VACUUM SANITATION

eawag aquatic research

STRATEGY

Vacuum sanitation systems are based on suction for the removal of excreta with minimal water for flushing, which results in important water savings compared to flush sanitation systems. The concentration of the vacuum-collected blackwater facilitates the recovery of nutrients and valorization of organics from the stream. Compared to conventional gravity sewerage systems, vacuum sewers enable flexible piping installations regardless of topography. A growing number of neighborhoods combine vacuum sanitation with food waste management strategies for biogas production, and with water reuse and heat recovery from greywater for a holistic, off-grid solution. Implementing vacuum sanitation can help projects attain green building certificates.

INPUT STREAMS

- Vacuum-collected blackwater

TARGET OUTPUTS

- Biogas
- Soil amendments & fertilizers
- Treated water

TOILETS

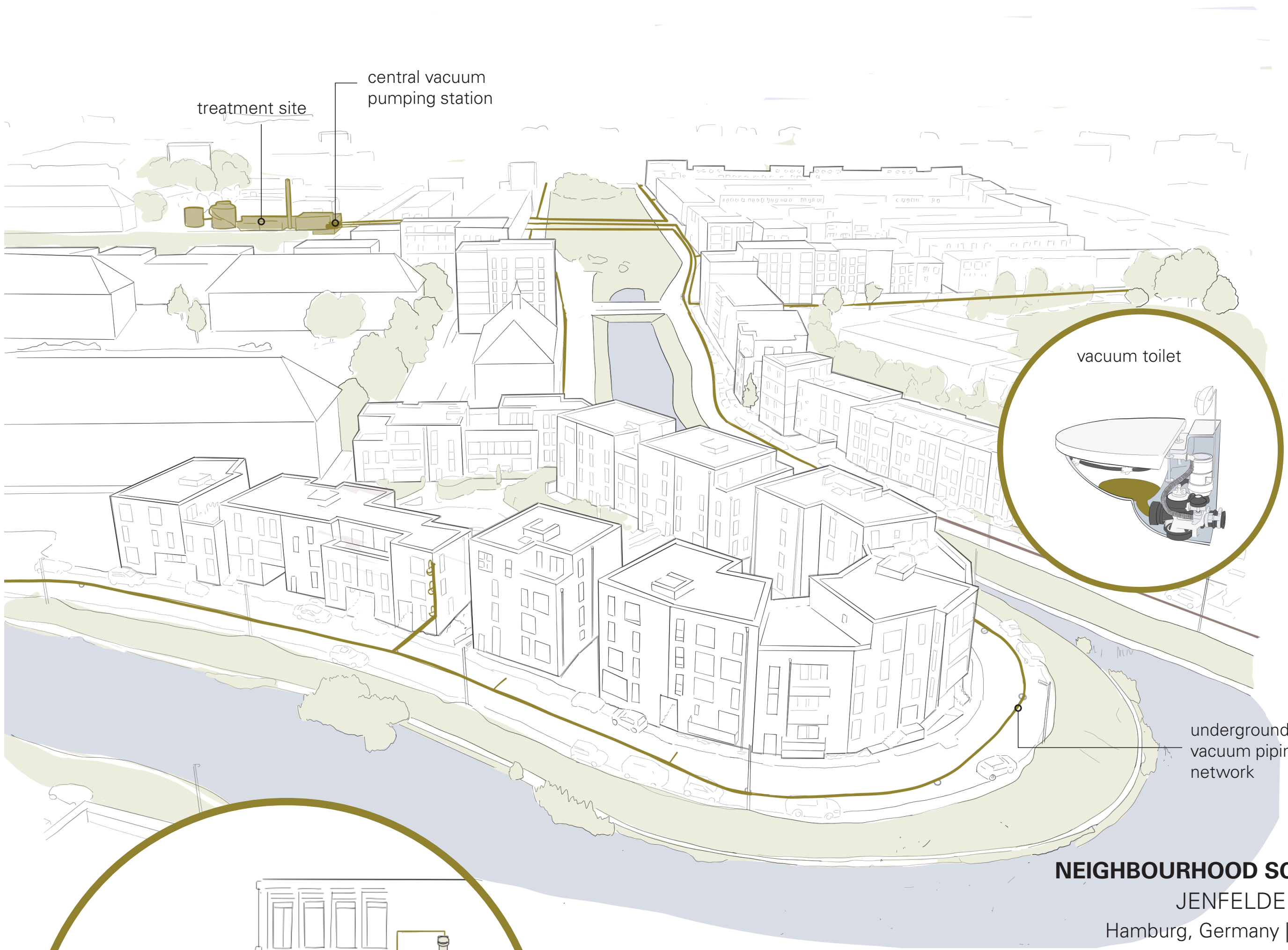
Commercially available vacuum toilets are similar in appearance and user experience to conventional flush toilets. When flushing, a small diameter opening at the base of the toilet bowl opens, and the vacuum in the pipes "sucks" out the excreta, toilet paper, and a small amount of water used to rinse the bowl.

PIPING

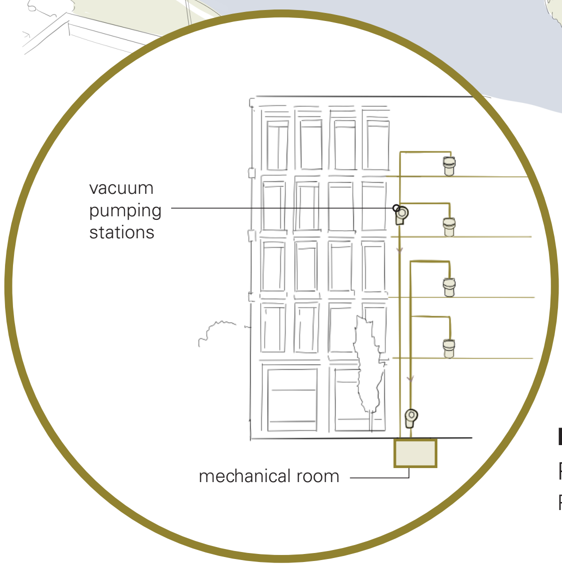
Vacuum systems require pumps that generate a vacuum, or negative pressure, in the vacuum piping system. Carefully planned vacuum piping systems can cover whole neighborhoods, with central underground pumping stations keeping the pipes under constant vacuum. At a building or household scale, vacuum pumps can be located close to the toilet or within the building and can operate on demand.

TREATMENT

Treatment and recovery sites can be integrated into a building structure or in a separate treatment location. Alternatively vacuum-collected blackwater can be sent to sewer for centralized treatment.



NEIGHBOURHOOD SCALE
JENFELDER AU
Hamburg, Germany | 2016



BUILDING SCALE
PAE BUILDING
Portland, OR, USA | 2020

TO CONSIDER

COLLECTED STREAM

The low water requirement of vacuum toilets (< 1 L, compared to 3-6L in conventional flush toilets) yields a concentrated blackwater from which organics and nutrients can be more effectively recovered. Solids in vacuum-collected blackwater are "macerated," due to shearing forces in the pipes.

SPACE & PLACEMENT

Vacuum pipes require a smaller pipe diameter than gravity systems, making them lighter and more compact. Independence from gravity offers additional layout flexibility (e.g., pipes can be installed vertically or laid in ceilings). Soundproofing measures should be considered during floorplan design and construction (guidelines exist), as well as the inclusion of inspection points.

RESOURCE INTENSITY

Vacuum sanitation requires more sophisticated technology and more regular maintenance than conventional toilets and gravity drainage. Spontaneous mineral precipitation in pipes can lead to deposit build-up and clogging which require preventative maintenance. Additionally, a constant, though small, energy source is needed to keep vacuum in the pipes. Contingency plans and careful design are thus necessary for power shortages and during maintenance.

NEW BUILD VS. RETROFIT

The installation of vacuum toilets and sewerage is easiest in new build planning and construction as it requires good coordination between all stakeholders. However, vacuum sanitation can also be retrofitted into buildings, which is facilitated by its high flexibility in piping layout.

HYBRID VS. DECENTRALIZED

Vacuum sanitation is implemented in combination with greywater reuse for a holistic, off the grid, solution. When reducing water demand is the primary driver, or in cases where the scale of recovery is not efficient, sending vacuum-collected blackwater to the sewer may be preferred.

USER EXPERIENCE

There is no significant change in user experience with respect to conventional flush toilets apart from a change in flush sound, which is slightly louder. However, vacuum toilet systems also provide certain advantages from the user perspective including lower risk of user exposure to pathogens (no aerosols are generated during flushing), better ventilation (a large volume of air is flushed with the vacuum), and lower water bills.

TREATMENT OPTIONS

Treatment trains for vacuum-collected blackwater typically consist of a biological treatment step for valorization of the organics (e.g., as biogas or compost) followed by nutrient extraction from the digestate or leachate, and sometimes water recovery.

VALORIZATION OF ORGANICS & NUTRIENTS

Biological anaerobic or aerobic treatment of vacuum-collected blackwater yields biogas and/or a soil amendment (e.g., compost, anaerobic sludge).

NUTRIENT EXTRACTION

Processes for the targeted extraction of phosphorus and/or nitrogen from digestate or leachate yield single-nutrient fertilizers (e.g., struvite, ammonia salts) which can be used directly or in fertilizer manufacturing.

WATER REUSE

Biological treatment, filtration and disinfection technologies can treat the remaining water stream, though the volume of the remaining effluent is usually small and thus, it often makes sense to treat it together with greywater (see for water reuse treatment options).

SAFE END USE

SAFE HANDLING OF BIOGAS

Biogas can be converted into heat via a burner or used in combined heat and power (CHP) systems for electricity and heat (often also used to heat the anaerobic reactor). Biogas is flammable and a greenhouse gas 28 times more potent than carbon dioxide (CO_2). Safety measures should be considered for storage and use, and to avoid release of biogas to the atmosphere.

PATHOGENS & PHARMACEUTICALS

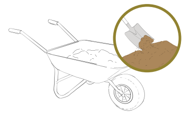
Risks from pathogens in blackwater-derived soil amendments and fertilizers can be reduced through additional treatment (e.g., compost maturation, struvite drying) or application measures (e.g., lag time between last application and harvest). Micropollutant removal varies per treatment. Risks are likely lower compared to sewage sludge or animal manure application.

PROCESS OBJECTIVE | TECHNOLOGY | PRODUCT(S)

BIOLOGICAL TREATMENT

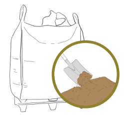
Anaerobic or aerobic biological treatment converts organics into biogas or compost. While vacuum-collected blackwater can be directly composted, more often composting (of the digestate) follows anaerobic digestion.

T21 ON-SITE COMPOSTING

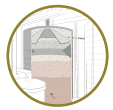


COMPOST

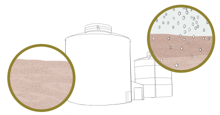
T22 OFF-SITE COMPOSTING



COMPOST



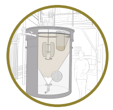
T23 ANAEROBIC DIGESTION



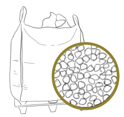
SLUDGE BIOGAS

NUTRIENT EXTRACTION

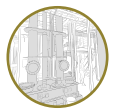
The extraction of one or more nutrients via chemical and physical mechanisms. Additives are often required (e.g., magnesium for precipitation, sulfuric acid for stripping).



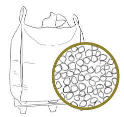
T4 STRUVITE PRECIPITATION



STRUVITE



T5 AMMONIA STRIPPING



AMMONIA SALTS