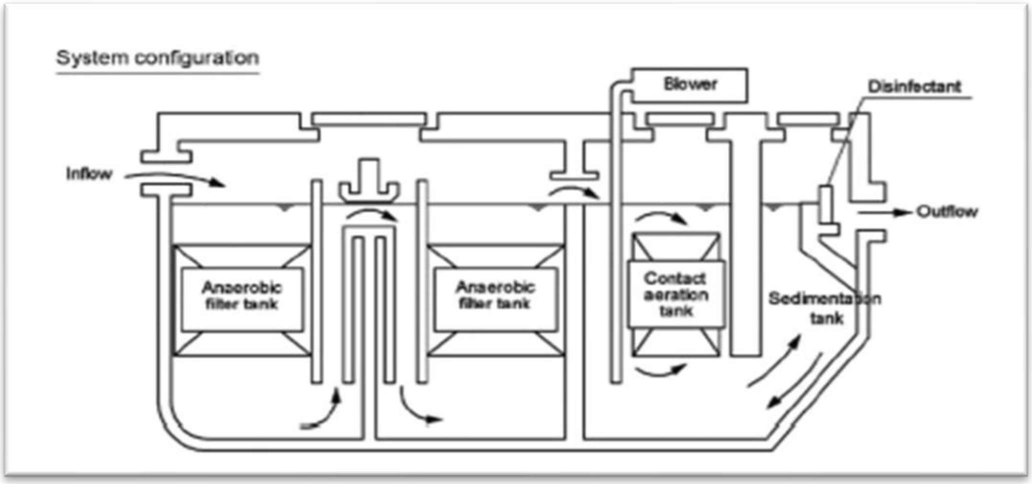
Johkasou **(Fig. 3.11)** are compact, decentralized wastewater treatment units widely used in Japan, especially in remote, cold, mountainous regions where centralized sewerage systems are not feasible. These units are typically installed outdoors and are exposed to natural elements, including snow and sub-zero temperatures during winter, making them specifically designed to operate under harsh climatic conditions.

Following World War II, flush toilets were rapidly introduced across Japan. With increasing industrialization, population shifted to urban areas, leading to sanitation challenges due to high population density. The transition from vault (pit) toilets to Johkasou systems facilitated the adoption of flush toilets in areas lacking sewer networks. Since then, Johkasou units and centralized sewers have developed alongside each other. By the year 2000, 91% of Japanese households had flush toilets. Current regulations mandate the installation of Johkasou for all new construction in areas not served by sewers.

Source: timesofindia.indiatimes.com



Source: Manual on Sewerage and Sewage Treatment Systems (Part – A on 'Engineering), 2013



Source: Manual on Sewerage and Sewage Treatment Systems (Part – A on 'Engineering), 2013

Fig. 3.11: Johkasou Packaged Sewage Treatment Unit

Johkasou systems typically involve multiple treatment stages:

- **Primary Treatment:** Solid-liquid separation to remove large particles.
- **Anaerobic Digestion:** Breakdown of organic matter in the absence of oxygen.
- **Aerobic Treatment:** Further decomposition using oxygen, employing technologies such as:
    1. **Moving Bed Biofilm Reactor (MBBR):** Utilizes floating media to support biofilm growth.
    2. **Membrane Bioreactor (MBR):** Combines biological treatment with membrane filtration to produce high-quality effluent.
- **Sedimentation and Disinfection:** Final clarification and pathogen removal before discharge or reuse.

These systems are compact and modular, suitable for both above-ground and below-ground installation, making them adaptable to a variety of site conditions. Key advantages include high treatment efficiency, compact design, energy efficiency, low maintenance, and scalability.

Adaptations for Effective Performance in Cold Regions

To ensure reliable operation of Johkasou systems in cold climates, several adaptations are recommended:

Insulation

- Tanks, pipes, and critical components should be insulated using materials like Polyurethane Foam (PUF), Expanded Polystyrene (EPS), or rubber-based insulation to minimize heat loss and prevent freezing. Often buried underground below the frost line.

- Insulation thickness can vary: 25–30 mm for buried tanks, 50–75 mm for exposed pipes.

Operational Adjustments

- **Seasonal Modifications:** Aeration and mixing rates can be adjusted according to seasonal temperature variations to maintain optimal microbial activity.
- **Winter Optimization:** Systems in cold regions are designed for reduced sludge production and extended hydraulic retention times (HRT) during winter months to compensate for slower biological processes.
- **Monitoring:** Regular checks of sludge levels, temperature, and effluent quality help ensure consistent treatment performance throughout the year.

Buried Tanks Below Frost Line

- **Purpose:** Burying tanks below the frost line helps prevent freezing by taking advantage of the earth’s natural insulation and warmth.
- **Milder Cold Areas:** In regions such as lower Himachal Pradesh and Uttarakhand, frost typically penetrates 300–500 mm below the ground. Burying the tank with its top at least 500 mm below ground level is generally sufficient to prevent freezing.
- **Severely Cold Regions:** In high-altitude areas like Ladakh, Lahaul-Spiti, and the Sikkim highlands, the frost line may reach 1–2.5 m. Tanks in these locations must be buried correspondingly deeper to ensure protection from freezing.

Heat-traced pipes

- To prevent the freezing of water and wastewater pipes, heat-tracing systems are often used. These are heating cables that keep the pipes warm, ensuring the flow of water doesn't freeze at low temperatures.

Reinforced Lids

In regions with heavy snow or freezing conditions, Johkasou systems (decentralized wastewater treatment systems) need to be equipped with snow-load resistant hatches or manhole lids to ensure continued safe operation and accessibility throughout the winter. If these lids fail, it could lead to frozen systems, blockages, or damage to equipment, which would disrupt the treatment process.

By providing reinforced lids, you ensure that:

- The system remains safe and accessible for maintenance and repair.
- The system performs optimally, without risk of damage from environmental stress.
- There is no risk of overflow or blockage caused by snow or ice entering the system.

Heated Blowers

- **Prevents downtime**: By ensuring that blowers and aeration systems remain operational even in freezing conditions, heated blowers eliminate the risk of system failure and the need for emergency repairs due to freezing equipment.
- **Continuous biological treatment**: Aeration is crucial for biological treatment in wastewater systems. Freezing air pipes or blowers can disrupt the oxygen supply to bacteria and other microorganisms, leading to poor treatment performance. Heated blowers ensure that this aeration process continues uninterrupted, even in the coldest conditions.
- **Improved system reliability**: Johkasou systems are often deployed in rural or remote areas, where maintenance access may be limited. Ensuring that blowers and pipes are equipped with heating elements reduces the likelihood of problems and increases the reliability of the system year-round.
- **Reduced maintenance needs**: Because the system is protected from freezing, there's less wear and tear on the blower components. This reduces the need for frequent maintenance or replacement of damaged parts.

Raised Vents

Raising the ventilation pipes above typical snow depths ensures that the airflow remains unobstructed, preventing blockages and ensuring the proper ventilation of gases like methane and other byproducts of wastewater treatment.

Typical Specification for a Cold-Region Johkasou Vent

- 150 mm insulated HDPE vent pipe
- Elevation: 1.2 m above maximum snow drift
- Frost-resistant vent cap with side louvers
- 25 mm closed-cell polyethylene insulation
- 45° angled termination to shed snow
- Anchored support bracket at 0.8 m height
- Option: passive solar black coating

Easy access for Maintenance

To ensure reliable operation of Johkasou systems, all components are designed for accessibility and dependable function even in harsh, snowy conditions.

A typical parameter:

Parameter	Specification
Capacity	1.0 KLD
Treatment Efficiency	BOD removal, 75-90%

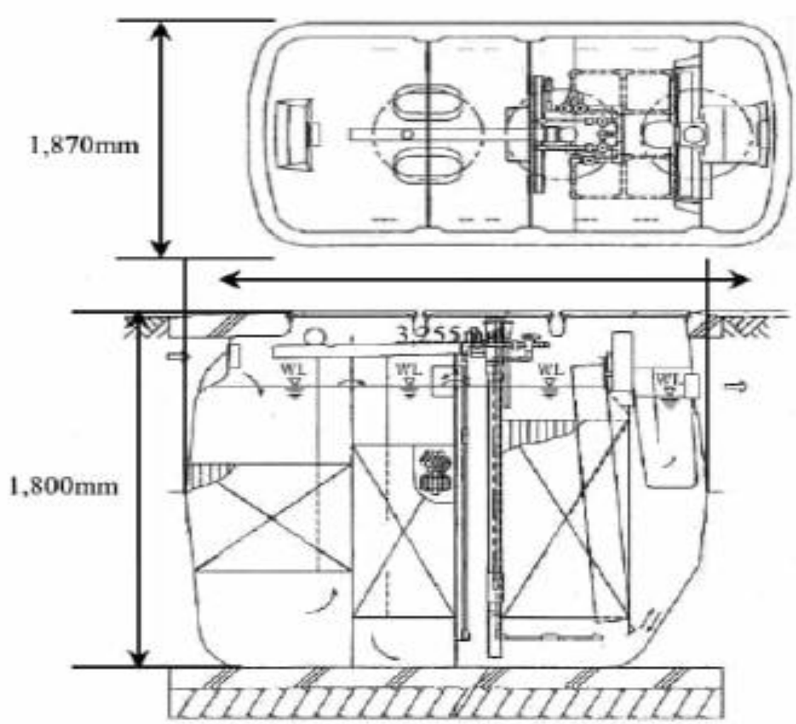
Cost	CAPEX: Rs. 2.2-3.4 lakh/KLD capacity higher unit cost for small capacity plants
	OPEX: Rs. 7,650/KLD/year

Source: CPHEEO Ready Reckner, 2022

Additional cost: 10-20% for cold-resistant measures

Details of a package-type treatment system (Johkasou) for 10 persons, as follows:

Capacity	10 persons (2.0 m^3/day)
Weight (equipment only)	470 Kg
Main Body Material	FRP
Tank Volume, Equipment Capacity	
Anaerobic Filter Tank	No. 1: 2.13 cum No. 2: 1.414 cum
Contact Aeration Tank	2.037 cum
Sedimentation Tank	0.717 cum
Blower	120 L/min x 130 W



Source: Manual on Sewerage and Sewage Treatment Systems (Part – A on 'Engineering), 2013

Below are some representative examples of how this technology is implemented:

Example 1
Location: MG Marg area, Gangtok, East Sikkim

System Type: Modular, Prefabricated FRP Johkasou (Decentralized Wastewater Treatment Unit)	
Climate Condition Winter temperatures often drop to 0°C or lower; heavy snowfall in surrounding higher altitudes	
Implementing Agency Sikkim Housing & Development Board (SHDB) with support from Japan International Cooperation Agency (JICA)	
STP Capacity 50 KLD (for decentralized use: small clusters, hotels, and commercial areas)	
Key Features • Modular, prefabricated FRP Johkasou unit for flexible deployment • Handles variable flow rates and fluctuating BOD loads efficiently • Insulated and thermally treated piping and reactor covers to withstand cold climates • Electric heating coils and internal bio-heating (from microbial metabolism) to maintain biological activity • Underground installation for natural temperature regulation	
Treatment Performance • BOD Removal: > 90% • Effluent Quality: Odour-free, colourless • Water Reuse: Suitable for landscape irrigation and toilet flushing	
Benefits • Compact footprint suitable for dense urban and hilly areas • Low energy consumption • Quick installation, ideal for difficult terrain • Proven performance in cold regions, similar to systems used in Japan	
Example 2	
Location: Multiple mid-hilly towns and Governor House (Raj Bhawan), Uttarakhand	
Stakeholders: IIT-Roorkee partnered with Daiki Axis India (under MoU since 2020)	
Performance • Demonstrates high BOD removal efficiency, ensuring reliable treatment quality. ▪ Nitrogen removal processes have been successfully optimized to perform well under cold climatic conditions typical of hill regions.	
Benefits	

- Compact, decentralized treatment units remove the need for conventional septic tanks and soak pits—an advantage in rocky, space-constrained, or steep hill terrains where civil construction is difficult.
- The system generates treated wastewater that meets regulatory standards, enabling safe on-site reuse for gardening, landscaping, and toilet flushing.
- With low energy requirements and simple installation and operation, the technology is well-suited for remote locations, challenging topographies, and hill environments where maintenance access is limited.

Example 3

Location: Ganga Vatika area, Dhalwala and the wider Tehri Garhwal region, Uttarakhand

Program: Uttarakhand Peyjal Nigam under the Namami Gange initiative

System Specification: 300 KLD Johkasou-based modular STPs

Features

1. Compact & Modular Deployment

- Minimal need for heavy civil construction; units are prefabricated and plug-and-play.
- Low land footprint, suitable for steep, space-constrained hill terrain.
- Flexibility to install above or below ground, depending on site constraints.

2. Energy-Efficient Operation

- Utilizes a single blower system supported by airlift recirculation, reducing mechanical complexity.
- Achieves ~50% lower energy consumption compared to conventional STPs of similar capacity.

3. Full-Spectrum Biological Treatment

- Employs the AAA (anaerobic–aerobic–anaerobic) process for comprehensive removal of organic load, suspended solids, and nutrients.
- Ensures consistent treatment quality suited for sensitive river-basin zones.

4. Resilient, All-Weather Design

- FRP encapsulation provides durability and corrosion resistance.
- Thermally insulated chambers maintain microbial efficiency during cold seasons.
- Subsurface installation options protect the system and retain biological activity in sub-zero Himalayan temperatures.

3.4 Dry Toilets

Dry toilets are a feasible sanitation option in areas with limited water availability. However, their use requires separate management of greywater—the wastewater generated from bathing, laundry, and cooking, which does not contain excreta. Greywater disposal becomes particularly challenging in cold climates, where the ground may be frozen and unable to absorb wastewater through conventional soak systems.

Dry toilet facilities require little to no water for operation and are generally more cost-effective to install than wet toilet systems. The faecal matter can be treated and stored on-site or periodically removed for safe off-site treatment or disposal, ensuring hygienic and environmentally sound waste management.

Mixing urine with faeces in a dry toilet can impede the natural degradation process. Urine diversion is therefore a key feature of many dry-toilet systems, as it helps maintain a drier internal environment, which is essential for effective decomposition and pathogen reduction. In Urine-Diverting Dry Toilets (UDDTs), urine is collected separately to prevent excess moisture from entering the faecal chamber. As a result, the dry, separated faeces break down more efficiently through composting, leading to safer and more manageable end products.

Dry toilet options are given below:

3.2.1 Pit or Composting Toilet

A pit toilet or composting toilet **(Fig. 3.12)** allows excreta to drop into a pit located below the toilet structure. In this system, solids are retained in the pit and gradually decompose, while liquids infiltrate into the surrounding soil, provided that soil and groundwater conditions are suitable.

Design considerations

The pit volume should be designed based on the number of users and the intended service life of the pit before it is filled. Global averages indicate that a person produces approximately 200–500 grams of feces and 0.6–1.1 liters of urine per day, though actual amounts vary with diet, health, and local conditions.

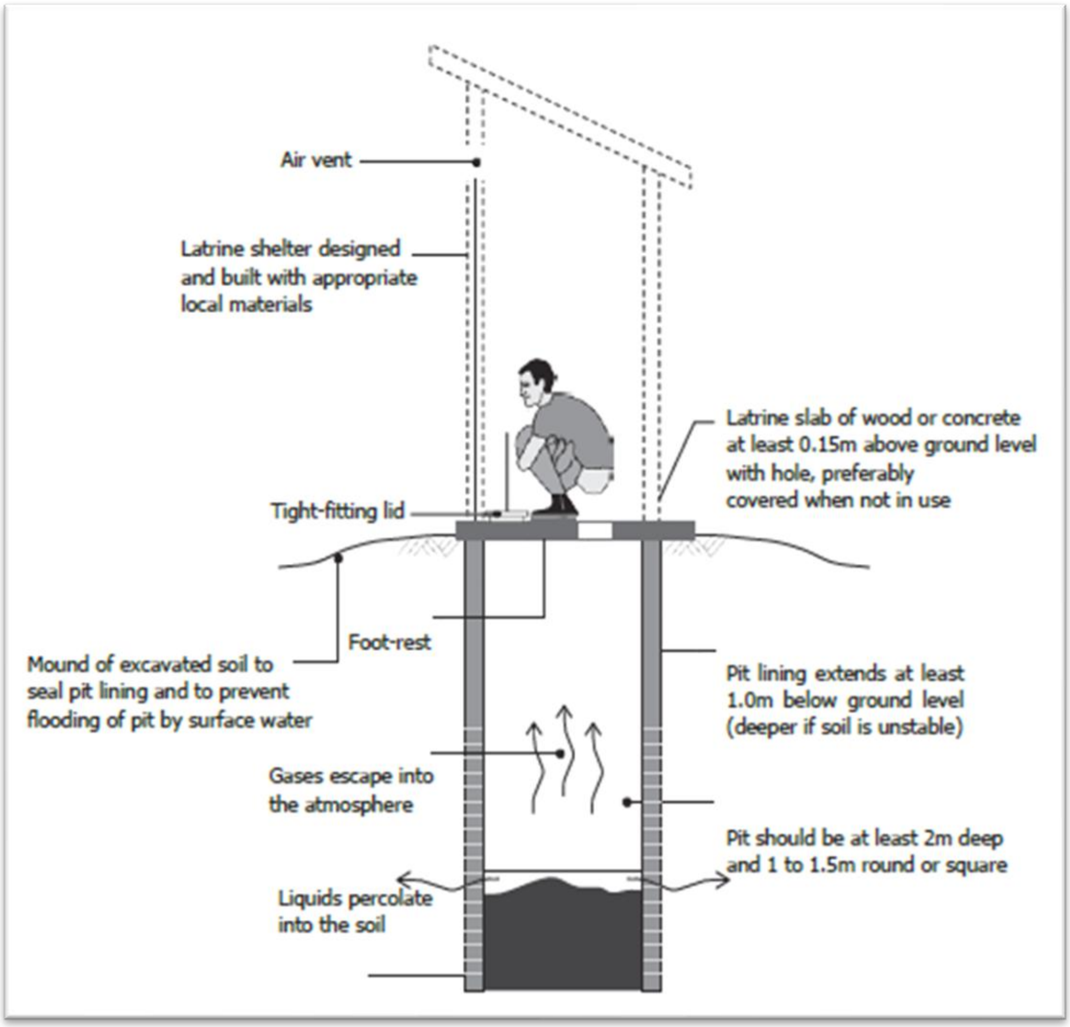
For estimation purposes, assuming a combined production of 1.25 liters of excreta (urine and faeces) per person per day:

- A household of four would produce roughly 5 liters per day of excreta.
- If the ground is frozen for four months (≈120 days), the household accumulation over this period would be about 600 liters.
- Therefore, the pit should have a minimum empty volume of 0.6 cubic meters at the start of the cold season to accommodate excreta.

For a shared latrine with eight users, the required pit volume would be about 1.2 cubic meters at the beginning of the cold season.

Over time, as solids decompose and liquids infiltrate into the ground, the annual accumulation is expected to be approximately 60 liters per person per year.

Finally, the bottom of the pit should be located 1.5–2.0 meters above the groundwater table to prevent contamination.



Source: World Bank, 2019

Fig. 3.12: Pit Toilet or Composting Toilet

Pit Management and Operational Considerations

When the toilet pit becomes full, users generally have two options:

1. **Close and Replace the Pit:** Cover the accumulated excreta with soil, seal the pit, and construct a new latrine.
2. **Empty and Reuse the Pit:** Safely remove the contents of the full pit for treatment or disposal, allowing continued use of the same pit.

To control odors and reduce insect activity, users can add dry materials such as leaves, ashes, or sawdust after defecation.

A typical pit toilet requires only 4–5 square meters of space. However, if households repeatedly close full pits and build new ones, the cumulative space requirement increases over time due to the need for additional replacement pits.

Greywater Management

- Pit toilets are generally designed to handle only small volumes of greywater.
- In cold climates, when the soil is frozen and infiltration is limited, users must take care not to exceed the pit's liquid capacity.
- Grease, fats, and oils should never be disposed of in the pit, as they can clog soil pores and reduce infiltration capacity, leading to overflow or groundwater contamination.

Potential for Reuse of Excreta

1. **Reusability of Decomposed Excreta**
    - Excreta from pit toilets can potentially be reused.
    - Direct use in agriculture is unsafe without additional treatment.
2. **Treatment Considerations**
    - Excreta must be stabilized and sanitized before reuse.
    - Cold climates slow down decomposition.
    - Warm climates accelerate the treatment process.
3. **User Acceptance**
    - Even when excreta has degraded into a soil-like, inoffensive material, people are often reluctant to handle it.
4. **Alternative Uses in Cold Regions**
    - Excreta could be converted into fuel pellets, providing an energy source.
    - Solar energy can assist in treatment and sanitation.

Implications

- **Health and Safety:** Proper treatment is crucial to avoid disease transmission.
- **Behavioral Considerations:** Social acceptance is a major barrier to reuse.
- **Resource Recovery:** Innovative uses like fuel production or solar-assisted treatment can improve sustainability.

Expected Life

- **Well-designed and constructed:** Ensures structural integrity, proper ventilation, and hygiene.

- **Well-maintained:** Regular cleaning and timely pit emptying prevent damage or collapse.
- **Lined pit with masonry:** Protects against soil erosion and structural failure.
- **Concrete slab:** Adds durability and prevents contamination.

A well-designed, well-constructed, and well-maintained latrine with a pit that is emptied periodically and lined with masonry, and with a concrete slab, can last for decades.

The advantages and disadvantages are given below:

Advantages

- **Low-cost system:** Affordable to construct and widely adopted, especially in colder regions where freezing prevents rapid decomposition.
- **Simplicity:** Easy to build with locally available materials.
- **Durable if maintained:** Properly designed and maintained latrines can last for long time.

Disadvantages

- **Hygiene issues:** Odor and fly breeding can occur if the toilet is poorly constructed or not maintained properly.
- **Pit management:** When the pit is full, sludge must be removed or a new toilet constructed, which can be inconvenient.
- **User discomfort:** Accumulation of excreta may be objectionable to users, affecting acceptance and use.

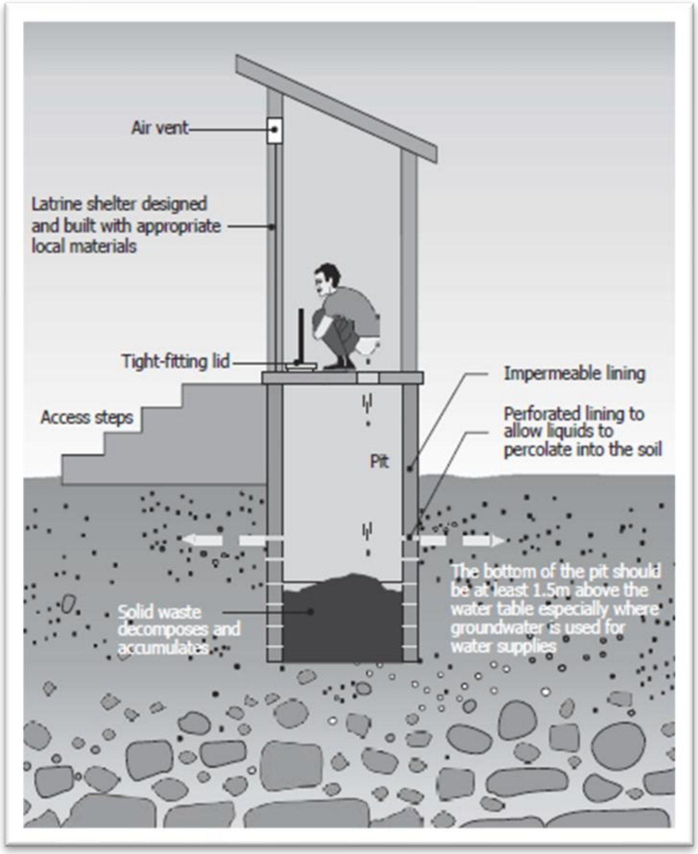
3.2.1.1 Modifications of Pit Toilet or Composting Toilet

A. Raised Pit Toilet

In areas where bedrock is near the surface or the groundwater table is high, digging a standard pit for a toilet can be very difficult or unsafe. Hard rock makes excavation labor-intensive, and a high-water table can lead to flooding or contamination. In those cases, a Raised Pit Toilet **(Fig. 3.13)** can be used.

Raised Pit Toilet Overview

- A pit that is partially or completely above ground, sometimes with a portion extending below ground, but generally shallower than a simple pit latrine.
- Designed for areas where bedrock or high-water tables make conventional pit excavation difficult.



Source: World Bank, 2019

Fig. 3.13: Raised Pit Toilet

Construction Features

- **Above-ground portion:**
  - Made of masonry or concrete walls for durability.
  - Can be surrounded by a built-up mound of soil to provide stability and reduce erosion.
- **Below-ground portion:**
  - Extends slightly into the ground, but not as deep as standard pit latrines.

Climatic Considerations

- In cold climates, materials in the above-ground pit freeze and thaw faster than the contents of an in-ground pit.
- Otherwise, maintenance and usage considerations are similar to a simple pit latrine.

The advantages and disadvantages are given below:

Advantages

- **Suitable for difficult terrain:** Works well in rocky areas or where the water table is high, making conventional pits impractical.

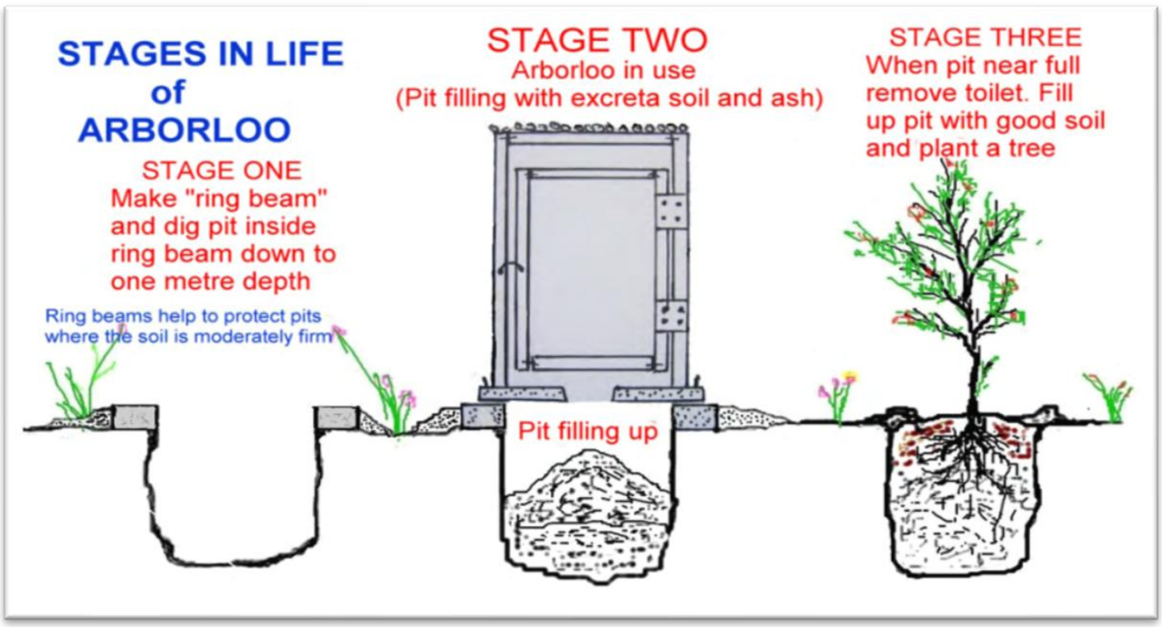
- **Flexible construction:** Can be partially above ground, allowing toilets to be built where excavation is limited.

Disadvantages

- **Accessibility issues:** Users with limited mobility may find it difficult to access raised toilets due to steps or uneven surfaces.
- **Cold climate effects:** Above-ground portions may freeze and thaw more quickly, potentially affecting usability.

B. Arborloo

An Arborloo (Ecological Pit Toilet) **(Fig.3.14)** is a version of a simple pit toilet with a relatively shallow unlined pit. A lightweight, movable cabin sits on top, supported by a ring beam. When the pit becomes full, the cabin and ring beam are moved to a newly dug pit. The filled pit is covered with soil, and a tree is planted in the enriched soil, turning human waste into fertilizer.



Source: SSWM

Fig. 3.14: Arborloo

The advantages and disadvantages are given below:

Advantages

- It is well-suited for areas with adequate space to relocate the toilet and plant trees afterward.
- Quick to construct and involves low cost and simple materials.

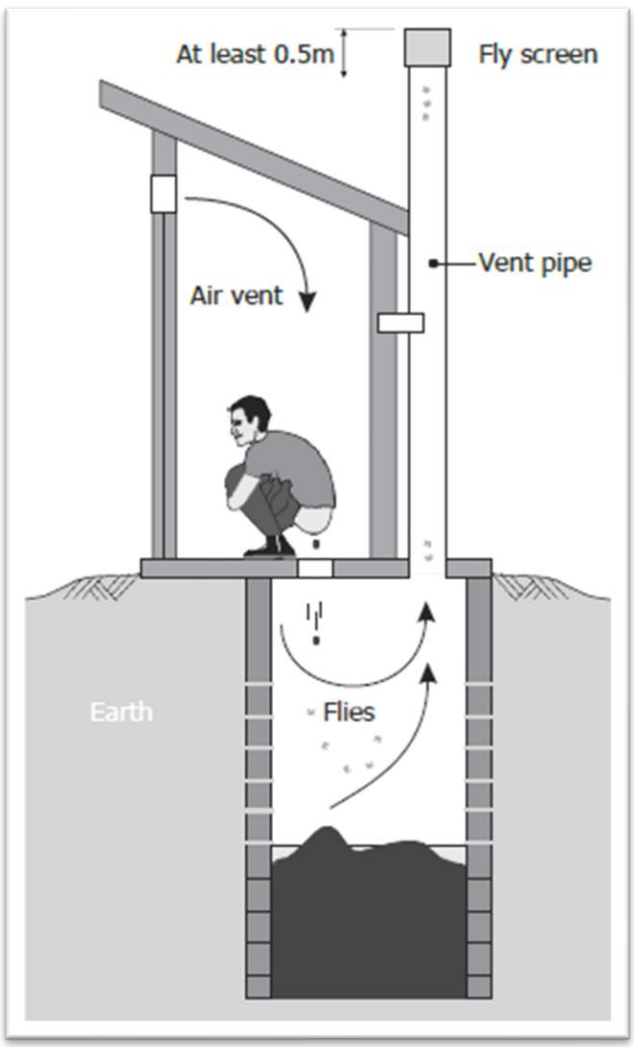
Disadvantages

- Requires ample space for planting trees, which may limit use in densely populated or land-constrained areas.

C. Ventilated Improved Pit Toilet

In a properly constructed and well-operated Ventilated Improved Pit (VIP) toilet **(Fig. 3.15),** odors are minimized by directing airflow through the system. Fresh air enters the superstructure, flows down through the seat or defecation hole into the pit, and then rises through the ventilation pipe, exiting above the latrine. This airflow prevents foul-smelling air from escaping into the cabin.

In cold climates, the contents of any unheated pit can freeze; however, the increased airflow in a ventilated pit can cool the contents even faster, causing them to freeze more quickly than in an unventilated pit. VIP systems also perform poorly in still air, especially when the outside air is colder than the pit contents. Under these conditions, airflow can reverse—moving down the ventilation pipe into the pit and then into the superstructure, leading to increased odors.



Source: World Bank,2019

Fig. 3.15: Ventilated Improved Pit Toilet

The advantages and disadvantages are given below:

Advantages

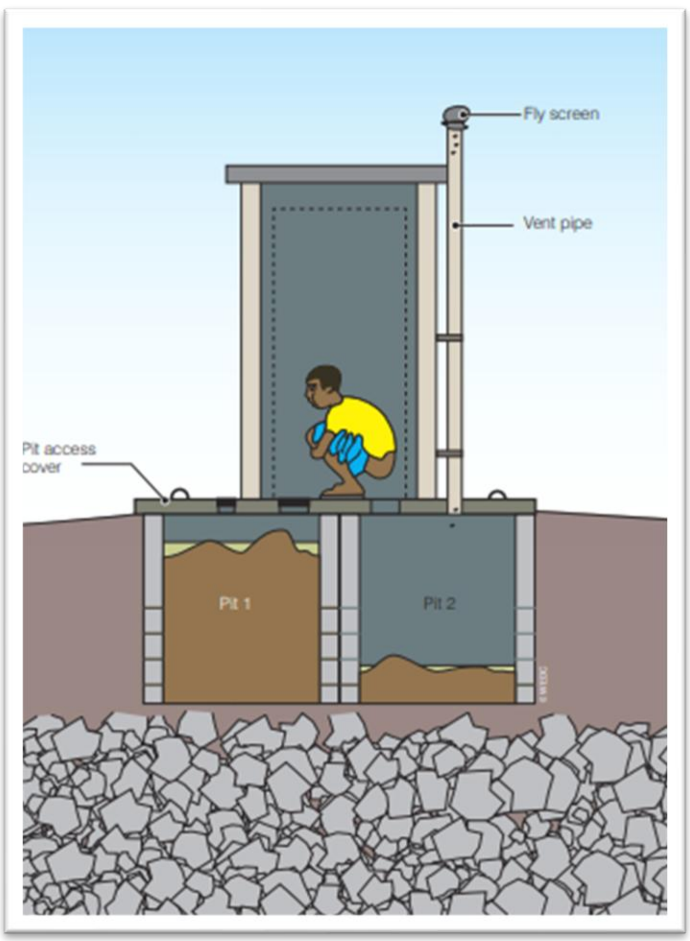
- Effectively controls odors and flies when properly designed, constructed, and used.

Disadvantages

- Ventilation is less effective in still air, especially when the outside air is colder than the pit contents, which can cause airflow problems and reduce odor control.

D. Double Pit Toilet

A Double Pit Toilet **(Fig. 3.16 and Fig. 3.17)** consists of two pits used alternately. While one pit is in use, the other remains sealed so that the excreta inside can decompose to form humus. When the active pit becomes full, it is closed and the second pit is used. By the time the second pit fills, the contents of the first are fully decomposed and can be safely removed and reused. With proper maintenance, this alternating cycle can continue for many years.



Source: https://wedc-knowledge.lboro.ac.uk/

Fig. 3.16: Double Pit Toilet

Source: gaonconnection.com

Fig. 3.17: Double Pit Dry Toilet used in Ladakh

The advantages and disadvantages are given below:

Advantages

- Lower initial cost, since the two pits can be built incrementally constructing one pit first and adding the second later.

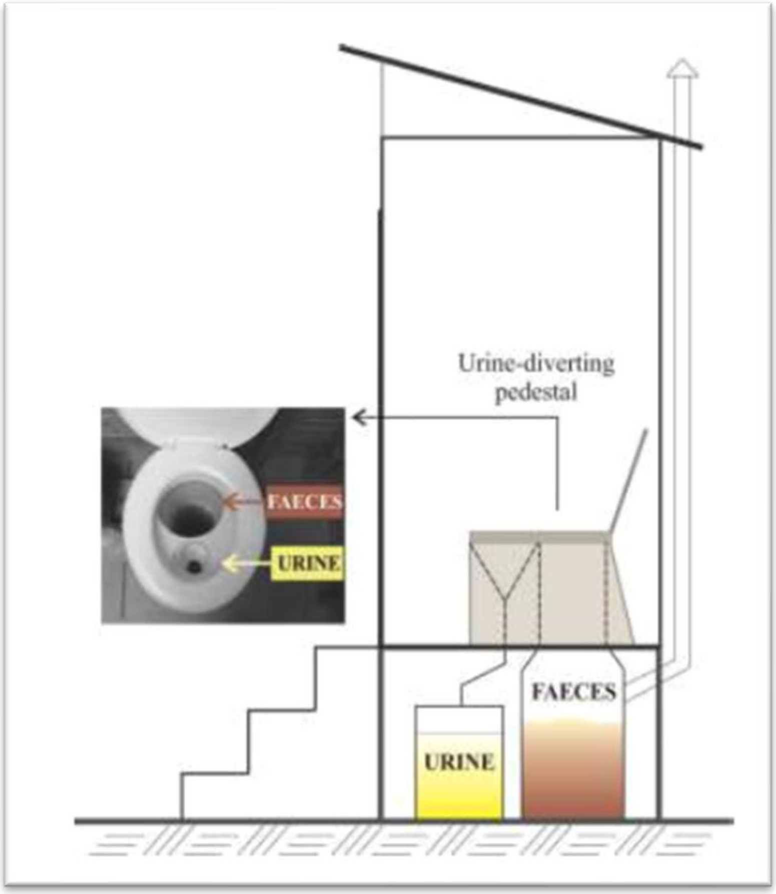
Disadvantages

- Uncertain decomposition time in cold climates, as low temperatures can slow pathogen reduction and delay the safe handling of pit contents.

3.2.2 Eco San (Ecological Sanitation) Toilet

An EcoSan (Ecological Sanitation) toilet **(Fig. 3.18 and Fig. 3.19)** is a sustainable sanitation system that keeps urine and faeces separate for improved hygiene and resource recovery. Faeces are collected on-site in a movable container, while urine is diverted and stored or used separately. The filled containers are periodically transported to a treatment facility, where their contents undergo further processing for safe reuse (such as fertilizer) or environmentally sound disposal.

EcoSan toilets are designed to safely manage human excreta while conserving resources and protecting the environment. The key idea is to treat waste as a resource, turning faeces and urine into useful products like fertilizer and soil conditioner instead of pollution.



Source: ResearchGate

Source: Wikiwand

Fig. 3.18: Urine-diverting Dry Toilet (Eco San)

Source: World Bank, 2019

Fig. 3.19: Urine-Diverting Dry Toilet (Eco San) in Ulaanbaatar, Mongolia

Design Features

- **Urine-diverting toilets:** Urine is separated from faeces at the source, usually using a specially designed pan or seat.
- **Faeces collection:** Faeces fall into movable containers or bins inside the toilet. These containers are periodically removed for treatment.
- **Container treatment:** The collected faeces are stored or composted until pathogens are eliminated, producing safe humus-like material.
- **Urine use:** Urine is rich in nitrogen, phosphorus, and potassium, and can be used as fertilizer.
- **Water conservation:** Most EcoSan systems are dry toilets or use minimal water, reducing water consumption compared to flush toilets.

Operation and Maintenance

- Containers must be emptied and replaced regularly.
- Proper storage or composting ensures pathogen reduction.
- Users must follow hygiene practices to prevent contamination during handling.

Treatment Processes

- **Faeces:** Stored in containers or composting chambers for several months to allow pathogen die-off, producing nutrient-rich compost. Temperature, moisture, and time are key factors.

- **Urine:** Can be stored for several months to reduce pathogens or diluted for direct application as fertilizer**.**

Resource Recovery

- **Soil conditioner:** Treated faeces can be used to improve soil structure and fertility.
- **Fertilizer:** Urine is a natural source of nitrogen, phosphorus, and potassium (NPK)**.**

The advantages and disadvantages are given below:

Advantages

- Faeces can be composted into a nutrient-rich soil conditioner, and urine can be used as a nitrogen-rich fertilizer.
- Separating urine and faeces reduces odors, fly problems, and the risk of contamination.

Disadvantages

- Higher construction cost compared to a simple pit toilet.

3.3 Greywater Disposal

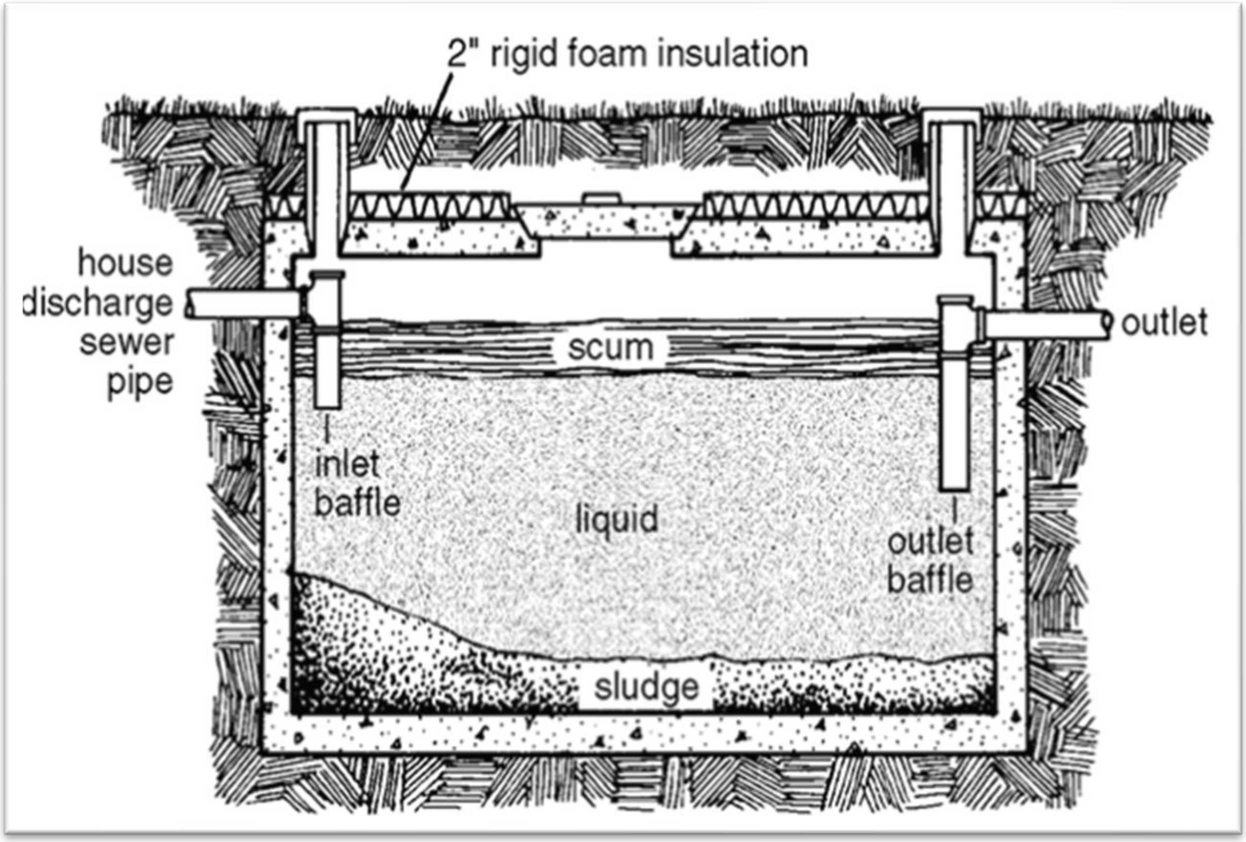
Disposal of small quantities of greywater is generally not a significant issue, provided it is not discharged onto the ground surface, where it could create icy hazards. Depending on local conditions, such as the depth of soil freezing and soil characteristics, greywater can either be infiltrated subsurface or stored for off-site disposal. In areas where the soil freezes to no more than 1 to 2 meters, a soak pit or infiltration trench **(see Fig. 3.4 and Fig. 3.5)** can be constructed for septic tanks, extending below the depth of soil freezing to ensure proper drainage.

4. Additional Considerations to enhance Sewage Treatment

4.1 Insulation

To protect critical sewer infrastructure from freezing, **insulation materials** such as **foam (e.g., Polyurethane (PUF), Polyisocyanurate (PIR), Expanded Polystyrene (EPS)**, **rubber (Nitrile)**, or **plastic-based pipe insulation (HDPE)** can be applied to pipes, tanks, and other sewer components. This insulation helps maintain temperatures above freezing, ensuring continuous sewage flow even under harsh winter conditions.

Tank Insulation: Apply a thick layer of mulch (8–12 inches) such as straw, leaves, or similar materials over the septic tank **(Fig. 4.1)** and drain field to provide additional insulation and prevent frost penetration. For shallowly buried tanks, use pre-insulated lids or add insulation on-site **(Fig. 4.2)** to further protect the system from freezing.



Source: NDSU

Fig. 4.1: Thick layer of mulch over the septic tank for insulation

Source: cabindiy.com

Fig. 4.2: Rigid foam board installed over ground above Septic Tank

Pipe Insulation: Insulate all exposed pipes **(Fig. 4.3)** to prevent freezing and maintain continuous flow of sewage.

Source: cabindiy.com

Fig. 4.3: Insulated exposed pipes to prevent freezing

Manhole Cover Insulation: Insulate manhole covers **(Fig. 4.4)** to prevent freezing and ensure accessibility during cold conditions.

Source: cabindiy.com

Fig. 4.4: Rigid foam cut to shape concrete Septic Tank cover

Recommended Thickness of Insulation Materials (Example: Polyurethane Foam [PUF] Panels)

For buried tanks / below the frost line:

- Polyurethane Foam (PUF) panel: 25–30 mm
- Include protective cladding or wrapper for mechanical protection

For exposed pipes and other components:

- Polyurethane Foam (PUF) panel: 50–75 mm

PUF panels are sandwich-type panels consisting of:

- **Outer sheet:** PPGI / GI / Aluminum sheet

- **Core:** Polyurethane rigid foam (PUR)
- **Inner sheet:** PPGI / GI / Aluminum sheet

4.2 Tank Burial below the Frost Line

Burying septic tanks below the frost line helps minimize temperature fluctuations and protects the system from freezing.

- In **milder cold areas** (e.g., parts of lower Himachal Pradesh and Uttarakhand), frost may penetrate only **300–500 mm** below the ground surface. In such locations, burying the tank so that its top is at least **500 mm below ground** is generally sufficient to prevent freezing.
- In **colder regions** (e.g., Ladakh, Lahaul-Spiti, and Sikkim highlands), the frost line can reach **1–2.5 meters**, requiring deeper installation for effective protection.

4.3 Temperature Control

To sustain biological activity in cold regions, it is advisable to implement temperature control measures in sewage treatment processes. These measures may include:

- Using aerators to deliver warmer air.
- Installing electric heating coils within treatment tanks **(Fig. 4.5).**
- Leveraging internal bio-heating generated by microbial metabolism.

Before **After**

Source: cabindiy.com

Fig. 4.5: Electric Heating Coil to control frozen condition

Heating Coil Specifications

- **For a 5–10 KLD Anaerobic Reactor**
    - Power: 1.5–2.5 kW
    - Coil length: 3–6 m (stainless steel)
    - Placement: Lower 1/3rd of the tank (active sludge zone)
    - Thermostat setpoint: 25–28°C

- **For a 25–50 KLD Anaerobic Reactor**
    - Power: 3.0–6.0 kW
    - Coil length: 10–15 m (stainless steel)
    - Placement: Lower 1/3rd of the tank (active sludge zone)
    - Thermostat setpoint: 25–28°C

5. Bioaugmentation with Microbial Culture

Increasing the concentration of beneficial microbes in a septic tank system through introduction of cold temperature-adapted microbes (bioaugmentation) can significantly enhance the breakdown of organic matter.

Animal dung **(Fig. 5.1)** obtained from **native cattle, goats, sheep, yaks, horses, and other herbivorous animals** may be used as an effective bioaugmentation material for onsite sewage treatment systems in cold regions. Such dung contains a diverse consortium of microorganisms, including psychrophilic and psychrotolerant species, which can survive and function at low temperatures and thereby support biological treatment processes under cold climatic conditions.

Fig. 5.1: Animal Dung Slurry used for Bioaugmentation in Colder Regions

Animal dung can be effectively used in colder Himalayan regions as a source of essential microbes and as a biocatalyst to enhance the breakdown of organic matter. Low temperatures slow down microbial activity, reducing the efficiency of biological wastewater treatment. Animal dung is naturally rich in diverse Psychrophilic bacteria as well as organic matter, which together sustain biological processes in low-temperature environments. Details as under:

1. Microbial Diversity

Animal dung contains a wide range of microbes capable of:

- Degrading organic matter
- Maintaining activity at lower temperatures
- Supporting both aerobic and anaerobic processes

These characteristics help stabilize biological treatment steps that otherwise slow down during winter.

2. Psychrotolerant (Cold-Tolerant) Microbes

In Himalayan climates, treatment plants often face:

- Reduced biochemical reaction rates
- Poor sludge digestion
- Lower biogas production

Animal dung naturally hosts organisms adapted to fluctuating temperatures, indirectly supporting ecosystem resilience within biological treatment systems.

3. Enhancement of Anaerobic Digestion

Cold climates inhibit methane production and slow sludge breakdown. Microbes present in animal dung may:

- Support the existing microbial consortia in digesters
- Help maintain stability under temperature stress

Animal dung contains several Psychrophilic bacteria like *Psychrobacter spp.* (Aerobic or facultative anaerobic*), Cryobacterium spp.* (*Aerobic), Acinetobacter spp.* (Aerobic), *Flavobacterium spp.* (Aerobic), *Pseudomonas spp.* (Aerobic; some species are facultative anaerobes)*, Arthrobacter spp. (Aerobic; some species are facultative anaerobes), Polaromonas spp. (Facultative anaerobic), Shewanella spp. (Facultative anaerobic), Planococcus spp*. (Aerobic),

These psychrophilic bacteria are not strict anaerobes. They are primarily aerobic or facultative anaerobic, means:

- They can contribute to cold-temperature biodegradation,
- But they are not the primary anaerobic digesters

Psychrotrophic Anaerobic Bacteria (Fermenters)

These bacteria are often involved in the hydrolysis and acidogenesis steps of anaerobic digestion at low temperatures:

- Clostridium spp. – Some species are psychrotrophic anaerobes (e.g., *C. estertheticum*, *C. gasigenes*, *C. algidixylanolyticum*)
- Bacteroides spp. – Facultative anaerobes that can ferment carbohydrates at low temperatures
- Lactobacillus spp. – Psychrotolerant lactic acid bacteria contributing to acidogenesis
- Prevotella spp. – Facultative anaerobic fermenters

Methanosarcina spp., Methanobacterium spp., and Methanobrevibacter spp. are anaerobic archaea commonly present in animal dung, including in cold-region species. These psychrotolerant methanogens are essential for biogas generation, while bacteria mainly do hydrolysis and acidogenesis.

Introducing animal dung into sewage treatment systems brings these beneficial microbes into the system, which accelerates the breakdown of organic waste, particularly under low-temperature conditions.

This approach is especially valuable in colder regions where natural microbial activity is slowed due to low temperatures. A measured dose of processed animal dung can be added to onsite sewage treatment systems to enhance biological activity, improve sludge digestion, and maintain operational stability during winter months.

Dung source (Native Herbivores)	Effectiveness
Cattle	Rich in robust fermenters and methanogens; widely used in biogas production.
Yak	Adapted to high-altitude and cold environments, capable of functioning efficiently under low temperatures.
Goat/Sheep	Contains bacteria's that can survive and remain active under challenging conditions, such as cold temperatures; dung has a higher dry matter but is still effective for use as slurry.
Horse	High fiber content provides an ideal environment for cellulolytic microbes, aiding in the breakdown of plant material.

Bioaugmentation Dosage using Animal Dung (Tentative)

Septic Tanks (cold regions):

- Startup: 2–3 kg fresh dung per m³ of tank volume
- Maintenance: 0.5–1 kg per m³ monthly

Anaerobic Digesters:

- Startup: 5–10 kg fresh dung per m³ of tank volume
- Maintenance: 1–2 kg per m³ weekly until gas production stabilizes

Dry/Composting Toilets:

- Adding dried dung powder enhances decomposition and odor control

Note: *Activation of animal dung significantly increases the microbial population, improving biological treatment efficiency in cold environments.*

Activation Procedure

- Collect fresh animal dung from sources such as cow, goat, sheep, or yak.
- Mix with warm water to form a slurry.
- Incubate in a covered bucket to allow microbial multiplication.
- Add the activated slurry to the septic tank, anaerobic digester, or composting toilet system.

Selected Research & Studies on Animal Dung/Manure as Inoculum or Microbial Source

Reference/Study	**Key Findings (Relevant to bioaugmentation/waste treatment)**
Low temperature anaerobic digestion of mixtures of llama, cow and sheep manure for improved methane production *(Álvarez et al., 2009)*	Showed feasibility of anaerobic digestion with highland animal manures at low temperature.
Psychrophilic dry anaerobic digestion of cow dung for methane production: Effect of inoculum *(Zhua, G. and Jha, A.K., 2013)*	Highlighted how using cow dung as an inoculum improves process stability and methane production in cold conditions.
Effect of different livestock dungs as inoculum on anaerobic digestion of food waste *(Dhamodharan et al., 2015)*	Comparison of goat, cow, poultry, etc. as inoculum shows livestock dungs differ in performance but are all useful inoculum sources.
Biodiversity and Biotechnological Applications of Psychrotrophic Microbes Isolated from Indian Himalayan Regions *(Yadav et al., 2017)*	Psychrotrophic and psychrophilic bacteria isolated from diverse sources including cow and yak dung in high-altitude Himalayan pastures.
A comparative study of cow dung compost, goat pellets, poultry waste manure and plant debris for thermophilic, thermotolerant and mesophilic microflora with some new reports from Pakistan *(Noreen et al., 2019)*	Cow dung is a microbiological pool containing several psychrophilic, mesophilic, and thermophilic bacteria and are responsible for the degradation of complex matter into the simpler ones at different temperature ranges.
Decoding multifarious role of cow dung bacteria in mobilization of zinc fractions along with growth promotion of *C. annuum L. (Bhatt, K. and Maheswari, D.K., 2019)*	Cow dung microflora includes about 60 bacterial species dominating by Bacillus sp., Corynebacterium sp., Lactobacillus sp., few fungal sp., (Aspergillus and Trichoderma), about 100 species of

	protozoa and 2 yeasts. Studies revealed that it contains diverse groups of bacteria *viz., Acinetobacter, Serratia and Alcaligenes spp.*
Anaerobic digestion of livestock manure in cold regions: Technological advancements and global impacts *(Yao et al., 2020)*	Reviewed strategies and advancements for livestock manure digestion in cold climates.
Physico Chemical and Metagenomic Profile Analyses of Animal Manures routinely Used as Inoculum in Anaerobic Digestion for Biogas Production (Mutungwazi et al., 2022)	Compared microbial communities in cow, pig, chicken, horse manures — shows cow dung often has favorable carbon utilization and microbial diversity for anaerobic digestion. Supports use of manure as inoculum in digesters.
Yak rumen fluid inoculum increases biogas production from sheep manure substrate *(Sohail et al., 2022)*	Showed yak microbiota/rumen fluid can boost biogas from ruminant manure and provide cold-tolerant microbial communities.
Anaerobic Digestion of Pig-Manure Solids at Low Temperatures: Start-Up Strategies and Effects of Adapted Inoculum *(Rajagopal et al., 2022)*	The study shows that anaerobic digestion of pig-manure solids at low temperature can be feasible when an adapted inoculum (manure) is used. With proper strategy and inoculum, acceptable methane yields were obtained under low-temperature conditions supporting the concept of dung-based inoculum for cold-climate digesters.
Elucidating Key Microbial Drivers for Methane Production during Cold Adaptation and Psychrophilic Anaerobic Digestion of Cattle Manure and Food Waste *(Rama et al., 2024)*	Explored using cold-adapted cattle manure inoculum containing specific bacteria and archaea to enhance methane production at low temperatures.
Psychrophiles: A Journey of Hope *(Indian Academy of Sciences Review, 2024)*	Discusses psychrophiles from extreme cold habitats including Himalayan soils and dung deposits, emphasizing their genetic adaptations for survival.
Anaerobic Co Digestion of Cattle Manure and Sewage Sludge Using Different Inoculum Proportions *(Pinto et al., 2025)*	This bench-scale digestion study demonstrates that mixing cattle manure (as inoculum) with sewage sludge

	significantly improves biogas production, reduces lag phase, and increases yield — suggesting that manure inoculum helps stabilize and boost anaerobic treatment performance.
Impact of bioaugmentation on psychrophilic anaerobic digestion of corn straw: Performance, metabolic regulation, and microbial response, Bioresource Techn. *(Shang, et al., 2025*)	Explored the profound effects of bioaugmentation on microbial community and metabolic pathways during cold digestion.
Plant growth-promoting bacteria from dung of indigenous and exotic cow breeds and their effect on the growth of pea plant in sustainable agriculture *(Sagar, S. et al., 2025)*	Cow dung is a microbiological pool containing several psychrophilic, mesophilic, and thermophilic bacteria and are responsible for the degradation of complex matter into the simpler ones at different temperature ranges.
Psychrophilic Micro-organisms and their Survival Strategies for Sustainable Development *(Singh & Bhutani, 2025)*	Animal dung in cold regions was highlighted as a microbial pool where psychrophiles thrive due to nutrient richness and low temperatures.

Concluding Remarks

- Animal dung of native herbivores contains a diverse microbial community that can act as inoculum for onsite sewage treatment systems in colder hilly regions.
- Inoculation (bioaugmentation) accelerates degradation of organic matter, supports both aerobic and anaerobic pathways, and improves treatment efficiency.
- There are scientific publications supporting the use of animal dung (especially cow dung) as a microbial inoculum/bioaugmentation source for sewage treatment. This lends credibility of using dung-derived inoculum in cold-region for onsite sewage treatment.
- In cold and high-altitude regions, animal dung from cattle, goats, sheep, yaks, horses, and other herbivorous animals serve as a natural reservoir of cold-adapted microbial populations. These microorganisms, including psychrophilic and psychrotolerant species, facilitate the degradation of organic matter and support methane generation under low and sub-zero temperature conditions.
- Hence, bioaugmentation using animal dung of native herbivores is a promising approach, it is reasonable to include animal dung-based bioaugmentation as a recommended supplementary measure to improve biological treatment efficiency in cold Indian Himalayan Region.

6. Conclusions

i. This document presents an assessment of sanitation approaches and onsite sewage treatment processes practiced in cold-impacted regions globally and examines their applicability under similar climatic conditions in India. The intent is to support evidence-based decision-making for planning, design, implementation, and operation of sanitation systems in cold and hilly regions of the country.

ii. Sewage treatment systems based on biological processes are significantly affected by prolonged low-temperature conditions. At temperatures around 10 °C, microbial growth rates, metabolic activity, and substrate utilization reduce by approximately 50 percent compared to normal operating conditions, while at temperatures below 4 °C, microbial activity largely ceases due to dormancy. These limitations must be duly considered while selecting and designing onsite sanitation systems for cold regions.

iii. The document provides guidance to administrators, engineers, and local communities for effective management of onsite sewage treatment systems to ensure functionality, service reliability, and improved living conditions. The sanitation technologies discussed are simple, robust, and field-proven, and can deliver the required level of service while ensuring protection of public health and the environment.

iv. The selection of sanitation systems in cold regions shall be based on local water availability, climatic conditions, settlement patterns, and operational feasibility. The primary options include wet (water-flushed) toilets and dry toilets. Wet sanitation systems shall be adopted only where adequate water supply is assured and all system components—including toilets, conveyance pipelines, and treatment units—are protected against freezing through appropriate insulation and design measures. Such systems require sufficient water for flushing and conveyance of excreta to treatment units such as septic tanks or packaged onsite sewage treatment systems.

v. In habitations experiencing seasonal migration and intermittent occupancy during winter months, discontinuation of piped water supply is a common practice to prevent freezing and pipe damage. In such cases, reliance on water-intensive sanitation systems may not be feasible, and alternative sanitation options shall be considered.

vi. In cold-impacted areas, conventional septic tanks followed by soak pits remain the most prevalent onsite sanitation systems. These systems shall be appropriately winterized using locally available materials, such as an insulating layer of 200–300 mm (8–12 inches) of mulch (straw, leaves, etc.) or suitable insulation materials including foam, rubber, or plastic, placed over tanks and drain fields to limit frost penetration.

vii. Alternative onsite sanitation systems such as Flush-Tank-Haul and cesspool systems may be considered where soil conditions, groundwater protection requirements, and service arrangements permit. Flush-Tank-Haul systems involve the collection of sewage in sealed underground holding tanks with no discharge to the soil and require periodic evacuation through mechanical pumping. Cesspool systems allow partial percolation of liquid effluent into surrounding soil while solids accumulate and require regular removal and shall be used only where environmental and public health safeguards can be ensured.

viii. Packaged onsite wastewater treatment systems, including anaerobic packaged systems and Johkasou units combining anaerobic and aerobic processes, provide technically sound and sustainable alternatives for cold regions. These prefabricated systems are based on established treatment processes such as sedimentation, biological degradation, and filtration, and shall be selected with due consideration to their performance under low-temperature conditions, ease of operation, and maintenance requirements.

ix. The use of animal dung from cattle, goats, sheep, yaks, horses, and other native herbivores as a source of microbial inoculum may be adopted as a supplementary measure to enhance treatment performance in cold regions. Bioaugmentation introduces diverse microbial populations that support both aerobic and anaerobic degradation pathways and can improve organic matter breakdown under low-temperature conditions

x. Dry toilets Is a viable, water-efficient, and cost-effective sanitation option in areas with limited water availability and severe cold conditions. Traditional dry toilets used in Himalayan regions demonstrate climatic suitability and local acceptance. Existing dry pit toilets may be upgraded to urine-diverting dry toilets (UDDTs) to improve hygiene, reduce moisture content, and facilitate safe treatment and reuse. In UDDTs, fecal matter shall be covered with sawdust or ash to control odor, reduce moisture, and support composting, thereby enhancing environmental sustainability.

Overall, onsite sewage treatment in cold regions requires climate-responsive planning, appropriate technology selection, and sound operation and maintenance practices. Adoption of the measures outlined in this document will help ensure year-round system functionality, protection of public health, environmental sustainability, and cost-effective sanitation service delivery in cold-impacted regions of India.

References

Alaska Rural Water and Sanitation Working Group. 2015. Alaskan Water and Sanitation Retrospective: 1970–2005. Anchorage, AK; Arlington, VA: United States Arctic Research Commission.

Álvarez, R., and Lidén, G. 2009. Low temperature anaerobic digestion of mixtures of llama, cow and sheep manure for improved methane production. Biomass and Bioenergy, 33(3), 527-533.

Bhatt, K. and Maheswari, D.K., 2019. Decoding multifarious role of cow dung bacteria in mobilization of zinc fractions along with growth promotion of *C. annuum L.* Nature Scientific Reports, 9, 14232.

BIS, GoI. 1985. Code of Practice for installation of Septic Tanks, (IS-2470 Part 1(1985), Design Criteria and Construction (Second Revision).

BIS, GoI. 1993. Code of Basic Requirements for Water Supply, Drainage and Sanitation, (BIS 1172: 1993).

BIS. GoI. 2024. Packaged Sewage Treatment Plant – Specifications (IS 18797:2024).

Bunce, J.T., Graham, D.W. 2019. A simple approach to predicting the reliability of small wastewater treatment plants. Water (Switzerland), 11, 2397.

CPHEEO Manual, 2013. Sewerage and Sewage Treatment Systems: Part A (Engineering), Part B (Operation and Maintenance), and Part C (Management) for design and construction, Operation and Maintenance, and Management guidelines for sewage treatment facilities.

CPHEEO, 2018. Advisory on Public and Community Toilets for planning, implementation, O&M and monitoring and evaluation of public sanitation facilities such as public and community toilets.

CPHEEO, 2018. Standard Operating Procedure (SOP) for Cleaning Sewers and Septic Tanks.

CPHEEO, 2020. Advisory on On-site and Off-site Sewage Management Practices.

Dhamodharan, K., Kumar, V. and Kalamdhad, A.S. 2015. Effect of different livestock dungs as inoculum on anaerobic digestion of food waste, Bioresource Technology, 180, 237-241.

Donati, P. 2015. Sanitation in Mongolia: Challenges and Recommendations. Ulaanbaatar, Mongolia: ACF (Action Contre le Faim).

Franceys, R., J. Pickford, and R. Reed. 1992. A Guide to the Development of On-Site Sanitation. Geneva, Switzerland: WHO (World Health Organization).

Grebot, B., Illes, A., Madzharova, G., Scarlat, A., Anderson, N. and Fribourg-Blanc, B. 2019. Urban Wastewater – Non-Connected Dwellings, Final report. European Environment Agency (EEA).

GV Jones and Associates, Inc. 2015. Improving Sanitation in Cold Regions: Technical Options Study for Ger Areas of Ulaanbaatar, Mongolia. Final Draft. Unpublished report for World Bank, 2015a.

Herrmann, I., Nordqvist, K., Hedstr¨om, A. and Viklander, M. 2014. Effect of temperature on the performance of laboratory-scale phosphorus-removing filter beds in on-site wastewater treatment. Chemosphere 117, 360–366.

Jenkins, Joseph. 2006. Feasibility Study: Sanitation Options for Ger Communities in Mongolia Focusing on Humanure Compost Toilet Systems, or 'Bio-Toilets. Grove City, PA: Joseph Jenkins, Inc.

Johannessen, E., Eikum, A.S., Ek, M., Krogstad, T. and Junestedt, C. 2012. Performance of Prefabricated Package Plants for onsite Wastewater Treatment in the Vansjø- and Hobøl Watershed (Morsa), Norway. Vatten - Journal of Water Management and Research, 68, 107–114.

Källqvist, T., Molvær, J., Oug, E., Berge, D., Tjomsland, T. and Johansen, S.S. 2002. Implementation of the Urban Wastewater Treatment Directive in Norway: An Evaluation of the Norwegian Approach regarding Wastewater Treatment. Norwegian Institute of Water Research (NIVA), Oslo. Report SNO 4466-2001.

Kinnunen J., Rossi P.M., Herrmann I., Ronkanen A-K. and Heiderscheidt E. 2021. Factors affecting effluent quality in on-site decentralized wastewater treatment systems in cold climate regions. Nordic Wastewater Conference, NORDIWA -2021.

Livingstone, A. J., Ch. Erdenechimeg, and A. Oyunsuvd. 2009. Needs Assessment on Institutional Capacity for Water Governance in Mongolia. Ulaanbaatar, Mongolia: UNDP.

Matikka, V. 2013. Rural wastewater treatment in Finland. Savonia University of Applied Sciences, Kuopio.

McConville, J.R., Kvarnström, E., Jönsson, H., Kärrman, E. and Johansson, M. 2017. Source separation: Challenges & opportunities for transition in the Swedish wastewater sector. Resources, Conservation and Recycling, 120: 144-156.

Mutungwazi, A., Ijoma, G.N., Ogola, H.J.O., and Matambo, T.S. 2022. Physico-Chemical and Metagenomic Profile Analyses of Animal Manures Routinely Used as Inocula in Anaerobic Digestion for Biogas Production. Microorganisms,10(4), 671.

Nedwell, D.B., 1999. Effect of low temperature on microbial growth: lowered affinity for substrates limits growth at low temperature. FEMS Microbiol. Ecol., 30, 101-111.

Noreen, N., Ramzan, N. and Shazad, S. 2019. A comparative study of cow dung compost, goat pellets, poultry waste manure and plant debris for thermophilic, thermotolerant and mesophilic microflora with some new reports from Pakistan, 91991993.

Paderi, V. 2021. Overview report on the regulation and management of decentralized sanitation. WHO Report.

Pinto, C.C., Paes, J.L., Gomes, A., Cecchin, D., Oliva, I.F., Valadao, R.C., Anna, V.R. 2025. Anaerobic Co-Digestion of Cattle Manure and Sewage Sludge Using Different Inoculum Proportions. Fermentation, 11(7), 373.

Rajagopal, R., Bele, V., Cata Saady, N.M., Hickmann, F.M.W. and Goyette, B. 2022. Anaerobic Digestion of Pig-Manure Solids at Low Temperatures: Start-Up Strategies and Effects of Mode of Operation, Adapted Inoculum, and Bedding Material. Bioengineering, 9(9),435.

Rama, H., Ndaba, B., Dhlamini, M.S., Cochrane, N., Maaza, M. and Roopnarain, A. 2024. Elucidating Key Microbial Drivers for Methane Production during Cold Adaptation and Psychrophilic Anaerobic Digestion of Cattle Manure and Food Waste. Fermentation,10(7), 370.

Ryndin, R., and E. Tuuguu. 2015. Composting Manual for Cold Climate Countries. Ulaanbaatar, Mongolia.

Sagar, S., Singh, A., Bala, J., Chauhan, R., Kumar, R., Badiyal, A. and Walia, A. 2025. Plant growth-promoting bacteria from dung of indigenous and exotic cow breeds and their effect on the growth of pea plant in sustainable agriculture. Biotechnology for the Environment, Springer Nature, 2(3), 1-20.

Seefeldt, Steve. 2011. Composting in Alaska. Fairbanks: University of Alaska.

Shaheen, H., Khan, S.M., Harper, D.M., Ullah, Z., and Qureshi, R.A. 2011. Species diversity, community structure, and distribution patterns in western Himalayan alpine pastures of Kashmir, Mt. Res. Dev., 31(2),153-159.

Shang, Z., Zhang, X., Cheng, X., Li, S., Liang, X., Tao, Y., Sun, Y. and Yu, Q. and Li, Y. 2025. Impact of bioaugmentation on psychrophilic anaerobic digestion of corn straw:

Performance, metabolic regulation, and microbial response, Bioresource Technology, 417, 131886.

Singh, M. and Bhutani, S. (2025). Psychrophilic Micro-organisms and Their Survival Strategies for Sustainable Development. Journal of Pharmacognosy and Phytochemistry 2025; 14(2): 179-182.

Smith, D.W., Ryan, W.L., Christensen, V., Crum, J., and Heinke. G.W. 1996. Cold Regions Utilities Monograph. 3rd ed. Reston, VA: American Society of Civil Engineers.

Sohail, M., Khan. A., Badshah, M., Degen. A., Yang, G., Liu, Hu., Zhou, J., and Long, R. 2022. Yak rumen fluid inoculum increases biogas production from sheep manure substrate. Bioresource Technology, 251700162.

Tendulkar, S., Hattiholi, A., Chavadar, M. and Dodamani, S. (2024). Psychrophiles: A Journey of Hope. Indian Academy of Sciences Review, J. BioSci, 46-64.

Tilley, Elizabeth, Lukas Ulrich, Christoph Lüthi, Philippe Reymond, and Christian Zerbrügg. 2014. Compendium of Sanitation Systems and Technologies. 2nd rev. ed. Dübendorf, Switzerland: Swiss, Federal Institute of Aquatic Science and Technology (Eawag).

Vuokko Laukka, Johanna Kallio, Inga Herrmann, Riikka Malila, Ritva Nilivaara, Elisangela Heiderscheidt. 2022. Governance of on-site sanitation in Finland, Sweden and Norway. Reports of the Finnish Environment Institute, 1-83.

WHO (World Health Organization). 2006. Guidelines for the safe use of wastewater, excreta and grey water. Vol 2, Wastewater use in agriculture. Geneva,

World Bank Report. 2019. Improving Sanitation in Colder Regions,1-71.

Yadav, A.J., Verma, P., Sachan, S.G. and Saxena, A.K. 2017. Biodiversity and Biotechnological Applications of Psychrotrophic Microbes Isolated from Indian Himalayan Regions. EC Microbiology ECO.01, 48-54.

Yao, Y., Huang, G., An, C., Chen, X., Zhang, P., Xin, X., Shen, J. and Agnew, J. 2020. Anaerobic digestion of livestock manure in cold regions: Technological advancements and global impacts. Renewable and Sustainable Energy Reviews, Elsevier,119.

Zhou, H., Li, X., Xu, G., Yu, H. 2018. Overview of strategies for enhanced treatment of municipal/domestic wastewater at low temp. Sci. Total Environ., 643, 225-237.

Zhua, G. and Jha, A.K. 2013. Psychrophilic dry anaerobic digestion of cow dung for methane production: Effect of inoculum. Science Asia, 39, 500-510.

APPENDIX

GLOBAL CASE STUDIES

1. Onsite Sanitation in Alaska and Canada

Pour-flush toilets are rarely used in Alaska and other cold regions due to issues with pipeline and vault freezing. In Canada, systems that use small flush volumes into insulated vaults—which are emptied regularly—have been employed successfully. To prevent problems, outside vaults must be well-insulated or heated, as frozen waste can damage the vaults and cannot be removed until it thaws.

Common Onsite Sanitation Systems in Alaska

- **Septic Systems**: Common in more accessible rural areas; consist of septic tanks and drain fields. Require well-draining soil for proper function.
- **Holding Tanks**: Used where soil conditions prevent infiltration; waste is stored and periodically removed.
- **Composting Toilets**: Popular in off-grid homes and cabins; treat waste on-site to produce safe compost.
- **Honey Bucket Systems**: Used in some small, remote villages; households collect waste in buckets, which are then manually disposed.

Common Onsite Sanitation Systems in Canada

- **Septic Systems**: Widely used in rural homes; consist of septic tanks with drain fields or treatment beds.
- **Holding Tanks**: Used in areas where soil drainage is not possible; waste is stored and periodically removed.
- **Composting Toilets**: Especially common in off-grid cabins and Indigenous communities; treat waste on-site to produce safe compost.
- **Packaged Treatment Plants**: Used in small communities, particularly in Northern Alaska and Indigenous areas; provide compact, pre-engineered wastewater treatment solutions.

Concluding Remarks

Septic Tanks with Drain Fields are the most common system in rural areas, relying on soil for wastewater treatment and infiltration. Composting Toilets are widely used in off-grid homes and Indigenous communities, treating waste on-site to produce safe compost. Packaged Treatment Plants are employed in small communities, particularly in Northern regions and Indigenous areas, providing compact, pre-engineered wastewater treatment.

2. Onsite Sanitation in Peri-Urban Areas of Ulaanbaatar, Mongolia

Ulaanbaatar, the coldest national capital in the world, experiences soil freezing to 3–4 meters in winter and some discontinuous permafrost. Only about 40% of the population has access to piped water and sewer networks at home. Over 75,000 peri-urban residents rely on basic pit toilets for sanitation (World Bank Report, 2019).

Container-Based Sanitation

The international NGO Action Contre le Faim (ACF) implemented a project from 2009 to 2015 to explore container-based sanitation as a solution to improve sanitation in Ulaanbaatar. The project focused on urine-diverting dry toilets with off-site composting.

Design and Operation

- Most models featured a raised user interface, with the faeces container placed on a ground-level slab below.
- One model used a movable ground-level superstructure, with receptacles placed in a pit; however, lifting full containers from the pit was difficult.
- Urine was diverted to a soak pit to seep into the ground.
- Sawdust was added to faeces after defecation to aid composting.

Collection and Treatment

- Containers filled with faeces and sawdust were transported to a central composting facility for treatment.
- During the warm season, the entire year's faecal sludge could be composed successfully.
- In the cold season, excreta is stored in household containers and collected in spring for treatment.

Findings

- The project demonstrated that container-based sanitation with off-site composting is technically feasible in Ulaanbaatar's cold climate.

Wet Sanitation

According to a World Bank (2019) socioeconomic survey, only about 3% of households in detached homes in the Ger areas of Ulaanbaatar have flush toilets, despite not being connected to sewer or piped water systems.

- Household Plumbing: These homes include flush toilets and piped water for kitchen, bathing, and laundry. Water is purchased and delivered by vehicle and stored in household tanks.
- Wastewater Management: Both greywater and blackwater flow through household sewer pipes to a storage tank or soak pit. The collected wastewater is then emptied by vacuum tanker and discharged into the city's sewer network.

Concluding Remarks

About 40% of the population has access to piped water and sewer networks in their homes. More than 75,000 peri-urban residents rely on basic pit toilets for sanitation

(World Bank, 2019). Only about 3% of households in detached homes in the Ger areas have flush toilets, even though they are not connected to a sewer or piped water supply. In these homes, both greywater and blackwater are conveyed through household-level sewer pipes to a storage tank or soak pit for later removal or treatment.

3. Onsite Sanitation in Greenland

Greenland has a cold climate with long winters and a scattered population living mainly in isolated coastal communities. Sanitation systems vary depending on the location:

- **Towns:** Residents use either traditional flush toilets or bucket toilets, depending on the availability of water.
    - **Flush toilets** are connected to either a sewer system or a holding tank. Holding tanks are emptied by municipalities or private companies, with waste eventually discharged to sewers. Greywater is often discharged onto the ground surface.
- **Scattered Communities:** The bucket toilet is almost universal. Some excreta are disposed of in sewers, while some are thrown onto open land or into the sea, raising concerns about pollution and health risks.

Common Onsite Sanitation Systems in Greenland

- **Honey Bucket Systems:** Still widely used; human waste is collected in buckets or containers and transported, often manually, to centralized disposal areas.
- **Composting Toilets:** Increasingly popular in eco-conscious and remote areas; suitable for locations with no water or plumbing.
- **Closed Container Systems:** Wastewater is collected in sealed tanks that are periodically emptied.
- **Basic Greywater Drainage:** Greywater is often separated from toilet waste and sometimes disposed of untreated into the environment.

Concluding Remarks

Greenland has long winters and a scattered population living in isolated communities. In towns, residents use either traditional flush toilets or bucket toilets, depending on the availability of water. In more remote, scattered communities, the use of bucket toilets is nearly universal.

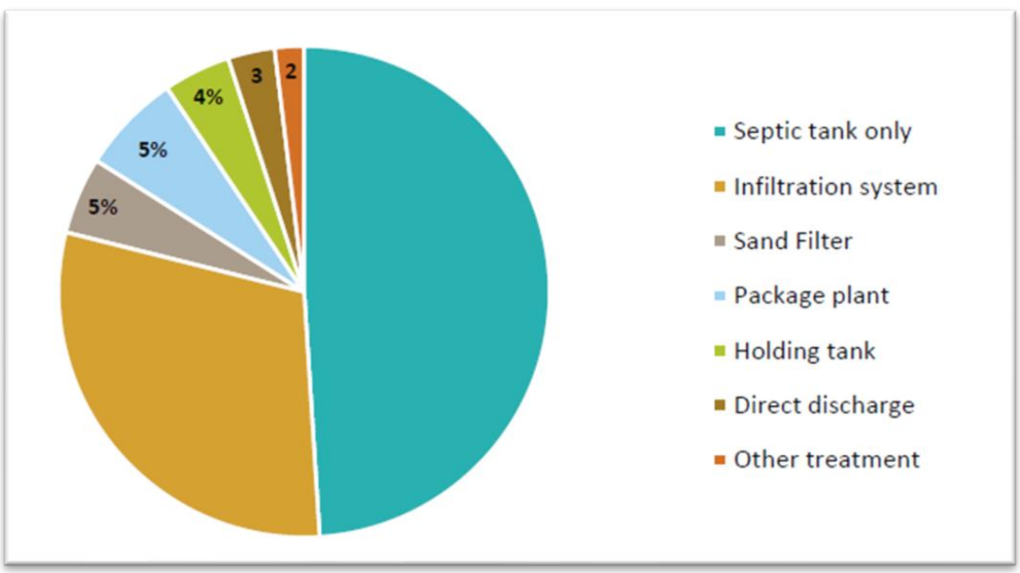
4. Onsite Sanitation in Norway

Onsite sanitation in Norway refers to decentralized systems serving areas not connected to municipal sewer networks.

- **Scale and Distribution**

- Approximately 377,000 small sewage plants (<50 PE) are in operation (excluding leisure homes), serving just over 792,000 people (Statistics Norway, 2021).
- The majority are septic tanks only (>184,500 units), while fewer than half use infiltration systems (>113,000 units) as secondary treatment.

- **Package Treatment Plants**
  - Introduced in the 1990s, these combine mechanical, biological, and chemical treatment in one unit.
  - While readily available, conventional systems (septic tanks followed by infiltration) remain the most common.
- **System Performance and Challenges**
  - According to a review of onsite wastewater treatment systems, 50–90% of facilities do not function as designed and require replacement.
  - Upgrading these systems requires significant investment, a skilled workforce, and proper design and execution services.
  - The available skilled workforce is limited in all regions of Norway.
- **Leisure Homes**
  - Norway has about 440,000 leisure homes, most located outside sewered areas, adding further demand for onsite sanitation systems.



Source: Finnish Environment Institute

Proportion of inhabitants connected to different treatment systems (serving <50 PE, excluding leisure homes) (Statistics Norway 2021)

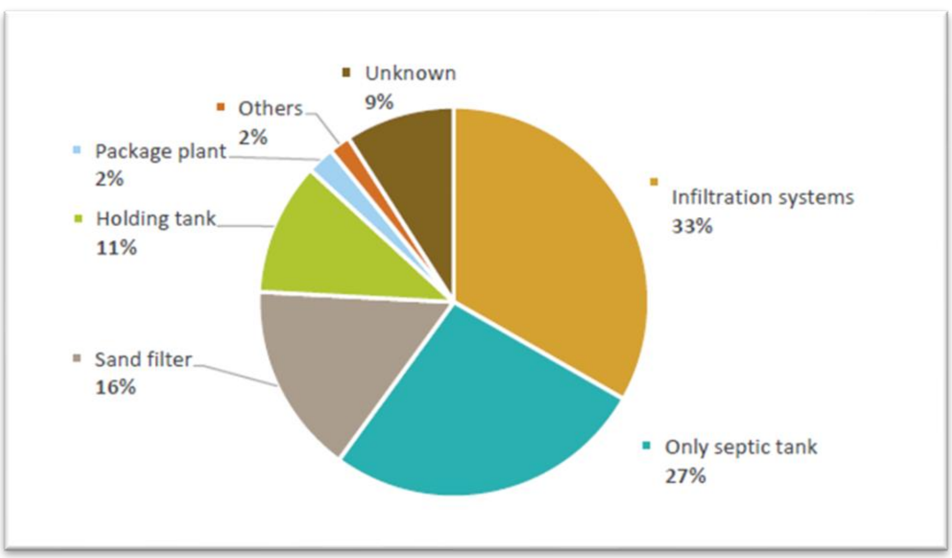
Concluding Remarks

Most units consist of septic tanks only (>184,500 units), while fewer than half use infiltration systems (>113,000 units) as secondary treatment. Although small package treatment plants are readily available and in use, conventional systems—septic tanks followed by infiltration—remain the most common onsite sanitation units in operation.

5. Onsite Sanitation in Sweden

About 12% of the population, or approximately 965,126 detached houses, are not connected to municipal sewer networks and must manage their own onsite sanitation systems (Statistics Sweden, 2019).

- **Types of Systems Used**
  - **Infiltration systems (wastewater drain fields):** Most common, used in 33% of households.
  - **Septic tanks only:** Used in 27% of households.
  - **Sand filter systems:** Used in 16% of households.
- **Challenges**
  - Many onsite systems are poorly maintained, resulting in insufficient treatment efficiency.
  - A significant number of systems are old and/or consist of only a septic tank, requiring upgrading.
  - In 2009, about 133,000 sites (~20% of all sites) still relied on septic tanks alone for wastewater treatment.



Source: Finnish Environment Institute

Types of sanitation systems used on properties with detached houses that are not connected to municipal wastewater services (2018)

In recent years, municipalities have become more active, initiating campaigns to systematically identify onsite treatment systems and improve them. Many systems have already been renewed or upgraded. However, as of 2018, approximately 27% of all onsite systems still consist of only a septic tank with no secondary treatment.

Concluding Remarks

- **Infiltration systems (wastewater drain fields):** Most common, used in 33% of properties.
- **Septic tanks only:** Used in 27% of properties, representing the portion of systems with no secondary treatment as of 2018.
- **Sand filter systems:** Used in 16% of properties.

Despite ongoing municipal efforts to upgrade and improve onsite systems, a significant proportion of homes still rely solely on septic tanks without secondary treatment.

6. Onsite Sanitation in Finland

- Approximately 15% of the population (~800,000 inhabitants) permanently live in dwellings not connected to municipal sewer networks (2021).
- There are around 500,000 leisure homes, of which 95% are not connected to municipal sewer systems.
- **Regulations and Treatment Requirements**
  - In 2004, regulations for onsite sanitation were established, setting treatment requirements for properties outside municipal sewer networks.
  - Options for improving wastewater treatment include:
    1. Connecting the property to the nearest sewer network (municipal or consortium-managed).
    2. Upgrading or constructing a new onsite treatment system.
- **Characteristics of Onsite Systems in Finland**
  - Typically, they serve one or a few households not connected to networks, though some small water associations serve fewer than 100 inhabitants.
  - Available system types include:
    - Holding tanks
    - Soil treatment systems (e.g., sand filter or infiltration field)
    - Packaged plants
    - Constructed wetlands
- **Assessment of Prevailing State**
  - Properties built after 2004 are assumed to have proper onsite sanitation systems.

- Data from 2013–2019, based on property visits without owner initiative, provide indicative estimates of the state of onsite sanitation in Finland (as presented in the accompanying table).

Estimation of the percentages of different types of on-site wastewater treatment systems in permanently inhabited properties constructed before 2004 (n = 18,942). The systems are divided according to how they meet the requirements of the Regulation. BW = Black Water, GW = Grey Water.

Treatment system presented by efficiency and type	Percentage (%)
System does not meet the required treatment efficiency	
Septic tank, no secondary treatment	42
Other (not sufficient treatment)	16
Source separation (treatment system varies)	9
Total	67
System meets the requirements, but requires minor maintenance work, or need upgradation	
Old sand filter or infiltration field	4
Source separation (treatment system varies)	6
Other	4
Total	14
System meets the requirements	
Functional and sufficient sand filter or infiltration field	6
Functional and sufficient package plant	5
All wastewater to holding tank	2
Holding tank (BW) + functional and sufficient sand filter or infiltration field (GW)	3
Holding tank (BW) + functional and sufficient package plant (GW)	0.3
Holding tank (BW) + other sufficient greywater treatment system	0.1
Dry toilet + functional and sufficient sand filter or infiltration field	0.3
Dry toilet + functional and sufficient package plant	0.1
Other	0.1

Total	**16.9**
No treatment requirement, amount of wastewater very less	
Dry toilet	**1.8**

This table organizes the efficiency and type of treatment systems clearly, showing which systems fail, partially meet, or fully meet regulatory requirements.

Concluding Remarks

The data indicates that for permanently inhabited properties, the most common onsite wastewater treatment system is a septic tank with no secondary treatment (42%), which does not meet regulatory requirements. Among systems that meet the requirements, the most frequently used are infiltration fields, followed by package plants and holding tanks.

For leisure homes, the most used systems are holding tanks and dry toilets.

7. Onsite Sanitation in Russia

Sanitation in Russia varies greatly between urban centers and rural or remote areas, with climate playing a significant role in system design.

1. Urban Areas

- **Coverage:** Most major cities (e.g., Moscow, St. Petersburg, Kazan) have modern wastewater treatment systems.
- **Technology:** Centralized wastewater treatment plants (WWTPs) handle sewage and greywater.

2. Rural & Remote Areas

- **Challenges:**
  - Limited or no access to piped water and sewer networks.
  - Harsh climates in regions like Siberia conventional sanitation is difficult.
- **Onsite Solutions:**
  - Septic tanks with percolation trenches.
  - Dry or composting toilets in Arctic and permafrost zones.
  - Small-scale treatment units, including biofilters and packaged plants.

3. Cold Climate Adaptations

- Insulated or heated toilets in permafrost areas.
- Vacuum toilets in high-rise buildings to reduce water use.
- **Johkasou-type decentralized treatment systems** are being piloted in extremely cold settlements.

Case Studies:

Location: Yakutsk, Russia (Sakha Republic)
Climate: Winter temperatures can drop to −50°C; continuous permafrost
Population served • Approximately 100,000 people are not connected to centralized sewage.
System used • Indoor dry toilets with sealed tanks. • Tanks are insulated and sometimes with heated arrangement.
Outcome • Systems are reliable during extreme winters, though heating costs remain high.
Location: Tiksi, Russia (Arctic Coast, Sakha Republic)
Region: Arctic coast, permafrost zone
Issue: Traditional sewer lines freeze; no centralized treatment.
System used • Installed modular dry toilets with composting units housed in insulated containers. Waste is composted and subsequently disposed of off-site.
Outcome • These onsite sanitation interventions have significantly reduced open defecation in the communities.
3. Chukotka Autonomous Okrug, Russia
Region: Extreme northeast, indigenous settlements.
Issue: Lack of sewer systems, extreme cold.
System used • Pilot project with solar-powered toilets. • Use of portable anaerobic digesters.
Outcome Reduced reliance on traditional “honey buckets”.

Concluding Remarks

In harsh climate conditions, many areas rely on conventional sanitation systems, such as pit toilets and septic tanks with percolation trenches. In Arctic and permafrost regions, dry or composting toilets are commonly used. Additionally, small-scale wastewater treatment units, including biofilters and packaged plants (Johkasou systems), are increasingly implemented.

Prepared by

Technical Support Unit

RITES
THE INFRASTRUCTURE PEOPLE

We Shape What Shapes Lives

Swachh Bharat Mission - Urban 2.0

www.sbmurban.org

@SwachhBharatGov | @SwachhBharatUrban | @sbmurbangov | @swachhbharaturban