CIRCULAR SANITATION | TOOLBOX

PRACTICAL GUIDES FOR RESOURCE-ORIENTED, DECENTRALIZED SANITATION

eawag
aquatic research

INTRODUCING THE TOOLBOX

BACKGROUND & SCOPE

Circular Sanitation*, as presented in this toolbox, refers to approaches for treating wastewater that focus on recovering valuable resources, such as water, nutrients, and energy, for safe reuse. These solutions also prioritize the protection of human health and the environment. Unlike centralized, sewer-based systems, circular sanitation often works best at smaller, decentralized scales and by separating waste streams at the source.

The Circular Sanitation TOOLBOX was created in response to requests from practitioners looking for know-how on resource-oriented and/or decentralized sanitation. Information in this emerging field is dispersed and difficult to navigate, particularly for newcomers. There is a demand for simplified information curated to stakeholders, beyond the environmental engineer, who play a key role in the planning, construction, and management of sanitation systems.

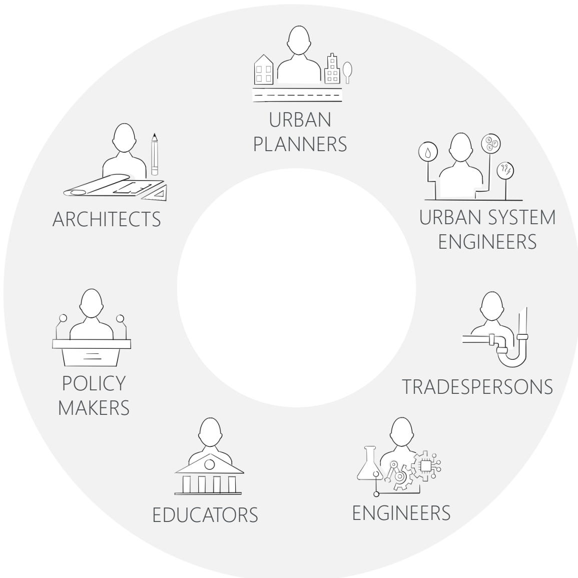
To this end, the toolbox facilitates access to knowledge by presenting information that is brief, structured, and visually engaging. It does so by categorizing information across three levels of guides: goals, strategies, and technologies (see 'What's in the Toolbox'). While each guide functions as a stand-alone document, guides can also be used together to build a narrative that answers to "What goal do I want to achieve? Which strategy can I implement to achieve that goal? And which technology, and/or treatment train, suits my context and needs?"

In addition to general information, the guides present case studies to illustrate strategies and technologies relevant for urban, peri-urban and rural contexts, from single household to neighborhood scales. The case studies also provide examples of relevant metrics, such as space requirements, scale, costs and energy. Typical values for such metrics are beyond the scope of the toolbox because they vary per configuration, context and implementation scale. Rather, the toolbox's success lies in the documents' brevity, structure, and visual appeal as a navigational portfolio to explore possible configurations for circular sanitation.

* Circular Sanitation is also referred to as: Resource-Oriented Sanitation, Decentralized Sanitation, Source-Separated Sanitation, Ecological Sanitation (EcoSan), New Sanitation, New Alternative Sanitation Systems (NASS), Non-sewered Sanitation, Productive Sanitation, Reuse-Oriented Sanitation

TARGET AUDIENCE

The toolbox is useful for architects and planners, that are responsible for including circular sanitation in projects and developments. For this audience it is intended to provide an initial overview of options and to function as a communicative planning tool with project stakeholders. The toolbox is also useful for policy makers, educators, engineers, and tradespersons looking for simplified information.



The Circular Sanitation Toolbox has been created and developed by the Water Hub, a research project on resource-oriented sanitation by Eawag: Swiss Federal Institute of Aquatic Science and Technology (www.eawag.ch). The Water Hub includes a laboratory located in the basement of the NEST building (www.empa.ch/web/nest), which offers a platform for the testing of new technologies for decentralized treatment of greywater, urine and feces, under real conditions. The Water Hub is open to testing and developing these technologies together with external industrial partners and stakeholders to accelerate the uptake of these innovative systems from research to practice. Exchange with external stakeholders during the projects prompted the Water Hub to fill the gap on access to knowledge on resource-oriented, decentralized sanitation.

WHAT'S IN THE TOOLBOX

BOOKLET

The booklet introduces the toolbox and its parts. It positions the broad portfolio of circular sanitation solutions within the boundaries of urban water management.

SUPPORTING DOCUMENTS

An online repository includes reference documents that are complimentary to the toolbox, such as factsheets, guidelines, decision support tools, and literature references, as well as a database of case studies.

Available at: www.eawag.ch/en/wh/toolbox

GUIDES

Guides present summarized information per goal, strategy and technology. The chosen categorization aims for detail and clarity, while avoiding repetition of information. Each guide functions as a stand-alone document, though used together they can help practitioners build a story: from identifying their goals, to exploring different implementation strategies, to selecting appropriate technologies.

The guides help users consider the potential of integrating circular sanitation strategies and technologies at a given location, however, do not specify design, space, cost and energy requirements. The many case studies do provide an indication of metrics as well as possible and opportune scales, configurations, and contexts.

New guides can be added to the stack as new goals and strategies arise, or new technologies are developed and established.

IDENTIFY
GOALS

- SAVE WATER
- RECOVER NUTRIENTS & ORGANICS
- SAVE ENERGY
- BUILD RESILIENT CITIES
- TREAT DECENTRALLY

EXPLORE
STRATEGIES

- URINE DIVERSION
- DRY SANITATION
- VACUUM SANITATION
- FLUSH SANITATION
- WATER REUSE
- WATER EFFICIENT FIXTURES
- RAINWATER HARVESTING
- HEAT RECOVERY

SELECT
TECHNOLOGIES

- T.1 URINE STORAGE | PASTEURIZATION
- T.2 NITRIFICATION ON BIOCHAR
- T.3 NITRIFICATION - DISTILLATION
- T.4 STRUVITE PRECIPITATION
- T.5 AMMONIA STRIPPING
- T.21 ON-SITE COMPOSTING
- T.22 OFF-SITE COMPOSTING
- T.23 ANAEROBIC DIGESTION
- T.41 WATER TANKS & CISTERNS
- T.42 SETTLING TANKS | SCREENS
- T.43 VERMIFILTERS
- T.44 CONSTRUCTED WETLANDS
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- T.61 HEAT EXCHANGERS | HEAT PUMPS

GOALS FOR CIRCULAR SANITATION

Practitioners are often driven to achieve one or more goals to respond to general, and often context-specific, challenges. A well-defined goal helps to identify context-appropriate solutions, and filter the option space of circular sanitation strategies and technologies. The overarching goals below serve as an entry point to the toolbox.

SAVE WATER

Freshwater resources are under growing pressure from climate change (e.g., heat waves, droughts) and rapid urbanization, leading to increased water scarcity in many parts of the world. Decreased and variable supply, paired with higher demand and greater water use contribute to this issue. Reducing demand, reusing water, and utilizing renewable sources like rainwater can enhance local water availability.

RECOVER NUTRIENTS & ORGANICS

Current linear nutrient flows involve: 1) resource-intensive fertilizer production dependent on fossil fuels and finite ore reserves, 2) farming systems that deplete soil nutrients and organic matter, and 3) waste management practices that lead to nutrient loss to air, water, and landfills, and pollution, like the eutrophication of surface waters. Recovering nutrients and organic matter from human excreta can reduce losses and produce renewable fertilizers.

SAVE ENERGY

Heating of domestic water often relies on fossil fuels. Residual heat from showers, sinks, and appliances quickly dissipates into the receiving sewer system and wastewater treatment plant. Energy savings can be achieved by reducing hot water usage or recovering heat from wastewater near the source. Additionally, organic matter can be valorized to produce biogas.

BUILD RESILIENT CITIES

Urbanization impacts resource flows, concentrating water, nutrient, and energy use and loss. Warmer weather increases cooling and irrigation demand, while heavy rainfall causes more stormwater overflows into sewers. Recovering resources from wastewater and linking urban functions (e.g., domestic wastewater and urban landscaping) can boost self-sufficiency and climate resilience. Sustainable building certifications like BREEAM and LEED* recognize sanitation contributions to meet their criteria. Certified projects often enhance public image and property values.

TREAT DECENTRALLY

In some areas, centralized infrastructure is absent, such as in remote locations or where urbanization outpaces development. In other contexts, existing systems may be at capacity. Decentralized treatment can extend infrastructure capacity to defer costly investments, and provide flexible, autonomous solutions for design and operation. Decentralized treatment can be an alternative or compliment centralized infrastructure.

* BREEAM: Building Research Establishment Environmental Assessment Method; LEED: Leadership in Energy and Environmental Design

APPROACHES TO URBAN WATER MANAGEMENT

Urban water management is the practice of managing water resources in the urban environment. Current management, often underpinned by large, centralized infrastructure, has greatly improved public health and protection of the natural and urban environment. In the face of growing global challenges such as resource scarcity, water pollution, climate change, urbanization, and aging infrastructure, it is beneficial to explore a broader range of strategies to achieve urban water management and sanitation. In other words, the coexistence of solutions of different scales and configurations may be considered.

Circular Sanitation focuses on the recovery of water, nutrients and organic matter, and energy from source-separated wastewater streams, to reduce impacts of resource extraction, use and pollution, while maintaining sanitation goals of protecting public health and the environment. In short, circular sanitation is resource-oriented and is underpinned by two guiding principles: decentralization and source separation, as illustrated in the four examples in the figure below.

OFF-GRID TREATMENT OF ALL STREAMS

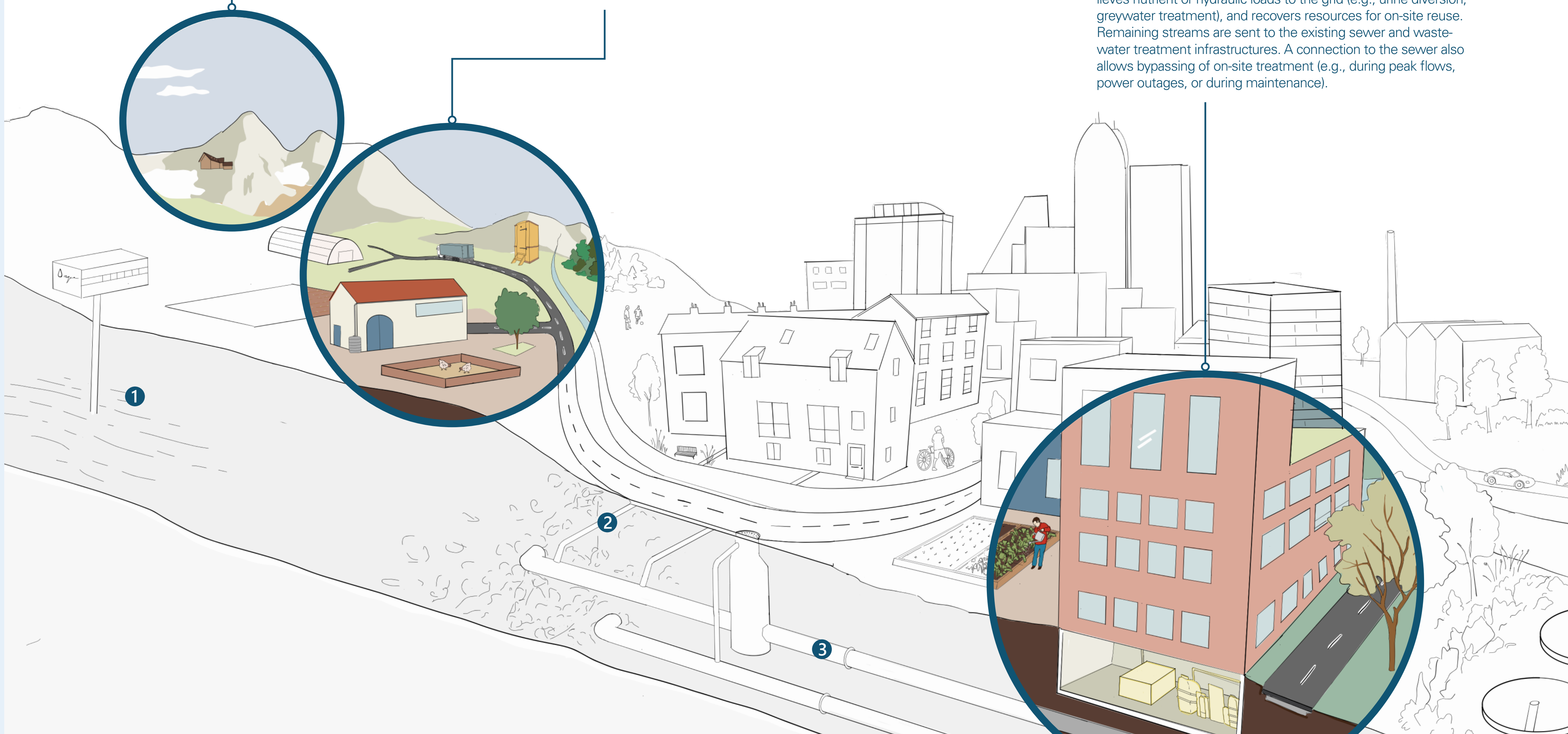
Remote huts, villages, or settlements, removed from centralized infrastructure, need autonomous solutions for the management of all waste for reuse or safe discharge.

TRANSPORT TO TREATMENT & RECOVERY HUBS

Urine and feces collected from public toilets, mobile units, or buildings are transported to a semi-centralized location for storage, treatment, and recovery of resources.

TREATMENT OF & RECOVERY FROM SOME STREAMS, REST TO SEWER

Separate collection and treatment of one (or more) stream(s) relieves nutrient or hydraulic loads to the grid (e.g., urine diversion, greywater treatment), and recovers resources for on-site reuse. Remaining streams are sent to the existing sewer and wastewater treatment infrastructures. A connection to the sewer also allows bypassing of on-site treatment (e.g., during peak flows, power outages, or during maintenance).



CENTRALIZED URBAN WATER DISTRIBUTION & TREATMENT

Drinking water is drawn from (1) groundwater aquifers, springs, or lakes and rivers, treated and distributed via extensive underground pressurized networks for domestic, industrial, commercial, and public use. Wastewater collected from (2) households is often mixed with industrial wastewater, and sometimes stormwater, and conveyed through piped (3) sewer networks to centralized wastewater treatment plants. (4) Treatment plants remove solids, organics, nutrients, pathogens, heavy metals, and micropollutants before (5) discharging treated water (effluent) into natural bodies of water. (6) Resource recovery technologies have been increasingly adopted to enhance these processes, including treatment of effluent for reuse, recovery of nutrients from concentrated streams or incinerated sludge ash, and biogas production from sewage sludge.

DECENTRALIZATION

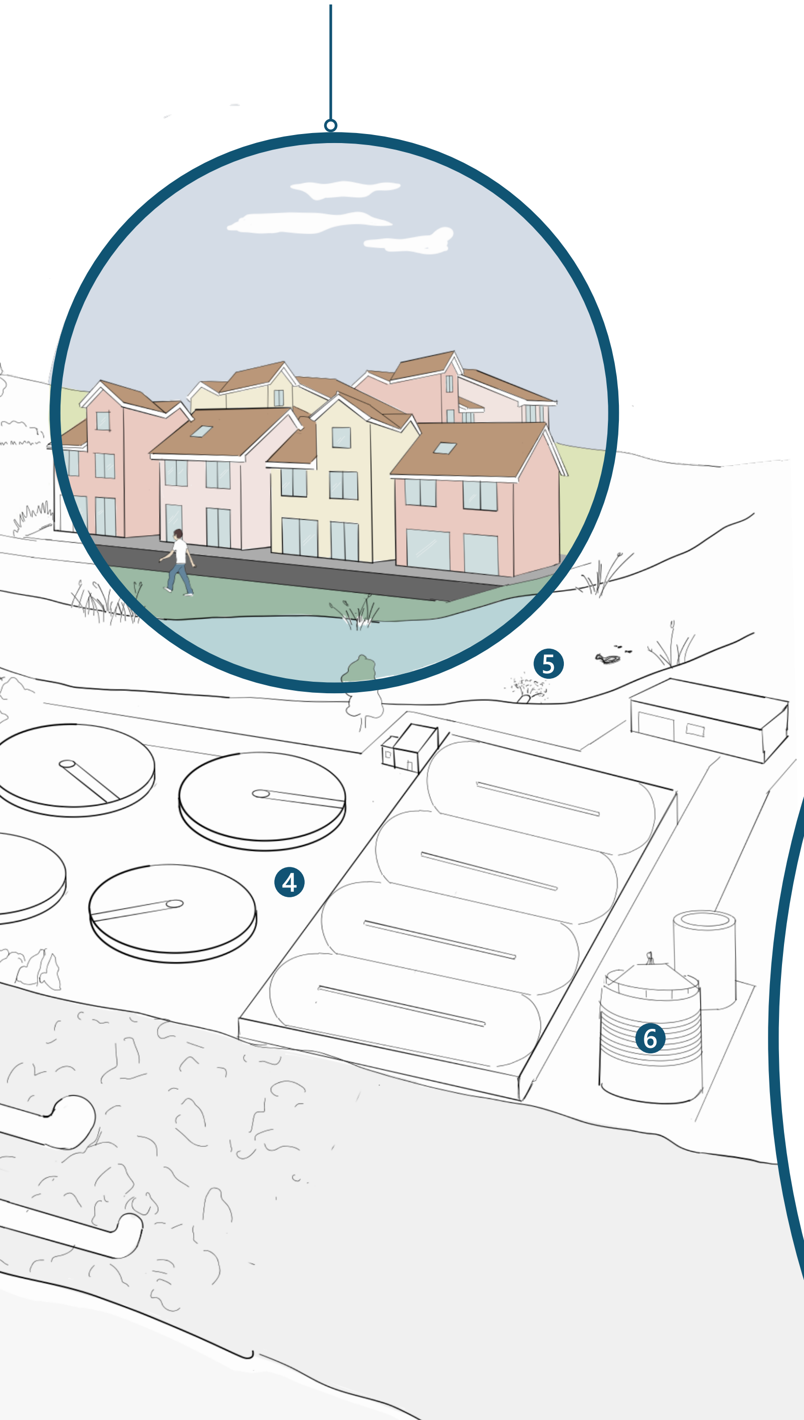
Decentralization refers to the collection, conveyance and treatment of wastewater on a smaller scale than centralized infrastructure. While decentralization is often used to describe sanitation in remote or low-density areas, it can also be applied in or near urban contexts, alongside centralized infrastructure, as hybrid solutions. Importantly, decentralization allows for the collection, conveyance and treatment of separate streams and promotes reuse close to the source (i.e., minimizing losses and often redistribution costs).

SOURCE-SEPARATION

Circular sanitation is based on the premise that resource recovery is more effective from streams with low dilution. Separating streams at the source facilitates treatment and recovery according to the stream properties. Specialized toilets (e.g., low flush, vacuum and urine diversion) and infrastructure modifications (e.g., separate or vacuum piping) enable the collection and conveyance of source-separated streams. Treatment and recovery technologies allow for the targeted recovery of water, nutrients and organics, and energy.

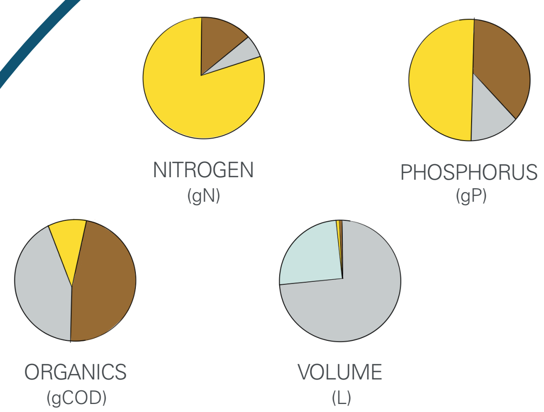
TREATMENT OF & RECOVERY FROM ALL STREAMS

Buildings, neighborhoods or districts can choose to collect and treat all waste streams decentrally to achieve grid autonomy, relieve existing infrastructure, or improve local resource cycles.



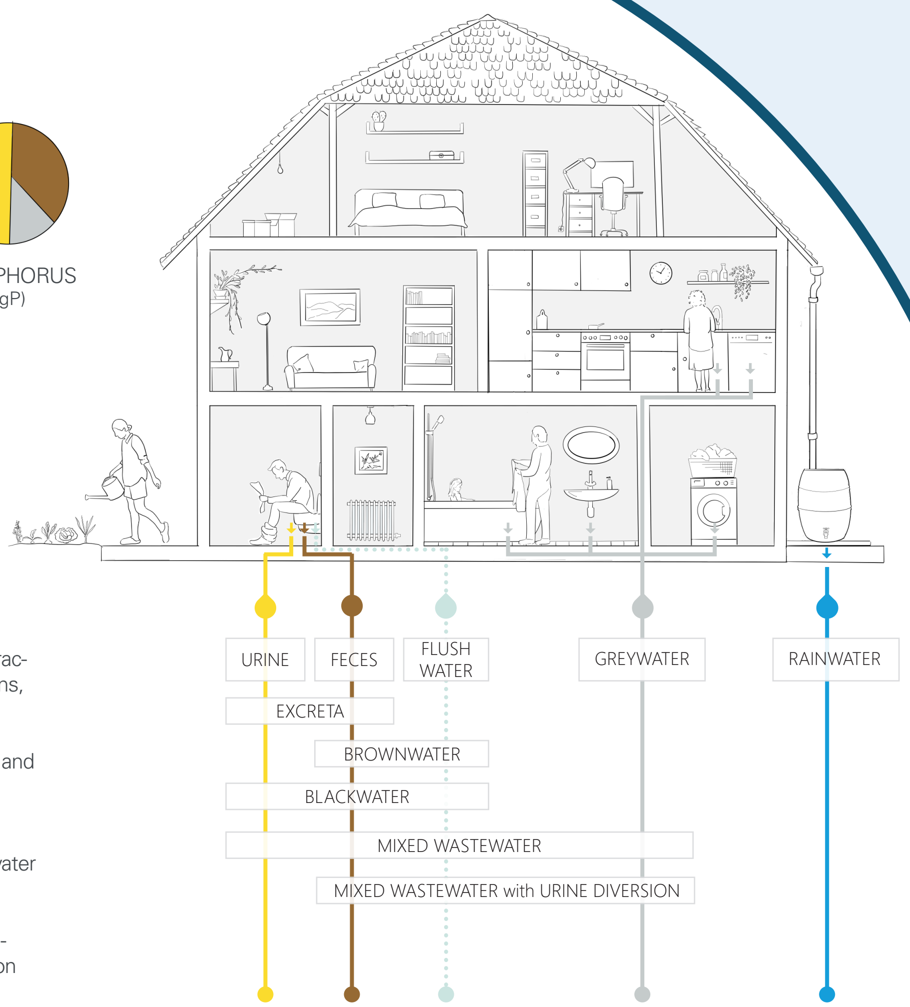
WHY SEPARATE STREAMS?

Separation of domestic wastewater streams prevents the dilution and mixing of streams, and allows for targeted recovery of water, nutrient and energy resources.



Contribution of separate streams to domestic wastewater.

- Urine and feces contribute the majority of nutrients and organic matter to domestic wastewater in a small fraction of the volume. However, they also contain pathogens, pharmaceuticals and hormones.
- Flush water significantly dilutes the nutrients, organics, and contaminants in excreta.
- Greywater includes water from showers, laundry, sinks and dishwashers. It contains the largest proportion of water in domestic wastewater, as well as residual heat.
- Rainwater can be collected from above-ground, impervious surfaces. Its availability depends on local precipitation events and collection surface areas.



IMPLEMENTATION STRATEGIES

Circular sanitation involves strategies for collection, conveyance, treatment, and resource recovery. Many strategies can be combined, while others are mutually exclusive (e.g., dry sanitation and vacuum sanitation). Most strategies can be implemented alongside existing centralized infrastructure. When selecting strategies, it is important to consider goals and context.

URINE DIVERSION

Urine diversion is the separation of urine from the rest of the remaining wastewater streams. This strategy helps divert nutrient loads from exisiting treatment plants and can yield nutrient-rich fertilizers.

DRY SANITATION

Dry sanitation refers to the collection of excreta or feces without flush water, contributing to water savings. Treatment of the excreta or feces yields soil amendments.

VACUUM SANITATION

Vacuum sanitation is the collection of excreta via vacuum piping under negative pressure, with minimal water for flushing. In addition to saving water, liquid and solid fertilizers, as well as soil amendments can be recovered. The organics can be valorized to produce biogas.

FLUSH SANITATION

Flush sanitation refers to the use of standard flush toilets to handle human excreta. Treatment allows for the recovery of water from the liquid fraction, and nutrients and organics from the solid fraction.

WATER REUSE

Water reuse includes the collection and treatment of greywater, or mixed wastewater, for non-potable or potable reuse. Water reuse results in drinking water savings.

WATER-EFFICIENT FIXTURES

Water-efficient fixtures include appliances and fittings that reduce water demand. If fixtures reduce hot water demand, energy demand for heating is also reduced.

RAINWATER HARVESTING

Rainwater harvesting refers to the collection of rainwater from above-ground surfaces (e.g., rooftops) during rainfall events. Rainwater can be used for non-potable and potable applications, replacing drinking water demand.

HEAT RECOVERY

Heat recovery refers to the use of heat exchangers or heat pumps to recover heat from greywater or mixed wastewater to save energy.

TREATMENT & RECOVERY TECHNOLOGIES

Resource treatment and recovery can be achieved using single or combined technologies, depending on the input stream, desired output, and context-specific factors (e.g., space, weather).

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1ST EDITION

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A free PDF copy of this publication, including the goal, strategy and technology guides, can be downloaded from: www.eawag.ch/en/wh/toolbox

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