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A complete recycling (ecosan) system at student dormitories in Norway

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The concept

The Agricultural University of Norway is pioneering environmentally safe solutions to organic waste and wastewater treatment. In 1997 a first generation recycling system based on ecological engineering principles was built serving 48 students. The system reduces water consumption by 30 %, it nearly eliminates pollution, it produces a valuable plant fertilizer and soil amendment product from the waste material.

The concept is based on:

- Separate treatment of toilet wastewater (blackwater) and water from kitchen and shower (greywater).
- Modern and reliable vacuum toilet technology with high comfort.
- Liquid composting of toilet waste and organic household waste for sanitation, stabilization, removal of odours and production of high quality liquid fertilizer. Liquid composting can be substituted for or combined with biogas production.
- Simple and reliable filtration of greywater for producing a water quality suitable for irrigation groundwater recharge or simply discharge to a nearby stream.
- A patented machine for fertilizer distribution that hydraulically ”shoots” the liquid bio-fertilizer into the ground, resulting in higher yields and less pollution from run-off.
- Water-saving devices for showers, characterized by high comfort.

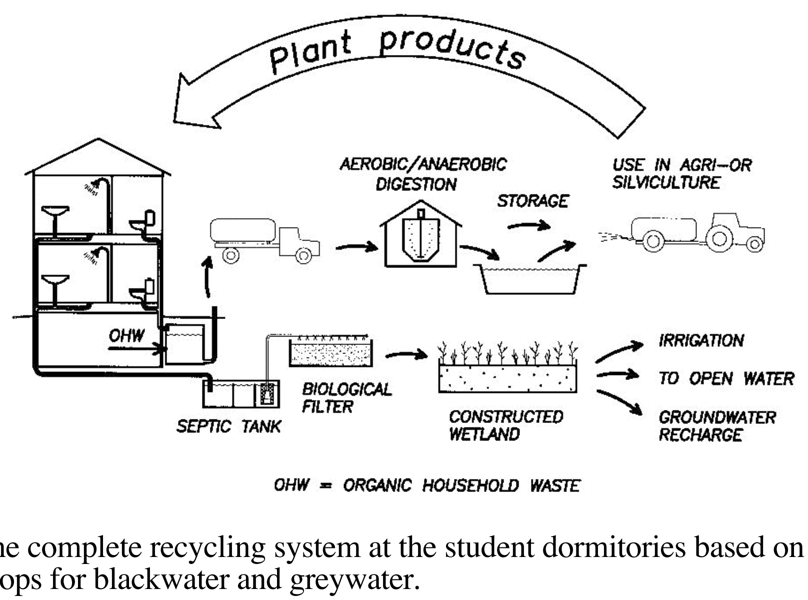

Figure 1. The complete recycling system at the student dormitories based on separate treatment loops for blackwater and greywater.

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Wastewater composition

The composition of nitrogen (N) Phosphorus (P) and Potassium (K) in domestic wastewater and organic household waste is close to an optimum ratio for plant growth. Hence, this waste material constitutes a near ideal plant fertilizer. The majority of the plant nutrients in wastewater - 90 % of the nitrogen and up to 85 the phosphorus (when phosphate free detergents are used as in Norway) - are found in toilet waste. In addition toilet waste contains the majority of other pollutants such as organic matter and pathogenic organisms.

Table 1. Wastewater composition, Norwegian figures.

Component	kg per person and year	% in toilet waste (blackwater)
Nitrogen	4.5	90
Phosphorus*	0.7	85
Potassium	1	79**
Organic matter***	35	40-75

** using phosphate free detergents, ** From Vinnerås (2002) ** as chemical oxygen demand (COD)*

The toilet concept

Conventional toilets use from 6 - 20 litres per flush and these account for up to 20 - 40 % of the water consumption in sewered cities (Gardner 1997). By the use of modern vacuum toilet technology the amount of water per flush is reduced to about 1 litre. First of all this makes it possible to save water, but it also reduces the blackwater volume to an amount that can be handled separately. The vacuum toilet technology have been developed through maritime use and is known for reliability and modern design. The price is comparable to that of ordinary water closets. The vacuum generator requires little electricity. The latest development in vacuum technology is vacuum on demand (VOD) where vacuum is generated only when needed. Such systems, which also are available in solar powered versions, have an energy consumption of 4KWh/person and year. The blackwater is collected in tanks, usually one separate tank for each building. 3-5 people will produce 5 - 10 m^3 blackwater per year. The 48 students produce 10m^3 of blackwater per month. The blackwater is collected monthly and trucked to the treatment facility.

a **b** **c**

Figure 2. a) wall mounted vacuum toilet, b) the liquid composting reactor, c) direct ground injection (DGI).

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Converting Blackwater into Fertilizer

In order to sanitize (kill pathogenic microorganisms - bacteria, virus and parasites) and to remove odours the blackwater must be treated. This is done by a liquid composting reactor (Skjelhaugen 1999). In the liquid composting reactor the blackwater is mixed with milled organic household waste (other organic waste material is also possible to use i.e. animal manure or food processing waste). The household waste is added in order to increase the concentration of organic matter and speed up the composting process. The biomass is composted at a temperature of 55-60° C and the end-product is an odourless fertilizer slurry. The liquid composting efficiently reduces the pathogenic organisms and the composted material meets the standards of the European Union sludge regulations with respect to bacterial content. The liquid composting unit runs with a net energy surplus in terms of heath, but this is not yet utilized. Biogas production alone ore combined with liquid composting or thermal hydrolysis is being considered both from an energy perspective and to meet future requirements with regard to health and hygiene. Hydrogen production using algae is also an interesting option combined with anaerobic digestion.

Direct Ground Injection – DGI Concept

The slurry from the liquid composting can be applied directly as liquid fertilizer using *Direct Ground Injection* technology, The DGI hydraulically "shoots" the liquid fertilizer into the ground, leading to a more efficient fertilizer use and thus avoiding over-use and run-off to rivers, aquifers, etc. Almost all of the nitrogen/ammonia is utilized and not evaporated as happens with traditional spreading through the air. Tests have shown comparable yields for the same amount of bio-fertilizer using the DGI method, making it possible to decrease the use of chemical fertilizer.

Greywater treatment

The daily greywater production is 115 liter/student. Primary treatment is in a a 10 m^3 three compartment septic tank, followed by an aerobic biofilter and constructed wetland both filled with light weight aggregate. The total area of the system is $100m^2$, the depth of the wetland 1m and the retention time is 7 days. The treatment results are shown in table 2.

Table 2. Average performance of the Kaja greywater treatment system over six years of operation (concentrations in mg/l).

Parameter	Effluent septic tank	Effluent wetland	Removal%	Total removal%*
BOD	87	5,6	94	97
Total phosphorus	0,97	0,05	95	99
Total nitrogen	8,7	2,6	70	97

**assuming 90% of N, 80% of P and 50% of BOD in blackwater*

Total phosphorus is effluent concentration1/10^{th} of the discharge concent for large advanced treatment systems in Norway and total nitrogen is below the WHO drinking water requirement of 10 mg/l. The high P-removal is due to the P-sorbing capability of the LWA. The Faecal Coliform (FC) counts in the outlet are generally below 100 TCB/100 ml and 8 out of 22 samples have shown 0 FC/100ml. The effluent values are very stable and no decreasing trend has been observed for any parameter over the first 6 years of operation.

Experiences, maintenance and economy

The vacuum system has worked reliably with no major problems. Most of the students are satisfied, but some complain that the vacuum system is a little more noisy. The service interval on the vacuum generating system is 2 years. The students are encouraged to use a biological toilet cleaner that helps prevent urine stone deposits in the toilet valve and piping system. The major cost is collection of the toilet waste once a month. Dual flush vacuum toilets that use about 0,5 litres on the average are now available. This would increase the emptying interval to once every two months. ISuch toilets, if they where installed, would reduce the main operating cost of the system by 50%.

The greywater treatment system has had no maintenance need the first 5 years. The sludge accumulation in the septic tank has not yet reached levels where emptying is necessary.

Because of a dual piping system the inhouse plumbing is more expensive. There is no need, however, for a secondary sewer collection system. This system is economically competitive especially in areas where no sewage network exist or where there is high costs connected to building or upgrading an existing sewer .

Conclusions

- Recycles 80 -90% of the nitrogen and phosphorus in the wastewater . Reduces nutrients and organic matter (BOD) >95%, hence; near zero emission
- Reduces the need for pipelines - the most expensive part in a traditional sewage network
- Replaces expensive chemical fertilizer
- Makes it possible to recycle nutrients locally, decreasing the need for transport of fertilizer.
- Makes energy production from waste resources possible
- Greywater treatment facilities can easily be adapted to the terrain
- Facilitates development of real estate in areas with no existing sewage network
- Saves 30% of the domestic water consumption. Adding more water saving devices makes it possible to save up to 50% or more
- It is possible to use the separated greywater for irrigation or groundwater recharge after filtration, thus saving even more water.

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