Source Separation of Toilet Waste for Nitrogen and Phosphorus Recovery and Water Reuse

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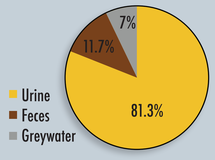
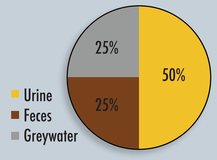
Toilet waste contains the most nutrients

Nitrogen Distribution among Wastewater Constituents



Phosphorus Distrubution among Wastewater Constituents



Pure urine, or vacuum-flushed toilet waste, can be collected with commercially available fixtures:

Urine-diverting Toilets (UDTs)

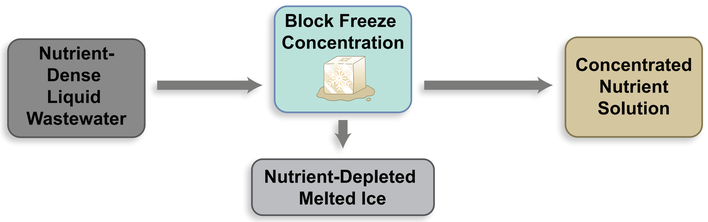
Waterless Urinals

Vacuum Flush Toilets (VFTs)

Diverting urine or all toilet waste from the wastewater system supports climate-resilient, circular economies for water and nutrients by facilitating non-potable water reuse and locally-sourced, natural fertilizer.

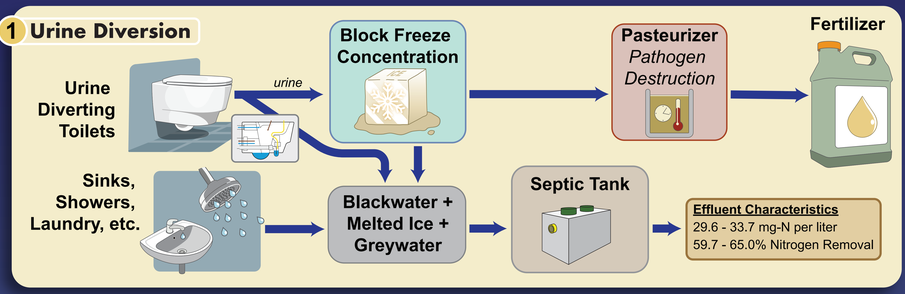
Freeze concentration partitions 90% of nutrients into a concentrated solution

The partial freezing of toilet waste creates two fractions: a nutrient-dense free liquid and a nutrient-depleted block of ice.

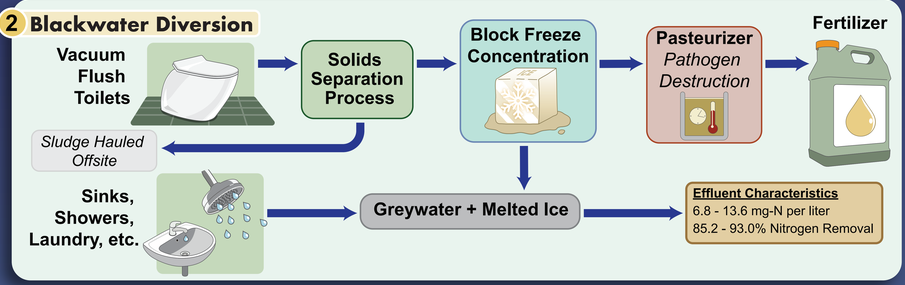


The nutrient-dense liquid is then purified for reuse as a sustainable fertilizer. The nutrient-depleted ice is combined with the building's greywater for light treatment and non-potable reuse, or discharged to a conventional onsite treatment system.

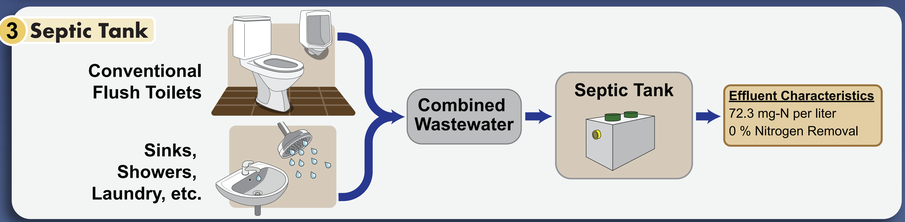
1 Urine Diversion



2 Blackwater Diversion



3 Septic Tank



4 Septic Tank with Nitrogen Removal

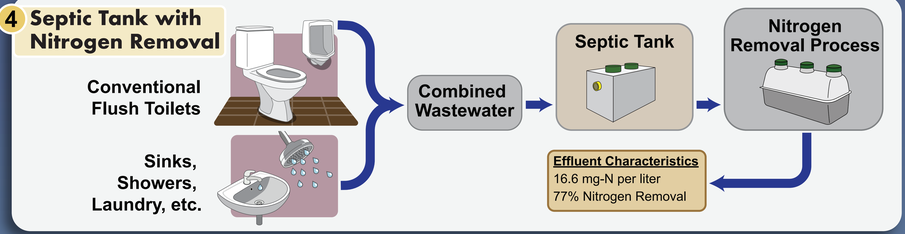


Diagram Number	Scenario	Total Effluent Volume (gal per person per year)	Fertilizer Volume Produced (gal per person per year)	Average Effluent Nitrogen (mg-N per L)	Nitrogen Removal (%)	Average Effluent Phosphorus (mg-P per L)	Phosphorus Removal (%)	Energy Usage (kWh per person per year)
1	Urine Diversion	9836	17* *(6.4x conc.)*	33.7	59.7	8.3	36.7	14.9
N/A	Urine Diversion (off-site processing)	9745	109* *(unconcentrated)*	29.6	65.0	7.9	40.0	N/A
2	Blackwater Diversion	8957	20* *(21.4x conc.)*	13.6	85.2	4.3	69.9	62.6
N/A	Blackwater Diversion (off-site processing)	8517	465* *(unconcentrated)*	6.8	93.0	3.8	75.0	N/A
3	Septic Tank	11378	0	72.3	0.0	11.3	0.0	0
4	Septic Tank with Nitrogen Removal	11378	0	16.6	77.0	11.3	0.0	175.2 based on FujiClean CEN5

* Variation in fertilizer volume between the two urine diversion (or blackwater) scenarios reflects the effect of onsite concentration. Total fertilizer nutrient mass is approximately equal regardless of concentration factor.

Source separation improves buildings' environmental impacts

1. Capturing toilet wastes for conversion into fertilizer can remove 59.7–93.0% of nitrogen from wastewater effluent. Effluent concentrations can be reduced to 6.8–13.6 mg-N/L (85.2–93.0% N removal) by diverting all blackwater, and 29.6–33.5 mg-N/L (59.7–65.0% N removal) by diverting urine. This produces a sustainable fertilizer product and non-potable water, and it is achieved without a nitrification/denitrification process.
2. Brightwater Tools' freeze concentration and pasteurization process is energy efficient, requiring 62.6 kWh ($9.96) per person per year to process diverted blackwater and 14.9 kWh ($2.37) per person per year to process diverted urine.

Nutrient Removal Calculation

Nutrient removal [%] for each treatment system, as shown in the table to the left, is calculated using the total mass of nitrogen or phosphorus in the treated effluent stream divided by the total mass of nitrogen or phosphorus contained in the effluent of the reference system (septic system).

$$\textit{Nitrogen Removal}\,[\%] = \left(1 - \frac{\text{Effluent Volume} \cdot \text{Effluent } \frac{\text{mg}-\text{N}}{\text{L}}}{11378\text{gal} \cdot \frac{3.785\ \text{L}}{\text{gallon}} \cdot 72.3 \frac{\text{mg}-\text{N}}{\text{L}}}\right) \times 100$$

Funded by: NSF · SBIR·STTR America's Seed Fund™ POWERED BY SBA

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